Al-Azhar University Civil Engineering Research Magazine (CERM)
Vol. (45) No. (2) October. 2023

Identifying significant Drivers propelling the extensive utilization of off-site construction technology methods in Egypt

Rana A. Shaker, Emad Elbeltagi, Ibrahim Motawa and Islam Elmasoudi

Structural Engineering Department, Mansoura University, Mansoura, Egypt.

Ranashaker@mans.edu.eg; eelbelta@mans.edu.eg; i_a_motawa@mans.edu.eg; Islamelmasoudi@mans.edu.eg

الملخص العربي :

في الآونة الأخيرة، تتبنى صناعة البناء والتشييد طرق البناء خارج الموقع كبديل أكثر استدامة وكفاءة عن طرق التشييد التقليدية التي تواجه عدة مشكلات. على هذا النحو، تهدف هذه الدراسة إلى استكشاف الدوافع التي تعزز الاستخدام الواسع النطاق لـ طرق البناء خارج الموقع في سوق البناء المصري, وتصنيفها للكشف عن أهم الدوافع التي تشجع أصحاب المصلحة على استخدام طرق البناء خارج الموقع بدلا من طريقة التشييد التقليدية. تم إجراء مراجعة الأدبيات لمعرفة الدوافع وراء اعتماد طرق البناء خارج الموقع على نطاق واسع .ومن ثم تم عمل استبيان استقصائي .وأخيرا، تم استخدام تحليل التباين ومتوسط الدرجات لفحص البيانات الكمية التي تم جمعها. ووجدت الدراسة أن زيادة الإنتاجية، وتعزيز مراقبة جودة المشروع، وتقليل المدة الإجمالية للمشروع، وتحسين جودة المنتج وتعزيز التفتيش والإشراف هم أهم خمسة عوامل تدفع إلى اعتماد طرق البناء خارج الموقع على نطاق واسع في مصر .وفي المقابل، تعتبر المبادرات والسياسات الحكومية هي الأقل تأثيرا. بالاضافة، تشير نتائج تحليل التباين إلى أن جميع الدوافع ذات دلالة إحصائية. تساهم هذه الدراسة في تسليط الضوء على أهم الدوافع التي من شأنها زيادة إمكانية تطبيق تكنولوجيا البناء خارج الموقع في صناعة البناء والتشييد المصرية، وهو أمر مفيد للدول النامية الأخرى التي تهدف إلى استخدام هذه التقنية .بالإضافة إلى ذلك، فإنها توفر منظورا أوسع حول الدوافع وراء اعتماد طرق البناء خارج الموقع ، مما قد يساعد أصحاب المصلحة في الصناعة وصانعي السياسات والأكاديميين على اكتساب فهم أفضل لنظام للقوى الدافعة لاعتماد طرق البناء خارج الموقع في مصر.

الكلمات المفتاحية: البناء خارج الموقع, متوسط النتيجة، تحليل التباين، مصر.

Abstract:

Recently, the construction industry is embracing off-site construction (OSC) as a more sustainable and efficient alternative to the flawed and environmentally damaging cast-in-situ method. As such, this study aims to explore the drivers promoting the wide use of OSC in the Egyptian construction market and rank them to reveal the key drivers that encourage stakeholders to use OSC over the conventional cast-in-situ method. A literature review was conducted to figure out the drivers of the widespread adoption of OSC. Then, a questionnaire survey was designed. Finally, analysis of variance (ANOVA) and mean score (MS) were utilized to examine the quantitative data that had been gathered. The study found that maximizing productivity, promoting project quality control, minimizing overall project duration, enhancing product quality and enhancing inspection and supervision are the top five factors driving the broad adoption of OSC in Egypt. In contrast, government initiatives and policies driver are the least influential ones. Meanwhile, ANOVA results evidence that all the drivers are statistically significant. This study contributes to the body of knowledge by highlighting the most crucial drivers that will increase the applicability of OSC technology in the Egyptian construction industry, which is beneficial to other developing nations aiming to use the technique. In addition, it provides a broader perspective on drivers for OSC adoption, which may help industry stakeholders, policymakers and academics gain a better understanding of the ecosystem of the driving forces of adopting OSC in Egypt.

Keywords: Off-site construction (OSC), Mean score, ANOVA, Egypt.

1. Introduction

In developing countries, the construction industry contributes significantly to the economy, in addition to providing employment [1]. Despite the industry's expansion, it continues to face substantial declines in performance [2], quality, productivity, safety control [3] and sustainability [4].

The demand for housing specifically as well as the construction market are both experiencing booms due to the ongoing population growth. In addition, the COVID-19 outbreak is causing a housing shortage in several areas. As a result of the poor performance of current traditional construction methods and the rise in market demand, construction practitioners and researchers are motivated to discover a faster and more sustainable strategy by integrating manufacturing roles and moving towards OSC [2].

Many developed countries have been utilizing OSC technology in the construction industry, while in a lot of developing countries, the implementation of OSC is quite limited. The main drivers behind the widespread adoption of OSC in a developing nation like Egypt are not well proposed in the literature. This study specifically investigates this issue by illuminating the most important drivers to extend the usability of OSC technology in Egyptian construction projects, which can serve as a solid starting point for other developing countries considering boosting the adoption of OSC. Additionally, it might assist stakeholders, government officials and academics in understanding the ecology of the drivers that led to the wide adoption of OSC in Egypt and consequently aid them in making more informed decisions about its utilization.

2. Literature Review

OSC is considered one of the most modern and innovative construction methods, which can be defined as the production of standardized or prefabricated structural components in an off-site facility, followed by their transportation to and installation on-site [5]. A variety of components can be created, including 1D single elements, 2D panelized systems and 3D volumetric units [6]. These components are typically made of concrete, steel frames or hybrid components. Similar to Lego brick assembly, the prefabricated components are placed on a foundation, stacked vertically and joined horizontally [7].

OSC has a lot of benefits over conventional construction. The sustainability features of buildings can be maintained in a stable and controlled industrial environment. Additionally, it lowers accidents by 80% [8] and helps to improve health and safety [4][2], [3]. In addition, OSC can maximize building quality [3], [9] through a quality-controlled production environment [8], [10]. It also encourages productivity [2] and lessens the industry's reliance on labor [4], cutting up to 25% of on-site labor expenditures [10], which reduces construction costs [8], [9]. The majority of earlier research [2], [4], [8], [9], [11], [12] agreed that OSC reduces construction time. In addition, OSC is regarded as a superior method of construction due to its ability to incorporate all current construction trends, including building information modelling (BIM), lean construction and green building. This is the reason for extensive research in OSC recently [12].

Despite the advantages of employing the OSC approach, widespread adoption and advancement of OSC technologies are still in their unmature stages in developing countries [3]. The conservative culture of the construction industry and resistance to change [2], as well as labor unions, are challenges to the broad use of OSC [11], as they worry that many workers may lose their jobs as rebar, formwork and concrete workers [8].

3. Methodology

This study aims to explore the most influential drivers promoting OSC usage. To meet this target, firstly, the drivers were identified through a literature review, followed by the development of a questionnaire survey to investigate key drivers enhancing the adoption of OSC in Egyptian projects. Finally, analysis of variance (ANOVA) and mean score (MS) were employed for data analysis.

3.1Identification of drivers

Drivers for widespread adoption of OSC have been collected through a literature review. Initially, a total of 43 drivers were identified and then categorized into 9 groups, as shown in Table 1. This categorization theme was adapted from similar studies as [2] and [10].

Table 1 Drivers of OSC adoption.

Group	Code	Driver	References
Time	D1	Less construction time	[8], [13]–[16]
	D2	Minimize overall project duration	[5], [7], [12]
	D3	Less unexpected delays	[5], [10], [13]
	D4	Ensure certainty of project schedule	[2], [7], [17]
	D5	Minimize lead times	[2], [7]
Cost	D6	Decrease overall project cost	[12], [14], [15], [18]
	D7	Reduce on-site cost	[10], [16], [17]
	D8	Decrease whole lifecycle cost	[10], [19]
	D9	Ensure project costs certainty	[10], [13], [17]
	D10	Decrease labor cost	[2], [5], [16]
Quality	D11	Enhance product quality	[3], [10], [13]–[15], [19]
	D12	Promote project quality control	[2], [10], [19]
	D13	Decrease defects and damages	[7], [15]
	D14	Enhance inspection and supervision	[2], [17]
Productivity	D15	Maximize productivity	[14], [15], [19]
	D16	Reduce site disruptions	[18]
	D17	Decrease reliance on manpower	[5], [10]
	D18	Improve site operations	[14], [15], [19]
	D19	Improve on-site operations management	[2], [7]
	D20	Less disruption to the surrounding community	[5], [7]
	D21	Repetitive components	[2]
	D22	Early design freeze	[16], [17]
Policy and Regulations	D23	Existence of adequate codes and standards supporting OSC	[14], [15], [18], [20]
	D24	Government initiatives and policies	[10], [14], [19]–[21]
	D25	Financial incentives	[10], [13], [21]
Safety and Health	D26	Enhance safety and health of labors	[10], [12], [19]
	D27	Decrease safety and health risks	[13], [16]–[18]
Environmental Sustainability	D28	Minimize generation of construction waste	[10], [17], [19]
	D29	Enhance sustainability	[3], [14], [15], [18]
	D30	Decrease greenhouse gas emission	[19], [21], [22]
	D31	Decrease energy consumption	[7], [19]
	D32	Decrease construction dust	[15], [19]
	D33	Decrease noise	[10], [19]
	D34	Produce more consistent product	[5]
Technicality	D35	Promote technologies such as BIM	[5], [15], [19]
	D36	Streamline construction activities	[7], [10]
	D37	Improve adaptability and design flexibility	[10], [13]
	D38	Improve constructability and buildability	[2], [13], [14]
Market forces	D39	Address deficits in housing supply	[3], [18], [21], [22]
	D40	Client's willingness and acceptance towards innovation	[16], [17], [19]
	D41	Boost client’s satisfaction	[3], [10], [14]
	D42	Existence of skills and expertise	[13], [16]
	D43	Existence of transportation infrastructure	[2], [7]

3.2 Survey development

To ensure that the findings did not exclusively rely on theoretical data, a questionnaire survey was created with the help of Egyptian construction industry practitioners. Individual respondents were contacted through email and requested to complete the survey.

There were two parts in the survey. The first part included respondent information such as organization type, job position and experience years in the construction business, as well as experience years in OSC projects, which was deemed a filter question functioning as an excluding criterion for the responses. In the second part, respondents were requested to rank the drivers according to their level of significance on a 5-point Likert scale. This scale's interpretation is as follows: 1 - extremely unimportant, 2 - unimportant, 3 - neutral, 4 - important and 5 - extremely important [14].

A total of 64 responses were initially received. Any response with zero years of experience in OSC projects is disqualified. However, the response with zero years of experience in OSC projects but familiar with the technique is deemed accepted. As a result, 7 responses were disregarded, leaving 57 valid for analysis.

3.2.1 Sample size

To perform statistical verification on the response rate, Equation (1) is used to determine the minimum number of responses required to accurately represent the total population [23].

$$\boldsymbol{n} = \frac{(\boldsymbol{t^2})\ (\boldsymbol{s^2})}{\boldsymbol{e^2}} \quad (1)$$

where n is the minimum number of responses required, t is the Z-statistic for the chosen significant value α, s is the variance deviation estimate for the used scale, which is produced by dividing the scale's range by the number of standard deviations for nearly all feasible range values and e is the number of scale points (in this case, 5), multiplied by the allowed margin of error (i.e., α). This test has been applied in several earlier investigations using a 95% significance level, which equates to a 0.05 α value [23]. As such, the corresponding t value is 1.96. The relevant s value is 5/6 and the associated e value is (5x0.05) considering the 5-point Likert scale used. The computed n is therefore 43, as illustrated below:

$$n = \frac{(1.96^2)\ (\frac{5}{6})^2}{(5 \text{ x } 0.05)^2} = 42.68 \approx 43$$

Therefore, the 57 valid responses are deemed sufficient (i.e., more than 43).

3.3 Research hypothesis

The study's goal was to determine what factors motivate broad OSC implementation in Egypt. To explore the goal of this research more thoroughly in quantitative terms, one null hypothesis was developed.

H0: There are no significant differences in the influence of the identified drivers on the widespread adoption of OSC in Egypt.

Due to the respondents' diverse backgrounds, the study utilized the analysis of variance (ANOVA) to look for statistically significant differences in the mean values across all drivers. Statistical significance is whether the influence is really significant or if it could have been the result of error or chance. It is determined based on the rho (ρ) value; if the ρ -value is less than 0.05, then there is enough evidence that the data is statistically significant (the influence is 95% reliable) [23].

4. Results and analysis

4.1 Demographic analysis

The demographic analysis of the respondents is displayed in Figure 1. Nearly 21% of respondents had substantial experience (more than 20 years in the industry); 21.1% had experience in construction ranging from 11 to 20 years; 33.3% had experience between 6 and 10 years; and the remaining 24.5% had experience between 1 and 5. Although there may have been a somewhat high percentage of participants with little experience, 75% of them had experience in OSC projects for at least four years, which was sufficient for this study.

While 40.3% of respondents had 4 to 10 years of experience working on OSC projects, 12.3% of respondents had more than 10 years of experience. Even though 29.8% of respondents only have 1-3 years of experience and 17.5% do not have first-hand experience with OSC buildings, the respondent profile is regarded as acceptable because it shows that there aren't enough professionals with extensive experience in OSC in Egypt, where OSC methods are still not widely applied in Egypt’s construction sector. Therefore, it's important to research what motivates widespread OSC use. However, this is acknowledged as a limitation of this study.

Directors make up 14% of respondents, senior managers make up 26.3%, project managers make up 26.3% and engineers make up 33.3%. These mixed respondent characteristics reduce questionnaire bias and improve sample representativeness [22].

To measure the internal consistency of the data collected, Cronbach’s alpha coefficient was computed, revealing high reliability of responses as its value (=0.96) was higher than 0.7 [15].

4.2 Key Drivers of OSC adoption

ANOVA and mean score (MS) analysis were used to conduct further analysis of the responses. Because the mean ranking of the respondents was necessary to adopt a statistical position, the MS analysis was deemed appropriate for the investigation. Similar previous studies ranked the drivers according to the mean rating score of the participants in a 5-point Likert scale survey [14].

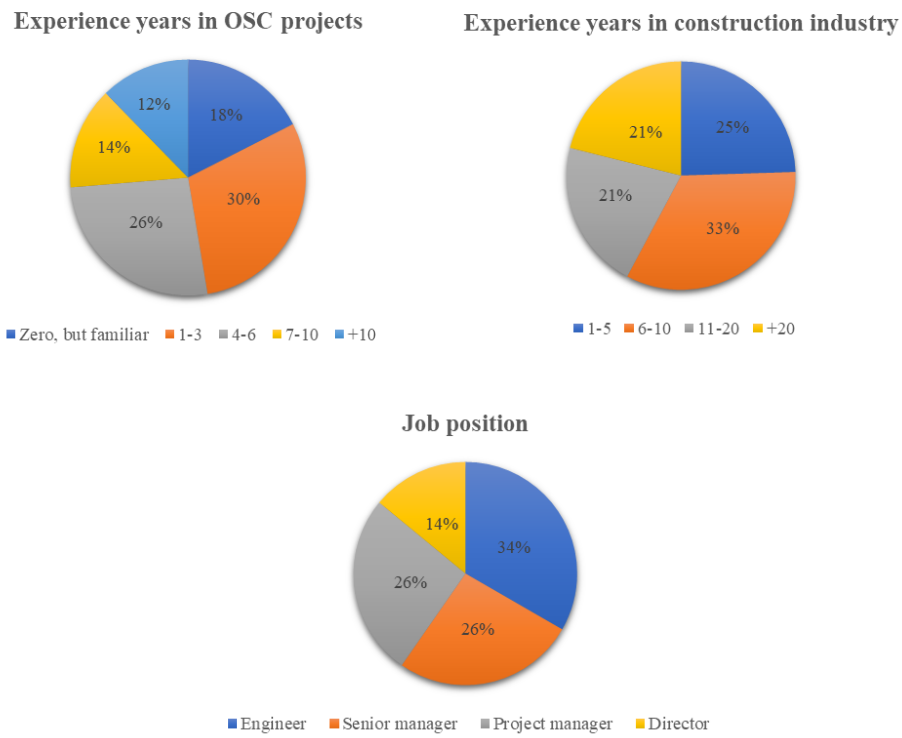

Figure 1 Demographic analysis of the respondents.

The ANOVA results revealed that the various respondents' backgrounds agreed in the importance of all the drivers in enhancing the wide usage of OSC because the ρ -value was 0.005 (<0.05), consequently rejecting the null hypothesis.

According to Table 2, maximize productivity (D15) was ranked first as the most influential driving force behind the widespread adoption of OSC in Egypt. In addition, promote project quality control (D12), minimize overall project duration (D2), enhance product quality (D11) and enhance inspection and supervision (D14) are the top five drivers, respectively. In contrast, government initiatives and policies (D24) is the least ranked driver.

Table 2 MS rating of drivers.

Rank	**Code**	**Driver**	**Group**	**MS**
1	D15	Maximize productivity	Productivity	4.035
2	D12	Promote project quality control	Quality	3.982
3	D2	Minimize overall project duration	Time	3.930
4	D11	Enhance product quality	Quality	3.912
5	D14	Enhance inspection and supervision	Quality	3.860
6	D1	Less construction time	Time	3.842
7	D19	Improve on-site operations management	Productivity	3.807
8	D28	Minimize generation of construction waste	Environmental	3.807
9	D4	Ensure certainty of project schedule	Time	3.737
10	D7	Reduce on-site cost	Cost	3.737
11	D16	Reduce site disruptions	Productivity	3.719
12	D38	Improve constructability and buildability	Technical	3.702
13	D42	Existence of skills and expertise	Market	3.702

14	D13	Decrease defects and damages	Quality	3.684
15	D32	Decrease construction dust	Environmental	3.667
16	D41	Boost client's satisfaction	Market	3.667
17	D37	Improve adaptability and design flexibility	Technical	3.649
18	D21	Repetitive components	Productivity	3.632
19	D26	Enhance safety and health of labors	Safety and Health	3.632
20	D27	Decrease safety and health risks	Safety and Health	3.632
21	D18	Improve site operations	Productivity	3.596
22	D20	Less disruption to the surrounding community	Productivity	3.596
23	D36	Streamline construction activities	Technical	3.579
24	D40	Client's willingness and acceptance towards innovation	Market	3.579
25	D29	Enhance sustainability	Environmental	3.561
26	D8	Decrease whole lifecycle cost	Cost	3.544
27	D9	Ensure project costs certainty	Cost	3.544
28	D34	Produce more consistent product	Environmental	3.544
29	D43	Existence of transportation infrastructure	Market	3.544
30	D17	Decrease reliance on manpower	Productivity	3.526
31	D3	Less unexpected delays	Time	3.509
32	D30	Decrease greenhouse gas emission	Environmental	3.509
33	D33	Decrease noise	Environmental	3.509
34	D35	Promote technologies such as BIM	Technical	3.491
35	D10	Decrease labor cost	Cost	3.474
36	D23	Existence of adequate codes and standards supporting OSC	Policy and Regulations	3.474
37	D6	Decrease overall project cost	Cost	3.439
38	D25	Financial incentives	Policy and Regulations	3.404
39	D31	Decrease energy consumption	Environmental	3.404
40	D22	Early design freeze	Productivity	3.386
41	D39	Address deficits in housing supply	Market	3.368
42	D5	Minimize lead times	Time	3.351
43	D24	Government initiatives and policies	Policy and Regulations	3.298

5. Discussion

The Egyptian construction sector faces various difficulties, but one of the most significant is productivity, which is mostly determined by labor efficiency due to the labor-intensive nature of the construction business. The shortage of labor monitoring and the lack of skilled labors are two of the top five issues influencing productivity in Egypt [24]. OSC offers a controlled factory environment where the work team is able to address resource planning issues, such as workforce variation and a shortage of skilled labors, by cross-training to create a multi-skilled team [19]. Additionally, by transferring on-site activities to the factory, construction monitoring can be improved by up to 19% [10]. This clarifies why D15 is considered as the primary driver by the surveyed respondents, encouraging the key stakeholders associated with the Egyptian construction industry to consider the OSC technique as an alternative construction method. This is consistent with the findings of [14], who placed productivity first while taking the Australian market into account. Also, productivity was regarded by [18] as a significant driving factor.

According to the study's findings, three of the top five drivers are from the quality group (D12, D11, D14), which indicates that quality-related drivers are significantly influencing the decision-making process to choose OSC over traditional on-site construction in Egypt. This result aligns with that of [16], who determined high quality as the main driver for adopting modular construction in Egyptian residential projects. The dominant position of the quality drivers makes sense due to the drastically declining product quality of Egypt's construction sector. Moreover, the fact that the quality control standards adopted in Egypt were inverted from those in the West and the Far East without any adaptation to the distinctive characteristics of the Egyptian environment has led to inadequate quality control standard implementation and failures to guarantee high-quality end products [25]. It was determined that maximizing product quality is one of OSC's main advantages. This can be linked to better engineering design and a controlled factory environment, where it is easier to achieve consistent products, unlike the traditional method, which exposes the production to unpredictable weather and resulting damage [7].

In this study, D2 is one of the top three key drivers affecting the widespread adoption of OSC within the Egyptian context, as well it considered a critical one in other contexts such as the US [17], the UK [13] and Australia [14]. This observation can be explained as delays are becoming a common global phenomenon in almost all construction projects, and Egypt is not an exception [26]. Because multiple construction activities can be completed concurrently rather than sequentially, as is required for traditional construction, OSC has been shown to be a time-saving construction technology, with projects frequently taking 40 to 50 percent less duration to be finished [5]. In addition, the controlled factory environment led to less exposure to bad weather [7], and there was also fewer machinery onsite, reduced downtime, reduced worker mobility and just-in-time material supply [10].

D24 is the least influential driver encouraging OSC in Egypt, as evaluated by the respondents. This finding is consistent with other studies that showed government regulations and support had little impact on OSC adoption in the US [17] and Malaysia [10]. However, government policy and initiatives have been pointed out as the key drivers of OSC implementation in other nations, such as Hong Kong [20], which mandates the use of a precast façade in all typical public housing [19], [21]. In addition, the Hong Kong Buildings Department (HKBD) mandates that 65% of the concrete components used in public housing be prefabricated. As a result, the desire of local developers to embrace the OSC approach has been markedly raised by these programs since 2001 [15].

6. Conclusions, limitations, and recommendation

Although OSC is considered a convenient solution for the challenges facing construction projects, it is still in its early stages of popularity, particularly in developing countries like Egypt. A small number of studies discussed the drivers for widespread OSC adoption, including a few that identified these drivers in the context of a developing country. As such, this research illustrates the key drivers that encourage decision-makers to choose OSC methods over traditional methods in Egypt.

Firstly, a literature review was performed to identify the drivers. Then, a questionnaire survey was created to reflect the opinions of Egyptian industry practitioners in rating the 43 drivers according to their importance. Consequently, some statistical analysis was utilized to validate the suitability and reliability of the data collected. Finally, ANOVA and MS were computed. The ANOVA results revealed that all the drivers are statistically significant in terms of influencing OSC's wider adoption. In addition, MS results indicated maximize productivity, promote project quality control, minimize overall project duration, enhance product quality and enhance inspection and supervision as the top five drivers enhancing the widespread adoption of OSC in the Egyptian construction industry, respectively. On the other hand, government initiative and policies is the least important factor. As well, these findings are consistent with earlier studies.

One limitation of this study is that the opinions of stakeholders may vary over time during the various development stages of OSC; the results of this study represent only the stakeholders' opinions regarding the initial development stage of OSC. Continuous studies on OSC adoption are required to continuously track the perspective of stakeholders towards OSC so that the promotion schemes of OSC can be altered accordingly. Although the priority of the drivers may vary depending on the project type, this should be considered in future studies. Additionally, future studies may use fuzzy and sensitivity analysis to investigate the link between the drivers in more detail.

However, the experts participating in this study did not consider the policy- and regulations-related drivers to be currently significant drivers of OSC diffusion. It is recommended that the government take the lead in motivating construction firms and developers to use OSC in all new projects by providing incentives such as subsidies on land prices. Moreover, manufacturers and researchers have a significant role in enhancing OSC; thus, the development of eligible manufacturers and the allocation of more funds for research institutions are needed.

7. References

[1] G. Adel, A. A. E. Othman, and N. Harinarain, "Integrated Project Delivery (IPD): An Innovative Approach for Achieving Sustainability in Construction Projects," in *Lecture Notes in Civil Engineering*, Springer Science and Business Media Deutschland GmbH, 2023, pp. 195–209. doi: 10.1007/978-3-030-97748-1_16.

[2] I. Y. Wuni and G. Q. P. Shen, "Holistic review and conceptual framework for the drivers of offsite construction: A total interpretive structural modelling approach," *Buildings*, vol. 9, no. 5. MDPI AG, 2019. doi: 10.3390/buildings9050117.

[3] Y. Han and L. Wang, "Identifying barriers to off-site construction using grey DEMATEL approach: Case of China," *Journal of Civil Engineering and Management*, vol. 24, no. 5, pp. 364–377, 2018, doi: 10.3846/jcem.2018.5181.

[4] I. Y. Wuni, G. Q. P. Shen, and A. T. Mahmud, "Critical risk factors in the application of modular integrated construction: a systematic review," *International Journal of Construction Management*, vol. 22, no. 2, pp. 133–147, 2022, doi: 10.1080/15623599.2019.1613212.

[5] C. Galante, S. Draper-Zivetz, and A. Stein, "Building Affordability by Building Affordably: Exploring the Benefits, Barriers, and Breakthroughs Needed to Scale Off-Site Multifamily Construction. About the Terner Center," 2017. [Online]. Available: www.ternercenter.berkeley.edu/

[6] Y. W. Lim, P. C. H. Ling, C. S. Tan, H. Y. Chong, and A. Thurairajah, "Planning and coordination of modular construction," *Autom Constr*, vol. 141, p. 104455, Sep. 2022, doi: 10.1016/J.AUTCON.2022.104455.

[7] A. Khan, R. Yu, T. Liu, H. Guan, and E. Oh, "Drivers towards Adopting Modular Integrated Construction for Affordable Sustainable Housing: A Total Interpretive Structural Modelling (TISM) Method," *Buildings*, vol. 12, no. 5, May 2022, doi: 10.3390/buildings12050637.

[8] S. Navaratnam, A. Satheeskumar, G. Zhang, K. Nguyen, S. Venkatesan, and K. Poologanathan, "The challenges confronting the growth of sustainable prefabricated building construction in Australia: Construction industry views," *Journal of Building Engineering*, vol. 48, May 2022, doi: 10.1016/j.jobe.2021.103935.

[9] S. Abdelmageed and T. Zayed, "A study of literature in modular integrated construction - Critical review and future directions," *J Clean Prod*, vol. 277, p. 124044, Dec. 2020, doi: 10.1016/J.JCLEPRO.2020.124044.

[10] S. Ismail, C. K. H. Hon, P. Crowther, M. Skitmore, and F. Lamari, "The drivers and challenges of adopting the Malaysia industrialised building system for sustainable infrastructure development," *Construction Innovation*, 2022, doi: 10.1108/CI-05-2021-0088.

[11] X. Gan, R. Chang, J. Zuo, T. Wen, and G. Zillante, "Barriers to the transition towards off-site construction in China: An Interpretive structural modeling approach," *J Clean Prod*, vol. 197, pp. 8–18, Oct. 2018, doi: 10.1016/J.JCLEPRO.2018.06.184.

[12] N. Lee and S. Jin Kim, "Factors Influencing the Construction Industry's Shift to Modular Construction."

[13] A. Agapiou, "Factors influencing the selection of a procurement route for UK off-site housebuilding," *Proceedings of Institution of Civil Engineers: Management, Procurement and Law*, vol. 175, no. 1, pp. 3–15, Oct. 2020, doi: 10.1680/jmapl.20.00027.

[14] M. Sutrisna, V. Ramnauth, and A. Zaman, "Towards adopting off-site construction in housing sectors as a potential source of competitive advantage for builders," *Architectural Engineering and Design Management*, vol. 18, no. 3, pp. 165–183, 2022, doi: 10.1080/17452007.2020.1807306.

[15] C. Mao, G. Liu, L. Shen, X. Wang, and J. Wang, "Structural Equation Modeling to Analyze the Critical Driving Factors and Paths for Off-site Construction in China," *KSCE Journal of Civil Engineering*, vol. 22, no. 8, pp. 2678–2690, Aug. 2018, doi: 10.1007/s12205-017-1705-4.

[16] A. H. Ali, G. M. El-Mahdy, A. H. Ibrahim, and A. O. Daoud, "Towards the Adoption of Modular Construction in Residential Projects in Egypt: Benefits, Barriers, and Enablers," *Towards a Sustainable Construction Industry: The Role of Innovation and Digitalisation*, pp. 72–81, 2023, doi: 10.1007/978-3-031-22434-8_8.

[17] M. Razkenari, A. Fenner, A. Shojaei, H. Hakim, and C. Kibert, “Perceptions of offsite construction in the United States: An investigation of current practices,” *Journal of Building Engineering*, vol. 29, May 2020, doi: 10.1016/j.jobe.2019.101138.

[18] H. Elnaas, K. Gidado, and A. P. Philip, “Factors and Drivers Effecting the Decision of Using Off-Site Manufacturing (OSM) Systems in House Building Industry,” *Journal of Engineering, Project, and Production Management*, vol. 4, no. 1, pp. 51–58, Jan. 2014, doi: 10.32738/JEPPM.201401.0006.

[19] Z. Wu, L. Luo, H. Li, Y. Wang, G. Bi, and M. F. Antwi-Afari, “An analysis on promoting prefabrication implementation in construction industry towards sustainability,” *Int J Environ Res Public Health*, vol. 18, no. 21, Nov. 2021, doi: 10.3390/ijerph182111493.

[20] X. Jin, E. M. A. C. Ekanayake, and G. Q. P. Shen, “Critical policy drivers for Modular integrated Construction projects in Hong Kong,” *Building Research & Information*, vol. 50, no. 4, pp. 467–484, May 2022, doi: 10.1080/09613218.2021.2010030.

[21] K. Oti-Sarpong, R. S. Shojaei, Z. Dakhli, G. Burgess, and M. Zaki, “How countries achieve greater use of offsite manufacturing to build new housing: Identifying typologies through institutional theory,” *Sustain Cities Soc*, vol. 76, Jan. 2022, doi: 10.1016/j.scs.2021.103403.

[22] X. Gan, R. Chang, and T. Wen, “Overcoming barriers to off-site construction through engaging stakeholders: A two-mode social network analysis,” *J Clean Prod*, vol. 201, pp. 735–747, Nov. 2018, doi: 10.1016/j.jclepro.2018.07.299.

[23] “Collaborative Planning in the Construction Industry: A Holistic Framework for Assessing Collaborative Planning Practices and Predicting Project Performance - ProQuest.” Accessed: Oct. 25, 2023. [Online]. Available: https://www.proquest.com/openview/0392490903efe0d5eeb0a1217c569f81/1?pq-origsite=gscholar&cbl=18750&diss=y

[24] S. M. Hafez, “Critical Factors Affecting Construction Labor Productivity in Egypt,” *American Journal of Civil Engineering*, vol. 2, no. 2, p. 35, 2014, doi: 10.11648/J.AJCE.20140202.14.

[25] C. Neilson, *THIRTY-SIXTH ANNUAL CONFERENCE 2020 September 7-8 PROCEEDINGS.*

[26] T. El-Rasas and M. Marzouk, “Fuzzy model for assessing delays in Egyptian residential projects,” *Journal of Financial Management of Property and Construction*, vol. 25, no. 2, pp. 225–246, Jul. 2020, doi: 10.1108/JFMPC-04-2019-0031/FULL/PDF.