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Potential for Prefabrication to Enhance the New Zealand Construction Industry

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Abstract: The New Zealand construction industry finds it increasingly difficult to meet the growing demand for housing. There is increased demand over the whole country but particularly in Auckland, where some 30,000 new homes are needed in the very near future. New Zealand's population is growing at a rate that will see it rise to some 6 million by 2068. To meet demand, the construction industry will need to produce housing more efficiently than it has been doing to date. This paper investigates the potential for increased use of prefabrication techniques to address these challenges. Prefabrication is well understood to be faster, more energy efficient, cleaner and safer than traditional construction methods. The uptake of prefabrication methods in New Zealand was around 32 percent of all new houses in 2013, which lies somewhere between 90 percent uptake in Sweden and around three percent in Australia; two countries with which New Zealand is often compared. The paper discusses the current needs of the construction industry and, after reviewing the potential benefits of prefabrication, speculates over how these methods could help address the current crisis of housing supply in New Zealand.

Keywords: Prefabrication; housing crisis; benefits and disadvantages.

1. Introduction

in the wake of vast destructionduring World War II, shortages of materials, resources, and labour led to a need for more effective methods of building. Prefabrication, or off-site construction, had been proven to be faster and more efficient than the traditional methods of the day and many turned to these methods to address these needs (Waskett, 2001; Turner and Partington, 2015). The new methods were effective and "some 156,623 temporary bungalows were produced for rent under the aegis of the 1944 temporary housing program, each with a design life of 10-15 years. Many have lasted much longer" (Vale, 1995).

It is also significant that the planet is facing significant challenges due to the effects of climate change and limited sources of non-renewable energy. The Network (2016) report advises that humans are using the earth's resources at the equivalent rate of 1.6 times that which is available. Contributing to this excessive consumption is the built environment, of which it has been noted that "buildings are responsible for more than 40 percent of global energy use and one-third of global greenhouse gas emissions, both in developed and developing countries" (UNEP, 2009).

With reference to these and other similar studies, it can be noted that prefabrication methods have considerable advantages in comparison with traditional methods, including lower construction waste, greater energy efficiency, lower financial cost, faster speed, higher safety levels, fewer construction defects and a potential reduction in other environmental impacts. Others have suggested that using prefabrication techniques could decrease consumption of non-renewable sources of energy and reduce environmental hazards such as Green House Gasses (GHG) emission (Gorgolewski, 2005).

Apart from energy and environmental concerns, other pressures such as the need to provide accommodation for a growing population, have led many people to consider other ways of building. Prefabricated construction has many advantages over more traditional methods and, because of these, may provide useful solutions, not only to meet present demand but also to push the country forward and keep New Zealand green and liveable for next generation.

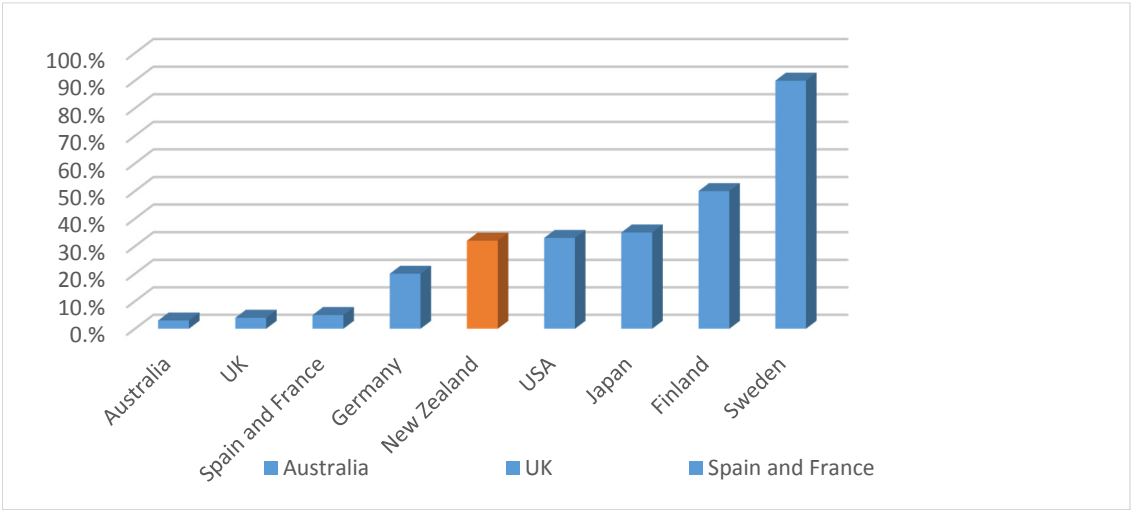

Figure 1: Uptake of prefabrication in the housing sector only (Source: Prefab New Zealand, 2014).

However, despite the well-understood benefits of prefabricated construction, only 27 percent of all new houses in New Zealand made use of prefabrication techniques in 2012 (BRANZ, 2013). Figure 1 compares the percentage of prefabricated buildings in New Zealand (Housing Sector only) with those of other countries. It is important to recognise that most of these prefabricated buildings simply use prefabricated building elements (trusses, roof and etc.) and less than 2% of all buildings were completely prefabricated. It would seem that the number of houses with at least one prefabricated element would begin to approach 100%, but all sources consulted in this review have pointed toward the 32%. More importantly, this comparison indicates that the industry contribution in New Zealand (32%) is low compared with other countries like as Finland (50%) and Sweden (90%).

2. What is Prefabrication?

The term *prefabrication*can be considered in the context of a time horizon, as the term is commonly misconstrued and suffers from historical misperceptions. Sir Richard Rogers once said “When we first

started seriously to think about the prefabricated home, everybody jumped to the conclusion that it would lead to monotony. I say it offers us a way of building truly imaginative and exciting homes" (Arieff, 2002). Vale (1995) describes Le Corbusier's opinions on prefabrication, which derived from a comparison with the automobile industry. Once production of individual cars by hand was replaced with an assembly style process, cars were made more affordable. Le Corbusier believed that if house production followed a similar process and became streamlined like cars, then these manufactured houses could be more practical andacceptable than traditional ones. Adrenaline mentions people's understanding of prefabrication including a wide range of description, "From 'cheap and flimsy' New Zealand classrooms from the 1970s to 21st century modern luxurious and highly energy efficient prefabricated homes offered by some European prefabricators" (Betz, 2015). Finally, it can be said that standardization, assembly, off-site or modular building, which we call prefabrication, means:

> Elements (from one component to a complete building) that have been manufactured in a factory some distance away from the final location, the pieces are sold, purchased and carried as a kit (or complete building), and the end result coming from assembling the kits (or attaching complete building to foundation) is usually a one-storey (or more), detached, eco-efficient house, built according to sustainable construction criteria. (Seratts, 2012).

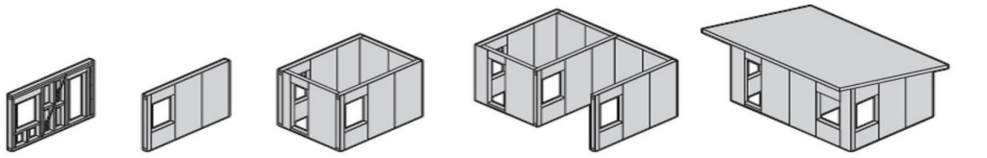

Figure 2: Different Types of Prefabrication

It is worth noting that, different types of prefabrication could be classified in different ways including, materials, system or degree of prefabrication. In the classification, based on degree of prefabrication (which is one of the most popular ways) this method is divided into five sub-categories (Figure 2). This classification ranges from component (lowest level of prefabrication), to panel, volume (3D module), hybrid (volume + panel) and complete building (highest degree of prefabrication).

3. A Brief History of Residential Prefabrication

Wherever ancient people were interested in migration or had to migrate due to external threats or environmental conditions, they required houses that were easy, fast and cheap to assemble, disassemble and transport (Herbers, 2004). So, the history of prefabricated houses can be understood to date back to the beginning of nomadic life. It can also be noted that "prefabrication in architecture is a tale of necessity and desires" (Smith, 2010).

In the industrial age, the first prefabricated iron framed house was built in England in 1830 (Herbers, 2004). However, it was after World War II that the idea of manufacturing a house in a factory was realised

on la larger scale (Vale, 1995). As Phillipson (2001) notes, following World War II, the international community was faced with vast areas of destruction and shortages of materials, resources and workforce. At the time, construction practices were changed from traditional, on-site methods to off-site prefabrication to help meet needs within prevailing constraints. According to Xu and Zhao (2010), the contemporary prefabricated housing industry grew with the mobile houses at the 1950s in the United States. These houses were the first steps toward more industrialised production of housing in the years that followed.

The prefabrication industry in New Zealand started with importing prefabricated houses for individuals around 1833. Early houses were dispatched from the United Kingdom, the United States and Australia as kits and pre-cut frames (Toomath, 1996; Bergdoll and Christensen, 2008). During the early period of colonisation, settler numbers rapidly increased and many had to spend their first days under canvas or in a crude shelter. The construction industry developed and expanded rapidly in response to the needs of migrants, who sought to live in permanent dwellings (Isaacs, 2008). Later, in the final decade of 19th century, the New Zealand Railways Department became the first producer of prefabricated housing in the country (Bowron, 2007).

4. Advantages and Effects of Prefabrication on Users and Society

Prefabrication methods have a number of tangible advantages that can help make the New Zealand construction industry more efficient and effective. Potential benefits arising through use of prefabrication can influence the overall performance of New Zealand's economy, as the building and construction sector is the fifth largest in New Zealand, contributing to 40% of landfill and employing more than 175,000 people (BRANZ, 2013).In the following sections, the nature of these advantages are briefly discussed.

4.1. Time

Time efficiency is one of the most important advantages of prefabrication when compared with traditional on-site construction techniques. Demand for construction has been increasing by up to 10% per year for some time in New Zealand, so it is very important to replace traditional methods by faster and more efficient ones (Prefab New Zealand, 2014). A 2012 study by BRANZ showed that a reduction in house construction time can mean a saving of between $1,000-$1,600 per week (BRANZ, 2012). These savings will be significant when considered in the context of an entire nation.

Prefabrication could be 35-55% faster (Phillipson, 2001; Britto and al, 2008) than traditional (on site methods). Shorter construction times will become increasingly important in New Zealand as the population continues to grow. The population has increased significantly between 1948 and 2016 and this trend is predicted to continue at least through 2068, when it will rise to some 6 million (see figure 3). The increased demand will be over the whole country but particularly in Auckland, where some 30,000 new homes are needed in the near future (Prefab New Zealand, 2014). It can be assumed that the country's need for residential housing will follow a similar upward pattern, which would advocate for faster, high-quality construction methods.

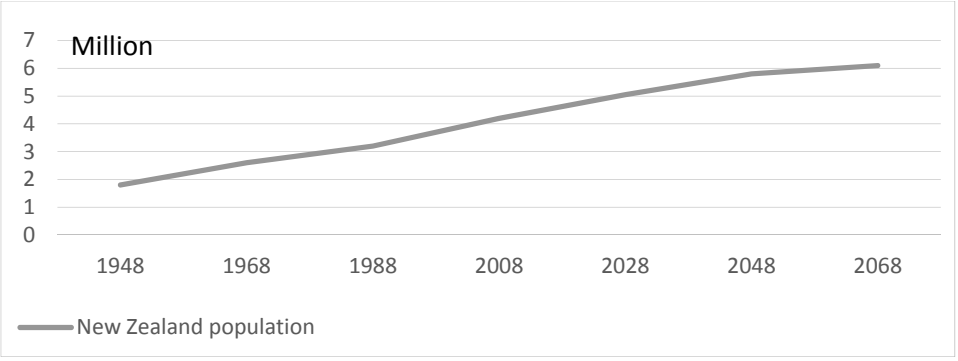

Figure 3: New Zealand population, 1948-2068 (Source: Statistics New Zealand (June year))

4.2. Environment

Increasingly, New Zealand and other countries of the South Pacific will face significant changes to climate as a consequence of human activities in different sectors, including the building industry. Figure 4 shows that CO_2 emissions in New Zealand have followed an upward trend from the late 20th century and is predicted to keep growing if changes to reverse this trend are not made. As a consequence, mean temperatures are predicted to increase 0.3 degree Celsius by 2040 and 3.0 degrees by 2110 (Mullan, 2016). There is an obvious need to change behaviours to keep the country green and moving forward in a sustainable manner. In the construction sector, this could potentially happen by replacing traditional methods by prefabrication due its environmental benefits. Prefabrication methods can reduce the amounts of waste (40%) and other environmental impacts (30-70%), and CO_2 emissions (35%), substantially. Such reductions could enhance public health as well as help combat climate change. Moreover, prefabrication uses less energy (55%), water (30%)and raw material (40%)resources (Gorgolewski, 2005; Britto and al, 2008). Using supplies of water, energy and raw material more efficiently can help guarantee that these resources will continue to be available for the next generation.

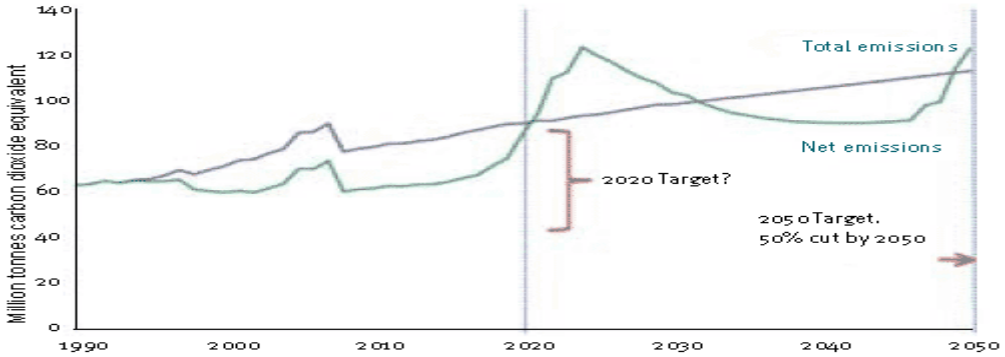

Figure 4: New Zealand's total and net greenhouse gas emissions and removals (historical and projected), 1990–2050(Source: Environment, 2009).

4.3. Quality and Safety

Phillipson (2001) notes that, as prefabrication methods are faster than traditional ones, components, materials and workers are less prone to natural hazards such as cold/hot temperatures, wind and rain. As a result, the quality of outcomes will be higher and the process is safer for all involved, particularly for those working on building sites. As control over the conditions of manufacturing and of the materials is increased in factory conditions, the components have a higher quality than equivalent parts constructed on site. The construction site is also less susceptible to damage that construction activities can cause.

Employing safer methods of construction through prefabrication is also very important because the construction sector in New Zealand has a worker fatality rate that is almost triple that of any other sector (BRANZ, 2013). This report identifies a 75% reduction in fatalities per unit of construction with factory-based construction. Accordingly, there are significant opportunities for cost savings to the Government in ACC and other government subsidised medical services. These savings could then be invested in different sectors and to enhance infrastructure.

4.4. Economy

Shahzad (2014) has found prefabrication to increase general (labour and construction) productivity between 7-11%. Hunt (2016) reports that a 1% increase in labour productivity is worth $300M to the NZ economy. This is a similar finding to Nana's (2003) report that a 10% increase in labour productivity would increase GDP by $2B in the New Zealand economy (Prefab New Zealand, 2014).

Increased prefabrication uptake leads to growth in New Zealand industry productivity by 2.5% (Productivity partnership, 2013). The Value Stream Mapping study points to savings of up to $113M per annum on a total construction turnover in New Zealand of $4.2B. These savings are made up of increased client education, reduced tendering, reduced changes on work in progress, faster construction, reduced rental costs for clients, and reduced weather delays (Employment, 2013).

5. Disadvantages of Prefabrication

> "There can be no mass production without mass marketing" (Kelly, 1951).

Although prefabrication has many benefits, there must also be some disadvantages perceived by those who make decisions about building methods, as there are clear preferences for traditional building methods based on the statistics (see 1. Introduction). A review of earlier studies undertaken in different parts of the world indicates that many other countries also face obstacles to the uptake of prefabrication. Figure 5 identifies the countries in which the four most significant barriers to prefabrication uptake are most prevalent, according to El_Abidi and Ghazalia (2015).

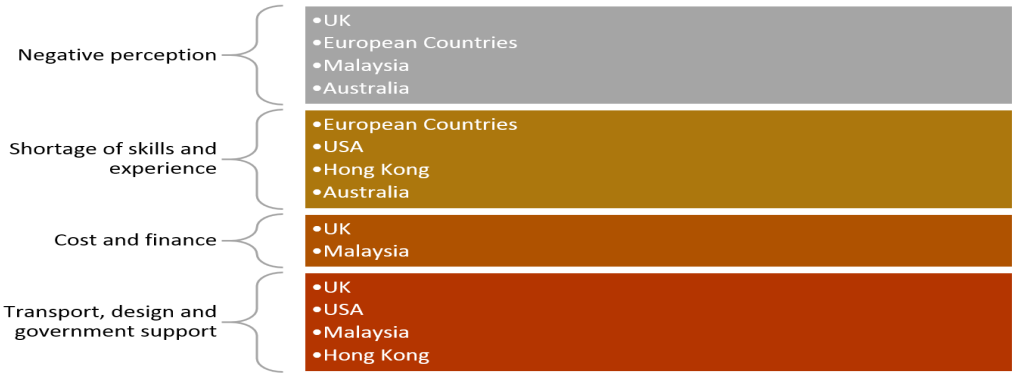

Figure 5: Obstacles against prefabrication extension in different countries (Source: El_Abidi and Ghazalia, 2015)

Public comprehension of prefabrication has an important role in the general acceptance of prefabricated buildings (Marquit, 2013). Rehfeld says this conception is greatly influenced by historical views and the imagination of the general public. This means people's perceptions are based on mobile houses and manufactured homes that are light, loose, temporary and uneconomical. Most users think prefabricated buildings are low-quality buildings, without aesthetic value, and which are the output of a repetitive, fully standardised and non-creative mechanical process (Jabar, 2014). As the prefabrication industry is relatively new, rules and standards through which the industry can be monitored have not yet been developed. Moreover, the industry is faced with shortages of skilled workers (Wilden, 2002).

Economic factors create one of the main barriers to increasing uptake of prefabrication methods. The general approach of people toward prefabricated houses is that they depreciate over time – contrary to dwellings constructed through on-site process, which generally appreciate - and that they are not appropriate as a rental investment (Phillipson, 2001). Financial institutions have little or no interest in granting loans for prefabricated construction, as large funds are needed for purchasing parts from a factory without the security of being fixed on a site (Khatavkar and Joshi 2015; Laing and al, 2001).

Other important barriers to prefabrication derive through limitations of transport. Transporting large and heavy prefabricated elements can demand significant time to prepare for legal and logistical requirements. This adds cost to projects with little apparent benefit. Transport restrictions (size and weight) can also limit designs. Often as a consequence, prefabricated houses have less design variety than traditional buildings and, in conjunction with limitations created by on-site erection processes, can only be erected on flattish sites (Stephen, 2012). Attempts to create diversity in design outcomes are often thwarted by the limitations of transport to site and installation processes.

5. Discussion and Conclusion

This paper has discussed the potential role of prefabrication technology on the future of the New Zealand construction industry. As the building industry is the fifth largest in New Zealand, the effects of prefabrication uptake may be tangible throughout the whole country. Replacing old and traditional (on-site) construction methods with prefabrication (off-site) will enable the country to directly benefit from

the recognized advantages of this method and move forward. Such benefits could be classified in two categories; short-term benefits (present time) and long-term benefits (future).

In the present view, using prefabrication methods can enable the country to save money by decreasing direct and indirect expenditures during the build, utilisation and demolition/recycling stages of the building lifecycle. Process efficiencies can help to increase the gross domestic product (GDP) by around $2B with direct savings of up to $113M per annum on a total build value of $4.2B. The savings are made up of reductions in the number of building defects and in workplace injuries, reductions in the number of changes to work in progress, improved speed of construction, reduced cost of financing, and improved quality. Moreover, as the demand for construction increases in New Zealand at a rate of 10% per year, the recognized benefit of increased speed of construction would give the country a better chance of meeting government targets on housing numbers and quality.

Looking beyond the immediate housing crisis, which simply demands more housing to be built, New Zealand should be moving forward toward more sustainable development in order to guarantee future generations the access they will need to resources and the opportunity to thrive. Prefabrication can reduce amounts of waste (40%), environmental impacts (30-70%) and CO_2 emission (35%) substantially and use energy (55%), water (30%) and raw material (40%) resources more efficiently

Taking into account potential limitations of energy resources, increasing environmental threats and ongoing population growth, the potential benefits of prefabrication can push the country forward. However, replacing traditional methods with prefabrication need will likely require stakeholders and users to change their perceptions of prefabrication and for deep seated, institutional barriers to be uplifted. This will require the cooperation of stakeholders such as builders, manufacturers, financiers, regulators and designers. Attitudes will need to change in order that appropriate guarantees, financial support, regulation and design capability can be provided to align with the characteristics of prefabricated construction. By paying more attention to stakeholder needs and expectations, and by enhancing perceptions of users toward prefabrication, this industry could become an effective alternative to traditional buildings methods in New Zealand.

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