A FEASIBILITY STUDY ON CONTAINER CONSTRUCTION IN MALAYSIA

Myzatul Aishah Kamarazaly
School of Architecture, Building & Design
Taylor's University, Malaysia
Email: MyzatulAishah.Kamarazaly@taylors.edu.my; Tel: +603 5629 5252

Thean Hai Xu
School of Architecture, Building & Design
Taylor's University, Malaysia
Email: theanhx@gmail.com ; Tel: +603 5629 5252

Azrina Md Yaakob
School of Architecture, Building & Design
Taylor's University, Malaysia
Email: Azrina.MdYaakob@taylors.edu.my; Tel: +603 5629 5252

ABSTRACT

Nations involved in freight exports and imports by using shipping containers through a global transportation network has caused enormous leftover of containers at ports due to the expensive repositioning cost for imported container to be transported back to their origin. This trade imbalance scenario stimulates the opportunity of recycling the empty shipping containers as an alternative green building component in construction industry. Limited by the technical ability of the designer and builder, shipping container offers a broad range of building types and configuration. The paper intends to identify the feasibility in adopting the shipping container as a prefabricated building component in Malaysia which significantly reduce construction cost, time and energy consumption. Descriptive research method was conducted with the contractors who mainly involve in building work in Selangor while anonymity was maintained in the whole process for unbiased feedback. To accomplish the objectives of the study, primary data was obtained through two-stage under the semi-structured interview and questionnaire surveys. The findings of this paper included the criteria of implementing container construction in relation to the architectural design, structural and constructability, as well as the benefits and constraints associated with the application of such construction techniques.

Key words: Container Construction, Pre-Fabricated, Trade Imbalance, Building Components

INTRODUCTION

Current trends in building industry show container construction arise as a practical alternative and appropriate type of architecture to fulfill the human's needs for emergency shelter, housing, workplace or recreational facilities due to its simplicity of construction and ideal strength. It is marked that the world is encouraging sustainable approaches in all sectors especially the construction industry which consumed huge limited resources and emitted large quantities of greenhouse gases. Reuse of shipping container acts as an innovative method to minimize such global issues in this digital age.

Numerous successful implementation of container construction emerged all over the world in several countries for over a decade, for instance Australia, Holland, Japan, USA, UK, South Africa and New Zealand (Bernardo et al., 2013). Instead of restraining in temporary buildings purposes, container building is now moving towards various kind of construction including residential and dwellings, public buildings and other types of non-permanent structures for example prototypes, portable units or mobile dwelling (Kotnik, 2008). The invention of containers for non-shipping appliances is mainly due to the excellent modular design where it reduces construction times and cost compared to traditional building techniques while remaining environmentally friendly; as well as its inherent strength and weatherproof nature which is designed to withstand the extreme weather condition on sea voyages (Intermodal Shipping Containers and Architecture, 2013).

ISSUES

The growth of global economic stimulates the demand for shipping services and seaborne trade volume even though the responsiveness of trade to gross domestic product (GDP) growth is considered moderate over recent years (UNCTAD, 2015). Referring to the review of Maritime Transport 2015, a preliminary estimate of the global seaborne shipment volume had increased by 3.4%, whereas the containerized trade itself was expanded by 5.3% and reached 171 million twenty-foot equivalent units (TEU) in 2014. It computed that containerized trade consisting of 15% of the overall seaborne trade.

Meanwhile, the maritime transport faces challenges of containers surplus caused by the trade imbalance issues. Thus, leading to additional operating expense incurred which discouraged carriers for repositioning the used container back to their origin (Pham, 2014). This results in the accumulation of empty containers which occupy huge spaces and cause congestion in ports. **Table 1** shows the statistic of the surplus of container in Port Klang, Selangor from year 2011 to 2015.

Table 1: Container Statistics in Port Klang, Selangor
(Source: Port Klang Authority, 2016)

Year	**2011**	**2012**	**2013**	**2014**	**2015**
Import	1,795	1,873	1,908	1,962	1,992
Export	1,721	1,822	1,861	1,943	1,962
Surplus	74	51	47	19	30

**All number in thousand unit (,000); TEUs.*

Concerning on how to overcome the surplus of container, recycle or reuse the containers for building purpose shall be emphasized as an alternative practice (Islam et al., 2016). However, the question that is recently highlighted in the construction industry; 'Does the shipping container architecture really make sense?' (Alter, 2011). Pagnotta (2011) reveals the issues of toxicity of the container as it is treated with the coating which contains numbers of harmful chemical such as chromate, phosphorous and lead-based painter. In term of size, Alter (2011) pointed out that shipping container has globalized the production in every scope except for housing, because dimensionally, houses are bigger than boxes. Nevertheless, Oloto and Adebayo (2015) had argued that as a module of system, containers are able to assemble to create practical habitat. Furthermore, Hogan (2015) opines the container building faced limitation in taking advantage of passive strategies like thermal mass if maintaining the container aesthetic. In ArchDaily, Pagnotta (2011) concludes that container construction technique shall not be neglected even though it is typically not the most appropriate method of design and construction.

Several similar studies had been conducted such as Ismail, Al-Obaidi, Abdul Rahman & Ahmad (2015) who studied the potential, constraints and compatibility of container architecture towards the climate condition; yet the findings did not specify the suitability of container houses in the hot-humid tropic. Giriunas, Sezen & Dupaix (2012) paper focused on the evaluation and analysis of the shipping container building structures. Likewise, the container building constructability and the effects of carbon footprint had been examined by carrying out life cycle assessment and case study method in Australia (Islam, Guomin, Suheeva & Bhuiyan, 2016). Various studies have been carried out to determine the aspects of container construction techniques. However, there is still a lack of indication on the feasibility of implementing container construction. Therefore, this paper serves the purpose to fill up the literature gaps by identifying the advantages and disadvantages of container construction as well as investigating on the considerations before implementing it in Malaysia.

RESEARCH OBJECTIVES

The study aims to achieve the following objectives:-

i) To identify the criteria to be considered prior implementing the container construction in Malaysia.
ii) To determine the significant benefits which influence the adoption of container construction in Malaysia.
iii) To ascertain the possible constraints associated with the container construction in Malaysia.
iv) To explore the feasibility of the container construction in Malaysia.

SHIPPING CONTAINER AS BUILDING COMPONENT

Shipping container is considered as an 'upcycle' material where it is reused with minimal modification while adding the value and quality (Islam et al., 2016). Abrasheva, Senk & HauBling (2012) acknowledge that the container construction is an affordable method of construction and sustainable design. Furthermore, the reuse of container as a prefabricated building component assist in minimizing the embodied energy compared to conventional building (Vijavalaxmi, 2010).

In fact, these advantages have prompted building designers to construct various unique and outstanding container architecture. Although container architecture is considered common in certain countries, it is still relatively new in Malaysia (Ismail et al., 2015). In Malaysia, the Container Hotel Group (CHG) had successfully constructed the Container Hotel **(Figure 1)** and Capsule **(Figure 2)** in Kuala Lumpur by incorporating the inspiration of green architecture and the reuse of renewable material (CHG, 2014).

Figure 1: Container Hotel, KL (Source: Wham, 2015)

Figure 2: Capsule, KLIA 2 (Source: McKelvey, 2014)

Repurposing shipping containers as a prefabricated building component is considered as a sustainable construction practice due to the majority of the structures are recyclable materials. Vijayalaxmi (2010) argues that the potentials of the container architecture should not limit to its prefabrication or modular characteristics, but should also be associated with other factors in terms of availability, durability, transportability and economic concern. This results in the risen awareness in the construction industry among the environment-related researchers, building professionals, developers, contractors and end-users.

CONTAINER CONSTRUCTION

Design Criteria

Shipping container comprises of corrugated steel panel (walls and roof), plywood flooring supported by steel grid, front doors with locking device, frame and rails; which form an integrated structural envelop suitable for construction (Bernardo et al., 2013; Islam et al.,2016) **(Figure 3)**.

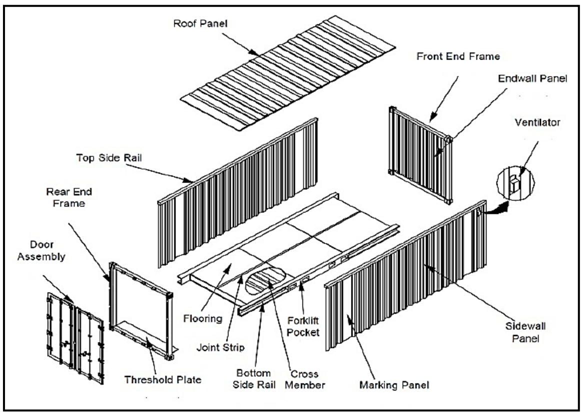

Figure 3: Typical shipping container exploded axonometric view (Source: RSCP, 2013b)

Common shipping container's dimensions for building purpose are 6.0m (20ft) or 12m (40ft) long with 2.4m (8ft) width and 2.6m (8.5ft) height; whereas high cube (HC) container offers extra one foot height which is 2.9m (9.5ft). Olivares (2010) opined that 20ft container is being the preferred choice compared to 40ft container when concerning the load bearing capacity. Regarding the ideal height, Ismail et.al (2015) recommended HC container as the extra space created is suitable for installation of services work as well as complies with international building by-law regulation. Container construction required similar foundation system as other residential buildings which are slab-on-grade foundation, pile foundation or concrete pier foundation (Michael, 2016). Moore (2015) described that the containers can be secured with bolts and fixtures set; or welded to the thick steel plates which connected to the reinforcement in foundation. In addition, corner locking mechanism with twist locks allows simple vertical connection of container during the construction when they are oriented in similar direction (Anderson, 1999).

Shipping containers are structural integrity which provides the strength to withstand 24 tons of loading (Naber, Duken, Mast & Schieder, 2013). However, container architecture often required certain modification such as removal of the sidewall of the container to incorporate into the design, which will cause a drastic effect on the stiffness and shear capacity (Nelson, 2011). Thus, Bernardo et al. (2013) proposed a preliminary solution of reinforcement by welding two external and lateral trusses along the entire length of the container to strengthen the structure **(Figure 4)**.

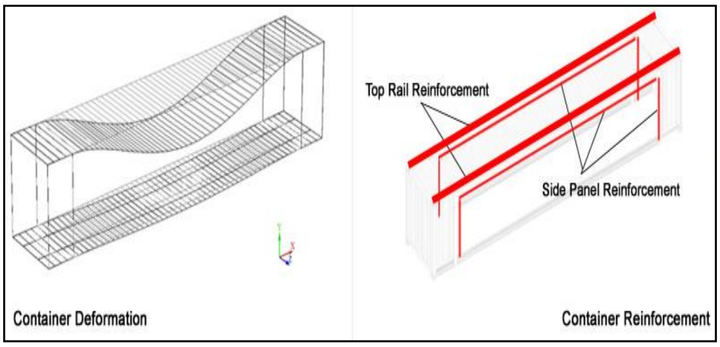

Figure 4: Container deformation and reinforcement (Source: Bernardo et al, 2013)

While considering shipping container as a high heat conductor, Botes (2013) highlighted that sufficient insulation is required for container architecture to ensure thermally comfortable indoor environment and to prevent condensation due to high moisture content especially in the hot-humid country. In order to provide thermal break, polystyrene insulating board, ceramic coating or polyurethane foam spray can be applied to insulate the metal surface (Fuller, 2006; Islam et al., 2016; Kennedy, 2009). Besides, ventilation also plays important roles when using the shipping container as a habitable home. Cross-ventilation system can be incorporated in the container house by allowing sufficient opening, which provide effective cooling with the assistance of mechanical ventilation system (Ismail et al.,2015) **(Figure 5)**. The Benjamin Garcia Saxe in Costa Rica acts as an excellent example, where the pitch roof is modified and equipped with a vent to suit the tropical climate (Tunas, 2013).

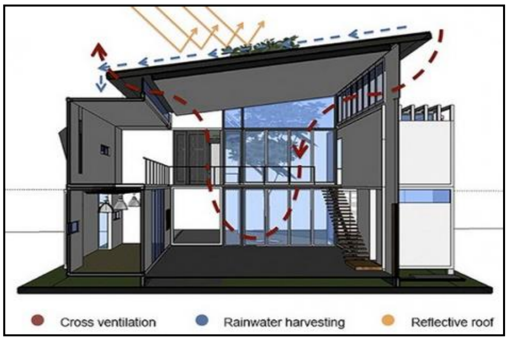

Figure 5: Cross ventilation system (Source: Kurt, 2015)

Benefits of Container Construction

Strength and Durability

Brandt (2011) pointed out the shipping container is designed by weathering steel with the inherent strength which can withstand heavy load and support multiple of stacked container. This corrosion resistant steel also known as 'Cor-ten' steel forms an amorphous inner layer by alloying elements to protect the container from the exposure to the harsh environment during the shipping activities (Moore, 2015). Excellent level of strength and durability provides structural support and longer life span, as well as ensuring low maintenance cost.

Availability

Due to the nature of maritime industry and trade imbalance issue, abundant of used containers is available in large amount around the world. Oliveira (2014) observes that the containers are cheap to reuse as a building material. Recycle of the container to a habitable structure potentially lowers the overall construction cost compared to the conventional building (Pauli, 2010). Garcia (2014) also opines that container houses can provide the solution to the increasing demand for affordable housing.

Modularity

Container construction trend continues to gain momentum due to the cost and time saving associated with container housing (Garcia, 2014). According to Sawyers (2008), the shipping container act as the giant 'Lego pieces' which can be assembled and dismantled to fulfill the instance needs of the particular area. In fact, Islam et al. (2016) claimed that the modular construction was 40-60% faster and generated 70% less wastage than traditional construction methods.

Transportability

In term of portability, various studies clearly stated that containers could be transported with ease from one destination to the other in shorter time. This achieved the main intention of the invention of the container to a building component, by making it compatible with various modes of transportation system (Levinson, 2006). Oliveira (2014) discussed this advantage allow prefabrication of container unit in the off-site location and be transported across a great distance to the construction site when needed.

Sustainability

By upcycling the used shipping container for construction purposes, container architecture often recognized as one of the sustainable or green building alternatives which offer low carbon footprint (Robinson, 2012). Islam et al. (2016) mentioned that container building could be constructed of about 75% recycled material by weight. On the other hand, Pauli (2010) studied that recycling of used container to steel blocks through melting process consumed 8000 kWh of energy; while reusing as building component only requires 400 kWh of energy without the emission of excessive greenhouse gases.

Constraints of Container Construction

Like other building components, the container construction also has its disadvantages. Container architecture will lose its inherent strength when there is over-modification. Bernaldo et al. (2013) studied that most of the container construction may perform certain amount of refurbishment for instance removing doors, replacing flooring or cutting steel wall sheets for opening in accordance with architectural requirements. These removals may lead to possible deformation or structural failure due to the inadequate strength to support the whole structure, thus additional reinforcement is required (Moore, 2015). Nelson (2011) also opined that the amount of strength loss is equivalent to the amount of removal.

Recycling the empty container leftover by the surplus issue is considered as sustainable approach, but in reality, many existing projects are constructed by brand new shipping containers (Hogan, 2015). Smith (2006) argues that high proportion of reused containers is in poor condition and superficially damaged due to the impact damage from bad packing and shipping. Besides, Olivares (2010) reveals that the lifespan of the container building only last fifty years which is half compared to conventional building. Another downside is that container building is highly depends on the topography of site, where practically not suitable for the sloping site (Olivares, 2010).

In addition, Botes (2013) pointed out that the container construction technique required more skilled labour for welding and steel work and special machinery like crane for assembling the building. It may be an uncommon method among the contractors and builders who practices conventional construction method and intensive labour force (Islam et al., 2016). Furthermore, shipping container has high heat conductivity as it is mainly made of steel and prone to condensation due to the high moisture content (Olivares, 2010). Therefore, Botes (2013) discussed that the appropriate layers of insulation are needed to ensure the indoor comfort which may also results in additional cost incurred during the construction.

RESEARCH METHODOLOGY

The descriptive survey methodology was adopted as it offers fast and effective method of data collection (Smith, 2006). To accomplish the objectives of the study, primary data was obtained through two-stages under the semi-structured interview and questionnaire survey. A pilot study was carried out as a pre-test with a convenience sample of five contractors selected randomly from the target sampling frame to assess the feasibility of the survey, collecting the preliminary data and identify the potential problems.

The scope of the study limited to the views expressed by contractor firms only which mainly involve in building works who registered under Construction Industry Development Board (CIDB) Malaysia; ranged from Grade 1 to Grade 7; and geographical location shall focus on Selangor, Malaysia only. The reason of selecting the building contractors as the sample target is that they are individuals who are responsible to coordinate, organize and manage all aspect of a building site. They are expert in planning how the project will be executed and completed in a manner which fulfill with all laws and regulation along the construction. Hence, they are more suitable in this study case compared to other construction players.

At the data gathering stage, semi-structured interview was conducted based on the implementation of container construction discussed in the literature review to collect the primary data with the contractor who involved in container project only. These targets are predetermined by purposive sampling as in the researcher judgement, this sampling strategy are best positioned due to the contractors are experienced and familiar with the container project. Thus, enable them to provide the significant information and necessary recommendation for this study.

On the other hand, several aspects associated with the implementation of container construction were analyzed by incorporating into the questionnaire, which pre-tested and distributed via mail to a randomly selected sample from the sampling frame; that did not undergo the interviews and pre-tests. Respondents were requested to rate on a five-point numerical Likert scale in the questionnaire based on the level of importance of the criteria, level of significant on the benefits and level of agreement on the constraints as well as feasibility of implementation of container construction. Both open-ended and closed question were incorporated in the questionnaire as in line with Kumar's (2011) recommendation; open-ended question provides respondents with the opportunity to express their opinions freely and virtually eliminate the possibility of researcher bias, resulting in a greater variety and in-depth information while answering the ready-made list of responses. The outcomes of the data analysis represented the basis for the implementation of container construction and the findings of this study were generalized and reflected the overall scenario in Malaysia.

RESEARCH FRAMEWORK

The research framework that provided insights into the expected outcome and use of the research findings is shown in **Figure 6**. It presented the relationship between the trade imbalance scenario and the implementation of the container construction as envisaged in this study. The framework proposed incorporated some significant components developed by Islam et al. (2016); the potential and constraints of implementing container architectural and further emphasized on important criteria which determine the feasibility of the container construction. This framework act as a guideline in assisting not only researchers, but also designers/ architects, developers or builders to identify the suitability of the implementation of this alternative construction technique in Malaysia.

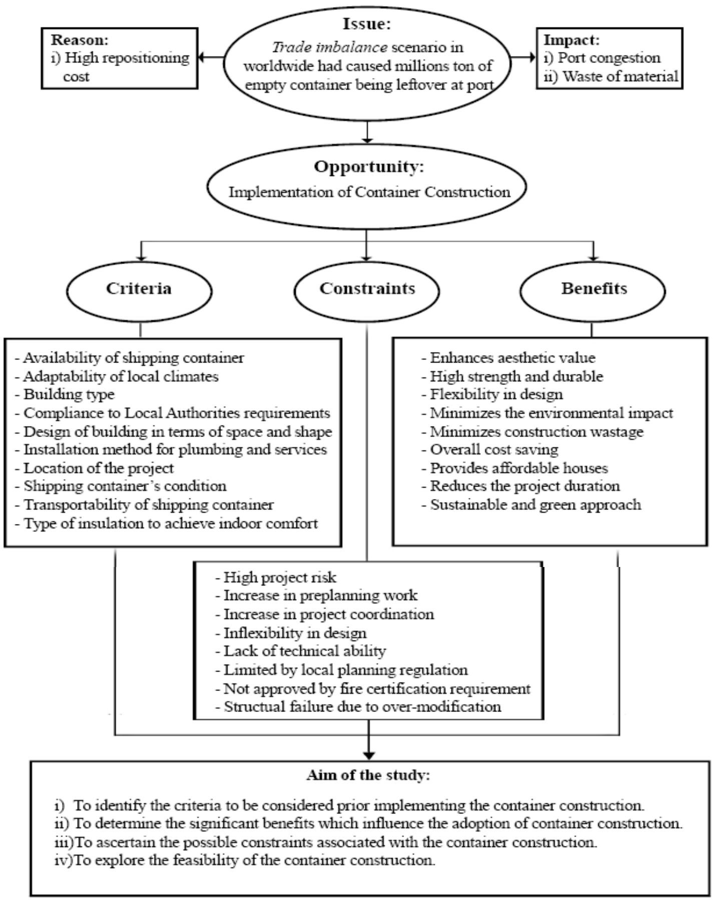

Figure 6: Research framework

DISCUSSION & FINDINGS

The following findings are analyzed according to the criteria, benefits, constraints and feasibility of implementing the container construction based on the data collected from the target respondents. **Figure 7** demonstrated the overall data analysis of this study. The type of insulation to achieve the indoor comfort is considered the most important criterion with the mean rating (MR) value of 4.18, followed by the compliance to local authority's requirements and the shipping container's condition which placed on second and third with both MR of 4.00. This finding is in line with the study by Botes (2013) and Ismail et al. (2015) who highlighted that the adequate and proper insulation is essential for container architecture, especially for the hot-humid country. Likewise, Smith (2006) argues that the recycled containers' condition should be a concern as the containers were facing a high chance of superficial damages caused by the bad packing and shipping event.

Besides, the result shows the reduction in the project duration is the most significant benefits which attracted people moving towards to container construction approach, which scores MR of 4.27. The second ranking of the advantage is minimizing the construction wastage with MR of 4.09; while the third significant benefit is overall cost saving with MR of 3.96. This finding corroborates Islam et. al. (2016)'s statement that container house provides a fast project delivery due to its standardized and effective factory controlled manufacturing. Container construction also produced approximately 70% lesser onsite waste by eliminating the complicated construction process of the conventional method.

Majority of the respondents strongly agreed on the inflexibility in design as the highest potential constraint in implementing the container construction with MR of 3.68. This contradict scenario occurred might due to the different perspective from the construction players. It is enlightened that the building contractor pursued the buildability aspect when determining the construction technique. Coupled with this constraint, structure failure issue due to over modification of shipping container also a vital limitation towards the overall architecture and structural design. This finding also in agreement with Moore (2015) opinion that additional reinforcement is required after removal of container components during the construction. Thus, it ranked at the second place, with MR of 3.55.

Importance Rating: *5 (VI) – Very important; 4 (MI) – Moderately important; 3 (N) – Neutral; 2 (SI) – Slightly important; 1 (LI) – Low important*

		Relative importance of criteria prior implementing the container construction								
		VI 5	MI 4	N 3	SI 2	LI 1				
	Criteria of implementing the container construction	%	%	%	%	%	TR	MR	RII	Rank
1	Type of insulation to achieve indoor comfort	40.9	36.4	22.7	0.0	0.0	66	4.182	0.109	1
2	Compliance to local authorities requirements	36.4	31.8	27.3	4.5	0.0	66	4.000	0.104	2
3	Shipping container's condition	40.9	31.8	18.2	4.5	4.5	66	4.000	0.104	3
4	Building type	27.3	36.4	36.4	0.0	0.0	66	3.909	0.102	4
5	Transportability of shipping container	18.2	50.0	27.3	4.5	0.0	66	3.818	0.099	5
6	Adaptability of local climate	27.3	36.4	27.3	9.1	0.0	66	3.818	0.099	6
7	Design of building in terms of space and shape	36.4	31.8	18.2	4.5	9.1	66	3.818	0.099	7
8	Location of the project	22.7	31.8	36.4	9.1	0.0	66	3.682	0.096	8
9	Installation method for plumbing and services	22.7	40.9	18.2	13.6	4.5	66	3.636	0.095	9
10	Availability of shipping container	27.3	27.3	31.8	4.5	9.1	66	3.591	0.093	10

Significant Rating: *5 (VS) – Very significant; 4 (MS) – Moderately significant; 3 (N) – Neutral; 2 (SS) – Slightly significant; 1 (NS) – Not significant*

		Relative significant benefits which influenced the adoption of container construction								
		VS 5	MS 4	N 3	SS 2	NS 1				
	Benefits of implementing the container construction	%	%	%	%	%	TR	MR	RSI	Rank
1	Reduces the project duration	50.0	27.3	22.7	0.0	0.0	66	4.273	0.125	1
2	Minimizes construction wastage	31.8	45.5	22.7	0.0	0.0	66	4.091	0.120	2
3	Overall cost saving	18.2	59.1	22.7	0.0	0.0	66	3.955	0.116	3
4	Provides affordable houses	27.3	45.5	22.7	4.5	0.0	66	3.955	0.116	4
5	Sustainable and green approach	31.8	31.8	31.8	4.5	0.0	66	3.909	0.114	5
6	Minimizes the environmental impact	13.6	45.5	36.4	4.5	0.0	66	3.682	0.108	6
7	High strength and durable	18.2	31.8	40.9	4.5	4.5	66	3.545	0.104	7
8	Flexibility in design	13.6	40.9	36.4	4.5	4.5	66	3.545	0.104	8
9	Enhances aesthetic value	9.1	31.8	40.9	9.1	9.1	66	3.227	0.094	9

Agreement Rating: *5 (SA) = Strongly agree; 4 (A) = Agree; 3 (N) = Neutral; 2 (D) = Disagree; 1 (SD) = Strongly disagree*

		Relative agreement on potential constraints associated with the container construction								
		SA 5	A 4	N 3	D 2	SD 1				
	Constraints of implementing the container construction	%	%	%	%	%	TR	MR	RAI	Rank
1	Inflexibility in design	4.5	63.6	27.3	4.5	0.0	66	3.682	0.135	1
2	Structural failure due to over modification	22.7	31.8	22.7	22.7	0.0	66	3.545	0.130	2
3	Limited by local planning regulation	18.2	31.8	36.4	13.6	0.0	66	3.545	0.130	3
4	Not approved by fire certification requirement	13.6	36.4	36.4	13.6	0.0	66	3.500	0.128	4
5	Increase in pre-planning work	4.5	40.9	40.9	13.6	0.0	66	3.364	0.123	5
6	Increase in project coordination	9.1	31.8	45.5	13.6	0.0	66	3.364	0.123	6
7	Lack of technical ability	0.0	40.9	40.9	18.2	0.0	66	3.227	0.118	7
8	High project risk	4.5	22.7	45.5	27.3	0.0	66	3.045	0.112	8

Impact Rating *: 5 (VH) – Very high; 4 (H) – High; 3 (N) – Neutral; 2 (L) – Low; 1 (VL) – Very low*

		Level of Impact								
		VH 5	H 4	N 3	L 2	VL 1				
	Broad categories of factors	%	%	%	%	%	TR	II	RII	Rank
1	Benefits	22.7	36.4	36.4	0.0	4.5	66	3.727	0.339	1
2	Constraints	13.6	40.9	45.5	0.0	0.0	66	3.682	0.335	2
3	Criteria	13.6	31.8	54.5	0.0	0.0	66	3.591	0.326	3

Figure 7: Data analysis

Among the factors, benefits of container construction scored as the highest impact on feasibility aspect with MR of 3.73. Constraints factors and criteria factors are placed in second and third respectively with the MR of 3.68 and 3.59. Results showed that the advantages of container construction influenced the most in feasibility perspective compare to the potential constraints and any important criteria need to be considered. Besides, **Figure 8** displays the agreement level in relation to the feasibility of implementing the container construction. Half of the building contractors accepted the feasibility of container construction being adopted in Malaysia while around 36.4% of contractors reserved their standpoint as neutral. This finding reflected the current state of container construction being recognized in Malaysia's construction industry, which also indicated the great potential development of said construction technique in the future.

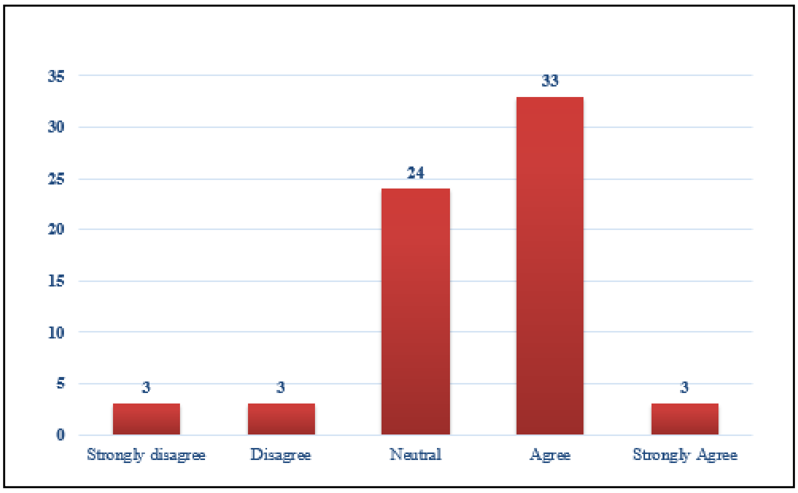

Figure 8: Agreement level of feasibility aspect

CONCLUSION

The invention of globally standardized shipping containers in the international export market brought a revolution towards the transportation industry and stimulated the world economic growth in the middle of the twentieth century (Olivares, 2010). In this digital age, shipping containers had been innovated in construction industry as an alternative structural design or a favorable approach for architectural development of unique building technologies and materials; which offers an innovative and intelligent solution for wide range use due to the flexibility, availability, modular character and rigidity (Olivares, 2010; Giriunas et al., 2012).

This research study has successfully explored the feasibility of implementation of the container construction in Malaysia and contributed as the basis of new sustainable construction approaches available in our country. This paper had specifically identified and ascertained the criteria to be considered prior implementing the container construction as well as its benefits and potential constraints. Results showed that insulation plays the important role in converting the container into a habitual space. Besides, container construction provides better time and cost saving compared to the traditional construction method. Nevertheless, container building would confront the issue of inflexible towards the design under some circumstance. Discussion of the overall findings had concluded the suitability of shipping container as a building component and its buildability for providing the affordable housing solution. The significant contributions of this study are as follows: (i) for builders – better understanding on possible build-ability using container, benefits derived from this initiative and how to succeed with container construction; (ii) for designers – concern more on what important aspects to be considered while proceeding with detail design, aesthetic and structural part and (iii) for quantity surveyors – providing better understanding on the overall view of costing aspects. Future research can embark into more in-depth case study of container project especially in terms of life cycle costing. The detail comparison between conventional construction method and container construction would provide a valuable basis for development in Malaysia's construction industry.

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