**Identifying and Evaluating Critical Success Factors for Industrialized Building Systems Implementation: Malaysia Study**

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**Abstract:** The drive toward implementing an industrialized building system (IBS) in Malaysia is in line with Malaysia’s Construction Industry Transformation Plan 2016­–2020, which seeks to increase more than double the construction industry’s productivity. IBS is able to accelerate the construction timeline, provide a safer working environment on site, produce a higher quality of construction, and save costs. Although the introduction of IBS in Malaysia is not new, its acceptance has not been extensive, and IBS implementation is still slow. Thus, to support the successful implementation of IBS, it is vital to determine the factors that influence the achievement of this aspiration. Therefore, this study aims to identify and evaluate the critical success factors (CSFs) that contribute to the smooth implementation of the IBS dimensions within the context of the Malaysian construction industry. By doing so, the uptake of IBS can be accelerated. In order to consolidate the set of candidate success factors, these CSFs were identified from the literature review and confirmed through a self-administered survey questionnaire. Then, the value of importance of each CSF was calculated in a second survey. Based on the factor analysis, 15 CSFs were identified and grouped into five major elements: strategy, sources of funding, process, people, and enabler, with each factor comprising its own set of components. The findings indicate that the CSFs in IBS implementation have different priorities and weights.

**Keywords:** Malaysia; Industrialized building systems; Implementation; Critical success factors; Analytic hierarchy process.

**1. Introduction**

Industrialized building systems (IBS) consist of innovative manufacturing methods to improve construction image and performance. The term “IBS,” was first formally defined in Malaysia in the early 2000s, encompassing the use of prefabricated, offsite, mass-produced, and standardized components [1]. Although the first IBS project was implemented in 1964, various construction parties in Malaysia are yet to accept IBS due to it failing to adequately deal with risks, as demonstrated by authors in previous surveys [2,3,4]. To date, the Malaysian government and IBS practitioners have become increasingly burdened by a large number of factors that limit IBS implementation. The construction industry, as a whole, remains very reluctant to explore IBS use as reflected by its slow uptake [3]. Indeed, the adoption rate is still low, as revealed in a report by Malaysia’s Construction Industry Development Board (CIDB) [5]. This slow uptake prevents any real efficiency in terms of its adoption from being leveraged across the industry [6].

The current work’s main goal is to identify the critical success factors (CSFs) that influence IBS implementation and to prioritize these factors based on their respective weights. Therefore, the findings of this work can help stakeholders understand the effects of adopting IBS based on the CSFs in their venture. Given this background, this study derived the following objectives:

(1) To evaluate IBS implementation by investigating the effects of CSFs on various dimensions of IBS. Thus, the industry can subsequently focus on these CSFs to achieve greater IBS implementation efficiency.

(2) To prioritize the CSFs according to their individual degrees of importance so that the industry can assess its current practices and adjust its resources to accelerate the uptake of IBS.

The CSFs will serve as invaluable guidelines for many stakeholders, including both the public and private sectors, with the former acting as a client to the construction sector, as its regulator, and as a provider of funds, in order to accelerate IBS uptake using strategic approaches that lead to a sustainable development in Malaysia. At the same time, this work can be extended to an international context so that the adoption of IBS in other developing countries could be better understood.

**2. Research Method**

This study adopts a mixed-method approach, combining a literature review, a self-administered survey questionnaire, and a self-administered *analytic hierarchy process* (AHP)-questionnaire. The self-administered survey questionnaire is designed to further verify the set of candidate CSFs, whereas the self-administered AHP questionnaire aims to prioritize CSFs. This work also conducts qualitative analyses of the literature review using content analysis, as well as the quantitative analyses of both questionnaires, where data from the first questionnaire was analyzed using Microsoft Excel, while the second was assessed using Expert Choice (EC) software.

**2.1. Study Design**

Different CSFs increase within industries and within enterprises operating in a specific industrial context. These CSFs are mainly defined based on three aspects (organizational, industrial, and environmental) and are classified as strategic, managerial, or operational [7]. On the basis of these notions, a strategy would represent a consciously formulated plan [8], whereas the organizational aspect emphasizes the qualitative measures, such as the balanced scorecard [9]. The present study identifies the CSFs of IBS implementation at the strategic level of organizational aspects and it also proposes a conceptual model that facilitates the identification of CSFs.

The CSFs approach has received wide acknowledgment in various studies, but there is no fixed rule on the identification of CSFs that has been developed so far. However, some studies [e.g., 10,11,12] have adopted systematic procedures to identify CSFs. As reported in these studies, the usual procedures are outlined in five stages: (1) identifying a group of selected success factors (SSFs); (2) conducting a survey to determine the importance of each SSF in accordance with a specific goal; (3) calculating each factor’s importance index value based on the survey data; (4) using the importance index value to determine the CSFs from the group of SSFs; and (5) analyzing and interpreting the identified CSFs. This current study adopted this five-stage process to identify the CSFs. In specific, the methods adopted in the five-step process are listed below:

1. ***Identify a full set of selected success factors through a comprehensive literature study.*** Although Kamar [13] and Kamar et al. [14] have identified the CSFs in relation to the success of IBS contractors in Malaysia, these studies did not focus on the role of the government. Nevertheless, their results serve as a good platform upon which to study CSFs more comprehensively for the purpose of IBS implementation. The literature on CSFs in IBS implementation is expected to be limited because failure factors are the exact opposite of the success factors. Hence, investigating the limitations, barriers, challenges, and issues involved in using this technique would significantly contribute to the findings of this study.
2. ***Conduct a survey to investigate the importance of each selected success factor via pilot study.*** The author invited industry practitioners via a pilot study including two academics, one manufacturer, one contractor, and one *Malaysian Investment Development Authority* (MIDA) officer. All of whom were urged to join and comment on the appropriateness, clarity, and comprehensiveness of the identified CSFs. At the same time, the number of success factors will be reduced as non-critical factors are excluded. By considering the comments and suggestions received from this group, redefinitions and modifications were made accordingly to consolidate the set of candidate success factors.
3. ***Calculate the importance of each factor via a self-administered survey questionnaire***. It is essential to rank CSFs based on the opinions of industry practitioners involved in IBS implementation. As suggested by Müller and Kam [15], experienced practitioners engaged in any field have the ability to identify candidate success factors in their respective fields. Therefore, when factors covered many intangible items or their actual performance data are not available, the candidate CSFs can be identified based on the experts’ opinions. These assumptions are suitable for the circumstances investigated in this step. Thus, this study designed a self-administered survey questionnaire to gather experts’ opinions. The questionnaire consisted of three main parts. The first part extracted the personal details of the participants. The second part (closed questionnaire) investigates the views of the respondents to evaluate the importance of each item in ensuring the success of IBS implementation. Many studies have stated that there is little evidence to support the definitive number of appropriate points on the scale. For example, Kaiser and Kaplan [16] put forth a curvilinear scale but noted that contextual influences would make comparisons difficult. Jacoby and Matell [17] noted that the three-point Likert scale was acceptable. This simplification of the questionnaire involved cutting down on the number of response options to increase the speed of completion [17,18]. Therefore, a three-point Likert-type scale was developed for the researcher-designed questionnaire in this study. The response options for frequency were a 1— “not important factor” 2— “important factor, but not critical,” and 3— “important and critical factor”. To avoid confusion and ambiguity, a brief definition of each factor was given. This was also done to enable all the respondents to understand and answer the questions on the same basis, thus limiting the respondent to one of the pre-coded responses. The final part of the questionnaire was included an open-ended question (“Do you have anything more to add?).
4. ***Calculate each selected success factor according to the value of importance index via an AHP survey***. Many researchers have adopted different weighting methodologies for prioritizing CSFs. For example, Rahman et al. [19] compared these methodologies and identified the AHP as the best-suited method to set priorities for CSFs. There was concern that respondents might find it difficult to answer technical AHP-related questions, so the researcher opted to use a self-administered survey. Consequently, the self-administered AHP questionnaire was developed via a pilot study, and then the opinions of the same experts who participated in the first survey were collected. Apart from the first part of the questionnaire that aimed to extract data on the respondents’ background information, the other queries invited the respondents to evaluate the degree of importance of each pair of CSF using a nine-point scale as shown in Table 1. Then, this study derives the priority vector for each matrix of pairwise comparisons by calculating the eigenvector for the matrix. In this way, we obtained the priorities based on the model for the criteria in terms of the goal, the sub-criteria in terms of their parent criteria, and the alternatives in relation to each covering criterion, were obtained.
5. ***Analyzing and interpreting the identified CSFs***.

Table 1: Pairwise comparison table for AHP with interpretation [26]

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Intensity of importance | 1 | 3 | 5 | 7 | 9 | 2,4,6,8 |
| Definition | Equal importance of criteria | Moderate importance slightly favor one criterion over another | Essential or strong importance strongly favor one criterion over another | Demonstrate importance, criterion is strongly favored, and its dominance is demonstrated | Extreme importance-the evidence favoring one criterion over another, is of the highest possible order of affirmation | Intermediate values between the two adjacent judgements when compromise is needed |

**2.2. Participants**

This study employed a stratified random sampling design, as sample stratification may generate a smaller bound for the error of estimation compared to a same-sized simple random sample [20]. Furthermore, this method can ensure that the survey achieves a high level of generalizability [21]. IBS decision-makers in the Malaysian construction industry were grouped into a stratum. The second stratum included academics in civil engineering and building technology, whose research works focused on IBS. The manufacturers and contractors that have worked with IBS in the Malaysian construction industry were selected and grouped into another stratum.

A Web-based invitation was created and sent to 79 respondents from four Malaysia States. These respondents expressed willingness to discuss the results with the researcher in the form of a self-administered survey questionnaire. The participants (e.g., IBS manufacturers and companies) were carefully selected from a list provided by CIDB. The selected academic selected have the title of “Ir,” which is specifically bestowed upon a Malaysian professional engineer, who has passed stringent requirements by the Board of Engineers Malaysia. A total of 38 respondents expressed willingness to take part in the self-administered survey questionnaire. The same experts who participated in the first survey also took part in the second survey, i.e., the self-administered AHP questionnaire. (See Table 2.)

Table 2: Details of the case study respondents

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Place | JKR | CREAM | IBS  centre | Academic (IR) | IBS manufacturer | IBS contractor | Total |
| Kuala Lumpur | 3 | 2 | 3 | 4 | 2 | 2 | 16 |
| Penang | 2 | – | 1 | 3 | 1 | 1 | 8 |
| Ipoh | 1 | – | 2 | 1 | 2 | – | 6 |
| Kuching | 2 | – | – | 2 | 3 | 1 | 8 |
| Total | 8 | 2 | 6 | 10 | 8 | 4 | 38 |

Public Works Department Malaysia (JKR). Construction Research Institute of Malaysia (CREAM)

The final participants (N = 38) consisted of 16 government officials, 10 academics, and 12 IBS manufacturers and contractors. These experts have been exposed to IBS for not less than 15 years, except three respondents from the branches of the IBS Centre and one respondent from the Construction Research Institute of Malaysia (CREAM) who has had 7 –10 years of experience. Interviews were conducted in English to maintain compatibility among the researchers and the participants, who have a good fluency in English. Benefiting from the same experts in the first survey, the CSFs could be ranked based on impact and can be identified through AHP based on the expert opinions.

**2.3. Location**

The majority of IBS manufacturers are located in Negeri Sembilan, Johor, and Selangor. Meanwhile, other States are still in the process of developing IBS precast factories to comply with the government rules in using such technology [22]. However, the CSFs developed in one state may be inappropriate in others because Malaysia has different levels of IBS usage. Nevertheless, by focusing on some administrative capitals in Malaysia, such as Kuala Lumpur as the largest city in terms of IBS usage, in addition to Ipoh, Penang, and Kuching that have variable levels of usage, the current findings will more likely be applicable for all the Malaysian States. Selangor is a state encircling the Federal Territory of Kuala Lumpur and has many close economic and social ties [23]; hence, this study considered both areas (Selangor and Federal territories) as Kuala Lumpur.

**2.4. Data Analysis**

***Analyzing the literature review:*** In the first stage, conducted a qualitative content analysis of 58 articles most of them published in peer-reviewed journals, was conducted. The outcomes of the analysis were used for identifying the full set of selected success factors. The literature analysis was done manually, based on the steps that suggested by Mayring [24], namely:

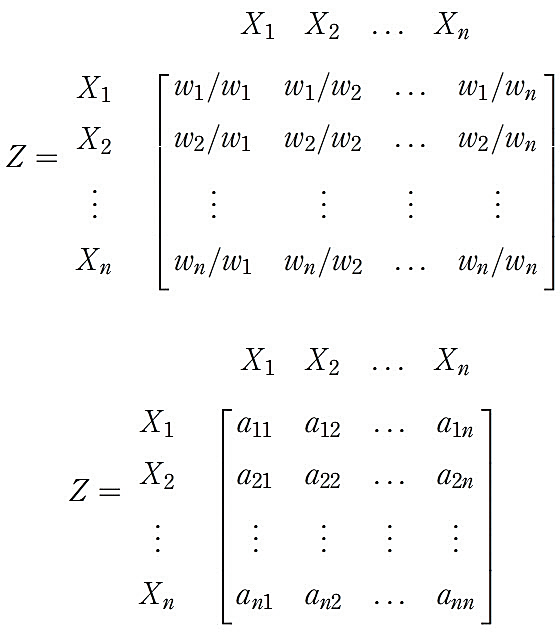
• *Descriptive analysis*: Formal aspects of the collected material are analyzed to provide a base for theoretical analysis;

• *Category selection:* Structural attributes and corresponding analytic categories are selected to categorize the collected material; and

• *Material evaluation:* The collected papers are analyzed based on the structural attributes to find relevant issues and trends in the literature.

***Analyzing the self-administered survey questionnaire:*** In the second stage, the close-ended questions were analyzed using Microsoft Excel software, quantitative methods were adopted to analyze these questions in a straightforward way, where a percentage was calculated for every question to determine the power of the answer to the question. The quantitative data of the first survey was not based on a large number of samples, e.g., not in hundreds, so made the merit of using a sophisticated software such as the Statistical Package for the Social Sciences (SPSS) was not applicable for handling the small sample size in this study [25]. The data was then sorted, stored, and analyzed, on an interim basis using Microsoft Excel software saving the time and effort to convert the data/analyses than if SPSS were used. Microsoft Excel produced better illustrative figures and was simpler to use than other sophisticated software. In the open-ended question, qualitative methods were adopted to deal with the analysis, where a classical matrix analysis was performed on the questions to derive the findings.

***Analyzing the factors’ weights via an AHP survey:*** This step is the third stage. Firstly, the different weights were computed by ascertaining the importance of each attribute with respect to each of the others through pairwise comparisons. Let there be X1, X2, X3, … Xn elements under the node “M” and their numerical weights are w1, w2, w3…wn. So, the pairwise comparisons of these elements in accordance to their relative weights are shown in the form of a matrix, where Z is a comparison matrix (n × n) representing the pairwise comparisons among the elements X1, X2, X3…Xn:



Where (i, j = 1,2...n) represents the quantified comparative importance among the pair of elements Xi and Xj. If i = j then aij = 1 and aij = 1/ aji for aij > 0.

The second stage consists of the computation of vector to priorities, which identify the priority weights of the elements through the maximum eigenvectors and eigenvalues. According to Saaty [26]:

The eigenvectors can be computed with the formula:

Where, W – eigenvector and largest eigenvalue of matrix Z.

The third stage is to measure the consistency ratio (CR) of the judgments for the answers. In the pairwise comparison, the inconsistency was measured via the consistency index (CI) and the coherence is measured via CR and is computed with the help of the formulae given below:

Where, n is the rank of the matrix and random index (RI) which is the CI of the matrices which are generated randomly. Satty [26] recommended acceptable CR values for different matrix’s sizes: (1) the CR value should be 0.05 for a 3×3 matrix; (2) 0.08 for a 4×4 matrix; and (3) 0.10 for larger matrices. Responses that did not meet the CR requirement were removed. In this step, the pairwise comparisons were analyzed using Expert Choice (EC) software to compute the weight of each factor. EC is an AHP-based multi-objective decision support tool. It is designed for the analysis, synthesis, and validation of complex individual or group decisions.

**3. Results**

**3.1 Derive Success Factors through a Qualitative Content Analysis of the Literature**

Based on the derived themes from the qualitative content analysis of the literature, about 15 success factors and 50 sub-factors (components) were identified. CSFs can be classified under several key elements. For example, CSFs classified in the context of the IBS of contractor’s research by Kamar [13], under four elements: strategy, process, people, and enabler. The present work grouped the CSFs into five major elements: (1) strategy, (2) sources of funding, (3) process, (4) people, and (5) enabler.

**3.1.1 Strategy**

1) Government leadership

In its bid to become a developed country by 2020, Malaysia looks to its construction industry as a major catalyst to achieve this vision [27]. The CIDB Malaysia, an agency that has been established to improve, develop, and expand the local construction industry, has recently identified several sustainability-related environmental issues as the major challenges faced by the country’s construction industry [28]. The government’s commitment to encourage the use of IBS is manifested through the development of the Roadmap IBS (2003–2010), the IBS Roadmap (2011–2015), and the current Construction Industry Transformation Program (CITP, 2016–2020). The IBS Center of CIDB has the duty to implement IBS activities and strategies with the aim of improving both construction performance and quality.

2) National policy

There is an increasing trend of countries going beyond strategic reviews to prepare national construction industry policies [29]. The possible actions in the national policies of the construction industry could include changes in the contracting approaches of IBS projects. According to the CREAM [30] the contracts and payment mechanisms of the IBS stakeholders must be more reliable than the traditional ones. In addition, Fateh et al. [4] reported that a development of a standard form of contract to act as a formal contract arrangement is a must to ensure all parties bind together, further promoting and encouraging integration among all. Meanwhile, although IBS is a construction method, the current building code in Malaysia does not address construction methods [31]. In view of this, the CIDB [3] reported that the slow IBS uptake could be attributed to existing constraints or loopholes in the regulations, specifications, requirements, and standards, which are consistent with IBS environment and processes. According to Zakaria et al. [6] the government—as a major construction client—plays its role by implementing promotions/advocacies, policies, rules and requirements, and by determining the competitive directions of the construction industry and the IBS decision-making process. Thus, indirect governmental efforts to encourage the wider usage of IBS components may be further materialized through continuous market demand.

3) Corporate leadership

In order to change the construction strategy from using a conventional approach to adopting the IBS method, massive support is required, along with clear managerial vision motivation, and commitment, all of which are critical in convincing the decision-makers, customers, clients, and one's own organizational structure to utilize the IBS method [32]. The mission statement is believed to be a prerequisite to any strategy formulation [33]. Leadership is also important because leaders demonstrate their direction and their level of commitment, initiatives, and support toward the IBS technology adoption [6]. Good leadership and support from the management ensure a better understanding of the change process strategy so that the players can steer through constraints, thus avoiding the tendency to return to conventional methods at the first difficulties [10].

4) Business strategy

IBS predicts that the building procurement system may diverge from the conventional one a system that includes the acquisition of materials and components prior to achieving progress in the actual work site. First, IBS companies must establish a specific business model so that they can position themselves in the emerging playing field [34, 35]. According to Malik [34] and Pan and Chris [36], this business process requires a clear business need statement, which must then be backed up by a long-term strategic plan. Moreover, the adoption of IBS requires the use of a new business approach, new investments and financial planning. These include, among others, the effective combination of cost control and the selection of projects that can provide enough volume to justify any major investment to be made [37]. On a strategic level, a risk assessment and mitigation plan must be devised to complement the decision-making during the trial-and-error stage. This normally occurs when the company first wants to adopt IBS [10], specifically in an environment of uncertainty. Table 3 shows the CSFs and components of the ‘strategy’ element.

Table 3: Critical success factors and the components for strategy element

|  |  |  |  |
| --- | --- | --- | --- |
| **Element** | **Critical Success Factors** | **Components** | **Reference** |
| STRATEGY | 1) Government leadership | 1 Vision and commitment  2 National development plan  3 CIDB roles through IBS Center | [27,28] |
| 2) National policy | 4 Contract procedures  5 National standards  6 Legal systems  7 Construction market risks | [40] |
| 3) Corporate leadership | 8 Vision and mission of the company  9 Leadership from top-level management | [13, 14] |
| 4) Business strategy | 10 Selection of contract and procurement system  11 Business model  12 Investment planning  13 Risk strategy | [13] |

**3.1.2 Sources of Funding**

5) Government incentives

The use of innovative materials and systems depends on imported technologies, which are often expensive and difficult for local contractors to purchase [38]. In order to solve this problem, and in accordance with the initiatives made by the Construction Industry Transformation Program (CITP) (2016 –2020), the Malaysian Investment Development Authority (MIDA) has formulated a plan to attract investments of RM 2 billion by 2020 from at least 100 new IBS manufacturers [39]. However, incentives to initiate widespread IBS implementation either from the government or from private agencies remain inadequate, thereby resulting in the poor implementation of IBS projects [31, 40].

On the one hand, the government incentives, levy exemption, and local authority requirements can increase contractors’ satisfaction toward IBS implementation [41]. Under the recent government plan CITP (2016 –2020) [3] more tax exemptions have been introduced such as construction levies for any residential development that achieve 50% of IBS contents (CIDB levy — 0.125% of the total cost of the project according to Article 520). Furthermore, only a few IBS suppliers are evident in a small market, resulting in the monopoly and high prices of materials. To avoid the monopoly of certain groups, according to Razak and Awang [42] is due to the promotion of the formation of other suppliers in big numbers. Thus, the government could provide flexible financing to encourage new suppliers.

6) Private investment

Funding constraints in several countries have driven various governments to seek alternative methods for financing infrastructure provision. The Private Finance Initiative (PFI), which has been used simply to place a great amount of debt “off-balance-sheet” [43], is an example of the Malaysian government’s efforts to strengthen the concept of partnership in the construction industry, especially because PFI is a subset of the Private–Public Partnerships (PPP) in Malaysia [44]. Meanwhile, the CIDB backed Construction Industry Master Plan (2006–2015) identifies and recommends partnering as a method to solve the inherent problems in the construction industry [45]. This method plays a major role in enhancing IBS implementation. Product manufacturing focuses on the technological aspect of construction. Offsite and onsite are two examples of product manufacturing, which is mainly concerned with how parties cooperate informally or on a contractual basis. Manufacturing products deal with Design-and-Build contracts or more advanced strategies like PPP/PFI. IBS implementation can derive benefit from PPP/PFI, which is tasked to provide the initial construction and design as well as enables better management of issues arising from manufacturing, design harmonization, and constructability. Therefore, faster project implementation, improved service quality, and additional generated revenue all lead to the creation of value for money.

Abdul-Aziz and Kassim [46] argued that value for money could take the form of lower operating and construction costs, as well as efficient and long-term maintenance. This argument implies that the project creates significant business potential, which can increase the engagement of numerous private parties and lead to the creation of an even more competitive bidding process [47]. The construction industry’s growth will further sustain the successful completion of major projects [48]. In this way, tendering processes can be more competitive, and the PPP system can be used to solve problems related to procurements. Furthermore, the local contractors could monopolize the construction industry. Moreover, under a good leader, cooperation among project teams could further stimulate innovation. Table 4 shows the CSFs and components for the ‘source of funding’ element.

Table 4: Critical success factors and the components for the source of funding element

|  |  |  |  |
| --- | --- | --- | --- |
| **Element** | **Critical Success Factors** | **Components** | **Reference** |
| SOURCES OF FUNDING | 5) Government incentives | 14 Flexible financing and tax reduction packages for manufacturers and contractors  15 Flexible financing packages to suppliers  16 Tax breaks and tariff reductions to suppliers | [3,31,39,41] |
| 6) Private investment | 17 Declining public funding  18 Incentives for competitive tendering  19 Great value for money for public projects | [45,46,47] |

**3.1.3 Process**

7) Design management and integration

Pan et al. [49] argued that, in the early stage, designers must seek the involvement of the project team during the decision-making and designing stages so that their inputs concerning manufacturing, design harmonization, and constructability are well integrated into the project. Yunus and Jay [1] suggested that a collaborative approach between the designer and manufacturer is significant in helping ensure joint decisions in the finalization of IBS design. According to Choi et al. [50] introducing the concept of the design-freeze principle into the schedule would be beneficial. Because doing so can mitigate the effects of any late design changes, which may not be easy to accommodate under IBS. Efficient communication during the design process, especially in the early design stage, also has a major impact on the overall cost and quality of the completed project, especially when the knock-on effects on downstream issues can be observed throughout each stage of the project [51]. Furthermore, there is a need for standardization efforts of components as long-term strategic initiatives are needed to drive the creation and adoption of IBS standards [52]. According to Jaillon and Poon [53] repeating the same precast elements at every floor is an important and often employed design factor when adopting IBS.

8) Project management

Yusof et al. [54] reported that, apart from being recognized as a key success factors for IBS projects, extensive and advanced planning and scheduling of activities is crucial in achieving better project delivery and IBS project coordination. Given the coordination that is required in IBS projects, effective communication is crucial to ensure the smooth flow of the entire process. Offsite fabrication also reduces the amount of work that is done onsite, thus reducing exposure to hazards [55]. However, in IBS, the safety aspect is crucial to avoid the transfer of site risks to the factory or the risks involving transferring components to the site and their installation. Moreover, the accurate estimation of the total project cost at the initial stage of the design process and the effective management of these costs throughout the completion of the construction period, play a significant role in a project’s overall success [56]. Hence, understanding project operations involve several important strategic considerations in project operations, such as measuring performance and the control of time, resources, site activities and quality [57], to create company success in implementing the IBS method.

9) Supply chain management and logistics

One of the challenges involved in the successful completion of IBS projects is the smooth integration of elements throughout the supply chain, which could have a value-added impact on the successful completion of IBS project implementation and delivery [58]. Nonetheless, contractors are still required to integrate key business processes in the supply chain from the end user due to the high demands on logistical activities in IBS construction [10]. Forging a strategic alliance among the supply chain providers is a strategy that has been adopted to solve the construction industry’s persistent problem of a fragmented supply chain [59]. Eriksson [60] argued that a long-term partnership with suppliers is one of the fundamental pillars in the adoption of the Just in Time (JIT) and lean construction principles in the construction industry. In addition, transportation management must concentrate on the plan design, site layout, construction schedule, and cost of plants [61]. In the installation phase, contractors must also determine the ground conditions, the size of the site, and the best routes and time to reach the site before installation works can begin [62,63]. Table 5 shows the CSFs and components of the ‘process’ element.

Table 5: Critical success factors and the components of the process element

|  |  |  |  |
| --- | --- | --- | --- |
| **Element** | **Critical Success Factors** | **Components** | **Reference** |
| PROCESS | 7) Design management and integration | 20 Design management  21 Standardization  22 Design integration | [13,14, 89,90,91] |
| 8) Project management | 23 Advanced planning and scheduling  24 Effective communication  25 Coordination of process  26 Cost, time, quality, and safety management | [13,14] |
| 9) Supply chain management and logistics | 27 Integrating supply chain with business process  28 Partnering and strategic alliances  29 Just-in-time (JIT) strategy and lean production  30 Transportation and installation management | [13,14] |

**3.1.4 People**

10) Skills

Nadim and Jack [64] and Alazzaz and Andrew [65] argued that laborers must be retrained and re-skilled so that they can develop IBS skill sets. The process of standardizing the precast elements and the involvement of massive production outputs requires a high level of design and labor specialization, and the installation of components must be carried out by well-trained, fully competent, and expert personnel [66]. The experience of a manufacturer in IBS projects is not only limited to product manufacturing but may also involve the entire process, including project planning, design, management, and implementation. This means that the range of knowledge and experience being covered is extensive compared to the comprehensive implementation needed for IBS. Management personnel must also be capable of managing and controlling offsite and onsite activities [64, 65]. Furthermore, in cooperation with an expert, consultant could provide better education, support, and onsite management. At present, consultants and designers are hesitant to apply IBS in their projects due to a wide range of issues, such as a lack of readiness in terms of knowledge, skills, technology, or experience [67]. Tam et al. [68] suggested educating designers and consultants early on with the necessary construction skills for using IBS.

11) Training and education

The role of the education curricula related to engineering and construction processes, which are employed in higher education centers and universities, must be improved by updating technology in the construction industry, especially IBS [69]. The degree to which higher learning program graduates are prepared to practice their profession can be enhanced by effective industry–university partnerships on such matters as the course content, design, curriculum, construction mission and objectives, resources, co-ops and internships, faculty qualifications and development, and others. IBS-related seminars held by universities, research centers, and professional bodies, in collaboration with CIDB or other related partners, have been actively initiated since 1998 [70]. Abdullah and Egbu [70] also observed that the knowledge-sharing initiative has been successfully implemented. Under the CITP (2016 –2020) plan, the allocated amount for training was increased tremendously from previous IBS plan. Comprehensive information and knowledge regarding factory setup and the technologies or machinery used are also important considerations related to cost [71]. Apart from these, the adequacy of project information must also be considered [72].

12) Corporate human resources management

An effective and efficient human resource (HR) development program is a crucial company asset, as it affects the company’s productivity and long-term viability [73]. In the construction industry, the project teams play an important role as the industry’s main core [74]. To implement IBS in every stage of construction, employee competency and skills should be evaluated for both soft and hard skills [40]. According to Sambrook [75] HR development must provide learning opportunities that target the achievement of business strategies and the enhancement of individual, team, and organizational performances. Accordingly, if the employees are sufficiently educated, developed, and nurtured, human resources can be considered the most important asset of an organization [76]. Table 6 shows the CSFs and components for the ‘people’ element.

Table 6: Critical success factors and the components for the people element

|  |  |  |  |
| --- | --- | --- | --- |
| **Element** | **Critical Success Factors** | **Components** | **Reference** |
| PEOPLE | 10) Skills | 31 Expert consultant  32 Skilled management personnel/ designer/ installer  33 Experienced manufacturer | [13, 14] |
| 11) Training and education | 34 Curriculum oriented at higher learning institutions  35 Promotion campaigns, awareness workshops  36 Providing information about the technical, research and training facilities  37 Direct industry–university partnership | [13, 14] |
| 12) Corporate human resources management | 38 Staff acquisition  39 Project knowledge  40 Team development (Perception) | [40, 75, 92, 93, 95] |

**3.1.5 Enabler**

13) Easy access guarantee

Cooperation among participants and enhanced individual motivations can be achieved by increasing their satisfaction levels [77]. Performance evaluation should include soft measurements that consider participants’ satisfaction as doing so could help improve the existing methods of IBS and evaluate contractors' satisfaction level, which is still neglected in the implementation stage in the IBS [41]. The client’s requirements also must also be considered in order to ensure that the requirements fit the constraints of IBS design and construction [71]. Leung et al. [78] asserted that participants’ satisfaction measurement could help improve project performance because it evaluates the key participants’ reaction to any conflict or problem.

The government has allocated significant funding to intensify IBS awareness and to encourage more efficient construction practices [6]. From the industry’s perspective, the government should play a more active role in implementing continuing awareness campaigns and training programs in accordance with the idea of continuous professional development (CPD) [40]. Such measures can help professionals adapt to spectrum changes, maximize available opportunities, and capitalize on the value of their professional qualification.

Colin and Davies [79] argued that, in the construction industry, measurement against targets, consistent innovations, enhanced teamwork, the selection and generation of novel ideas, innovation performance management, and the development of suitable teams are all important factors that influence the success of project-based innovation. The contextual factor relates to the constantly evolving nature of technology development in the construction industry and also emphasizes the need to identify and respond to the relevant changes that occur in terms of future growth opportunities and improvements in a more specific and knowledgeable way [80].

14) Technology enhancement

Benchmarking and technology transfer initiatives can be instrumental in achieving the goal of continuous learning by encouraging learning from a team’s own projects and from the industry's best practices in IBS [49]. According to Steinhardt et al. [81] in order to identify trends, one must have the ability to measure progress in shifting to IBS. It is unlikely that clear policy guidelines are without clearly defined assessment tools that target measurable and observable outcomes [1]. Thus, measures of the prevalence of IBS should be developed and regularly collated and shared among all stakeholders [81].

Although Malaysian construction companies use Information Technology (IT) to improve their respective management processes, they have yet to maximize IT assistance with work flexibility in their construction projects [82]. In the construction industry, using IT to facilitate timely communication and information sharing can help programs enhance their partnering efforts; however, such an undertaking requires efficiency and expertise in those areas [83].

15) Research and development

The various previous works in this field stated that the extent of research and development (R&D) in the field of IBS is limited in terms of the development of local design and a manufactured building system, new materials for IBS components, modern approaches and innovations, and advanced scientific information [84]. Many researchers have explored the potential of R&D in IBS especially in terms of improving productivity, efficiency, and quality of the labor, management, and materials and equipment. The government should pour more funds into research grants through the relevant agencies and offer a wide range of incentives, such as tax reductions, and increased R&D inputs in the construction industry, especially in the area of IBS [85]. Table 7 shows the CSFs and the components for the ‘enabler’ element.

Table 7: Critical success factors and the components for the enabler element

|  |  |  |  |
| --- | --- | --- | --- |
| **Element** | **Critical Success Factors** | **Components** | **Reference** |
| ENABLER | 13) Easy access guarantee | 41 Participants’ satisfaction measurement  42 Enhancing professionalism of the industry  43 Continuous improvement of industry practices and techniques | [13] |
| 14) Technology enhancement | 44 Benchmarking and technology transfer  45 Information technology (IT) infrastructure  46 Technology diffusion | [13, 14] |
| 15) Research and development | 47 Means for improving quality, productivity, and efficiency of the materials, equipment, labor, and management  48 Improving construction methods and developing technology for automation  49 Means for generating new ideas in management and technical fields  50 Generating new ideas for administering the construction industry | [84,85] |

**3.2 Results of Factor Importance via the Self-Administered Survey Questionnaire**

Table 8 presents the findings of the rankings shown in Fig 1. This table illustrates the findings obtained from the data analysis of the questionnaire survey. The results reveal that the identified 15 factors are the CSFs for IBS implementation and that none of the respondents proposed any new factors. According to Table 8, the two highest weighted average scores of factors are “Training and Education” (100%) and “Skills” (94.74%). This shows that respondents consider “Training and Education” crucial in meeting future skill/expert requirements. They also argued that “Skills” helped reduce the complexity of IBS application. In contrast, the lowest weighted average score was 63.16% for “Research and Development.” Hence, from the perspective of most government experts, “Research and Development” was not a critical factor for IBS implementation.

Table 8: Critical Success Factor Impact Survey Results

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| IMPACT: Contribution for CSFs of IBS implementation | | | | |
| |  | | --- | | Weight **→** | | 1 | 2 | 3 | Weighted Average |
| factors | No. of Responses (n=38) | | |
| CSF 1 | 2 | 6 | 30 | 78.95 |
| CSF 2 | 0 | 3 | 35 | 92.11 |
| CSF 3 | 1 | 4 | 33 | 86.84 |
| CSF 4 | 2 | 4 | 32 | 84.21 |
| CSF 5 | 0 | 3 | 35 | 92.11 |
| CSF 6 | 3 | 8 | 27 | 71.05 |
| CSF 7 | 0 | 9 | 29 | 76.32 |
| CSF 8 | 1 | 3 | 34 | 89.47 |
| CSF 9 | 2 | 2 | 34 | 89.47 |
| CSF 10 | 0 | 2 | 36 | 94.74 |
| CSF 11 | 0 | 0 | 38 | 100.00 |
| CSF 12 | 0 | 6 | 32 | 84.21 |
| CSF 13 | 3 | 4 | 31 | 81.58 |
| CSF 14 | 2 | 5 | 31 | 81.58 |
| CSF 15 | 4 | 10 | 24 | 63.16 |

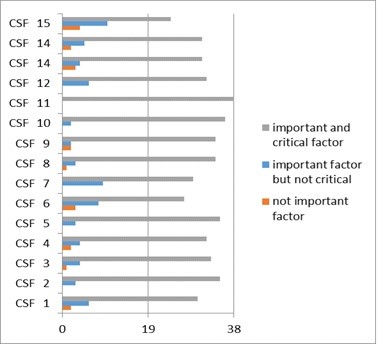


Fig 1. A percentage calculated for each question to determine the power of the answer

The researcher took advantage of the open-ended question to determine why respondents' chose “no” for some components of the CSFs, as well as to rearrange, merge and/or separate components. For example, the component *“Curriculum oriented at higher* *learning institutions”* fell under the component *“Direct industry-university partnership”* but when separated, both components fell under the “**Training and Education**” factor. On the other hand, the component “*Partnering and Strategic Alliances*” fell under the “**Supply Chain Management and Logistics**” factor, reflecting uncertainties among respondents becausethey confirmed that “Partnering” in Malaysia was currently not widespread. However, mostexperts agreed that “*Partnering*” was hugely significant in addressing the fragmented supplychain in the industry. This also applies to the component “*Information Technology (IT)**Infrastructure”* that was under the “**Technology Enhancement**” factor. Currently, ITusageis only limited to design in Malaysia.

***3.3 Results of Selected Success Factors According to the Value of Importance Index via the AHP Survey***

From the AHP results, the final acceptable sample included thirteen government official experts, ten academics, and twelve IBS contractors and manufacturers. Meanwhile, three responses were excluded from the analysis due to their high inconsistency ratios. Overall, the decision-maker’s pairwise comparison matrices proved to be of acceptable consistency level. An example in Fig 2 shows the pairwise comparison judgment under the five key elements of IBS implementation. This figure demonstrates the relative importance of each dimension against the goal of the framework criteria based on their priorities.



Table 9: AHP weights and dimension rankings.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Critical Success Factors | Government participants | | Academic participants | | Contractors and Manufactures | |
| Weights | Rank | Weights | Rank | Weights | Rank |
| Government Leadership | 0.198 | 1 | 0.175 | 1 | 0.027 | 8 |
| National Policy | 0.153 | 2 | 0.073 | 4 | 0.186 | 1 |
| Corporate Leadership | 0.105 | 4 | 0.049 | 7 | 0.085 | 4 |
| Business Strategy | 0.061 | 6 | 0.048 | 8 | 0.085 | 4 |
| Government Incentives | 0.118 | 3 | 0.126 | 2 | 0.129 | 2 |
| Private Investment | 0.093 | 5 | 0.126 | 2 | 0.042 | 7 |
| Design Management and Integration | 0.008 | 11 | 0.067 | 6 | 0.049 | 6 |
| Project Management | 0.008 | 11 | 0.034 | 10 | 0.49 | 6 |
| Supply Chain Management and Logistics | 0.008 | 11 | 0.034 | 10 | 0.49 | 6 |
| Skills | 0.059 | 7 | 0.070 | 5 | 0.14 | 11 |
| Training and Education | 0.053 | 8 | 0.012 | 12 | 0.22 | 9 |
| Corporate Human Resources Management | 0.051 | 9 | 0.020 | 11 | 0.18 | 10 |
| Easy Access Guarantee | 0.029 | 10 | 0.039 | 9 | 0.089 | 3 |
| Technology Enhancement | 0.029 | 10 | 0.039 | 9 | 0.089 | 3 |
| Research and development | 0.029 | 10 | 0.084 | 3 | 0.066 | 5 |

Related to the results presented in Fig 2, Table 9 indicates the AHP weights and dimension rankings. As can be observed, Government Leadership was the most important dimension in both the government’s and academic experts’ opinion, while National Policy was the most important dimension identified by the contractors and manufacturers. These experts believed that factors related to the organization are less important compared to those related to the government. This opinion shows that the transformation to IBS by conventional contractors is based primarily on the government's role. Fig 3 (c) illustrates that contractors and manufacturers ranked the Skills-related aspect the lowest. This is because generating Skills is based on “Education and Training” and “Corporate Human Resources Management.” However, even if it was ranked low in this figure, it does not mean that “Skills” is not an important factor for successful IBS implementation.

It can be concluded that different group of stakeholders in the construction industry have different perspectives of IBS implementation due to different constraints, needs, and the different motivations for using IBS. Finally, all CSFs were ranked according to the participants’ opinion. The ranking in Fig 3 is presented in the form of a bar chart. This graphical image depicts the priority-level of all CSFs by each stratum of participants.

AHP helps in quantifying the subjective judgments of stakeholders and allots corresponding numerical scores for these. AHP also allows a slight inconsistency in judgment because human opinions judgments and perspectives are not always consistent. Stakeholders can become more attentive to the impact ratios of all the factors in the different dimensions of IBS through the numerical results of CSFs, which can result in the smoother implementation of IBS. However, realizing different parties’ benefits simultaneously may not always be possible due to the goal incongruity in the fragmented construction process [86, 87].

The results show that the focus varied based on the three strata of IBS stakeholders from many administrative capitals in Malaysia: government official experts, academics, and IBS contractors and manufacturers. There exist incongruities among different stakeholders' strata in terms of constraints, needs, and motivations for implementing IBS. The problems affecting the major actors in the initial stages of IBS implementation may likely vary from those in the mature stages. However, having a better understanding of these problems allows the major actors to take proper measures to ensure IBS success. These findings may indicate additional useful information about the status of IBS implementation in other Malaysian States.



Fig 3. Priority-level of critical success factors: (a) Government official experts, (b) Academic experts, and (c) IBS contractor and manufacturer experts

**4.** **Discussion**

The findings in this study have several implications for both the government policy and IBS practitioners. It can increase awareness on the critical issues of IBS implementation. The CSFs identified in this work could also serve as a checklist that comprehensively covers possible success factors associated with the implementation of IBS, setting the stage for some additional guidance for IBS implementation. The CSFs that supports the implementation of IBS were based on five elements: strategy, sources of funding, process, people, and enabler. Currently, the government only focuses on leadership, whereas more strategic plans have been implemented to increase the numbers of IBS projects, despite some limitations that the government faces. The government needs to develop a standard form of contract procedures and to propose new standards and legal systems that are suitable and practical for IBS projects in Malaysia. Besides that, top management support needs to be obtained by contractors and their business model must be aligned with the companies’ vision and mission related to IBS. This will drive the companies forward in terms of investment and risk strategy.

The study found that some CSFs are more essential to the successful implementation of IBS than others. For example, “Skills” need to be developed for the general IBS process, yet the issue of “Training and Education” still needs to be addressed by the government. On the other hand, contractors who have not gained the ability to change and embark on IBS, require some initiatives to develop people and skills first, followed by the improvement of their strategy and process. In this case, corporate human resources management will enhance the overall organization's readiness in adopting IBS. Based on the results, government incentives and private investment are the important sources of funding that can strengthen IBS as a method to improve the image and performance of the construction industry. Besides that, it is discovered that easy access guarantee, technology enhancement, and research and development are important enablers and support tools that uphold the development of strategy, people and process related to IBS implementation.

The development of study models based on these relationships is a major finding of this work, which can be applied in the decision-making process. AHP is a procedure that is suitable for any kind of complex economic, sociopolitical, and technological decision-making [88]. In accordance with this approach, a specific problem is organized into a hierarchy, with the ultimate goal occupying the top spot (Level 1). Level 2 consists of the main criteria for achieving the goal, and the levels below it comprise elements with further details. In the current work, ranking the factors of IBS implementation was considered the goal, which formed the first level in the hierarchy. The second level consisted of the five key elements, whereas the third level consisted of various constructs based on the IBS CSFs to be compared and ranked. The fourth level consisted of components of each factor. Thus, a hierarchical model for the CSFs affecting IBS implementation was developed based on the factors identified from the first survey. These results are shown in Fig 4.



Fig 4. The hierarchy model of the critical success factors

**5.** **Conclusion**

IBS implementation is considered a high-risk strategy because the many stakeholders that participate in this process are very closely linked to one another. Thus, the chances are always high that something may go wrong at any given point. Therefore, the factors that determine the success of IBS implementation must be fully investigated. The obtained results showed that CSFs could serve as valuable references that help IBS stakeholders develop the effective uptake of industry strategies, which could lead to the creation of a favorable environment for implementing IBS in Malaysia. The relative importance of all these factors and their impacts on different IBS implementation dimensions were determined in this study via adopting the AHP method. The results clearly demonstrated the varying levels of CSFs importance regarding IBS implementation, which depends, more or less, on the position and economic interest of each stratum.

Directions for further research include reconciling the distinct perspectives of stakeholders, managing the industry’s transition to IBS, improving efficiency and quality measures, encouraging partnerships in IBS, and managing the interface between the emerging industry and IT advancements. Similar research on IBS implementation may also be conducted in other developing countries, and such studies could use the present study’s findings as the bases for their future research frameworks and for subsequent comparative.

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