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Sains Humanika

A Review on Embodied Energy Through Industrialised Building System Implementation in Construction Industries

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Abstract

In Malaysia, the implementation of Industrialised Building System (IBS) has been recommended as one of the alternative to minimize the quantity of material used and reduce the construction time and wastage. However, the implementation of this approach still remains in doubt because the benefits have not been fully recognised and well defined in the construction industry. Other factors that contribute to save cost and energy should be investigated in order to popularized other alternative of construction method.The process of the material's production, transportation, erection and installation at construction site consume embodied energy and emit carbon dioxide (CO_2) that gives negative impacts on the environment. Therefore, it is necessary to consider embodied energy and CO_2 amongst other factors in selecting building materials to be used in construction projects. The aim of this paper is to explore the significance in assessing energy consumption through application of IBS construction technique in order to evolve stakeholder perspective towards the application of IBS during the stage of decision making.

Keywords: Industrialised Building System (IBS), conventional building system, embodied energy, co_2 emission, environmental impacts, malaysian construction industry

Abstrak

Pelaksanaan Sistem Binaan Berindustri (IBS) di Malaysia telah dicadangkan sebagai salah satu alternatif kaedah binaan bagi mengurangkan penggunaan kuantiti bahan binaan di samping dapat mengurangkan pembaziran dan tempoh pembinaan. Walaubagaimanapun, pelaksanaan kaedah pembinaan ini masih diragui memandangkan keberkesanan kaedah ini masih belum mendapat pengiktirafan dan difahami sepenuhnya oleh pihak yang terlibat dalam industri ini. Faktor lain yang menyumbang ke arah penjimatan kos dan sumber tenaga harus dikaji bagi meningkatkan populariti kaedah binaan ini sebagai alternatif kaedah binaan yang berkesan. Proses pengeluaran bahan binaan, pengangkutan, pembinaan dan pemasangan di tapak pembinaan menggunakan tenaga (EM) dan membebaskan karbon dioksida (CO2) memberi kesan negatif terhadap alam sekitar. Oleh itu, tenaga (EM) dan karbon dioksida (CO2) merupakan antara beberapa faktor utama yang perlu diambil kira dalam pemilihan bahan binaan yang akan digunakan dalam projek pembinaan. Tujuan kajian ini adalah untuk melihat lebih dalam lagi kepentingan dalam menilai jumlah tenaga hasil daripada pelaksanaan IBS sebagai kaedah binaan. Di samping itu dapat mengubah persepsi pihak terlibat dalam industri pembinaan dalam memilih kaedah binaan yang hendak dilaksanakan.

Kata kunci: Sistem Binaan Berindustri (IBS); Kaedah Pembinaan Konvesional; tenaga; pembebasan CO2; kesan alam sekitar; Industri Pembinaan Malaysia

■1.0 INTRODUCTION

One of the primary roles of construction industry is to generate wealth to the country. However, construction industry is not just concerned about financial return, but also on the long term impacts of living standards for both present and future generations (Ding & Shen, 2010). It has been recognised that environmental impacts are important to the survival of our construction industry. Essentially it has to minimize the use of natural resources as well as reduction in energy and carbon emission in order to secure the needs of future generations (Bari *et al*., 2012; Henry *et al.*, 2014). Nowadays, the construction industry consumes more natural resources than necessary, therefore, generate large amount of construction waste. In addition, the construction industry is also reluctant to change their conventional practices which to consider environmental matters in early stage. Thus, there is an urgent need for construction industry to minimise or eliminate activities that contribute to climate change and negative impacts towards our environment. With recent increase in sustainability awareness, sustainability agenda has attracted global to help countries in achieving solutions to tackles this challenge. Some example of the efforts are the improvement of energy efficiency in construction processes and techniques, adoption of passive design, use of renewable energy and the appropriate selection of construction materials(Hamid *et al.*, 2011; A. Mohamed Nor Azhari *et al*., 2013; Henry *et al.*, 2014). In addition, different methods of construction have been applied in the industries which are conventional building system and Industrialised Building System (IBS). IBS is a construction process that utilizes techniques, products, components or building systems involving prefabricated components and on-site installation (Roadmap, 2010; Kamar *et al*., 2011).

Embodied energy and CO_2 emission are currently two main parameters commonly used in evaluating the importance of construction materials (Hammond & Jones, 2008). Research shows that the embodied energy of buildings can contribute up to 40% of life cycle stage of buildings (Manish *et al*., 2013). When the embodied energy and carbon emissions are considered and become an important share of the total life cycle, it shows that construction materials have a high importance which is often ignored when only the energy efficiency of running the building is considered (Airaksinen & Matilainen, 2011). Nowadays, most of the studies have concentrated largely on energy efficiency during operation of building. Study by Ibrahim *et al*. (2013) indicated that IBS approach could help not only the economical, time and cost factor but also in the thermal comfort condition by controlling the quantity of the building materials. However, these measures result in an increased use of construction materials (Airaksinen & Matilainen, 2011; Henry *et al*., 2014;). In decreasing of operation energy, amount of embodied energy and carbon emission has increased (Dixit *et al*., 2010).

The environmental impact of buildings is often underestimated, while the perceived costs of green buildings are overestimated (Samari *et al*., 2013). The amount usage of construction materials contribute to 60% of total construction cost (Baba *et al*., 2005; Jayasinghe, 2013; Omar & Doh, 2013; Henry *et al*., 2014). The emerging nature of embodied energy and CO_2 emission are among the leading parameters in assessing energy consumption on the two types of construction methods in Malaysia which are conventional building system and Industrialised Building System (IBS). The objective of this paper is to overview and analyse the current significant of embodied energy analysis in implementation of Industrialised Building System.

2.0 SIGNIFICANCE OF EMBODIED ENERGY ASSESSMENT IN INDUSTRIALISED BUILDING SYSTEM (IBS)

The construction industry has continuously developed during the years for a technical change. A number of researchers claim that IBS method of construction has a lot of benefits compared to the conventional method and IBS offer potential for reductions in cost, time, defects, health and safety risks, environmental impacts and a consequent increase in predictability, whole life performance and profits (Baba *et al*., 2005; Nawi *et al*., 2014; Kamar *et al*., 2014). Adoption of IBS is also encouraged to overcome environmental issues associated with conventional methods. In IBS, time, cost and quality are the three key issues that are main thrust of the sustainability in construction. Figure 1 shows that these elements complement each other, which is pertinent to be part of the holistic structure for sustainable construction in considering safety, security, environmental and health in construction (Hamid *et al*., 2011).

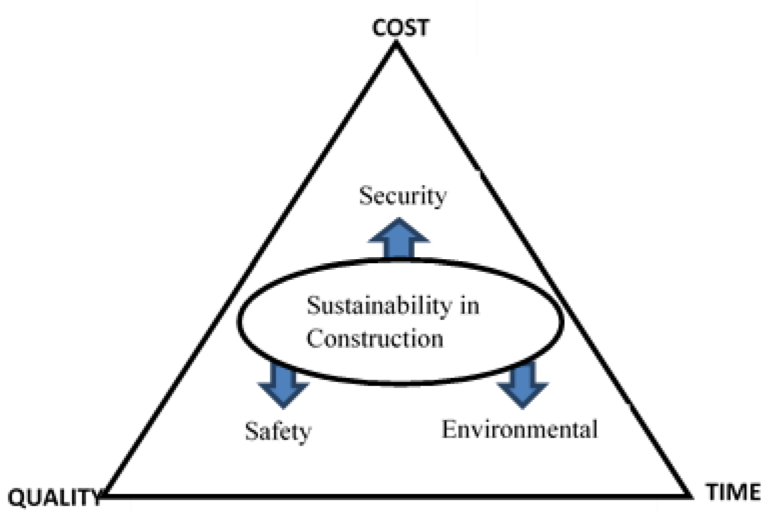


Figure 1 Elements of sustainability in constructions (Bari *et al*., 2012)

The construction industry have regarded as labour intensive, dangerous and huge contributor to pollution. Conventional construction methods involving the use of formworks and other construction materials and the quality is highly dependent on skilled and unskilled labour. Furthermore, construction industry is known as the highest level of accident injuries and fatalities (Bari *et al*., 2012). Therefore, the adoption of IBS in the Malaysian construction industry is to reduce construction time as well as the number of foreign labour admission to our country.

As highlighted in The Construction Industry Master Plan 2006-2015 (CIMP, 2006), one of the challenges faced by Malaysian construction industry is the availability of low cost foreign labour which encourages labour-intensive construction methods over the use of other alternative methods. Therefore, the adoption of IBS one of the modern construction methods may help to ease the pressures of labour requirements as well as improving quality and productivity of construction industry. In addition, IBS also encouraged to overcome environmental issues associated with conventional methods. In terms of cost, IBS has potential of reducing long term construction cost even if the initial construction cost may be higher. However, Malaysia must put a great concern not only on time, cost and quality but also in energy consumption which has to be monitored in order to achieve the energy efficiency benefits promised by IBS. One way of dealing with the issue on sustainability and green construction is by reducing energy conservation in the operation of building (Chen *et al*. 2001). For example, the energy used to heat and cool premises, run appliances, heat water and also room light. Until recently, attention has been mainly focused on energy conservation in operating building (Chen *et al*., 2001). However, operation energy is not the only contribute to energy consumption in construction industry. Recently, research shows that the embodied energy of buildings can contribute up to 40% of life cycle stage of buildings (Chen *et al*., 2001; Manish K. *et al*., 2013)

Embodied energy divided into two parts: initial and recurring embodied energy. The initial embodied energy is the energy used in maintaining and repairing of the building over its effective life. Most embodied energy figures for specific materials are quoted using a "cradle to gate" boundary (includes primary resource extraction, transport unfinished product, process and manufacturing). Transportation, assembly, maintenance and demolition components of embodied energy should also be taken into account (Haynes, 2013).

■3.0 INDUSTRIALISED BUILDING SYSTEM (IBS) TOWARDS SUSTAINABILITY

The best sustainable way to minimize environmental impacts in construction industry, through proper management at the early stage of decision making. The potential of IBS should be exploited in a right way to maximize the benefits to the environment, society, and economy. Adoption of IBS can only be realized if it is socially and politically acceptable, economically viable and legally possible (Parriaux *et al*., 2006). Therefore, a study on implementation of IBS should be done, focusing on the elements in Figure 1.

The benefits attributed to IBS adoption are numerous and well documented, providing impetus for its implementation in the industry. The adoption of IBS is strongly advocated in the Malaysian construction industry to reduce construction time as well as the industry's dependence on foreign labour. The wider adoption of IBS is also encouraged as a means to overcome environmental issues associated with conventional methods. However, the construction industry in Malaysia has low acceptance towards IBS due to the resistance to change and also lack of knowledge in this area, causing the advantages of IBS cannot be leveraged entirely. From the previous IBS studies, issues such as success factors, benefits, barriers, perceptions, challenges and supply chain regarding IBS are widely being discussed (Hamid *et al*. 2011; Tiong *et al*. 2011; Nawi *et al*. 2011; Nawi *et al*., 2012; Nawi *et al*., 2014; Yahya *et al*. 2012; Bari *et al*. 2012; Azman *et al*. 2012; Mazzuana *et al*. 2013;). However, benefits of IBS in energy consumption and carbon emission are rarely discussed. According to Mohammad (2013), one way to deals with sustainable issue in Malaysia is by using low embodied energy materials. Omar & Doh (2013) has conducted preliminary works on methodology in assessment on embodied energy and CO_2 emission of building and construction processes in Malaysia. This research find out that embodied energy and carbon emission important to achieve sustainability and demonstrate different methods in tracing energy path are deemed capable to incorporate wider range of path.

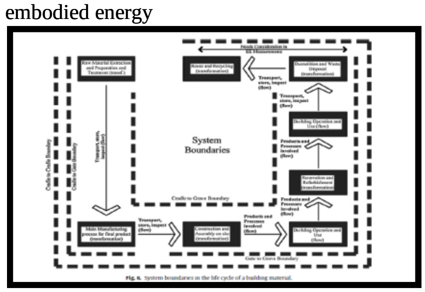
Review shows that there is lack of quantitative studies in Malaysia regarding embodied energy and carbon emission of buildings. Therefore, it is important to review, as well as modify, current construction practise such as design and engineering methods, construction techniques and manufacturing technology to minimize energy consumption (Manish *et al*., 2013).

■4.0 SIGNIFICANT OF EMBODIED ENERGY AND CO_2 ASSESSMENT IN CONSTRUCTION PROJECTS

The total energy demand includes energy used in various processes during transporting the building materials and components for the production and demolition of the building. Embodied energy describes as the amount of energy consumed during the manufacture of the building materials and components, in transporting these to site and during the construction process itself (Haynes, 2013). Transportation of materials is a major factor in the cost and energy of a building (Venkatarama Reddy & Jagadish, 2003). The transportation distance may vary depending upon the location of construction activity. The production of building materials (e.g., extraction, transportation and manufacturing processes) releases CO_2 mainly due to the use of fuel and electricity (Jayasinghe, 2013).

For many years, embodied energy content of a building was assumed to be small compared to operational energy. Consequently, attention has been mainly focused on energy conservation in operating building (Chen *et al*., 2001; Manish *et al*., 2013). Operating energy is the energy required in keeping the indoor environment within the desired range and to power equipment and other services. According to research by the Australian-based CSIRO (Commonwealth Scientific & Industrial Organisation), an average household contains about 1000 GJ of energy embodied in the materials used in the construction of the house, and this is equivalent to 15 years of normal operational energy (Henry *et al*., 2014). According to Milutien (2010), selection of low impacts building materials can reduce approximately 10-15% embodied energy. In addition, the selection of building materials with low impacts consume 30% less energy, 30-50% less water, and produce 35% less carbon emissions (Hossaini & Hewage, 2011).

In the recent years, there were some restrictions imposed on using natural resources for the manufacturing of building materials due to increased awareness of environment impacts. As a result, the prices of conventional building materials have increased by a considerable amount. This is the main reason why IBS has been introduced in Malaysia. However, the implementation of this approach still remains in doubt. In order to popularize alternative construction method, it is essential to evaluate the total performance of such materials in terms of strength, durability, cost, energy consumption and the environmental concerns. Thus, the consideration of embodied energy and carbon emissions are quite important in environmental building assessment. Table 1 shows the review on significant of embodied energy in construction industry.

AUTHOR S	FIELD OF STUDY	ISSUE	KEY FINDINGS	RESEARCH GAP
Chen *et al*. (2001)	Analysis of embodied energy use in residential building of Hong Kong	Recent research indicated that embodied energy used in residential buildings up to 40% of life cycle energy used. Therefore analysis of embodied energy use in high rise building of Hong Kong have been undertaken	The findings of the study, the use of recycle steel and aluminum as alternative to non-structural concrete walls confer saving of more than 50%.	Not touch on benefits and energy consumption in IBS aspects but focusing more on calculation of embodied energy and comparison of two alternative construction techniques.
Yeen (2012)	Analysis of carbon footprint on IBS	Level of acceptance to IBS still consider low. One of the reasons is Lack awareness towards sustainable development.	Identify the elements of IBS that can contribute to carbon footprint calculated using "Carbon Calculator"	This study has applied the suitable tools to calculate carbon footprint, but no comparison towards conventional methods. Not touch on relationship between carbon footprint, time, cost and quality of case studies
Bari *et al*. (2012)	Comparative studies of environmental awareness and benefits of IBS	Past studies have concentrated on benefits of IBS. However, lack of research on how IBS differ from conventional methods of construction.	Provide data that the advancement of prefabrication and interlocking blocks systems can contribute to significant economics and environmental benefits.	Focus only on residential building. Not include energy consumption in manufactured IBS components and transportation to construction site.
Omar & Doh (2013)	Discussion methodology in assessment on embodied energy and carbon emission of building and construction processes in Malaysia	Due to increasing demand of building materials and various alternatives of building technology, the acceleration of environmental impact is inevitable. Recent research shows that LCA has shifted from pollution prevention to assess environmental impact of construction materials and components.	Find out that embodied energy and carbon emission important to achieve sustainability and demonstrate that different energy path such as the capital and services affecting a product.	The study use IBS as case study and discussed more on energy path in life cycle of IBS components from manufacturing to installation on site and conventional as base case studies. However, all the issues has been discussing in general and not touch in detail on transportation involve. Method used data from oversea.
Haynes (2013)	Calculation of embodied energy within life cycle analysis of Residential Buildings	Reduction in energy demand relate to the cost of living. Life cycle energy analysis clearly identifies strategies for reducing both energy demand and gas emission. Therefore, important on contributions of embodied energy need to be discussed in detail and also estimation of embodied energy in buildings.	`Recommendation of the study – breakdown on calculation of embodied energy – need to consider transportation, assembly, renovation and demolition	Not touch on energy used during life cycle of IBS components and relation to time, quality and cost but discussed in detail on breakdown on calculation of embodied energy.
Manish K. *et al*. (2013)	Review the identification of parameters for embodied energy measurement	Current interpretation on embodied energy was found unclear. It gathers opinions to identify differing parameters so that development of a consistent and comparable database can be facilitated.	Come out with the parameters which standardized approach to data collection of embodied energy  Besides, it also highlights the benefits in reducing energy in the construction industry in terms of embodied energy.	The study only reviewing on current interpretation and parameters of embodied energy to set out the system boundary for building materials. Therefore, the further study is needed to look into different construction techniques and relationship towards time, cost and quality.

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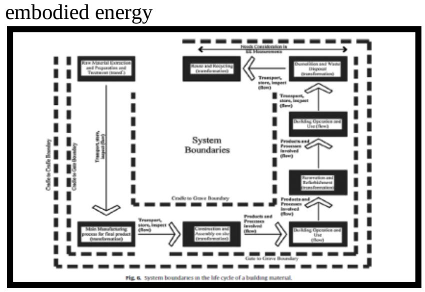
Manish K. *et al*. (2013)	Review the identification of parameters for embodied energy measurement	Current interpretation on embodied energy was found unclear. It gathers opinions to identify differing parameters so that development of a consistent and comparable database can be facilitated.	Come out with the parameters which standardized approach to data collection of embodied energy  Fig. 6. System boundaries in the life cycle of a building material. Besides, it also highlights the benefits in reducing energy in the construction industry in terms of embodied energy.	The study only reviewing on current interpretation and parameters of embodied energy to set out the system boundary for building materials. Therefore, the further study is needed to look into different construction techniques and relationship towards time, cost and quality.

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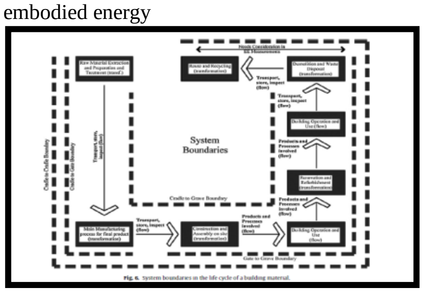
Manish K. *et al*. (2013)	Review the identification of parameters for embodied energy measurement	Current interpretation on embodied energy was found unclear. It gathers opinions to identify differing parameters so that development of a consistent and comparable database can be facilitated.	Come out with the parameters which standardized approach to data collection of embodied energy  Fig. 6. System boundaries in the life cycle of a building material. Besides, it also highlights the benefits in reducing energy in the construction industry in terms of embodied energy.	The study only reviewing on current interpretation and parameters of embodied energy to set out the system boundary for building materials. Therefore, the further study is needed to look into different construction techniques and relationship towards time, cost and quality.

■5.0 CONCLUSION

The perspective of stakeholders in construction industries towards application of IBS should be evolved through energy consumption assessment. Realization on benefits from implementation of IBS when compared to conventional building system will guide in decision making at early stage of design. In addition, the outcome of this study will be the platform for IBS to be recognized and well defined in the construction industry. In conclusion, IBS has a great potential in lowering the embodied energy and carbon emission which will minimize the quantity of construction material used and at the same time lower the total construction cost.

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