Prefabrication and Waste Minimisation in Construction Projects: Perspectives from New Zealand

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Abstract The benefits of prefabrication are well known and include increased efficiency, greater economy, and safety in construction operations. There have also been anecdotal references to the reduction of construction waste as a result of prefabrication but there are little empirical studies to support this assertion. The current study undertakes an investigation to establish the influence, prefabrication can have on the amount of construction waste generation. Data was gathered through the collation of the perspective views of 47 construction practitioners and stakeholders who have professional experience in the New Zealand construction industry. Quantitative method of analysis was chosen for ease of understanding. The results indicated greater levels of prefabrication corresponded to lower levels of construction waste generation. However, the key to achieving construction waste minimisation targets lies in better supervision of the quality of prefabricated products. The study concludes that more training, education, and awareness is needed within the prefabrication sub-sector to realise waste minimisation on construction projects.

Keywords Construction waste · New Zealand · Prefabrication · Waste minimisation

1 Introduction

The activity level of the construction industry in New Zealand is in full swing to fulfil the residential and infrastructure requirements of the country's growing population (MBIE 2018). It is a well-established fact that construction activities consume a

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lot of natural and man-made supplies and yield enormous volumes of construction waste as a by-product (Tam et al. 2007). One-third of the world's greenhouse gases are produced due to construction activities and buildings consume 40% of energy (UNEP 2009). Construction industry is responsible for up to 40% of waste generation in many countries, where enough measures are not been taken to reduce construction waste (Chung and Lo 2003).

A New Zealand study (Jaques 2013) reports that around 1.7 million ton of construction waste is sent to landfills each year. This translates into 50% of all the waste transported to the country's landfills annually. This is an alarming situation for the country. Not only a lot of materials, that has potential to be reclaimed and reused in going to the landfills without any check, but this will also have long term implications including but not limited to wasting a large area of land filled with waste, causing harm to the environment by adding scores to air and water pollution. Another impact of this waste is soil contamination that leads to serious health threats (Tam et al. 2007).

As per synopsis of Jaques (2013), the best way of controlling the amount of construction waste is to curtail its production i.e. avoid generation construction process as much as possible. Various researchers have acknowledged that more uptake of prefabricated construction technology is an effective way of reducing the construction waste generation (Shahzad 2016; Tam et al. 2012; Jaillon et al. 2009). New Zealand construction industry is the fifth largest industry of the country in terms of employment opportunities and contributes to 6% of nations' GDP (MBIE 2018). But still, it's a traditional industry where the majority of construction activities take place onsite and use of innovation is very low (Shahzad et al. 2015). However, some recent demand-based developments in the country present new opportunities for prefabricated construction as traditional and old-school practices are unlikely to create a supply-demand balance. Prefabrication technology offers many benefits like reduced cost, shorter project duration, better quality workmanship, improved wellbeing of construction workers and reduction in construction waste generation. Some recent studies have provided shreds of evidence that prefabricated construction can offer a substantial amount of cost savings, time savings and enhanced productivity benefits to the New Zealand construction industry (Shahzad 2016). However, not enough research has been done to investigate waste minimisation aspect of prefabricated construction. This study aimed at knowing the impact that prefabrication technology can have for New Zealand in terms of reduction of waste generated by construction industry.

2 Literature Review

2.1 Construction Waste in New Zealand Context

Many researchers have defined construction waste differently. However, the definition of construction waste provided by the United States Environmental Protection Agency (USEPA) is by far the most widely used definition, which states "waste generated during the construction, modification, and demolition of building structures (including bridges, roads, buildings, etc.)" (EPA 1998). Further to this construction waste is broadly classified into four categories according to the guidelines of the European Commission. These categories are (i) demolition waste (ii) construction waste (iii) waste generated during renovation and refurbishment (iv) waste generated by roading works (Symonds and COWI 1999). Another definition of construction waste is established by Hong Kong Environmental Protection Department, according to which any byproduct of construction activity, whether it is disposed off or stored for later disposal (EPD 2012).

The variance in the definitions of construction waste curbs any direct appraisals and use of construction waste data from different countries. For this study, Jaques's (2013) definition of construction waste is adopted who defines construction waste as solid waste, this includes the wrapping of new construction materials; bits and pieces of wood, plasterboard and metal; concrete, and gravel scraps.

According to the estimates of Building Research Association of New Zealand (BRANZ), 3.5 tons of construction waste is generated by new residential development (BRANZ 2012). Of all the waste that goes to New Zealand landfill's half of the waste comes from construction industry (Jaques 2013). In summary, 1.7 million tons of waste originating from construction industry making its way to landfills in New Zealand every year. This construction waste is occupying and continues to rule a large area of land. This land being occupied by construction waste contributes to air pollution, water pollution and soil contamination (Jaques 2013; Tam et al. 2007).

2.2 Types and Sources of Construction Waste

As New Zealand construction industry is timber based, most common form of construction waste is various forms of timber followed by concrete, fixings, roofing, etc. (Jaques 2013). The composition and content of construction waste, however, fluctuate depending on the factors like type of structure, selection of construction material and technology, etc. For example, the proportion of wood is more in construction waste generated by residential construction rather than commercial or infrastructure projects. Wood waste is also generated by wet works on a traditionally built project. Careless handling by the labourers can easily lead to damage of plywood and wooden board, contributing to construction waste. If the wood is properly stored and protected against weather, it is easily damaged by the weather. Lack of care during transportation can also lead to damage and consequently adds up to wasted wood (Poon et al. 2004; Osmani 2012; Tam et al. 2006).

Broken brick also constitutes construction waste. Primarily, bricks are used for construction of load-bearing walls and retaining walls. Many factors can lead to the production of broken bricks: wrong placement, design errors, selection of wrong quality or the wrong size of brick, fragile nature of bricks, transportation and handling, poor quality of the purchased bricks etc. (Jaillon et al. 2009; Tam and Hao 2014).

Mortar waste is another type of prominent construction waste. Tam and Hao (2014) investigated the reason of mortar waste generation and observed following aspects: waste of material due to oversize orders for masonry works, waste generated during surface decoration, unused materials, unusable waste generated during rework and lack of workers responsibility to pay attention to the waste of mortar caused by saving. Luo (2018) observes that when the concrete is processed on site, the waste is generated during the mixing and production process of the concrete, running of the slurry, improper installation of the formwork, the waste of concrete caused by the improper operation of the pouring of the workers and the wrong calculation of the required amount of concrete.

Although steel is a fully recyclable material, steel on construction projects can go to waste due to workers attitude, who cannot make full use of steel bars. Bending deformation of steel makes it useless for construction works and hence it is sent to landfills (Osmani 2012; Tam et al. 2006).

Construction materials are often delivered to the project site in packaging to protect them during transportation and storage. This packaging generally does not recycle and hence become part of the construction waste that goes to landfills (Osmani 2012).

2.3 *Minimising Construction Waste*

Continuous development of the built environment has drastically increased the amount of construction waste, which not only causes enormous waste of resources but endangers the environment and wellbeing. And hence, reduction and treatment of construction waste have become a topic of global interest (Luo 2018).

The United States has laws related to waste generation stipulating: "Any company that produces industrial waste must properly handle it and cannot pour it without authorization". This law limits the amount of construction waste generated. Reducing waste generation at the construction site and reusing it as much as possible is the main principle of Japan's disposal of construction waste. By setting standards and regulations, stakeholders are involved in limiting construction waste to "zero" emissions. The source control approach reduces resource extraction, reduces manufacturing and transportation costs, and reduces environmental damage, making it more effective than treatment at the end (Luo 2018).

Construction industry in Germany has some best practices in place. It is a prevailing culture that every role player of construction waste generation cycle has to contribute in some manner to result in the reduction of waste generation. to reducing waste and recycling (Gavilan and Bernold 1994; EPD 2012).

Further to this, the designers and builders are educated to minimize the construction waste generation. Reducing waste from sources is considered a better environmental and economic benefit option.

The above discussion concludes that construction waste reduction is achieved differently by different countries. Some countries employ prevention of waste generation and other go about effective management. Similarly, New Zealand requires a rigorous policy to minimize construction waste generation.

2.4 *Prefabrication in Perspective*

Prefabrication is a construction technology that shifts the bulk of construction activities from the project site to a remote factory or workshop area (Shahzad 2016). The remotely manufactured components or modules are transported to the project site, where they are assembled. It is also known as off-site construction (OFC) and off-site manufacturing (OSM) (Cao et al. 2015; Boafo et al. 2016; Page and Norman 2014). Shahzad et al. (2015) have presented categorization of prefabrication as "(i) component prefabrication, (ii) wall panel prefabrication, (iii) modular prefabrication, (iv) mixed prefabrication and (v) complete construction prefabrication".

In New Zealand's construction industry, almost all new buildings use some percentage of prefabricated components, ranging from simple building elements such as doors and window frames to complex prefabricated building modules (Shahzad 2016; Luo 2018). A New Zealand study documents that the share of prefabricated components for residential buildings is about one third and is on an upward trajectory (Roberti 2014). New Zealand recognizes prefabrication technology as effective, productive and of good quality (Chiu 2012; BRANZ 2012).

A New Zealand study by BRANZ (2012) notes that when compared with traditional build, prefabrication offers huge efficiency in time performance of the projects. Prefabrication offers low risk alternatives to complex construction related issues (Shahzad 2016). Mass standardization achieved with prefabrication reduces the construction cost during all phases of construction. Chiu (2012) notes that precast technology not only reduce the on-site cost but also eliminates the cost over runs. The probability of little or no reworks greatly reduces the amount of waste generation. Improved quality workmanship offered by prefabrication makes the entire building life cycle more affordable (Shahzad 2016). Use of this technology can hugely improve the management of site operations. The layout and environment of the construction site improves as prefabrication technology reduces the need for processing and storage of raw materials (Luo 2018). Prefabricated construction addressed issues like labour shortage and construction technology defects. Prefabrication can also effectively reduce other risks associated with construction, such as workers' health and safety issues, fire risks, and limited construction sites and material damage caused by accidents (Li et al. 2014; Shahzad 2016).

2.5 Role of Prefabrication to Reduce Construction Waste

Prefabrication technology is known for its effectiveness to reduce construction waste. Here, "Reduce" refers to minimising the amount of construction material entering the solid waste stream and also to reduce the overall environmental degradation (Gavilan and Bernold 1994). Reducing the amount of materials used or by reusing existing materials can effectively minimize the construction waste generation. As prefabrication is carried out at the factory in a standardized manner construction materials and workers are less vulnerable to natural disasters, such as cold/hot temperatures, wind and rain. This factory mode of production helps to improve the process and quality of construction (Tam et al. 2007). Factory-controlled production and quality audits of building components can improve the consistency of construction standards and construction quality and reduce construction defects (Shahzad and Razeen 2018). It also simplifies on-site work during installation and enables site workers to greatly increase work efficiency without being interrupted by others and avoiding the possibility of duplication of effort (BRANZ 2012).

Prefabricated construction reduces generation of construction waste compared to traditional construction methods, as waste generation is prevented from occurring at the source of construction waste. Some studies have documented that through the use of prefabrication, different building materials an achieve 80–100% reduction in waste generation (Tam et al. 2007; Jaillon et al. 2009; Li et al. 2014).

Tam and Hao (2014), compared traditional construction with four projects constructed by prefabrication technology and observed that prefabrication technology can reduce plastering waste up to 100%. Similarly, timber formwork waste can be reduced by 80%, and the concrete waste can be reduced up to 60%. In a study, Cao et al. (2015) noted that prefabrication has potential of reducing construction waste compared to traditional construction methods between 25 and 81.25%. This result is consistent with findings of Tam et al. (2007) that documented reduction of construction waste generation by up to 84.7% compared to conventional methods.

According to Luo (2018), there are some possible shortcomings of the above presented studies. Firstly, the definition of construction waste was not the same for each study. Secondly, the number of samples were small and were based on different building types. In contrast, few studies have quantified the construction waste generated in New Zealand's new residential projects or assessed the perception of professionals on waste reduction. Foregoing in the view, this paper aims to study the effects of prefabricated technology used in recent residential projects in New Zealand to reduce waste. The purpose of this research is to compare prefabrication with the traditional method of construction, and to quantify their benefits in reducing waste; to investigate the factors of prefabrication technology that contribute to minimisation of construction waste generation; to explore the measures that can help to improve the current state of construction waste generation.

3 Research Objectives

The aim of this study was to investigate the impact of prefabrication technology of construction on reducing the generation of construction waste. In order to achieve this aim, two research objectives were developed (1) Investigate the factors that contribute to minimisation of construction waste generation by the adoption of prefabricated construction. (2) To explore the measures that can help to improve the current state of construction waste generation. The scope of this study is limited waste generation benefits of prefabrication technology and the findings are based on the views of construction industry professionals in Auckland New Zealand only.

4 Research Methodology

This is a three-stage study that started with the review of existing literature in the subject area, this process enabled the understanding of current state of research and knowledge that led to the identification of gaps in the existing literature. Information for this research was sourced from academic publications and New Zealand construction industry reports including the reports of PrefabNZ, Building Research Association of New Zealand (BRANZ) and Ministry of Business, Innovation and Employment (MBIE). In the next stage four (4) pilot interviews are conducted with project managers to get more information on the subject matter (Saunder and Lewis 2017). These interviews captured the experience of construction professionals on the various features of prefabrication technology that can help to minimise the construction waste generation. During the interviews, questions were also asked to know what some of the measures are that can improve the current state of construction waste generation in New Zealand. Based on the findings of the literature review and pilot interviews, a survey questionnaire was developed to collect data from the construction industry practitioners including consultants, contractors, prefab manufacturers, and suppliers. Questionnaire surveys have the ability to collect views of the larger populace. This method of data collection also facilitates the collection of data in a comparatively shorter period of time (Denscombe 2014). The questionnaire was pretested before the start of data collection. This pre-testing was done by construction industry practitioners who provided feedback to improve the questionnaire.

5 Data Collection and Analysis

The questionnaire contained closed-ended questions based on 5-point Likert scale answering options. A scale from 5 points—1 point was used to record the participants' response. In this scale, 5 represented 'Strongly Agree', 4 represented 'Agree', 3 represented 'Somewhat Agree', 2 represented 'Disagree' and 1 represented 'Strongly

Disagree'. To eliminate any prejudice in participants' responses a "No Idea" answering option was also postulated. The questionnaire divided into three sections, at the end of each section, open-ended questions were asked to have a better understanding of participants' point of view. The target population for this survey included professional members of the trade and professional organisations including members of New Zealand Institute of Architects (NZIA), Architectural Design New Zealand (ADNZ), New Zealand Institute of Building (NZIOB), New Zealand Institute of Quantity Surveyors (NZIQS) and Building Industry Federation (BIF). Denscombe (2014) recommends the use of the snowball method of sampling to improve the effectiveness of the survey due to the ability of this approach to spreading the questionnaire to a larger populace. With the foregoing in view, the snowball sampling method was adopted for this study. The multi-attribute analytical method was employed to analyse the data, that was collected using the questionnaire survey. In the multi-attribute method, ratings provided by the survey participants are analysed to ascertain the mean rating value. Mean rating value also abbreviated as 'MR' is calculated for each of the factor included in the questionnaire.

Shahzad et al. (2015) supports this technique of analysing the ratings provided by the respondents to ascertain the mean rating value (MR) for each sub-set in a set which represents various rating points assigned by the respondents. Ranking of factors was based on the mean rating values. Computation of mean rating values was carried out using the equation No. 1, presented below as recommended by Shahzad et al. (2015).

$$MR_i = \sum_{n=1}^{5} (R_{pjk} X \% R_{jk}) \tag{1}$$

Here: MRj = Mean Rating value for factor j, R_{pjk} = Rating point k (value range 1–5) and $\%R_{jk}$ = Percent response rate at point k, for factor j.

The factor that has highest value of MR is regarded as most significant factor that has high impact and vice versa. Factors having an average or higher value will have impact on reducing the construction waste with the use of prefabrication technology.

For a 5-point Likert rating scale 1 < MR < 5 on, flowing applies:

$$\text{MR} > 2.5 = \text{Factor is significant}$$
$$\text{MR} < 2.5 = \text{Factor is non-significant}$$

6 Findings and Discussion

A total of 47 usable survey responses were obtained for research. These responses came from members of PrefabNZ (30%), NZIA (30%), ADNZ (13%), NZIQS (12%), NZIOB (9%) and BIF (6%). Findings of this study are dominated by the views of architects. This is a good deduction as architects play a vital role is selection of construction technology to be adopted for the project delivery as well as the selection of construction materials. Awareness of architects on the issue of construction waste generation can immensely change the future practices.

6.1 Features of Prefabrication Facilitating Minimisation of Construction Waste

The first objective of this study was to find out the various features of prefabrication technology that help to minimise the construction waste generation. Nine features of prefabrication were identified to be the reason that leads to minimisation of waste generation in the construction process. Computed mean rating values reveal that all of these features are significant and carry a huge impact on waste minimisation (Table 1). It is evident that the New Zealand construction industry is aware of waste minimisation benefits of prefabrication technology. However, this potential of prefabrication technology is not fully utilised due to the overall low interest of New Zealand's construction industry in prefabrication (Shahzad 2018).

The first four highest ranked and most significant features of prefabrication technology are associated with the opportunity of closely and carefully monitoring the manufacturing process of prefabricated components, which is otherwise not possible in on-site construction. The first ranked feature is that: better supervision under factory setting improves the quality of process and products, which facilitates the minimisation of construction waste generation. The second most significant feature of this technology that helps in minimising waste generation is careful packaging and transportation of prefabricated components that curtail the probability of any material going wasted during transportation to the site. Additionally, prefabrication technology employs a process that involves careful calculation of construction materials curtailing the excessive order of the materials that ultimately becomes part of

Table 1 Prefabrication features contributing to waste minimisation

Features of prefabrication technology facilitating construction waste minimisation	MR value
Precision and better supervision of prefabrication process	4.23
Careful transportation of packaged prefabricated components	4.04
Prefabrication process involves careful calculation of material quantities	3.89
Use of CNC machines in prefabrication process	3.83
Construction material is not exposed to direct weather	3.81
Fewer chances of material stealing	3.72
Leftover construction materials can be used later on	3.68
Possibility of reusing and recycling construction materials	3.51

MR (Mean Rating value)

construction waste generation. Similarly, the use of CNC (Computer Numeric Control) machines in prefabrication yards saves a lot of usable material going to be wasted.

Next set of facilitating features of prefabrication are associated with sheltered factory setting environment. In prefabrication yards, construction materials are not directly exposed to harsh weather conditions which reduces the wastage of construction material. These yards/factories have proper raw material storage sheds. Secure storage also inhibits the chances of material stealing. The finished products are also stored to prevent damage. The probability of any extra and left-over materials to be used in future rather than directly going to waste landfills is higher in case of prefabricated construction due to the secure storage facilities and direct stake of prefabrication manufacturer. According to survey participants, prefabrication technology allows the potential of reusing and recycling construction material more than in traditional construction practices.

6.2 *Measures to Improve the Current State of Construction Waste Generation*

The second objective of this study was to investigate the various measures that if taken can enhance the current state of practice. Table 2 presents the results of the industry survey with regards to this research objective.

The construction industry has a consensus that more training and education is vital in reducing the amount of construction waste generation, as this was pointed out to be the most significant factor. Respondents indicated that due to the lack of knowledge about construction waste, most workers are not aware of the potential of reducing waste generation, neglecting the classification and recycling of on-site waste. Furthermore, they do not see a benefit in hiring someone to be responsible for supervision. This observation is in line with current situation of New Zealand

Table 2 Measures to improve current state of waste generation

Measures to improve current state of construction waste generation	MR value
Training, education and awareness about construction waste	4.19
Tax relaxation and fiscal subsidy for sustainable practices	4.10
Rewards for companies to re-use and recycle construction materials	3.93
A dedicated team member to manage material requests and avoid over orders	3.82
Professional are involved in all phases of project	3.81
Management of entire construction process to ensure waste minimisation	3.75
Selection of construction process that minimises waste generation	3.72

MR (Mean Rating value)

construction industry, that faces acute shortage of skilled workers and relies heavily on a work force that is poorly educated (MBIE 2018).

Next most important factor to improve current practices was “Tax relaxation and fiscal subsidy to the developer for sustainable practices”. In this way, stakeholders will see a direct benefit in adopting sustainable practices.

Findings reveal that construction workers have an important role in reducing the construction waste generation and they can play a vital role in many different phases of construction. Technicians should be familiar with the drawings to implement on-site supervision to meet the requirements set by New Zealand Building Code (NZBC), make a budget for building materials, and reduce the probability of converting excess building materials into construction waste. According to survey participants, establishing a sound system that will allow workers to recognize the dangers of wasting building materials to individuals and society as a whole can effectively change the behaviour towards material handling. Material personnel should strictly control the quality, communicate with the construction management personnel, carefully approve the request list, and avoid the waste caused by excessive material demand. Ensuring quality control and durability of buildings reduces the need for unnecessary maintenance, reinforcement and even reconstruction works.

Management methods are vital to improving construction waste generation. The ratio of construction waste is different for different construction forms and the amount of garbage varies greatly from site to site due to different construction management conditions. Professional work is handled by specialized departments and can greatly reduce the generation of construction waste. Individual projects can be contracted to individuals in a subcontracted manner, and contractors can find ways to reduce the generation of construction waste in order to ensure efficiency.

Reducing construction waste generation from the construction process was also identified to be of significance for example replacing the wood form-work with a reusable steel form-work can reduce the generation of waste wood, using assembly instead of on-site production is also a good way to reduce construction waste; using industrial production methods, the building’s components can be mass-produced at the factory, which was ranked 10th in these options. It reduces various unstable factors on the traditional construction site, which can save building materials and reduce construction waste.

7 Conclusion

The study establishes that more use of prefabrication technology corresponds to a reduced amount of construction waste generation during the project. New Zealand construction industry has a good understanding of this potential benefit of prefabrication technology. It is evident that precision and better supervision of the prefabrication process is a key factor for achieving waste minimisation targets. Careful packaging and transportation and carrying out work in a covered factory setting that also has the provision of secure material storage sheds also adds to the value of the overall process and significantly minimises the waste generation. The study concludes that more education, training, and awareness is needed within the prefabrication sub-sector to realise waste minimisation on construction projects. In addition to awareness, management methods and the right choice of construction process can further improve the current state of construction waste generation.

In conclusion, prefabrication technology is a construction method that can effectively reduce construction waste generation in New Zealand due to its high quality and precision. More uptake of prefabrication technology will be a sustainability value addition that can hugely minimise the amount of construction waste going to the country's landfills.

References

Boafo F, Kim JH, Kim JT (2016) Performance of modular prefabricated architecture: case study-based review and future pathways. Sustainability 8(6). https://doi.org/10.3390/su8060558

BRANZ (2012) Value of time saving in new housing. SR259, Building Research Association of New Zealand, Wellington, New Zealand

Cao X, Li X, Zhu Y, Zhang Z (2015) A comparative study of environmental performance between prefabricated and traditional residential buildings in China. J Clean Prod 109:131–143. https://doi.org/10.1016/j.jclepro.2015.04.120

Chiu STL (2012) An analysis on the potential of prefabricated construction industry

Chung SS, Lo CW (2003) Evaluating sustainability in waste management: the case of construction and demolition, chemical and clinical wastes in Hong Kong. Resour Conserv Recycl 37(2):119–145

Denscombe M (2014) The good research guide: for small-scale social research projects, 5th edn. McGraw-Hill Education/Open University Press, Maidenhead, England

EPD (2012) Construction waste. Environmental protection department, Hong Kong. http://www.gov.hk/en/residents/environment/waste/constructionwaste.htm

EPA (1998) Characterization of building-related construction and demolition debris in the United States. The U.S. Environmental protection agency, Washington, DC

Gavilan RM, Bernold LE (1994) Source evaluation of solid waste in building construction. J Constr Eng Manag 120(3):536–552

Jaillon L, Poon CS, Chiang YH (2009) Quantifying the waste reduction potential of using prefabrication in building construction in Hong Kong. Waste Manag 29(1):309–320. https://doi.org/10.1016/j.wasman.2008.02.015

Jaques R (2013) Building basics: minimising waste. Building Research Association of New Zealand, Wellington, New Zealand. Master's dissertation (unpublished). Massey University, New Zealand

Li Z, Shen GQ, Alshawi M (2014) Measuring the impact of prefabrication on construction waste reduction: An empirical study in China. Resour Conserv Recycl 91:27–39. https://doi.org/10.1016/j.resconrec.2014.07.013

Luo Y (2018) Waste minimization in New Zealand construction industry through prefabrication technology

MBIE (2018). National construction pipeline report 2018. Ministry of Business, Innovation and Employment. Wellington, New Zealand

Osmani M (2012) Construction waste minimization in the UK: current pressures for change and approaches. Procedia Soc Behav Sci 40:37–40. https://doi.org/10.1016/j.sbspro.2012.03.158

Page IC, Norman D (2014) Prefabrication and standardisation potential in buildings. Building Research Association of New Zealand, Wellington, New Zealand
Poon CS, Yu ATW, Jaillon L (2004) Reducing building waste at construction sites in Hong Kong. Constr Manag Econ 22(5):461–470
Roberti JR (2014) Trends in new residential construction in Auckland, a case study based on the Auckland atlas of construction. Building Research Association of New Zealand, Wellington, New Zealand
Saunders MNK, Lewis P (2017) Doing research in business and management. Pearson. ISBN-10: 129213352X. ISBN-13: 978129213352
Shahzad W, Mbachu J, Domingo N (2015) Marginal productivity gained through prefabrication: case studies of building projects in Auckland. Buildings 5(1):196–208
Shahzad WM (2016) Comparative analysis of the productivity levels achieved through the use of panelised prefabrication technology with those of traditional building system. Doctoral thesis, Massey University, New Zealand
Shahzad W, Razeen M (2018) Potential of New Zealand trades to export prefabricated timber panels. In: AUBEA 2018 conference, Singapore
Shahzad W (2018) Panellised prefab's benefits. Build Magazine, BRANZ, Wellington
Symonds A, COWI YPB (1999) Construction and demolition waste management practices, and their economic impacts. Ìn: Report to DGXI, European Commission
Tam VW, Le KN, Zeng S (2012) Review on waste management systems in the Hong Kong construction industry: use of spectral and bispectral methods. J Civ Eng Manag 18(1):14–23
Tam VW, Tam CM, Chan JK, Ng WC (2006) Cutting construction wastes by prefabrication. Int J Constr Manag 6(1):15–25
Tam VWY, Hao JJL (2014) Prefabrication as a mean of minimizing construction waste on site. Int J Constr Manag 14(2):113–121
Tam VWY, Tam CM, Zeng SX, Ng WCY (2007) Towards adoption of prefabrication in construction. Build Environ 42(10):3642–3654
UNEP (2009) Buildings and climate change summary for decision-makers. Sustainable consumption and production branch, 15 Rue de Milan