ANALYSIS OF SKILL SHORTAGES IN PREFABRICATED RESIDENTIAL CONSTRUCTION: A CASE FOR NEW ZEALAND

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In New Zealand, the demand for affordable housing and concerns about the performance of residential buildings provide a strong case for using prefabrication technologies. However, the New Zealand construction sector suffers from severe labour and skill shortages, preventing widespread adoption. The overarching aim of this study is to identify the major constraints affecting the uptake of prefabrication in New Zealand residential construction, and the barriers to meeting essential skill requirements for prefabrication. To achieve this, an online questionnaire was administered to construction stakeholders within the residential construction sector; this semi-structured survey contained closed- and open-ended questions. It found four major barriers to prefabrication uptake: a lack of research and development; a scarcity of skilled workers; a lack of previous work experience; and complexity and fragmentation in New Zealand’s prefabricated construction supply chain. The industry must work on training and recruiting workers with skills relevant to the design, manufacture and installation of prefabricated elements, to promote prefabrication in New Zealand residential construction.

Keywords: New Zealand; prefabrication; residential construction; skills shortage

INTRODUCTION

In recent years, the global construction industry has suffered from continuous increases in wages and materials costs (Statistic Sweden, 2019; StatsNZ, 2019). Industry experts are beginning to explore new technologies to enhance construction productivity and efficiency ratios, to reduce building timeframes and costs, and to improve availability and comfort. One prominent technique is prefabrication (Leu and Hwang, 2002). Prefabricated buildings have tangible benefits in terms of time, quality, and cost. Mitchell (2017) discovered that prefabrication can decrease the cost of building by up to 15%, increase productivity by 10% and reduce construction time by up to 60%. Prefabrication also enhances the health and safety of construction workers and improves construction quality (Li et al., 2011). Although prefabrication

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offers a wide variety of advantages, the industry remains unconvinced by the new technology.

The United States of America (USA) was one of the first countries to adopt prefabrication (Shahzad, 2016), considering it the best innovative solution for its construction industry (Azman, Ahamad, Majid and Hanafi, 2010). Organisations like Modular Building Institutes (MBI) actively promote prefabrication in the USA through publications and research. MBI believe by promoting prefabrication, the construction industry can increase productivity, deliver better quality outputs and lower project costs. However, its industry still faces issues such as costly labour and materials, poor quality and an overuse of resources (Shahzad, 2016). MBI (2010) found a lack of skilled labour related to prefabrication. Similarly, the UK Commission for Employment and Skills says its prefabrication sector suffers from skills shortages that prevent its development (McGinnis, 2015). In recent years, the UK market for prefabricated construction has shown positive signs of becoming more attractive for developers and owners (PBC today, 2020). In Australia, prefabricated construction was among eight visions identified by Hampson and Brandon (2004) to increase the construction industry's contribution to the national economy by 2020. Navaratnam et al., (2019) believe prefabrication could increase its market share in Australia; but, as in other countries, there are barriers limiting its potential. Most relate to a lack of knowledge about tools and the flexibility of prefabrication systems, as well as limited public information about the sustainability aspects of prefabrication.

There is low use of innovative technologies in New Zealand construction as practitioners prefer traditional construction methods (Clark-Reynolds and Pelosi, 2016). The industry has been characterised by a lack of productivity due to a skills shortage limiting the uptake of new technologies. To promote productivity, prefabrication technology was introduced to New Zealand in the 19th century. Prefabrication was considered cheap, fragile and temporary (BRANZ, 2013). In recent years, organisations such as PrefabNZ have introduced international standards to improve performance, but the use of prefabrication is still relatively low. In residential construction, prefabrication has not been sufficiently introduced or examined as a solution for increasing housing supply (Samarasinghe, 2021). This study aims to increase the uptake of prefabrication technology, particularly in the residential construction sector in New Zealand. It attempts to encourage the upskilling of industry practitioners around prefabrication as a solution for productivity improvement and, eventually, the nationwide housing affordability crisis. It explores barriers to prefabrication, and the essential skills required for its promotion. It hopes to enhance understanding of prefabrication as a way to mitigate, or even eliminate, the country's housing crisis.

**LITERATURE REVIEW**

The New Zealand construction industry has grown steadily in recent years, contributing about $15 billion to Gross Domestic Product (GDP) in 2019 (Statista, 2020). In the same year, there were 37,538 consented dwellings -14% higher than in 2018 (StatsNZ, 2020). The value of newly approved dwellings in 2019 was about $14 billion, an increase of 14% on the previous year (Ninness, 2020). This remarkable upsurge in the number and value of approved residences reflects the growth in residential construction. With the pressing need for new housing construction, the New Zealand Government has promised to quickly build thousands of affordable houses, despite the pressure of existing skills shortages in the construction sector.
Similarly, the UK Government also intends to build 300,000 dwellings by the year 2025. Both governments rely on a new generation of prefabricated homes to fulfil their promises, however, they lack skilled workers to design, manufacture and install prefabricated building components. Mirus et al., (2018) emphasise that although prefabrication has potential for success in New Zealand, it requires government legislation, financial support, a new educational approach for the workforce and mitigation of current risks in the prefabricated construction supply chain.

Prefabrication in New Zealand

Prefabrication is a construction technique whereby building components, and even entire buildings, are manufactured in controlled manufacturing plants (Smith, 2010). In New Zealand, about 17% of commercial and residential construction is built using prefabricated parts (Construction Industry Council, 2012). Past research has examined the potential of better applications prefabrication in the New Zealand construction sector (Samarasinghe and Wood, 2021; Shahzad, 2016; Page and Norman, 2014; Scofield, Wilkinson, Potangaroa and Rotimi, 2009). Page and Norman (2014) found prefabrication is mainly used in wall and roof framing in New Zealand, and worth about $2.95 billion per year. Using prefabrication for other building components or whole buildings would increase that value to $5 billion per year (Shahzad, 2016). The New Zealand construction industry is characterised by low productivity and a reluctance to take up new technologies (Samarasinghe, 2020), yet sustainability and efficiency in construction are main concerns for the Government (Scofield et al., 2009). A study conducted by Chen and Samarasinghe (2020) found construction contractors still show a strong resistance to adopting prefabrication. According to Hunt (2016), an increase of 1% in construction labour productivity could lead to a growth of $139 million in GDP. Prefabrication offers higher labour productivity as it involves minimum on-site work. In the long term, limited natural resources, population growth and environmental threats could push the construction industry towards prefabrication. This could decrease waste by 40%, reduce carbon dioxide emissions by 35% and cut energy consumption by 55% (Moradibistouni and Gjerde, 2017). Although prefabrication has benefited significantly from cutting-edge technologies such as Computer Aided Designs (CAD) and Computer Aided Manufacturing (CAM), its adoption in New Zealand is still below target (Burgess et al., 2013).

The application of prefabrication in New Zealand goes back to the early 19th century where prefabricated panel housing components imported from the United Kingdom and the United States were installed in houses (Scofield et al., 2009). Currently, the New Zealand prefabrication industry comprises of companies that manufacture building components, panels, pods and complete buildings. A study conducted by Prefab (2018) reported that prefabrication is mainly used in manufacturing concrete products, prefabricated wooden buildings and prefabricated metal buildings. A healthy uptake requires an understanding of industry concepts and technologies, a cooperative approach between supply chain stakeholders and full support from government agencies (Samarasinghe and Wood, 2021). Better connections with potential clients and more accessible technical information could improve prefabrication acceptance (PrefabNZ, 2014).

Skills shortages in the prefabricated construction industry

BRANZ (2014) states a lack of adequately skilled people has negatively affected prefabrication uptake. Recent studies by Masood et al., (2021) and Sooriyamudalige...
et al., (2020) highlighted skill shortages in off-site products, such as modular construction and panelised construction. Therefore, even if demand for prefabricated components is high, production efficiency remains low. The prefabrication industry needs upgraded technical skills to support the huge demand (BRANZ, 2014). Bell (2011) pointed out that research and design are vital in prefabrication. Chen and Samarasinghe (2020) acknowledged that most training programmes provided by construction firms relate to traditional construction, with poor adoption of new techniques. They noted that emerging construction technologies require talented people to operate them; a shortage of such people makes contractors unenthusiastic about embracing prefabrication.

Skill shortages in traditional construction have been analysed in depth by past researchers (Ho, 2016; McGrath-Champ, Rosewarne and Rittau, 2011; Lobo and Wilkinson, 2008; McGuinness and Bennett, 2006; Mackenzie, Kilpatrick and Akintoye, 2000). The tangible advantages of shifting towards prefabricated residential construction have been debated both globally and locally. However, the skills and knowledge required for transition in New Zealand have not been addressed. A prefabricated construction transformation requires transferring on-site work to manufacturing factories, involving significant stakeholder relationship management. The importance of interpersonal relationship management skills has been stated by Ginigaddara, Perera, Feng and Rahnamayiezekavat (2019). The prefabricated construction industry is an emerging one in New Zealand, and the skills required are constantly changing; therefore, education providers find it difficult to provide systematic prefabrication training. As the industry expands, young practitioners with a higher acceptance of digitisation will be better suited to developing new skills related to prefabrication (Ginigaddara, Perera, Feng and Rahnamayiezekavat, 2019).

DATA COLLECTION AND ANALYSIS

The study collected both secondary and primary data in the context of residential construction in New Zealand. Secondary data were collected through an intensive literature review of journals, research articles, reports and official websites. This exposed several concepts, such as technology acceptance, constraints, lack of skills in the supply chain and suggestions for possible future uptake of prefabrication. Primary data were collected through an online survey (semi-structured) using Qualtrics. An online survey seems to be an efficient way of gathering a considerable amount of data, with the minimum human efforts and mistakes (Regmi et al., 2016). Ethics approval was granted by the Ethics Committee of the Auckland University of Technology before primary data collection began, which was in line with (Mertens, 2018).

The pilot survey was administered to multiple construction industry practitioners. Pilot study was conducted as a means of justifying the reliability and validity of the research. In addition, it gives the researchers an indication of the probable outcomes of their studies (Van Teijlingen et al., 2001). While 20 questionnaires were provided, only 14 were returned. The requirement of having at least 12 participants in a pilot survey is fulfilled in this study (Moore et al., 2011). The survey (n=14) was completed by prefabricated product manufacturers, suppliers, engineers, architects, head-contractors and sub-contractors practising residential construction in New Zealand. The online survey had five key sections, including demographic information, skill shortages in prefabrication, barriers to the use of off-site technology and possible measures for increasing prefabrication use. Other topics within the questionnaire fall outside the scope of the current paper. Response options were
provided on a Likert scale of 1 to 5, where 1 represented strongly disagree and 5 represented strongly agree. The mean score of each response was generated through descriptive statistical analysis in Qualtrics. Responses with mean values of 2.5 and above were considered.

RESULTS AND DISCUSSION

Demographic data
Survey participants indicated their age, years of experience in the construction industry, business type, highest qualification, location and the type of prefabrication projects they had worked in. Participant profiles were generated from this demographic data. The survey results reflected feedback from engineers (50%), consultants (22%), architects (7%) and contractors (7%), as well as professionals (14%) representing organisations like Suppliers, New Zealand Institute of Architects, Association of Consulting Engineers New Zealand, New Zealand Institute of Quantity Surveyors, New Zealand Institute of Building and PrefabNZ. Most participants (43%) had 11-15 years’ experience in the industry; 29% had 6-10 years’ experience; 14% had over 25 years’ experience; and 14% between 16-20 years.

Major barriers limiting the use of prefabrication technology
Participants were presented with four main barriers identified from literature and indicated their agreement on a five-point scale (5 being strongly agree and 1 being strongly disagree). These barriers are shown in Table 1.

Table 1: Descriptive Statistics - major constraints impacting prefabrication uptake

<table>
<thead>
<tr>
<th>Rank</th>
<th>Frequency (N)</th>
<th>Mean (M)</th>
<th>Standard deviation (S)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lack of research and development (R&amp;D)</td>
<td>14</td>
<td>4.43</td>
<td>1.20</td>
</tr>
<tr>
<td>Lack of prefabrication-related skills in New Zealand</td>
<td>14</td>
<td>4.07</td>
<td>1.06</td>
</tr>
<tr>
<td>Lack of previous experience with prefabrication technologies</td>
<td>14</td>
<td>3.79</td>
<td>0.97</td>
</tr>
<tr>
<td>The complexity of the prefabricated construction supply chain</td>
<td>14</td>
<td>3.29</td>
<td>0.86</td>
</tr>
</tbody>
</table>

The most statistically significant barrier was a lack of research and development (N=14, M=4.43, S=1.20), an area identified by Bell (2011) as a key factor for enhancing the prefabrication construction method. The second constraint related to a lack of specific skills in prefabrication (N=14, M=4.07, S=1.06). This is compatible with a study by Gibson (2019), that indicated skills shortages in the prefabricated construction supply chain are among the most critical factors for implementation. The third barrier was a lack of experience with prefabrication technologies (N=14, M=3.79, S=0.97); participants noted this lack of accumulated knowledge has a notable effect on the sector, preventing greater use of prefabrication. The final constraint was the complexity and fragmented nature of the prefabricated construction supply chain (N=14, M=3.29, S=0.86). Similarly, Doran and Giannakis (2011) stated that better integration is required in the supply chain to compete with traditional on-site methods.

Skills issues in prefabrication
This section sought to understand skill issues in prefabrication supply chain. The study found four statistically significant skills issues affecting prefabrication in New Zealand residential construction. Table 2 displays these.

The most statistically significant issue was recruiting prefabrication-specific skilled workers (N=14, M=4.00, S=1.04). Recruiting skilled workers is considerably difficult, particularly in prefabrication. The next statistically significant issue was
recruiting labour with multiple skills (N=14, M=3.79, S=0.97). Laubier et al., (2019) discussed difficulties associated with sourcing labour from overseas as a solution for prefabrication skills shortages. In contrast, about half of the research participants agreed that recruiting overseas workers (N=14, M=3.21, S=0.850) could help overcome the residential construction skill shortage.

Table 2: Descriptive Statistics - skills issues in prefabricated construction

<table>
<thead>
<tr>
<th>Rank</th>
<th>Frequency (N)</th>
<th>Mean (M)</th>
<th>Standard deviation (S)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recruiting prefabrication-specific skilled workers</td>
<td>14</td>
<td>4.00</td>
<td>1.04</td>
</tr>
<tr>
<td>Recruiting labour with multiple skills</td>
<td>14</td>
<td>3.79</td>
<td>0.97</td>
</tr>
<tr>
<td>Recruiting overseas labour</td>
<td>14</td>
<td>3.21</td>
<td>0.85</td>
</tr>
<tr>
<td>The adequacy of training placements in the industry</td>
<td>14</td>
<td>2.29</td>
<td>0.95</td>
</tr>
</tbody>
</table>

Participants were asked about the adequacy of industry investment in training permanent staff to acquire new skills. Most responses were between strongly disagree and disagree; therefore, the adequacy of training placements in the industry (N=14, M=2.29, S=0.95) is unsatisfactory. As a solution, Professor Ngo (as cited in Climo, 2018) suggests workers from other fields train to join the construction industry, to alleviate the skill shortage.

Measures to increase the prefabrication uptake

In terms of ways to increase the uptake of prefabrication, the study found four possible measures (see Table 3) to boost prefabrication in residential construction. Participants delivered feedback on five possible methods.

Table 3: Descriptive Statistics - measures to increase prefabrication uptake

<table>
<thead>
<tr>
<th>Rank</th>
<th>Frequency (N)</th>
<th>Mean (M)</th>
<th>Standard deviation (S)</th>
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<tbody>
<tr>
<td>Use modern technologies to provide better upfront planning in the residential prefabrication sector</td>
<td>14</td>
<td>4.50</td>
<td>1.23</td>
</tr>
<tr>
<td>Maintain a high level of collaboration between the different industry stakeholders to benefit the prefabrication sector</td>
<td>14</td>
<td>4.29</td>
<td>1.14</td>
</tr>
<tr>
<td>Provide sufficient training placements to enhance industry acceptance of prefabrication</td>
<td>14</td>
<td>4.00</td>
<td>1.04</td>
</tr>
<tr>
<td>Implement BIM and lifecycle assessment (LCA) to positively impact on the prefabrication sector</td>
<td>14</td>
<td>4.00</td>
<td>1.04</td>
</tr>
</tbody>
</table>

The result with the highest statistical significance (N=14, M=4.50, S=1.23) showed most participants strongly believed the prefabrication industry would benefit from integrating modern, cutting-edge technologies in planning and workflow. The second-highest measure (N=14, M=4.29, S=1.14) revealed participants felt a higher level of collaboration between industry stakeholders would benefit the prefabrication sector and soften reluctance to change. The third measure (N=14, M=4.00, S=1.04) was adequate training placement. Providing sufficient prefabrication training reduces rework due to human error; the cost of rectifying defects is estimated at 6% of the total cost of construction (Johnsson and Meiling, 2009). The same outcome was received (N=14, M=4.00, S=1.04) for the need to implement BIM and LCA to increase prefabrication uptake.
CONCLUSIONS

A global surge in population and housing demand has created skill shortages in the residential construction sector, encouraging researchers to investigate skill shortage issues and potential solutions. This study aimed to identify the main constraints affecting the uptake of prefabrication in New Zealand residential construction, and to explore issues around the essential skills required to promote prefabrication. It also sought to determine measures to increase prefabrication uptake. The study found four major barriers: a lack of research and development in prefabrication; a lack of prefabrication-specific skills in New Zealand; construction practitioners' lack of previous experience in prefabrication; and the complexity and fragmented nature of the prefabricated construction supply chain.

Other findings showed the industry must recruit workers with skills specific to the design, manufacture and installation of prefabricated elements. These skills are crucial, allowing workers to actively move between off-site and on-site construction environments. Upskilling within the industry would make prefabrication more attractive for those reluctant to participate. Modern technologies allow for better upfront planning in residential prefabrication; similarly, BIM and LCA are important for positive change in the prefabrication sector. It is recommended that industry stakeholders work together to increase the awareness of prefabrication benefits among traditional construction practitioners. Key stakeholders, including the Government, must also provide sufficient training placements to enhance industry acceptance of prefabrication. This research is limited by the number of study participants; nevertheless, it will assist future studies analysing aspects of prefabricated residential construction.

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REFERENCES


