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Towards Safe Cities & Resilient Communities

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TOWARDS AUTOMATION AND ROBOTICS IN INDUSTRIALISED BUILDING SYSTEM (IBS): A LITERATURE REVIEW

Mohd Najib Abd Rashid [1]*, Mohd Rofdzi Abdullah [2], Dzulkarnaen Ismail [3], Muhammad Naim Mahyuddin [4]
[1,2,3,4] Department of Building, Faculty of Architecture, Planning and Surveying, Universiti Teknologi MARA, Perak Campus, Seri Iskandar 32610 Perak,Malaysia
Email of corresponding author *: mohdn613@perak.uitm.edu.my

Abstract **-** The construction industry demands effective construction organisations, efficient construction processes and innovative construction techniques to effectively compete under increasing globalisation, market competition and technological advancements in the twenty-first century. The problems associated with construction such as decreasing quality and productivity, labour shortages, occupational safety, and inferior working conditions have opened the possibility of more revolutionary solutions within the industry. One of the prospective options is in the implementation of innovative technologies in construction such as automation and robotics is through the Industrialised Building System (IBS), which has the potential to improve the industry in terms of productivity, safety and quality. This is the review paper describe on the potential used of Automation and Robotics through Industrialised Building System as well as to adopt the concept of Industrilisation towards the better future of Malaysian Construction Industry.
Keywords **-** Industrialised Building System, Industrialisation, Automation and Robotics

1 INTRODUCTION

According to Thanoon et al., (2003) the IBS agenda in Malaysia begun in the early 1960's when the Ministry of Housing and Local Government of Malaysia visited a number of European countries and evaluated their housing development programmes. Following the successful visit, the government initiated an IBS pilot project in 1964 which aimed to speed up the delivery time, and to build affordable and quality houses. The statement also supported by Kamar, Alshawi & Hamid (2009) as the introduction of Industrialized Building System (IBS) is to cope with an increasing request of affordable housing, solving issues associated with foreign labours and improving image, quality and productivity of construction industry. With the era of 4th Industrial revolution the construction industry also has to move forwards. Recently The Construction Industry Transformation Program (CITP 2016 – 2020) reported that Malaysian construction industry productivity level is one of the lowest in the economy and as compared with develop economies, with slow uptakes on technology and modern practices such as Building Information Modelling, Automation and Robotics to increase productivity (CIDB, 2015). The potential capability of Automation and Robotics is to generate higher output at a lower unit cost; with better quality products could in turn improve global competitiveness. The construction work site could, theoretically, be contained in a safer environment, with more efficient execution of the work, greater consistency of the outcome and higher level of control over the production process (Mahbub, 2008).

2 LITERATURE REVIEW

2.1 Overview of Automation and Robotics in Industralized Building System (IBS)

In Malaysia construction industry, the best ways to implement the Automation and Robotics is through the Industrialized Building System as the system has a clear direction in adopting those technologies. Industrialized Building System was define by the Construction Industry Development Board (CIDB) as a construction technique in which components are manufactured in a controlled environment (on or off site), transported, positioned and assembled into a structure with minimal

additional site works (CIDB, 2003). Ismail and Abdul Rahim (2007) defined IBS as a set of interrelated elements that act together to enable the designated performance of a building. In a wider sense, it may also include various procedures (technological and managerial) for the production and assembling of these elements for this purpose. Abdullah & Egbu (2009) define IBS as a method of construction developed due to human investment in innovation and on rethinking the best ways of construction work deliveries based on the level of industrialization. On the macro construction perspective, IBS should be looking on to the bigger picture as it adopting the degree of industrialization. Richard (2005) stated that Industrialization is based on quantity. An important market can justify the investment in strategies and technologies capable, in return, of simplifying the production of complex goods. That is the very nature of industrialization: the production of a large quantity of units divides that investment into small (eventually infinitesimal) fractions, thereby reducing the fixed production costs of a single unit down to marginal amounts and getting the product available to a large audience. Richard (2005) also explains the degree of industrialization in Industrialized Building system. The first four are prefabrication, mechanization, automation and robotics. They do require an important investment in production facilities, but very often, they duplicate the traditional processes, merely transferring the tasks from the craftsperson to the machine. The fifth degree, which we will call reproduction, implies research and development of innovative processes truly capable of simplifying the production.

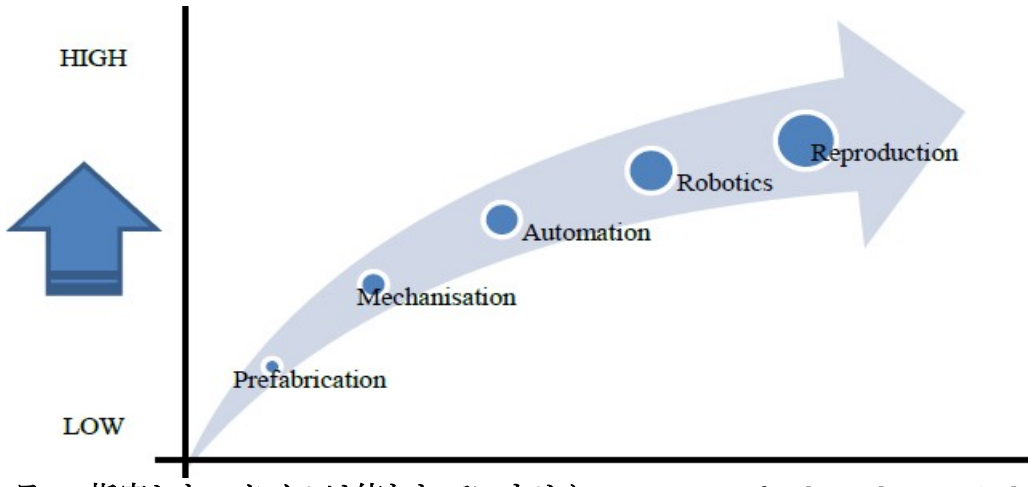

Figure エラー! 指定したスタイルは使われていません。 : Degree of Industrialisation (Adopted from Richard, 2005)

A study conducted by Mahbub (2012) to measure the implementation of automation and robotics showed that only 12% who uses the technologies on-site (majority in Earthwork)'', 12% use in the design stage, 13% in costing and tendering and 13% in project management. The study shows the implementation of automation and robotics is still low. Lundeen et al., (2017) stated that the construction industry is often considered an industry of slow change, hazardous conditions, old technology, and stagnant productivity levels. Robotics in IBS offers the potential to change that by reducing construction project cost, shortening project lead time, improving construction quality, and improving worker safety (Kapliński et al., 2002). However, the construction industry's adoption of robotics has proven slower than other industries, such as manufacturing. This is largely attributable to technological challenges arising from the unique characteristics of the construction industry (Mohd Amin et al., 2017). Yunus et al., (2017) also stated that the problem in applying modern methods of construction not only an issue in Malaysia but also plaguing contractors in developed countries such as the United Kingdom and Australia. For example, a study through interviews and questionnaires on perspective of UK house builders using offsite modern method of construction were conducted by Pan et al., (2007), found that the United Kingdom house builders are still using the conventional method to determine the cost, quality and productivity in deciding whether to use offsite technologies.

2.2 Industrialisation of Construction Industry

The concept of industrialization has put forward the construction industry to increase productivity and deliver quality construction end products. Industrialisation is the combination of a large market to divide into fractions the investment in strategies and innovation, in return, of simplifying the production and, therefore, reducing the costs. Industrialisation is defined by Musa et al., (2016); Shamsuddin et al., (2013) as modernisation process through the development of innovations, machinery, technologies and modern methods of production. Industrialisation usually requires offsite plant or factory where the work is centrally organised; production operations are mechanised and focused on mass production. (Warszawski, 2005) define Industrialization as a process of an investment in equipment, facilities, and technology with the purpose of increasing output, saving manual labour, and improving quality. Rashidi & Ibrahim, (2017) on the other hand stated that industrialization can be considered as a business strategy that transforms the traditional construction process into a manufacturing and assembly process by embracing new and advanced technologies, engaging people, and translating clients' needs into building requirements. They also stated in one major study in 2012. Mohammad et al., (2016) conclude that the IBS players in Malaysia should start looking seriously at the possibility of moving up to the higher degree of industrialisation as mentioned by Richard (2005) in Figure 1 which incorporates prefabrication, mechanization, automation, robotics and reproduction in the process. Developers should also be encouraged to participate and involved in promoting, investing and constructing new housing schemes that adopts the Modular System that has many strong points and benefits especially in promoting sustainable, high quality and much desired end products which thereafter will lead to quality living. To gain a clear understanding on the concept of automation and robotics and its application in the construction industry, there is a need to understand the concept of industrialization which promoting automation and robotics through the IBS

2.3 Degree of Industrialisation

The Degree of Industrialisation study by Richard (2005) which is prefabricated, mechanization, automation, robotics and reproduction is in line with the Malaysian government's vision to be a developed nation by 2020, to push forward the use of innovative technologies in most industries including the construction industry (Musa et al., 2016).

2.3.1 Prefabrication

Prefabrication is define by Azman et al., (2012) as a complete process system of construction works where almost all the component structures is manufactured onsite or offsite, and the product is transported to the site and to be installed in the high precision coordinate joint as well as achieve high quality works, and accelerate the time of completion of the projects. The massive used of prefabrication is After the World War II, prefabrication of building was the best method to fulfill the housing demand. The houses are constructed in a controlled factory environment based on the national building code specified by the US and the entire structure is transported to the site and installed onsite (Azman et al., 2012). But to ease understanding on prefabrication Richard (2005) suggested "Prefabrication starts with pre which means before and/or elsewhere. In the building industry, prefabrication generally implies building (in a factory) components or full modules very similar to the ones done on a traditional construction site, very often using the same processes and the same materials".

2.3.2 Mechanisation

Richard, (2005) define Mechanisation comes in whenever machinery is employed to ease the work of the labour (power tools, etc.). Usually, prefabrication will be accompanied by some mechanization. For instance, the modular housing manufacturers will use pneumatic hammers, rolling bridges, etc. Mechanisation can be described as the process of applying the use of mechanical plants in carrying out a task. The level of mechanisation is defined as the number of plants and equipment employed or the number of activities carried out by mechanical plants in an operation. It can also be defined as the act of implementing the control of equipment with advanced technology, usually involving electronic hardware (Kamaruddin et al., 2016).

2.3.3 Automation

Kamaruddin et al. (2016) defined automation as "the replacement of human labour by machines; or the operation of a machine or device automatically, or remote control". Automation can also be defined as a self-regulating process performed by using programmable machines to carry out a series of tasks. Automation goes one step further than mechanisation in that the process is not only supported by machines, but these machines can work in accordance with a programme that regulates the behavior of the machines (Mahbub, 2008). Study by Andritsos & Perez-Prat (2000) described that automation is basically accepted as the technology concerned about the application of complex mechanical, electronic or completed based systems for the operation and control of production or manufacturing.

2.3.4 Robotics

The word robot initially came from a Czech play called Rossum's Universal Robots, published in 1920 and premiered in Prague in 1921. The author, Karel Capek (1890- 1938), borrowed the word robot from the slavic robota, meaning a forced labour (Gossin, 2002). According to Mahbub (2008) robotics is a discipline overlapping artificial intelligence and mechanical engineering. Mahbub, (2015) define robotics Self-governing mechanical and electronic devices that utilize intelligent controls to carry out construction tasks and operations automatically. The construction work tasks and operations are regulated through programmable controls and sensors which are set up as a series of individual computer-controlled or robotic equipment with electro-mechanical links. According to Bock (2006) the first construction robots had been designed in the beginning seventies in order to increase the quality in prefabrication of modular homes in Japan and the late 70's planning started for use of robots in construction sites. In the 80's the first construction robots appeared on sites and in the 90's, integrated automated building construction sites had been developed and implemented.

2.3.5 Reproduction

The word reproduction is borrowed from the printing technology, obviously not from biology. The analogy with printing will serve hereafter to extrapolate a methodology bringing productivity and economy in architecture. Reproduction is the introduction of an innovative technology capable of simplifying the multiplication of complex goods. The purpose of reproduction is to short cut the repetitive linear operations which are the trademarks of the craftsmanship approach, like nailing wood studs, laying bricks, etc. Instead of investing straight into machinery, reproduction is first calling upon research and development for ideas to generate a simplified process. Reproduction is not necessarily available as a down- right option; it usually accompanies some of the other degrees of industrialisation (Richard, 2005). Musa et al., (2016) stated that the real message of reproduction is to give priority to ideas rather than to machinery. A clear vision of the performance expected from the product. The ability to imagine a simplified topology and the knowledge of the processes presently available will lead to solutions capable of delivering quality architecture to the mass majority of people.

2.4 Current Development in Industrialised Building System (IBS)

Lots of previous research has focusing on the Critical Success Factors CSFs in the Industrialised Building System. Kamar (2011) for example has listed the success factors toward implementation of IBS in general and produce a framework to successful adoption of IBS which depending on four factors which is strategy, people, process and enabler. Nasrollahzadeh, Marsono & Tap (2016); Yunus et al. (2017) in their his study has establish the CSFs on the lean approach to IBS focusing to maximizing the productivity which is classifieds in seven groups namely; just-in-time factors, total quality management factors, business process reengineering factors, concurrent

engineering factors, last planner system factors, teamwork factors and value based management factors. Hadi, Muhammad, & Othman (2017) has conducted a CSFs study in Sarawak focusing on the implementation of IBS and has concluded the incentive, number of manufacturer, logistics and payment method is the CSFs of IBS in Sarawak. M. Nawi et al., (2016) have conducted a study on CSFs of IBS focusing in team integration practice. They have concluded based on the Focus Group Discussion (FGD) among construction industry stakeholders revealed the main barriers to the IBS adoption in Malaysia's construction industry to be poor integration among project stakeholders during the planning and design phase. This was due to the domination of the fragmentation concept of the traditional method. Musa et al., (2017) in their study has provided a Framework for modular construction based on IBS approach that focusing in quality and promoting sustainability in construction. They urged that the success factor in integration of modular construction which is design, manufacturing and construction is people, technology and process. Ariffin et al., (2017) have conducted a study on the economics of scale (EOS) for IBS and come out a framework on the EOS based on the associated factors that affect Economy of Scale (EOS) and their relationships in catalyzing the IBS manufacturer especially precast concrete as the scope of study to continue their business in the construction industry. Azam Haron et al., (2015) have developed a model to enhance adoption of IBS based on the quality factor and customer satisfaction in housing project. Mahazir (2015) has conducted study on IBS and focusing on the sustainable issues. He urged that by using IBS many of the issues pertaining to sustainable will improved. Yunus et al., (2017) in their study of developing a model on the quality of IBS. He stated that the quality is one of the successes of IBS and his study will provide a fundamental in developing a guideline for construction players in integrating TQM in IBS application effectively. Yunus et al., (2015) have provided a conceptual framework based on the contractor satisfaction in IBS. The developed framework is expected to help the project team in performing IBS projects more efficiently, ensuring the quality meet the standards and encouraging effective communication between participants. There seem a limited of study has been conducted to identify the critical success factor to automation and robotics in IBS. Table 1 show the summary of studies conducted related to critical success factors in industrialised building system.

Table 1 Current Study in Industrialised Building System IBS

Bil	Previous Study	Cobb, 2001	Mahbub, 2008	Kamar, 2011	Kamaruddin et al., 2013	Haron et al., 2015	Azam et al., 2015	Mahadzir, 2015	Yunus et al., 2015	Luo et al., 2015	Ang et al., 2016	Mahbub, 2016	Shukor et al., 2016	Nasrollahzadeh et al., 2016	Nursal et al., 2016	Tamrin et al., 2016	Nawi et al., 2016	Franco et al., 2016	Yunus et al., 2016	Yunus et al., 2016	Salah et al., 2016	Fakhimi et al., 2016	Yunus et al., 2017	Hadi et al 2017	Musa et al., 2017	Ariffin et al., 2017	Yunus et al., 2017	Xue et al., 2017	Gan et al., 2017
1	CSFs of Readiness in IBS										*					*													
2	Risk factors of IBS									*																			
3	Quality factors of IBS					*																							*
4	Supply chain in IBS												*																
5	CSFs to IBS			*																				*					
6	CSFs to lean approach to IBS													*									*						
7	CSF to quality and sustainability in IBS						*	*																	*		*		
8	CSFs to Team Integration in IBS																*	*				*							
9	CSFs to automation and robotics in IBS																												
10	CSFs to economic of IBS																									*		*	
11	CSFs to contractor satisfaction in IBS								*																				
12	Barrier to automation and robotics in construction		*																										
13	Automation and Robotics in construction																												
14	Performance of automation and robotics in construction	*																		*									
15	Decision making choosing IBS														*						*								
16	Motivational factors of IBS																		*										
17	Mechanisation and Automation				*							*																	

3 RESEARCH METHOD

This research is still at the initial stage; therefore, the information presented in this paper is primarily based on the thorough review of the relevant literature within the scope of industrialisation and Industrialised Building System (IBS). In the course of the literature review, the definition, characteristics, benefits, and related issues of automation and robotics as well as IBS in the construction industry is examined and highlighted. All the data and information gathered directly from libraries, books, articles and other printed materials searched in the international and national journals, proceeding and bulletin.

4 CONCLUSIONS

The review in this paper describes current and potential used of automation and robotics through Industrialised Building System (IBS). As the government effort to strengthen the usage of IBS, the adoption of the Industrialisation concept as propose by the Richard (2005). It is essential as it has a very clear path on the direction of Malaysian construction industry would be.

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