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Investigating the resilience of civil infrastructure firms in New Zealand

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Abstract

The civil infrastructure sector plays a significant role in the community, particularly contributing to the overall economy and the improved resilience of society. Despite this, the resilience of the sector on its own has not been fully investigated. Building on previous studies, this research aims to develop a resilience framework for New Zealand civil infrastructure firms. From case studies of sampled civil contractors, it was found that strong leadership and management, well-trained staff, strong supply chain relationships and alliances, and the ability to foresee and cope with unexpected changes in the market were considered as the top indicators that constitute their resilience. External factors such as streamlined procurement systems, integrated crisis management systems, standardised procedures for legislation compliance, guidelines for resilient industry practices, improved training systems, and assurance of the work pipeline play a role in affecting their level of business resilience. The findings contribute to the literature concerning organisational resilience, and are intended to encourage the development of resilience strategies and policies for the New Zealand construction sector and generate lessons for other countries.

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1. Introduction

The construction sector is a significant component of an economy, contributing between 4 to 10% of the gross domestic product or GDP [1]. As of 2015, the sector contributes to 8% of New Zealand's GDP and 10% of its national employment [2]. Responsible for providing society with housing, buildings, and infrastructure, the sector plays an essential role in communities' quality of life, in achieving government policies, and in driving economic growth [3, 4].

Recent studies highlight the role of the construction sector in improving society's resilience [4-7]. As society becomes increasingly dependent on critical infrastructures such as power, water, telecommunications, and transportation, there is a growing need for these infrastructures to be resilient [8, 9]. If critical infrastructures are continuously able to maintain a certain level of service after a disruptive event and recover quickly, crises can be prevented, resulting in a more resilient society [8, 10]. However, resilient infrastructures are not only defined by robust physical assets; to ensure that these infrastructures are continuously available to communities whether during crises or business as usual, organisations which build, operate and manage these infrastructures must also be resilient [8, 9]. Without reliable contractors to carry out civil infrastructure projects, communities and governments could be crippled.

Despite the critical role of the civil infrastructure sector, its resilience has not yet been fully investigated. To do so, a tool to measure their resilience must be developed [1, 7]. This study aims to determine what indicators can be used to measure the resilience of the civil infrastructure sector. The authors first make a comprehensive review of organisational resilience frameworks from past studies, with a focus on the construction sector. By doing case studies of large civil contractors, existing generic organisational resilience indicators are modified to develop a resilience framework for civil contractors. Using this framework, the resilience levels of civil contractors are benchmarked and compared to each other. Finally, the significance of the study in terms of practical use, policy, and educational value is highlighted, and suggestions for future studies are made.

2. Literature review

2.1. Defining 'resilience'

The concept of resilience is an emerging paradigm and a growing research topic in the recent years, acquiring a variety of definitions across disciplines [11-13]. One of the early definitions of resilience was presented in the context of ecology, when Holling [14] defined resilience as the capacity of systems to absorb change and persist despite disturbances. Gunderson et al. [15] further built on Holling's [14] definition and identified two kinds of resilience: engineering and ecological. Whereas engineering resilience is the ability of a system maintain functionality during a disturbance and subsequently return to its stable state, ecological resilience recognises the presence of multiple stable states, and is defined as the capacity of a system to absorb disturbances before restructuring to a new stable state [15].

In the context of psychology, the resilience of an individual is defined by Masten et al. [16] as the capacity to adapt despite adversity or threatening circumstances. On the other hand, infrastructure resilience is the ability to anticipate a disruptive event, to provide a certain level of service after a disruptive event, and to recover quickly, to prevent a crisis from escalating. [10, 17, 18].

Nowadays, the concept of resilience is also widely associated with disaster risk reduction [5]. According to the United Nations International Strategy for Disaster Reduction [19], the resilience of a community depends on its ability to resist, absorb, accommodate and recover from the impacts of a hazard. To be resilient, countries, communities and households must be able to either maintain their living standards despite shocks and stresses, or adapt to the changes caused by such events without compromising their long-term prospects for development [12, 20].

Though there appears to be a lack of consensus on the definition of resilience, several commonalities on the concept of resilience can be observed. These are:

- the ability to anticipate and prevent potentially disruptive events;
- the ability to maintain a certain level of functionality during disruptive events;
- the ability to recover quickly from the negative impacts of disruptive events and
- the ability to adapt to the changes brought about by disruptive events

2.2. Defining organisational resilience

In today's fast-changing and unpredictable business environment, resilience in businesses and organisations demands more than just being able to withstand crises and extreme events [21, 22]. To be resilient, an organisation must know how to turn challenges into opportunities and flourish in the face of adversity [13]. Organisational resilience is then defined as the ability to quickly identify potentially problematic situations, to find solutions to minimise impact of disruptive events, to adjust to changes in the environment, and to flourish in the face of difficult situations [23, 24]. Lee et al. [25] also mentions the connection between the resilience and the competitiveness of an organisation— characteristics found in resilient organisations such as strong leadership, awareness of the operating environment, and the ability to manage vulnerabilities are the same characteristics found in competitive organisations that can quickly adapt to rapid changes in their market or industry.

2.3. Measures for organisational resilience

Resilience is an abstract concept, and measuring the resilience of a system or an element is difficult and complex. However, resilience indicators developed through research can be used to benchmark resilience levels. Past studies by McManus et al. [23], Stephenson et al. [26], and ResOrgs [27], which are summarised in Table 1, serve as examples.

Through case studies of ten New Zealand organisations differing from one another in industry, ownership, size, business type, and locality, McManus et al. [23] developed a resilience framework with 15 key indicators for organisational resilience, which were grouped into three attributes: Situation Awareness, Management of Keystone Vulnerabilities, and Adaptive Capacity. Stephenson et al. [26] built on McManus et al. [23]'s study by surveying 249 individuals from 68 organisations in the Auckland Region, narrowing McManus et al.'s framework into 13 indicators reorganised into two attributes: Adaptive Capacity and Planning. Finally, ResOrgs [27] reorganised Stephenson et al. [26]'s 13 key indicators by grouping them into three attributes: Leadership and Culture, Networks and Relationships, and Change Ready. This model is currently used by ResOrgs in the Benchmarking Resilience Tool, a tool for assessing and improving the resilience of organisations in New Zealand.

Table 1: A summary of different measures for organisational resilience from past studies.

Source	Attribute	Indicators
McManus et al., 2007	Situation Awareness	Roles and responsibilities; Understanding of hazards and consequences; Connectivity awareness; Insurance awareness; Recovery priorities
	Management of Keystone Vulnerabilities	Planning strategies; Participation in exercises; Capability and capacity of internal resources; Capability and capacity of external resources; Organisational connectivity
	Adaptive Capacity	Silo mentality; Communications and relationships; Strategic vision and outcome expectancy; Information and knowledge, Leadership, management and government structures
Stephenson et al., 2010	Adaptive Capacity	Silo mentality; Internal resources; Staff engagement and involvement; Information and knowledge; Leadership; Innovation and creativity; Decision making; Situation monitoring
	Planning	Planning strategies; Participation and exercise; Proactive posture; External resources; Recovery priorities
Resilient Organisations, 2012	Leadership and Culture	Leadership; Staff engagement; Situation awareness; Decision making; Innovation and creativity
	Networks and Relationships	Effective partnerships; Leveraging knowledge; Breaking silos; Internal resources
	Change Ready	Unity of purpose; Proactive posture; Planning strategies; Stress testing plans

2.4. Organisational resilience in the construction sector

To assess the applicability of ResOrgs's resilience indicators to the construction sector, Sapeciay et. al. [7] conducted a questionnaire survey of 50 construction firms and interviewed 23 construction professionals in New Zealand. Survey respondents were asked to identify the degree of importance of each of ResOrgs's 13 organisational resilience indicators. Overall, Leadership was perceived as the most important indicator of resilience, followed by Staff Engagement, Decision Making and Situation Awareness. On the other hand, Breaking Silo and Leveraging Knowledge were deemed least important.

3. Methodology

The resilience frameworks developed by McManus et al. [23], Stephenson et al. [26], and ResOrgs [27], along with the results of Sapeciay et al. [7]'s study are used as a benchmark to identify indicators that are most applicable to the civil infrastructure sector. Through a discussion with two researchers who have relevant experience in organisational resilience and the New Zealand construction sector, 12 indicators are initially proposed. The proposed indicators and their descriptions are listed in Table 2.

Table 2. Proposed organisational resilience indicators

	Proposed indicator	Description
1	Leadership and management	The way to manage the business and staff and the ability to be responsive and make the right decisions
2	Robustness of network	Having a robust supply chain and social capital
3	Access to external resources	Having access to funding, resources, materials and other in-kind support
4	Adaptive ability to changes	The ability to adapt to external shocks or disruptions
5	Having preparedness plans in place for the unexpected	Having plans such as Health and Safety, First Aid, hazard mitigation strategies, insurance, etc.
6	Sensitivity to market	The ability to tune into any changes in the market place such as regulation, competition, changes to products and suppliers
7	Aligned business practice	Ensuring compliance to regulations
8	Innovation and diversification	Having new ideas and models to do business
9	Core competence of staff	The quality, work ethic and capability of staff
10	Ability to leverage knowledge and information.	Having access to information and use of knowledge to gain advantages
11	Situational awareness	Knowing about all the risks such as natural hazards and failure of lifelines, which can affect the business
12	Reflective business model	Constantly reflecting on business operations in terms of where it is and where it wants to be

To determine which among the proposed resilience indicators are most applicable to the civil construction sector, semi-structured interviews with large civil contractors were conducted. A multiple case study approach was adopted to individually analyse each organisation, and later collate the results and compare their resilience levels. Due to the small number of large civil contractors in New Zealand, qualitative analysis is an effective way to capture their perspective on resilience.

The study focuses on large firms because they, rather than SMEs, dominate the New Zealand civil infrastructure sector [3, 28]. Moreover, large firms generally have longer experience in the market and therefore may have more insight regarding the nature of the sector. Sapeciay et al. [7] also remarked that large construction firms tend to have more awareness of resilience, allowing the study to better capture specific resilience indicators for the sector.

The sampling of case study organisations was done using the following checklist:

- Has the firm been involved as a contractor in civil infrastructure projects (e.g. road, rail, dams, bridges, tunnels)?

- Is the firm considered large-scale (i.e. has more than 500 employees)?
- Does the firm operate in New Zealand?
- Does the firm have an office in Auckland?

Of the ten large civil contractors that were identified in Auckland, New Zealand, nine were invited to an interview and five responded. An interview with one construction professional from each firm was conducted. The case study organisations and respondents are summarised in Table 3.

Table 3. Summary of interview respondents

Case Study Organisation	Respondent's Designation
CS1	National Health, Safety, Environment and Quality Manager
CS2	Quality and Systems Manager
CS3	Procurement Engineer
CS4	Northern Regional Manager for Infrastructure
CS5	North Island Surfacing Operations Advisor

Interviewees were presented with a list of the 12 proposed indicators, and asked to identify which they thought were most relevant to their firms. They were, however, not limited to the 12 proposed indicators, as they were allowed to write other indicators they thought applicable. This was followed by a series of open-ended questions with some leads provided by the researcher so that the interviewees could elaborate on certain topics. They were asked to share their perspectives on resilience and what they thought constitutes a resilient business practice in the construction sector. They were asked about the challenges and issues they were currently facing or had faced in the past, as well as other potential vulnerabilities. Finally, they were asked to share the resilience practices that exist in their firms, which could demonstrate a resilient business.

Using analysis software NVivo 11, interview notes were individually analysed to identify the most important resilience indicators to each firm, and were later collated. The proposed 12 resilience indicators were revised according to the results of the interviews, and then used to develop a specific resilience framework for civil contractors. Using the new framework, the resilience levels of the case study organisations are benchmarked and then compared to each other. To validate analysis results, consultations with experts on organisational resilience and New Zealand's construction sector were held.

4. Results and discussion

4.1. The perspective of civil contractors on resilience

There appears to be a good understanding of the concept resilience in all five case study organisations. They shared a common concept of resilience: the ability to foresee changes in the market and cope with them, which matches with the common definitions of resilience found in existing literature. CS3 also perceives resilience as the ability to do things right across various levels of operation, while for CS4 and CS5, a resilient business is one that delivers exceptionally. Though these do not exactly match literature definitions of resilience, they match what Lee et al. [25] said about the link between resilience and competitiveness. It can be said that for CS3, CS4 and CS5, being able to achieve their goals as businesses is one of the results of being resilient.

4.2. Resilience indicators for civil contractors

Based on the resilience perspectives of the case study organisations, 12 indicators grouped into two attributes are identified as key to the resilience of civil contractors. These are summarised in Table 4.

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Table 4. A summary of resilience indicators for civil contractors

Attribute	Indicator	Description
Leadership and culture	Leadership and management	The organisation has strong leaders with a clear vision of its goals, who can make quick and level-headed decisions even during difficult situations. It has robust management systems and fosters a company culture that encourages the realisation of its goals.
	Core competence of staff	Staff have the right skills, experience and competencies, and are provided with the right training. They are encouraged to be proactive and empowered to respond if they see a possible source of crisis.
	Aligned business practice	The organisation implements protocols and procedures that are compliant with legislation.
	Reflective business model	The organisation regularly undertakes review processes (e.g. self-evaluation and assessment) so that it can reflect on its operations in terms of where it is relative to its goals.
	Situational awareness	The organisation has a good understanding of risks so that it can identify the all the things that could go wrong, such as construction site hazards, environmental/natural hazards, failure of lifelines etc.
	Sensitivity to market	The organisation understands what drives the market and the foresight to predict changes in the market including regulations, competition, and changes to technology, products and suppliers.
Coping Capacity	Innovation	The organisation finds new and innovative ways to develop more efficient and effective solutions.
	Flexibility and diversification	The organisation can adjust resource allocation to cope with market cycles, and to provide extra capacity during crises. It also has a diverse set of skills, allowing it to expand to other markets when its usual markets are down.
	Ability to leverage knowledge and information	The organisation can leverage information available to them to improve itself and gain advantage. This is characterised by using lessons learned from past experiences, having succession strategies for when staff leave, and having access to experts' opinions and specialists and knowing when to tap them.
	Robustness of network	The organisation has a robust supply chain and social capital, characterised by having good supply agreements as well as partnerships with other construction firms that allow them to mix and match capabilities and balance skills. During crises, it integrates resources with other organisations to come up with combined solutions.
	Access to external resources	The organisation has a good cash flow and access to funding resources that can be tapped during crises.
	Preparedness strategies	The organisation manages its vulnerabilities and prevents events from turning into crises by putting preparedness plans in place.

4.3. External factors that influence resilience

Due to interdependencies that exist within and across industries, it is inevitable that there are external factors that affect the resilience of construction firms. A common issue that emerged during interviews is standardising procedures for legislation compliance, considering the recently passed Health and Safety at Work Act 2015 in New Zealand. CS1 and CS5 also stressed the importance of having standards and guidelines for resilient industry practices.

Another issue facing the case study organisations is the current procurement system. CS2 suggested that the procurement process should be streamlined to favour more capable and experienced companies. Moreover, as CS4 mentioned, tendering is a time-consuming and expensive process, and therefore streamlining procurement will not only benefit construction firms, but also save government money. CS3 also urged that the current procedures be simplified to allow new construction firms to penetrate the market, and help satisfy the current unprecedented construction demand in New Zealand.

CS3 also mentioned the difficulty in finding the right people with long experience in New Zealand as immigration regulations restrict them from bringing in people. This relates to CS4's point regarding the need for an improved training and education system for the construction sector in New Zealand.

Finally, CS4 noted the importance of work pipeline assurance, particularly for civil infrastructure firms. With the large infrastructure demand currently experienced in New Zealand, construction firms need to expand and invest more

in human and material resources. However, they need guarantees of workflow continuity to assure that their investments will not be wasted. An assured work pipeline can also address skills resourcing challenges in the long term by guaranteeing the tenure of workers in the sector.

4.4. The resilience of civil infrastructure firms in New Zealand

Using the resulting framework and by studying the resilience practices of the case study organisations, it was observed that CS2 has a slightly higher level of resilience than the rest. This can be attributed to the fact that CS2 is an alliance venture, which has recently been perceived as a good model for very large infrastructure projects in New Zealand, particularly due to its feature of sharing risks and outcomes [29]. With the risks distributed among its member organisations, the whole alliance unit becomes more capable of coping with risks and therefore more resilient. Moreover, an alliance does not undergo the procurement difficulties that construction firms typically do.

CS1, CS4, and CS5 seem to operate at around the same fairly high resilience levels, likely because they are all well-established construction firms in New Zealand with a wide diversity of projects. Finally, it was observed that CS3 has a slightly lower level of resilience compared to the other case study organisations. This can be attributed to the firm being new to the New Zealand market and therefore less familiar with the environment. However, its resilience level remains moderately high; due to their expertise, vast experience, and a partnership with a local firm, CS3 is able to offset its vulnerabilities and catch up with other firms.

With the case study organisations having resilience levels between moderately high to high, it appears that the New Zealand civil infrastructure sector operates at a moderately high level of resilience. In reference to Sapeciay et al. [7]'s study, this level is to be expected of large construction firms.

5. Conclusion and future work direction

The civil infrastructure sector plays a critical role in driving economic growth and in improving society's resilience. However, there is little research on the resilience of the civil infrastructure sector on the organisational level. This study builds on existing organisational resilience frameworks from literature, and uses five large civil contractors in New Zealand as case studies to develop a specific framework for civil contractors, comprising 12 indicators that were identified as most relevant.

It is found that resilience in the civil infrastructure sector is mainly indicated by strong leadership and management, competent staff, robust supply chain relationships and partnerships, and the ability to foresee and cope with unexpected changes in the market. External factors such as streamlined procurement systems, standardised procedures for legislation compliance, guidelines for resilient industry practices, improved training systems, and assurance of the work pipeline also contribute significantly to the improved resilience of the construction sector. Using the new indicators, it was found that despite changes in the market and resource shortages currently faced by the New Zealand construction sector, the case study organisations remain resilient.

The study contributes to the body of literature concerning organisational resilience, and demonstrates the significance of developing sector-specific resilience indicators, thus creating research opportunities not only in the civil infrastructure sector but in other sectors as well. Overall, the study has significant implications for measuring and improving the resilience of the civil infrastructure sector. It opens an opportunity for contractors to reflect on the resilience of their businesses and develop management strategies that will not only improve their resilience but also make them more competitive. It is also hoped that it will motivate the government to collaborate with the construction sector in developing guidelines and suitable policies that will help the sector improve its resilience.

The outcomes provide a baseline for an improved resilience assessment methodology by developing more tangible measures for each indicator to better quantify resilience. It must be noted that this study is only the first iteration, and is limited to the five case study organisations. Future work can include expanding the methodology to other firms, particularly SMEs. 98% of New Zealand construction firms are considered as SMEs [30], which are generally considered to be less resilient compared to large firms mainly due to differences in management structures [7, 31]. There could be some indicators presented in this study that are not applicable to SMEs due to differences in management structures, and some indicators that can only be captured in SMEs.

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