THE POTENTIAL OF BUILDING INFORMATION MODELLING (BIM) FOR IMPROVING PRODUCTIVITY IN SINGAPORE CONSTRUCTION

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Since 2013, it has been compulsory for practitioners to prepare proposals for building plan approval using Building Information Modelling (BIM). Moreover, raising productivity has been accorded the top priority in the current growth strategy for Singapore's economy. The utilisation of BIM in the Singapore construction industry is examined, and the possibility of deriving further benefits from the potential of BIM to improve productivity in the industry is explored. A series of interviews was carried out and an online questionnaire-based survey was undertaken in 2014 to investigate the views of practitioners on the current state of productivity and BIM application in the Singapore construction industry, and explore the potential of BIM to help in the efforts to improve productivity on construction projects. The interviewees comprised a representative cross-section of relevant parties in the industry including policy makers, contracting companies, architectural firms, a consultancy firm, a professional institution and a trade association. The respondents to the online questionnaire were contractors, architectural firms, structural engineering firms, mechanical and electrical (M&E) engineering firms and quantity surveyors. The findings suggest that the framework set up by the Singapore government has laid the necessary foundation for the implementation of BIM in the construction industry. The respondents acknowledge that BIM has the potential to enhance elements of practice beyond the preparation of models for mandatory submission, through pre-project planning, identification of documentation errors and productivity monitoring using actual construction site data. However, BIM is used more widely at the beginning stages of the projects. In the long term, much more needs to be done to use BIM in a strategic and more sophisticated manner, in particular, to further improve productivity in the industry.

Keywords: BIM, improvement, potentials, productivity, Singapore.

INTRODUCTION

Overview

The Building and Construction Authority (BCA) and buildingSMART Singapore have been promoting the use of Building Information Modelling (BIM) in the construction industry in Singapore. BCA has set a target that at least 80% of the construction industry should be using BIM widely by 2015. One of the strategies which are being implemented in order to achieve this target is the introduction of the legal provision which makes it compulsory for proposals being submitted for building plan approval to have been prepared using BIM.

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At the broader level of the economy, one of the strategies of a government-appointed committee was to increase productivity in all sectors (Economic Strategies Committee 2010), and this has been accorded the top priority in the nation's current growth programme. The Economic Strategies Committee (2010) set a target of two to three percent per year of productivity growth over the following ten years. This has formed the background for a major programme to enhance the productivity performance of the construction industry. A major segment of this programme is to promote the application of advanced information and communication technology (ICT), especially BIM.

Hence, it is pertinent and timely to consider how the potential of BIM to enhance construction productivity can be fully exploited given the current national focus on the improvement of productivity. The results of an empirical study on productivity and BIM which formed part of a larger study on productivity, safety and BIM in the construction industry in Singapore are reported. The larger study examines the relationship between productivity and safety in Singapore's construction industry; explores how BIM can be used to improve productivity and safety performance in the industry; and seeks to develop a system using BIM to monitor and improve productivity and safety throughout the project. While a semi-quantitative approach had been used at this exploratory part of the study, a quantitative approach of productivity measurement will be used in the development of the system, which forms the next stage of the study.

The objectives of the study reported on here are to (i) assess the current situation of the construction industry in Singapore, particularly pertaining to productivity; (ii) ascertain the level of BIM implementation in the industry; (iii) find out the potential of BIM in improving productivity of the industry; and (iv) propose further actions to accelerate the implementation of BIM in the construction industry, and particularly for the purpose of improving the industry's productivity level.

BIM and productivity

BIM is defined as the development and use of a computer software model to simulate the construction and operation of a facility, resulting in a data-rich, object-oriented, intelligent and parametric digital representation of the facility (AGC 2010). Views and data can then be extracted for decision making and process improvement. According to Smith (2007), the concept of BIM is to build a building virtually, prior to building it physically, in order to work out problems, and simulate and analyse potential impacts. Smith (2007) argues that because of the use of BIM, the construction process can become more efficient and many uncertainties can be eliminated before the start of physical construction on site.

The benefits from the application of BIM in construction are well documented. They include: faster and more effective processes; better design and quality of the built item (Azhar 2011); provision of a collaboration tool for all project participants (Benjaoran and Bhokha 2010); reduction in manual efforts; time and cost savings (Gong and Caldas 2011); and identification of possible conflicts and risks that would have arisen (Gu and London 2010).

The potential of BIM to help in the efforts to enhance productivity is the main reason behind the Singapore government's policy to promote and facilitate the application of BIM including making it mandatory at the building plan approval stage (BCA 2013a). However, the literature suggests that the concept of productivity is not well understood in the construction industry. Pekuri *et al*. (2011) note that productivity is a commonly used, but often poorly defined term. In general, productivity is defined as a ratio of output of work produced to a unit of a particular input which is used in the production process. In construction, it can be measured at various levels, including the trade, project, company or industry levels. At any of these levels, construction productivity can also be measured in many different ways. As there are many ranges and features of productivity measures, this study considers project-level productivity, which, in Singapore, is measured based on total units of output over total man-hours utilised (BCA 2013b).

During the construction phase, BIM contributes to the success of a project by enabling practitioners to effectively control schedule, budget and quality, and to reduce risks (Ku and Mills 2008). Sacks and Barak (2006) report that the total number of hours spent on three projects were reduced by 21 per cent, 55 percent and 61 per cent respectively owing to the use of 3D modelling instead of 2D. Nath *et al*. (2015) found that there could be improvements in the workflow for precast shop drawing generation using BIM. They show that there could be an overall productivity improvement of approximately 36 per cent in processing time and 38 per cent for total time.

Challenges and problems which might be encountered in the implementation of BIM are also well catalogued; some of these are relevant to the construction industry in Singapore. Rajendran and Clarke (2011) outlined a number of these challenges including the cost of BIM implementation and the training of the personnel required. BIM implementation may require some changes in the contractor selection process, since owners and contractors should now select subcontractors with BIM experience. There are also technical challenges such as the development of various construction elements to be added into BIM. On top of that, there may be resistance from some people in the firms, especially those on site, who may not believe in BIM. They suggested that for these reasons, it will take some time before BIM becomes a norm in the construction industry.

Implementation of BIM in Singapore

The government of Singapore, through the BCA, has put in place a series of initiatives under a broad programme for enhancing productivity in the construction industry. The BCA formulated a Construction Productivity Roadmap in November 2010 (BCA 2011). Its vision is to build a highly integrated and technologically advanced construction industry led by progressive firms and supported by a skilled and competent workforce by 2020. One of its strategic thrusts is *"driving adoption of BIM"*. A National BIM Steering Committee was set up in 2011 to provide a governing framework to steer the implementation of the BIM Roadmap. The committee comprises representatives of professional institutions, trade associations, major government procurement entities and regulatory agencies. The committee led the development of the *"Singapore BIM Guide"* and *"BIM Particular Conditions"* (BCA 2013c). It also provides advice to the professionals involved on the effective implementation of BIM in a construction project.

BCA (2011) outlines the various initiatives to encourage the adoption of BIM in the industry in Singapore. Among the early activities, BCA and buildingSMART Singapore, developed BIM submission templates, a design objects library and project collaboration guidelines. BCA then started the use of BIM through a number of pilot projects in 2011, working with the public sector client agencies. Subsequently, BCA has been releasing regulations making it mandatory that the submission of architectural, structural as well as mechanical and electrical plans for building works for approval be in the BIM format. First, from 1 July 2013, all architectural plans must be submitted in BIM format; this applied to proposals for new building projects with gross floor area (GFA) of 20,000 sq. m. and above. This was followed by the mandatory requirement for BIM electronic submission (e-submission) of engineering plans of new building projects with GFA of 20,000 sq. m. since 1 July 2014. In the third phase, from 1 July 2015, all plans of new building projects with GFA of 5,000 sq. m. and above are to be submitted in BIM format.

To address the challenge to meet the high demand for skilled BIM manpower, BCA has been working closely with various institutes of higher learning (IHLs) to incorporate BIM training into more than 30 academic programmes. The agency's own educational institution, BCA Academy, and BIM vendors have also organised training for industry professionals.

Under the BCA BIM fund, incentives are offered to construction firms to adopt BIM. The fund, which is part of the Construction and Capability Fund (CPCF), covers the costs for training, consultancy services and purchase of hardware and software for businesses and projects.

It is suggested that the various initiatives have increased the level of adoption of BIM in the industry. According to a recent survey conducted by BCA, 65% of the industry has adopted BIM as compared to 20% two years earlier (Quek 2013).

FIELD STUDY

Empirical data were collected through face-to-face interviews and an online questionnaire-based survey.

Interviews

A series of face-to-face interviews was conducted from January to December 2014. The interviewees were 30 key people from 12 firms and institutions, which included six contractors, two architectural firms and one cost consultancy firm. There were also a representative from the government, and leaders of a professional institution and a trade association.

The interviews were intended to ascertain the current state of the industry's practice of BIM and productivity. This enabled the research team to develop the questionnaire for the much wider questionnaire-based survey.

The interviewees were asked to relate their views and concerns about the level of productivity in the construction industry in general, and the enablers and obstacles to productivity. They were also asked to share their views on the merits of, and challenges in, implementing BIM, and the potential of BIM to help in improving productivity.

Questionnaire survey

The questionnaire survey sought to ascertain how senior personnel in Singapore’s construction industry perceive the current state of productivity and BIM in the industry, and the potential of BIM in improving productivity of the industry. A five-point Likert scale was used. The respondents were requested to indicate the level of effectiveness of, importance of, and necessity of, the various statements, as relevant. For example, when respondents were asked to rate their level of agreement with each of the statements on the obstacles to the use of BIM, they were required to select a number from 1 to 5, where 1 represented *“strongly agree”* and 5 stood for *“strongly disagree”*.

Sampling
The respondents of the questionnaire-based survey can be classified into two groups: main contractors and consultants. The target population for main contractors comprised companies registered with the BCA under registration heads CW01 (general building) and CW02 (civil engineering). A total of 383 contractors were identified from the BCA Directory of Registered Contractors and Licensed Builders (BCA 2014a).

The consultants consisted of architects, structural and mechanical and electrical (M&E) engineers, and quantity surveyors. The interviewees were selected from the lists of members provided by the respective professional institutions in Singapore, which include the Singapore Institute of Architects (SIA), Association of Consulting Engineers Singapore (ACES) and Singapore Institute of Surveyors and Valuers (SISV). A total of 454 consultants were selected. Hence, the total number of target respondents is 837.

Responses
A total of 837 e-mail messages containing the links to the questionnaire survey were sent to the identified target respondents in August 2014. Some 55 e-mail messages bounced back because of wrong e-mail addresses. 59 usable responses were received, which reflected a response rate of 7.54 per cent (Table 1).

Table 1: Response rate

Respondents	Population	E-mail invitations sent out	Wrong e-mail addresses	Correct e-mail addresses	Usable responses	Response rate
Main contractors	2,709	383	22	361	25	6.93%
Architects	377	323	15	308	15	4.87%
Structural and M&E engineers	142	87	13	74	17	22.97%
Quantity surveyors	623	44	5	39	2	5.13%
	3,851	837	55	782	59	7.54%

Of the 59 firms in which the respondents were working, 34 were consultants. Of these, 12.00 per cent were architectural firms, 26.47 per cent were structural engineering firms, 14.71 per cent were M&E firms, 8.82 per cent were multi-disciplinary firms and 5.88 per cent were quantity surveying firms.

The respondents were those in the upper management level, such as managing directors, directors, partners and general managers (33.90 per cent), the middle management level, which comprised project managers, contracts managers, IT managers, BIM managers and architectural managers (32.20 per cent) and professionals, who included engineers, quantity surveyors, architects and BIM executives (33.90 per cent). It was made clear in the cover letter accompanying the questionnaire survey that the responses should reflect the views of their firms.

In terms of the degree of subcontracting, the majority of the contractors subcontracted a significant amount of their work. Forty per cent of the firms subcontracted 41 to 60 per cent of the value of their projects. Another 40 per cent subcontracted over 60 per cent of the value of their projects.

RESULTS AND DISCUSSIONS

Interviews

The general perception of the interviewees was that there has been some improvement in the productivity performance of the construction industry in Singapore. However, there was general concern among them about the shortage of skilled workers, BIM-trained personnel and architects. Many interviewees were also concerned with a low degree of skill retention, leading to low productivity. In particular, due to the current transient site workforce, the industry has to constantly train new people who mainly come from neighbouring countries. Hence, there is a lack of experienced supervisors, as well as a lack of commitment among the (transient) workforce.

The regulations force the contractors to change the way they work. For example, the buildability and constructability framework pushes the contractors to change their mindset towards precast and prefabrication.

The interviews also revealed that there is a lack of uniformity in the methods adopted for productivity measurement across the industry. The methods adopted generally follow the requirements specified by the clients or the authority. However, some companies have developed their own methods of measuring productivity. Examples include being based on schedule (number of months required to complete the project), cost (number of days worked per unit cost), structure (monitoring which construction method is faster) or earnings per month.

The interviews revealed that there are different levels of BIM utilisation since the industry is undergoing a transition period in terms of BIM utilisation. While some companies have achieved advanced levels in its application, some mainly use BIM for the compulsory submission.

The interviewees agreed that BIM brings about many benefits which will eventually improve productivity. BIM is a useful communication tool among the project participants, within the design team, and between consultants, contractors and clients. BIM may speed up the construction process since it allows all project participants to work simultaneously, minimises changes during construction, helps to eliminate a lot of construction errors and reduce rework.

The interviews revealed that the most common obstacles to BIM implementation are interface issues, legal issues, cost and time. Government incentives have been a great help for the companies; many of them have used up the maximum sum to which they are entitled to make the appropriate investment. More help and support, especially for subcontractors, is needed.

Questionnaire survey

The respondents were asked to express their views on the effectiveness of various measures in improving the productivity level of the construction industry in Singapore on a scale of 1-5 (1 being *"very effective"* and 5 being *"not effective at all"*). Table 2 shows that the incentives provided by the government such as the schemes for technology adoption (which includes BIM), incentive schemes for workforce training and upgrading and the Construction Engineering Capability Development Programme (CED Programme) are preferred. The CED Programme is an incentive scheme from the BCA for main contractors taking on complex construction projects. The scheme provides financial incentives for manpower development, engineering capability development and construction financing (BCA 2014b). Meanwhile, the industry gave lower support to mandatory requirements such as the mandatory submission of buildability score, constructability score and productivity data.

*Table 2: Measures that have improved the productivity level of the construction industry**

	N	Mean	Standard error	Standard deviation	Variance
Incentive schemes for technology adoption	55	2.11	0.141	1.048	1.099
Incentive schemes for workforce training and upgrading	55	2.22	0.144	1.066	1.137
Construction Engineering Capability Development Programme (CED Programme)	55	2.24	0.149	1.105	1.221
Mandatory submission of buildability score	55	2.76	0.168	1.247	1.554
Mandatory submission of constructability score	55	2.84	0.168	1.244	1.547
Mandatory submission of productivity data	55	2.93	0.162	1.200	1.439

** The measures were extracted from the Construction Productivity Roadmap (BCA 2011). Most of the respondents are familiar with the measures, as only 5 out of the 59 respondents selected "not aware" of the particular measure.*

Next, the respondents were asked to indicate their agreement (or otherwise) with the obstacles to the use of BIM in their firms on a scale of 1-5 (1 being *"strongly agree"* and 5 being *"strongly disagree"*). Table 3 shows that the top three obstacles to the use of BIM as follows: difficulty in finding personnel competent in BIM; cost of implementation, excluding staff training; and cost of staff training. As discussed in the earlier section, the Singapore government has implemented some initiatives to help address the obstacles by organising training and giving incentives to construction firms to adopt BIM.

*Table 3: Obstacles to the use of BIM**

	N	Mean	Standard error	Standard deviation	Variance
Difficulty in finding personnel competent in BIM	59	2.02	0.133	1.025	1.051
Cost of implementation, excluding staff training	59	2.15	0.162	1.243	1.545
Cost of staff training	59	2.20	0.147	1.126	1.268
Lack of support from clients	59	2.27	0.143	1.096	1.201
Inadequate incentives	59	2.31	0.137	1.055	1.112
Maintenance costs	59	2.37	0.153	1.173	1.376
Lack of clarity of government policies	59	2.61	0.151	1.160	1.345
Lack of direct benefit from implementation	59	2.61	0.147	1.130	1.276
Insufficient demand for the application of BIM	59	2.76	0.150	1.150	1.322

** The obstacles were extracted from literature review (Arayici et al. 2009, Smith and Tardif 2009, Gu and London 2010, Azhar 2011, Rajendran and Clarke 2011) which were confirmed by the findings from the interviews.*

More than half of the firms cited co-ordination, submission, planning, clash detection and visualisation as the main reasons for using BIM (Table 4). The least mentioned reasons were facility management, sales and simulation of carbon emission. Most of the firms used BIM at the earlier stages of the projects (Table 5). As many as 45 firms use it at the design and pre-construction stage; while the degree of use lessened towards the end of the projects. Only eight firms use BIM at the post-construction stage. Next, the respondents were asked to indicate their agreement with the potential of BIM on a scale of 1-5 (1 being *"strongly agree"* and 5 being *"strongly disagree"*). The first two potential uses and benefits indicated by the respondents were what BIM has been commonly known for: pre-project planning and identification of documentation errors (Table 6). The third potential was productivity monitoring using actual construction site data. The last three indications of BIM potential relate to utilising BIM for safety: safety monitoring, hazard identification and safety simulation.

Table 4: Reasons for the use of BIM

Reasons for the use of BIM	Number of firms	Percentage	Reasons for the use of BIM	Number of firms	Percentage
Coordination	44	74.58	Communication	16	27.12
Submission	40	67.80	Training	16	27.12
Planning	38	64.41	Prefabrication	15	25.42
Clash detection	33	55.93	Simulation of materials	10	16.95
Visualisation	32	54.24	Code reviews	8	13.56
Quantity take-off or cost estimation	25	42.37	Facility management	6	10.17
Project management	24	40.68	Sales	5	8.47
Sequencing	17	28.81	Simulation of carbon emission	3	5.08

Table 5: The stage at which BIM is used in the projects

The stage of which BIM is used in the projects	Number of firms	Percentage
Design and pre-construction stage	45	76.27%
Tender documentation stage	21	35.59%
Construction stage	30	50.85%
Post-construction stage	8	13.56%

Table 6: Potentials of BIM

	N	Mean	Std error	Std dev	Variance
Pre-project planning	59	1.97	0.130	0.999	0.999
Identification of documentation errors	59	2.29	0.130	1.001	1.002
Productivity monitoring using actual construction site data	59	2.37	0.151	1.158	1.341
Location tracking	59	2.51	0.140	1.073	1.151
Conformance to performance standards and regulations	59	2.51	0.122	0.935	0.875
Safety monitoring using actual construction site data	59	2.64	0.134	1.030	1.061
Hazard identification	59	2.66	0.140	1.077	1.159
Safety simulation	59	2.69	0.159	1.221	1.492

CONCLUDING REMARKS

The development and application of IT in the construction industry in Singapore has been broadened with the use of BIM as the platform to facilitate the integration of knowledge and information among the practitioners participating in construction projects.

Regulations have resulted in improvements in many aspects of construction in Singapore, and have been the main driver of BIM implementation. BCA and buildingSMART Singapore, have been launching a number of initiatives to promote the use of BIM in the industry in Singapore. Despite all the efforts, the findings from the study indicate that much more can be done in the effort to promote the use BIM at a higher level, and to explore to a greater extent the potential that BIM can offer. The respondents acknowledge that BIM has the potentials beyond the mandatory submission, through pre-project planning, identification of documentation errors and productivity monitoring using actual construction site data. However, many firms still use it only at the design and pre-construction stage. Very few of the firms use BIM at post construction stage and for facilities management. In future, further studies including a larger sample size such as facilities management firms and clients are necessary to clarify the findings.

In the long term, regulation alone will not be adequate; the construction industry needs to be more proactive. Several issues need to be resolved in order to exploit the potential of BIM in improving productivity to a greater extent. There is a need for holistic co-ordination among the industry's stakeholders including the government, industry, BIM vendors, clients and educational institutions. Many years into the implementation of BIM, the industry still face the same obstacles as encountered elsewhere (Arayici *et al*. 2009, Chien *et al*. 2014 and Murphy 2014). For example, as highlighted by the respondents of the questionnaire survey, the first obstacle is the difficulty in finding personnel competent in the usage of BIM. To address the shortage of BIM practitioners, the industry and academic institutions should work together to develop syllabuses that are in line with developments in industry practice and procedures. There should also be a system within each firm to ensure that the practitioners retain, actually apply and also share the knowledge gained from such programmes.

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