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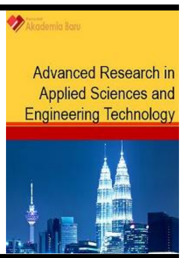

Industrialized Building System Evaluation Framework For Highway Construction In Malaysia

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ABSTRACT

Sustainability and Industrial Building System (IBS) closely linked each other due to the unique characteristics of IBS that help promote sustainability in construction. IBS is a construction technique in which components are manufactured in a controlled environment, transported, positioned and assembled into a structure with minimal additional site work. IBS promoted by CIDB which most of the implementation on the IBS only assessed and evaluated on the buildings. In the new highway project development, the Government through implementing agency, Malaysian Highway Authority (MHA) have set the requirement to the new highway project to achieve at least 20% of the IBS in the construction works and 70% of IBS's component application in the structural works. Reviews of literature revealed that Malaysia is still lacking of a mechanism in determine the IBS's component application in the structural works for highway. In view of this issue, this study is carried out to develop an IBS evaluation framework for structural works in highways construction. Also the existing level of IBS acceptance in the highway construction industry and IBS's component used in the highways have been investigated and evaluated. The findings lead to establishment of the evaluation frameworks on the IBS's components in the structural works for highway. The proposed of the evaluation framework enables the implementation on the IBS's components in the structural works for highway more structured and organized towards enhancing the overall performance of highway construction in Malaysia.

Keywords:
Industrial Building System (IBS); IBS score; highway; structural works

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1. Introduction

The Sustainable and IBS are intimately connected due to the IBS's unique characteristics that encourage sustainability in construction activities. According to Yunus *et al*., [1], due to the extremely specific features of IBS that will help encourage sustainability in construction, IBS can easily be recognized as one of the most appropriate ways to serve sustainable construction projects. IBS is considered an alternative option for maintaining sustainability in construction through better control of human resources and costs, shortening construction time and improving building quality, and enhancing occupational health and safety [2-3]. IBS construction structural components consist of precast component systems, fabricated steel structures, innovative mold systems, modular block systems and prefabricated timber structures [4]. Based on the Manual for IBS Content Scoring System

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CIS18:2018 (IBS Score) by CIDB, the IBS scoring evaluation only focuses on buildings. There is a lack of a standard evaluation method to measure the implementation of IBS in highway construction. Thus, this study is intended to propose an IBS evaluation framework for structural components of highway construction in Malaysia. The outcome of the research may contribute directly to the highway industry, especially to the related government agencies and concession companies.

2. Literature Review

2.1 Definition of IBS

According to Abedi *et al*., [5], since the first IBS project was started in Malaysia in 1966, there has been no absolute definition of the IBS that can fully describe the system of building construction. The terms used by the construction industry are loosely defined, often interchanged with other terms, and their exact interpretation is highly dependent on user experience and understanding, and they vary by country [6]. The term "Industrialized Building System" (IBS) refers to a construction technique in which components are produced in a controlled environment (on or off site), transported, positioned, and assembled into a structure with minimal additional activity [7-8]. The definition by Rahman *et al*., [9] limits IBS as a component produced off-site. [10] define IBS as a means of expanding construction by investing in human innovation and reconsideration of the best method for the delivery of construction work at the industrial level. Malaysia's Roadmap of IBS by CIDB highlights the most significant, feasible, and practical definition of IBS, which is defined as a construction technique in which components are fabricated in a controlled environment (either on or off site), transported, placed, and installed into a structure with minimal additional in situ work [11]. However, regardless of the term used, the principle of IBS implementation is the same: move some initiatives from the construction site to the production floor in a controlled environment.

2.2 Classification on IBS System in Malaysia

As with the various definitions of IBS, IBS also has various classifications that are differentiated based on materials, processes, and systems. IBS can be classified as a frame system (either pre-cast concrete or steel), a panel system, on-site fabrication, sub-assemblies and components, block work systems, and hybrid systems, the latter of which are volumetric and modular systems [6]. According to CIDB [8], IBS construction components include precast component systems, innovative mold systems, fabricated steel structures, prefabricated timber structures, and modular block systems. According to [12], for the construction of private projects, the most frequently used IBS system is the concrete pre-panel casting system, followed by other systems such as block and mold systems. The latest classification of IBS in the new circular by Malaysia Treasury effected on 15 January 2020, lists Innovative System as a new classification that covers the new innovations as well as Dry Wall System, Expanded Polystyrene System (EPS) Wall and other innovative products. IBS is based on the manufacturer’s ability to produce IBS components for the IBS system as well as the Precast Concrete System, Metal Framing System, Timber Framing System, Blockwork System, Re-usable Formwork System, and Innovative System [13].

2.3 Government Policies on IBS

The history of IBS in Malaysia began in the 1960s, when the government, through the Ministry of Housing and Local Government, sent a delegation of officials to explore numerous European countries. The visit was aimed at evaluating housing development programs in the countries involved implemented using precast concepts. However, the implementation of IBS in Malaysia only began in 1966, when the government decided to find a solution to address the issue of housing shortages, while at the same time reducing the construction period and producing high-quality, affordable housing. Following that, two IBS pilot projects utilizing the precast concept were launched; the Tuanku Abdul Rahman Flat in Kuala Lumpur and the Rifle Range Road Flat in Penang. The continuous encouragement from the government towards the adoption of the IBS concept comes with the dwindling objective of reducing dependence on foreign labor and reducing the outflow of Malaysian currency, which has caused losses to the country. In 1999, the use of IBS was stated by the government as the only solution to the problem of a scarcity of skilled local labor and an influx of unskilled immigrant workers.

The first IBS strategic plan was announced by the government, followed by two IBS Roadmaps, i.e. 2003-2010 and 2011-2015 [14]. Various measures have been taken by the government to increase the use of IBS in the construction industry [15]. And most recently, the government's commitment to the implementation of IBS has been translated into the Construction Industry Transformation Program 2016-2020. Rahim *et al.*, [16] found that the government intends to make the implementation of IBS mandatory for contractors by 2020. However, the move in that direction faces various issues and challenges. The CITP 2016-2020: Midterm Review for Enhancement reported that the level of use of IBS in private projects was 31.7% in 2016, compared to 14% in 2014 [17]. Recognizing the importance of IBS, the Manual for IBS Content Scoring System CIS18:2018 (IBS Score) has been developed as a reference to measure IBS performance on all residential, commercial, industrial, institutional buildings and other projects as categorized [18]. Most recently, in tabling Budget 2021, the government has proposed to extend the IBS tax incentives for a period of five years [19].

2.4 Highway Development in Malaysia

Highway infrastructure is not only an essential component of a country's economic development and ensures the continued growth of trade and industry; in reality, this infrastructure is critical to a country's continued growth and prosperity. The planning and development of a highway is intended to encourage people’s movement and to serve as an effective tool for improving the country's economic sector [20]. Major highways, especially interurban highways that link the capitals of states, serve as the backbone of people and goods transportation. According to [21], the government provides opportunities for the private sector to be involved in the construction of toll road infrastructure in Malaysia under a public-private partnership. As of December 2018, data from the MHA reports there are around 1,776 km of highways with 30 total toll highways in operation, while 6 new highways are under construction with a length of 362.30 km. A list of 6 new highways under construction with their respective lengths and costs is listed in Table 1. Responding to the government’s call to encourage the use of IBS, the MHA has taken the initiative to include criteria related to the percentage of use of IBS in the new highway concession agreement. New highways in privatization through signed Concession Agreements have laid down conditions for at least 20% of IBS implementation in construction works and 70% application of IBS components in structural works.

Table 1
Six (6) new highways under construction.

No	Highways	Length (KM)	Cost (RM)
1	West Coasts Expressway (WCE)	233.0	5.044 billion
2	Sungai Besi – Ulu Kelang Expressway (SUKE)	24.40	5.275 billion
3	Damansara - Shah Alam Expressway (DASH	20.10	4.178 billion
4	Putrajaya – KLIA Expressway (MEX2	16.80	1.250 billion
5	Setiawangsa – Pantai Expressway (SPE)	32.00	3.700 billion
6	East Klang Valley Expressway (EKVE).	36.00	1.500 billion

2.5 Manual for IBS Content Scoring System CIS 18:2018 (IBS Score)

Recognizing the importance of IBS in the construction industry in Malaysia, the Manual for IBS Content Scoring System CIS18:2018 (IBS Score) has been developed as a reference to measure IBS performance on all residential, commercial, industrial, institutional buildings and other projects as categorized [18]. The IBS Score is a systematic and structured assessment system to measure the use of IBS consistently. First introduced in 2005, the IBS score is used to measure the implementation of IBS in any building project. The IBS Score contains formulas, tables, procedures, and examples for calculating IBS Scores for all residential, industrial, commercial, institutional, and other building projects [18]. The IBS score emphasizes 5 attributes, namely use of IBS components, use of standard components based on the Guide to Modular Coordination in Buildings (MS 1064), structural layout repetition, and use of other productivity enhancement solutions such as volumetric modular units, Building Information Modelling (BIM) and modular grid lines [18]. Higher IBS scores are a reflection of 9 important values; higher productivity, reduced on-site manpower, lower wastage, fewer site materials, cleaner environment, better quality, tidier and safer construction sites, faster project completion, and lower total construction costs. The IBS Factor of the structural and wall elements utilized was used to award points as illustrated in **Figure 1**.

The formula IBS SCORE

$$= 50\Sigma\left[\frac{Q_S}{Q_{ST}} F_S\right] + 20\Sigma\left[\frac{Q_W}{Q_{WT}} F_W\right] + S$$

SCORE FOR STRUCTURAL SYSTEMS

+

SCORE FOR WALL SYSTEMS

+

SCORE FOR OTHER SIMPLIFIED CONSTRUCTION SOLUTIONS

Where:

Σ - Sum of
Q_S - Construction area of a structural system
Q_{ST} - Total construction area of building; including roof
F_S - IBS Factor for structural system from Table 2 and Table 3
Q_W - Length of a wall system (external and internal wall)
Q_{WT} - Total wall length (external and internal wall)
F_W - IBS Factor for wall system from Table 4
S - IBS Score for other simplified construction solutions from Table 5

Fig. 1. The Method of Calculating IBS Score using Manual for IBS Content Scoring System. Source: [18]

However, the manual by CIDB only focuses on buildings as mentioned. Initiatives focusing on IBS evaluation on the highway/road are still inadequate. According to Alfan *et al*., [22], currently there is no evaluation guide to measure the IBS performance on highways/roads projects in Malaysia. Thus, the need to develop a standard evaluation guide to measure the implementation of IBS components for structural work in highway construction has evolved to be a significant challenge.

2.6 IBS implementation in the Setiawangsa Pantai Expressway (SPE)

The calculation of the IBS Score for Setiawangsa Pantai Expressway (SPE) is carried out based on the typical bridge structure sections used for the project [23] as shown in Figure 2. This typical cross-section of the mainline structure consists of the elements; column, precast crosshead, crosshead infill, pedestal, beam, diaphragm, deck slab, parapet wall, and new jersey barrier.

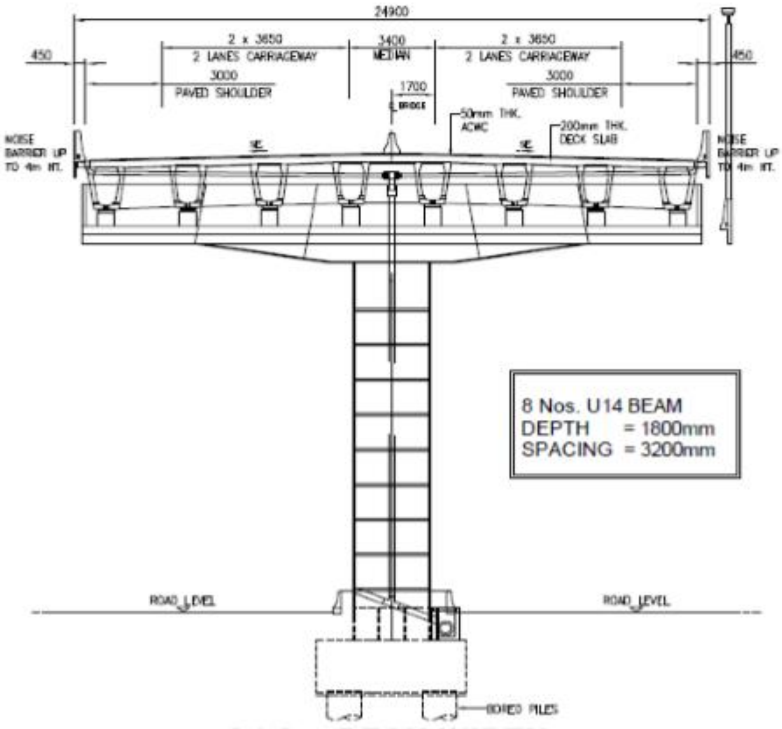

Fig. 2. Typical cross-section of the bridge structure. Source: [23]

As there is no standard measurement method for the IBS score for infrastructure projects up to date, the IBS score approach calculation in the Manual for IBS Content Scoring System is adopted by the SPE to evaluate the IBS performance of the Setiawangsa Pantai Expressway Project. The principles of IBS Score have been considered and adopted where possible in the calculation, especially on the IBS attribute and IBS Factor, as well as Precast (1.0), Cast in –situ with permanent formwork (0.8), Cast in –situ with reusable formwork (0.6) and Cast in –situ with timber formwork (0.0). The following principles are taken into consideration: the use of prefabricated and precast concrete components, off-site production of components, the use of standardized components, and repeatability. However, the Modular Coordination concept is not considered in the calculation because it is applicable for building construction only. For the purpose of the calculation, the other components of this project, such as ground improvements, foundation works, pavement, M&E services, road furniture, and signage, are not considered. The IBS Score is then calculated for each of the structural elements and the score is subsequently aggregated evenly based on its individual weightage of volume. The following formula is applied:

$$IBS\ Score = \frac{(F_{s1}\,V_{E1} + F_{s2}\,V_{E2} + \cdots + F_{sn}\,V_{En})}{V_{all}}$$

Where:

Fs is the IBS Factor
VE is the volume of structural element
$Vall$ is the overall structure volume
n is the total number of structural elements

Based on the formula and IBS Factors, resulted IBS score for SPE is 82%.

3. Methodology

The methodology adopted for this research includes both a quantitative and a qualitative approach, including a questionnaire survey, document analysis, and Focus Group Interview for validation. The quantitative method involved close-ended questions in a questionnaire survey, while the qualitative method involved open-ended questions in a questionnaire survey and focus group discussions. A total of 25 questionnaires were distributed to the MHA, the government agency that is supervising the highway construction, the concession company of a highway project and the consulting engineer that prepares the planning, design and supervises the construction on behalf of the concession company. The questionnaire consisted of five parts by combining both types of questions, closed and open-ended questions. A detailed summary of the questionnaire by part is shown in Table 2.

Table 2
Summary of the Questionnaire by Parts

Part	Question Type	Questionnaire Information
A	Fully closed ended	Respondent Profile
B	Fully closed ended	Level of knowledge and awareness in IBS concept.
C	Open and closed ended	Implementation of IBS concept in highway construction.
D	Open and closed ended	Barriers and impact in implementation of IBS in highway construction.
E	Open and closed ended	Perception on the implementation of IBS measurement in the construction of highways in Malaysia.

A common method used in the study to access measurement reliability is using Croanbach's Alpha-Coefficient analysis with a value of 0.60. In general, it can be assumed that all variables have an acceptable range of consistency measurements. In terms of data analysis, quantitative data was analyzed using the SPSS application, while qualitative data was used using a manual thematic process. The information and data collected through the questionnaire will be processed using the frequency, mean, Average Index Method (AIM) and Relative Important Index (RII). From the analysis, critical elements were derived before the development of the evaluation framework. The validation of the proposed IBS evaluation framework by the relevant party to ensure that the IBS evaluation framework is relevant to the highway industry.

4. Results

4.1 IBS in the Highways Construction in Malaysia

This section discusses the results obtained from the analysis of the data collected through questionnaires and focus group interviews. The level of knowledge, the most IBS elements used in highway construction and the proposed IBS evaluation framework for highway construction are discussed in the next sub section.

4.1.1 Respondent's Frequency and Education Level

The majority of the respondents involved are consultant engineers' firms doing highway engineering, that is 10 (40%) people. Followed by a government agency that is 8 (32%). While the rest, 7 (28%) of the people involved are from the concession company, as shown in Table 3. The majority of the respondents have a Bachelor's education level of 16 (64%) people. This was followed by a respondent with a Master's qualification of 9 (36%). Since this topic involves the technical aspects of IBS, it is better for the questionnaire to be filled in at least by senior engineers, project executives, and project managers, as they are the people directly involved in making any decisions regarding the development of a highway.

Table 3
Respondent's Organization

Organization	Frequency	Percentage
Government Agency	8	32%
Concession Company	7	28%
Consultant Engineer Firm	10	40%
Total	25	100%

4.1.2 Respondent's Experiences

The majority of the respondents have more than 10 years' experience in the highway sector, that is 16 (64%). Followed by experience of between 7 to 10 years, that is 5 (20%) people. While the rest, only 4 (16%) people have experience of between 4 and 6 years in the highway sector. Given that most of the respondents have more than 7 years of work experience, this means that the questionnaires provided were filled by senior professionals with vast experience.

The majority of the respondents have between 4 to 6 years' experience in IBS involving the highway sector, that is 10 (40%) people. This was followed by respondents having experience of more than 10 years and 7 to 10 years, that is 9 (36%) and 4 (16%) people respectively. While the rest, only 2 (8%) people have experience of between 1 to 3 years in IBS involving the highway sector. This shows that the respondents were qualified to be involved in the survey.

4.2 The level of IBS Acceptance in the Highway Construction Industry

The level of knowledge of IBS among the majority of respondents (84%) is moderate with a mean value of 3.16. Table 4 shows the respondent's level of knowledge of the IBS. The relatively high percentage of respondents who know about IBS is because most of the respondents are working engineers and experienced in construction. Due to this, it is something that is common for them to follow the latest technology developments to be more competitive in the job market.

Table 4
Respondent's level of knowledge of IBS.

Factor	**Frequency of Respondent**				**Mean**	**Std. Deviation**
	Nothing	**Low**	**Moderate**	**High / Expert**		
Score	**1**	**2**	**3**	**4**		
Level of knowledge in IBS	-	-	21	4	3.16	0.374

Assessing further regarding respondents' understanding of the elements and components of IBS, most respondents did not limit IBS only to use for buildings. Various other elements and components involved in highway construction are also referred to as IBS. However, there is some misunderstanding of the basic concept of IBS among the respondents. For example, some respondents did not classify steel mold in building construction as an IBS element. Thus, there are some areas for improvement in the highway industry's understanding of the IBS's concept and elements.

4.3 IBS Element used in the Highways Construction in Malaysia

The use of IBS components mainly involves the construction of highways in urban areas involving tall structures on existing roads. This is becoming increasingly important as existing congestion as well as construction using IBS is faster and can reduce the duration of disruption and safety risks to traffic coupled with the effects of Covid-19 [24]. Currently, there are six (6) highways under construction. They are the West Coasts Expressway (WCE), Sungai Besi – Ulu Kelang Expressway (SUKE), Damansara-Shah Alam Expressway (DASH), Putrajaya – KLIA Expressway (MEX2), Setiawangsa – Pantai Expressway (SPE) and East Klang Valley Expressway (EKVE) with the cost amounted to RM20.497 billion. The mean score and ranking of IBS elements/components involved in highway construction involving respondents' organizations is shown in Table 5. The precast element in bridge/road construction has been the most IBS element used in the construction of highways in Malaysia, followed by the precast element in major drainage/road construction (i.e. culverts, tunnel lining) and steel structure in road furniture (i.e. signage). The following rank is governed by the steel component element in building construction (i.e. roof truss) and the steel component element in bridge structure/road construction (i.e. steel girder/steel beam).

Further evaluation was made of the IBS elements/components involved in road construction involving the respondent's organization according to the highway category to see the impact of the highway category on the use of IBS elements/components. Based on the analysis, the use of elements and components differs according to the category of highway. For urban highways, precast elements in bridge/road construction recorded the highest usage, followed by steel structures in road furniture (i.e. signage), steel moulds used in bridge/road construction and IBS/precast elements in building construction. For intra-urban highways, precast elements in the major drainage/road construction (i.e. culverts, tunnel lining) recorded the highest usage. This is followed by the same rank by precast elements in the bridge/road construction, IBS/Precast elements in the building construction, steel component elements in the bridge structure/road construction and brickworks/precast drains in the drainage construction. For inter-urban highways, the frequency of use also varies, where steel structures in road furniture (i.e. signage) recorded the highest usage. These results indicate that the highway category has a significant impact on the use of IBS elements and components in highway construction.

Table 5
Mean Score and Ranking of IBS elements/components involved in highway construction.

Factor	Frequency of Respondent					Mean	Rank
	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree		
Score	**1**	**2**	**3**	**4**	**5**		
IBS/Precast element in the building	-	-	5	16	4	3.96	3
Steel mold in the building	-	6	7	10	2	3.32	9
Precast element in the bridge/road	-	-	2	17	6	4.16	1
Steel mold used in the bridge/road	-	3	3	14	5	3.84	5
Steel component element in the building (i.e. roof truss)	-	1	8	14	2	3.68	7
Steel component element in the bridge structure/road (i.e. steel girder/ steel beam)	1	0	3	16	5	3.96	3
Precast element in the major drainage/road (i.e. culvert, tunnel lining)	-	1	3	16	5	4.00	2
Brickworks/precast drain in the drainage.	-	1	5	14	5	3.92	4
Steel structure in road furniture (i.e. signage)	-	2	4	11	8	4.00	2
Innovation in the building (i.e. EPS)	2	1	9	11	2	3.40	8
Innovation in the road (i.e. EPS)	1	1	6	13	4	3.72	6

4.4 The Parties that Make the Decision Regarding the use of IBS.

In determining the decision regarding the use of IBS elements or components in highway projects, the majority of respondents (34%) agreed that the clients were the parties who decided to use IBS in highway construction involving their organization. Figure 3 shows the parties that are making decisions regarding the use of IBS elements or components in highway projects. It is noted that some respondents chose more than one party in this question of the survey.

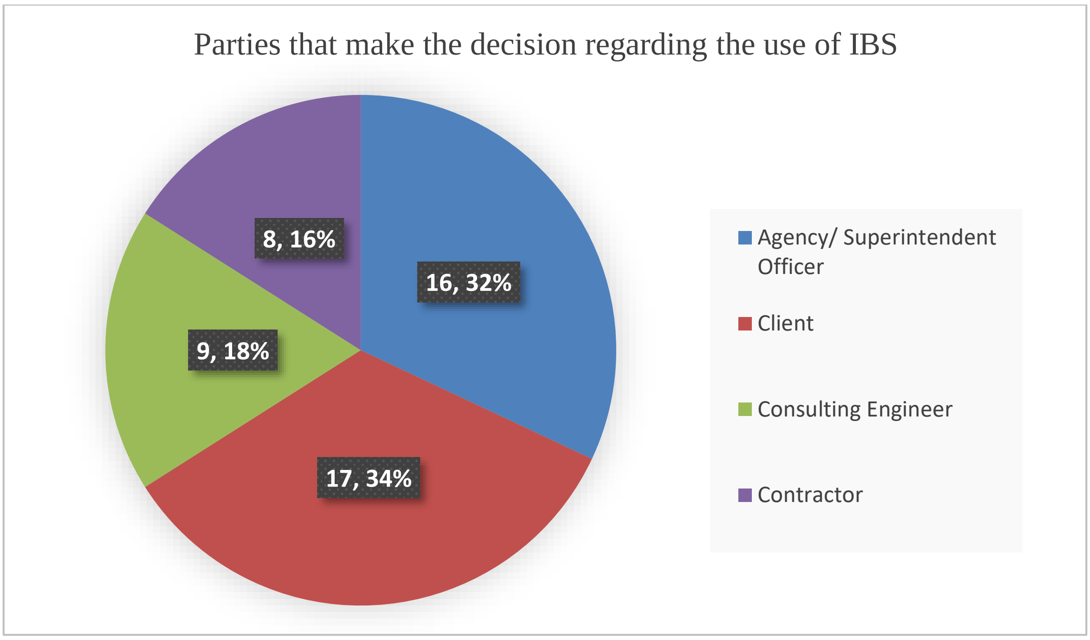

Fig. 3. The parties that make the decision regarding the use of IBS.

4.5 Decision on the Use of IBS

In the highway construction cycle, which covers the planning, design, construction, and operation stages, the majority of respondents agreed that decisions on the use of IBS elements and components should be made at the highway planning stage followed by the design stages, which are 57.9% and 34.2 % respectively, as shown in Figure 4. It is noted that some respondents chose more than one stage in this question of the survey.

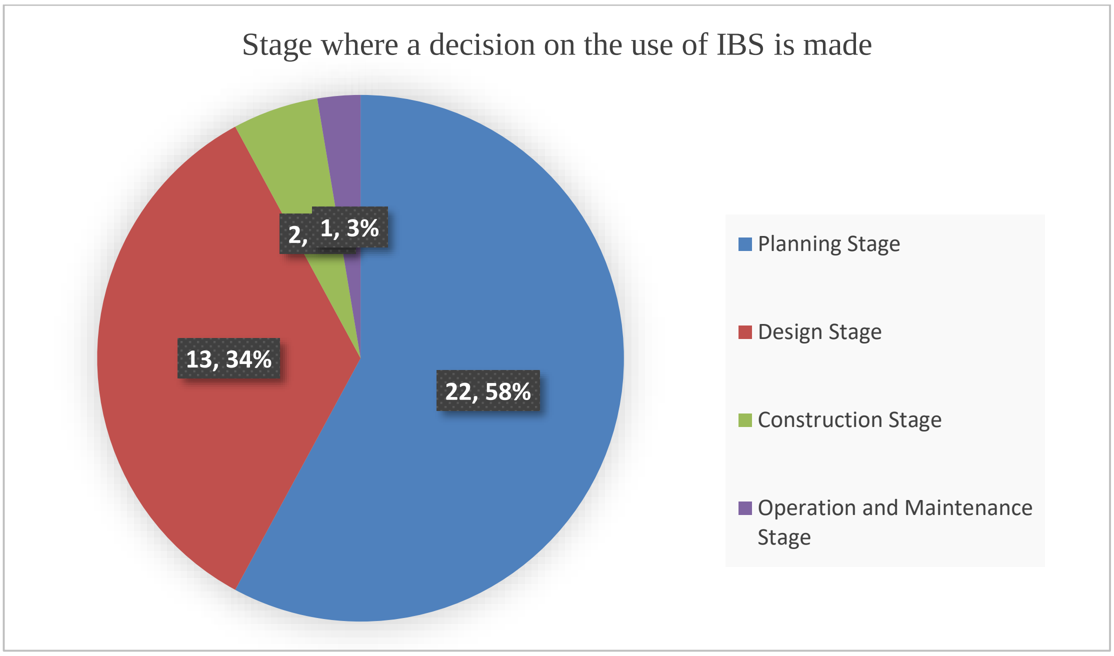

Fig. 4. Stage where a decision on the use of IBS is made.

4.6 Barrier to the Use of IBS in Highway Construction in Malaysia

In determining the relative importance of various barriers, the Relative Importance Index (RII) was used. High implementation costs are the most common barrier to the use of IBS in highway construction in Malaysia, with the highest RII, 0.712. This is followed by lack of awareness, lack of enforcement, lack of incentive from government/client and lack of client interest in the use of IBS with RII, 0.704, 0.696, 0.680 and 0.640 respectively as shown in Table 6.

Table 6
Barrier of the use of IBS in highway construction.

Factor	Frequency of Respondent					RII	Rank
	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree		
Score	**1**	**2**	**3**	**4**	**5**		
High implementation cost	-	5	3	15	2	0.712	1
Lack of client interest in the use of IBS elements/components	-	7	7	10	1	0.640	5
Difficulty in obtaining supply of IBS components/elements in the country	-	7	8	9	1	0.632	6
Difficult to get information of IBS in country	-	14	4	5	2	0.560	11
Difficult in obtaining local expertise in IBS	-	11	8	5	1	0.568	10
Difficulty in transportation of component to site	1	8	5	10	1	0.616	7
Lack of awareness	-	5	7	8	5	0.704	2
Difficulty in obtaining machinery and technology for installation on construction sites	-	9	5	11	0	0.616	8
Constrains on work area	-	11	4	8	2	0.608	9
Lack of enforcement	-	3	9	11	2	0.696	3
Lack of incentive from Government/client	1	2	11	8	3	0.680	4
Increase in operation and maintenance cost	1	14	5	5	-	0.512	12

4.7 IBS Evaluation Framework for in Highways Construction in Malaysia.

The impacts that will arise as a result of the implementation of the IBS on the construction of highways are also analysed using RII. The majority of respondents agreed that the use of IBS in highway construction had the highest impact on reducing construction duration, followed by reducing environmental pollution levels. Table 7 shows the RII and overall ranking of the impacts.

Table 7
Impact that will arise as a result of the implementation of the concept/ element or component of IBS in the construction of highways

Factor	Frequency of Respondent					RII	Rank
	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree		
Score	**1**	**2**	**3**	**4**	**5**		
Reducing the construction period	-	1	0	17	7	0.840	1
Increasing project cost	-	5	9	11	-	0.648	5
Increase in toll rate	1	6	12	6	-	0.584	6
Increase in operation and maintenance cost of highway	-	12	8	5	-	0.544	7
Reducing traffic disruption	-	4	3	17	1	0.720	4
Reducing pollution level	-	1	2	16	6	0.816	2
Improve in environment quality	-	1	3	16	5	0.800	3

4.8 Factors/Criterion for Evaluation of the IBS in Highway Construction

Assessing the finding shows that cost has become the highest factor/criterion to be used in evaluating the performance of the IBS in highway construction. This was closely followed by Special Factorization and Quantity, at 72% and 68% respectively. Volume was recorded as the lowest choice factor at 40%, as shown in Figure 5. Based on the respondents' opinion on the open-ended questionnaire on related issues, in addition to the criteria stated in the closed-ended questionnaire, 'time' is an additional criterion suggested by 3 respondents. In terms of the critical elements that were asked in an open-ended questionnaire, 15 of 25 respondents reiterating the statement that 'cost' is the most critical element for an evaluation framework, followed by 'quantity' by 10 of 25. It is noted that some respondents chose more than one factor in this question of the survey.

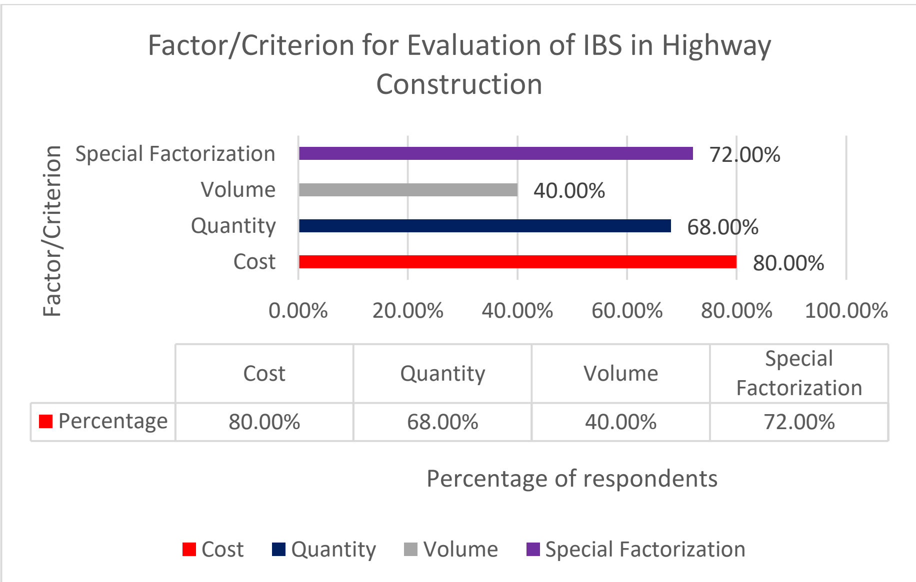

Fig. 5. Percentage of Factors/Criterion for Evaluation of the IBS in Highway Construction.

4.9 IBS Evaluation Framework for in Highways Construction in Malaysia.

In the development of the IBS evaluation framework for highways under construction in Malaysia, its elements and contents have been identified and shaped. Through an understanding of the principles of IBS as well as the highway components that meet the characteristics of IBS, an IBS evaluation framework can be prepared. The combination of critical elements that have been identified provides an overview of the IBS evaluation framework model. The IBS evaluation framework was subsequently validated by the Malaysian Highway Authority through a validation process. Based on the validated framework, the IBS assessment framework for highways under construction covers the roles and responsibilities of various parties, ranging from government policy to implementing agencies, and further focuses on the elements and criteria of IBS assessment.

The framework consists of two stages. The first stage focuses on the role and mandate of the government as a pillar to implement the IBS assessment framework for highway construction in Malaysia. At this stage, the IBS requirements in the Highway Concession Agreement need some improvement to provide a clear picture of the need to adopt IBS to support the sustainability of the country's construction sector related to highway construction. At the same time, actions leading to the production of specific guidelines for IBS evaluation which involve highways under construction are also determined.

Based on the validated framework, the IBS assessment framework for highways under construction covers the roles and responsibilities of various parties ranging from government policy to implementing agencies and further focuses on the elements and criteria of IBS assessment. The Industrialized Building System Evaluation Framework for Highway Construction in Malaysia as shown in Figure 6.

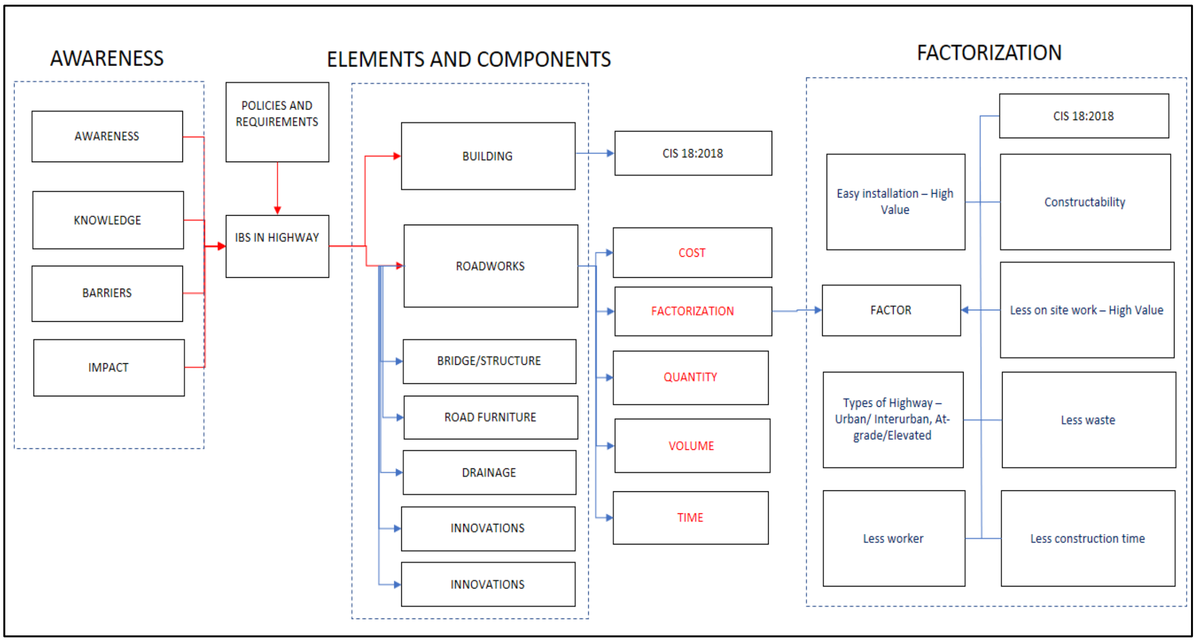

Fig. 6. Industrialized Building System Evaluation Framework for Highway Construction in Malaysia

The IBS evaluation framework developed brings hope that it can be used in the development of sustainability involving the construction of highways in Malaysia. At the same time, the findings of the study regarding the barriers to the implementation of IBS that have been identified can be addressed in stages. Furthermore, this IBS evaluation framework can make a significant contribution as guidance to the development of IBS evaluation guidelines to be implemented by highway authorities in the future. It is hoped that this study will trigger efforts to conduct academic research on the use of IBS in the highway industry in the interest of the country.

5. Conclusions

This paper provides a brief introduction to the Industrialized Building System in Malaysia, followed by awareness and level of knowledge of IBS among the highway construction industry, IBS's components used in structural work in highway construction, barriers and impacts on the use of IBS, and factors/criterion to be used in evaluating the performance of the IBS in highway construction. Lastly, we have proposed an Industrialized Building System Evaluation Framework for Highway Construction in Malaysia. The level of knowledge of IBS among the people in the highway industry in Malaysia is moderate. The precast element in bridge/road construction has been the most IBS element used in the construction of highways in Malaysia, followed by the precast element in major drainage/road construction (i.e. culverts, tunnel lining) and steel structure in road furniture (i.e. signage). The findings of this study have the potential to be improved in the future through the following recommendations; for a better view of IBS, data collection through questionnaires should be extended to contractors and manufacturers, and other experts involved in the construction of highways, whether privatized or conventionally built. This expansion will be able to reflect the views of all parties involved in the highway construction industry in the country. The scope of this study can be improved with involvement that covers the entire life cycle of the project, whether the project is at the planning, design, or operational stages; and with an appropriate period of the implementation. Testing of this framework will be able to increase the relevance of the evaluation framework in the industry.

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