The Understanding and Readiness of Malaysian Contractors to Apply Additive Manufacturing Technology in Construction Industry

Muhammad Zamir Ismail[1], Zul Zakiyuddin Ahmad Rashid[2], Hamimah Adnan[3], Norazian Mohamad Yusuwan[4]

[1,2]School of Housing Building and Planning, Universiti Sains Malaysia, Gelugor, Penang, Malaysia
[3,4]Centre of Studies for Quantity Surveying, Universiti Teknologi Mara, Malaysia

[1]muhammadzamirismail@gmail.com
[2]zulzaki@usm.my
[3]mimad856@gmail.com
[4]azianyusuwan@gmail.com

***Abstract*— One of key technology in industrial revolution 4.0, additive manufacturing, has a potential great influence to construction industry in the future. Construction players especially contractors are expected to involve widely and directly with the technology but their understanding about the technology are unidentified. In the same time, Malaysian's construction industry appears lack to embrace for technology that might lead the local industry be uncompetitive if it cannot engage with the new technology. The research is prepared to study the contractors understanding and readiness of additive manufacturing within the scope of a Malaysian state's construction industry, Penang. Literature reviews have been conducted to understand about the additive manufacturing technology, its impact and future prospect in construction industry and further produced a set of survey questions, distributed to contractors and analyzed using mean score. The outcome has identified that the local contractors do not have understanding and not ready for addictive manufacturing technology. The study suggested that the authorities can learn the AM adoption rate among contractors and further formulate strategies for them to venture into the technology.**

***Keywords*—** *Additive Manufacturing, Construction, 3D Printing, Industrial Revolution 4.0*

1. Introduction

The worlds we live today have seen momentous and rapid changes in the industrial sectors. These changes are fuelled by inventions and innovations that give birth to revolutions in industry, progressing over time until the current Fourth Industrial Revolution or Industrial Revolution 4.0 or IR4.0 or even simply named as Industry 4.0. It is significantly affect every aspect of human life [1] and will deeply impact human kind in terms of how they work, live and communicate to one another [2]. Its scale of influence is too big to ignore, global rather than local, unprecedented breadth and depth (WEF, 2017b) and able to manipulate the economy, business, society and individual in both national and international stages [2]. To a further degree, the latest revolution may bring the unthinkable moment that can realized science fictions and illusion which previously beyond reach and impossible to happen. Therefore, considering the massive influence brought by the revolution, it will be appropriate now to study about the revolution sphere, its key drivers and impacts that will shape the human kind in the future. A survey by WEF identified the technological driver of change in the fourth industrial revolution elements [3]. The drivers of change can be considered as the key element in the IR4.0. Accordingly, AM is listed as one of the technological driver of change in the fourth industrial revolution elements. The result is presented in Table 1.

Table 1: Technological Driver of Change

Driver of Change / Key Element in Fourth Industrial Revolution	Definition/ Explanation
Mobile internet and cloud technology	The mobile internet enables efficient way to deliver services and opportunities to increase productivity. The cloud technology permit minimum or zero local software or processing power deliver applications and enabling the fast flow of internet-based service models
Advances in computing power and Big Data	Realization of full technological advances potential will require suitable systems and capabilities such as Big Data to allow a record flood of data generated by advance in computer power
New energy supplies and	Innovative energy technologies and supplies such

technologies	as hydraulic fracturing (fracking) and renewables, interrupt the global energy field and disrupt existing players with deep and complex geopolitical and environmental consequences
The Internet of Things (IoT)	The use of remote sensors, communications, and processing power in industrial equipment and everyday objects that will release a massive volume of data and the chance to see designs system and pattern on an unprecedented scale
Crowdsourcing, the sharing economy and peer-to-peer platforms	Peer-to-peer platforms allow firms and individuals do things that formerly required large-scale organizations.
Advanced robotics and autonomous transport	Advanced robots with improved senses, skill, and cleverness can be better than traditional human workers in manufacturing and growing number of service jobs such as maintenance and cleaning. It is now possible to create partly or completely autonomous vehicles
Artificial intelligence and machine learning	Advance in artificial intelligence, machine learning, and natural user interface (e.g. voice recognition) are making it possible to automate knowledge-worker tasks
Advanced manufacturing and 3D printing (Additive Manufacturing)	3D printing (building stuffs layer by layer from a digital master design file) permits customize production and has far-ranging consequences for production networks and global supply chains
Advanced materials, biotechnology and genomics	Recent advance in genetics could have deep impacts on industry such as medicine and agriculture. The manufactured synthetic molecules through bio-process engineering will be critical to pharmaceuticals, plastics and polymers, biofuels, and other new materials and industrial processes

Sources: (WEF, 2016b)

2. Problem Statement

According to a report by World Economic Forum (WEF) in collaboration with BVL International, IR4.0 disrupt the supply chain and transform all end-to-end stages in production and business model in most sectors of the economy [4]. For example, one important component in IR4.0, namely Additive Manufacturing (AM) technology that can produce home-grown product will lead to a world whereby worldwide become domestic, mammoth become miniature, and extensive supply chain will be narrowed down [5]. The ultimate ability to eliminate some chains in the current supply chain raise the eyebrow and shall be handle accordingly. Generally, in Malaysia, the Government through the Ministry of International Trade and Industry (MITI) has identified and oversee nine main pillars of the Industry 4.0 i.e. Autonomous Robots, Big Data Analytics, Cloud Computing, Internet of Things (IoT), Additive Manufacturing (3D Printing), System Integration, Cybersecurity, Augmented Reality and Simulation [6]. Besides, in order to improve the status of the country while realizing the challenges brought by IR4.0, the Government has introduced National Transformation 2050 or TN50, which the aim to prepare the nation to be the top of developed country in terms of economic, social welfare and innovation [7]. According to the then Malaysian Prime Minister Dato' Seri Najib Razak, the TN50 would prepare the people to face the Fourth Industrial Revolution [8]. This statement is in-line with the global acceptance and practices towards IR4.0. However, despite the government efforts, the local industries are left behind and still ranging in Industrial Revolution 2.0 to 3.0 status with some progresses in electric & electronics (E&E), aerospace and automotive sectors which are more advance toward industry revolution 4.0 [9]. Giving past experiences in perspective, the utilization and application of IR4.0 will face challenges in the Malaysian industries especially in the construction industry. According to Ahmad Ibrahim, the Malaysian construction industry itself suffers lack of responsive towards technology [10]. Further illustration to the lack of response to technology can be seen in the utilization of Industrialize Building System (IBS) which was lower than expected although the Government has made huge campaign for it [11-14]. A survey conducted by Mui et. al. to understand the internet usage in Malaysian Construction Industry suggested that the respondents not fully utilize the advantages of the technology [15] thus denied the very basic element in IR4.0 i.e. Information Technology (IT) [16]. Besides, little knowledge of technology, limited resources and poor integration between application and/or organisation were the causes of lagged behind the other industries [17-18]. According to

Haron et. al., the construction industry cannot afford to stay in future business while do today's works with yesterday's methods [19]. The delay to familiarize and adapt technologies will make the industry left behind and become uncompetitive to be in the local and global market as required by the Government. Therefore, it is very important to learn, understand and adapt to the technological revolution to ensure greater development in the future and no one is being left behind. This paper is meant to study the understanding and level of readiness among Contractors in facing the enormous impact of IR4.0, focusing on one key element of IR4.0, namely Addictive Manufacturing (Multi-Dimensional Printing) technology. Focus on AM is due to its prospect to interrupt current supply chain such as reducing labour resources, expensive start-up involvement, extra formwork and so on[20].

2.1 What is Additive Manufacturing (AM)?

Additive Manufacturing (AM), as opposed to traditional formative and subtractive manufacturing, is an advance manufacturing processes that refers to a procedure to assemble materials to make objects from 3-Dimensional (3D) model data, usually layer after layer [21]. AM involve the processes of transforming simulated solid model information into physical models in a fast and easy way [22] and able to print complex form of geometry with the absent of any tools, dies and fixtures [23]. It also known as direct digital manufacturing, rapid manufacturing, solid freedom fabrication and rapid prototyping, [24]. Besides, the AM is widely referred as 3D Printing in general term [25] although its scope is wider than the 3D Printing. Due to its ability to enable customized material properties and create complex form of geometries, AM has gained significant industry and academic interest [26]. AM has been applied in various industries such as aerospace, energy, automotive, biomedical, consumer goods and other industries [27]. A precedent attempt to utilize cement-based materials was conducted in 1997 in order to investigate potential effectiveness of AM in construction automation. The result was positive as it suggests AM is effective and compatible for small construction such as residential houses [28]. To represent AM in construction, some researcher has termed it as "Additive Construction" which means the method of assembling materials to generate construction by using 3D model data [25]. In 2012, a number of entities exploring 3D printing for construction burst into seemingly-exponential growth, move forward from the previous linear progression [29]. At the same period of time, there are three available large-scale AM techniques related to construction and architecture namely Contour Crafting, D-Shape (Monolite) and Concrete Printing [30]. All three techniques were founded by University of Southern California, British Monolite Company and Loughborough University respectively [32]. As suggested by the researchers, all three processes proven to be appropriate for construction and/ or architecture applications and successful in manufacturing significant size of components [31]. AM in the future can be integrated with recent technology of Building Information Modelling (BIM) [30, 33] through BIM-based automated construction system (BIMAC) and has potential to improve conventional construction method. AM can unleash full potential to realize the construction provided continuous improvement being made to deliver new and faster processes, new materials, data on mechanical properties and assured quality [32].

3. Research Objectives

Given the rapid digitalisation of construction practices, it is submitted that AM will play an integral part in the process. As such, this paper is meant:

a. To identify the understanding of additive manufacturing applications in construction industry among Contractors.

b. To identify the readiness of Contractors to apply additive manufacturing technologies in the construction industry.

4. Methodology

It is essential to decide a method used for a set of a research problem in a research design throughout the research processes [35]. Therefore, to choose the best method to resolve the problem and achieve the objectives, a deep focus on research objectives as well as research questions have been given. As a result, a set of questionnaires were generated to collect data from respondents and to gain as much as accurate information. This study consumed both primary data and secondary data in order to get the best result. For the primary data collection, a close-ended questionnaire with utilization of "Likert Scale" which is good choice to rank and measure is used in order to get the data [35]. Besides, secondary data by means of literature review from books, journals etc. is used to understand the research topic with focus on technical aspects then developed to provide input in preparing the questionnaires. Primary data is obtained by questionnaires from a random sampling in a target population. The rationale of using this method is because it can save lots of time and resources to complete the data. Moreover, the questionnaires can be distributed easily by using email or by-hand to the respective respondents. Furthermore, questionnaires enable respondent to be focus on given topic and slim down their choices of answers.

A pilot survey is conducted prior to actual survey exercise to ensure the questionnaire is valid in terms of construct and phrases used. The respondent's ability to understand and answer the questions will determine if the construct and phrases are valid or not. The study is conducted in Penang, a northern state in Malaysia. Penang meets the requirement due to its size, increasing construction activities and importance to the nations' development specifically in the northern region of Malaysia. To illustrate, according to Datuk Lim Kai Seng, the Penang Master Builders and Building Materials Dealers' Association (PMBBMDA) immediate past president, the Penang construction industry has been in rising trend from year 2016 to year 2017 with the value of jobs generated in the first six month of 2017 reached RM2.86 billion instead of the same period in year 2016 that only gained RM1.68 billion [36]. Besides, the local state government willingness to support and depend more on construction industry due to its growing demand will further strengthen and stabilize the Penang construction industry [37]. The target population for data collection is the G7 Contractors registered with Construction Industry Development Board (CIDB) in Penang. The rationale of choosing the G7 Contractors because they were expected to first-hand use the AM technology in Penang due to high initial capital and sophisticated approach requirement to apply AM technology. G7 Contractor is a class of contractors that possesses the highest standard in terms of capitals, workforces and facilities that enable them to bid and tender for a limitless project value. A search on Centralized Information Management System (CIMS) application provided by CIDB has found a total of 491 G7 Contractors registered with CIDB in Penang [38]. The questionnaires were distributed to all reachable contractors in the list to their official or registered email. 15 respondents replied and answered the questionnaires. For data analysis, Statistical Package for Social Science software (SPSS) was used for reliability test, frequency analysis and mean score. Frequency analysis was used to identify the regularity among the respondents in answering the questionnaires. Mean score was used to identify the respondents' central tendency towards the answers.

5. Findings

5.1 Background of the respondents

Designation of Respondents responded to the questionnaire are as follows. Quantity surveyor was (27%), followed by project manager and engineer (20% respectively), assistant project manager and supervisor (13% respectively) and director (7%). Accordingly, all respondents involved directly in construction project, furnishing reliable data for the research. Most respondents have 6-10 years of experience (34%), followed by respondents with 16-20 years of experience (33%), 21-25 years of experience (20%) and 11-15 years of experience (13%). The minimum range of experience is 6 to 10 years, indicated that the respondents have sufficient understanding on how construction project operates.

5.2 Understanding of additive manufacturing (AM)

5.2.1 Application in architectural field

From the reply, 66.7% of the respondents understand the ability of AM to be applied in architectural field while the other 33.3% do not understand it. The mean score of 3.80 shows that the respondents' tendency between not sure and agree whether AM that can be applied in architectural field.

5.2.2 Application in construction

The findings indicated that 33.3% of the respondents understand the ability of AM to be applied in construction while the other 66.7% do not understand its ability. The mean score of 3.33 show the respondents' tendency between not sure and agree about AM whether it can be applied in construction industry.

5.2.3 Material useable in AM-concrete

From the findings, 33.3% of the respondents understand that concrete can be used as AM material while the other 66.7% do not understand the usability of concrete in AM. The mean score of 3.07 show the respondents' tendency between not sure and agree that concrete can be used as AM material.

5.2.4 Material useable in AM –steel

From the data, 26.7% of the respondents understand the usability of stainless steel in AM process while the other 73.3% do not understand the usability of stainless steel in AM. The mean score of 3.00 show the respondents' tendency, being not sure about stainless steel usability in AM process.

5.2.5 AM usage to build multi-storey building

Data indicated that 20.0% of the respondents understand the usage of AM to build multi storey building while the other 80.0% do not understand such usage. The mean score of 2.93 show the respondents' tendency between disagree and not sure that AM can be used to build multi storey building.

5.2.6 AM usage to build functional bridge with stainless steel

Findings indicated that 6.7% of the respondents understand the ability of AM to build functional bridge with stainless steel while the other 93.3% do not understand the subject matter. The mean score of 2.60 show the respondents' tendency between disagree and not sure whether AM can be used to print functional stainless steel bridge.

5.2.7 **Concrete printing enabling on-site printing in AM**

Data indicated that 33.3% of the respondents understand the process of concrete printing that enable on-site printing in AM while the other 66.7% do not understand it. The mean score of 3.20 show the respondents' tendency between not sure and agree whether concrete printing will enable printing on site.

5.2.8 **AM integration with BIM**

From the findings, 80.0% of the respondents understand the possible integration of AM with BIM while the remaining 20.0% do not understand it. The mean score of 4.00 show the respondents' tendency on possible AM and BIM integration.

5.2.9 **Adequate knowledge of AM**

Findings show that 100% of the respondents admitted that they do not have enough knowledge in AM. The mean score of 1.87 show the respondents' tendency between strongly disagree and disagree that they possessed sufficient knowledge in AM.

5.2.10 **Readiness to further equipped with AM knowledge**

The survey indicated that 80.0% of the respondents are ready to further equip themselves with AM knowledge while the other 20.0% do not ready do so. The mean score of 3.93 show the respondents' tendency between not sure and agree on learning more about AM.

6. Conclusion and recommendation

The findings indicated that majority of the respondents do not understand AM application in the construction industry and the contractors are not ready to apply AM in construction works. By identifying the understanding and readiness of contractors towards AM application in construction, the construction players especially the authority such as CIDB and Works Ministry can learn and know the AM adoption rate and tendency by contractors and further formulate strategies to enable and allow them to venture into this technology. Among the effort to boost the application of AM among contractors is by providing incentive for AM technology adoption and application. Continuous learning process on AM might be introduced in existing Continuous Company Development program (CCD) and Continuous Professional Development program (CPD) by CIDB.

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