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Barriers and Impact of Mechanisation and Automation in Construction to Achieve Better Quality Products

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Abstract

The major concern to the construction industry in general, would be the decreasing quality and productivity of end products; labour shortages; occupational health and safety; and allowing work to be performed where people cannot do. This paper discusses how the quality of life may be achieved by tackling the barriers and their impact to this initiative which could improve the industry in terms of productivity, safety and quality. This will also ensure the harmony between the environment and energy management with productivity enhancement for better quality products that could lead to better quality of life for the end users.

Keywords: Quality; products; mechanisation and automation; construction

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1. Introduction

The construction industry is large, pervasive and acts as the bellwether of economic growth. Periods of national prosperity are usually associated with high levels of construction activity (Clough et al., 2000). The construction process requires the contribution of many different stakeholders and involves various processes, different phases of work, and a great deal of inputs from both the public and private sectors (Abdul-Aziz and Mohmad, 2010). The construction industry is complex and has become more so during the late 20th century. This complexity is due to the failure of planning mechanisms and the apparent inability of plans to represent the reality of on-site construction. The construction, housing, and property sectors play an important role in the Malaysian economy.

One option to address the construction industry problems is to move towards industrialisation by adopting mechanisation and automation in the construction industry. In the construction industry, time is money. Since mechanisation and automation are considered faster than humans at work operations, contractors should expect to complete projects sooner when using these technologies. Industrialisation is a part of a wider modernisation process through the revolution and the development of modern methods of production and technology system, mainly factory production (Lessing, 2006). One of the most influential studies on industrialisation categorisation in construction was the work by Roger-Bruno Richard (2005).

Technology is changing and developing around the world at a rate and pace never experienced before. Construction is one of the largest industries in both developing and developed countries in terms of investment, employment and contribution to GDP. Its impact on the environment is considerable across a broad spectrum of its activities. For this matter, the construction organisations have aggressively embraced new technology in order to remain competitive in the current market (Alshawi et al., 2010).

The industry is also struggling to cope with issues related to performance, productivity, environment and health and safety, and to deal with the influx of foreign labour in construction sites. Azman et al., (2010), have stated that in the context of the Malaysia, the construction industry has currently been transformed into a mass production developing the standardisation of products in line with the global market. Furthermore, as mentioned in a study by Mohammad et al., (2014) the construction industry is highly concerned with addressing the evaluation of manufactured products in relation to enhancing sustainability and waste generation.

Therefore, this study aims to learn about mechanisation and automation among industry players regarding barriers and their impact, as well as their knowledge about mechanisation and automation. This study may complement precedent studies and contribute to a better public awareness of mechanisation and automation implementation in Malaysia.

2. Literature review

2.1. Overview of mechanisation and automation

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 (Idoro, 2008). It can also be defined as the act of implementing the control of equipment with advanced technology, usually involving electronic hardware. According to Parker (1989) and Navon (1996) automation is defined 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 (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.

Mechanisation, automation, and robotics have proven the improvement of construction process in all aspects. The most popular advantages of mechanisation and automation in building are: mechanising, robotising and automating construction processes can speed up construction as well as reduce production time and overall cost (Idoro, 2011; Gassel, 2008; Idrus, 2008; Wakisaka et al., 2000; Martinez et al., 2008; Crowley, 1998). Other than that mechanisation and automation can improve working conditions, avoid dangerous work, and allow work to be performed that people cannot do (Gassel, 2008).

Therefore, the mechanisation and automation approach has in many aspects proven to become more sustainable in terms of cost, time and quality. However, the value creation of industrialisation can only be enhanced using appropriate mechanisation and automation manufacturing processes which are different from current conventional projects. Adopting mechanisation and automation will reduce the construction activities on site to just a simple transport and assembly process and thus, becomes less complex. Clearly, if Malaysia wishes to imitate the success of developed countries parallel with the government’s goal, the industry must move forward and the industrialisation of building and the construction sector should be pursued (Kamar, 2012).

2.2. Degree of industrialisation

There are five degrees of industrialisation described by Richard (2005). They are prefabrication, mechanisation, automation, robotic and reproduction (Figure 1). The first four degrees are still influenced by the traditional methods of building. Prefabrication aims rather at the location of the production, whereas the next three degrees (Mechanisation, automation and robotics) aim at substituting labour with machineries (Richard, 2005). According to Kamar et al., (2012), sustainability involves innovation and the adoption of modern method of construction through industrialisation. It is a centrally organised, mechanised and automated production operation and focuses on mass production.

![Fig.1 Degree of industrialisation](Source: Richard, 2005)
Prefabrication is a manufacturing process that takes place at a specialised facility, in which various materials are joined to form a component part of the final installation. Mechanisation comes in whenever machinery is employed to ease the workload of the labourer. Automation is a situation when the tooling (machine) completely takes over the tasks performed by the labourer. Robotics comprises the ability of the same tooling which has the multi-axis flexibility to perform diversified tasks by itself. This allows the mass-customisation concept to be applied in the production. Reproduction implies that the research and development of innovative processes are truly capable of simplifying the production process. According to Richard (2005), the first four degrees are still influenced by the traditional methods of building. Prefabrication aims rather at the location of the production where the next three degrees (mechanisation, automation and robotics) aim at substituting labour with machineries (Richard, 2005). The range of this research is between the mechanisation and the earlier stage of automation implementation on site.

2.3. Barriers and their impact

There is a lack of investment in heavy equipment and mechanised construction system due to high capital investment that can hamper the move to industrialisation (Rahman and Omar, 2006). The heavy capital cost of acquiring machineries and technologies in IBS has resulted in an insufficient capacity for contractors to secure projects (Hamid et al. 2008). Kamar et al., (2009) believed that it is extremely hard for new local companies to compete for opportunities with international competitors that are stronger in terms of financial capability, technology or specialisation. Therefore, the contractors prefer not to use industrialisation as they find it easier to stick to the traditional construction methods (Nawi et. al., 2007a and Thanoon et. al., 2003). Adopting a new system means that there is a need for a substantial and sustained budget, allocated time for training of labour and specialised equipment and machineries. Based on previous studies (Kamar et al., 2009; Nawi et. al., 2005), the lack of greater implementation of equipment and machineries proves to be a difficult hurdle that hinders the implementation of industrialisation.

Mahbub (2012) categorised the barriers to the implementation of automation and robotics in construction as high costs/financial commitments in acquiring and maintaining the technologies, fragmented nature of the construction industry which inhibits the implementation of new technologies, the technologies are difficult to use and not easily understood, incompatibility of the technologies with existing practices and current construction operations; low technology literacy of project participants/need for re-training of workers; unavailable locally and difficulties in acquiring the technology and, lastly, the technologies are not easily accepted by workers. From the results of the descriptive and test statistics performed for the barrier variables, it was established that the cost of acquiring the technologies was ranked first, with the majority of participants (87.7%) agreeing that the more expensive the technology, the greater the barrier to implementation. Here, cost considerations were discussed by participants not only in terms of purchasing costs but maintenance and updating costs as well and the construction industry is seen to be fairly price sensitive towards technology utilisation (Mahbub, 2012).

Mahbub (2012) highlighted that the problems associated with the construction industry such as, decreasing quality and productivity, labour shortages, occupational safety and inferior working condition have highlighted the need for innovative solution within the industry, including the push for further use of industrialisation and construction automation and robotics application on site. Rwamamara (2004) cited a journal publish by Swedish (Betongforeningen, 1999) which stated that generally construction efficiency can be improved through the increase of the industrialisation intensity, which includes the following main components: change of the construction site from a workplace of manual handling efforts to a place of assembly. Exerted efforts are reduced through the use of equipment with a higher level of mechanisation. CIDB (2012) listed down several recommendations to encourage the use of mechanisation and
automation in construction: they are expanding the construction machinery manufacturing industry, developing capacity and capability, strengthening research, development and commercialisation, reduction of construction levy for the contractors, a leasing model for buying the machines, financial assistant and tax exemption from the government, and reduction of import duty and sales tax on heavy machineries.

However, the industry has found it difficult to implement mechanisation and automation to fully realise its potential. This is mainly due to the fact that contractors lack the experience in using mechanisation and automation and do not have the knowledge to implement mechanisation and automation in their projects effectively (Tam et al., 2007). There was a strong belief that mechanisation and automation was the key to better building construction and was very important for improving as per design intent and cost planning requirement.

3. Methodology

A qualitative approach was taken to conduct this study through a brainstorming workshop as the primary means of data collection. A well planned and structured workshop was conducted on 23rd April 2014 at the Grand Bluewave Hotel in Shah Alam, Selangor, Malaysia in order to extract initial views and ideas from experts and experienced practitioners in the Malaysian construction industry. Among the objectives of the workshop are to gather initial data on sources of mechanisation and automation in the construction industry. The discussion during the workshop was divided into four groups which were given the same issues, barriers and their impact. Prior to the discussion of mechanisation and automation, four keynotes speech were engaged to provide an overview of the issues of mechanisation and automation, namely; (1) ‘Construction Cost of Industrialised Building System (IBS) Projects: The Influencing Factors’ by academician, (2) ‘Economic Perspective of IBS Manufacturer (Labour/Plant/Material) by Chief Executive Officer (C.E.O) of Teraju Precast, (3) ‘Cost Appraisal Of Mechanisation And Automation In Industrialised Building System (IBS) by academician, and (4) ‘IBS Challenges to reduce cost from the manufacturer’s perspective’ by Chief Executive Officer (C.E.O) of KUB Builders.

A total of 67% response rate was obtained from various government agencies (i.e Public Work Department (JKR), Construction Industry Development Board (CIDB), Construction Research Institute of Malaysia (CREAM), contractors, manufacturers, academia and postgraduate students for the workshop. The profile of the respondents is illustrated in Table 1. Based on the designation and professional background of the participants, it is reasonable to infer that the majority of the participants have sound knowledge on the issues of mechanisation and automation in construction.
Table 1. Profile of respondents

<table>
<thead>
<tr>
<th>Types of Organisation</th>
<th>Expected participants</th>
<th>Participants attended</th>
</tr>
</thead>
<tbody>
<tr>
<td>JKR, Malaysia</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>SPNB, Malaysia</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>CIDB, Malaysia</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>CREAM</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Manufacturers</td>
<td>20</td>
<td>7</td>
</tr>
<tr>
<td>Contractors</td>
<td>50</td>
<td>32</td>
</tr>
<tr>
<td>Academia</td>
<td>25</td>
<td>12</td>
</tr>
<tr>
<td>Students</td>
<td>40</td>
<td>34</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>150</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

The outcomes of the workshop discussion were processed by means of content analysis techniques. Content analysis can be categorised into conceptual analysis and relational analysis. In this study, a conceptual analysis technique was adopted, specifically the thematic analysis concept (Busch et al, 2005). Thematic analysis is a process for encoding qualitative information and combine analysis of the frequency of codes with analysis of their meaning in the context (Boyatzis, 1998; Marks and Yardley, 2004). The data were analysed by means of transcription of information, identification of a set of themes and categories of themes, level of generalisation of the observed themes, organising the codes and finally analysing the results (Ismail and Takim and Nawawi, 2010; Yardley et al, 2006). NVivo Version 8 was used to analyse the data.

4. Finding and discussion

Table 2 and 3 presents the findings of the workshop in terms of the barriers (i.e. cost, skill resources, maintenance and availability of technology) and their impact (i.e., social problem, foreign labour, quality of end product, safety and speed up construction time) in the construction industry of Malaysia. The outcomes are discussed in turn.

4.1. Barriers of mechanisation and automation

There were four (4) barriers identified which are capital cost, skill resources, maintenance and availability of technology. Table 2 shows, that all groups agreed that cost is the major barrier of mechanisation and automation and that the purchase of plants and machineries will increase the capital cost. The mechanisation and automation costs can be very high. The cost of acquiring machinery can reach up to 1 Million Ringgit Malaysia to 2 Million Ringgit Malaysia per purchase. That is only the initial cost. The machines are all imported because there is no local technology as yet that can compete with the quality of the imported machines. Even in China, the industry has yet to produce machineries for construction. This is followed by the maintenance cost whereby mechanisation and automation are expensive to operate and maintain. Therefore, the operational and the maintenance costs must also be considered when machineries are used. This finding is in line with Navon (1996) and Warszawski (1985) who stated that among the cost of mechanisation and automation are the investment cost, repair and maintenance cost, operating cost as well as labour cost. Here, cost considerations were discussed by participants not only in terms of purchasing costs but maintenance and updating costs as well based on the
fact that the construction industry is seen to be fairly price sensitive towards technology utilisation (Mahbub, 2012).

Adopting a new system means that there is a need for a substantial and sustained budget, allocated time for training of labour and specialised equipment and machineries. Based on previous studies (Kamar et al., 2009; Nawi et al., 2005), a lack of equipment and machineries proves to be a difficult hurdle that hinders work in the construction industry. Moreover, some technologies are perceived to be complex, hi-tech and expensive. This is because, the application of mechanisation and automation is desecmed to be a specialized area that requires high technology machines and high skilled operators which will always lead to high overall cost, whether it is produced locally or abroad.

Furthermore, studies by Kamar et al., (2009) established the belief that it is extremely hard for new local companies to compete for opportunities with international competitors that are stronger in terms of financial capability, availability of technology or specialisation. Therefore, the technological cost is the foremost concern in the global industry as the optimum or feasible development costs of using IBS will depend on the number of projects secured the from public and private sectors.

Table 2: The barriers of mechanisation and automation

<table>
<thead>
<tr>
<th>Topic</th>
<th>Group 1</th>
<th>Group 2</th>
<th>Group 3</th>
<th>Group 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barriers</td>
<td>Increased Initial Cost- High costs/substantial financial commitment in acquiring mechanisation and automation.</td>
<td>Increased Initial Cost. Increased Maintenance Cost- Mechanisation and automation are expensive to operate and maintain.</td>
<td>Increased Initial Cost- High costs/substantial financial commitment in acquiring mechanisation and automation.</td>
<td>Financial Cost. Increased Maintenance Cost- Mechanisation and automation are expensive to operate and maintain.</td>
</tr>
<tr>
<td></td>
<td>Increased Maintenance Cost of the machineries and plant- Mechanisation and automation are expensive to operate and maintain.</td>
<td>Skill Resources- The plant /machineries and equipment are not easily accepted by the workers and workers union.</td>
<td>Increased Maintenance Cost- Mechanisation and automation are expensive to operate and maintain.</td>
<td>Skill Resources- The plant /machineries and equipment are not easily accepted by the workers and workers’ union.</td>
</tr>
<tr>
<td></td>
<td>Skill Resources- The plant /machineries and equipment are not easily accepted by the workers and workers union</td>
<td>Availability of equipment.</td>
<td>Skill of operator- The plant /machineries and equipment are not easily accepted by the workers and workers’ union.</td>
<td></td>
</tr>
</tbody>
</table>

4.2. The impacts of mechanisation and automation

There are two (2) impact issues critically discussed which include unemployment issues and total cost. It was found that the heavily mechanised approach has displeased a substantial number of the work force from the building construction industry. As shown in Table 3, there can be a variety of factors that will impact the implementation of mechanisation and automation in construction with long-term sustainability. Among the main impacts of mechanisation and automation applicable to Malaysian construction industry would be the reduction of foreign labour, which has become a long-standing national issue. Therefore, the effective way to reduce the number is to implement a structured and effective mechanisation and automation in the construction process. According to Kaplinski et al., (2002) mechanisation and automation significantly increase work efficiency, with improvement in working conditions and safety of the builders and improvement in quality of work done or product. Another aspect
that could be taken into account is the reduction of costs, mostly due to the decrease in work load per task, and eliminating or cutting down the need to use scaffolding, security system and additional transport equipment. In line with Wakisaka (2000) had also listed other impacts of automation in construction which are: improvement of productivity, quality stability, short construction period, and high degree of design freedom, improvement of construction environment, safety parameters, reduction of debris and reduction of total cost.

The Groups also proposed that the government take action on all the above issues so that it would become practical for the construction industry to move into mechanisation and automation. Amongst the perceived impacts and achievements that will greatly affect the application of mechanisation and automation are resolving the foreign labour workforce issues, improving the quality of the product, minimising the volume of material consumed in finishing the projects, and promoting a better perception towards the construction industry, where it is currently known to be dirty, low quality and dangerous. The key results from the workshop are highlighted, and the focus group was upon enhancing the quality of life by adopting mechanisation and automation by overcoming the barriers and identifying the impacts. In other words, the importance of the implementation of mechanisation and automation is essential in order to effectively perform in a competitive market.

Table 3. The impact of mechanisation and automation

<table>
<thead>
<tr>
<th>Topic</th>
<th>Group 1</th>
<th>Group 2</th>
<th>Group 3</th>
<th>Group 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Impact</td>
<td>Reduce Social Problems.</td>
<td>Reduce Foreign Labour.</td>
<td>Speed up the construction work- construction time within the schedule using mechanisation/plant and machineries.</td>
<td>Speed up the construction time.</td>
</tr>
<tr>
<td></td>
<td>Increased Productivity-Mechanisation and Automation of the activities increase the amount of work done.</td>
<td>Increased Productivity-Mechanisation and Automation of the activities increase the amount of work done.</td>
<td>Decreased Material Cost- Optimised use of construction materials can ensure minimal wastage.</td>
<td>Decreased Material Cost- Optimised use of construction materials can ensure minimal wastage.</td>
</tr>
<tr>
<td></td>
<td>Increased Quality of end product.</td>
<td>Decreased Safety on Site- the automated systems may carry out work in environments and zones of danger for humans, making it possible to reduce labour accidents.</td>
<td>Safety (Less accidents)- the automated systems may carry out work in environments and zones of danger for humans, making it possible to reduce labour accidents.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Increased Productivity.</td>
<td></td>
<td></td>
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</tbody>
</table>

5. Conclusion

To conclude, mechanisation and automation offers many benefits to the betterment of the Malaysian construction industry. However, many aspects of our industry still have a lot of room for improvements. Adopting mechanisation and automation will help to improve the construction productivity and fulfill the government’s target to become a developed country by the year 2020. The introduction of industrialisation has certainly made an impact to the industry but so far it has not achieved the level of the technology adopted by developed countries especially where mechanisation and automation are concerned (Kamaruddin et al., 2013). This statement is in line with Mahbub (2012) who stated that the problems associated with the construction industry, such as decreasing quality and productivity, labour shortages, occupational safety and inferior working condition, have highlighted the need for innovative
solutions within the industry, including the push for further use of industrialisation, construction automation and robotics on site. The results emphasise the importance of making the right decisions towards mechanisation and automation. The main contribution especially for the decision makers who involve in project implementation will benefit this research by understanding the factors and are use these results to better define priorities and move forward into a culture of knowledge in mechanisation and automation to increase their ability to innovate and ensure continuous improvement as demanded in today’s dynamic IBS construction environment. In addition, an attempt to address Malaysia’s concern about the dependency on foreign labour, encouraging the use of labour saving devices at an optimum cost with applications of innovative technologies is a one way forward. Ultimately, the quality and durability of buildings that are delivered to the end users will promote better quality of life.

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