Paper submitted to the *Joint Symposium 2018: Innovative Technology Fusion for Next Challenging Century*, 21 Nov 2018 (Wed), Hong Kong.

From BIM to VDC: strategies for innovation and transformation

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ABSTRACT

Building information modelling (BIM) has grown significantly in the world and has become a very important trend to support the development of virtual design and construction (VDC) which can streamline integrated project delivery workflow and improve business performances and productivity throughout the total lifecycle of building assets. It is believed that BIM application is an important first step towards the digitalization of the construction industry; it will eventually become one of the essential competencies for construction practitioners. However, despite its many advantages, BIM adoption has been slow in Hong Kong. This research paper investigates the key factors affecting the adoption and implementation of BIM and discusses the strategies to transform the construction industry in Hong Kong via BIM innovation. To fully realize the benefits and power of BIM, there is an urgent need to promote high-quality professional education and advanced training.

Keywords: Building information modelling, virtual design and construction, Hong Kong.

1. INTRODUCTION

In recent years, building information modelling (BIM) has grown significantly in the world (Barnes and Davies, 2015; Holzer, 2016; MHC, 2009). BIM has become a very important trend to support the development of virtual design and construction (VDC) which can streamline integrated project delivery workflow and improve business performances and productivity throughout the total lifecycle of building assets (SMACNA, 2017). In essence, BIM is a collaborative working process in which all parties involved in a project use 3-D design applications, which can include additional information about assets' scheduling, cost, sustainability, operations and maintenance to ensure information is shared accurately and consistently throughout total assets' lifecycles (WEF, 2018).

The use of BIM technology has had more than a decade of history in Hong Kong (DEVB, 2017). With an incremental strategy in using BIM in public works projects and the experience gained in the BIM pilot projects launched over the years, the Hong Kong Government, together with the related consultants and contractors, now have started to proactively apply the BIM technology in more construction projects. It is believed that BIM application is an important first step towards the digitalization of the construction industry and it will eventually become one of the essential competencies for construction practitioners. However, despite its many advantages, BIM adoption has been slow in Hong Kong. This paper investigates the key factors affecting the adoption and implementation of BIM nowadays and discusses the strategies to transform the construction industry in Hong Kong via BIM innovation. It is hoped that the research findings could provide useful hints for enhancing understanding and accelerating the BIM adoption.

2. WHAT IS BIM?

In general, BIM can be defined as the process of creating and using digital models for design, construction, and/or operations of projects (MHC, 2009). Such digital models are meant to simulate the construction project in a virtual environment and can be used for planning, design, construction, and operation of the facility. The models can help architects, engineers, and contractors visualize what is to be built in a simulated environment to identify any potential design, construction, or operational issues (Azhar, 2011; Holzer, 2016). Figure 1 shows the typical applications of BIM at different stages of the project life cycle. In short, BIM is a digital form of construction and asset operations while it promises better decision making throughout the lifecycle of a project (EU BIM Task Group, 2017).

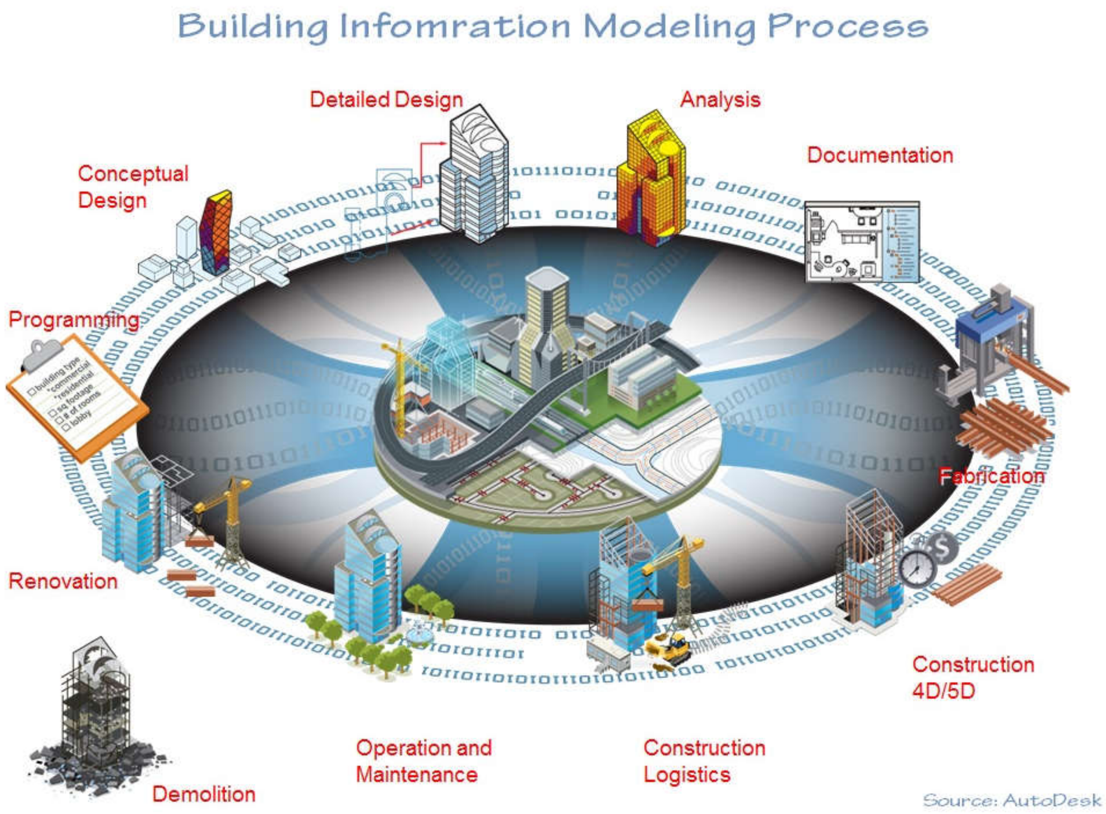

Figure 1. Basic concepts of BIM (Source: Autodesk)

A building information model can be used for visualization, enhanced documentation, detection of conflict, interference and collision, building performance and structural analysis, code reviews, construction sequencing, prefabrication and automated assembly, cost estimating and facility management (Azhar, 2011). The key benefit of BIM is its accurate geometrical representation of the building and its components in an integrated data environment. Other potential benefits of BIM include enhanced efficiency, lowered overall risk, improved project sustainability, decreased project cost, increased productivity and quality, and reduced project delivery time (Holzer, 2016).

In practice, BIM can be adopted and implemented in numerous ways, but it is essentially a software-facilitated working process used by the stakeholders in the construction industry. The use of BIM models is an integrated process whereas designers and contractors can derive many functions from its use. As an integrated design and management tool used to enhance communication and collaboration among all the project stakeholders, BIM is changing the way architects, engineers, surveyors, contractors, building owners, facility managers and suppliers work together (Crotty, 2012). BIM allows the stakeholders to simultaneously share, amend and access the building's physical and functional information on a building project or facility.

3. VIRTUAL DESIGN AND CONSTRUCTION

Virtual design and construction (VDC) is the process through which design and construction partners collaboratively simulate all work on a construction project in a 3D virtual environment before performing any work on-site, in the real world (SMACNA, 2017). Basically, VDC is the management of integrated multi-disciplinary performance models of design-construction projects, including the product (i.e., facilities), work processes and organization of the design-construction-operation team in order to support explicit and public business objectives. Figure 2 indicates the VDC process and its relationship with BIM. Not only engineering models, analysis and visualization, the VDC process can also consider and include business metrics, strategic management and economic impact analysis on the cost and value of capital investment.

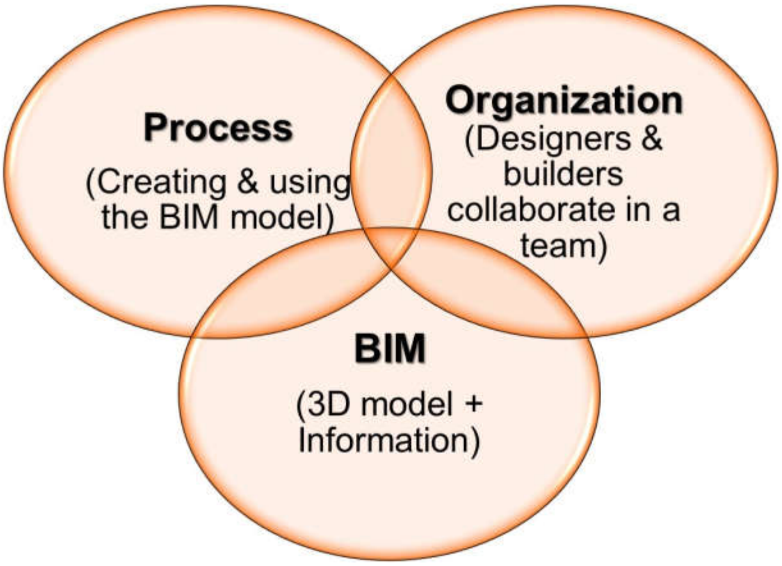

Figure 2. Virtual design and construction (VDC) process

BIM and VDC are very closely related, but not the same. VDC begins with the use of BIM solutions, but it goes well beyond the adoption of new technology. Its focus is on data-driven project collaboration, where all members of the project communicate to produce a project that is on time, on schedule, and exactly as the owner expects it (SMACNA, 2017). The VDC process is a technology-based solution that takes the next steps to ensure that the BIM model is used in a practical and highly effective manner throughout the lifespan of the project. The five elements that enable VDC are: BIM model, level of development (LOD), advanced digital tools, collaboration space and collaborative mindset. VDC allows project members to work in a common language, where all necessary information is transparent and instantly available. Challenges are solved proactively and cooperatively. Innovation is made possible by leveraging all team members' strengths and exploring creative solutions.

In other words, VDC is a "verb" or taking action on BIM. When BIM is described as a process, it translates into VDC. VDC is simply a visual management methodology using BIM as part of our proven construction analysis and work processes. Usually, BIM involves the

3D modelling and data input of physical objects; it is virtually building an object statically and with associated information. On the other hand, VDC uses BIM models to plan the construction process from beginning to end. It focuses on the construction planning of the BIM model and includes elements such as budget, cost estimation and scheduling.

With the introduction of VDC often follows the creation of new jobs and new ways of communicating within construction projects. It is believed that the role of VDC or BIM professionals is becoming more and more important in the construction industry (Gustafsson *et al.*, 2015). VDC can contribute in the entire building and construction industry and enable design consultants, engineers, contractors, and building owners to improve operational efficiency without compromising to quality and in the meantime reduce potential risk and costs in any construction projects.

4. KEY FACTORS AFFECTING BIM ADOPTION

Although BIM or VDC can offer many advantages, it is noted that its adoption in many countries and cities in the world nowadays is much slower than anticipated (WEF, 2018). Alreshidi, Mourshed and Rezgui (2017) have studied the barriers to BIM adoption and the key factors for effective BIM governance. They have found that the major barriers include both technical and non-technical problems which are related to socio-organizational changes, as well as financial, contractual, and legal issues. Table 1 summarizes the most significant BIM adoption barriers identified in their research findings.

Table 1. BIM adoption barriers [adapted from Alreshidi, Mourshed and Rezgui (2017)]

Social-organizational • Resistance to change • Lack of trust in and apprehension towards new technology • Lack of BIM understanding • Variations in practitioners' skills • Lack of BIM training • Lack of motivation • Clients' awareness • Adoption of traditional practices and standards • Avoiding/hiding potential risks and liability for mistakes **Technical** • Maturity of BIM-based technologies • Interoperability issues • Issues with existing BIM modelling and collaboration tools • Massive data inputs/outputs • Massive data and limited data storage • Limited accessibility and access rights • Lack of data sharing mechanisms • Lack of data tracking, checking and versioning control mechanisms • Difficulties coordinating large BIM models • Lack of notification mechanisms	**Financial** • BIM adoption cost and start-up costs • Personal Indemnity Insurance (PII) is not covered • BIM training cost • Limited budget • Expensive human-based services costs **Contractual** • Contractors benefit from confusion • BIM contracts are not yet mature • Lack of BIM-related aspects in current contracts • Failure to address BIM legal concerns in current contracts • Contracts need to accommodate changes in BIM collaborative environment **Legal** • BIM models ownership: intellectual property and copyright concerns • Liability for wrong or incomplete data • Lack of legal considerations in existing BIM contracts • Lack of legal framework for adopting collaborative BIM • PII does not cover legal aspects of collaborative work

In fact, BIM adoption has its own set of complexities that include inadequate software interoperability, additional (hardware and software) costs, and lowered productivity at the beginning stages of implementation. From the business point of view, the major concern that influences the decision makers is a lack of clear benchmarks to determine return on investment (ROI) for BIM implementation (WEF, 2018). A relevant calculation methodology and baseline to properly evaluate and measure the benefits of have not been established, thus there are mixed perspectives and opinions of the benefits of BIM, creating a general misunderstanding of the expected outcomes (Barlish and Sullivan, 2012). Even if the BIM benefits and costs can be identified and quantified, without a set of effective sharing agreements, it is not possible to convince and attract the project stakeholders.

4.1 BIM Risks, Technical and Managerial Factors

Azhar (2011) has studied the risks and future challenges of BIM. He indicated that the legal or contractual risks may come from the issues of ownership of the BIM data (i.e. copyright of the design models), licensing of equipment and material designs, responsibility and indemnities of the BIM users. It is a fact that the integrated concept of BIM blurs the level of responsibility so much that risk and liability are likely to be enhanced.

Usually, technical and managerial factors are the two main reasons affecting BIM adoption (Azhar, 2011). The technical factors can be broadly classified into three categories:

(a) The need for well-defined transactional construction process models to eliminate data interoperability issues,
(b) The requirement that digital design data be computable, and
(c) The need for well-developed practical strategies for the purposeful exchange and integration of meaningful information among the building information model components.

On the other hand, the management issues cluster around the implementation and use of BIM. At present, problems may arise as there is no clear consensus on how to implement or use BIM. Also, there is no single BIM document providing instruction on its application and use. Furthermore, little progress has been made in establishing model BIM contract documents. There is a need to standardize the BIM process and to define guidelines for its implementation.

4.2 Challenges with BIM Implementation

Langar and Criminale (2017) have investigated the challenges with BIM implementation at the project and organizational level and identified 36 barriers. They found that most of the challenges were at the organization level and the commonly identified challenges are related to the training of employees, lack of national standards for BIM, management of data, and interoperability of the software. Moreover, they indicated that two most common barriers are the time and cost needed for hiring/training people to use BIM. This shows clearly that the ability of the company to invest in maintaining innovativeness and competitiveness is critical to successful BIM implementation.

It should be noted that BIM offers a new paradigm to design, construct, operate, and maintain a building or facility. However, there still remains many challenges that continue to hinder the wider adoption and implementation of BIM. Even with the most conscientious use, stakeholders can run into trouble during its implementation. Antwi-Afari *et al.* (2018) have conducted a comprehensive review on the critical success factors for BIM implementation and identified some universal factors including collaboration in design, engineering, and construction stakeholders; earlier and accurate 3D visualization of design; coordination and planning of construction works; enhancing exchange of information and knowledge management; and improved site layout planning and site safety. It can be observed that many critical issues are associated with team collaboration and organization during construction projects. Figure 3 shows three key aspects for successful BIM implementation. It is believed that thorough understanding of the key aspects will provide hints for developing the strategies for accelerating BIM adoption.

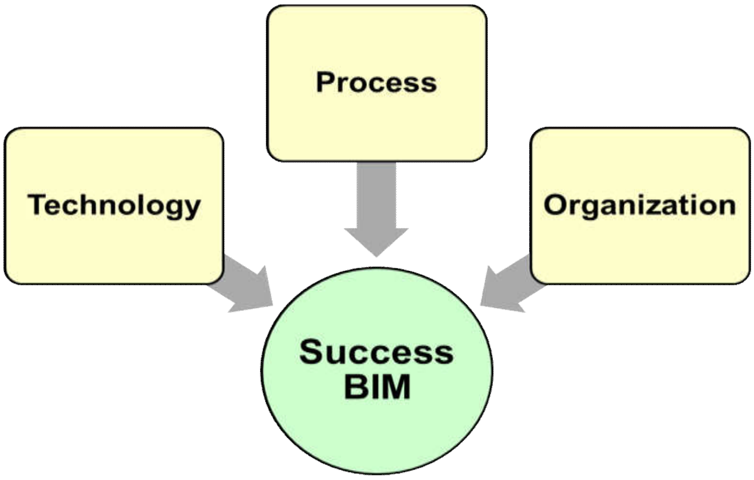

Figure 3. Three key aspects for successful BIM implementation

5. STRATEGIES FOR DIGITAL TRANSFORMATION

WEF (2018) has identified actions that could facilitate faster BIM adoption, as shown in Table 2. It is believed that increasing BIM adoption requires greater collaboration and that stakeholders be motivated and given the right capabilities. Also it is important to attract new talent with digital and BIM skills, upskill existing workers, and change corporate cultures to support the new processes with BIM.

Table 2. Recommended actions to increase BIM adoption [adapted from WEF (2018)]

Set the right motivation for BIM adoption - Understanding of BIM's benefits across the entire lifecycle - Think of BIM as a value creator rather than a cost factor - Approach BIM as the first step to construction digitalization
Enhance collaboration on projects - Use integrated contracts and redefine risk-return mechanisms - Set up early collaboration and communication among stakeholders - Establish data sharing and open standards
Enable all stakeholders - Establish BIM skills along the full value chain - Change behaviours and processes, not just technology - Make a long-term commitment and support innovative financing

More often than not, the role of the government is crucial for promoting BIM adoption and diffusion. To be effective, the government must make a long-term commitment to the technology by piloting it in public works projects and creating regulations conducive to its acceptance, including backing innovative forms of financing. Government policy and public procurement methods are recommended as powerful tools to support the transformation. However, it should be noted that BIM will only succeed if all the stakeholders (including companies, industry groups and the government) work together towards a joint vision through a common plan.

5.1 BIM Digital Transformation

Because BIM is a combination or a set of technologies and organizational solutions, its implementation requires local experimentation and continuous learning, in addition to following the usual technical standards and guidelines (Miettinen and Paavola, 2014). In reality, the technologies for BIM and VDC are evolving and developing continuously. It is essential to keep updated about the available solutions tools and the latest technology trends when planning for BIM adoption and implementation. For example, the current BIM tools can support parametric modelling and scripting capabilities which are important for generative design and optimization. It is necessary to gain experience with parametric modelling by applying it to common pilot projects and by spending time to learn the respective programming knowledge.

Nowadays many people consider BIM as a major driver for the digital transformation of the construction sector and the built environment (BSI, 2017; EU BIM Task Group, 2017). Using digital technology and the latest advances in digital construction, it can create a digitally integrated built environment. Moreover, BIM is considered as an innovation that is transforming practices within the Architectural, Engineering, Construction and Operation (AECO) sectors (Ahmed and Kassem, 2018; Crotty, 2012). The digital transformation with BIM/VDC offers significant opportunities for innovation and integration of other new technologies such as 3D laser scanning, drones, virtual reality, prefabrication, automated equipment, and mobile applications for team collaboration. Figure 4 shows BIM collaboration and the stakeholder value chain.

Figure 4. BIM collaboration and the stakeholder value chain (Source: https://www.buildingincloud.net/en/bim-collaboration-2/)

In principle, BIM is a collaborative platform that improves coordination and cooperation in a project, from architects and technical consultants to building teams and suppliers, all the way to the future property and facility managers. It can act as a strategic enabler for improving collaboration and decision making for both buildings and public infrastructure assets across the whole lifecycle (EU BIM Task Group, 2017). BIM can be applied to managing new build projects as well as supporting the renovation, refurbishment and maintenance of the built environment, which is the largest share of the sector in most cities in the world. In order to move to digital collaboration effectively and achieve the desirable outcomes, it is crucial to have the evolution of a new social-ecosystem for the AECO sectors with the support of suitable BIM collaborative tools. It should be noted that widely adoption of BIM does not change the fragmented nature of construction sector. A throughout understanding of BIM concepts as a socio-technical system is important (Turk, 2016).

5.2 Implications to Building Services Engineering

It can be seen that BIM is causing a major paradigm shift for the AECO sectors. From practical field experience, usually architects are the heaviest users of BIM. Unfortunately, there is a common perception amongst clients, architects and contractors that building services engineers are lagging behind in delivering BIM. In order to overcome the barriers and enhance the adoption of BIM in building services engineering (BSE), cooperation from both upstream and downstream delivery partners is needed. For the upstream, it refers to a client who knows what to demand and what to expect when using BIM. For the downstream, BIM-readiness of suppliers of BSE equipment and materials is critical.

A survey research by Lai, Ng and Chiu (2016) has indicated that BIM adoption in the BSE field in Hong Kong is limited. The research also revealed a range of measures conducive to wider adoption of BIM for BSE. The top measures include:

(a) Establish data exchange standard and management framework for information sharing,
(b) Incentive given by government on the use of BIM,
(c) Set up a BIM object library for BSE components and develop standardized BSE legends for better integration with other disciplines,
(d) Provide training and guidance on the use of BIM, and
(e) Allow enough time in project programme for BIM model development.

Since BSE is closely related to facility management (FM) in practice, it is believed that more innovative commercial BIM applications can be developed by building services professionals to support the operation and maintenance of buildings and public infrastructure assets. At present, facilities managers have been included in the building planning process in a very limited way (IFMA Foundation, 2013). In the future, BIM modelling may allow them to enter the picture at a much earlier stage, in which they can influence the design and construction.

Nowadays, BIM methodology is still mainly developed and applied for new building projects (Scherer and Katranuschkov, 2018). Its use for renovation and retrofitting projects is seldom (Volk, Stengel and Schultmann, 2014). The potential of BIM application in operations and maintenance, facility management and retrofit projects of existing buildings is considered to be very large and more innovative technologies are needed. For instance, in order to generate and manage the BIM data for existing or old buildings, new capturing method using 3D laser scanning for model generation can be applied; the BIM model and information can then be used for building energy modelling to support energy retrofitting, or for smart building control with Internet of Things (IoT).

Furthermore, other opportunities for BIM innovation with BSE include the prefabrication capabilities of BIM for BSE components (Jang and Lee, 2018) and the applications of BIM to support green building performance analysis and green building assessment (Lu *et al.*, 2017). It can be seen that if BSE or other companies do not change and incorporate the innovation, they may not be able to survive in the long run – as has been seen in other industries where new technology innovators have disrupted and completely changed their market. For the BSE practitioners, a BIM skilling process is required that starts by asking what skills are needed and then provides the mechanisms by which they can be delivered so that the transition and transformation can be satisfactory.

6. IMPORTANCE OF EDUCATION AND TRAINING

It is believed that BIM will soon become one of the core skills of the construction industry participants, just like the migration to computer-aided drafting in the 1980s. The growing importance of BIM gave rise to a strong demand for BIM professionals, coordinators and specialists who have good technical and strategic planning skills for BIM projects. As the popularity of BIM has grown tremendously in the past decade, there is an urgent need to enhance BIM training and education for the relevant professionals, such as architects, engineers, builders, construction managers, quantity surveyors and facility managers.

The desire to design and build in virtual environments using the BIM technology has resulted in rising demand for building professionals and engineers with the BIM knowledge and skills. In fact, it is believed that the shortage of specialist BIM professionals is one of the major reasons for the slow adoption and ineffective development of BIM in Hong Kong. To maintain and enhance the long-term competitiveness of Hong Kong's construction and engineering industry, it is very important to improve the BIM education and training in the society.

6.1 Current Situation in Hong Kong

At present, many government departments and private companies of the construction and building industries in Hong Kong would like to train and develop their staff to be "BIM-ready" and to have sufficient insights on VDC as well as integrated project delivery. As BIM adoption by the building and construction industry increases, it is becoming clear that there is a growing need for universities, educational and training organizations to provide their graduates and trainees with appropriate BIM-related skills in different relevant domains such as architecture, engineering, building construction, project management and facility management. The recognized potential of BIM has also motivated many institutions and universities around the globe to include appropriate online BIM courses and modules in the exiting curricula of construction education.

While the government and professional organizations are mandating the use of BIM for complex built environment projects, many educational institutions have devised specialized curriculum and educational programmes on BIM to prepare fresh graduates as well as provide training to existing workforce. The demand of the building and construction industry and various employers in the public and private sectors for well-trained BIM professionals is high, but the education places for this sector of people are still limited. In Hong Kong at the present moment, there are only a few education and training providers on BIM and most of them focus on hands-on (proprietary) software training and short-term basic educational courses. To fully realize the benefits and power of BIM, there is an urgent need to promote high-quality professional education and advanced training.

6.2 BIM Education and Training

It should be noted that the development of BIM knowledge and skills is not just confined to software training. To prepare people with enhanced skills in BIM, it is necessary to transfer the idea of digital design and collaboration among the participants of the construction process into the pedagogical process (Kozlovska and Spisakova, 2013). The development of skills for virtual design and management of construction involves logical and critical thinking in the use of digital technologies as well as communication and teamwork aspects. By establishing professional and managerial aspects in BIM education, it can ensure the graduates have the essential understanding and job-specific competencies to manage the BIM innovation and digital transformation. For instance, when a company hires an engineer or architect trained in BIM, this professional can help get the company started on its VDC journey and educate others within the organization on what further training and resources might be needed to gradually transform the company to a data-driven services company and VDC advocate.

An analysis of BIM jobs and competencies by Uhm, Lee and Jeon (2017) indicated eight major BIM job types including BIM project manager, director, BIM manager, BIM coordinator, BIM designer, senior architect, BIM mechanical, electrical, and plumbing (MEP) coordinator, and BIM technician. They have also identified 43 competency elements which can be categorized into essential, common, and job-specific competencies for the eight BIM job types. The research findings can contribute to the industry on how to set up guidelines for recruiting and training BIM experts, as well as to the educational institutes to allow them to develop effective BIM-related courses. To illustrate the different levels of BIM jobs, a BIM career ladder is shown on Figure 5.

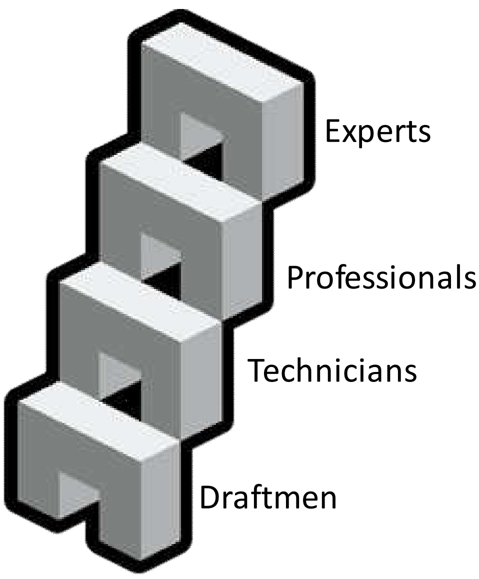

Figure 5. The BIM career ladder

7. CONCLUSIONS

BIM is emerging as an innovative way to virtually design and manage projects. It represents a new paradigm that encourages integration of the roles of all stakeholders on a project. The productivity and economic benefits of BIM are becoming widely acknowledged and increasingly well understood. Also, the technology to implement BIM is readily available and rapidly maturing. Yet BIM adoption has been much slower than anticipated.

BIM is being recognized as a collaborative process that creates value through the entire lifecycle of the built environment. The industry has accepted BIM as an effective tool to overcome design and construction-related challenges and started removing barriers to its implementation. The development of education and training for BIM technology is very important for further advancement and implementation of BIM in Hong Kong.

It is foreseen that BIM adoption in Hong Kong will increase and it will eventually become one of the essential competencies for construction practitioners. The BIM knowledge and skills are important for consultants, contractors, government officers and building managers. Development of professional education and advanced training of BIM technology is urgently required to satisfy the manpower demand for BIM and enhance the capacity and capability of existing workforce in Hong Kong. It is hoped that the research findings here will help shorten the learning curve and assist in achieving a more widespread adoption of BIM throughout the industry.

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