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Mapping construction industry roles to the disaster management cycle

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Abstract

The construction industry is central to the promotion of disaster resilience through building procurement, design, construction, etc. It plays a key role in responding to disasters - dealing with collapsed and damaged buildings and infrastructure and providing temporary shelter and services to affected communities - and also in post-disaster reconstruction efforts.
This research identifies the disaster resilience roles of construction professionals on the basis of the literature and maps these to the disaster management cycle in order to draw on the emerging framework to determine potential construction industry education and research opportunities associated with the pursuit of societal disaster resilience.

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1. Introduction

Over the past decade, annual global fatalities from natural disasters have averaged 106,000 and estimated average annual losses have been US$165bn. The long-term trend has seen both of these numbers rising. (Munich Re, 2012) The unprecedented rate of urban growth, increasing dependence on complex technical systems and infrastructure

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networks combined with climate change predictions, all suggest that exposure to anthropogenic and natural hazards is increasing. (Baker, 2012; Hill et al., 2012; IPCC, 2013)

Disaster resilience has consequently gained in prominence and has been increasingly seen as a central concern for construction professionals. With emergent mass urbanisation and climate change issues, this is set to continue if not strengthen and increasingly drive construction industry developments. The World Bank's Economics Adaptation to Climate Change (EACC) team estimate that climate change adaptations to cope with a 2 degree C warmer world by 2050 will require between \$75bn and \$100bn annually dominated by infrastructure adaptation costs. (EACC, 2010) Despite this, disaster resilience-related education and research remains a relatively small and specialised area within the built environment academic context.

This paper attempts to draw together the many examples of construction professionals' involvement in disaster resilience from the literature and organise them into a coherent framework. By doing so, it is intended to gain a more comprehensive overview of the roles of construction professionals through the disaster management cycle in order to identify education and research needs. These needs will, in turn, inform the curriculum for a disaster resilience-focused Professional Doctorate programme for built environment professionals which is currently being developed under the Collaborative Action towards Disaster Resilience Education (CADRE) project.

2. Framework for considering construction industry roles in disaster resilience efforts

Numerous calls for increasing the engagement of the construction industry in disaster resilience efforts, including those of Hecker et al. (2000), Prieto (2002), Godschalk (2003), Liso et al. (2003), Lorch (2005), Aldunate et al. (2006), Rees (2009), Haigh and Amaratunga (2010) and Bosher and Dainty (2011) have indicated a need for greater integration of disaster resilience concepts into the general education of construction professionals. In addition, they have suggested that specific, additional opportunities exist for expanding construction education and research further into disaster resilience-related areas.

Whereas a large number of sources refer to specific construction industry roles in disaster resilience (e.g. the seismic design of buildings), there is comparatively little available in the literature relating to overall frameworks for systematically defining the scope of construction professionals' potential contribution to disaster resilience and therefore on which to base educational and research programmes supporting disaster resilience in the built environment.

Haigh et al. (2006) proposed that research should explore ways in which the construction industry could contribute towards improved resilience and recommended the adoption of a more expansive view of the construction life cycle to encompass the need to anticipate, assess, prevent, prepare, respond to and recover from disruptive challenges. This implies a framework resulting from the integration of the typical construction life cycle (planning – design – construction – operation – decommissioning) with the disaster management cycle (pre-disaster (prevention / mitigation) – disaster – post-disaster (response / recovery)).

Investigations of the involvement and inputs of key stakeholders (architects, engineers, developers, clients, etc.) with respect to disaster risk reduction through the construction life cycle have notably been carried out by Bosher and Chmutina (Bosher, 2013; Chmutina and Bosher, 2014). Their work has emphasized the actual versus ideal inputs of key stakeholders thus exposing gaps in existing practice. However, it has been focused on 'built-in' resilience, i.e. the preventative /mitigation-oriented, pre-disaster interventions mapped to a 'normal' (as opposed to a more expansive) construction life cycle so that disaster response and recovery / reconstruction have been beyond the scope of their research.

Prieto (2002), in his address to the Royal Academy of Engineering on the lessons drawn from the September 2001 terrorist attacks on the World Trade Center towers, framed his vision of future education requirements with reference to the disaster management cycle. He proposed a new '3Rs' - resist, respond and recover - as the cornerstone for the education of engineers. With regard to both 'respond' and 'recover', he drew attention to specific, additional roles and the corresponding training and educational needs of construction professionals relating to infrastructure operation during emergency response and subsequent recovery of critical infrastructure to normal operation. Similarly, Peña-Mora et al. (2008) identified specific disaster response roles for civil engineers and recommended their inclusion into the emergency response team traditionally comprising only the police, fire and ambulance services.

It appears that, while the incorporation of disaster resilience interventions into the normal construction life cycle is of great importance, there are, in addition, further disaster resilience roles for construction professionals which fall outside the normal construction life cycle as they arise only in the event of a disaster but which should nevertheless be taken into account in the education and training of construction professionals.

In addition to this, the World Economic Forum's Engineering and Construction Disaster Resource Partnership has highlighted the various ways in which construction and consultancy firms can deploy their assets (labour force, materials, equipment, supply chains, etc.) and expertise in support of disaster response and relief efforts. (WEF, 2010) This suggests the scope of construction professionals' engagement in disaster resilience is again wider and a framework comprising the construction life cycle as well as the disaster management cycle would still be insufficient for capturing all the relevant roles. Beyond the project-specific construction life cycle, a multi-project, contextual level to capture firm, industry, locality-specific and other, higher level roles should seemingly be incorporated into the framework.

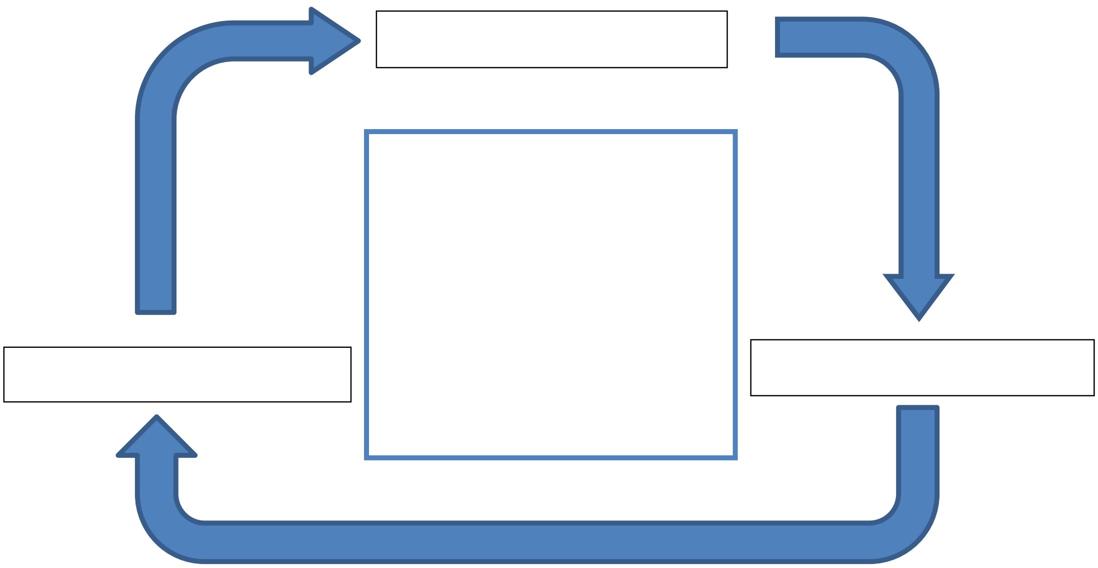

Fig. 1. Framework for capturing the disaster resilience roles of construction professionals through the disaster management cycle

Figure 1 shows a tentative framework aimed at incorporating all of the roles of construction industry professionals through the phases of the disaster management cycle and relating these to the (project level) construction life cycle of individual assets as well as to the wider (multi-project) contextual aspects. The following section draws on the literature to provide specific examples of roles falling into each of these categories.

3. Disaster prevention roles

3.1. Disaster prevention at the multi-project (contextual) level

Numerous authors, including Gavieta and Onate (1997) and Chmutina and Bosher (2014), have noted the importance of appropriate building regulations and land-use zoning in disaster mitigation and that their absence or non-enforcement has been a contributory factor in many disasters, particularly in developing countries. However, in the anticipated, increasingly hazard-prone and dynamic context of the future, even the best current regulations, codes, practices and preparations will require revision. To enable this, a better understanding of the interdependencies of infrastructure systems and the interconnections between the built environment and the dynamic properties of the wider technical – biophysical – social system in which it is contained is needed. This has profound implications for the design of the built environment and calls for multidisciplinary and multi-hazard approaches, regular review (and tightening) of urban planning policies and building codes and the continual re-assessment of design guidance and the vulnerability of existing assets. (Benson and Twigg, 2007; Chang, 2009; Anderies, 2013; Bosher, 2013)

Despite increasing annual losses from disasters, there is a considerable deficit in resilience investment even in the richest and most hazard-prone countries. (Hill et al., 2012) Owners are often unwilling to invest in disaster risk reduction measures and a relatively small proportion of natural disaster-related property damage is covered by insurance (about 30% on average in developed countries and much less in developing countries) and this is mostly the result of government regulation rather than owners' initiative. (Kenny, 2012; Chmutina and Bosher, 2014) Considerable work remains to be done in terms of raising hazard and vulnerability awareness among stakeholders, the economic and financial evaluation of disaster resilience interventions and, more generally, to engender a culture of resilience. (Egbelakin et al., 2011; Bosher, 2013) To this end, some work has been carried out to date, including that of Kaluarachchi (2013) on stakeholders' awareness of the vulnerability of their built assets to extreme weather events, and Eeing and Kruse (2007) and Simmons and Sutter (2010) on the market premium associated with tornado shelters.

At the level of construction industry firms, a number of studies consider the issue of business continuity planning including Webb et al. (2000), Yoshida and Deyle (2005), Lee et al. (2013) and Xiao and Peacock (2014), though Kenny (2012) suggests that these efforts have been limited in their effectiveness.

3.2. Disaster prevention through the (project-specific) construction life cycle

Project-level measures for disaster prevention and mitigation begin with site selection for developments and the enforcement of planning regulations and building codes throughout the design, construction and use of facilities. (Gavieta and Onate, 1997; Benson and Twigg, 2007; Chmutina and Bosher, 2013) As Meli and Alcocer (2000) have pointed out, enforcement of codes is not merely a legal issue but rather one of communication and understanding between the intentions of the well-informed specialists and academics who develop the codes and the practices of the design professionals and construction personnel who must implement them.

Disaster risk reduction measures for incorporation in the design of new facilities have always received considerable attention and, ultimately, have formed the basis of most building codes. Recently, special consideration has been given to the design of critical facilities (e.g. hospitals) and infrastructure and their need to resist extreme loading and catastrophic failure (Prieto, 2002; Benson and Twigg , 2007; O'Rourke, 2007).

A far greater challenge than the incorporation of disaster risk reduction measures into new developments is to increase the resilience of existing facilities. Surveys of the current building and infrastructure stock including multi-hazard appraisals, vulnerability assessments and the design and implementation of retrofit solutions are all urgently required. Similarly, deferred maintenance has been identified as a major contributory factor to disasters through its effect on capacity reduction. (Prieto, 2002; Camilleri, 2003; Benson and Twigg, 2007; Chmutina and Bosher, 2014)

4. Disaster response roles

4.1. Disaster response at the multi-project (contextual) level

As mentioned above, the World Economic Forum's Engineering and Construction Disaster Resource Partnership has investigated ways in which construction industry firms can deploy their assets and expertise in the event of a disaster to support response and relief efforts. For example, construction companies could contribute labour, materials and equipment as well as their organizational, structural engineering and temporary works expertise and existing networks, supply chains and communications systems to aid relief operations. (WEF, 2010)

Prieto (2002) argues that emergency response training (covering actions, interactions, communications and decision-making) needs to be incorporated into infrastructure system operational training and integrated with first responder protocols. He goes on to suggest that the increasingly engineered urban environment also calls for the inclusion of construction professionals among the traditional emergency response team of police, fire and ambulance services.

4.2. Disaster response at the project-specific level

With respect to specific built facilities, the need for emergency response plans including predetermined evacuation routes and off-property staging areas is evident. (Prieto, 2002)

The role for civil engineers in disaster response includes:

- Identification, assessment and monitoring of structural hazards and safest routes for response personnel
- Design and implementation of structural hazard mitigation measures (bracing and shoring of unstable structures)
- Identification of priority search areas for victims trapped in collapsed buildings
- Providing advice concerning the placement and operation of heavy equipment
- Coordination and management of contractors (Peña-Mora et al., 2008)

El-Tawil and Aguirre (2010) note the importance of training structural engineering search and rescue personnel and explore the use of simulations and virtual environments for such training.

5. Disaster recovery roles

5.1. Disaster recovery at the multi-project (contextual) level

The concept of 'learning' as a means of disaster risk reduction applies particularly to capturing post-disaster lessons. (Gregory et al., 2012; Thorvaldsdottir and Sigbjörnsson, 2014). Benson and Twigg (2007) note the importance of carrying out diagnostic surveys with the intention of revising land-use planning, regulations, building codes, design criteria and construction requirements in the aftermath of any disaster.

Post-disaster reconstruction efforts pose both challenges and potential opportunities for construction enterprises and numerous investigations into these issues have been carried out by, for example, WEF (2010), Chang et al. (2011), Haigh and Sutton (2012) and Tatum and Terrell (2012). Primarily, they indicate that the construction sector, particularly the larger, multinational enterprises have much to offer in the way of expertise, resources and networks. However, strategic as opposed to humanitarian post-disaster engagement is seen as problematic. Haigh and Sutton (2012) suggest that explicit and transparent terms of agreement should form the basis of partnerships with construction enterprises. This raises the possibility for development of new procurement arrangements specifically for the post-disaster context.

5.2. Disaster recovery at the project-specific level

Consideration of specific project issues in the post-disaster context includes that given by Olsen and Porter (2011) to the phenomenon of price rises in construction following a disaster, Camilleri (2003) on the siting of temporary shelters, Swan (2000) on the management of debris and Grosskopf (2010) on the particular safety challenges and training requirements for disaster recovery and reconstruction.

6. Summary of the disaster resilience roles for construction professionals identified from the literature

The diverse roles of construction professionals through the disaster management cycle identified from the literature review are summarized in Table 1. It is notable from the table that, in some cases, the boundary between the multi-project and the project-specific contexts is not entirely clear. This suggests that some of the roles span both domains and, in addition, some roles appear to bridge across multiple phases of the disaster management cycle. However, to the extent that a coherent, though not necessarily comprehensive list of roles has emerged, the framework appears to have proven moderately useful in the role identification process.

Table 1. Summary of construction professionals' roles in disaster resilience.

Disaster prevention roles at the multi-project (contextual) level
Continual re-assessment and revision of high level requirements and guidance (building regulations, land-use zoning, building codes, design guidance).
Continual re-assessment of the vulnerability of the existing built environment
Understanding the complex nature of the built environment, its interdependencies and interconnections with the wider context in which it is contained
Understanding the complex, dynamic and multi-hazard nature of the wider context
Evaluating the cost-benefit of disaster risk reduction measures including insurance premiums and property market value effects
Raising hazard and vulnerability awareness among stakeholders (effectively communicating vulnerability and disaster resilience information)
Business continuity planning for construction industry enterprises
Disaster prevention roles through the (project-specific) construction life cycle
Site selection for disaster resilience
Interpretation and implementation of regulations, guidance and best practices at the project level
Developing and implementing specific disaster resilience enhancements for critical facilities and infrastructure
Developing and implementing retrofit solutions for existing facilities
Investigating and taking action to rectify capacity reductions arising through deferred maintenance
Disaster response roles at the multi-project (contextual) level
Leveraging construction industry firms' assets and expertise to contribute to disaster response and relief operations
Integrating infrastructure systems' operation in emergencies into first responder protocols
Disaster response roles at the project-specific level
Development of disaster response plans for individual facilities
Identification, assessment and monitoring of structural hazards and safest routes for response personnel
Designing and implementing emergency structural hazard mitigation measures
Identification of priority search areas for victims trapped in collapsed buildings
Advising on the placement and operation of heavy equipment in rescue efforts
Coordination and management of contractors participating in disaster response
Disaster recovery roles at the multi-project (contextual) level
Carrying out post-disaster diagnostic surveys to assess the performance of land-use planning, regulations, codes, design criteria and construction practices
Investigating private sector participation in post-disaster reconstruction and developing procurement arrangements in support of mutually beneficial participation
Disaster recovery roles at the project-specific level
Siting and servicing of temporary shelters
Post-disaster debris and waste management
Managing health and safety issues specific to post-disaster reconstruction operations

7. Emerging needs and the Collaborative Action towards Disaster Resilience Education (CADRE) project

Each of the roles identified above reflect the need for corresponding educational and research programmes to support their efficient performance by construction professionals. The literature review reported here is part of a research effort carried out under the Collaborative Action towards Disaster Resilience Education (CADRE) project funded by the European Commission's Lifelong Learning Programme. CADRE aims to address current and emerging disaster resilience needs through the development of curricula for construction professionals. In particular, CADRE will develop an innovative professional doctoral (DProf) programme that integrates professional and academic knowledge in the construction industry to develop societal resilience to disasters.

8. Conclusions

Despite some overlap between the multi-project and project-specific domains and some roles bridging more than one phase of the disaster management cycle, this attempt to organize the many and varied disaster resilience roles of construction professionals identified in the literature by mapping them to the disaster management cycle appears to have been successful in deriving a coherent, if not comprehensive, list of construction industry roles in disaster resilience. Each of the roles identified reflects a corresponding need for construction education and research inputs.

Undoubtedly, additional roles could be included in the list and further refinement of the framework might enable gaps in the list of roles to be more easily identified.

Beyond the specific requirements of educating construction professionals for greater societal disaster resilience, consideration of the challenges facing the built environment from a 'disaster perspective' provides new insights. The trends of mass urbanization, climate change and an increasingly engineered urban environment suggest that research, innovation and investment in the built environment will increasingly be driven by disaster resilience considerations.

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