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The Absence of Smart Technology as One of The Key Factors of Transportation in Modular Construction: A Case Study in Malaysia

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ABSTRACT

Modular construction is a new method introduced to meet the modernisation agenda in the Malaysian construction industry. It provides various benefits to the construction industry, such as speedier construction, quality improvement, waste minimisation, and sustainability. Despite all the promoted benefits, it still needs to be widely implemented in the Malaysian construction industry due to a need for knowledge and readiness towards modular construction. The construction industry player needed to be more sceptical about applying this new construction method in their project. Further, the application's success in modular construction is highly associated with good transportation management; however, achieving good transportation management may be challenging because it depends on the manufacturer's understanding of designing and allocating the module. Understanding modular construction is essential to select the suitable modular type because it affects the whole process and transportation. This research aims to investigate the essential factors to be considered in the transportation of modular construction. The data collected is by interviewing modular construction companies in Malaysia. The study reveals that transportation should be taken as early as the design stage. Under the transportation process, among the factors that need to be considered are the size of the module, types of trailers, road or highway regulations, suitable route, time for transport and technologies. It is concluded in this paper that contractors managing modular transportation still have to take smart technology factors into account. Therefore, the findings of this study are hoped to be a reference for modular construction companies and other construction industry players in terms of modular construction transportation considerations.

1. Introduction

Prefabrication and modular construction are commonly considered in line with technological and material innovations to achieve modernisation in the construction industry. The process of sending integrated, ready-cut building components have been part of the United States (US) construction process since the 17th century. In the 1850s, the balloon frame system of construction revolutionised

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the speed of new housing. In the early 20th century, people could order a Sears, Roebuck & Company house from a catalogue and wait for a house assembly kit. In World War 2, prefabrication allowed soldiers to be housed in portable shelters and then spawned as comfortable houses in US suburbs inhabited by returning soldiers from the war [1]. Prefabrication is a general term for a prefabricated building or building component manufactured in a factory before its final assembly at the construction site.

In contrast, modular construction refers to a component built or organised in self-contained units, which generally look like building blocks. Construction Industry Development Board (CIDB) has classified modular construction as part of the Industrialised Building System (IBS). Prefabrication and modular construction have made recent strides for architects, contractors, and developers to find new applications for the technology beyond the single-family house. Now, even towers can be constructed from prefabricated components and modular units. However, the widespread adoption of prefabrication and modular construction faces several challenges. For instance, the construction project personnel must be competent to implement this new construction process. The lack of integrating prefabrication and modular construction application into the design process has resulted in its implementation in many projects. The industry players remain using conventional methods due to the lack of reward given to them and the reluctance to take the risk of trying something new. Further, modularity associated with trailer houses has led to public perception as unattractive, unstable, and difficult to coordinate the delivery systems. Despite all the challenges, modular construction is a less costly, faster, and more straightforward means of construction with broad applications across many building needs [1].

The adoption of modular construction in Malaysia is less widely used than in other countries. A study by Musa *et al.,* [2] stated that the modular construction project in Malaysia is located at Universiti Malaysia Pahang (UMP) (Figure 1), which the Portland Group of Companies has developed. Malaysia can develop modular construction by referring to other countries like the UK, Japan, Korea and Europe, but it may require some adjustments to comply with Malaysia's environment.

Fig. 1. 72 units of lecturer rooms in UMP, Gambang

2. Problem Statement

The success of modular construction implementation depends on the transportation and logistics of these large-sized components. Impact during transportation sometimes requires special care and needs to be considered during the design and construction. The weight limits and dimensions of roads, bridges and tunnels are essential for transportation and logistics. There is also the difficulty in transporting large-sized module components from the factory to the project site due to travel restrictions and the requirements for expensive escorts, thus making it the most significant barrier

[3,4]. Implementing good transportation management may be complex because it depends on the manufacturer's understanding of allocating the modules. As a manufacturer that produces the modules, they should be concerned about transportation problems [5]. Usually, the module sent to the site is complete with coordination and fabrication of mechanical, electrical and plumbing (MER). Although the module is complete with these services, it becomes a challenge to deliver the module from factory to site. In addition, the tax, distance, delivery and type of vehicle or equipment of transportation are a part of selecting the construction method. According to Said *et al.,* [6], the module form causes a large vehicle to be required for the delivery process of modular units to the site. All transportation has a limit for the module's height, width and length. If it exceeds the standard size set by the local authority, it requires additional permits and costs that mainly want to be avoided by the owner. Oversized vehicles must also consider traffic if they use public roads or highways. In Malaysia, any issues related to the road may refer to the Jabatan Pengangkutan Jalanraya (JPJ), PLUS or Malaysia Highway Authority.

3. Definition of Modular Construction

Modules can be described by their shape, which is square or rectangular. It is also known as a box or container nowadays. The definition of modular construction may vary for every country. Based on Table 1, to summarise the definitions, the modules are made in complete 3D boxlike, unlike in panels or component levels of prefabrication; in modular construction, most of the interior and exterior finishes are put into place in the factory, which makes them are almost complete when they leave the factory thus make it easy assemble.

Table 1
The definitions of modular construction

Authors	Definitions
O'Connor *et al.,* [7]	• Modularisation: the preconstruction of the complete system away from the job site that is then transported to the site. • Module: a significant section of the plant resulting from a series of remote assembly operations may include portions of many systems, usually the facility's largest transportable unit or component.
Said *et al.,* [6]	• Modular construction depends on moving a portion of project work to offsite, is manufactured in modules, transported to the site and erected in the designed configuration. • Made of sizable components that are volumetric in shape, constitute finished parts of the building and include finishing different construction trades (structural, electrical, plumbing, finishes). • Manufactured offsite and transported to the construction site after the foundation was already completed.
Musa *et al.,* [8]	• The construction method that produces a building consists of modular units or modules that are mass-produce offsite in a manufacturing facility. • The construction process produces a building component or modules with the same decision and standard in a manufacturing facility, then transported and installed to become a building.
Azhar *et al.,* [9]	• The manufacturing process is generally conducted at a specialised facility where various materials are joined to form a part of the final installation. • Modules may contain prefabricated components or assemblies and are frequently constructed away from the job site.
Musa *et al.,* [2]	• Due to their benefits, offsite prefabrication and modern construction methods are used in developed countries such as the US, the UK, Japan, European countries, and Australia.

Lawson *et al.,* [10]	• Modular construction comprises prefabrication room-sized volumetric units usually fully fitted out in manufacture and installed on-site as load-bearing "building blocks".
Lu and Korman [11]	• It consists of one or more structure units prefabricated in a manufacturing plant away from the job site and complete with trim work, electrical, mechanical and plumbing installed. • Factory-built building units completely assembled or fabricated • Transported and assembled on-site in a manufacturing plant away from the job site.

4. Application of Modular System

Modular construction has benefits in many aspects, making it an excellent choice to be adopted by the industry. The modular unit that comes to the site in an almost complete state may speed up the construction duration. It is suitable for various buildings, including low and high-rise buildings. The type of building depends on the demand in a particular area. Due to social pressures, there is widespread demand for modular low-rise buildings or a single housing. For example, people who come to cities to work or study will increase the population in that area and the demand for housing. For countries facing land scarcity issues and requiring rapid human settlement, modular units in high-rise building construction will solve the problem. According to Lawson *et al.,* [10], modular construction can be implemented for students' residents, medium-rise residential buildings, mixed residential and commercial buildings, private and social housing, 4 to 12 storeys of hotels and 3 to 4 storeys of military accommodations, up to 3 storeys of health sector buildings, up to 3 storeys of educational sector buildings, bathroom pods, secure accommodations, plants rooms and other serviced units, rooftop extensions and new balconies and lift.

5. Key Factors in the Transportation of Modules

One of the benefits of modular construction adoption is that it provides an opportunity for the transportation business. The module's design required creativity to suit the available transport. Literature shows several key factors related to transportation to be considered in the modular application construction, as listed below.

5.1 The Size Limitation of Modules

The size of modules affects all the transportation processes, especially in cost. According to Azhar *et al.,* [9], there are three categories for transportation dimension, legal dimension (14ft height, 8ft width, 48ft length), oversized (14ft height, 14ft width, 105ft length) and superload. As the standard module is a legal dimension, it does not need any transport permit. In contrast, the oversized and superload modules need a routine permit. It also requires a police escort and must travel overnight to avoid traffic during the daytime. Table 2 showed size limitation of modules by several researchers.

Table 2
Size limitation of modules from three different authors

Author	Width (ft)	Height (ft)	Length (ft)
Velamati [12]	16	13	60-65
Said *et al.,* [6]	8-14	11-13	70
Lawson *et al.,* [10]	11-14	-	20-30

5.2 Trailer and Capacity of the Trailer
5.2.1 Standard flatbed

This trailer is commonly used in transporting components as it is the cheapest rental cost (Figure 2). It has limitations in width and height, so it is suitable for small modules. It allows a longer length of the route due to the lightweight load. The company should concern with the equivalent size of modules to the limitation of the standard flatbed trailer to allow smooth transportation and avoid overload.

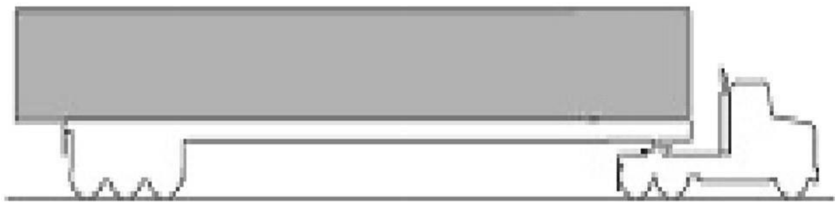

Fig. 2. Standard flatbed trailer [13]

5.2.2 Single-drop deck

The single-drop deck is in the average trailer rental cost and is rarely used (Figure 3). It is an alternative if the standard flatbed or the double-drop deck cannot be used due to the limited number of the trailer from the supplier or the modules came large over the trailer limitation size or capacity.

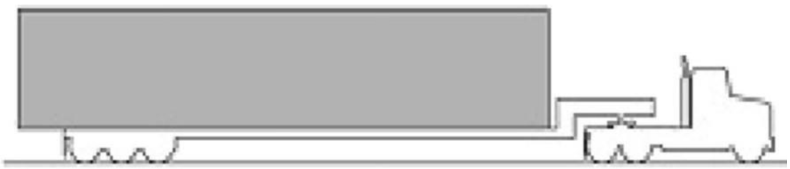

Fig. 3. Single-drop deck [13]

5.2.3 Double-drop deck

The common platform can identify Double-drop (Figure 4). The most expensive trailer is a double-drop deck as it allows an extra 1 foot of height of modules than the standard flatbed and single-drop deck. The double-drop deck is the most suitable trailer if the module is heavier or overweight. However, it has a width limitation of width as the single-drop deck. Due to the heavy load, the module's length to transport is less than a single drop.

Fig. 4. Double-drop deck [13]

5.3 Location

The location of manufacturing and construction also affects the transportation of modules, especially in cost. If the construction site is far from industrial cities, there is no choice other than to increase the transportation cost—the factory or yard of modules is supposed to be close to a major highway. Shipping the modules extremely far from the manufacturing plant is not feasible due to road size, load restriction, and fragility.

Two different studies discussed the distance. The study by Salama *et al.,* [13] indicated that the maximum distance for the module from the manufacturing plant to the construction site is 125 miles or about 202 km, while Smith [14] stated that the maximum distance is 322 km. The concern about the transportation costs, which were perceived to be much higher than that of the conventional approach, especially where long-distance hauls are required, is the factor having the most profound impact on the uptake of the modular technology. According to Velamati [12], the transportation of modules also can lead to time delays due to delayed transportation permits for the oversized load, delay to customs issue with border and dimensional restriction.

5.4 Public Road/Highway Regulation

Every travel of modules to the construction site should comply with the highway height restriction established by Malaysia Highway Authority. As the modules used the large truck or trailer, the essential dimension does not have any problem being transported due to no restriction. However, a vast load of modules more than 16 feet wide require police escort, and they prefer to travel overnight. It is because they need to avoid traffic during the daytime. Said *et al.,* [6] showed that the larger module size needs special traffic control measures such as staging areas, traffic officer control and parking prohibition. As a result, the module's construction is not used widely compared to traditional construction. The regulation for transportation over the highway is quite complicated and keeps changing.

5.5 Cost

"The larger the size of modules, the higher cost of transportation" this statement is the best to describe the actual situation in module construction. The additional cost can be related to the size of the modules. For owners or contractors, the additional cost arising from the transportation may affect their budget and the progress of work [15]. Thus, the companies avoid that risk by remaining in conventional construction. In addition, most of the machinery is large and uses diesel as a fuel. It can be worsened if the black smoke is produced and pollutes the air absorbed by the public. The cost to settle the future effect of the transportation activities needs to be considered.

5.6 Routes

The routes taken by the manufacturer created different ways of transportation. For example, a trailer and truck using a road or highway, a railway for heavier truckloads and a boat for delivery over the river or ocean. The first design parameter established for a modularised plant is the maximum size and weight of a practical and economical module to transport from its construction yard to the plant site" [16].

5.7 Smart Technologies

According to Whitlock *et al.,* [17] and Niu *et al.,* [18] adopting Building Information Modelling (BIM) in construction logistics, stakeholders better understand the logistics process by using clearly defined and easily understandable information. Cheng and Kumar [19] developed an automated logistics planning and management framework that integrates geometrical, scheduling, and material information derived from BIM models with dynamic site layout models. A Geographical Information System (GIS) technology captures, manages, analyses, and displays geographically referenced information using computer hardware, software, and geographical data [20]. According to Niu *et al.,* [18], as a result of the combination of GIS and operational research techniques, researchers have applied GIS to solve problems such as vehicle routing and time-critical logistics, site location, and warehouse management [21-23]. The integrating BIM and GIS into the logistics process for stakeholder decision-making requires more geographical and spatial information, which is why BIM has been neglected during the logistics stage of modular building projects [18].

6. Case Study Findings on Factors to Be Considered In Modular Construction Transportation

Two case studies have been compared for this study. The data collection based on semi-structured interviews has been conducted with two modular construction companies (A and B). The summary of the findings is shown in Table 3.

Table 3
Summary of factors considered in transportation by respondents

Factor	COMPANY A	COMPANY B
Size of the modules	Standard size = 3.5m - solutions for modules that exceed standard size: • Template system (frame) • Divide the module into several parts • Retractable roof	The standard size of container: • 40ft x 8ft • 20ft x 8ft - the container has grades: Grade A (new), Grade B and Grade C (used) - container brought buy from a vendor
Transporter	Suggest two types of trailers can use low or High loader trailer - preferred low loader Other transporters: crane, lorry, forklift	Use low loader trailer - expensive due to extra space - need an escort at the back and in front of the trailer - other transporters: crane
Public road and highway regulation	Allowable time for transportation: • The congested route suggests delivery after midnight • During daytime - permission from local authority	Not an issue due to using the container. The size already approved by the local authority
Route	- choose the fastest and less traffic - not exceed the maximum radius distance to avoid over cost	- choose the fastest and less traffic - transportation during the night and unloading at the site in the morning
Location and cost	- able to send anywhere if the client agrees to accept the cost of transportation	- able to send anywhere if the client agrees to accept the cost of transportation
Smart Technology	- the company not using any specific technology to managing transportation	- the company not using any specific technology to managing transportation

6.1 Size of Modules

Based on the findings, a different installation method resulted from the sizes of the modules. The height and width of the module should be designed by considering the obstacles along the selected routes, such as flyovers, bridges, walkways or cables. Both companies used different methods to resolve their module size limitation to transport it to the site.

There are three solutions used by Company A if the modules are more than the allowable size. The first choice they develop the module framing in the template system. The Template system is like a scissor concept in which the module can be pressed to reduce the height. The second choice is to divide the module into several parts accordingly to the allowable size. The third choice is retractable (also known as collapsible or inflatable) roof structure, which is applied for the pitch type of roof. This roof used a special connection to be erected back when the module arrived.

Meanwhile, Company B used two different sizes, which are 40ft x 8ft (13m x 3m) and 20ft x 8ft (9m x 3m). These are standard sizes suitable for transportation as they do not exceed the maximum height on the highway. The container of 40ft is usually used for 2 number rooms or living rooms, and it is the most suitable size for an office as more people can occupy it compared to a 20ft container with a ratio of 6 to 2 (6:2). For 20ft container, it is suitable for toilet or small space. Regarding quality, the container has a different grade: Grade A for a new container, while Grade B and Grade C are used containers (second-hand).

6.2 Transporter/Trailer

Based on the findings, both companies used the same transporter types to deliver the modules to the low-loader site. The low loader is similar to the double-drop deck in finding. Company A stated two types of loaders used in modular transportation: low and high. The contractor commonly uses the low loader due to the more considerable allowable height or space for modules. The overall size allowed on highways or roads is 4.5m, but in a specific cases, it can reach up to 5m.

In addition, Company B stated that the low loader is quite expensive due to its extra space. However, it is economical for the maximum size of the container. There is a requirement for the transporter to be escorted because it is crucial as a safety measure. After all, the transporter carries a large and wide container. Besides the low loader, the crane, lorry, and forklift were used during the handling and installation.

6.3 Public Road and Highway Regulation

The module needs special traffic control measures with a specific time to transport the modules stated by the Malaysian authority. According to company A, the weight limits and dimensions of roads, bridges, and tunnels are important aspects of transportation. For certain public roads or highways, the permission to transport is after midnight to minimise the risk of accidents or traffic jams. The container size is advantageous to company B, where local authorities approve the modules' size.

6.4 Routes

Company A and B suggested that the fastest and more minor traffic route be selected to minimise the cost and time of travelling. All costs involved, like fuel, toll, and route distance, influence the transportation cost. The route selection also depends on modules and lorry/trailer size. The route also must be within the maximum radius to avoid the cost of transportation over budget.

6.5 Location and Cost

Both companies agreed that transportation costs are influenced by the location of their factory and the site. The modular unit can be delivered anywhere in Malaysia, provided the client is prepared to absorb extra delivery costs.

6.6 Smart Technology

There are no specific technologies that both companies use to improve transportation management.

7. Discussion on Findings

To summarise the findings, several key factors should be taken into consideration in modular construction transportation; amongst the critical factors are the size of modules, the capacity of the transporter, the road regulation (permission and time), and the types of routes taken by the company, allowable time for travel, location and cost. To get a smooth transportation process, the contractor should use the standard size stated by the authority. The standard size of modules is designed based on the limitation of the transporter available in Malaysia. Usually, the low loader type will be the first choice for the contractor or manufacturer because it allows maximum modules. The creativity in managing the modules, especially in the design (size standardisation), is vital to ensure the modules are applicable on-site and suit the transporter. The delivery process of modular from the factory to the site involve highways or public roads, so the consideration of related regulations help ease the transportation process. For example, in a particular situation, the requirement of the police escort for an extra-long and wide transporter is to assure the safety of the trailer and other users on the road. One of the main factors had been left behind by the modular contractors are technology. Based on research done by Niu *et al.,* [18] with the help of smart technology such as BIM and GIS, the installation schedules of modules and the logistics scenario for transporting modules are optimised and visualised in a 3D city-wide GIS environment with optimised trailer routes to sites that were highlighted and calculated, as well as storage yards where modules could be loaded.

8. Conclusion

The modular construction implementation required comprehensive transportation consideration, including planning, designing and transporting. Transportation is quite challenging as the contractor usually rents transporters, such as trailers, cranes or lorries, with a third party. The parties involved should know the transportation requirements for modular construction modules. The objective of this paper is to present the factors that should be considered in modular transportation management when it is important to ensure the success of the project. The future study will examine the procurement aspect of modular construction as a whole or as a part of transportation management, where all modular players must be integrated to optimise the overall modular construction process. Finally, this paper is a part of a current ongoing study that will enhance the process and the application of modular construction and IBS in Malaysia.

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