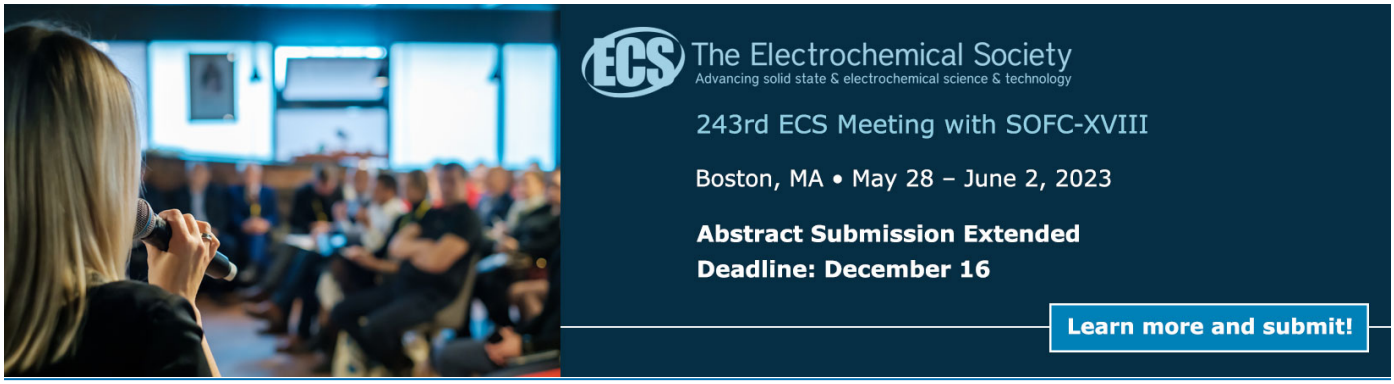
Transaction Cost of Offsite Construction (OSC): A New Zealand Study



Transaction Cost of Offsite Construction (OSC): A New Zealand Study

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Abstract. Offsite construction (OSC) has been put forward as a solution to many prevailing challenges facing the construction industry, including but not limited to low productivity, housing shortage, lack of innovation, and poor-quality outputs. The uptake of OSC is relatively slow in the New Zealand construction industry. With only 10% of all the new builds using the OSC approach, it is evident that the potential of this construction approach is under-utilised. Many barriers have been identified as responsible for low uptake, including cost-related barriers. This study investigates the transaction cost of OSC, which is an extra cost to the project development cost and is generally overlooked in the project planning and development stage. This study aims to identify the factors that contribute to the transaction cost of OSC in New Zealand, alongside investigating the impact of transaction cost on overall project delivery and factors that can minimise the transaction cost. A questionnaire survey was conducted involving OSC practitioners in New Zealand. It was noted that consultation with building consent authority, the complexity of interface design, limited capacity of offsite manufacturers, and highly skilled workforce requirements contribute to transition cost during concept design, technical design and procurement, manufacturing, and on-site assembly stages. Consequently, disputes between stakeholders, uncertainty, an overall increase in project cost, and reluctance to use OSC may occur. It is noted that the use of innovation like automation, building information modeling, design for manufacturing and assembly, and consenting process to suit OSC holds the potential to reduce the transaction cost.

1. Introduction

The construction industry in New Zealand is under much pressure due to its poor productivity performance and inability to meet the demands for housing and infrastructure projects for its ever-increasing population [1]. The housing situation in the country is at a critical level, and there is a need to build 70,000 more houses to create a balance between housing supply and demand [2]. Policymakers acknowledge that the New Zealand construction industry is very traditional, with limited uptake of innovation, and hence the industry suffers a declining productivity trend [3]. The traditional nature of the New Zealand construction industry hinders the acceptance of the innovative technologies available due to its small size, i.e., lack of economies of scale due to lower volume and the boom-and-bust nature of this sector [4, 5]. There is a strong consensus that the New Zealand construction industry requires transformation to keep up with the nation's demands [6]. Incorporating more effective building methods in the construction industry, like offsite construction (OSC), is essential to meet the growing demand for housing [7].

Replacing traditional construction practices with OSC has the potential to increase the quality and speed of construction [8]. OSC is widely used in countries like UK, USA, Sweden, and Japan. This construction method holds the potential to increase production speed, increase productivity, lower construction cost, increase quality, and lower manufacturing defects resulting in a reduction in waste generation and improved environmental performance [9, 10, 11, 12]. OSC can also increase construction projects' health and safety performance [13, 14]. All these benefits lead to improved environmental, social, and economic stability. Despite the many known benefits of OSC, some barriers limit the adoption of this construction technology. According to Wu et al. [15], some of the constraints that limit OSC adoption are cost, lack of regulation, and knowledge shortage. Among these, the cost is the most critical barrier, inhibiting OSC uptake. Effective and efficient management of financial resources is critical to make OSC the mainstream construction approach to utilise its full potential in the successful delivery of construction projects [16].

When it comes to managing project costs, the capital or physical production costs are generally the main focus, and not much attention is paid to unveiling the hidden cost involved in the process. The capital cost of a construction project governs the estimation of the construction budget and forecast. In other words, it is a fixed, one-time cost involved in acquiring a building, equipment, and materials used in the construction. The transaction cost is the hidden cost which includes communication charges, legal fees, informational cost of finding the price, quality, and durability, and may also include transportation costs. In short, these are the cost related to the economic exchange of a product or services of a construction project [16]. Given the potential of offsite construction to meet the demand for rapid housing and transform the project delivery in the New Zealand construction industry, this paper reports a study on investigating the transaction cost for offsite construction. The specific objectives of this study included, (i) Identification of the factors contributing to Transaction cost in offsite construction in New Zealand; (ii) Identification of the factors that can reduce the transaction cost; (iii) Investigating the impact of transaction cost on overall project delivery.

2. Literature Review

2.1. Overview of Offsite Construction

Offsite construction (OSC) is the method of construction in which the manufacturing of building panels and components takes place in a controlled factory environment. These manufactured units are then transported to the project location for installation [7, 8]. Luo et al. [17] defined OSC as the first industrialisation level in the construction industry, followed by mechanization, automation, and reproduction. The traditional construction method is very labour intensive, site-based, and often constrained by the prevailing weather. It adopts standard procedures but lags behind other industries in terms of technology adoption and integration [18]. OSC is an innovative technological process of construction that can be employed in the construction of houses and multi-story buildings [19]. Many researchers e.g., Gan et al. [20] and Musa et al. [21] have documented that OSC offers various benefits including an increase in the speed of construction, better quality management, enhanced sustainability, reduction in Green House Gases (GHC), alleviation of skill shortage, improved site coordination with fewer trades involved, and increased worksite productivity.

However, the adoption of OSC is very limited in the New Zealand construction industry. Many factors are limiting the uptake of OSC in New Zealand. Shahzad [5] identified many constraints, including cost, value, industry and market culture, lack of skills, regulatory environment, and lack of supply chain integration. Jin et al. [16] noted that cost is the most inhibiting factor limiting the OSC uptake. OSC's application requires effective and efficient management of financial resources. Wu et al. [22] observed that transaction cost could be a major contributor to limiting the economic efficiency of offsite construction projects. The concept of transaction cost and its implication on construction projects is discussed in the next section.

2.2. Transaction Cost in Context of Construction Projects

Transaction cost is associated with the economic exchange of goods and services, which are incurred in overcoming imperfections in the market. This cost differs from the material production costs of construction projects [23]. It is defined as the hidden cost that covers a wide range of things, including legal fees, communication charges, cost of preparing and administering the contract, costs of finding the information about the price, quality, durability of a product, and transportation costs [16]. Abdel-Galil et al. [24] documented that transaction costs include costs of preparation for bidding packages, estimation and drawing up a contract, contract administration cost, cost associated with any variation from conditions of contact, the cost to resolve any contractual claims, change orders, and dispute resolution. Based on the transaction cost economics [25], the factors that influence transaction costs are bounded rationality and opportunism. Bounded rationality occurs when an individual or organization possesses limited information to process and operate. This limited information limits organisational decisionmaking. On the other hand, opportunism is when an individual involved in a transaction decides on his interest, which results in creating uncertainty in dealings and mistrust between the parties involved in a transaction. Rajesh et al. [26] and Ali et al. [27] noted that transaction cost economics provides the framework for analyzing uncertainty within the transaction environment to facilitate understanding of the unseen costs associated with pre-contract and post-contract works. It was further documented that pre-contract transaction cost includes costs associated with gathering information and procurement. In contrast, the post-contract transaction cost is related to contract administration costs and enforcement. A recent study quantified pre-contract and post-contract transaction costs of construction projects to be 3%-4% and 8%-9%, respectively [24]. According to Antinori and Sathaye [28], the four main production characteristics that influence the transaction costs are (i) asset specificity, (ii) uncertainty and unpredictability in the market, (iii) frequency of transaction, and (iv) complexity of the production process. Wu et al. [15] and Kiss [29] defined three categories of the transaction cost. The first category, 'Search and Information Cost', refers to the cost of determining products available in the market, finding a suitable supplier, due diligence cost, cost of consultations with stakeholders, identification of customers, pre-feasibility study, procurement of subcontractors, risk insurance for projects and decision-making cost. The second category, 'Bargaining Cost' includes the cost of decision making, cost of negotiations, cost of acquiring a permit, coordination cost, negotiating contract, and approval costs [28]. The third and last category, 'Policing and Enforcement Costs' is the cost incurred on developing a monitoring plan for agreement and contracts, execution of monitoring plan, and other activities involved in the enforcement of contract [26, 30]. Hughes et al. [31] presented the classification of transaction costs by project phases as pre-tendering phase, tendering phase, and post-tendering phase transaction costs. Wu et al. [15] investigated the transaction cost for offsite construction. They classified the transaction cost by phases of the offsite project cycle i.e., concept stage, plan and design stage, manufacturing stage, construction stage, and operations. For this study, the transaction cost of OSC is categorised as the concept design stage, technical design stage, manufacturing stage, and onsite assembly stage.

3. Research Methodology

This study utilised an exploratory approach for investigating the factors responsible for the transaction cost of OSC in New Zealand, the factors that can minimise the transaction cost associated with OSC, and the impact of transaction cost on uptake of OSC in New Zealand. After extensive literature review, a questionnaire survey was developed as a data collection tool for data to be evaluated and subjected to statistical analysis to achieve research objectives [32, 33]. After pre-testing the questionnaire by industry experts and academics to ensure the suitability of the questionnaire to effectively collect the data from the target population [34], the survey was sent to the members of the trade and professional organisations of New Zealand, including New Zealand Institute of Building (NZIOB), New Zealand Institute of Quantity Surveyors (NZIQS), OffsiteNZ, New Zealand Institute of Architect (NZIA), Registered Master Builders Federation (RMBF), and Architectural Designers New Zealand (ADNZ). Snowball method of sampling was adopted to collect the data, considering it is an efficient way to reach an adequate number

of the targeted population in a short time, particularly when data is sought from the respondent who has relevant experience in a particular area [35, 36].

The questionnaire comprised of two sections; the first section had questions about the demographic profile of the respondents, and the second section comprised of close-ended multiple-choice questions about the factors contributing to the transaction cost and improvement measures. A 5-point Likert Scale was used to measure the participants' degree of agreement. Responses ranged on a scale of 1 (strongly disagree) to 5 (strongly agree). The data obtained from the questionnaire survey were analysed using SPSS (Statistical Package for the Social Sciences) software. A Multi-attribute technique was used to analyse the obtained data. In this technique, a mean rating is generated for each factor in the survey based on the participants' rating involved in the questionnaire survey [37]. The highest mean values obtained represent the most important factor in the subset. The factors with a mean rating value greater than 2.5 are regarded as significant factors (i.e. MR > 2.5 is significant). The factors with a mean rating less than 2.5 are defined as insignificant (i.e. MR < 2.5 is insignificant). The survey was distributed to 125 experienced professionals in New Zealand, and 27 usable responses were received until the survey cut-off date. A low response rate due to COVID-19 related disruptions is recognised as a limitation of this study. These twenty-seven responses were from engineers (59.09%), project managers (9.09%), architects (9.09%), quantity surveyors (4.55%), other professionals (18.18%). Response rate implies that engineers' point of view dominates the research findings.

4. Findings and Discussion

Findings relating to the three objective objectives of the study are presented and discussed in the following subsections.

4.1. Factors Contributing to the Transaction Cost in OSC

The first objective of this study was to identify the factors that contribute to the transaction cost of the OSC projects. For that reason, survey participants were asked to provide their feedback on the level of significance to the factors that contribute to the transaction cost of projects during four main stages of the OSC project lifecycle, i.e., concept design stage, technical design stage, manufacturing, and onsite assembly. For each of these stages' significant factors responsible for transaction cost were identified and discussed in the subsequent sections.

4.1.1. Transaction Cost of OSC at Concept Design Stage. The perceptions of New Zealand construction industry experts about the significance of factors that contribute to the transaction cost of OSC at the concept design stage are presented in table 1. It is observed that the cost of consultation with the building consent authority and approval of design features is the most critical source of the transaction cost. Another important contributor of transaction cost at the concept design stage is planning and procurement strategy. This is because procurement of construction projects is complex, and an unsuitable procurement strategy will increase the cost of the whole project. Accuracy, timeliness, and quality of the procurement process are documented to be crucial for meeting the project cost targets [38]. Feasibility studies carried out for OSC projects and financing arrangements were also rated as significant contributors to the transaction cost. This finding is supported by Mohammed et al. [39], who emphasised that thorough project feasibility and well-managed cashflow can avoid any undue increase in overall project cost. Surprisingly, factors related to the education of project stakeholders, the expertise of the project team, and the development of the project proposals were not deemed significant by the industry experts.

Table 1. Source of Transaction Cost at Concept Design Stage of OSC

Sources of Transaction Cost	Level of Agreement (Percentage)					Mean Rating
	SA(5)	A(4)	SWA(3)	D(2)	SD(1)	
Consultation with Building Consent Authority	19.2	50.00	7.69	15.38	3.85	2.73
Permission and approval cost	17.86	50.00	14.29	7.14	3.57	2.65
Planning and procurement strategy	25.00	46.43	14.29	7.14	3.57	2.53
Feasibility study of the project	14.81	55.56	25.93	3.70	0.00	2.53
Project financing	26.32	36.84	15.79	15.79	0.00	2.51
Education project stakeholders	33.33	37.04	18.52	11.11	0.00	2.46
Setting up experienced project team	36.00	36.84	36.84	10.53	0.00	2.43
Development of project proposal	39.29	7.14	7.14	3.57	0.00	2.26

Note: SA=Strongly Agree, A=Agree, SwA=Somewhat Agree, D=Disagree & SD=Strongly Disagree.

4.1.2. Transaction Cost of OSC at Technical Design Stage. Six factors were investigated for the technical design stage of offsite construction (OSC), as shown in table 2.

Table 2. Source of Transaction Cost at Technical Design Stage of OSC

Sources of Transaction Cost	Level of Agreement (Percentage)					Mean Rating
	SA(5)	A(4)	SWA(3)	D(2)	SD(1)	
Architectural design	25.93	62.96	18.52	7.41	3.70	2.62
Procurement of sub-contractors	7.41	51.85	29.63	7.41	3.70	2.58
Design consultation	7.41	37.04	18.52	14.81	0.00	2.57
Engineering design	14.81	59.26	14.18	3.70	3.70	2.53
Obtaining building consent	18.51	37.04	18.52	3.70	0.00	2.53
Technical solution for offsite construction	23.08	42.31	26.93	7.41	3.70	2.30

Note: SA=Strongly Agree, A=Agree, SwA=Somewhat Agree, D=Disagree & SD=Strongly Disagree.

Five out of these six factors had a mean rating value greater than 2.5, indicating their significance. The cost of architectural design is deemed the most critical source of transaction cost for OSC in New Zealand. This corroborates with the findings of Kamali and Hewage [40], that the cost of architectural design increase much more in the case of OSC due to the complexity of design and the need to freeze project design at a much earlier stage.

The cost associated with procurement sub-contractor was rated as the second most significant factor. This cost includes the cost of preparing and organizing the bidding, assessment of sub-contractors, and cost of signing the contract with the sub-contractors [29]. Design consultation, engineering design cost, and cost incurred for obtaining building consent were rated comparatively of lower significance. Mao et al. [41] also made similar observations about transaction cost.

4.1.3. Transaction Cost of OSC at Manufacturing Stage. Table 3 presents the factors that contribute to the transaction cost of OSC during the manufacturing stage. Most of the survey participants rated the offsite manufacturer's capacity as the most influential factor that contributes to the transaction cost of OSC in New Zealand during the manufacturing stage. This aligns with Jiang et al. [42] findings that the initial cost for setting up the factory is high, and manufacturers need huge investment capital to achieve the required production capacity. The survey participants rated the cost of communication as the second

and production supervision cost as the third most influential factor. Production supervision cost includes supervising the company and monitoring the manufacturing process of the components [43]. Another contributor of transaction cost is the cost incurred on the storage of manufactured components. The need to create additional storage can arise onsite, if the assembly process is slower than expected [44].

Table 3. Source of Transaction Cost in Manufacturing Stage of OSC

Sources of Transaction Cost	Level of Agreement (Percentage)					Mean Rating
	SA(5)	A(4)	SWA(3)	D(2)	SD(1)	
Capacity of offsite manufacturer	4.35	47.83	21.74	13.04	0.00	2.96
Cost of communication	3.57	57.14	10.71	25.00	0.00	2.71
Cost of supervision during production	10.71	50.00	14.29	21.43	3.57	2.57
Storage of manufactured units	11.11	48.15	33.33	0.00	3.70	2.50
Hiring of skilled labour	17.86	35.71	32.14	14.29	0.00	2.43
Transportation of components	12.00	56.00	16.00	16.00	0.00	2.36
Building inspections	21.43	39.29	25.00	14.29	0.00	2.32
Quality assurance at manufacturing yard	17.86	46.43	21.43	14.29	0.00	2.19
Note: SA=Strongly Agree, A=Agree, SwA=Somewhat Agree, D=Disagree & SD=Strongly Disagree.						

4.1.4. Transaction Cost of OSC at Onsite Assembly. Findings related to onsite assembly (table 4) revealed that educating the workforce involved in the onsite assembly process is the most significant source of OSC transaction cost during this stage.

Table 4. Source of Transaction Cost during Onsite Assembly of OSC

Sources of Transaction Cost	Level of Agreement (Percentage)					Mean Rating
	SA(5)	A(4)	SWA(3)	D(2)	SD(1)	
Educating workforce	10.71	35.71	39.29	7.14	7.14	2.68
Completion Compliance Certificate (CCC)	7.41	55.55	17.86	7.14	3.57	2.58
Availability of lifting equipment	11.11	51.85	22.22	11.11	3.70	2.54
Monitoring of assembly process on site	14.29	57.14	17.86	7.14	3.45	2.29
Cost of design variation	14.29	64.29	7.14	10.71	3.57	2.25
Note: SA=Strongly Agree, A=Agree, SwA=Somewhat Agree, D=Disagree & SD=Strongly Disagree.						

This finding is corroborated by Jiang et al. [42] that OSC has a higher requirement for the skilled workforce due to its innovative nature. The cost associated with obtaining a completion compliance certificate is observed to be the second most influential factor. Availability of lifting equipment is noted to be another significant factor. The onsite assembly of manufactured components hugely depends on the lifting equipment. Therefore, intense planning to ensure the availability of the lifting equipment is much needed to complete the project on time and within budget [40]. Monitoring the offsite assembly process and the cost associated with design changes were rated as the least influential factors.

4.2. Measures to Minimise the Transaction Cost of OSC

Several measures were investigated during the survey to understand their significance, these results are presented in Figure 1. It was observed that there is a strong consensus among the industry experts that the use of Building Information Modelling (BIM) can reduce the transaction cost of OSC in New Zealand. BIM has ability to pick up functional design clashes, resulting in a design that is robust. Automating the manufacturing process is rated as the second most effective way to minimize transaction

cost in OSC. Darlow et al. [8] also highlighted the need for New Zealand OSC to uptake automation to improve its cost performance. Automation of OSC has several other benefits as well such as higher production rate, increased efficiency, more productive use of materials, improved product quality, improved safety, and less amount of waste generated.

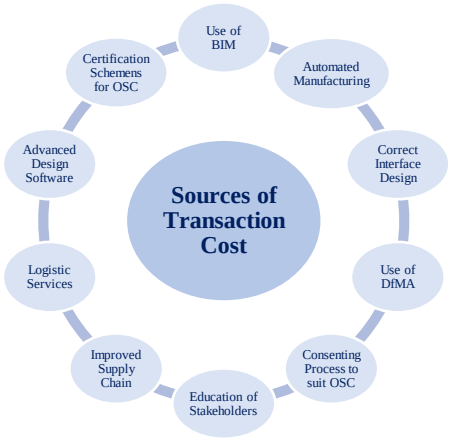

Figure 1. Measures to Reduce the Transaction Cost of OSC

Correct design of interfaces was seen as the third most significant measure to reduce transaction cost. Uptake of Design for Manufacturing and Assembly (DfMA) is also observed to be a facilitator in reducing the transaction cost. Among other significant measures to reduce transaction cost are the use of advanced design software and educating the construction stakeholders about the whole OSC paradigm.

4.3. Impact of Transaction Cost on Uptake of OSC

A strong consensus exists among the industry experts for the impact of transaction cost on OSC uptake in New Zealand. It is observed that the respondents have acknowledged all the sources of transaction cost identified in this study as to have a significant impact on the uptake of OSC by the New Zealand construction industry (Figure 2).

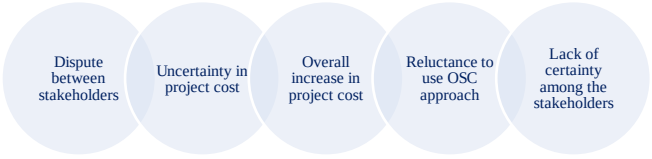

Figure 2. Transaction Cost Impact on Uptake of OSC

Industry experts have rated ‘dispute among the stakeholders’ as the most dominating impact of the transaction cost. According to Arditi and Pulket [45], disputes between the stakeholders directly influence the overall project performance. Uncertainty in project cost is another significant impact on the use of OSC. An increase in transaction cost creates an environment where overall acceptance of OSC is very low. Transaction cost also creates uncertainty among the project stakeholders, particularly the investors and financers, leading to constraining the uptake of OSC.

5. Conclusion and Further Research

The aim is this study was to investigate the sources of transaction cost for OSC projects in New Zealand and how the transaction cost can be minimised. Various sources of transaction cost and its negative impact on limiting the uptake of OSC in New Zealand construction industry is widely acknowledged by the construction industry practitioners. The main source of transaction cost in the concept design stage includes the cost of consultation with the building consent authority and approval of design features. However, during the technical design stage of OSC, the architectural design and procurement of sub-contractors incurred the highest transaction cost. According to industry practitioners, during the manufacturing stage of OSC, the capacity of offsite manufacturers incurs the maximum amount of transaction cost. This is followed by the cost of communication and the cost of production supervision. In the last stage of the OSC lifecycle i.e., onsite assembly; educating the workforce, obtaining completion compliance certificate, and availability of lifting equipment are the most common sources of the transaction cost. During this investigation, it is identified that adoption of the right procurement strategy, robust designing, and adoptions of innovation like Building Information Modelling (BIM), automation in manufacturing, Design for Manufacturing and Assembly (DfMA), and use of advanced design and planning software can effectively minimise the transaction cost of OSC. It is further noted that the transaction cost of OSC leads to dispute among project stakeholders and uncertainty of project cost, which leads to a negative perception about the OSC and constrains the uptake of this construction approach.

As the scope of this study was limited to New Zealand only, it is recommended to carry out more in-depth research on transaction cost in New Zealand and other economies by investigating case studies on the real-time project by distinguishing the production cost and transaction cost for OSC. Documentation of costs involved at different OSC stages can also help develop a better understanding of the cost involved in OSC projects.

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