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Prefabrication: New Zealand's golden ticket?

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Abstract: The construction industry within New Zealand is currently experiencing a boom and is the largest sector of the country's infrastructure. Although substantial, the industry continues to suffer from inflated costs, low-productivity and lack of innovation. Sparsely developed methods from the beginnings of construction in New Zealand are still practiced today, attributing to low-productivity and the current 'housing crisis'. With recent government schemes that aim to provide 100,000 homes in a decade, the demand for innovation and efficiency in the industry is under pressure and prefabrication is suggested to help evolve the industry for the demand. Through a literature analysis, this paper will investigate a brief history of prefabrication on an international and national scale. Other industry models will also be analysed, including Sweden and Japan, providing insights to the questions concerning New Zealand. The analysis informs the conclusion that prefabrication is unable to instantly infiltrate the New Zealand construction industry. Additionally, implementation of this alternative method will require the servicing of other areas, including the supply chain and skilled labour.

Keywords: Prefabrication; Housing crisis; Government schemes.

1. INTRODUCTION

Prefabrication methods have been entering the housing industry globally since the mid-nineties (Bell, 2012) and today New Zealand is looking to provide housing to the masses with such methods. In announcing the KiwiBuild scheme, New Zealand Housing Minister, Phil Twyford, has recently promised 100,000 affordable homes over the next ten years, predicting over half to use prefabrication methods (Trevett, 2018). This promise of prefabrication providing the majority of homes, raises a question of practicality. Is prefabrication really the answer to the 'housing crisis' and if so, can the current construction industry within New Zealand adopt the methods to supply the demand?

This paper uses literature analysis to learn from other countries successes and shortfalls with prefabrication methods in their housing industries. Other nations in this paper that provide a general insight include Japan and Scandinavia with some reference to the United States of America and the United Kingdom. Historic and current examples also answer the question of prefabrications predicted success within New Zealand. After outlining the housing construction industry and prefabrication within New Zealand, comparisons of other countries are made to again, help inform the future of prefabrication within the industry.

In the analysis of prefabrication, it becomes apparent that there is a three-part division in how the methodology can improve traditional construction methods including cost, quality and time. Countries such as Japan highlight the notion that in using prefabrication to improve elements, such as time and cost, the third element, quality, subsequently becomes low-priority. National organisations such as PrefabNZ encourage prefabrication within the country and oppose the notion seen within the Japanese industry stating that prefabrication can simultaneously; improve quality; reduce up to 60% of construction time; see a 15% savings in cost; reduce construction waste; provide mass-customization options; increase productivity; and reduce health and safety risks (PrefabNZ, 2013). Claims such as these suggest that prefabrication will improve upon most or even all shortfalls within the current New Zealand construction industry. Yet, through analysing other competent international industries and New Zealand's current prefabrication industry, the claims become improbable rather than obtainable goals.

With focus on 'the success of prefabrication solving housing crisis' conclusions are drawn for this construction methods potential, and what areas need prior servicing for prefabrication to dominate the industry. Additional arguments raised cover other possible long-term solutions to the housing crisis in New Zealand that look to prevent a history of housing shortages from repeating.

2. METHOD

The purpose of this paper is to investigate through a literature review, as a prerequisite to gain further understanding about the potential of prefabrication methods in the housing industry. This review uses academic and other sources to gain inspiration to develop further ideas on the topic, helping understand prefabrications ability to 'solve' the New Zealand housing crisis (Walliman, 2011).

After a background of prefabrication is outlined the literature will investigate, Sweden and Japan's prefabrication practices, past and current; a history of prefabrication in New Zealand; the current status of the New Zealand housing industry; prefabrication in New Zealand today; and the supply chain and workforce in New Zealand. A discussion of the findings from the literature review will subsequently draw conclusions regarding, how to implement prefabrication methods; prefabrications actual potential in New Zealand; and additional solutions to the New Zealand 'housing crisis'.

The main conclusions made from this investigation is that current claims of prefabrications potential in New Zealand is misleading, creating ambitious and unobtainable goals, such as the KiwiBuild Scheme. Additionally, it is understood that multiple issues within the New Zealand construction industry attribute to the current housing crisis, and that they must first be serviced to implement this alternative construction method.

3. BACKGROUND

Much needed housing supply in the United Kingdom, during and after the war was provided under government initiatives. Although the houses became a permanent fixture, the design intent was based on the knowledge that the houses would be temporary and focused on speed rather than quality (Smith, 2010). At the end of World War II, a housing shortage provided opportunities for the building industry to uptake technical industrial prefabrication abilities and factory production. Unfortunately, this alliance between architecture and industry did not always prove to be successful and subsequently lent prefabrication a bad name that many are accustomed to (Bargdoll, 2008). Links of this phenomena can be drawn to the British built temporary prefabricated homes of post war and the multi-storey concrete council flats of the 1950s and 1960s (Bell, 2012) or the Levittown housing communities by Levitt and Sons Inc. in the United States.

Between the 1980s and 1990s innovation in terms of prefabrication had very little development, this could be attributed to industries focus on bespoke dwellings (Bell, 2012). Nations such as Sweden and Japan however defy these trends for various reasons, such as combating weather conditions, large population base and most importantly social perception (Sweet, 2015).

4. JAPAN AND SCANDINAVIA

The Japanese prefabrication systems are more industrialised than other areas around the world. This social view towards housing, has lead housing companies to market successive housing models like cars, with extensive customizing options, such as the 'Toyota production system' (Oshima, 2008). A house built in the United States is expected to last well beyond a century, while a in Japan, a house might last thirty-eight years (Campbell-Dollaghan, 2014). In contrast to the rest of the world, for Japan it is a common practise to remove an existing house before selling the land (Buntrock, 2107). Utilizing prefabrications potential to improve cost and construction time, quality becomes a minor value. The undervalued element of quality compliments the needs of the Japanese housing industry, whose 'scrap and build' mindset provides homes with a significantly shorter shelf-life in comparison to New Zealand homes (Campbell-Dollaghan, 2014).

Large production volumes, along with standardized processes, just-in-time manufacturing principles, automation and flow line-like production are what drive the industry (Linner & Bock, 2012, P 159). Today, approximately 150,000 or 15 percent of the houses in Japan are produced in factories every year.

With the Japanese housing market and industry ruled by the 'scrap and build' notion, it is difficult to obtain applicable methodologies for the New Zealand industry. With Twyford's promise of 100,000 homes, over half prefabricated, New Zealand must surpass Japan to adopt prefabrication methods at a dramatic rate in the short window of ten years, whilst being affordable and of a long-lasting quality.

Another nation that builds with longevity goals similar to the American and New Zealand industries is Scandinavia. Yet like Japan, Scandinavia has also turned to industrial processes to accommodate the demand for mass housing. By 1924, the first catalogue house was published by Borohus Company in Sweden. By the end of 1930s there were more than 20 manufactures of these catalogue houses (Waern, 2008). The Swedish architect Fredrick Blom deconstructed a wall into a series of parts that had the ability to be assembled and disassembled. Blom envisioned a construction system for military applications such as movable barracks instead of tents (Lindelov, 2017). By the 1940's, Blom's system was eventually realised for the wealthy with 140 summer homes produced. The system favoured by their clients as it featured personalization options and was believed to be a solid build (Waern, 2008).

In Sweden, 85% of detached houses are prefabricated, using methods such as Borohus Company catalogue homes and Fredrick Bloms deconstructed wall. In other developed countries such as the United Kingdom the number is only 5%, while in Germany and Netherlands 9% and 20% of homes are prefabricated respectively (Sweet, 2015). Scandinavia, once a small industry built on the backs of small saw mills producing placeless buildings, has now become international juggernauts (Waern, 2008, p31). Prefabrication in Sweden can be attributed to the country's large selection of premium timber and its challenging winter climate conditions.

The Swedish government set up the Million Homes Programme from 1965 to 1975 to combat a housing crisis that engulfed the nation. The houses were by no means quick, cheap and temporary, but were required to follow strict quality controls (Lindelow, 2017). This intense period of building required housing to be manufactured for one-sixth of the population. Although the programme was a success to house a large population in need, inhabitants ended unhappy with the large focus on technical production over the importance for customer personalisation and aesthetic quality.

Sweden's efficient timber and construction industry is utilized by the prefabrication industry. In comparison, New Zealand's forestry industry, like Sweden's, is significant to its economy with an annual gross income of approximately \$5 billion at 3% GDP (Forestry New Zealand, 2018). The similar conditions provide hope for wide spread adoption of prefabrication methods within New Zealand. Yet, the percentage of forestry products being exported from New Zealand has been increasing reaching over 30% in 2012 (Stats NZ, 2014) and might need adjustment to suit the demand generated from prefabrication construction within the country. Although the supply and demand of prefabrication is high, combined with an efficient supply chain or timber industry, Sweden is still facing a current housing crisis with a predicted 255 of Sweden's 290 municipalities (Boverket, 2018) now report a housing shortage. A prime example of a construction industry dominated by panelised or 'flatpack' prefabrication systems, Sweden's housing crisis suggests that although efficient, prefabrication is not a sole solution.

5. THE HOUSING AND CONSTRUCTION INDUSTRY IN NEW ZEALAND

5.1 History of prefabrication in New Zealand

Historically, prefabrication in New Zealand can be traced back to the 1833 Waitangi Treaty House and the commercially available Manning's Portable Colonial Cottage in 1839. Both houses were kit set dwellings, with the former made in Sydney and the latter within carpenter's workshop in London (Bell, 2012, p50).

The New Zealand Railways Department heavily invested into prefabricated housing for five decades from the 1880's (Ferguson, 1994). The housing shortage after the First World War led to the establishment of a large factory in Hamilton in the 1920's to supply mass produced homes. Within a six-year period, over 250 houses a year or a house every day and a half was produced (McKay & Stevens, 2014). The houses were simple, small and fulfilled the need, but lacked innovative design regarding layout and functionality (Ferguson, 1994, 96). The attempt of standardized prefabricated housing realised that the 'one-size-fits-all design' was not a popular option for public housing within New Zealand. By 1929 the Railways housing scheme was shut down due to complaints that it threatened private enterprise and that it had outstripped demand (McKay & Stevens, 2014).

The State housing Programme lead was introduced by the Labour Government in 1937 to resolve issues around a shortage of houses and substandard living conditions (Bell, 2012). Construction companies such as 'Fletcher's Construction' took full advantage of state housing schemes by constructing factories at the governments expense to manufacture weather boards, interior finishing's, standardized windows, doors, and kitchen and bathroom fittings (McKay & Stevens, 2014). A single specification document that dictated the design of the state house confined the construction to a standardised range of parts that could come together to create over 100 homes. By the end of 1939, the government reached its target of producing 5000 state homes (McKay & Stevens, 2014).

During the second World War, factories were subjected to military construction activities with over 30,000 huts and transportable military buildings prefabricated (Isaacs, 2008). After the second World War concluded, returning soldiers banded together to create construction gangs to build and assemble prefabricated wall panels, complete with wall claddings for a national state housing scheme (Bell, 2012). The loss of trained skilled labour during the war resulted in large proportions of men working within the construction industry that had no formal training. A fear that old craft-based apprenticeship was disappearing led to the Rehabilitation Department opening trade training centres. The courses led to greater speed of construction and reduction of some cost. Although a welcome measure, it was an ineffective approach to combat rising cost within the post-war economic period (Ferguson, 1994, 128). The scheme stopped in 1953, as houses needed level sites, had limited plan options and incorporated expensive joinery additions.

Due to rapid population growth in the 50's (Bell, 2012, p56), the New Zealand Government developed the Group Building Scheme in 1953 to encourage speculative purchasing and building of affordable homes. The conditions of the scheme were to push the speed of building by asking builders to agree to form groups of six or more to build homes under the premise of speculation. If a home was not sold within two months after completion, the government would agree

to purchase it at a prearranged price. As the government had a large stake in the scheme, builders were provided with specifications and were encouraged to prefabricate as much as possible. By the 1964, the Group Building Scheme was abolished due to the government largely considering the housing shortage being resolved. The schemes success ensured many small companies to enter the market (Ferguson, 1994, p184).

Between the 1950's and 1970's solid wood component systems were developed including companies such as Lockwood, Fraemoths, Solwood, Putarura Timber Yard and Conecta. Today, only the two former enterprises became commercially successful and are still in operation (Bell, 2012). Dutch emigrants moving to New Zealand, Johannes La Grouw and John Van Loghem, founded Lockwood in 1951. By 1953, the pair developed a construction system based on locking solid laminated timber planks together with aluminium jointing corner profiles (Isaacs, 2008).

The '70s impacted not only the prefabrication industry, but the building industry at large. Macroeconomic factors such as the 1978 recession, design to manufacture shortcomings such as customization, and social cultural issues around marketing, led to the demise of prefabrication. The loss of many innovative systems within the construction industry can be contributed to lack of marketing, financing, customer awareness, business and product. Innovation points that Lockwood has kept, attributing to their success. Today, Lockwood builds 500 houses a year, having completed 40,000 since 2008. Between the 1980s and 2000s the prefabrication industry was left to work away quietly in the shadows of the 'traditional' building industry (Bell, 2012).

5.2 Current status of the New Zealand housing industry

With the promise of around 50,000 homes to use prefabrication in New Zealand, the demand is there as housing within the country proves to be sparse and expensive. A 2017 Ministry of Business report states that the current 'housing crisis' within New Zealand has been inflating prices within the market, resulting in 81.4% of citizens unable to afford a first home (MBIE, 2017). Yet recently the 'red-hot' housing market in New Zealand has been 'cooled' as Susan Edmunds explains in a New Zealand Herald article citing Barfoot and Thompson (Edmunds, 2018). Edmunds outlines that, measures introduced by the Reserve Bank, difficult lending systems from trading banks and apprehension in buyers has led to cooling of the market. Although cooled housing prices are still out of reach for most, this can be attributed to a shortage in housing and the speculative nature of the market initiated by past government schemes (Bell, 2012). This leaves first home buyers with an unaffordable housing market and a lack of accessible financing.

Due to a demand for affordable housing, Westpac plans to provide builders with more accessible financing of prefabricated home construction (Westpac, 2018). Today in New Zealand, banks are financing prefabrication only after the construction has been brought to site. Westpac has currently been making headlines with a plan to tackle this gap in the financing area of 'prefab'. Although Westpac's plans are only to test the effectiveness before implementing an 'off-site' financing scheme, this proactive step is much needed for prefabrication in New Zealand to take off. Such builders joining Westpac through the funding scheme include, Branderson Homes in Canterbury (Fletcher & Parker, 2018). Through easier access to funding, more builders can adopt prefabrication and extend this affordability to the purchasing public. The stepping stones for prefabrication implementation are now in place. With banks and the New Zealand government beginning to prove proactive interest in new construction methods, as well as a market that demands greater housing.

5.3 Prefabrication in New Zealand today

Existing companies utilizing prefabrication methods also provide a foundation for this construction methods potential within New Zealand. Understanding their successes and shortfalls helps realise the additional steps needed to implement mass prefabrication to meet demands such as Twyford's.

New medium-density housing developments, such as Hobsonville Point in Auckland, have been meticulously master planned to cater to housing demands, creating a window for greater prefabrication. Controls put in place by the Hobsonville Land Company involved items such as density, parks or public zones and price brackets to provide comfortable, healthy homes at an 'affordable' price (HLC, 2015). The restrictions opened the door for multiple contractors and group home builders to enter the development at a level playing field, including 'The Grounds development' by The Tallwood and Stanley group whom specialise in off-site construction and modular design (Tallwood, 2018). 'The Grounds' is a debut project from the recently merged group and is a competitive example of innovation in prefabrication within the construction industry. Rob Marshall, CEO of Tallwood explains the merger with The Stanley group and how it enables the company to provide a package deal to customers including design, manufacturing and installation (Tallwood, 2018). Although the Stanley group outnumbers Tallwood with decades of industry experience, modern methodologies, such as the digital fabrication techniques provided by Tallwood, integrate the newly formed group into the now evolving construction industry.

Other companies playing part in the prefabrication industry include Concision and eHomes. Mike Greer Homes and Spanbuild originally formed Concision, providing off-site panelised prefabrication to reduce construction time from 20 to 12 weeks (PrefabNZ). In comparison the independent consortium, eHomes, provided a competitive result, with the ability to construct one home within eight hours (Gibson, Biggest house prefabricator in hands of receivers, 2015). Although methodology proved innovative and economical within eHomes, an unaccepting market failed to provide the demand

required for the company to endure. This and the 'independent operating' status of the company, lead to its liquidation in 2015 (Gibson, 2015). Alternatively, Concision, containing a group home builder foundation, has remained within the industry, without solely relying on prefabrication to stay competitive (Wood, 2014).

5.4 Supply chain and workforce in New Zealand

Although prefabrication is practiced within the industry, traditional building methods continue to dominate with most homes built by small contractors. High-costs within housing construction in New Zealand are also attributed to the fragmentation of the industry, due to the multiple small firms building one-off bespoke homes (Samarasinghe, 2014). The unpredictable and bespoke nature from these firms shapes a difficult to predict, high-cost supply chain (Page & Curtis, 2011). In the construction prefabrication industry two main areas have been identified as points of weakness by Chang, Han, Kim & Yi (2015) including supply chain management and the supply of skilled labour required to implement the concepts. The location of New Zealand as well as heavily relying on material exports has resulted in extensive lead times.

This high-cost nature of the supply chain and minority nature of prefabrication in New Zealand means the method tends to equate or marginally improve traditional construction costs. In a BRANZ funded 2014 study report, Ian Page and David Norman outline savings within studies located in the United States and United Kingdom prefabrication industries, with the former seeing a mere 6% cost savings (Page & Norman, 2014). Additionally, PrefabNZ founder, Pamela Bell predicts a 15% total cost savings based on a Vale Case that utilizes bathroom pod and wall panel assembly within the construction (Bell, 2014).

In an interview with a small-scale builder in the 2014 BRANZ report by Page and Norman, the builder stated that to adopt more prefabrication processes such as preconstructed panels, it would have to be more cost-effective to change (Page & Norman, 2014). Although prefabrication provides a safer and faster on-site construction process, the similar cost continues to be a deterrent to current practices who must provide additional training to staff to employ such methods.

In implementing prefabrication, New Zealand can look to solve other issues also common in the UK industry, being lack of innovation and skilled labour (Farmer, 2016). In the United Kingdom their construction model was reviewed by Mark Farmer in the 'Modernise or Die' report. For the United Kingdom, Farmer suggests additional funding directed to innovating the construction industry and educating the workers to suit is how prefabrication processes can be realized. Similar to what Mark Farmer suggests in the 'Modernise or Die' report, New Zealand is in need of educating the workforce in order to implement prefabrication and improve the industries resilience.

6. CONCLUSION

6.1 Discussion

In New Zealand there is a demand for prefabrication to save the housing crisis, providing homes at a lower cost, shorter time and at a higher quality with allowance for customization. Prefabrication veterans such as Japan provide an example of the success of the methodology. With the Japanese industry prioritising cost and time, homes are built with a shorter shelf-life of around 38 years (Campbell-Dollaghan, 2014). It is the relationship between cost, quality and time in Japan's industry that highlights the success of two elements at expense of the other. Like the American industry which expects homes to last well over a century, New Zealand values quality and will therefore find it difficult to reduce cost and construction time simultaneously. Hence, making the promises of prefabrication from the government and organisations such as PrefabNZ appear unfeasible.

Mass-customisation, as practiced in Sweden, will also need to be adopted to satisfy the wants of the Kiwi client. Investigations into Sweden's prefabrication industry additionally provides hope for the success of the methodology in New Zealand. Yet, current conditions of housing shortages in Sweden show that prefabrication is in fact, is not a sole solution to a 'housing crisis'.

It also becomes difficult to use current examples from countries such as Sweden and Japan to apply to New Zealand's prefabrication industry as years of experience have infiltrated their supply chain and skilled labour sectors for nearly a century. With New Zealand suggesting a ten-year window to achieve high prefabrication production rates, there are multiple barriers that must be tended to before it can simply appear and dominate the industry.

Historically it is important to understand that adoption of housing schemes in New Zealand enabled prefabrication, but after housing demands were met, financial assistance was disbanded, halting the demand and therefore practice of prefabrication methods. This 'boomerang' trend coincides with government intervention, the solution today being the 'KiwiBuild' initiative. The 'KiwiBuild Scheme' and new financing plans like that of Westpac, will help kick start prefabrication in New Zealand but to prevent history from repeating itself, consistent funding and long-term plans, for example 10, 15, 50 years etc., from both the government and our banks should be considered.

Prefabrication processes adopted within multiple companies in New Zealand, such as Fraemoths, Stanley and Tallwood, Lockwood, and Mike Greer Homes have proven successful, providing sound examples on how prefabrication can endure in the country. Yet, the common practice within the country still entails traditional methods of 'assemble on site' timber or steel frame construction. To combat this, developers can choose to follow planning like that of Hobsonville Point. The opportunity for prefabrication will therefore have equal potential to enter the industry and begin to compete and surpass current traditional methods. With the recent Treaty of Waitangi settlements enabling residential land developing opportunities for local Iwi in Auckland (Cook, 2007), prefabrication gains the ability to enter these vast developments if they mimic such models.

Contractors will also need to understand the shortfalls within the New Zealand supply chain that leads to high-material costs and marginal savings. Therefore, theories of prefabrication improving all aspects of the nation's construction methods should be recognized as assumptions rather than guarantees. Over time, prefabrication will provide predictability to the supply chain and perhaps reduce costs, but the main drivers for adoption of this new methodology should remain to be that of increased safety, predictable construction time and reduced labour on site.

Skilled labour is also a major shortfall within the industry that effects both group home builders and smaller firms. In comparison to what Mark Farmer suggests for the United Kingdom, educating labour prior to entering the industry can not only increase the number of contractors, but further implement prefabrication into the New Zealand industry.

6.2 Summary

After Phil Twyford's announcement of 50,000 homes being built with prefabricated methods over the next ten years, prefabrication seemed to be New Zealand's golden ticket to the current 'housing crisis'. In understanding the relationship between cost, quality and time, prefabrication's ability to improve all these areas instantly and simultaneously is an unlikely promise to be fulfilled. The potential of 'prefab' is undeniable, yet with a variety of national issues in the areas of skilled labour, supply chain, favoured traditional methodologies by contractors, and financial assistance, the proposed ten-year window seems unobtainable.

If prefabrication is to be adopted by a majority of the housing industry, New Zealand must first acknowledge these shortfalls to provide a solid foundation for the method and its success. The key to the New Zealand 'housing crisis' therefore cannot be immediate implementation of prefabrication through government schemes such as the KiwiBuild initiative. To utilize prefabrication, New Zealand must first see consistent government schemes, legislation and financial assistance, education of the workforce, and management of the current supply chain. All these areas require servicing and will take time to infiltrate the industry. Prefabrication has potential to innovate the construction industry and goals to 'solve the housing crisis' must take a back seat to a sustainable implementation of the methodology.

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