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Article

Marginal Productivity Gained Through Prefabrication: Case Studies of Building Projects in Auckland

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Abstract: Several studies have documented benefits of prefabrication system (prefab) compared to the traditional building system (TBS). However, the documented benefits have been anecdotal or fragmented with reports of isolated case study projects. Few studies have looked at the objectively quantified benefits from statistical significance point of view and across building types in New Zealand. This study contributes to filling this knowledge gap by analyzing cost and time-savings, and productivity improvement achievable by the use of prefab in place of the TBS. Records of completion times and final contract values of 66 building projects implemented using prefab in Auckland were collected. The building types included commercial, houses, apartments, educational, and community buildings. The project details included final contract sums, completion dates, gross floor areas, and number of floors. Based on these details, the equivalent completion times and the final cost estimates for similar buildings implemented using the TBS were obtained from the Rawlinsons construction data handbook and feedback from some designers and contractors. Marginal productivity outcome for each building project was computed as the product of the cost and time-savings achieved using the prefab. Results showed that the use of prefab in place of TBS resulted in 34% and 19% average reductions in the completion times and costs, respectively. This also translated to overall 7% average improvement in the productivity outcomes in the building projects. Univariate ANOVA-based hypothesis test results showed that 'building type' had no significant effects on the cost and productivity improvement outcomes, but had significant effect on the time savings analyzed in the case study projects. The greatest productivity gain of 11% was achieved in house projects. These evidence-based results could guide optimized use of prefab for specific building application. The hypothesis-testing outcome provides insights on one of several potential influences on prefab improvements, which will be analyzed in subsequent research.

Keywords: building systems; efficiency; off-site manufacturing; prefabrication; productivity

1. Introduction

Offsite manufacture or prefabrication of building components and systems has been acknowledged globally by many industry-driven commissions of enquiry as an effective solution to the several problems faced by the construction industry [1]. The technique readily supports standardization and rapid prototyping (including 3D printing/additive manufacturing technologies), which are expected to re-engineer the future of the construction industry [2].

Numerous benefits that prefab offers compared to the traditional building system (TBS) have been documented in several studies. These included better quality of work [3,4], better environmental performance and safety records [5,6], significant cost and time savings [2,7], and enhanced productivity and efficiency [4]. However, the benefits have been anecdotal or fragmented, and involved reports of isolated case studies [5,8]. Few studies have looked at the evidence-based and quantified benefits from statistical significance point of view and across building types. The low level of industry uptake of prefab hinges in part on the lack of quantifiable evidence to support claims about the numerous benefits credited to the technology [1]. This research contributes to filling this knowledge gap by seeking and analyzing hard data on the marginal benefits of the technology.

1.1. Prefabrication in Context

The Modular Building Institute [9] defines "prefabrication" as the process of manufacturing and assembling the major building components at remote offsite locations for their subsequent installation on construction site. Operationally, prefabrication is a construction innovation, which aims to take as much as possible the construction activities away from the project site to the factory to ensure better quality and safer production under controlled working conditions. This construction approach is seen as being more environmentally friendly, safer and productive than the conventional stick-built approach [10,11]. Shahzad and Mbachu [1] argue that there is increasingly little differentiation between the conventional building types and the "componentized" and the "panelized" prefabrication types. This is because conventional buildings involve some form of "componentized" and "panelized" prefab units or the other. In this context, the differentiation is made by checking the value or proportion of the prefabrication components compared to the onsite manufactured components. On this basis, a building is classified as a prefab building where the prefab component is more than 50% of the total building value, or *vice versa*.

1.2. Benefits of Prefabrication Compared to Conventional Construction Methods

Several studies have explored benefits of prefabrication technology. These benefits included reduced project cost, shorter project duration and on time delivery of projects [12], enhanced quality of construction [12,13] improved onsite health and safety [14], reduced onsite wastage and environmental impact, and reduced whole life cycle costs [1]. Lu [14] observes that prefab does not only save construction costs but also offers more reliable estimates of the upfront costs, total investment outlay and overall returns on investments. Other advantages of the modular prefabrication over and above conventional construction methods include better compliance with the Building Codes, quicker processing of the building consents/permits, and fewer building inspections [1]. In addition, Modular Building Institute [9] maintains that prefabrication optimizes the use of construction materials, resulting in less amount of waste generation.

1.3. Issues with Prefabrication System of Construction

Despite the benefits of prefabrication, there is still low-uptake of the technology in many countries [1]. Several studies explored the issues with the prefabrication technology in general. Some of the issues relate to the need for expensive haulage and cranage for handling large prefab components [9,13], the long lead time required for ordering and supply of prefab components, and the lack of flexibility to permit bespoke designs at the design phase [15].

From a socio-cultural perspective, Bell [3] notes the misperceptions about the technology based on cultural issues and social stigma attached to the technology due to negative experiences in the past about the quality of prefab buildings, especially, during the post-world war reconstruction era, as well as the temporary nature and poor aesthetics of prefab buildings. Shahzad and Mbachu [1] note the building owner's penchant for bespoke designs which allows them to make changes to suite lifestyle preferences throughout the design and initial construction stages. The conventional building approach offers this flexibility to a large extent and also allows room for more proactive change management, whereas the prefab approach usually limits the extent of the owner's changes to the standard designs. If significant changes are made, especially at the construction phase, the outcomes for the prefab technology in terms of costs, speed and wastage will be less desirable when compared to the corresponding outcomes for the conventional system. Other issues include the logistic challenge (especially for projects located in traffic congested areas), onsite connection or interface problems, and the reality that construction-phase changes are bound to be made due to the variability of site conditions from the initial design assumptions. In these circumstances, the conventional building method proves to be more suitable than the prefab system.

In sum, prefab is still globally viewed as the way of the future in the construction industry. Its benefits certainly outweigh its shortcomings. The question is, why is it then that the technology suffers low industry-wide uptake? Part of the answer to this problem could be lack of empirical evidence with which to support the numerous benefits credited to the technology. To enable a choice to be made between prefab and conventional building systems, owners would want credible and quantified evidence of the marginal benefits the technology offers. Current evidence is still anecdotal or is not robust enough due to hasty conclusions being made on isolated case study results.

1.4. Research Objectives

The main objectives of this study were: (1) To quantify the marginal benefits of the prefab building system in terms of the cost, time and productivity improvements it can offer over and above the corresponding benefits achievable with the TBS; (2) To examine how any observed benefits may be affected by the "building type" as a fixed independent factor.

1.5. Scope and Limitations

The study is limited to the historical records of final contract sums and durations of 66 building projects completed in Auckland. The building types covered included commercial, houses, apartments, educational, and community buildings. The need to limit the project locations to Auckland is to minimize any bias which location as a fixed independent factor could have on the research outcomes. Case study building projects investigated under each building category comprised 33 houses (50%), 16 commercial (24%), 7 educational (11%), 5 community (8%), and 5 apartment (8%) buildings, totalling 66 projects. Majority of the case study building projects were houses.

Proportions of the prefab systems used in the 66 case study projects were as follows: Componentized and panelized (CP) 30 (45%), hybrid (modular and CP) 20 (30%), modular 13 (20%), and whole house 3 (5%). The CP form of prefab therefore constituted the greatest proportion of the projects investigated.

2. Research Methods

Historical cost information on some completed projects provided empirical data for the study. A mixed method of archival research and case study was therefore adopted as the appropriate research method as it permitted the extraction of information from archived records [16]. This method also aligns with the research objective of obtaining multiple sources of evidence from different cases (*i.e.*, building types) [17].

In addition, Cooper and Emory [18] recommend the use of case study research method where data samples are chosen for relevance to the breadth of the issue under investigation rather than on the basis of how well they represent the target population. Investigations were focused on exploring the potential marginal time and cost savings that could be achieved by the use of prefab system over and above the outcomes for conventional building system. With no pre-defined sampling frame for the study, final contract sums and completion times of the prefab buildings covered in the study were obtained through contacts with contracting and consulting firms in Auckland. In total archived records of 66 prefab building projects were examined. For the purpose of comparative analysis, the key historical project information required for each prefab building type was mainly the building characteristics that determined the price information in the Rawlinsons Construction Handbook [19]. Information for each of the five building types included cost at completion, duration, gross floor area (GFA) and number of floors. The need to adjust the effects that differing regimes of inflation and exchange rates had on the historical cost information was obviated by the use of percentage differences as the common denominator for comparison.

To obtain the empirical data, purposive sampling method [20] was used, since there were no databases from which to sample the projects. Through the assistance of the Registered Master Builders

Federation of New Zealand, contractors who were willing to release records of their past projects for the purposes of the research were contacted. They were promised anonymity, assuring that the data would be used solely for academic research purposes with no revealing details about their projects, their companies or their clients. The efforts in this direction yielded 66 prefab project records. The equivalent completion times and the final cost estimates for similar buildings implemented using the TBS were obtained from the Rawlinsons construction data handbook as well as feedback from some designers and contractors.

2.1. Method of Data Analysis

The data required for the first objective were the final costs and completion times of prefab buildings under each building category. The data analysis involved computing for the following parameters for the *j*th project within a set for a particular building type *i*:

2.1.1. Marginal Cost Saving (MCS_{ij})

This was computed as the difference between the final cost of the prefab building and the corresponding cost for a similar building erected using the traditional system, expressed as a percentage of the latter. Equation (1) provides the expression for the MCS_{ij}:

$$\mathrm{MCS}_{ij} = \left(\frac{C_{\mathrm{TRAD}ij} - C_{\mathrm{PREFAB}ij}}{C_{\mathrm{TRAD}ij}} \right) \tag{1}$$

where MCS_{ij} is marginal cost saving (MCS) achieved in the *j*th project within the set of buildings for the particular building type *i*; $C_{\mathrm{PREFAB}ij}$ is final cost of the *j*th prefab building; $C_{\mathrm{TRAD}ij}$ is corresponding final cost of a similar building completed using the traditional building system.

The rationale for computing the productivity improvement as a product of marginal time and cost savings draws upon two streams of thoughts:

First, in the construction industry context, productivity performance depends largely on the cost and schedule performance [21]. This strategic perspective of the concept of productivity differs to some extent from the economist's perspective of productivity which is basely solely on output *versus* input resource ratio, featuring variants, such as labour, capital and multi-factor productivity measures. Mbachu and Shahzad [7] clearly made this distinction. The mathematical expression for an integrated productivity measurement based on the two key parameters of cost and time savings draws from the fact that productivity is directly proportional to the cost and schedule performance, *i.e.*:

$$P \propto (S_p, C_P) \tag{2}$$

$$P = \beta(S_P \times C_P) \tag{3}$$

where P is the productivity performance achieved in a project; β is an empirically determinable constant of proportionality that depends on the dynamics of the operational environment. The constant could be taken as unity (*i.e.*, value of 1) for projects executed under normal operating conditions as assumed in the study; S_p is the schedule performance computed using a modified form of Equation (1); C_p is the cost performance computed using Equation (1).

2.1.2. Average Marginal Cost Saving ($AMCS_i$)

This was computed as the average of the MCS for all the case study projects for a particular building type. Equation (4) provides the expression for evaluating the average marginal cost saving ($AMCS_i$):

$$\mathrm{AMCS}_i = \left(\frac{\sum_{j=1}^{n} \mathrm{MCS}_{ij}}{n} \right) \tag{4}$$

where $AMCS_i$ is average marginal cost savings achieved in all the *n* case study buildings for the building type *i*.

2.1.3. Marginal Time Saving (MTS_{ij}) and Average Marginal Time Saving ($AMTS_i$)

These were computed as for the MCS_{ij} and $AMCS_i$ in Equations (1) and (4) above, respectively.

2.1.4. Productivity Improvement (PI_i)

This was computed on two levels: At the level of the individual building types, it was computed as the product of the marginal cost and time savings achieved in each case study project *j* within the set for the building type *i*, *i.e.*:

$$\mathrm{PI}_{ij} = \mathrm{MCS}_{ij} \times \mathrm{MTS}_{ij} \tag{5}$$

where PI_{ij} is productivity improvement achieved in the *j*th project for the building type *i*; MCS_{ij} is marginal cost saving achieved in the *j*th project for the building type *i*; MTS_{ij} is marginal time savings achieved in the *j*th project for the building type *i*.

At the level of the building type *i*, the productivity improvement was computed as the product of the average cost and time savings achieved in the case study projects for a particular building type *i*:

$$\mathrm{PI}_i = \mathrm{AMCS}_i \times \mathrm{AMTS}_i \tag{6}$$

where PI_i is productivity improvement achieved in all the *n* case study buildings for the building type *i*; $AMCS_i$ is average marginal cost savings achieved in all the *n* case study buildings for the building type *i*; $AMTS_i$ is average marginal time savings achieved in all the *n* case study buildings for the building type *i*.

2.1.5. Average Productivity Improvement (API_{av})

This was computed as the average of the productivity improvements achieved across all *m* building types:

$$\mathrm{API}_{\mathrm{av}} = \left(\frac{\sum_{i=1}^{m} PI_i}{m} \right) \tag{7}$$

where API_{av} is Average Productivity Improvement achieved in all the *m* building types.

2.2. Hypothesis Testing

The statistical tests of significance, which informed the second objective of the study involved a null hypothesis that "building type" as a fixed independent factor did not have significant effect on any marginal benefits achieved by the use of prefab system in the case study projects. The alternative hypothesis assumed otherwise. The hypothesis testing required a single factor analysis of variance (ANOVA) given the single independent factor involved (*i.e.*, "building type") and the interval scale of the empirical data [22]. The hypothesis testing was conducted separately for the observed cost, time and productivity marginal benefits. Typical procedure for the test involving time savings is defined as follows:

H0T: There is no significant difference in the average time-savings achieved in the five building groups. If this were true, it would mean that "building type" would have no significant effect on the time-savings achieved by the use of prefab in place of conventional method.

The alternative hypothesis was formulated as follows:

HaT: The differences in the average time-savings achieved in the five building groups are significant.

Acceptance condition: Accept H0T if the *p*-value or confidence level of the single factor ANOVA test is higher than the 0.05 alpha value for the test.

Rejection condition: Reject H0T if the *p*-value is equal to or lower than the alpha value for the test; accept the alternative hypothesis instead.

The above hypothesis tests were replicated for the cost and productivity improvements.

3. Results and Discussions

Results relating to the two objectives of the study are presented and discussed in the following subsections.

3.1. Cost, Time, and Productivity Improvement Achieved by Use of Prefab

The first research objective was to quantify the marginal benefits of the prefab building system in terms of the cost, time and productivity improvement it delivers over and above the outcomes achievable with the traditional building system (TBS). Table 1 presents typical example of the marginal benefit analysis for the office/commercial building projects. This building category comprised 18 case study projects. Similar computations were done for the other 4 building categories. The results were summarized for all the buildings types and plotted in Figure 1 for better visual appreciation.

Figure 1 shows that the marginal cost saving delivered by the prefab system over the TBS was 19% on average. The highest cost saving (24%) was achieved in the community building projects. Perhaps, the relatively simpler design nature of community buildings might have contributed to this result.

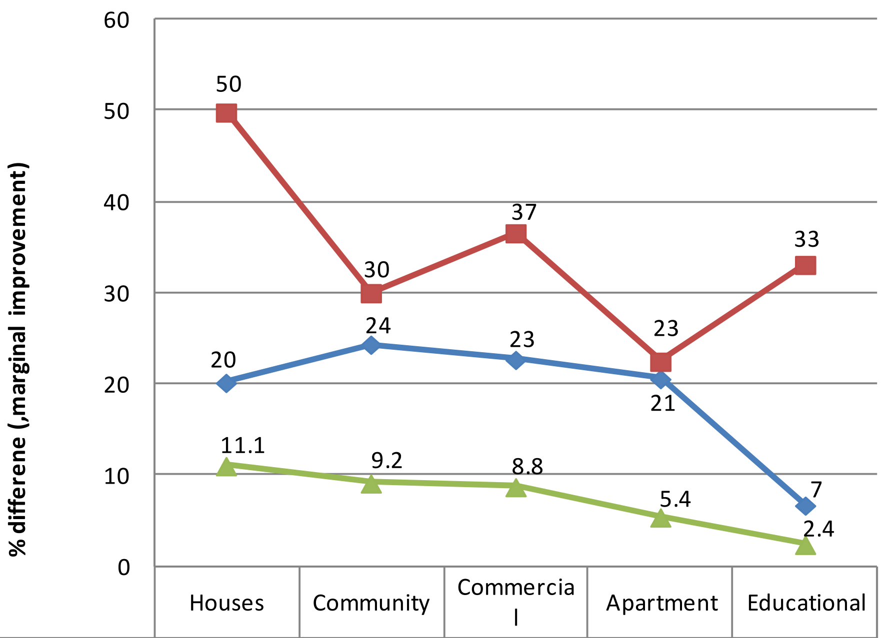
On the other hand, the average marginal time saving achieved by the prefab system in the case study projects was 34%. The highest time saving (*i.e.*, 50%) was achieved in the house projects. This result could be due to majority of the houses being developed off standard plans provided by group home builders. Such houses lend readily to standard components, which make for faster manufacture and installation, thereby enhancing speed of construction. In addition, in terms of costs, this method of housing procurement has been found to be 15% cheaper than houses that were of one-off designs [23]. The overall marginal productivity improvement offered by prefab system was 7%, with the house projects having the highest (11%) productivity gain. This result might suggest that prefab could provide the most effective approach to delivering the 400,000 houses planned to be built over the next 3 years under the Auckland Housing Strategy [24], as well as the $30 billion Canterbury rebuild [25].

Overall, the findings of this study in relation to the prefab marginal cost, time and productivity improvements were in agreement with conclusions reached in previous studies overseas. For instance, Egan [26] argues that the use of prefab system has many benefits including speed of construction, lower cost, reduced need for skilled labour and achievement of zero defects, all of which could have significant impact (about 30%–40% improvement) on on-site productivity level. However, some New Zealand studies did not concur with overseas results on superior economic benefits of prefab system. For instance, Burgess *et al.* [27] found that prefabricated buildings did not yield better economic choice than onsite construction in a case study house investigated in their work. This can be associated to small size of the New Zealand market and its inability to exploit the scale efficiencies offered by mechanized bulk production of similar products. It was not clear whether the New Zealand results were due to inadequate sample size—with the study being based on a few case study projects.

Table 1. Prefab marginal benefits (typical analysis for commercial building projects).

Project	GFA (m^2)	Storey	Date Completed	Prefab Cost ($)	* Equiv TBS Cost ($)	% Cost saving [a]	** Prefab dur (wks)	*** Equi TBS dur (wks)	% Time Saving [b]	Productivity Improvt [c]
1	5,900	6	5 October	6,000,000	14,553,000	58.77	72	84	14.29	8.40
3	1,290	2	8 August	1,500,000	3,160,500	52.54	24	52	53.85	28.29
4	2,850	2	8 April	5,500,000	6,982,500	21.23	32	64	50.00	10.62
6	5,400	1 and 2	13 August	7,000,000	10,665,000	34.36	48	72	33.33	11.45
7	4,082	1	13 November	7,000,000	8,061,950	13.17	32	66	51.52	6.79
8	1,001	1	12 August	2,000,000	3,461,000	42.21	36	50	28.00	11.82
9	9,000	1	11 March	8,000,000	14,085,000	43.20	32	84	61.90	26.74
10	150	2	9 January	160,000	189,000	15.34	4	10	60.00	9.21
11	100	1	13 March	220,000	243,000	9.47	16	18	11.11	1.05
12	10,000	8	12 October	30,000,000	35,400,000	15.25	80	100	20.00	3.05
13	2,100	2 and 3	12 March	3,200,000	3,831,100	16.47	30	52	42.31	6.97
14	10,000	4	8 July	19,000,000	20,488,000	7.26	60	90	33.33	2.42
15	23,000	6	13 February	105,000,000	112,125,000	6.35	112	130	13.85	0.88
16	5,240	4	8 June	9,600,000	12,602,200	23.82	40	76	47.37	11.28
17	2,100	1	12 October	6,500,000	6,615,000	1.74	40	60	33.33	0.58
18	1,547	5	13 September	7,800,000	7,967,050	2.10	44	64	31.25	0.66
–	–	–	–	–	Averages [d,e,f]	22.71	–	–	36.59	8.76

Notes: [a] % Cost saving = Marginal Cost Saving (MCS_{ij}); (see Equation (1)); [b] % Time saving = Marginal Time Saving (MTS_{ij}); (modified Equation (1)); [c] Productivity improvement (PI_{ij}) (see Equation (5)); [d] Average % cost saving = Average Marginal Cost Saving ($AMCS_i$); (see Equation (4)); [e] Average % time saving = Average Marginal Time Saving ($AMTS_{ij}$); (modified Equation (4)); [f] Average productivity improvement (API_{av}) (see Equation (7)). * Equivalent TBS cost in NZ$; ** Prefab duration in weeks; *** Equivalent TBS duration in weeks.



	Houses	Community	Commercial	Apartment	Educational
% Cost saving (19% avg)	20	24	23	21	7
% Time saving (34% avg)	50	30	37	23	33
% Productivity Improvement (7% avg)	11.1	9.2	8.8	5.4	2.4

Figure 1. Time, cost and productivity improvement achieved by the use of prefab in place of traditional building system in the case study projects.

3.2. Influence of Building Type on the Analyzed Prefab Marginal Benefits

The second research objective was to examine how any observed benefits offered by prefab building system could be affected by "building type" as a fixed independent factor. As discussed under the methodology section, achieving this objective required testing for the null hypothesis formulated to imply that "building type" as a fixed independent factor did not have significant effect on any marginal benefits achieved by the use of prefab system in the case study projects. Results of the single factor ANOVA employed in the test are presented in Table 2. The tests were carried out separately for prefab marginal productivity improvement, cost saving and time saving.

Table 2 shows that the *p*-value analyzed in the null hypothesis test for the productivity improvement was greater than the alpha value of 0.05 used in the test (*i.e.*, 0.09 > 0.05). Additionally, the F-ratio of 2.11 was less than the χ^2 *F*-critical value of 2.52. On account of these results, the null hypothesis could not be rejected. It was therefore concluded that "building type" had no significant influence on the marginal productivity improvement benefits delivered by the prefab system.

Similar conclusion was also reached for the marginal cost saving. However, the result was different for the time saving: A *p*-value of 0.005 which is less than the alpha value of 0.05 meant that building type impacted significantly on the observed prefab marginal time saving. This suggests that the use of prefab system may result in shorter completion times of buildings than the TBS depending on the building type, whereas the cost and productivity improvement benefits are not influenced by building type, and are likely to be consistent across all building types. Thus, claims about the superior benefits of prefab can only be generalised in respect of cost and productivity improvements across all building types, whereas claims about time savings should be cautiously applied to specific building types. There is no empirical evidence in this study to conclude that the technology is superior to the traditional building system in terms of time savings across all building types. This latter finding contrasts with conclusions reached in a number of New Zealand and overseas studies which seemed to generalize the benefits across all building types. Burgess *et al.* [27]—Citing Kaufmann and Remick [28], Atkin and Wing [29], and Bell [3]—Stated that "time savings for prefabricated construction for residential applications is between 30% and 60%" (p. 25). The qualified statement (*i.e.*, "residential applications") made by Burgess *et al.* [27] is therefore worthy of emulation when it comes to reporting on the time saving benefits of prefab system. The question that may be worthy of further investigation is why the superior time saving benefits of the technology may not be consistent across all building types. A possible clue might be found in the observations of Shahzad and Mbachu [1] that there is increasingly little differentiation between the conventional building types and the "componentized" and the "panelized" prefabrication types. This is because conventional buildings involve some form of "componentized" and "panelized" prefab units or the other. This is true for most non-residential building constructions. On the other hand, clear differentiation exists in the application of the technology to residential buildings—a clear departure from the traditional stick-built system which dominates residential construction. The large proportion of residential prefab projects (about 50%) might have influenced the hypothesis test result in this regard. However, then, why were the cost and productivity improvement benefits not also influenced by the larger proportion of residential building project samples? These are issues to be resolved in future research.

Table 2. Univariate ANOVA analysis results for hypothesis testing.

Dimension	Variation Source	[a] SS	[b] DF	[c] MS	[d] *F*-ratio	[e] *p*-value	[f] *F*-crit	Result
% productivity improvement	Between groups	505.7	4	126.4	2.11	0.09	2.52	Do not reject H0 (*p*-value > 0.05)
	Within groups	3,651.6	61	59.9	–	–	–	–
	Total	4,157.2	65	–	–	–	–	–
% cost saving	Between groups	1,441.0	4	360.3	1.50	0.21	2.52	Do not reject H0 (*p*-value > 0.05)
	Within groups	14,618.8	61	239.7	–	–	–	–
	Total	16,059.8	65	–	–	–	–	–
% time saving	Between groups	5,617.3	4	1,404.3	5.81	0.0005	2.52	Do not accept H0 (*p*-value < 0.05 a)
	Within groups	14,747.0	61	241.8	–	–	–	–
	Total	20,364.3	65	–	–	–	–	–

Notes: [a] SS (Sum of squares) = sum of squares of variations of data points from the means for the between and within group; [b] DF (degree of freedom) = sum of degrees of freedom for each group computed for each group as number of data points − 1); [c] MS (mean squares) = SS/DF; [d] *F*-ratio = χ^2 test statistic = MS (between groups)/MS (within groups); [e] *p*-value = probability value associated with the *F*-ratio; [f] *F*-crit = critical *F*-ratio value from statistics tables corresponding to the alpha level of test (*i.e.*, 0.05).

4. Conclusions

This study has quantified the marginal benefits of the prefab building system in terms of cost, time and productivity improvements it can offer over and above corresponding benefits achievable with the traditional building system (TBS). Potential influence of building types on the observed benefits was also examined. Results showed that the marginal cost saving delivered by the prefab system over the

TBS was 19% on average. The highest cost saving (24%) was achieved in community building projects. On the other hand, average marginal time saving achieved was 34%, with the highest time saving of 50% achieved in the house projects. The overall marginal productivity improvement offered by prefab system was 7%, with house projects having the highest productivity gain of 11%. This result might suggest that prefab could provide the most effective approach to delivering the 400,000 houses planned to be built under the Auckland Housing Strategy over the next three years [24], as well as the $30 billion Canterbury rebuild [25].

Results of ANOVA tests on how the observed benefits offered by prefab building system could be affected by "building type" were mixed. Whereas cost and productivity improvement benefits offered by the system were consistent across building types, time saving benefits were influenced by the building type. Empirical evidence therefore supports the generalization of the cost and time benefits across building types. This is not applicable to time savings, which require being reported only in relation to specific building types.

Influences of other fixed factors such as location, project size/complexity, procurement and contract strategies, type of prefabrication and the degree of standardization or replication are key limitations of the study which are recommended for further investigations. It should also be noted that variability issues could be associated with the limited dataset of 66 projects used in the study; these could raise some reliability concerns if the findings were to be generalized beyond the scope of this study.

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Author Contributions

The research was part of a thesis undertaken by the author for correspondence Wajiha Shahzad. It was supervised by Jasper Mbachu (principal supervisor) and Niluka Domingo (assistant supervisor).

Conflicts of Interest

The authors declare no conflict of interest.

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