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Contextualising mainstreaming of disaster resilience concepts in the construction process

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Abstract

Purpose – Construction industry and the built environment professions play an important role in contributing to society's improved resilience. It is therefore important to improve their knowledgebase to strengthen their capacities. This paper aims to identify gaps in the knowledgebase of construction professionals that are undermining their ability to contribute to the development of a more disaster resilient society. The paper also provides a series of recommendations to key actors in the built environment on how to more effectively mainstream disaster resilience in the construction process.

Design/methodology/approach – The paper reports the findings of 87 stakeholder interviews with: national and local government organisations; the community; non-governmental organisations, international non-governmental organisation and other international agencies; academia and research organisations; and the private sector, which were supplemented by a comprehensive analysis of key policies related to disaster resilience and management. The findings were validated using focus group discussions that were conducted as part of six organised stakeholder workshops.

Findings – The primary and secondary data generated a long list of needs and skills. Finally, the identified needs and skills were combined "like-for-like" to produce broader knowledge gaps. Some of the key knowledge gaps identified are: governance, legal frameworks and compliance; business continuity management; disaster response; contracts and procurement; resilience technologies, engineering and infrastructure; knowledge management; social and cultural awareness; sustainability and resilience; ethics and human rights; innovative financing mechanisms; multi stakeholder approach, inclusion and empowerment; post disaster project management; and multi hazard risk assessment. The study also identifies a series of recommendations to key actors in the built environment on how to more effectively mainstream disaster resilience in the construction process. The recommendations are set out in five key themes: education, policy, practice, research and cross-cutting.

Research limitations/implications – This study is part of an EU funded research project that is seeking to develop innovative and timely professional education that will update the knowledge and skills of construction professionals in the industry and enable them to contribute more effectively to disaster resilience building efforts.

Originality/value – The paper provides an extensive analysis of the gaps in the knowledgebase of construction professionals that are undermining their ability to contribute to the development of a more disaster resilient society. Accordingly, the paper recommends major changes in construction education, research, policy and practice with respect to mainstreaming disaster resilience within the construction process.

Keywords Construction, Built environment, Education, Disaster resilience, Knowledge gaps

Paper type Research paper

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1. Background

The past decade has seen a concentration of disaster events causing major social, economic and financial impacts. Seven of the ten most costly disasters since 1980 have occurred in the past decade (Munich, 2015). This increasing trend of disaster losses is due mainly to the unprecedented rate of urban growth, increasing dependence on complex infrastructure and changes in climate that are increasing exposure to anthropogenic and natural hazards (IPCC, 2014).

To tackle these increasing losses, the Sendai Framework for Disaster Risk Reduction, 2015–2030 (UNISDR, 2015), endorsed by 187 UN states in 2015, promotes disaster risk reduction practices that are multi-hazard and multi-sectoral, inclusive and accessible to be efficient and effective. The Framework also identifies: "A need for the private sector to work more closely with other stakeholders and to create opportunities for collaboration, and for businesses to integrate disaster risk into their management practices" (p. 10) and "A need to promote the incorporation of disaster risk knowledge, including disaster prevention, mitigation, preparedness, response, recovery and rehabilitation, in formal and professional education and training" (p. 15).

As a process, building disaster resilience involves supporting the capacity of individuals, communities and states to adapt through assets and resources relevant to their context (Manyena, 2006). Buildings and infrastructure are severely disrupted by disasters; the construction industry and the built environment practitioners are expected to play a predominant role in reducing the disaster risks and recovering from natural and human-induced disasters. Accordingly, the importance of engaging built environment professionals more extensively in disaster risk reduction, response and recovery is widely recognised (Haigh and Amaratunga, 2010; Bosher *et al.*, 2007; Max Lock Centre, 2009). More importantly, early attention is needed to engage the right expertise to address problems of buildings, infrastructure and land in reducing disaster risks and strengthening resilience (Max Lock Centre, 2009). Similarly, multi-sectoral involvement, significant resources and a wide range of skills are required for post disaster reconstruction (Silva, 2010). Thayaparan *et al.* (2010) highlighted the peculiarities of post disaster reconstruction and emphasised the importance of receiving continuous skill development to respond to disaster situations. Similarly, Sanderson (2016) highlighted the importance of architects to move beyond their traditional role to build up processes that involve people in places of uncertainty and rapid change. It is therefore important to improve the knowledgebase of built environment practitioners to successfully tackle these challenges.

This paper is an account of a study to identify gaps in the knowledgebase of construction professionals that are undermining their ability to contribute to the development of a more disaster resilient society and preventing the mainstreaming of disaster resilience within the construction process. The paper also reports the development of the analytical framework which was used as the basis to identify gaps. The paper concludes with a series of recommendations to key actors in the built environment on how to more effectively mainstream disaster resilience in the construction process. This study is part of an EU funded research project, CADRE, which is seeking to develop innovative and timely professional education that will update the knowledge and skills of construction professionals in the industry and enable them to contribute more effectively to disaster resilience building efforts.

2. Role of the construction sector

The environments with which people interact most directly are often products of human-initiated processes. The importance of this built environment to the society it serves is best demonstrated by its characteristics; Bartuska (2007) identifies four that are interrelated. First, it is extensive and provides the context for all human endeavours. More specifically, it is everything humanly created, modified or constructed, humanly made, arranged or maintained. Second, it is the creation of human minds and the result of human purposes; it is intended to serve human needs, wants and values. Third, much of it is created to help us deal with, and to protect us from, the overall environment to mediate or change this environment for our comfort and well-being. Finally, every component of the built environment is defined and shaped by context; each and all of the individual elements contribute either positively or negatively to the overall quality of environments.

The economic scale, size and impact of the built environment are significant. In the UK, construction is one of the largest sectors of the economy. It contributes almost £90bn to the UK economy (or 6.7 per cent) in value added, comprises over 280,000 businesses, covering some 2.93 million jobs, which is equivalent to about 10 per cent of total UK employment (Department for Business Innovation and Skills, 2013). It generates about 9 per cent of gross domestic product (GDP) in the European Union and provides 18 million direct jobs. The European Union's internal market offers international partners access to more than 500 million people and approximately €13tn in GDP (Internal Market, Industry, Entrepreneurship and SMEs Directorate, 2016). As a major consumer of services and intermediate products, such as raw materials, chemicals or electrical equipment, construction impacts many other economic sectors.

From these characteristics, Haigh and Amaratunga (2010) identify several important consequences for the development of more disaster resilient societies. The vital role of the built environment in serving human endeavours means that when elements of it are damaged or destroyed, the ability of society to function – economically and socially – is severely disrupted. Disasters have the ability to severely interrupt economic growth and hinder a person's ability to emerge from poverty. The protective characteristics of the built environment offer an important means by which humanity can reduce the risk posed by hazards, thereby preventing a disaster. Conversely, post disaster, the loss of critical buildings and infrastructure can greatly increase a community's vulnerability to hazards in the future. Finally, the individual and local nature of the built environment, shaped by context, restricts our ability to apply generic solutions.

The damage to the built environment accounts for most of the economic losses of disasters, and its failure often determines the number of fatalities (Witt *et al.*, 2014). As such, professionals related to the construction sector are expected to play a major role in mitigating the impacts of such disasters. At the same time, it is the duty of the professionals attached to the construction sector, to plan, design, construct and operate the necessary risk reduction infrastructure and other services to protect the communities exposed to hazards (Malalgoda *et al.*, 2015). As such, the built environment should be planned, designed, built and operated in such a way that it can withstand a disaster. Therefore, it is clear that the construction industry and the built environment professions play an important role in contributing to society's improved resilience (Haigh and Amaratunga, 2010).

In recognition of the built environment's importance to a society, there have been growing calls for greater engagement by the construction industry in disaster resilience building efforts. Hecker *et al.* (2000), Prieto (2002), Godschalk (2003), Liso *et al.* (2003), Lorch (2005), Aldunate *et al.* (2006), Haigh *et al.* (2006), Rees (2009), Haigh and Amaratunga (2010) and Bosher and Dainty (2011) have indicated a need for the greater integration of disaster resilience concepts in the education of construction professionals.

Supporting this view, one of the construction sector's key professional bodies, the Royal Institute of Chartered Surveyors, called recently for "A massive rethink around how we build up skills across our sector to meet the challenges we're facing and how we ensure economic viability for land and real estate firms while delivering on social needs and managing finite resources" (Cook and Chatterjee, 2015, p. 11).

The scope of this contribution to resilience building efforts would appear to be considerable. Witt *et al.* (2014, p. 109) stated that "The many and varied disaster resilience roles of construction professionals identified in the literature" to the disaster management cycle. They noted that each of the roles identified also reflected a corresponding need for construction education and research inputs. Supporting this view, the Sendai Framework has re-emphasised the importance of educational measures in reducing the disaster risk and called for integrated and inclusive educational measures that strengthen resilience (UNISDR, 2015). Education and training on disaster resilience can be provided in numerous ways, and the Sendai Framework highlighted the importance of promoting the incorporation of disaster risk knowledge in formal and non-formal education, as well as in civic education at all levels, in addition to professional education and training which will help to, build the knowledge of government officials at all levels, civil society, communities and volunteers, as well as the private sector (UNISDR, 2015).

3. Disaster resilience knowledge and skills and the changing role of the construction sector

Accelerating urbanisation, changing demographics, resource scarcity and sustainability are some of the trends reshaping the world that we live in (Cook and Chatterjee, 2015). Of these, urbanisation is one of the most critical global issues (Allen, 2009; Institution of Mechanical Engineers, 2013; UN, 2014). Urbanisation generally means a shift of population from rural to urban areas, which puts pressure on land and resources. More than half of the world's population is now living in urban areas (UN, 2014) or cities. The high concentration of population and economic and cultural capital in cities threatens sustainable development and increases susceptibility to natural disasters (Cook and Chatterjee, 2015; Institution of Mechanical Engineers, 2013; UN, 2014). All of these prompt the need to promote sustainable and resilient cities (Allen, 2009; Malalgoda and Amaratunga, 2015; UN-ISDR, 2010) and demand new knowledge and skills to rethink land use planning, management of cities and connections of urban and rural areas (Cook and Chatterjee, 2015).

Moreover, the world's population is growing and getting older (Cook and Chatterjee, 2015; O'Brien *et al.*, 2009; WSP Global Inc., 2015). As a result, a larger population will need more homes, schools and infrastructure (WSP Global Inc., 2015). Due to the change in age demographics, complex and long-term planning is required to cater for the social and economic needs of different age groups (Cook and Chatterjee, 2015). For example, the older population will require more hospitals, short and long-term care facilities and protection services (Weiner, 2014). Additionally, some will need specially designed buildings, and more attention will be needed in terms of accessibility and health issues in design, build and retrofit (WSP Global Inc., 2015).

Besides, the construction industry has a direct impact on energy and resource efficiency and is responsible for promoting sustainability to combat climate change (European Commission, 2016). As a result of the growing population, an increased pressure is placed on land and resources. Construction is a resource-intensive sector and the resources that the construction sector relies on are becoming more difficult to extract. Their use has caused environmental problems such as climate change, waste production and pollution (Cook and Chatterjee, 2015). Increasing concerns about global warming and concepts such as sustainability, energy efficiency, zero waste and green building have gained growing recognition among the built environment professions

(O'Brien *et al.*, 2009; WSP Global Inc., 2015). As such, increased need for sustainability in the built environment is another area of concern where much effort is still needed to promote the environmental agendas in the built environment (Cook and Chatterjee, 2015). In light of the new developments in the global environmental agendas, the time has come for the built environment professions to incorporate sustainable development more deeply into its practice (O'Brien *et al.*, 2009; Liyanage, 2016).

As discussed, built environment sectors face immense challenges as a result of these social and economic trends. In overcoming the challenges, it is important that we continuously improve the skill base of the built environment practitioners. Furthermore, increased occurrences of geological and climate-related hazards demand that built environment professions plan, design, build and retrofit buildings and infrastructure which can adapt to and withstand the threats posed by natural disasters (Haigh and Amaratunga, 2010; Bosher *et al.*, 2007; Malalgoda *et al.*, 2015).

To address the complex challenges associated with resilience building, the role of the built environment professional will need to change. This signals the importance of a rethink around the types of knowledge that will be needed across the construction and property sector so that it can contribute towards the aims of the Sendai Framework for Disaster Risk Reduction, 2015-30 and other global agreements on sustainability, climate and development.

Accordingly, this paper is an account of a study to identify gaps in the knowledgebase of construction professionals who are undermining their ability to contribute to the development of a more disaster resilient society and preventing the mainstreaming of disaster resilience within the construction process.

Studies such as Max Lock Centre (2009) and Ireni-Saban (2012) show how the relevant professional skills and expertise of construction professionals can be applied at all stages of disaster management. Accordingly, Max Lock Centre (2009) lists out some key activities where construction and property professionals can contribute to which includes, risk and vulnerability assessment; disaster risk reduction and mitigation; emergency water supply and sanitation; logistical planning; relief and transitional shelters; project planning and management; design, construction and monitoring; physical condition surveys and audits; compensation packages; resource mapping; housing need assessment; land survey and acquisitions; physical planning; infrastructure planning and implementation; property rights and claims; financial planning and management; and advice on regulations and codes. This shows the key areas where construction and property professionals' professional skills and expertise can be deployed. However, there are no much research studies that identify gaps in the knowledgebase of the construction professionals in contributing to the development of a more disaster resilient society. Nevertheless, Cosgrave (2013) identified skill gaps in water, sanitation and post disaster settlements, while Karunasena and Amaratunga (2015) identified capacity gaps in post disaster construction and demolition waste management. Furthermore, some gaps were reported within the literature with regard to soft skills. For an example, based on a study conducted in sub-Saharan Africa, Norman and Binka (2015) revealed that leadership capacities need to be strengthened through continual professional developments and formal education to build resilience and to improve response. Ireni-Saban (2012) highlighted the importance of collaborative actions, and according to Uhr (2017), collaboration is very problematic in multi organisational setting. Inter-disciplinary collaboration is essential when working in multi-disciplinary teams, and according to Lloyd-Jones (2006), this kind of activities require new set of professional skills across all built environment disciplines.

The next section elaborates the analytical framework of the study.

4. Analytical framework

The consequences outlined above serve to underline and support the growing recognition that those responsible for the built environment have a vital role to play in developing societal resilience to disasters. It has also revealed the perceived challenges needed to deal with developing a more resilient built environment. There is a dire need for the construction industry and its professionals to adopt disaster resilience concepts and practices, incorporating the multi-dimensional nature of the problem.

To this effect, a detailed study to capture knowledge gaps in the construction industry to increase societal resilience to disasters was conducted by using the analytical framework depicted in Figure 1 as the basis. This framework was developed through an extensive consultation process with CADRE project partners. It was refined with the emerging literature findings and with the opinion of stakeholders, who were interviewed to capture the knowledge gaps.

As shown in Figure 1, the framework is three-dimensional, consisting of the following parameters: property cycle, dimensions of resilience and built environment stakeholders.

4.1 Property cycle

The first axis of the framework consists of different stages of the property cycle. The property cycle represents a sequence of recurrent activities associated with a construction project from its inception to the end of use. The aim of the framework is to understand gaps in the knowledgebase of construction professionals to contribute to the development of a more disaster resilient society. Accordingly, the property cycle was acknowledged as the first axis to reflect the construction perspective in the analysis framework. Having the property cycle as the first axis provided a sound basis to understand the needs and skills associated with a construction professional in contributing to the development of a more disaster resilient society throughout the property lifecycle.

Across the construction industry, various terminologies are used to identify different stages of the property cycle. Some of the established forms of property cycles include: RIBA Plan of Work, 2013, BIM digital plan of work 2013, BS 6079-1:2010, ISO 21500:2012 and OGC

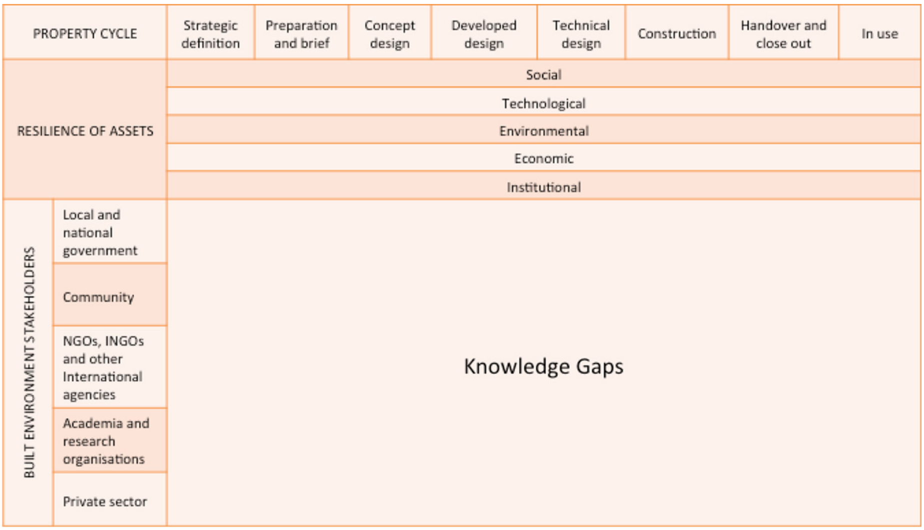

Figure 1. Analytical framework

gateways (CIOB, 2014; Ashworth *et al.*, 2013). RIBA Plan of Work, 2013 is the definitive UK model for the building design and construction process, and therefore, it was used as a basis in defining key stages of the property cycle. RIBA Plan of Work (2013) organises the process of briefing, designing, constructing, maintaining, operating and using building projects into eight work stages. The core objectives of the different stages are outlined below based on the RIBA Plan of Work (2013):

Strategic definition: Identify client's business case and strategic brief and other core project requirements.

Preparation and brief: Develop project objectives, including quality objectives and project outcomes, sustainability aspirations, project budget, other parameters or constraints and develop initial project brief; undertake feasibility studies and review of site information.

Concept design: Prepare concept design, including outline proposals for structural design, building services systems, outline specifications and preliminary cost information along with relevant project strategies in accordance with design programme. Agree alterations to brief and issue final project brief.

Developed design: Prepare developed design, including coordinated and updated proposals for structural design, building services systems, outline specifications, cost information and project strategies in accordance with design programme.

Technical design: Prepare technical design in accordance with design responsibility matrix and project strategies to include all architectural, structural and building services information, specialist subcontractor design and specifications, in accordance with design programme.

Construction: Offsite manufacturing and onsite construction in accordance with construction programme and resolution of design queries from site as they arise.

Handover and closeout: Handover of building and conclusion of building contract.

In use: Undertake *in use* services in accordance with schedule of services.

4.2 Dimensions of resilience

The dimensions of resilience were acknowledged as the second axis to reflect the disaster resilience perspective in the analytical framework. Having dimensions of resilience as the second axis provided a sound basis to understand the disaster resilience needs and skills associated with a construction professional in contributing to the development of a more disaster resilient society.

Within the scope of disaster risk, the concept of resilience can be applied in a range of contexts for example, to individuals, households and communities and to their knowledge, assets and livelihoods, to cities or specific sectors within city economies and to national economies (Satterthwaite, 2013). This research aims to mainstream disaster resilience within the construction process, and therefore, resilience is defined within the context of the built environment. However, the research classified resilience into five dimensions to ensure all aspects of resilience are considered.

Different dimensions of resilience are discussed in academic literature. Seneviratne *et al.* (2010) classified their study into eight categories: Technological, social, environmental, legal, economical, functional, institutional and political. Tierney and Bruneau (2007) identified four dimensions or domains of resilience: technical, organisational, social and economic. Giuliani *et al.* (2016) conducted a study on social and technological aspects of disaster resilience and based on these studies; five dimensions of resilience were considered: economic, environmental, institutional, social and technological. The terminologies used are defined below.

Economic Resilience: According to Seneviratne *et al.* (2010), economic factors are two-fold: economic planning measures and financial measures. Aspects relating to production, distribution and consumption of goods and services were considered as economic planning measures and aspects relating to money and management of monetary assets were considered under financial measures.

Environmental resilience: Factors relating to environment, ecology and sustainability were considered under environmental resilience.

Institutional resilience: Institutional resilience, as defined in this research, refers to the political, legal and institutional factors. Aspects relating to government and policies were considered as political factors. Aspects relating to law, accepted rules and regulations in managing disasters were considered under legal factors, and aspects relating to an organisation linked to disaster management were considered under institutional factors (Seneviratne *et al.*, 2010).

Social resilience: Social resilience was defined based on the definition of Cacioppo *et al.* (2011) of social resilience, which is revealed by the capacities of individuals, or groups, to foster, engage in and sustain positive social relationships and to endure and recover from disasters.

Technological resilience: The final dimension of resilience was about technological resilience. This includes "Application of scientific advances including any tool, technique, product, process and method to benefit disaster management" (Seneviratne *et al.*, 2010, p. 3).

4.3 Built environment stakeholders

Disaster resilience and management is a complex task which requires numerous efforts by various stakeholders such as local government decision makers, city officials and departments, central and provincial governments, the private sector, civil society, non-governmental organisations, community-based organisations, research institutions and institutions of higher learning (Niekerk, 2007). Accordingly, all these stakeholders engage with built environment practice in increasing societal resilience to disasters. The third axis of the framework consists of built environment stakeholders. The aim of the framework is to understand gaps in the knowledgebase of construction professionals to contribute to the development of a more disaster resilient society. Construction professionals provide their services to a number of built environment stakeholders and as such, built environment stakeholders were acknowledged as the third axis. Accordingly, based on extensive consultations with the CADRE project partners and based on Ginige *et al.* (2010), all stakeholders were grouped into five categories: national and local government organisations; the community; non-governmental organisations (NGOs), international non-governmental organisation (INGOs) and other international agencies; academia and research organisations; and the private sector. All private sector organisations, including construction service providers, contractors, clients, professional bodies, insurance providers and small- and medium-sized enterprises, were considered under *private sector*.

There is growing recognition that those responsible for the built environment have a vital role to play in developing societal resilience to disasters. If construction researchers and practitioners are to contribute to reduced risk through resilient buildings, spaces and places, it is important that capacity is developed for modern design, planning, construction and maintenance which are inclusive, inter-disciplinary and integrative. This provided the basis for the identification of this multi-dimensional framework combining the construction life cycle, key stakeholders and the elements of resilience. This further supports the view that resilience needs to be created and embedded through the products and processes of the built environment. In this context, the importance of a community's built environment – the processes and physical products of human creation that enable society to function economically and socially – was examined in the context of broader, societal resilience. The study also considered the relative importance of the end product and the process used to create it. To what extent should those responsible for the planning, design and management of the built environment focus upon the elements of resilience? The starting point is, as society becomes more complex, resilient communities tend to be those which are well coordinated and share common values and beliefs and a sense of interconnectedness.

5. Methodology

The initial investigation aimed at capturing current and emerging skills for built environment professionals that could contribute to enhancing societal resilience to disasters across the property cycle (strategic definition, preparation and brief, concept design, developed design, technical design, construction, handover and closeout, in use), the needs of key stakeholders (local and national government, the community, NGOs, INGOs and other international agencies, academia and research organisations and the private sector) involved in disaster resilience and management and across five dimensions of resilience (social, economic, institutional, environmental and technological).

A broad range of practitioners from Europe and Asia involved with five stakeholder groups were interviewed: local and national government (20), community (15), NGOs, INGOs and other international agencies (12), academia and research organisations (21), and the private sector (19). The aim was to understand gaps in the knowledgebase of construction professionals to contribute to the development of a more disaster resilient society. Separate interview guidelines were prepared for each stakeholder to match their circumstances. The interview guidelines were prepared to capture the needs of the stakeholder groups, and the current and emerging skills, applicable to construction professionals. In total, 87 qualitative semi-structured interviews were conducted. All interviews were voice recorded, transcribed and thematically coded using NVivo data analysis software.

The data gathered from respective interviews were subsequently analysed separately for each stakeholder using the analytical framework depicted in Figure 1 as the basis. Conceptual content analysis was used in this research to identify the key concepts and themes pertaining to the study. Based on Krippendorff (2004) view, the study considered all relevant and significant concepts irrespective of the word/phrase count. Accordingly, the content analysis adopted in this research took the form of qualitative content analysis. The analysis was done using NVivo (Version 10) data analysis software. The themes were presented under two main headings: needs and skills. The category *Needs* covers the stakeholder requirements that emerged from the interviews and the demands specifically made by the interviewees. In addition, the aspects which interviewees believed should be in place while professionals related with them to enhance societal resilience were categorised under the heading *Needs* in the analysis. During the interviews, sets of skills emerged, some of which were displayed by professionals, while serving to reduce the threats posed by natural and human-induced hazards, and some which were desired by interviewees. These sets of skills were categorised under the heading *Skills*. An excerpt of final coding structure is presented in Figure 2.

The interviews generated a long list of needs and skills with respect to the property lifecycle stages under the respective dimensions of resilience. The identified needs and skills were then combined "like-for-like" to produce a broader level of knowledge gaps. Accordingly, 35 knowledge gaps were generated for the stakeholder category "national and local governments", 29 knowledge gaps were generated for the stakeholder category "community", 35 knowledge gaps were generated for the stakeholder category "NGOs,

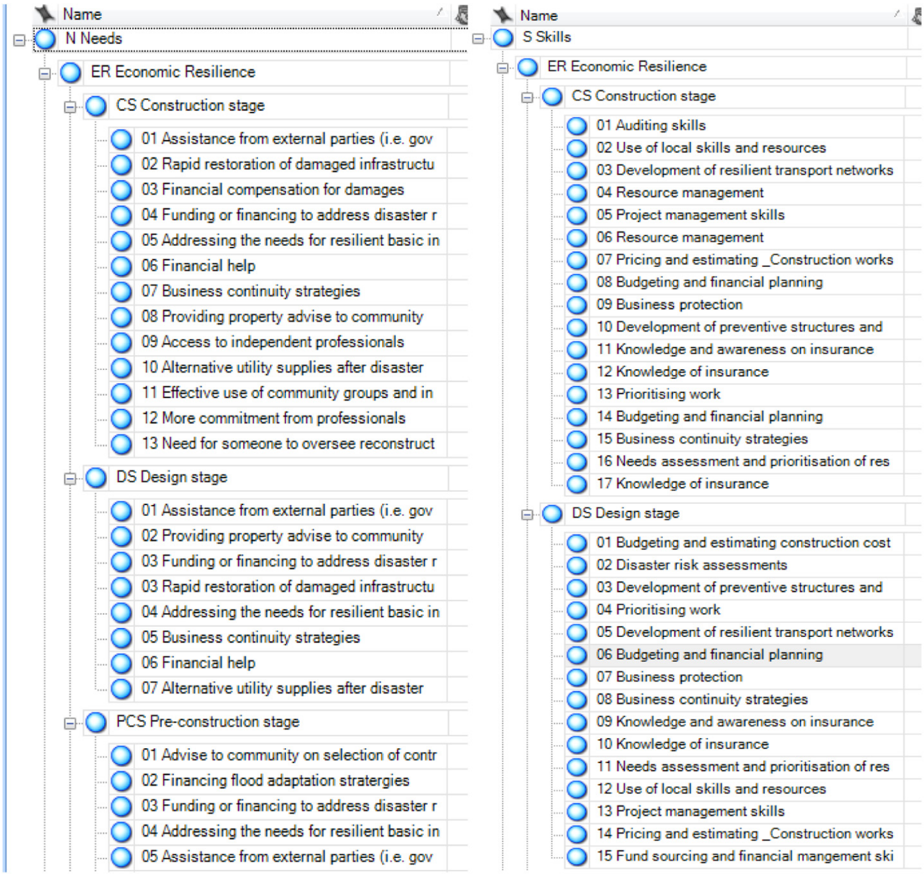

Figure 2.
An excerpt of coding structure for needs and skills

INGOs and international organisations", 32 knowledge gaps were generated for the stakeholder category "academic and research organisations" and 67 knowledge gaps were generated for the stakeholder category "private sector". Finally, a cross-stakeholder analysis was conducted to identify the most relevant and significant concepts which generated 33 knowledge gaps. In addition to semi-structured interviews, a desk review of key policies related to disaster resilience and construction was carried out to reinforce the gaps yielded from the primary data. Based on the desk review of key policies, identified gaps were refined and re-grouped based on the policy level needs across the domain of disaster resilience and construction. Accordingly, 13 key knowledge gaps were identified with a number of associated sub themes.

The findings were then validated using focus group discussions that were conducted as part of six organised stakeholder workshops with the participation of construction and property professionals, disaster management practitioners and policymakers. During the workshops, knowledge gaps identified as part of the research was presented to the participants, and the identified gaps were validated based on the comments of the participants. In addition, brainstorming sessions were conducted during the workshops to discuss key actions that can be carried out in mainstreaming disaster resilience concepts within the construction process. The next section presents the knowledge gaps identified through this process.

6. Knowledge gaps

Analysis of primary and secondary data revealed 13 knowledge gaps and a number of associated sub-themes, as shown in Table I. Almost all of the stakeholders were in agreement about the key knowledge gaps, with the exception of *ethics and human rights*, which was only identified by private sector stakeholders. However, due to the importance placed on human rights in the Sendai Framework, it was considered as one of the key areas.

Among others, the importance of governance, legal frameworks and compliance were strongly highlighted by many interviewees. Interviewees also indicated the importance of greater engagement by the construction industry in developing and implementing building codes and land-use regulations in disaster resilience building efforts. Both primary and secondary data revealed a gap in the knowledgebase of the construction professionals in this context, especially at the planning, design and construction phases of the property cycle. Similarly, many interviewees highlighted the role construction professionals can play in developing resilient technologies, engineering and infrastructure and highlighted a gap in this area. This is applicable for all phases of the property cycle, however, interviewees placed particular emphasis on the *use stage* and outlined the importance of strengthening and retrofitting vulnerable infrastructure.

While recognising the importance of a multi-stakeholder approach in disaster resilience and management, interviewees emphasised the importance of soft skills such as team working, communication and leadership while highlighting the need for alliances, partnerships and interdisciplinary working. All stakeholders equally acknowledged the gap in this area and highlighted the importance of promoting a multi-stakeholder approach and interdisciplinary working. Another key gap identified in the study was about business continuity management (BCM). Although all stakeholders emphasised the importance of BCM, community and private sector stakeholders were more concerned about it. In terms of the construction industry's role, interviewees outlined the importance of effective supply chain management to ensure uninterrupted services during disaster times.

The construction industry's role in multi-hazard risk assessment, disaster response, contracts and procurement and post disaster management were equally highlighted by all stakeholder groups. Another key area was knowledge management. Within knowledge management, data and information management were particularly highlighted by the interviewees, along with related areas such as big data, analytical skills, standardisation and integration of data and performance metrics, which emerged from the secondary data. Furthermore, all stakeholders agreed on the importance of indigenous knowledge and cultural intelligence in planning, designing and constructing houses for disaster affected people. Interviewees from Asia in particular, highlighted the abandoned post-tsunami housing in Sri Lanka due to a lack of social and cultural awareness at the planning and designing stage.

In terms of innovative financial mechanisms, all stakeholders emphasised the importance of risk transfer mechanisms such as insurance. Stakeholders attached to academia particularly highlighted the gaps related to affordable and cost-effective designs and cost benefit analysis, while private sector stakeholders indicated the importance of investment appraisals at the planning stage. However, areas such as public–private partnerships and the economic loss of disasters did not emerge from the interviews. These

No.	Key knowledge gaps	Stakeholders GOV	COM	NGO	ACD	PVS
1	*Governance, legal frameworks and compliance*	x	x	x	x	x
1.1	Building codes, regulations and planning	x	x	x	x	x
1.2	Urban planning and land-use	x		x	x	x
1.3	Health and safety	x	x			x
1.4	Principles of accountability and transparency	x	x	x	x	x
1.5	Inclusive economic planning			Secondary data		
1.6	Changing practice and policies			Secondary data		
2	*BCM*	x	x	x	x	x
2.1	Supply chain management	x	x			
3	*Disaster response*	x	x	x	x	x
3.1	Emergency and temporary shelters	x				
3.2	Evacuation	x	x	x	x	x
3.3	Damage assessment	x	x	x	x	x
3.4	Temporary services	x	x	x	x	x
4	*Contracts and procurement*	x	x		x	x
4.1	Supply chain management	x	x			
4.2	Dispute resolution		x	x		x
4.3	Community wide engagement	x		x	x	x
5	*Resilience technologies, engineering and infrastructure*	x	x	x	x	x
5.1	Capacity and adequacy of critical infrastructure	x	x	x	x	x
5.2	Strengthen/retrofit the vulnerable infrastructure	x	x	x	x	x
5.3	Infrastructure interdependencies	x	x	x	x	x
5.4	Clean and environmentally sound technologies and processes			x	x	
5.5	Automation and standardisation			Secondary data		
5.6	Project complexity			Secondary data		
5.7	Climate change adaptation technologies				x	
6	*Knowledge management*	x	x	x	x	x
6.1	Data and information management	x	x	x		x
6.2	Communication	x	x			x
6.3	Big data analytical skills			Secondary data		
6.4	Standardisation and integration of data			Secondary data		
6.5	Performance metrics			Secondary data		
7	*Social and cultural awareness*	x	x	x	x	x
7.1	Cultural intelligence	x	x	x	x	x
7.2	Indigenous knowledge	x	x	x	x	x
8	*Sustainability and resilience*	x				
8.1	Environmental impact assessment and management	x	x	x	x	x
8.2	Sustainable design principles	x	x	x	x	x
8.3	Waste production and pollution of land water and air					x
8.4	Sustainable retrofitting			Secondary data		
8.5	Debris management					x
9	*Ethics and human rights*					x
9.1	Reflecting social demographics			x		
9.2	Social responsibility			x	x	
10	*Innovative financing mechanisms*	x	x	x	x	x
10.1	Budgeting and estimating	x	x	x	x	x
10.2	Investment appraisals and cost benefit analysis				x	x
10.3	Economic loss of disasters			Secondary data		
10.4	Affordable and cost-effective design and usage				x	

(*continued*)

Table I. Knowledge gaps

No.	Key knowledge gaps	Stakeholders GOV	COM	NGO	ACD	PVS
10.5	Claims and insurance	x	x	x	x	x
10.6	Public-private partnership (PPP)			Secondary data		
11	*Multi stakeholder approach, inclusion and empowerment*	x	x	x	x	x
11.1	Team working – collaboration and cross professional working	x	x	x		x
11.2	Soft skills of communication	x	x			x
11.3	Community empowerment	x		x	x	x
11.4	Leadership and people management	x	x		x	x
11.5	Disaster awareness	x	x	x	x	x
11.6	Alliances and partnerships	x	x	x	x	x
11.7	Interdisciplinary working				x	
11.8	Change management		x		x	
12	*Post disaster project management*	x	x	x	x	x
12.1	Time management	x	x		x	
12.1	Human resource management	x		x		x
12.2	Leadership and people management	x	x		x	x
12.3	Process and quality management	x	x	x	x	x
12.4	Materials and resource management	x	x	x	x	x
13	*Understanding disaster risks*	x	x	x	x	x
13.1	Vulnerability, risk and exposure mapping	x	x	x	x	x
13.2	Multi hazard risk assessment	x	x	x	x	x

Stakeholders	Abbreviation
Local and national government	GOV
Community	COM
NGOs, INGOs and International agencies	NGO
Academia and research organisations	ACD
Private sector	PVS

Table I.

areas were cross-cutting areas of the Sendai Framework, and as a result, they were included under innovative financing mechanisms. Only the government stakeholders highlighted the importance of sustainability and resilience. However, all stakeholders emphasised the importance of environmental impact assessment and management.

7. Recommendations

This paper is an account of a study to identify gaps in the knowledgebase of construction professionals that are undermining their ability to contribute to the development of a more disaster resilient society and preventing the mainstreaming of disaster resilience within the construction process. In addition to the reported gaps in the knowledgebase of construction professionals, the study further sets out a series of recommendations to key actors in the built environment on how to more effectively mainstream disaster resilience in the construction process. These recommendations were formulated through an extensive consultation process with CADRE project partners and refined with the opinion of the workshop participants. The recommendations are set out as five key themes: education, policy, practice, research and cross-cutting.

7.1 Education

This section highlights the recommendations for higher education.

Multi-stakeholder approach: Built environment researchers and educators must interact and collaborate with policymakers and practice-based actors at the local, national, regional and global levels. Collectively, they must work to identify and address problems and knowledge gaps in the field. Rather than being passive recipients of new knowledge, policymakers and practitioners should join with construction and property groups in higher education to form multi-stakeholder groups that work together from the outset to design and deliver new knowledge. The scientific results will be more relevant and actionable.

Multi-hazard approach: An all-hazard, problem-focused approach should be used in built environment research and education to address the complexity of disaster risk. This will require collaboration and communication across the scientific disciplines. Built environment departments can promote this approach by providing construction and property researchers and students with exposure to a variety of disciplinary work, exposure to interdisciplinary work, exposure to and experience with tools and methods from a variety of disciplines, exposure to and experience with interdisciplinary tools and methods and experience working with others in an interdisciplinary model.

Address problems in the field by providing localised knowledge and solutions to the local context: Built environment educators and researchers must recognise the importance of public engagement before, during and after research, in particular, with institutions and individuals at risk of disasters. A lot of disaster knowledge has been developed at an abstract level, or based on a specific context. Public engagement can help calibrate knowledge to a local context, extending the impact and reach of existing research.

Develop open educational resources that are freely accessible: The recent shift towards open access of research outputs and education is to be welcomed and should continue to be encouraged. This includes the use of green publishing routes where possible, or financially supporting gold publishing as necessary. Higher education should be supported to develop open educational resources that are freely accessible and openly licensed, for use in teaching, learning and assessing as well as for research purposes linked to building resilience.

Flexible and customisable educational programmes: There is currently a lack of programmes which meet employer needs. Higher education must develop flexible and customised programmes and curricula, whether this is a module in regular masters or the undergraduate curriculum, or, as dedicated postgraduate programmes such as professional doctorates. Detailed market research will help to ensure that the educational programmes address the problems from the field and can promote affordable solutions, as per local context, including the cultural calibration of technology. Educational programmes should promote a multi-disciplinary approach and understanding, drawing upon a combination of different faculties. Built environment disciplines should be at the core of such programme offerings. The problem-based nature of the field determines that programmes should offer an appropriate balance of theory and field experiences. Internship programmes for students in government, NGOs, UN agencies, private sectors and research institutions should be strongly promoted.

7.2 Policy

This section highlights the policy recommendations to mainstream disaster resilience in the construction process.

Development of the Sendai Framework "Words into Action" Implementation Guide for Construction Policy and Practice: Through the UN Words into Action process, one or more implementation guides should be developed on construction policy and practice. These guides can be used as practical guidance to support implementation, ensure engagement and ownership of action by all construction industry stakeholders. They should translate the global targets and four priorities into meaningful actions that can be adopted by the various actors in the construction industry, including professional bodies, industry regulators, clients and construction and property companies.

7.3 Practice

This section highlights the actions that are proposed for built environment practice to mainstream disaster resilience in the construction process.

Built environment professional bodies to recognise disaster resilience through accreditation: Built environment professional bodies are responsible for setting professional standards for their members and for accredited degree programmes. Therefore, it is vital that construction and property professional bodies continuously update the accreditation or services needed to identify and verify expertise in weak or new, emerging areas of practice highlighted as knowledge gaps in this paper. Without this recognition, it is unlikely that construction professionals will value education and training in related skills.

Disaster resilience to be part of ethics and professional standards: Construction and property professional bodies must ensure that ethical behaviours are practised across the sectors they represent. All professional bodies have created a set of professional and ethical standards to guide their members and it is important that disaster resilience is also a part of ethics and professional standards.

Regulatory frameworks are required for reconstruction following large-scale disasters: Resourcing is a key challenge for post disaster project management and successful resourcing depends on multi stakeholder collaboration, market flexibility, donor management and government intervention. Whilst routine and sometimes existing construction processes have often proved adequate for smaller scale disasters, a greater degree of coordination is required for programmes of reconstruction following a larger disaster which must be addressed through formal, regulatory frameworks.

7.4 Research

This section highlights the recommendations to the research community in the built environment on how to mainstream disaster resilience more effectively in the construction process.

Understand the audience and devise appropriate dissemination mechanisms for scientific knowledge: The research community must make more effort to translate traditional outputs into practical methods that can readily be integrated into policies, regulations and implementation plans towards building resilience. National research assessment exercises, the European Union and national funding bodies and higher education promotion policies, which often emphasise traditional academic outputs (e.g. peer-reviewed journal articles), should appropriately incentivise and reward non-standard scientific outputs, such as research summaries and policy briefs.

Translate traditional outputs into practical methods that can readily be integrated into construction policies and regulations related to resilience building: Science provides an evidence base that can be relevant to, and therefore draw together, different areas of policy. Knowledge integration provides a starting point for building and operationalising resilience through the co-design of policies and interventions by scientists, practitioners, policymakers and communities themselves. Standardised definitions are essential to the operationalisation of concepts such as resilience for research, monitoring and implementation purposes.

Collaboration across disciplines regionally and internationally: There are already a number of regional initiatives that promote collaboration in Higher Education towards building resilience. These networks and events have helped to gather a wide and advanced set of competencies in the field of disaster resilience. These networks should be supported and encouraged to grow. Given their different capacities, the EU must continue to strengthen its engagement with developing countries through international cooperation and global partnership for development, and continued international support, to strengthen their efforts to reduce disaster risk. In supporting this, the current regional networks should collaborate to form a global higher education network that can influence strategic agendas.

Coordination mechanisms for science: Funding bodies for science should coordinate their efforts to ensure that resources are being deployed effectively and efficiently, and to promote collaboration across disciplines, as well as regionally and internationally. This will help to avoid duplication of effort and integrate funding.

An aggregator of knowledge to improve access and focus on quality: The volume of built environment research activity and associated outputs has rapidly increased over recent decades, none more so than that relating to disaster risk reduction and resilience building. Therefore, identifying and accessing the most recent and high-quality science is proving increasingly challenging, despite the advance of technology. Methods and tools for aggregating knowledge must be developed to facilitate access to science, technology and innovation outputs that help inform policy-making and practice and also ensure that educational programmes and researchers have access to, and can build upon, state of the art information.

7.5 Cross-cutting

Some of the recommendations were not directly linked to the four themes discussed in the above sections and were related to one or more of the themes: education, policy, practice and research. Therefore, these proposals were identified as cross-cutting recommendations. This section highlights the key cross-cutting recommendations proposed to mainstream disaster resilience in the construction process.

Link research, education and practice: The Sendai Framework for Disaster Risk Reduction 2015-2030 aims to achieve the substantial reduction of disaster risk and losses, and in doing so, it is important that the policy-science gap is closed with research that can be translated into action. Research studies document a trend of increasing disaster losses, but the translation of research findings into practical actions has proven difficult and remains a barrier which prevents the best use of science. As such, there is a need for construction and property groups in higher education, through researchers and educators, to provide and communicate actionable knowledge with explicit links to inform effective, evidence-based decision-making.

Common language: Scientific results are often subject to misunderstanding due to poor comprehension of numbers and statistics, as well as conflicting languages and terminology. Correct comprehension depends not only on the skills and knowledge of the reader but also on the way the information is presented. Therefore, it is important that educators and the research community take time and effort to understand the audience they are seeking to inform. Also, it is important to add information to help readers better understand the strengths and limitations of the scientific evidence. Adding meta-information that explains concepts such as the quality of the evidence may help eliminate frustration and trigger reflection.

8. Conclusions

There have been growing calls for greater engagement of the construction industry in disaster resilience building efforts. This paper investigates the gaps in the knowledgebase of construction professionals who are undermining their ability to contribute to the development of a more disaster resilient society and preventing the mainstreaming of disaster resilience within the construction process. The paper reports the findings of 87 stakeholder interviews, which were supplemented by a comprehensive analysis of key policies related to disaster resilience and management. The primary and secondary data revealed 13 key knowledge gaps and a number of associated sub-themes. The key knowledge gaps identified are governance, legal frameworks and compliance; BCM; disaster response; contracts and procurement; resilience technologies, engineering and infrastructure; knowledge management; social and cultural awareness; sustainability and resilience; ethics and human rights; innovative financing mechanisms; multi stakeholder approach, inclusion and empowerment; post disaster project management; and multi hazard risk assessment. The study identifies a series of recommendations to key actors in the built environment on how to mainstream disaster resilience more effectively in the construction process. Accordingly, the study proposes key recommendations for education, policy, practice and research. This study is part of an EU funded research project, CADRE, which is seeking to develop innovative and timely professional education that will update the knowledge and skills of construction professionals in the industry and enable them to contribute more effectively to disaster resilience building efforts.

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