An organizational capability framework for earthquake recovery

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Engineering and construction capability affects the cost and pace of post-disaster recovery. An organizational capability framework for effective earthquake recovery was developed after studying longitudinally 15 engineering and construction organizations following the 2010/11 earthquakes in Christchurch, New Zealand. The longitudinal case studies, conducted from 2012 to 2015, revealed insights regarding the multitude of decisions that affected demands for engineering and construction post-earthquake, and thus the capability of organizations to meet demands. The framework presents five major challenges faced by organizations operating in an earthquake recovery environment and three core organizational capabilities required to address these challenges: disaster recovery know-how, organizational adaptive capacity to meet changing demands, and collective support among organizations. The findings offer real experience to help engineering and construction industries anticipate capability challenges and prepare for them as a business, as a sector, and as a partner with government agencies in a disaster management context.

INTRODUCTION

When the Darfield earthquake struck Christchurch in 2010, the New Zealand engineering and construction sectors were going through a recession period of low activity. There was a limited pool of engineering professionals in the country who had earthquake damage assessment and design experience (PWC, 2011). Professional institutions, universities and building regulatory agencies assembled in workshops and seminars to share solutions for damage assessment and safety evaluation of damaged buildings. The Canterbury region

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subsequently suffered a sequence of aftershocks. These earthquakes are together termed the Canterbury earthquake sequence. The earthquake of magnitude 6.3 on 22 February 2011 was the most severe aftershock, taking the lives of 185 people and causing buildings to collapse, further damage to infrastructure and widespread liquefaction (GNS Science, 2011). This earthquake also triggered incidents of land movement, the collapse of cliffs and rock falls in the Port Hills (Stevenson et al., 2011). The effects of liquefaction resulted in the need for substantial land review and zoning across the city (Environment Canterbury Regional Council, 2012).

Unlike the September 2010 event, when limited-to-moderate damage was observed in engineered reinforced concrete (RC) buildings, the February event in 2011 severely damaged about 16% of 833 RC buildings in the Christchurch Central Business District (CBD) (Elwood et al., 2012). Nationwide engineering resources were greatly stretched in dealing with structural and land issues, and large numbers of professionals were brought in from countries with earthquake risk by local consultancies and authorities to assist (Chang et al., 2012c). Some national development activities and large construction projects that had been planned before the earthquakes had to cease as funding was re-allocated for disaster recovery projects (Parker & Steenkamp, 2012). One year on from the February 2011 event, increases in construction demand had posed challenges for the supply of labor and building materials throughout the country (Chang & Wilkinson, 2012; MBIE, 2012).

From the initial earthquake response to longer-term reconstruction, activities such as initial and detailed assessment of building safety and damage, emergency repairs for restoring basic utility and service functionality, and restoration of damaged infrastructure and housing, all require sufficient engineering and construction tools, processes and human resources with appropriate skills and knowledge. However, a long-standing issue in rebuilding following major disasters has been the inadequacy of human resources and capacities in the engineering and construction sectors (Chang-Richards et al., 2014). There is a need to respond quickly, using or building on existing skills, capacity and arrangements (Johnson & Olshansky, 2013). The urgency to replace lost built facilities within a short timeframe often generates a surge in demand for materials and labor, resulting in higher repair or rebuild costs (Chang et al., 2012; Olsen & Porter, 2013).

There are a number of interdependencies through both pricing mechanisms and construction industry pooling of resources that influence a region's ability to rebuild (Wein &

Rose, 2011). Factors, such as revised building codes and standards (Chang-Richards et al., 2013; Chang et al., 2010), regulatory requirements (Le Masurier et al., 2008; Rotimi et al., 2006), altered housing needs and budgetary constraints (Boen, 2006; Mukherji, 2010), affect the demands on engineering and construction following a major disaster.

Although the role the engineering and construction organizations play in large disaster settings was recognized in the literature (Haigh et al., 2006; Myburgh et al., 2008; Ofori, 2002), very little is known about how they can cope with changing reconstruction demand from a capability perspective (Chang et al., 2010). The research reported in this paper seeks to fill this gap by studying the Christchurch earthquake recovery[1] and answering the following questions:

1) What challenges are faced by engineering and construction organizations operating in earthquake recovery?
2) What critical organizational capabilities are needed for them to address the identified challenges?

The study was undertaken longitudinally with 15 engineering and construction organizations over a period of four years (2012-2015). A framework of key organizational capabilities required for effective earthquake recovery was developed from the case studies. The framework can be used by engineering and construction organizations as a tool to measure their capability gaps and to guide them in developing those critical capabilities needed for operating in an earthquake recovery environment.

The first section of this paper presents a review of literature, drawing on the organizational capability studies to develop a theoretical background relevant to the context of this study. The case studies are then introduced, detailing the data collection and analysis methods. The results in relation to the post-earthquake decisions that have affected demands for engineering and construction in Christchurch are reported, followed by findings with regard to an organizational framework for disaster recovery. We then discuss the results of our analysis and conclude by reflecting on their practical implications, as well as the relevance of organizational capability theory for disaster management research.

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[1] In this study, we use the definition suggested by Lindell (2013) that disaster recovery is a phase in the emergency management cycle that frequently overlaps with the emergency response. It has four functions: disaster assessment, short-term recovery, long-term reconstruction, and recovery management.

THEORETICAL CONTEXT

In this study, we define 'organizational capability' as the attributes of an organization, in terms of resources, skills, processes and knowledge that enable it to pursue desired outcomes. It is a concept that has been used to encapsulate the resource-based theory in regard to organizational sources of sustainable competitive advantage (Collis, 1994; Sharma & Vredenburg, 1998). As yet there is no consensus on the definition of organizational capability in literature. Teece et al. (1990) defined capability as a set of differentiated skills, complementary assets and routines that contribute to an organization's competitive capacities and high performance. Makadok (2001, p389) suggested a capability as being an organizationally embedded, non-transferable, firm-specific resource whose purpose is to improve the productivity of other resources possessed by the firm. By founding the concept of organizational capability on the broader concept of organizational routine, Winter (2003, p991) considered an organizational capability as a high-level routine (or collection of routines) that, together with its implementation input flows, confers upon an organization's management a set of decision options for producing significant outputs of a particular type. Routine represents a general way of doing things. Therefore, routines are recurrent patterns of behaviors or activities in some context that has been learned by an organization.

When comparing the terms 'resources' and 'capabilities', many scholars, such as Grant (1991) and Day (1994), regarded organizational capabilities as the abilities of an enterprise to deploy resources, using organizational processes, to achieve a desired end. These capabilities are firm-specific and can be developed over time through complex interactions among the firm's resources (Amit & Schoemaker, 1993). The capability approach is also closely linked to the knowledge-based view of the firm. Dosi et al. (2000) identified organizational capabilities with the know-how of a firm to undertake practices to solve a specific problem. Gold et al. (2001) further suggested a knowledge infrastructure, consisting of technology, structure and culture, along with a knowledge-based process for acquisition, conversion, application, and protection of knowledge resources, as an essential organizational capability.

As capabilities are deeply rooted within the fabric of a firm, it is difficult for competitors to identify and imitate them (Alimin et al., 2012; Helfat & Peteraf, 2009; Schienstock, 2009). Winter (2003) argued that organizational capability is essentially constituted of the high-level organizational practices used to coordinate the productive activities of the firm. These practices represent a distinctive set of problem solving actions or competencies that organizations can rely on when pursuing key goals (Feldman & Pentland, 2003). Although slightly different, the term 'competencies', has been interchangeably used in literature to characterize organizational capabilities (Schienstock, 2009).

A recent stream of studies in organizational literature suggested that organizations should develop and deploy specific capabilities for facing complexity or environmental volatility, termed dynamic capabilities (e.g. (Eisenhardt & Martin, 2000; Townsend & Busenitz, 2015; Wu, 2010)). The concept of dynamic capability was introduced by Prahaland and Hamel (1990), and is concerned with a firm's ability to address rapidly changing environments while retain competitive advantages (Teece et al., 1997). This concept of dynamic capability is similar to terms coined by other scholars. For example, Kogut and Zander (1992) used the term 'combinative capabilities' to describe organizational processes by which firms synthesize and acquire knowledge to expand in new but uncertain markets in the future. Henderson and Cockburn (2000) used the term 'architectural competencies' while many others, such as those mentioned to earlier, simply used 'capabilities'.

It is widely agreed that a firm's competitiveness in a normal operating environment depends on the development of only a few core organizational capabilities that embody proprietary knowledge unique to the firm and superior to that of other competitors (Grant, 1996; Haas & Hansen, 2005). Regardless of the type of capability (an organizational attribute, a routine or a practice), identifying the determinants and enablers of organizational capability has been a key topic in strategic management literature (Eisenhardt & Martin, 2000). According to Leonard-Barton (1995), the core capabilities in which all organizations must innovate include; skills and knowledge base, physical systems, managerial systems, and values and norms of behavior. Inter-personal networks were further added to the list by Nahapiet and Ghoshal (1998). In addition, the quality of leadership and management within an organization, the effectiveness of its strategic and operational management practices, and the links between each of these attributes, together with the productive activities, constitute the organizational capabilities to achieve its goals (Andrews et al., 2016, p 241).

Certain capabilities become more important for an organization to attain its goals in a more complex and turbulent environment. De Toni et al. (2016) proposed four organizational capabilities to cope with complexity: interconnection, redundancy, sharing and reconfiguration. Other capabilities, such as technological capability (Figueiredo, 2002), organizational learning capability (Alegre & Chiva, 2013; Camps et al., 2016; Gardiner et al.,

2001) and employee flexibility (Bhattacharya et al., 2005; Ketkar & Sett, 2010), all help firms navigate the challenges faced when operating in turbulent environments. In a review paper, Schienstock (2009) summarized four key problems commonly faced by organizations in the context of a turbulent environment and proposed four capabilities to deal with these problems: 1) ability to use available resources, 2) capacity to create and acquire resources, 3) effective stakeholder management, and 4) ability to cope with various societal demands and fulfil its social responsibility.

Although organizational capability theory was developed with firms operating in a competitive environment in mind, the core ideas have great relevance to a disaster recovery environment (Crawford et al., 2012; Gardoni & Murphy, 2010; Kusumasari et al., 2010). In particular, the dynamic capability concept speaks to the fact that engineering and construction organizations often operate in a rapidly changing environment after a major disaster. For example, the construction markets in countries that were struck by the 2004 Indian Ocean tsunami was described by Nazara and Resosudarmo (2007) as being in disorder, contested and highly adversarial. Construction organizations often found it difficult to bring in skilled people, due to logistics challenges such as the shortage of accommodation in disaster-affected areas (Olsen & Porter, 2011) or other economic factors at play at the time of reconstruction (Lindell, 2013). As capability is embedded in context (Alimin et al., 2012; Piening, 2013), identifying the core organizational capabilities in large disaster settings will be particularly beneficial for reconstruction organizations and agencies in preparing for disaster recovery.

RESEARCH METHODS

This paper draws on longitudinal research undertaken in Christchurch to help improve the capability of engineering and construction organizations in undertaking building assessments during earthquake response and in providing reconstruction services during recovery. We conducted empirical studies of 15 construction organizations from 2012 to 2015, all of which were actively engaged in earthquake reconstruction-related work in Christchurch. The research was designed to develop a conceptual framework that can be used by engineering and construction organizations as a tool to measure their capability gaps and to guide them in developing those critical capabilities needed in earthquake recovery.

A case study method was adopted for this research due to its theory-building nature (Eisenhart, 1989). As suggested by Yin (1984), the case study design develops an empirical approach to research of a contemporary phenomenon within its own context. Lorch (2005) highlighted the importance of longitudinal research for evidence-based post-disaster recovery decision-making. In this particular research, the case study was important as it allowed us to understand the interplay during earthquake recovery among different actors, especially between government authorities, engineering and construction organizations and industry bodies. The study was undertaken over an extended period of four years from 2012 to 2015, as the Christchurch recovery proceeded, which enabled us to capture real-time data and examine patterns and trends in depth.

The selection of case study organizations was based on such criteria as the type of organization, size of organization[2], business characteristics, and involvement in the earthquake recovery process. The key strategy used for selecting the sample was that all organizations would come from a spectrum of areas in the New Zealand construction industry. The case study sample was selected from the New Zealand Construction Industry Council (NZCIC) membership database. Sample organizations were all based and operated in Christchurch and registered with regional industry bodies under the umbrella of NZCIC.

The sampling process started with an online questionnaire survey investigating the challenges faced by engineering and construction organizations between October 2011 and January 2012. Invitations to participate in the survey were sent via the NZCIC's internal mail system, targeting the CIC member organizations in the Canterbury region. Of a sample of 155 organizations, 61 responded (39% response rate). We conducted follow-up interviews with 35 selected survey participant organizations in May and September 2012. We reviewed all organization profiles and stratified them by type of organizations, then applied the set of case study selection factors. In September 2012, a total of 15 engineering and construction organizations were selected for more in-depth case studies over an extended period (Table 1).

[2] The size of the organization was pre-defined in the survey in terms of the number of employees. A large organization has more than 100 employees; a medium sized organization has more than 50 but fewer than 100 employees; a small organization has 50 or fewer employees; and a micro-sized organization has fewer than 10 employees.

Table 1. Case study organizations and their characteristics

Case study time	15 Case study organizations*	Characteristics
November-December 2012	6 Engineering consultancies (E1-E6)	3 large-sized and 3 Small & Medium Enterprises (SMEs)
May-June 2013	5 Contractors/builders (C1-C5)	2 large civil contractors, 1 subcontractor, 1 home builder, 1 large construction company
May-June 2014	2 Building supplies companies (Bs1 and Bs2)	2 large concrete product manufacturers
October 2015	2 Project Management Offices (PMO1 and PMO2)	Horizontal infrastructure rebuild & Earthquake Commission residential repairs

Note: * Each participant organization was assigned a reference number which is used in this study to link to the results/data reported by that organization.

The design of the case study included a common structure of questions to gather the same type of information from each case study organizations (Leedy & Ormrod, 2010). Case studies were undertaken through field observations and repeated semi-structured interviews with the same representative from each of the 15 organizations in the study. Interviews sought to collect the same type of information at each time point on 1) the emerging challenges faced by the organization and their employees, 2) the organization's perceived capability gaps in undertaking current tasks; 3) specific capabilities the organization needed to address the identified challenges; and 4) suggestions to improve overall capability for further events and/or long-term recovery in Christchurch. The time period for each case study, however, was decided according to the availability of each interviewee. We attempted to organize interviews all together each time when we were in the field. Key changes in the findings of the case studies at different time points were noted.

The cases were analyzed using thematic cross-case analysis, an approach which treats each organization as an individual case and allows evidence from each organization to be compared to generate common patterns. According to Yin (2008), this type of analysis can produce elements of both explanation building and hypothesis generation. We approached the analysis with the intent of exploring the capability elements of organizational processes following the Canterbury earthquakes. By aggregating the findings in case studies, we were able to identify key capability dimensions that were relevant across the range of organizations studied.

Because the capability framework refers to the ability of engineering and construction organizations to meet demands, it is important to identify the relevant decisions made by authorities or recovery agencies that affected these demands. We used focus groups (Krueger & Casey, 2000) to collect such data. A series of four focus groups in the form of research workshops were organized in Christchurch, in September 2012, November 2012, July 2013 and September 2014. The focus groups involved eleven participants, from government agencies, industry bodies and engineering and construction organizations which were different from those involved in the case studies (See Table 2). The dates of focus groups were decided according to the consensus on availability of each participant.

Table 2. Participants in the focus groups

Date	No. of participants (Fr1-Fr9)	Organization affiliated
12 September 2012 13 November 2012 23 July 2013 16 September 2014	1	Building Research Association of New Zealand (BRANZ)
	1	Canterbury Earthquake Recovery Authority (CERA)
	2	Ministry of Business, Innovation & Employment (MBIE) (1 from Building and Housing Group & 1 from Labor Group)
	1	Earthquake Commission (EQC)
	1	Infrastructure Recovery Project Management Office (SCIRT)
	2	Contracting companies
	1	Large building supplies company
	1	Engineering consultancy
	1	Academia

Note: * Each participant was assigned a reference number which is used in this study to link to the results/data reported by that person.

Each focus group was used to present the updated case study results and discuss the effects of relevant decisions in relation to earthquakes on the demands for engineering and construction. The preliminary capability framework was developed from a synthesis of case study findings and focus groups from 2012 to 2014. This framework was further evaluated empirically in the final focus group held in September 2014 in which representatives were asked to comment on the significance of core capabilities identified in the framework. Questions about the relevance of identified capabilities in the framework to the ongoing recovery were also added in the final case studies conducted in October 2015.

The interviews used for case studies and focus group discussions were recorded, transcribed, and further analyzed using NVivo 9 qualitative data analysis software. The

NVivo 9 coding comparison of queries[3] allowed similar comments and suggestions to be synthesized under common themes. In what follows, the research results are presented in the form of a synthesis of case study and focus group results.

POST-EARTHQUAKE DECISIONS

Significant decisions that affected demand for engineering and construction in Christchurch post-earthquake are compiled in Table 3 below. We analyze these decisions in four categories: legal requirements, professional requirements, residential land zoning decisions, and insurance decisions.

Table 3. Significant decisions that affected demands for engineering and construction

Category	Decision made in the aftermath of the earthquake sequence
Legal requirements: changes to the building regulations	Amendment to the New Zealand Building Code clause for Structure (B1)* including a 36% increase in the basic earthquake design load for Christchurch
	Christchurch City Council (CCC) amended their Earthquake-Prone Building Policy and increased the level to which a building was required to be strengthened from 34% to 67% NBS
	Canterbury Earthquake Recovery Agency (CERA) required all owners of commercial buildings and multi-unit residential buildings in the Central Business District (CBD) to undertake a detailed engineering evaluation of their building
	The Government introduced the Building (Earthquake-prone Buildings) Amendment Bill in August 2013
Professional requirements	The Institution of Professional Engineers New Zealand (IPENZ)'s decision to engage members as volunteers in rapid damage assessment
	Requirement for many engineers to provide input into the Canterbury Earthquakes Royal Commission's Inquiry and other investigations
Residential land zoning	The Government's residential land zoning and buyout decisions
	The Department of Building and Housing (DBH)'s new standards (technical guidance) for house repairs and reconstruction following the Canterbury earthquakes
Insurance decisions	The Earthquake Commission Act required claim apportionment between Earthquake Commission (EQC) and private insurers
	Insurers established appointed contractors as their Project Management Organizations (PMO) to manage earthquake repairs

Note: * B1 is the number of the clause for 'Structure' in the New Zealand Building Code.

[3] A coding comparison query enables the comparison of data collected from two informants and measures the degree of agreement between the informants. For more information about the coding and coding comparison queries in NVivo, see http://www.qsrinternational.com/nvivo-support/faqs/understanding-coding-comparison-queries.

Legal requirements

There were three main changes to the building regulations following the earthquakes. First was an amendment to the New Zealand Building Code clause for Structure (B1). This amendment introduced changes to earthquake design loads for Canterbury, including a 36% increase for Christchurch (DBH, 2011). Second was Christchurch City Council (CCC)'s amendment to its Earthquake-Prone Building Policy, which increased the level that a building was required to be strengthened from 34% to 67% of New Building Standard (NBS) (CCC, 2010). Lastly, to improve the system for managing earthquake-prone buildings, the Government introduced the Building (Earthquake-prone Buildings) Amendment Bill in August 2013. The key decisions in the Bill stipulate that all commercial and large residential buildings across the country will be assessed against potential earthquake damage within five years of this legislation taking effect, and all earthquake-prone buildings will have to be strengthened, or demolished, within twenty years of this legislation taking effect. Any change to the performance levels of either existing buildings or earthquake-damaged buildings, however, required considerably more engineering involvement in the assessment of buildings (Lawrance et al., 2014). This put a huge demand on engineering resources nationwide in New Zealand.

Another critical decision that had influenced the demand for engineering and construction resources was related to the recovery of Christchurch CBD. In April 2011, the Government through its on-the-ground agency, the Canterbury Earthquake Recovery Authority (CERA), required all owners of commercial buildings and multi-unit residential buildings in the CBD to undertake a detailed engineering evaluation of their building. Such investigation involved a significant element of forensic engineering and considerable judgement as alternative repair strategies were needed as part of the building evaluation. The associated technical procedures for undertaking such investigation was subsequently provided by the Engineering Advisory Group[4] following the February 2011 earthquake (Hare et al., 2012). However, engineering firms (E1-E6) reported in case studies in 2012 that they still faced difficulty to quantify the residual capacity and categorize the strength of the building in terms of the percentage of NBS, especially for moderately damaged buildings.

[4] The Engineering Advisory Group, including structural and geotechnical experts from the public and private sectors, was initially established by EQC after the Darfield earthquake to investigate how residential structures responded to liquefaction. It was subsequently engaged by the Department of Building and Housing (now known as the Building and Housing Group of the Ministry of Business, Innovation and Employment (MBIE)) in developing its series of technical guidelines, and acted as a committee to offer technical advice.

Professional requirements

The effects of the 22 February 2011 earthquake on buildings and the subsequent loss of human life led to public scrutiny of the adequacy of policy settings and regulations to rectify earthquake-prone buildings, and the effectiveness of their implementation and administration. At the time of the Darfield earthquake, only a limited number of engineers nationwide had undertaken training in building safety evaluation. The damage assessment following this earthquake, however, was largely driven by individual engineers and professionals on a ‘good will’ basis. Case studies undertaken in November 2012 reported that many consulting engineers were engaged by the Institution of Professional Engineers New Zealand (IPENZ, NZ's professional body for engineers) as volunteers in the rapid building evaluation process during the emergency period. In its report to the Royal Commission of inquiry into building failure caused by the Canterbury earthquakes, the New Zealand Society of Earthquake Engineering (NZSEE) (2011) suggested building safety evaluation be a function defined in and carried out under the Building Act. Such a legislative mandate would enable an effective organizational structure and management process for deploying qualified engineers in undertaking rapid building assessment.

There had been professional requirements for many engineers to provide input into the Canterbury Earthquakes Royal Commission’s Inquiry and other investigations into the failure and collapses of some buildings (Brunsdon et al., 2012). Interviews with engineering companies between May and June 2013 reported that the public reporting of the Royal Commission hearings placed additional pressure on many engineering professionals, especially those who volunteered their services following the Darfield earthquake. How to interpret earthquake risks for buildings, communicate building safety messages to the public, and interface with different stakeholders (e.g. insurers, building owners and regulatory authorities) in meeting their objectives have challenged engineering organizations in the face of liability concerns[5].

Residential land zoning

The earthquake-induced liquefaction caused extensive damage to land. After the February 2011 earthquake, it became apparent that it would not be economically or technically feasible

[5] A charted professional engineer who has breached the code of ethics, or has performed engineering services in a negligent or incompetent manner may face legal liability in New Zealand. The Charted Professional Engineers of New Zealand Act 2002 is the legal document that stipulates the types of disciplinary penalties and legal actions against professional engineers’ misconduct.

to rebuild in some areas which are exposed to liquefaction, flooding or landslide hazards. The land zoning process took more than one year, from June 2011 to the end of 2012, following a major decision made by CERA. All land in Christchurch was zoned into either red (no rebuilding allowed) or green (rebuilding allowed). In areas that were zoned green, or suitable for residential restoration and new construction, the Department of Building and Housing (DBH) further subdivided the land into three technical categories (TC1, TC2, and TC3). Further details on the three technical categories of land in the green zone are provided in (van Ballegooy et al., 2014).

In December 2010, DBH published technical guidance on the repair and reconstruction of houses damaged in the September 2010 earthquake. This guidance was updated in November 2011 and again in January 2013 to include new land zoning decisions. The updated guidance reflects new scientific and geotechnical information and knowledge about the impact of earthquakes and the effects of liquefaction on residential dwellings (MBIE, 2013). In particular, a large number of houses damaged in the earthquakes would require a new foundation in order to withstand the effects of liquefaction in future events. Engineering companies in case studies between May and June 2013 suggested that this required new engineering knowledge and skills that few previously possessed in the engineering sector.

Insurance decisions

In comparison with many other countries, New Zealand has a high insurance penetration (i.e. a high ratio of insured losses to economic losses), especially in the residential sector with the existence of the Earthquake Commission (EQC). Several studies revealed the paradoxical effects of the strong insurance base on earthquake recovery in Christchurch (e.g. (Brown et al., 2013; Chang-Richards & Wilkinson, 2016; King et al., 2014)). In particular, heavy reliance on insurance meant that the decisions and capabilities of insurers influenced what needed to be done and the way the reconstruction was undertaken.

Because of the open wording of insurance policies (e.g. replacement as ‘when new’), the compliance to new building standard has increased the costs covered by insurance and the complexity of claims (Elwood et al., 2015). Under the Earthquake Commission Act, each claim needed to be attributed to a separate insurance event so losses can be apportioned between EQC, private insurers and re-insurers. Such a lengthy and complex apportionment process created significant delays in residential repairs. When asked about how the fluctuated demand affected organizations, case studies in 2015 revealed that a lack of clear and adequate information on the prospective work streams from the insurers had affected their decisions on the appropriate levels of workforce planning.

Another critical decision made by most insurers was to adopt a project management method to manage their clients' earthquake repairs, using appointed contractors as opposed to providing cash payment. As increased building costs, or demand surge, is often a prominent feature in post-disaster environments (Olsen & Porter, 2013), insurers elected this option in order to control building costs and reduce losses for themselves. In Christchurch, insurers set up their own Project Management Offices (PMOs) through a credited contractor. Such a process gives homeowners less scope to use the recovery opportunity to innovate their properties (increasing the value as compared to the insured value). Findings from case studies in 2013 showed that construction subcontractors and tradespeople who worked on different insurers' projects also struggled to meet the varying technical and procedural requirements between PMOs.

AN ORGANIZATIONAL CAPABILITY FRAMEWORK

An organizational framework for earthquake recovery is provided in Figure 1. Five major challenges faced by engineering and construction organizations were identified, including 1) technical incompetence (lack of know-how), 2) additional technical requirements, 3) lack of disaster psychology/social interaction training and coping skills, 4) shortfalls and temporary supply of talent pool (lack of capacity) and 5) delayed, fluctuating and uncertain demands. The core capabilities required to deal with these challenges included A) disaster recovery know how which addresses the challenges 1 to 3 (as labelled above), B) adaptive capacity within the organization which addresses the 4^{th} and 5^{th} challenges, and C) collective support among organizations which could enable solutions to all five challenges.

Figure 1. An organizational capability framework for earthquake recovery

Disaster recovery know-how

The Canterbury earthquake sequence had several unique characteristics, including the extended period over which the sequence of damaging events occurred and the number of events (Bradley et al., 2014), the intensity of shaking produced in the Christchurch CBD by each of the major aftershocks in February, June and December 2011 (Brunsdon et al., 2012) and the significant damage from secondary effects of ground deformation and slope damage across the hill suburbs (King et al., 2014). These unique characteristics, in addition to the decisions that affected demand, posed technical challenges to many aspects of engineering activity.

The New Zealand Society of Earthquake Engineering (NZSEE) (2011) highlighted that the emergency context and assessment process is a departure from usual engineering practice and not one that engineers are familiar with or extensively trained in. When asked about how to deal with engineering requirements in earthquake recovery, organizations studied suggested an enhanced engineering profession. It includes the understanding of the differences between the emergency context and customary engineering and construction practice, and the knowledge to address any technically and socially related issues. The significance of organizational knowledge was well recognized in empirical studies of product- and technology-based industries in the context of changing conditions (Amsden & Hikino, 1994; Helfat, 1997; Schulze et al., 2014). Cetindamar et al. (2009) suggested that knowledge consists of not only the 'know-what', but also the 'know-how' and 'know-why' of an organization's employee. In particular, the know-how of employees is the intangible asset which results in distinctive skills or competencies (Hall, 1992).

The first know-how for structural engineers was to ensure appropriate investigation of damage in order to determine the relative safety of a building and initiate insurance claims. Technical requirements around such investigation process, commonly cited by case study organizations, included assessing damage to reinforcement in reinforced concrete structures and quantification of residual capacity and loss of fatigue life. Structural engineers in New Zealand, however, were under-equipped for detailed engineering assessment, especially for assessing the residual capacity of a damaged building. A lack of understanding of building damage also created differences in engineering assessments and technical investigations among engineers. In some cases, several organizations (E1-E3, E5, C1, C3-C5 and PMO2) in case studies from May to June 2014 highlighted the differing investigation results between the building owner's and the insurer's engineers.

The second know-how relates to the engineering and construction organizations' ability to integrate and build knowledge to meet additional technical requirements caused by the changes to the building regulations both in Christchurch and across New Zealand. This requires training and practicing hazard specific engineering design. Bahhru (2007) argued that the transformation of technological knowledge into a competitive asset enables firms to create new techniques, products and processes that can build up their core competencies. During case studies in October 2015, some engineering firms (E2-E5) acknowledged that their newly created or acquired knowledge in dealing with the uniqueness of the Canterbury earthquakes had set them up to compete in similar environmental conditions and/or prepare them for future earthquakes.

Another aspect of post-disaster know-how relates to an understanding of recovery issues for those affected by the disaster and the associated social skills required. This relates to knowledge concerning social interaction with people outside the organization (Coriat & Weinstein, 2002). In case studies from May and June 2014, organizations (E1-E3, E5-E6, C1-C5) involved in repairs of earthquake-damaged houses reported that their work may have proceeded more smoothly if their workers had been trained for those situations and had possessed the following knowledge/information in advance:

- What psychological impacts exist for home owners whose houses had suffered major damage, or for those who were severely traumatized by the quake and ongoing aftershocks;
- What external social assistance is available for home owners; and
- How to respond to unexpected enquiries and disruptions posed by affected home owners.

Organizations reported that residents affected by the earthquakes tended to have higher expectations and preferences for house repairs than for house construction at normal times. Barakat and Zyck (2011) reported that cases of dissatisfaction and dispute between home owners and those who repair or rebuild houses are conspicuous in a disaster recovery environment. For construction and engineering organizations operating in such an environment, this aspect of know-how refers to the ability to cope with various societal demands (Schienstock, 2009). Awareness and a better understanding of the main social issues of post-quake victims is valuable for acceptable or appropriate delivery of works in a socially sensitive environment (Barakat & Zyck, 2011; Barenstein, 2008).

Organizational adaptive capacity

The engineering and construction industries are subject to demand cycles. When the Darfield earthquake struck Christchurch in 2010, the New Zealand construction industry was going through a recessional period of low activity caused by the 2008 global financial crisis. Case studies in 2012 and 2013 showed that many construction businesses had managed to come out of the bust of the economic cycle and were aiming for an opportunity for revival in post-earthquake reconstruction. The case study organizations recognized that having adaptive capacity, through organizational learning, innovation and partnership, is crucial for them in coping with disruptive events such as earthquakes.

When comparing the results of case studies from 2012 to 2015, we found that some of the organizations studied (E2-E4, E6, C2, C4-C5, Bs2) tended to change their means of employment from offering long-term or permanent positions to recruiting temporary workers under short-term contracts. This is related to the fact that engineering and construction organizations often faced delayed or fluctuating demands in earthquake recovery. In particular, they had to cope continuously with problems such as skills shortages and lack of capacity. In addition to accumulating technical know-how, case studies in May and June 2014 found that many engineering and construction businesses had invested in technological and administrative innovation in their services and profession. For example, some firms (E1-E3, E5-E6, C2, C4-C5, PMO1) upgraded computer software and meeting facilities while others installed satellite phones for inter-site communication (E4-E6, C1-C3, Bs1-Bs2, PMO2).

It was also found that to gain competitive advantage, small construction organizations were likely to opt for partnership with other organizations to gain core competencies, whereas organizations of larger size were more inclined to attract skilled expertise. The use of an alliance strategy of sharing human resources was increasingly observed across case studies, either through contractual arrangements with domestic or overseas partners (e.g. E3, E5 and C2-C3, C5) or inter-organizational secondment and relocation (e.g. E1-E6, C1-C2, Bs1). This is not surprising as collaboration in terms of resource-sharing helps organizations to foster competitive advantage under environmental volatility (Allred et al., 2011; Wu, 2010). Its success, however, largely relies on organizational networks and relationships that have been formed previously (Townsend & Busenitz, 2015).

Collective support among organizations

Collective support among organizations (i.e. support from all organizations collectively) was identified as another essential capability required in order to address all the challenges identified. During the earthquake recovery period, there was inconsistent workflow information released by recovery agencies. The focus group in July 2013 highlighted that the lack of information as to when projects were going to market and the resources they may have required had a detrimental effect on workforce planning in the engineering and construction industries. This finding contributes to strengthening the scarce empirical research on the relationship between external decision makers' communication and support, and organizational performance (e.g. (Alimin et al., 2012; Nahapiet & Ghoshal, 1998)).

The capability challenges faced by engineering companies, particularly the lack of know-how in earthquake design and land liquefaction, and lack of skilled personnel with such experience, created a sense of urgency for an enhanced earthquake engineering discipline. However, organizational learning cannot happen in isolation without the intellectual inputs of other knowledge-creating organizations (Alegre & Chiva, 2013). Case study organizations suggested that a consistent training system, embracing all the technical and social lessons learned from the Canterbury earthquakes, should be offered by tertiary education and training organizations. This training is timely in an environment where the amended earthquake-prone building policies require inspection and associated strengthening work for earthquake-prone buildings across New Zealand.

Having leadership in the engineering and construction sectors, which was lacking prior to the earthquakes, was also considered an important aspect of collective support. The first and second focus groups defined certain industry leadership characteristics that will facilitate capability building of individual construction organizations in a disaster recovery environment. Among them are:

- A well-recognized lead organization (either a new entity or an existing organization, such as an industry association or a relevant government agency)
- a vision of what the reconstruction time path could and should be like;
- an ability to monitor the demand and supply of necessary skills for the development of the construction industry;
- an ability to negotiate with public agencies and the private sector on policies and actions to address critical capability issues that curtail the industry's effective participation in post-disaster recovery;

- ability to facilitate training for hazard specific engineering design, dealing with anxious home/building owners, preparing for inquiries such as the one from the Royal Commission; and
- strong inter-organizational links to other decision makers, both in the public and private sectors.

According to Eisenhardt and Martin (2000), a dedicated lead organization in the industry provides an important formalization mechanism through which collective know-how can be articulated, codified, shared and internalized within the organization. As many challenges faced by organizations resided with the decisions made post-earthquake, case study organizations suggested that collective support offered by well-defined leadership in the industry will have a positive effect on reducing the uncertainties in demand caused by those decisions.

CONCLUSIONS

Engineering and construction organizations have been playing a pivotal role during the recovery of Christchurch following its earthquake sequence in 2010 and 2011. The extent and scale of damage caused by the earthquakes, coupled with requirements in response to the uniqueness of such events, have tested their ability to meet the demands of the recovery. This study has developed a framework exhibiting the challenges faced by engineering and construction organizations and the core capabilities required to address these challenges.

The results from longitudinal analyses suggest that critical decisions made post-earthquakes, including the changes to the building regulations, professional requirements, residential land zoning and insurance decisions, together with their associated technical requirements, have contributed to the fluctuation of demand for engineering and construction. To effectively address the technical, social and capacity challenges in managing earthquake recovery work, engineering and construction organizations should be equipped with three core capabilities, namely, disaster recovery 'know-how', organizational adaptive ability to meet changing demands, and collective support among organizations. This study and its findings give rise to several important implications.

From a research perspective, applying an organizational capability approach to a disaster management context can help shed light on organizational functioning and preparedness

(Kusumasari et al., 2010). In extending the definition of capability beyond organizational capability in a competitive environment to a disaster recovery environment, we have illustrated that the organizational capability theory has considerable relevance to disaster management research. In particular, collective support among organizations seemed to play a more prominent role in dealing with disaster recovery challenges than would be the case in a normal competitive environment. Wu (2010) emphasized that by incorporating the dynamic capability view into different types of environments, a comparison of core capabilities in such environments offers the potential for a more enriched theoretical comprehension of the core organizational capabilities. In the meantime, focusing on the engineering and construction sector, our framework can underpin the development of better-targeted practical recommendations for senior managers in these organizations making strategic choices about organizational improvements.

A number of lessons can be drawn from the experience of the engineering and construction sectors participating in Christchurch's earthquake recovery. Our results suggest that engineering firms should pay particular attention to enhancing the engineering profession in relation to evaluation of earthquake risks, damage assessment, communication of building safety messages, and interaction with owners of homes/buildings. While much of the learning from Christchurch have been translated into useable tools, guidelines and recommendations within individual organizations, there is still a need to improve engineering design and construction practice in New Zealand through collective initiatives, such as a cohesive engineering education program and strong industry leadership and advocacy for developing organizational capabilities.

Our study provided evidence on the relationship between post-earthquake decisions and capability in engineering and construction organizations. It is hoped that the framework can be of value to those decision makers attempting to address key engineering and construction challenges that influence the outcomes of disaster recovery. In particular, reconstruction stakeholders need to manage demand fluctuations to reduce their impact on organizational capability development. For example, by sharing reconstruction demand information and avoiding the delays in demand, decision makers are more likely to help facilitate proactive knowledge acquisition and skills development within organizations and effective workforce training in the industry. In addition to training engineers in social skills in dealing with disaster repair situations, recovery agencies (i.e. government and insurers) should also develop intermediate organizations to address these social needs or to factor in costs to address these needs.

Research findings over each case study period, together with information from each focus group were disseminated in the form of a report to the organizations studied and the wider industry. Case study results were also presented to the representatives of decision making agencies at the next set of focus group. The expected impact is that the organizations studied could use the information to measure their capability gaps and developing those critical capabilities needed for continued operation over recovery. Focus group participants could also feed research findings back to their organizations to increase informed decision making. This research method highlighted the value of a longitudinal study which would not have been possible from data collected all at one time. For example, by repeating interviews with the same representative from each case study organization, we are able to identify changes in their behaviors, attitudes, perceptions or operations. Analysis of longitudinal data allows comparison of data between or among data collection points so that we can gauge change over time during the observed earthquake recovery period as well as the effects of an intervention or decision on the demand for engineering and construction.

The framework developed in this research is unique to New Zealand, as the core capabilities identified were particularly important for engineering and construction organizations in addressing specific challenges posed by the Christchurch earthquake sequence. However, this research provides an opportunity for learning for other countries with earthquake risk, for instance, the initiatives taken by organizations studied in developing adaptive capacity to cope with fluctuations in demand. It offers knowledge gained from actual experience to help engineering and construction industries anticipate likely capability challenges and prepare for them as a business, as a sector, and as a partner with government agencies in a disaster management context.

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