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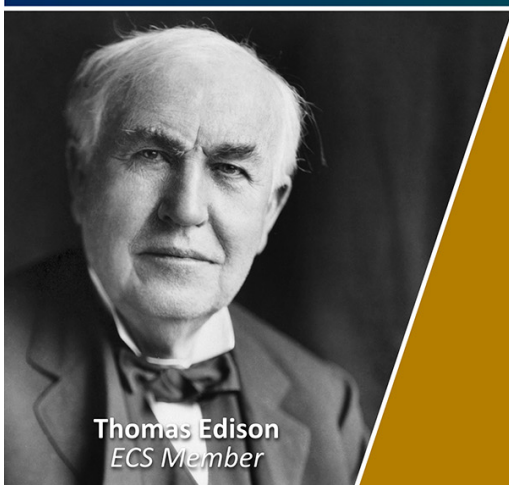
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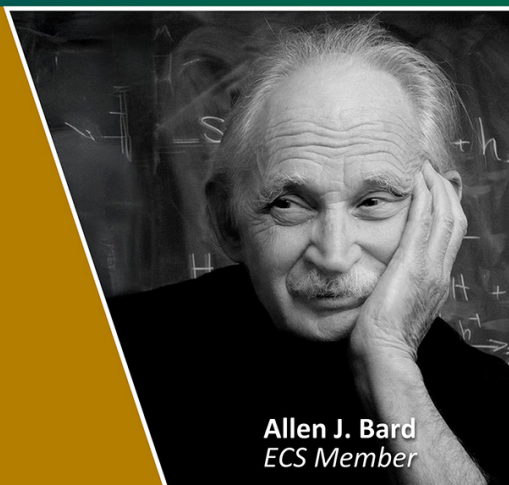
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Exploring Off-site Construction and Building Information Modelling Integration Challenges; Enhancing Capabilities within New Zealand Construction Sector

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Abstract. Over the last few years off-site construction (OSC); which is essentially manufacturing different components in a controlled environment, has become popular in the construction industry. This method has the advantages of simplicity, speed, reducing project duration, and minimising construction waste. Therefore, a growing body of literature recognises the importance of OSC to gain better project performance. While OSC has received considerable critical attention, to enhance OSC applications, integrating advanced technologies such as building information modelling (BIM) is essential. There is a lack of research addressing the integration of BIM and OSC, particularly in New Zealand, and few studies investigated the current subject. Therefore, this study focuses on finding the existing OSC and BIM integration challenges within the New Zealand construction sector. The objective of this study has been investigated through literature review and interviews with experts. The common challenges of OSC and BIM integration were identified and classified. Human resources, documentation, managerial, and organisational are the main challenges. This paper is dedicated to exploring OSC and BIM integration in New Zealand, an essential step for the OSC application strategies within the construction sector. This study findings will lend to the construction sector expanding capabilities to improve the status quo and optimise OSC applications through advanced technologies.

1. Introduction

New Zealand's construction industry has a considerable impact on Gross Domestic Product (GDP), contributing 6% of GDP [1]. This industry is an essential part of New Zealand's infrastructure, yet it faces high pricing, low productivity, and a lack of innovation [2]. On the other hand, the construction sector in New Zealand has become less productive due to lack of innovation, lack of procurement performance, lack of management capability, lack of skill, and lack of workability [3]. Using modern tools such as digital technologies and off-site manufacturing procedures in construction is one of the best tactics for increasing productivity in this sector [1, 4-6].

Off-site construction (OSC) is a method of reducing construction time, errors, and hazards by fabricating building components in a factory-like setting and then installing them on-site [7]. Through a cleaner construction method [8, 9], OSC provides a sustainable and integrated platform. Despite the recognised benefits, OSC still faces several challenges as researchers discuss these issues and suggest ways to overcome them [10]. One of these ways is using Building Information Modelling (BIM) as an



advanced technology [11, 12]. BIM in the manufacturing sector has improved the efficiency and quality of prefabricated construction items [13]. Even though it has not gotten broad attention, BIM has been utilised to expedite the flow of information while allowing digital technology in off-site construction [10].

With OSC's potential to improve the construction industry's economic, environmental, and social sustainability, it is critical to use BIM to realise these benefits [14]. In summary, BIM-enabled OSC is essential for collaboration, compliance checking, knowledge sharing, clash detection, and design optimisation [15, 16]. However, to achieve proper integration, there are some challenges too. While many studies investigated the OSC, BIM, and their level of integration, few studies reviewed their integration challenges, especially in New Zealand. By addressing these challenges, project stakeholders can devise action plans to overcome these challenges ahead of time. Thus, this study intended to investigate OSC and BIM integration challenges to improve the productivity of OSC projects in New Zealand.

2. Literature Review

Compared to site-built construction, OSC has consistently achieved higher productivity growth [17]. This is the flexibility to adapt manufacturing principles common to other industries and produce high-volume and high-quality products [18]. Despite the well-documented benefits of prefabricating building components in improving productivity and efficiency [18, 19], the uptake of OSC has been limited [20, 21]. It has been argued that the most significant growth in construction productivity will come from automated off-site activities facilitated by BIM [22].

OSC has been identified as a critical enabler to increase the timely supply of housing in New Zealand [23]. The uptake of OSC, however, remains relatively low. While only five to 10 per cent of newly built homes in New Zealand are currently built off-site to some degree, in parts of Europe, this figure is as high as 80 per cent [24]. With the advent of Kiwi Build and renewed government focus on stimulating housing supply, it is timely to understand any challenges to the uptake of OSC and mitigate them. This includes challenges created by regulatory processes, particularly resource and building consents [5].

To overcome the challenges of OSC and improve the benefits using new technologies is recommended by several studies [11, 12, 25, 26]. One of these technologies is BIM. Even though its deployment has not garnered significant attention, BIM has been utilised to streamline information flow while facilitating OSC digital technology [27]. Furthermore, it may be used to quickly detail each building trade [28] and identify and correct trade interferences to create exact and fully linked modelling [16, 29]. Because of its ability to retain component attributes and share steel reinforcing information, BIM has been employed in off-site modelling disciplines such as the parametric design in Autodesk Revit Structure [8, 30].

As a result, it is vital to think of BIM as a creative model for enhancing current benefits and overcoming existing OSC issues [11]. Despite many studies that have been done in OSC and BIM [30-36], the integration between them needs more investigations [37-39], especially in New Zealand. Lack of knowledge and experience, lack of training, the financial problem are some of the challenges for OSC and BIM integration [11, 26, 38-40]. This study intends to identify challenges for integrating OSC and BIM in the New Zealand construction industry. The findings will base on other investigations that will help the industry present the strategies for integrating OSC and BIM. The following section will discuss the research methodology in this paper.

3. Research Methodology

A combinational approach was undertaken for this study. First, a literature review identified OSC and BIM integration challenges, followed by interviews with New Zealand specialists to confirm the findings. The literature review examined the existing literature and prior findings in depth. The deductive literature review provided the research with the background knowledge to conduct the interviews. It assisted in identifying the difficulties in implementing BIM and OSC. The interviews offered a detailed and complimentary conceptualisation of the findings in the following stage [41-43].

semi-structured interviews with New Zealand experts were undertaken during 2021 to identify potential obstacles for OSC and BIM integration. However, due to the COVID-19 restrictions, the interviews were all conducted online.

The original pool of respondents consisted of experts with more than ten years of expertise in construction projects and a bachelor's degree or higher education level. Experts with experience in prefabrication, OSC, and BIM in New Zealand were also included in the selection process. The number of interviewees was decided based on theoretical saturation, and eight interviews were conducted. The term "theoretical saturation" refers to the point in the interview process when more interviews can no longer supply new information for the study's specific aim [44].

Each interview was digitally recorded and transcribed and lasted about 40-60 minutes. Interviews were prepared with core questions followed by additional questions about the study's goals for maximum tangibility and comprehension of responses [45]. The interview transcriptions were analysed using Nvivo12. The qualitative coding technique was done iteratively to discover patterns throughout the interviews. The goal was to identify specific integration problems for BIM and OSC. The interviewees' information is presented in table 1.

Table 1. Interviewees details

Expert	Current role	Experience (years)
R1	Digital Assets & Engineering Lead	11
R2	Digital Engineering Leader	21
R3	Head of Product Design	19
R4	Project Analyst and Planner	19
R5	Head of Modular Design for Manufacture	20
R6	Architectural Technician	10
R7	Chief Executive Officer	30+
R8	Consultant	20

4. Findings and Discussion

This section presents the findings of the reviewed literature and interview findings. The OSC and BIM integration involves multi-parties with a high level of collaboration [46]. However, poor collaboration has been observed because of the fragmented nature of the construction industry. It is challenging to develop a collaborative relationship between stakeholders in a project-based industry, where each party works individually as an independent organisation [47]. Moreover, OSC and BIM implementation is challenging due to a lack of suitable trained and unskilled workers [48, 49].

According to Tang et al. [50], college graduates with OSC and BIM understanding may save money on the training programs. Lack of contractor's knowledge and poor understanding of OSC processes and BIM benefits are other challenges based on the literature [48, 51, 52]. Lack of experience and skills can cause a problem for OSC and BIM integration. According to Zhang et al. [52], the industry, particularly in the private sector, currently lacks experience in designing, transporting, and installing prefabricated components. When these issues mix with other technologies, the problem may arise.

Another major challenge is the lack of contractor experience [49]. Prefabricated buildings may be expensive and of poor quality due to a lack of contractor experience. In a competitive market, experienced suppliers will deliver high-quality components at a fair price. Designers will create a wide range of designs, and experienced contractors help the prefabrication approach execute appropriately [52]. Other challenges for integrating OSC and BIM are lack of incentives, stakeholders' reluctance, and resistance toward any changes. Rahman [53] stated that stakeholders believe that because of the quick adoption of OSC, maybe the creativity in the architecture destroys. Because of that, many stakeholders do not desire to use it. As a result, there are still many challenges with people to change their attitudes.

Experts also named this challenge as a common one in New Zealand. In their view, many people in the projects are old-fashioned and are not interested in using new methods.

BIM application creates the capability to retain data and information for future reuses and other project stages such as maintenance and operation [11, 40]. On the other hand, all parties will be aware of any project details and can act correctly because of this knowledge. The interviewees also emphasised the dearth of data documentation and digital libraries in New Zealand. They believed that having digital archives and files in BIM would help stakeholders learn from past mistakes and that by leaving a staff, the information would remain in the organisation. As a result, all stakeholders can communicate directly with the information stored or linked to BIM models [54].

According to the interview findings, the industry participants poorly understand OSC in New Zealand. Many of them are not familiar with its concepts and processes. Therefore, having a broad view of what is going on in the industry is a necessity. On the other hand, New Zealand's geographical isolation from international markets makes the OSC expensive. While importing is very expensive, it is not economical to have plans for mass production of prefabricated components because of the small market size and low demands. These issues and the high capital cost required are challenges encountered by industry experts. Experts believe that when it comes to applying BIM in New Zealand construction, many consultants charge the clients with extra cost, while one of the main objectives of BIM is to reduce the total cost.

Another identified challenge was the ignorance of decision-makers such as financial managers. Many do not have technical backgrounds and do not understand the technical processes. The other ones may not believe in new technologies and find replacing the traditional process with new ones challenging [8, 52]. This has also been reflected in other research work as well [55-57]. Thus, some of the interviewees mentioned that a lot of time and effort is required for using new technologies in New Zealand. On the other hand, the principal staff must explain the whole process step by step for the employees due to the character of new technology. From the interviewee's point of view, the lack of regular meetings is another challenge in New Zealand. Meetings, seminars, webinars, and educating the employer through an expert panel might help overcome this challenge. They believed that during these meetings, less time would spend on presenting problems and more time to attempt to solve the problems. Therefore, the collaboration will arise in the project life cycle.

Moreover, high productivity and quality will result from that. Finally, lack of knowledge, experience and educated labour are other challenges that experts refer to in the interviews. Figure one presents the challenges in the four main groups.

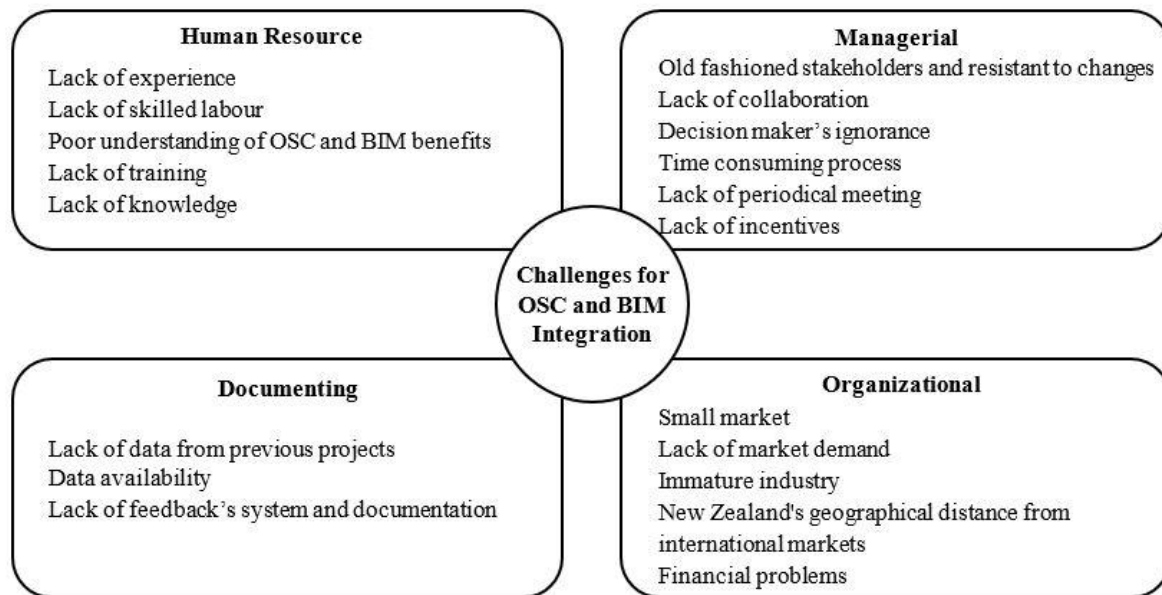


Figure 1. Challenges for OSC and BIM integration in the New Zealand construction industry

The other identified challenge is related to the managerial part. Periodical meetings, decision makers' ignorance, and lack of collaboration are some of the challenges in this group. Decision-makers must first be familiar with and believe in the benefits of the OSC and BIM to support the team. If they ignore the new technologies, detecting the problem in time and tardiness decision-making always lead to project error, heavy rearrangement operations, and project delay [58]. On the other hand, having regular meetings will allow better relationships with other staff in various project stages and improve collaboration among different parties. As a result, reworks decrease, and more sophisticated solutions for unexpected situations will be created during these meetings [26, 59, 60].

Using experiences from previous projects is an excellent opportunity to reduce the problems. Lack of a database for recording the experiences causes many reworks [61]. The interview's findings show that digital documentation is not very common in New Zealand's construction industry. However, according to different researchers, creating a database and an integrated information system for decreasing the reworks among OSC and BIM parties eliminates most spatial conflicts [26, 38].

Organisational challenges are mostly out of the project's control, and more power and resources are required to reduce them. These challenges are mentioned by the experts only, and some, like geographical distances from the international and New Zealand small markets, may not be solved as they are unrelated to the construction industry. Imposing initial extra capital at the beginning of the project is another challenge in this group. Using OSC and BIM needs more investment, but in the end, the total cost will be decreased. Overall, identifying these challenges will help the project stakeholders and managers figure out the significance of the integration of OSC and BIM. They help to improve the quality and decrease the total cost.

5. Conclusion and Future Research

OSC, as described before, is a response to the construction problems in New Zealand. However, like many other new technologies, it has several challenges too, and in order to decrease them, the construction sector needs to use other tools. One of these tools is BIM, which will reduce OSC issues, and as a result, OSC and BIM integration became more popular. However, this integration has many challenges, too and the first step to facilitate it is to identify the integration challenges and then figure out the strategies to solve them. Therefore, this study's objective was to discover existing OSC and BIM integration challenges in New Zealand through literature review and interviews. The literature review findings provided the required information for the next step, which was the interview. With the help of NVivo 12, the interviews were categorised into codes. Four groups of challenges were identified and

presented in figure 1. Human resource, managerial, documenting, and organisational are the main themes, and each of them consists of various factors. These research findings will provide a database for future studies to identify OSC and BIM integration strategies in New Zealand.

The outcomes of this study can help industry participants in New Zealand identify and understand their needs for BIM and OSC development and integration better. The limitations include finding the industry experts in New Zealand familiar with OSC and BIM. Furthermore, face-to-face interviews with specialists were impossible due to the Covid-19 restrictions. Because of the global nature of the subject of study, the ideas and conclusions presented here can be used to enable and improve BIM and OSC integration in any construction industry.

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