The Use of BIM in the Singapore Construction Industry: Opportunities and Challenges

Evelyn Ai Lin Teo,
Department of Building, National University of Singapore
(bdgteoal@nus.edu.sg)
George Ofori,
Department of Building, National University of Singapore
(bdgofori@nus.edu.sg)
Imelda Krisiani Tjandra,
Department of Building, National University of Singapore
(imelda.tjandra@gmail.com)
Hanjoon Kim,
Department of Building, National University of Singapore
(e0013536@u.nus.edu)

Abstract

The Singapore government has been actively promoting the use of Building Information Modelling (BIM) in the construction industry. Since 1 July 2015, all plans of new building projects with gross floor area (GFA) of 5,000 sq. m. and above have to be submitted in BIM format. Moreover, raising productivity in all sectors has been the top priority. On the safety part, the government has introduced a number of initiatives, with the main aim of reducing fatalities to 1.8 per 100,000 workers by 2018. Taking advantage of these initiatives, there are opportunities to maximise the potential of BIM to help improve productivity and safety in the industry. Semi-structured interviews were carried out from January to December 2014 to find out the industry’s views on the current state of BIM, productivity and safety in the construction industry in Singapore. It was revealed that despite the support from the government and the opportunities offered by BIM, the industry faced a number of challenges in the implementation of BIM. They include collaboration, technical, legal issues, time and cost consideration. Many of the respondents acknowledged that BIM has a lot of potential, yet this had not been maximised. Much more needs to be done to further utilise BIM for improving productivity and safety in the industry. Hence, the paper highlights an intelligent system which has been designed to provide solutions for the challenges and create opportunities for the industry to derive greater benefits from BIM. The system incorporates both productivity and safety performance, using BIM as the platform.

Keywords: BIM, challenges, opportunities, productivity, safety

1. Introduction

1.1 Overview

The Singapore government has been actively promoting the use of Building Information Modelling (BIM) in the construction industry. It has identified BIM as a critical tool in the national productivity drive, which has the aim of raising the level of productivity in all sectors of the economy, including construction. Since 1 July 2015, all plans of new building projects with gross floor area (GFA) of 5,000 sq. m. and above have to be submitted for development approval in BIM format. On the safety part, the government has introduced a number of initiatives, with the main aim of reducing national fatalities to 1.8 per 100,000 workers by 2018. Singapore's Workplace Safety and Health Council (WSHC) outlined the national WSH 2018 vision, which is "A safe and healthy workplace for everyone and a country renowned for best practices in WSH" (WSHC, 2010). Taking advantage of these initiatives, there are opportunities to maximise the potential of BIM to help improve productivity and safety in the industry. However, the implementation of BIM by the firms is not without challenges. The paper outlines the opportunities offered by BIM and some of the challenges encountered by some of the firms in the construction industry of Singapore on their BIM journey. The paper also highlights an intelligent system which has been developed to address the challenges. The system was designed to provide solutions for the challenges and create opportunities for the industry to derive greater benefits from BIM.

1.2 Singapore's BIM Roadmap

Governments worldwide, including Denmark, Finland, Norway, South Korea, UK, and USA play an important role in leading the construction industry in BIM adoption. Singapore is one of a few countries in Asia which have implemented BIM (Wong *et al.*, 2009). Others are Hong Kong, PRC and South Korea. In Singapore, the Building and Construction Authority (BCA) implemented the BIM Roadmap in 2010 with the aim that 80 percent of the construction industry would use BIM by 2015. This is part of the government's plan to improve the construction industry's productivity by up to 25 percent over the next decade (BCA, 2011). The latest survey on BIM adoption (Lam, 2014) shows that almost all the firms in Panel One of the public-sector panel of consultants have adopted BIM (Figure 1). However, the adoption rate was not that high for contractors (Figure 2).

BCA introduced a number of initiatives to prepare the industry, following the BIM Roadmap (Figure 3). After the first BIM Roadmap was launched, a National BIM Steering Committee, comprising representatives of professional institutions, trade associations, major government procurement entities and regulatory agencies, was set up in 2011 to provide a governing framework to steer the implementation of the BIM Roadmap (BCA, 2013b). The committee led the development of the "Singapore BIM Guide" and "BIM Particular Conditions". Platforms such as BIM Manager Forums have been organised to discuss and address technical issues faced by the industry.

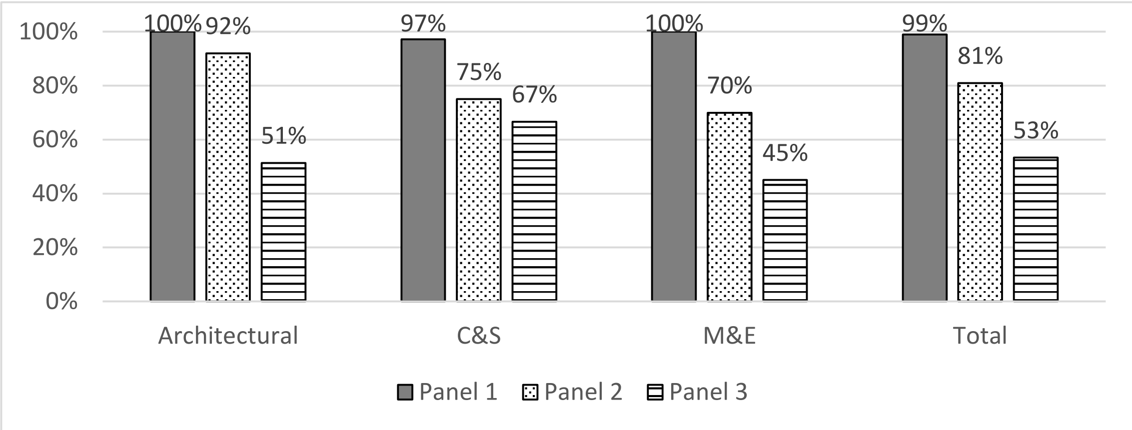

Figure 1. BIM adoption landscape of the public sector panel of consultants in the Singapore construction industry. Source: Lam (2014).
** Tendering limits:*
Panel 1: S$90 million
Panel 2: S$42 million
Panel 3: S$14 million

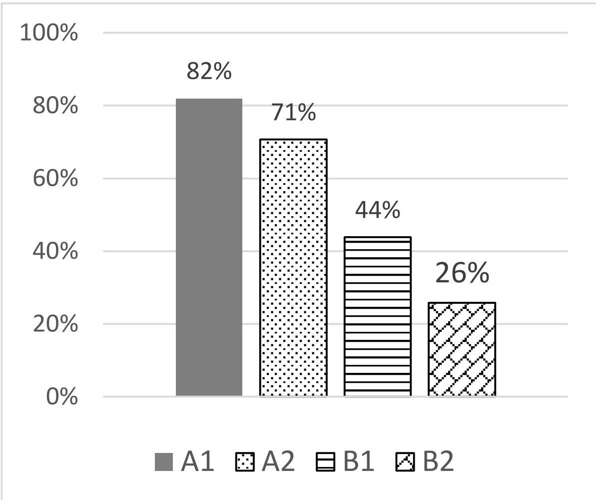

Figure 2. BIM adoption landscape of the Grade A1-B2 contractors. Source: Lam (2014).

** Tendering limits:*
Grade A1: unlimited
Grade A2: S$90 million
Grade B1: S$42 million
Grade B2: S$14 million

One of the initial challenges recognised in the BIM Roadmap is the need to obtain the manpower and financial resources needed to build up BIM expertise. To meet the high demand for skilled BIM manpower, BCA had been working closely with relevant Institutes of Higher Learning (IHLs), BCA Academy and BIM vendors to organise training and incorporate BIM in academic programmes. To overcome the challenge of obtaining the financial resources, the BCA BIM Fund provides incentives to construction firms to adopt BIM.

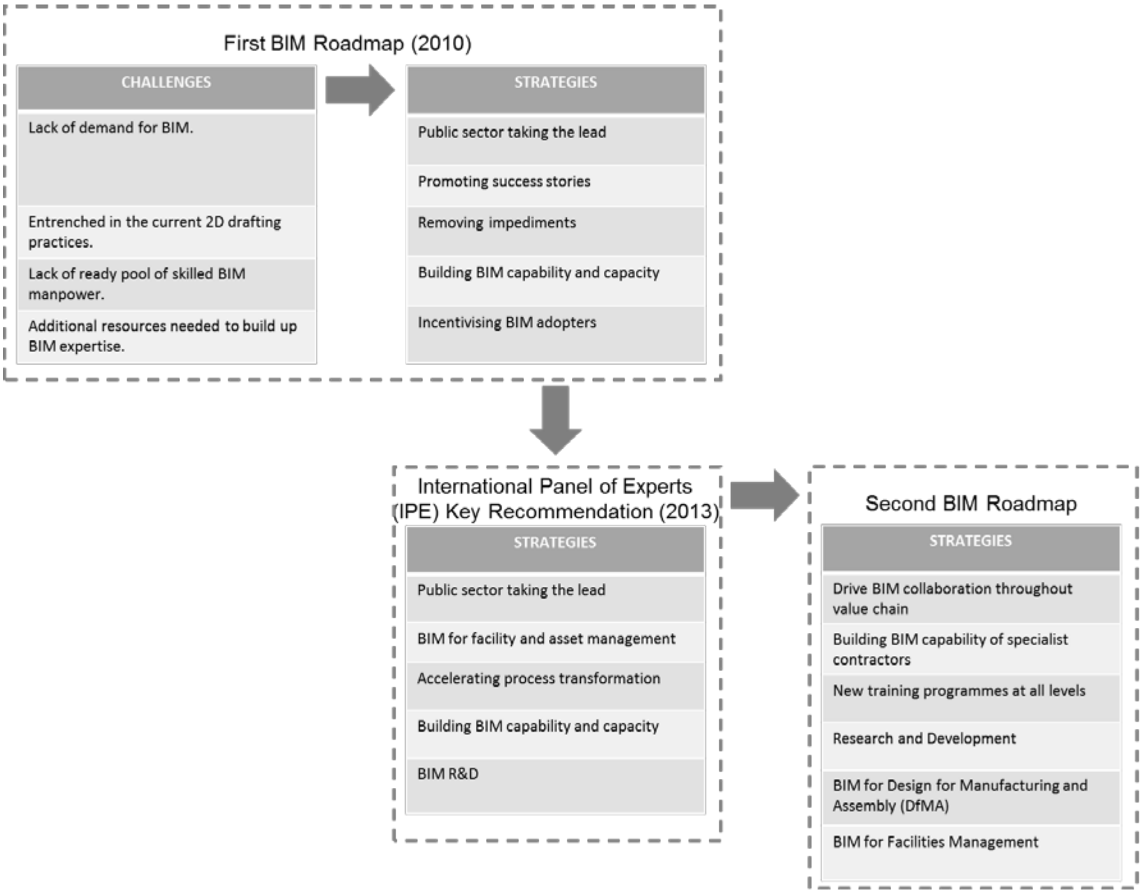

Figure 3: Singapore's BIM Roadmap. Source: Adapted from Lam (2014).

In 2014, the second BIM Roadmap was launched after the International Panel of Experts in BIM proposed a number of key recommendations, which included the public-sector taking the lead, BIM for facility and asset management, accelerating process transformation, building BIM capability and capacity and BIM R&D (Lam, 2014). The report presented a review of the current state of BIM adoption. The developers are detached from the BIM process and lack the know-how to drive the process. The consultants focus too much on e-submission and lack the time to undertake design co-ordination. Main contractors commented on the lack of quality models from consultants. The main contractors are currently not taking advantage of the full potential of BIM to resolve issues with consultants and subcontractors. The specialist subcontractors lack BIM skills. There is a lack of BIM usage for facilities management. It was also highlighted that there is a lack of BIM collaboration among project participants.

Hence, the main focus of the second BIM Roadmap is to drive BIM collaboration throughout the value chain. The funding level from the BCA BIM Fund had been increased from 50 percent to 70 percent for Project Collaboration Scheme. The "Singapore BIM Guide" and "Public Sector BIM Requirement" would be reviewed to include BIM coordination and model handover. Procurement methods and contract conditions would be developed based on BIM.

2. Literature Review: Opportunities and Challenges

The emphasis on national productivity and safety improvement, together with the drive for industry-wide BIM implementation, provides an opportunity for investigating how BIM could be used for improving productivity and safety in the construction industry.

BIM, as a process, allows the exchange of information among the project stakeholders, such as architects, engineers, contractors, consultants and clients. BIM is able to generate and analyse different views, data and information appropriate to various users' needs, which can be used to facilitate decision making and to improve the process of delivering the facility (AGC, 2010). The important feature of BIM is its capability to enable the item to be constructed to be built virtually, prior to building it physically, in order to identify and resolve problems, and simulate and analyze potential impacts (Smith, 2007). BIM can be used for many other purposes in the design and construction process such as visualization, scope clarification, trade coordination, collision detection and avoidance, design validation, construction sequencing planning, plans and logistics, marketing presentations, options analysis, walk-throughs and fly-throughs, virtual mock-ups and sight-line studies (AGC, 2010).

Teo (2014) discussed how BIM could be utilised help to improve productivity and safety in a number of ways. BIM could result in productivity improvement due to reduction in the disruption of the flow of information in the design and construction stages; effective response to changes during the construction stage; improved communication and collaboration among stakeholders in the construction project; informed decision-making; information sharing and interoperability; and fewer changes, less workload and more savings. The application of BIM in construction may improve the performance of onsite operations due to the reduction of manual efforts, time and costs involved (Gong and Caldas, 2011). 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 the reduction of total number of hours spent on three construction projects owing to the use of 3D modelling instead of 2D. Nath *et al*. (2015) found productivity improvements in the precast shop drawing generation due to the use of BIM.

Teo (2014) further argued that BIM could lead to safety improvement because BIM helps practitioners visualise the compatibility of architectural, structural and mechanical and electrical (M&E) design aspects, as well as feasibility of construction of design features or elements. BIM is able to simulate each step of work activities so that construction sequencing and the required safety measures may be identified. BIM also facilitates the communication of any identified safety risks to relevant stakeholders. Zhang *et al*. (2013) developed an automated safety checking platform which is able to inform construction engineers and managers of the various safety measures needed to prevent fall-related accidents before construction starts. The system automatically analyses a building model to detect safety hazards and suggest preventive measures to users. Benjaoran and Bhokha (2010) developed a rule-based system that is able to detect any work-at-height related hazards and propose necessary safety measures. Factors related to building components and activities such as component type, dimensions, placement, working space, activity type, sequence, and materials and equipment are used as input data. These factors are examined to find any work-at-height hazards. Thereafter, the system is able to suggest necessary safety measures including activities or requirements. Choi *et al*. (2014) developed a BIM-based evacuation regulation checking system for high-rise and complex buildings. Their system allows architects, designers and owners to evaluate the design at the design stage to ensure that the design meets the design requirements. Continuous checks are possible due to an automated system and detailed guidelines.

Although BIM has the potential to improve overall construction project performance, it is also widely acknowledged that BIM brings about various challenges in its implementation. Among others, BIM requires collaboration among the project stakeholders. To implement BIM, owners and general contractors must select subcontractors with BIM experience. This changes the contractor selection process, which traditionally focuses on the lowest bidder. Meanwhile, BIM implementation requires a significant up-front investment. Furthermore, construction safety professionals often are involved late in the project development process, which does not allow them to contribute to BIM effectively. Technical challenges are also commonly encountered (Rajendran and Clarke, 2011). For example, adding construction safety elements and temporary systems such as scaffolding, boom lifts, cranes and scissor lifts into BIM can be a challenge.

3. Field Study

3.1 Interviews

The information for the part of the field study reported on this paper was obtained from a series of semi-structured interviews with representatives of twelve firms and institutions in the construction industry in Singapore. Semi-structured, face-to-face interviews were carried out from January to December 2014. The main objective of the interviews was to find out the views of the practitioners in Singapore’s construction industry on the current state of BIM, productivity and safety in the industry.

There was a total of 30 interviewees from six contractors, two architectural firms, one cost consultancy firm; and representatives of a professional institution, a trade association, as well as representatives from the government. Selection of the interviewees involved a snowballing sampling technique. The first group of interviewees was identified from reports and articles indicating that they had played a key role in implementing BIM in their projects; or their companies had exceptional productivity and safety performance records.

3.2 Findings: Opportunities and Challenges

The interviews revealed that the firms were utilizing BIM at different levels. Some firms had been using BIM at relatively advanced levels. Some other firms still used BIM at the beginning stage, mainly for meeting the statutory requirements of building plan submissions in BIM format. One firm was still testing the use of BIM internally, to prepare itself for full BIM implementation.

The interviewees acknowledged that BIM brings about many benefits. It helps to visualise, highlight the problems and propose solutions before construction starts. Project stakeholders could view, discuss and analyse different scenarios. BIM is also able to minimise communication and coordination problems among the different disciplines involved in a construction project.

The form of support from the government which had been most popular with the firms was the financial support provided. The majority of the firms of the interviewees had utilised the BIM Fund to the maximum limit. They acknowledged that the funding had been useful and expected that there will continue to be assistance from the BIM Fund in the future.

The interviews gathered that the firms faced a number of challenges in the implementation of BIM, three of the main ones of which are now highlighted. Firstly, BIM implementation requires a multi-disciplinary approach. Specifications in great details from consultants and contractors are required to develop a useful BIM model. For example, to integrate scaffolding specifications with design specifications, information from formwork or scaffolding suppliers is needed. However, many of the parties were concerned with the confidentiality of the information on their projects; hence, it sometimes took a longer time than necessary to share the required information.

Most of the time, an initiative from one of the project stakeholders is able to push the implementation of BIM. For example, one contractor took the initiative to develop an in-house BIM division and train its own personnel in BIM. The contractor developed the BIM models obtained from the consultants further. It also made sure the subcontractors (for the M&E works in this case) to update the BIM models so that the models could be coordinated with the architectural and structural models. It required a great deal of commitment as a significant amount of investment in terms of time, training and equipment is required. Some of the challenges include additional time commitment required for updating the models throughout the duration of the project. For example, subcontractors prefer 2D drawings to 3D and BIM models as they had more experience with the former than the latter. A significant amount of time was spent on modelling and checking as models submitted for submission often are not up to the standard required in the subsequent stages of the project. Hence, they still need to be further developed. In terms of human resources, it was always a challenge getting the people competent in BIM, since there was an acute shortage of these persons. The BIM team in the office needed more support from the site, hence the site team needed to be trained as well. The reluctance of the site personnel to provide this support was mostly due to lack of knowledge, skills and time. As contractors and subcontractors are often under pressure to meet project deadlines, there was no sufficient time for developing the BIM competence required. For similar reasons, there was also no time for continuous and complete updating of the models.

Secondly, in terms of legal framework, there are still uncertainties of the legal responsibilities. For example, a BIM server is expensive. There is also an issue of maintenance costs. Thus, the server will have to be put into the contract for the project. There are also issues of intellectual property from, and ownership of, the BIM developed in earlier stages of the project, as well as responsibility for errors in the BIM. Furthermore, when the project ends, there is a question of who should take ownership of the BIM on the project. Most of the firms interviewed suggested that it would be most appropriate for the client to take ownership of the BIM models.

Some consultants and contractors acknowledged that there is a need to align what the developers want with what the project team can deliver. Many consultants were still not ready to meet the developers' expectations; such as the need to launch the sale of units in the project as soon as possible. Some contractors and consultants also provided the feedback that they were not ready for a full-scale BIM implementation. Hence, some contractors and consultants proposed that BIM should be implemented in stages. There was a need for all project participants to collaborate effectively. All in all, the interviewees suggested that developers should take the lead in the process of developing and using the BIM, but have realistic expectations from the project teams.

Thirdly, there were technical issues. Those which were most commonly encountered by interviewees were: interface issues, the loss of information when transferring the models from one software to another, licenses, bandwidth and security. One technical issue that was commonly encountered by the industry was because BIM models were created using different versions of the popular software. If the models had been prepared using earlier versions of the software, which are no longer available in the market, there will be some productivity loss due to the time spent contacting the manufacturer directly to obtain the particular version of the software before they were able to gain access to the models.

Another example was when one contractor was trying to transfer the BIM models to another party. They were discussing with the BIM vendor on how to transfer the models without losing much information. However, the BIM vendor was unable to resolve the issues. As a result, the other party had to use BIM models which were not the most comprehensive; a considerable amount of time was needed to put in additional information before the BIM models could be used by the other party.

Some other difficulties encountered were because the BIM models were of low level of detail. Hence, a great deal of time and effort was needed to improve the quality of the models so that rule-checking and quantity calculation could be performed.

4. Proposed Intelligent System for Productivity and Safety Improvement

Realising the challenges that the Singapore construction industry faced, an intelligent system has been developed which incorporates both productivity and safety performance, using BIM as the platform. The proposed system is the key deliverable of a research project funded by the

Ministry of Manpower, Singapore. The system, named Intelligent Productivity and Safety System (IPASS), was designed to provide a solution to improve productivity and safety performance by addressing the challenges and creating opportunities for the industry to maximise the benefits of BIM (Figure 4). IPASS enables collaboration among the project stakeholders as they analyse the productivity and safety performance before the start of a project. The system comes with a BIM modelling guide which specifies the method of inputting information in some detail. Thus, it will help to minimise disputes and improve the level of details of the BIM models developed by the consultants and contractors.

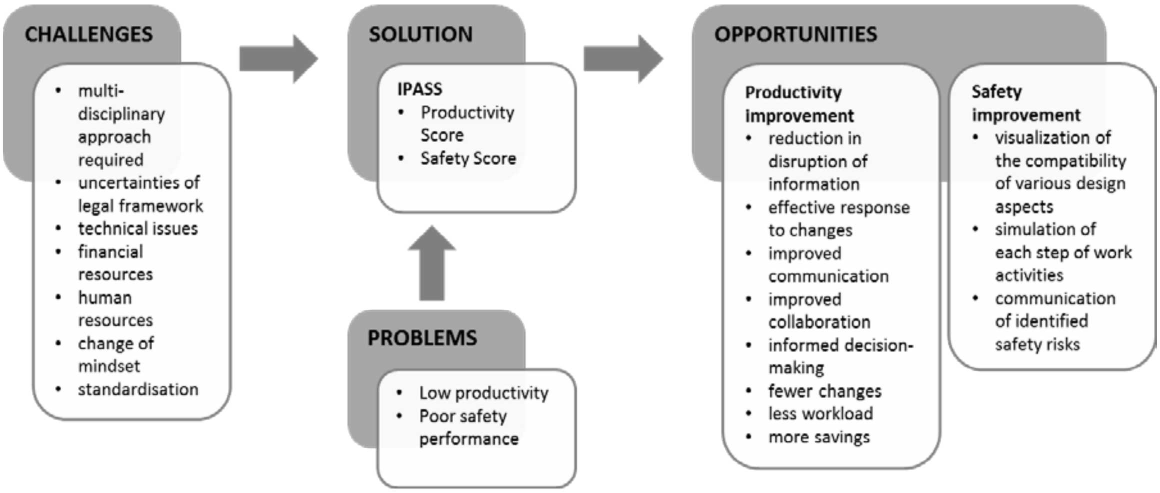

Figure 4. The development of IPASS as one of the solutions which can overcome the problems and challenges faced by the industry and create opportunities.

The system is also able to act as a monitoring tool for productivity and safety performance as the project progresses. IPASS automatically identifies safety hazards and provides solutions to mitigate the identified hazards. IPASS also allows the users to apply different structural and wall systems and see how they affect the buildability score individually or in combination, and to work to achieve the targeted score. Hence, during different stages of a construction project (pre-construction, design and construction stages), IPASS is able to help designers look at and improve the productivity and safety aspect of the design of a building. BIM models generated will help to visualize the different scenarios, enabling continuous productivity and safety monitoring.

The productivity score is computed based on the Buildable Design Score (BD Score) of the BCA's Buildable Score Assessment System (BDAS). The BD Score of a project is made up of three parts: Structural System (maximum 45 points), Wall System (maximum 45 points) and Other Buildable Design Features (maximum 10 points). The maximum productivity score achievable is 100 points. The BDAS was developed by the BCA as a means to measure the potential impact of a building design on the usage of site labour (BCA, 2014). Over the years, BCA has increased progressively the minimum BD score for building plan approval; this is aimed at boosting productivity. Hence, it is necessary for designers to include more productive technologies and standard components in the building design.

The safety score is computed based on the prevention and control of hazards detected in the structural systems and wall systems, and the Construction Safety Audit Scoring System (ConSASS) assessment. ConSASS is a tool to measure the maturity of the WSH system which includes its documentation and implementation, aiming at providing a standardized scoring system for the construction industry (MOM, 2013). ConSASS is aimed to provide an easy comparison between construction sites in term of their effectiveness in managing safety and health risks. ConSASS consists of an audit checklist and a score card. The audit checklist is derived from the Singapore Standards for Occupational Safety and Health Management System (SS506), Code of practice for safety management systems for construction worksites (CP 79) and the Universal Assessment Instrument (UAI) published by the American Industrial Hygiene Association (AIHA). The questions in the checklist are grouped into bands, from Band I to IV, in order to reflect the increasing level of maturity of the elements being audited. The results are tabulated in the score card, which shows the maturity of the different elements in the Occupational Safety and Health Management System (OSHMS).

The maximum safety score that can be achieved based on the prevention and control of hazards is 90 (maximum 45 points for the structural system and maximum 45 points for the wall system). ConSASS assessment is taken into consideration by giving the building a score for each band attained (from Band I to IV). The maximum score that can be achieved through ConSASS assessment is 10, which is when the building under assessment could achieve the highest band (Band IV). The maximum safety score achievable from the prevention and control of hazards as well as ConSASS assessment is 100 points. The full details on the development of the system can be found in other paper/s.

5. Conclusion

The Singapore government is playing an important role in leading the industry construction industry in adopting BIM through the first and second BIM roadmap, launched in 2010 and 2014 respectively. The roadmap put in place a number of strategies necessary for BIM implementation in the industry. However, it would appear that many firms in the construction industry in Singapore have yet to utilise BIM to its maximum potential. There are a lot of opportunities to utilise BIM for more strategic and important tasks than the current application for visualisation and meeting the requirements of building plan submissions.

The paper highlighted three challenges commonly encountered by the local firms. Firstly, successful BIM implementation requires a multi-disciplinary approach, but many players are still not ready for full collaboration since developing a useful BIM model requires sharing of information and specifications in great details. Secondly, there are still uncertainties of the legal responsibilities. The firms were still unclear about maintenance costs and the ownership of the BIM. Thirdly, there are still some important technical issues that have to be solved.

To bring BIM and its application to a higher level, it is essential to address those challenges. BCA had been trying to address some of the challenges. The second BIM Roadmap focuses on this. BIM can be utilised at a more advanced level when the construction industry has addressed the more fundamental issues. Some suggestions include involvement of all project stakeholders (rather than leaving it to the authority); initiatives and drive towards process transformation; and closer collaboration between consultants and contractors so that BIM can be utilised to achieve higher productivity and safer projects in the construction industry.

To address the challenges, an intelligent system has been developed which incorporates both productivity and safety performance, using BIM as the platform. The system, IPASS, was designed to provide solutions for the challenges and create opportunities for the industry to derive greater benefits from BIM. It was developed in line with the second BIM roadmap which emphasises collaboration to achieve higher productivity. IPASS enables collaboration among the project stakeholders as they analyse the productivity and safety performance before the start of a project. The system is also able to act as a monitoring tool for productivity and safety performance as the project progresses.

6. Acknowledgements

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