Sixth International Conference on Construction in the 21st Century (CITC-VI)
"Construction Challenges in the New Decade"
July 5-7, 2011, Kuala Lumpur, Malaysia

Readiness of a Developing Nation in Implementing Automation and Robotics Technologies in Construction: A Case Study of Malaysia

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Abstract

The government's vision for Malaysia to be a developed nation by 2020 has pushed forward the use of innovative technologies in most sectors and industries, including the construction industry. Through the Economic Transformation Programme (ETP), major projects launched, such as the proposed high-capacity rail transit network, is expected to provide a great catalyst for the market and the economy. These projects may become the platform for increasing the use of automation and highly enhanced plants and machineries in the construction industry, thus bringing the use of innovative technologies to the fore. Innovations in most countries are mostly driven by the need to find revolutionary solutions to problems, such as a shortage of skilled labour, decreasing quality of product and processes, inferior working conditions, declining productivity and increasing costs of labour and materials. Automation and robotics technologies encompass a wide range of innovative technologies using technologically advanced machineries to improve the speed and efficiency of a given process. In construction it may apply to the prefabrication of materials off-site and assembly of components on-site using dedicated machines, or even the automated production of drawings or schedules using software during the design and planning stage. This paper discusses the readiness of a developing country in embracing innovative technologies such as construction automation and robotics, with specific reference to the Malaysian construction industry.

Keywords

Automation and Robotics, Malaysia, innovative technologies, construction industry.

1. Introduction

The contribution of the construction industry in terms of Gross Domestic Product (GDP) in the overall production of goods and economy of a country has generally been recognized as an important factor in determining the development and progress of the country, as it is engaged in a wide range of activities relating to building, maintenance, demolition, landscaping, infrastructure and civil engineering; carried out within the public and private sectors. The problems associated with the construction industry such as, decreasing quality and productivity, labour shortages, occupational safety and inferior working conditions have highlighted the need for innovative solutions within the industry, including the push for further use of industrialization (prefabrication and modularization); an influx of high-end software used for design, scheduling and costing; computer integrated design and construction; and to a lesser extent, construction automation and robotics application on site.

In Malaysia, as a result of the government's initiative and future outlook in advancing the use of innovative technologies, the Industrialized Building System approach is actively promoted through several strategies and incentives as an alternative to conventional building methods. The use of IBS is widely endorsed through the ***IBS Roadmap*** effort by the Construction Industry Development Board (CIDB) Malaysia, with the target of having an industrialized construction industry and achieving Open

Building (CIDB Malaysia, 2003). The use of construction automation and robotics, technically, follows the same route, with an emphasis on the assembly and installation of components using these technologies. The type that would be most relevant to Malaysia would be enhancements to existing construction plants and equipment; and to a lesser extent, task-specific, dedicated robots. Specialist contractors could adopt a number of machines specifically designed for this purpose, for example, Kajima's Mighty Hand for the lifting of heavy components; Shimizu's Glazing Robot for lifting and fixing of glazing panels; or Takenaka's Welding Robot for steelwork positioning and welding (Kajima Corp, Shimizu Corp and Takenaka Corp websites, 2010)

2. Automation and Robotics Technologies in Construction

Numerous studies have shown that construction output in developing countries grows particularly fast, often exceeding the rate of growth of the economy as a whole, as countries put their infrastructure in place during the early stages of development. In some cases, these countries more than double their share of construction output and development, creating a rapidly developing industry bursting at the seams, that is in need of a more efficient and innovative solution to increase productivity and quality of work produced. To this end, many developed countries have also shifted, in recent decades, from traditional craft methods to the production of components in factories and their subsequent on-site assembly (Mahbub, 2006).

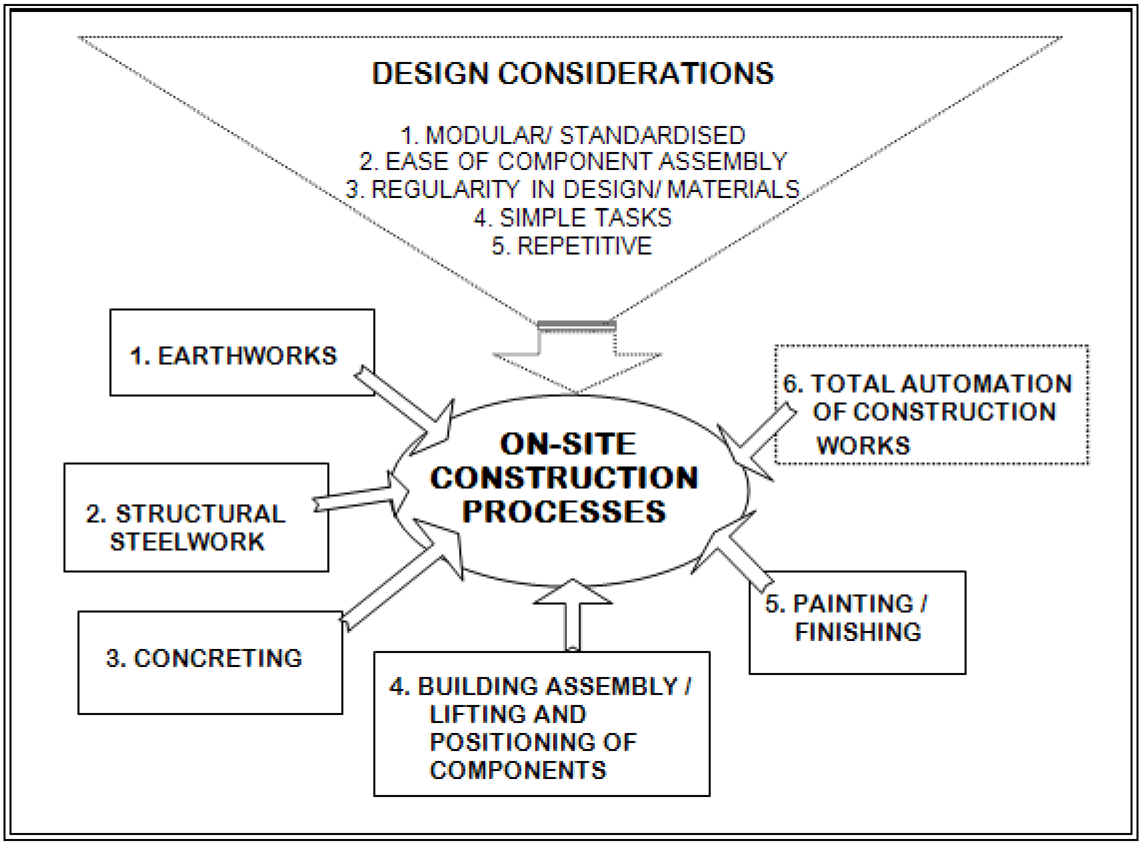
Investigating ways where technology fusion is most likely to happen in construction can assist in identifying the areas where automation and robotics in all probability will be most relevant. These technology areas may include phases of construction, such as adopting a greater percentage of innovative technologies during the design phase, as compared to the construction phase; or it can be in terms of the construction process itself. Some construction processes, like the installation of building components, are easier to automate as opposed to substructure or building foundation works. In this case, the drive to innovate is facilitated by the relatively straightforward technological process that is already in place within this area.

It can be construed from the characteristics and the overlapping of the traditional and new technologies in terms of technology fusion that the prospect for implementation of automation and robotics technologies during the on-site phase of construction may be more widespread for some stages of the construction process compared to others. However, these factors should not be looked at in isolation, as the other phases of construction, such as design, also play an important role in facilitating the adaptation of these technologies on to the work site.

For on-site construction, the six main stages that have the most potential for automation and robotics implementation that were identified for further investigation are; earthworks, structural steelwork, concreting, building assembly / lifting and positioning of components, painting / finishing, and total automation of the construction works which involves the whole building process. The diagram (**Figure 1**) summarizes the on-site construction stages investigated under this research.

Subsequently, in the data collection phase of the research, using a questionnaire survey, participants involved in the use of automation and robotics technologies for on-site operation were asked to rank level of usage (from never to highly used) within the six main stages listed above. This is to gauge which areas have the highest implementation rate and give an indication of the technologies most available for the six stages of the construction processes under study. To provide a more comprehensive overview, the participants were also requested to rank the construction projects they think are most suited to automation and robotics, from four categories of residential, non-residential, civil engineering works and infrastructure, and specialized sub-contracting work.

Figure 1: On-site Construction Stages Facilitating Automation and Robotics Technologies



3. The Construction Industry in Malaysia

The construction industry in Malaysia is generally affected by the state of the economy and investment environment; government intervention, for instance, privatization of public services and private finance initiative; state and federal legislation; and population mobility and social trends. Population mobility and social trends usually dictate the supply and demand of types of buildings and their locations, for example commercial construction is usually concentrated in the high-growth area of Kuala Lumpur and its surrounding suburbs.

The construction industry in Malaysia shares 3.2% of the country's Gross Domestic Product in the last quarter of 2010 and employs over 1,000,000 workers (Department of Statistics Malaysia, 2011). The strength of the construction industry is closely linked to the state of the economy, and reacts fairly quickly to economic downturn. Malaysia's construction sector was amongst the first area to suffer during the previous major recession, but has performed better when the government injected RM2.4 billion worth of projects under the 9th Malaysia Plan in 2005.

Malaysia's industry is actively involved in the construction of residential buildings; with the construction of low and medium-cost houses remaining to be supported through the Malaysian Government's housing programme. Luxurious and high-end landed residential properties, such as semi-detached and bungalows are also in demand, but on a selective basis depending on its price, location and accessibility. The construction industry has also been mainly supported by the development of infrastructure projects throughout the main high growth areas of cities and towns. (Austrade, 2008) There are also various new development regions and major infrastructure projects under construction or recently completed, such as the Iskandar Development Region and the Light Rail Transit (LRT) system connecting key areas or towns in Klang Valley. Under the Economic Transformation Programme (ETP), major projects will be launched and implemented within the next 10 years. ETP requires RM1.4 trillion, of which 92 percent is of private investment; and seeks to increase Malaysia's gross national income (GNI) to RM1.7 trillion.

A shortage of labour is one of the factors behind the drive in many countries to mechanize production in order to increase productivity by replacing labour with machines. In many developed countries, such as Japan, there has been a shift to a more industrialized construction approach, such as greater use of automation and robotics technologies in the industry; including production of components in factories and their subsequent assembly on site. The move to mechanization and prefabrication makes sense in economies where full employment is creating upward pressures on wages, or where labour shortages are acute.

Most developing countries have seen a dramatic increase in both output and employment in the construction industry over the past 30 years. In Malaysia, due to this rapid and prolonged growth, the construction industry's demand for labour could not match that of local supply, and dependency on foreign labour, especially from neighbouring Indonesia, is high. There is consensus among employers in the industry that it will continue to depend on imported labour, regularized or otherwise, in the foreseeable future. The distribution of foreign labour in the Malaysian construction industry has increased from 25100 in 1990 to 269100 in 2004 (Department of Statistics Malaysia, 2005). It is within this area that construction automation and robotics can prove to be most useful in terms of decreasing labour-intensive work processes and thus reducing the country's over-dependency on foreign workers. This will also translate into a long term measure of ensuring sustainable growth as well as minimising socio-economic implications.

One of the greatest opportunities for the Malaysian construction industry to embrace automation and robotics technologies is the various incentives and encouragement from the government for adopting innovative technologies. A prime example of this, as mentioned earlier, is the implementation of the Industrialised Building System (IBS) in the construction sector. The use of IBS assures valuable advantages such as the reduction of unskilled workers, less wastage, less volume of building materials, increased environmental and construction site cleanliness, better quality control, and many more. (CIDB Malaysia, 2003)

4. Data Analysis and Discussion on Findings

For this research, a questionnaire was developed and distributed to construction firms of contractors, specialist sub-contractors, developers and consultants to establish the extent of usage and related value of automation and robotics technologies within the variable factors. These companies were asked to provide input regarding industry perception, suggested practices, barriers and future trends for implementing the technologies. The type chosen is a closed questionnaire, divided into five main sections, that is, demographic information; the level of implementation and development of automation and robotics technologies; issues and concerns pertaining to the use of automation and robotics technologies; perceived barriers and their impact; and future trends and opportunities.

The research was also supported by one-on-one semi-structured interviews to gather more in-depth information on the subject to supplement the data gathered from the questionnaire. To ensure better coverage of the topic being investigated, the sample group for the interview is selected from the management i.e. the decision makers, through to the engineers or users of the technologies. This is done to enable the researcher to investigate the questions on *why* the technologies are adopted in their construction firms i.e. the decision to take them on board; as well as how it is used in the work processes i.e. facilitating their use on site or at workers' level. The interviews were also conducted to provide an insight into the use of automation and robotics technologies in selected construction companies; with the characteristics of the company, technologies in use, and other details investigated to further facilitate understanding on the use of these technologies and the level of implementation in the construction industry. The results of the interview were used to support and cross-validate the questionnaire findings.

In totality, the research which was conducted in 2006 involved 240 respondents for the questionnaire survey and 21 respondents for the interviews, and extended across three countries; Malaysia, Japan and Australia. For the purpose of this paper, only results from Malaysia will be discussed and cross referenced with a more recent but simplified survey conducted in 2010. Sample size for Malaysia is 80 for the questionnaire survey and 7 for the interviews. Selection is based on the nature of work (project managers, company director, consultants, engineers, contractors); the company they work in (large multi-conglomerate, medium size or local companies); familiarity with construction automation and robotics technologies (both ends of the spectrum were selected); and their willingness to participate. 24 responses were received out of the total of 80 sent out, which translates to a response rate of 30%. The majority of participants, 71% (17 out of the 24 received) chose to answer using the website option that has been set up for this phase of data collection.

4.1 Demography of Respondents

Business type: Contractors and developers form an equally significant number of respondents (38% each) for Malaysia whilst sub-contractors form the minority at less than 10%.

Sector of industry that company operates: The majority of the respondents at 40% operate in all sectors of construction from residential, non-residential to civil engineering works and infrastructure. This may be a direct reflection of a fact discovered under literature review that the majority of construction companies implementing high-end technologies are the larger ones that are usually involved across the board in all sectors of the construction industry in both the domestic and international market.

Size of company: An indication of the size of the company can be ascertained by the annual revenue or the number of full time staff working in the company. The majority of Malaysian companies in the sample is made up of smaller companies, with annual revenues peaking at RM4.5 million to RM75 million. In terms of number of employees, companies are more or less evenly distributed from 1 to 10 people (category 1) at 21%, 251 to 500 people (category 5) at 34% and 501 to 1000 people (category 6) also at 34%.

4.2 Level of Implementation

In Malaysia, half the number of respondents at 50% uses the technology. However, a more useful indication of usage is in looking at areas within which the technologies are used, as most companies may only use automation in the design stage (in the form of design software such as Computer Aided Design) rather than for on-site construction. Measurement of usage is via a Likert scale of 1 to 5 (with 1=Never, 2=Seldom, 3=Sometimes, 4=Regularly and 5=Highly)

In **Design**, more than 12% of companies use automation and robotics technologies "*Highly*", with more than 25% at "*Regularly*" and more than 12% at "*Seldom*". In **Scheduling and Planning**, about 10% uses the technologies equally at "*Sometimes*", "*Regularly*" and "*Highly*". In **Costing and Tendering**, about 13% uses the technologies equally at "*Sometimes*" and "*Regularly*"; which is the same as in **Project Management**, where about 13% uses the technologies equally at "*Sometimes*" and "*Regularly*". However, for **On-site Construction**, almost all the companies at 88% said that they have never used the technologies. This shows that the technologies in Malaysia are mostly used in the Design phase, and to a lesser extent, the Scheduling and Planning phase, but almost never for on-site construction.

Areas of usage for on-site construction: Of the percentage of companies (12%) who uses the technologies on-site, areas of on-site usage investigated include **Earthworks**, **Structural Steelwork**, **Concreting**, **Building Assembly**, **Painting/ Finishing** and **Total Automation**. For the Malaysian sample group, predominantly, there is no usage in all these areas except structural steelwork (very limited usage at 14% for *sometimes* used).

4.3 Analysis: Cross Tabulation for Variables in Section A and B

Cross-tabulation is used to determine whether there is an association between two variables; including describing their relationship, the *strength* of the association, and in some cases, the *direction* of association. For this research, cross tabulation is used to investigate and answer the following questions:

Question 1: Is there an association between type of business and level of use?

This is investigated by studying the relationship between **Type of Business** and **Usage of Automation and Robotics.** Cross-tabulation of these two variables shows the following:

Table 1 Cross-tab Table for Type of Business and Level of Use

Does company use A&R?	Frequency Count And Percentages	Type of Business				
		1 Contractor	2 Sub-Contractor	3 Consultant	4 Developer	Total
1 Yes	% within Type of Business	69.4%	87.5%	63.3%	66.7%	68.6%
2 No	% within Type of Business	30.6%	12.5%	36.7%	33.3%	31.4%
Total	% within Type of Business	100.0%	100.0%	100.0%	100.0%	100.0%

Examining the cross-tab table, it can be seen that 87.5% of companies using automation and robotics are sub-contractors, suggesting it is possible that sub-contractors who may be involved in specialist works are more likely to use the technology. To examine this further, there is a need to consider the following question:

What is* the strength of association *between the type of business and level of use?
Here, as the researcher is only measuring the strength and not the direction of association, phi coefficient or contingency correlation coefficient(C) are used. Both measures have the general interpretation of showing stronger relationships as they approach 1 (*with the range of phi being -1 to 1 and C being 0 to approaching 1*). For these variables, the value of Phi is 0.129 and C is 0.128, which shows a fairly weak association.

Question 2: Is there an association between the size of company and level of usage within areas of construction?

After the entire cross-tab tables have been generated for all the areas of construction under study, that is design, scheduling/planning, costing/tendering, project management and on-site construction, the results are studied, and the gamma and Kendall's tau-*c* value is calculated for each area. Kendall's tau-*c* is used to confirm the results from the gamma value in this case, as the cross-tab tables for these variables does not exhibit equal number of rows and columns (thus it is not possible to use Kendall's tau-*b*). Only the cross-tab results for ***on-site construction*** will be discussed here as this is the main area of interest for this research; whilst the rest is performed and saved as output files in SPSS. The values of gamma and Kendall's tau-*c* for these variables are tabulated below.

Table 2 Values of Gamma and Kendall's tau-*c* for Annual Revenue and Usage Areas

Areas Of Usage	*Gamma	*Kendall's Tau-*C*	Comments
Design	- 0.035	- 0.027	Negligible, negative association
Scheduling/Planning	0	0	No association
Costing/Tendering	0.103	0.071	Very weak positive association
Project Management	0.154	0.103	Weak positive association
On-Site Construction	0.296	0.122	Low positive association

***NOTE:** Value of -1 indicates perfect negative association and value of +1 indicates perfect positive association. A value of 0 indicates no association.

Studying the cross-tabs for Annual Revenue and Design, there is no clear indication of association between these variables, and the gamma value suggests negligible association. It can be presumed that the decision to use automation during the design stage, such as in the form of software, is undertaken by most companies, regardless of their size. The cross-tabs between annual revenue and areas of scheduling/planning, costing/tendering and project management also show a similar pattern; although larger companies demonstrate a slightly higher tendency to take up the technology (distribution skewed to the left) in these areas compared to design. The gamma values confirmed that, at least for project management, there is a fairly weak, positive relationship.

Exploring the cross-tab results for on-site construction and annual revenue, indicated that there is a stronger tendency for companies to use automation and robotics the larger they are. Although the gamma value for these variables does not really show a very strong association, but at 0.296, it is the highest compared to the other areas.

4.4 Cross-referencing and Updating Research Results

To update the research results, a simplified survey involving 24 respondents was conducted in 2010, in which the problems of implementation and state of readiness for using the technologies were investigated. It was found that in terms of implementation, there has been a slight increase in usage of about 5-6% across all areas of construction. Some comments from respondents indicated that the slight increase may be due to more industry players getting on board and adopting the IBS approach; thus taking on the government's initiative and subsequent incentives in encouraging greater use of innovative technologies in construction.

5 Conclusions

Is the Malaysian construction industry ready for automation and robotics technologies? To a certain extent, readiness can be measured in terms of equipment (components and machines), technical knowledge and availability, compatibility with existing practices and current construction operations, construction characteristics and market culture, labour situation, materials and product support, and costs or financial commitments. Based on the results of the survey, it can be concluded that the Malaysian construction industry is ready, to a certain degree, for embracing the technologies in limited areas such as prefabrication and assembly and in the design, planning and costing phases. This however, heavily depends on the capacity and capability of the companies that form the Malaysian construction industry, which is related to size and type of business, and existing government incentives and policies. The use of software during the design, scheduling and planning, costing and tendering and project management phases is more widespread compared to actual application of the technologies on site, but the government's vision for a more knowledgeable and innovative construction industry has created greater awareness and technical capacity, thus encouraging further use of IBS and the associated technologies and machineries. For on-site construction, a minority of industry players in Malaysia are ready, in a limited way, to take up the challenge of using the technologies for structural steelworks and assembly of prefabricated components.

Further implementation of construction automation and robotics technologies is envisaged in specialized areas of building assembly and jointing /welding work using enhanced construction plant and equipment and innovative technologies and processes. However, the cost factors and improvement on the low technology literacy of project participants need to be taken into account to fully enable the nation to progress as an industrialized nation of the new decade.

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