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Studies the Roles of Professional Land Surveyors in the Emerging Trend of Building Information Modeling(BIM) – Final Draft

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Disclaimer

Whilst reasonable efforts have been made to ensure the information contained in this report is accurate, the authors nevertheless would like to remind readers that BIM development in Hong Kong and worldwide is very dynamic. Information quoted in this report may quickly become obsolete or out-of-date. Readers are encouraged to seek appropriate professional advice and should not treat or rely on this report as the only source of information.

Acknowledge

We would like to express our sincere gratitude to the Hong Kong Institute of Surveying (HKIS) for giving us the opportunity to prepare this report. BIM is certainly a hot and exciting topic in Hong Kong. We sincerely hope that members of HKIS, especially from the land surveying division, would benefit by reading the materials in the report and also share the vision that we perceived.

We would like to thank Miss Alex Kong Nga Lai, graduate of the BSc (Hons) Surveying and Geo-informatics programme offered by The Hong Kong Polytechnic Univeristy. She kindly accepted our suggestion to study BIM's impact on the land surveying profession as her final year project. Some of her works were reproduced in this report. Throughout the development of this report, we visited BIM consultants, land surveyors, hardware and software vendors and construction project managers. We sincerely thank them for spending valuable time with us and giving us valuable comments and advices. Last but not least, we would like to thank the Department of Land Surveying and Geo-Informatics, The Hong Kong Polytechnic University for providing an excellent platform for us to conduct the study.

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1 Introduction

1.1 Project Background

AECOO (Architecture, Engineering, Construction, Owner and Operator industry) has been going through a revolutionary change with the emerged of Building Information Modeling (BIM). BIM's impact is not just affecting the AECOO industry but also the land surveying profession. The name, Building Information Modeling (BIM), may be miss-leading to those who are new in this arena. This project is attempted to provide a clear concept of BIM by reviewing the development of BIM in the world. In addition, the integration of BIM and Geographic Information System (GIS) will also be explored. Through literature reviews, interviews and discussions with industrial players, the project is attempted to clarify the roles of professional land surveyors in BIM and the opportunities ahead.

Land surveying professionals have been in the leading roles in precise location determination for various applications in Hong Kong such as land boundary determination, establishment of geodetic control networks, map production and building & construction surveying. Furthermore, with the development of Geographic Information System (GIS) technologies, Land Information Center (LIC) of the Surveying and Mapping Office was established and has been producing the most comprehensive digital map database of Hong Kong. This database has been widely adopted by various government departments such as Planning Department and Transport Department as their digital map base. Maintenance and development of this core dataset has been one of the important roles of modern land surveyors. Most recently, LIC has released 3D map data which can be used for urban planning and to facilitate large scale infrastructure development in Hong Kong.

On the other hand, BIM technology has been widely discussed and adopted in the AECOO industry for the last few years. The benefits of BIM technology and related business practices are well-established oversea. The purpose of BIM is to support the planning, design, fabrication and construction of new facilities and software products are optimized to facilitate these processes (Przybyla, 2010). While building engineers are keen to use this new technology for energy analysis, code compliance checking and cost estimating for building projects; the functions of land surveyors in this technology evolution are not clearly defined. RICS (RICS, 2012) quotes that BIM is an essential tool for property professionals and is revolutionizing the surveying industry.

1.2 Project Objectives

The objectives of this study are to:

1. provide an overview of the BIM technologies;
2. review the current BIM development in Hong Kong;
3. investigate the impact of BIM technology in the land surveying profession; and
4. discuss the roles of land surveyors and the opportunities and challenges ahead.

1.3 Organization of this Report

To review the roles of land surveyors in the emerging trend of BIM, the definition and knowledge of BIM are discussed first. The three important words: digital databases, coordination and collaboration are the key focus of discussion. Then, the benefits of adopting BIM in the construction industry are reviewed through three perspectives: project owner, AEC industry and society. Further on, the advantages of BIM and some misconceptions and extensions are discussed. Chapter 3 outlines the three major technologies: BIM tools, scanning tools and GIS.

The current BIM development in Hong Kong is reviewed in Chapter 4. Chapter 5 analyzes the possible roles of land surveyors in construction survey, as-built survey and 3D spatial data management under the influence of BIM. Recommendations and action items are summarized in Chapter 6.

2 What is BIM?

It has been generally agreed that the term Building Information Modeling (BIM) has been accepted by the AEC industry when Autodesk released the white paper entitled, *Building Information Modeling*, in 2003. In the white paper (Autodesk, 2003), it outlines the characteristics of BIM with the words: *digital databases, coordination and collaboration*. Building information is stored in a database in a coordinated matter through the collaboration of the project team.

2.1 Definition of BIM

The National Building Information Model Standard (NBIMS) Project Committee defines Building Information Modeling as

"*Building Information Modeling (BIM) is a digital representation of physical and functional characteristics of a facility. A BIM is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle; defined as existing from earliest conception to demolition.*"

(Definition of BIM, NBIMS)

The digital database or digital representation of a building is further elaborated by Kymmell (2008) as 3D models of the project components with links to all the required information connected with the project planning, construction or operation and decommissioning.

In the recent report published by HKCIC (HKCIC, 2013b), BIM model composes of the following five characteristics:

1. A parametric, relational database to store every object in a building and information far beyond design and construction details.
2. A "smart" model that a change to a component is reflected in all components and all levels of operation.
3. A constant 3D representation of a building which supports the generation of a 3D view, from any angle, at any section and at any time.
4. An intelligent tool that can be used to study and analysis across multiple

disciplines.
5. A permanent, living document.

From the surveyors' perspective, RICS (RICS, 2012) states that BIM contains representations of the actual parts and pieces being used to construct a building along with geometry, spatial relationships, geographic information, quantities and properties of building components. Combining the model with other essential elements such as time, cost, performance, etc., BIM provides a common single structure in a coordinated environment to support all stakeholders throughout the entire building lifecycle from the design stage to the as-built stage. The virtual BIM 3D model created, with coordinated collaboration efforts by all parties involved in the delivery process, would eventually become a "true" physical representation of the building in space. The true building model can then be integrated to a city wide information model to form part of the digital city. Sharkey and Young (2014) state that when BIM coupled with geospatial data - an intelligent, 3D model driven environment can be visualized as 3D city models.

For the purpose of this study, the following three key characteristics of BIM are highlighted:

- A digital database. A 3D BIM building model database is a content rich virtual model embedded with geo-referenced building parts (building component objects), accurate geometric representation and implicit/explicit spatial relationship.

- A model-centric coordinated process. BIM is a process based on a common single structure constructed in a coordinated environment. Information being updated in the database may affect the design and workflow of other parties. The process of updating must be managed in a coordinated matter so that the immediate benefits of BIM can be realized.

- A collaborated effort by all parties. BIM's success relies on the collaboration amongst all parties involved during the building lifecycle and extended to the as-built stage. The collaboration should not be ended when the project (building) is completed. The accurate virtual model should be transformed to a true model which can be used for future building operation and management, and integration to a city information model.

HKCIC (2013a) states that BIM is not only a drawing tool but a new management tool to manage information relating to construction projects from preparatory stage, to construction and operational stages.

"Building Information Modeling (BIM) is the process of generating and managing building data during its design, construction and during the building or assets life cycle. Typically, the process uses 3-dimensional building modeling software to increase productivity of consultants and contractors during design and construction. The process produces the BIM, which encompasses building geometry, spatial relationships, geographic information, and quantities and properties of building elements. "

(Hong Kong BIM Standards, BIM PEP Draft 1, 2014)

BIM is more than just a tool. BIM brings transformation to construction industry and it revolutionizes the industrial practice and changes the way how construction projects should be managed. It is a major cultural change and much more intense compared with the adoption of CAD for the replacement of manual drafting 20 years ago. Worldwide, there is that "wait and see" mentality causing a slow adoption of BIM. As stated earlier, project owners would be able to realize the immediate benefits of BIM but contractors and engineers will have to first invest before they can enjoy the merits of BIM. The investments are not limited to technology but also organization change, cultural change and people. The MacLeamy Curve shown in Figure 2.1 demonstrates the shift of the BIM design process towards the beginning of the project lifecycle when compared with the traditional design process. Other than upfront investments and skepticism issues, 2D engineering plans with very specific drawing standards are still required under the current legislative requirements for plan submission. Contractors and engineers may have to duplicate their works to create 2D drawings for the fulfilment of the legislative requirements in addition to the development and maintenance of the 3D BIM model. Ms. Ada Fung, Deputy Director of Housing, in many vocations, shared Housing Authority (HA)'s experience in facing these challenges. More discussion about the implementation of BIM in HA will be discussed later.

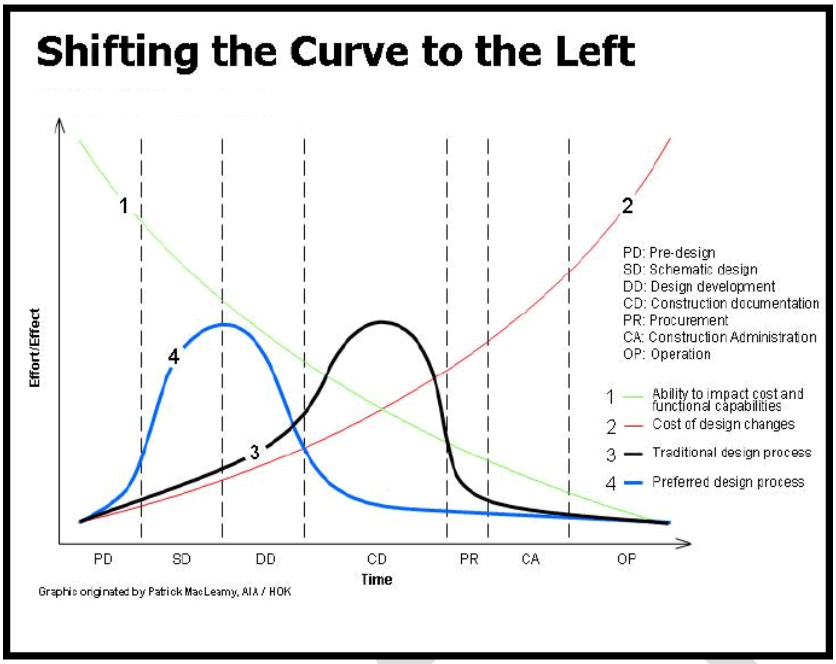

Figure 2.1. The MacLeamy Curve

2.2 Why BIM?

The Government Construction Strategy from the UK Cabinet Office states that for the construction industry, the most compelling benefits arising from this strategy lie in the immediate prospects for improved growth and in increased competitiveness: in eliminating waste and inefficiency and stimulating higher levels of innovation that will make construction more affordable for customers at home and create new opportunities abroad. While the UK Government is expecting to achieve a minimum saving of 15% on infrastructure cost, similar savings should be achieved across all construction sectors.

Other than the possible cost savings, in the report recently published by HKCIC on the *Roadmap for BIM Strategic Implementation in Hong Kong's Construction Industry*, there are 7 drivers pushing the construction industry to the adoption of BIM. The 7 drivers are:

1. Increase in Productivity and Effectiveness,
2. Cost Saving and Reduction in Wastage,
3. Better Quality and Integration,
4. Improvement of Public Understanding to a Proposal,
5. Better Management Control and Reduce Project Risk,
6. Public Client Initiatives, and
7. Private Client Initiatives.

Detail discussions on these drivers can be found in the report (HKCIC, 2013b). In Singapore, one of the key driving forces is a labor shortage problem in the construction industry. With the projected population estimation of 6.5-6.9 million by 2030, the Building and Construction Authority (BCA) of Singapore aims that 80% of the construction industry will use BIM by 2015. The target is to improve the construction industry's productivity by up to 25% over the next decade. Zeiss (2013) also states that unprecedented rate of urbanization globally and the increasing demand for energy efficient green buildings are the major drivers for investment in BIM for the coming years. However, the implementation of BIM is not as simple as the adoption of a new piece of software program. It requires the AEC industry to revolutionize its practices which have been operational for many years. Different participants have to start working together in a well-coordinated and collaborative manner on the drawing board before the first peg even put into the construction site. Instead of using the traditional construction supply chain model, all involved parties have to adopt a shared project model as illustrated in Figure 2.2. Different participants can share and exchange information on a common platform.

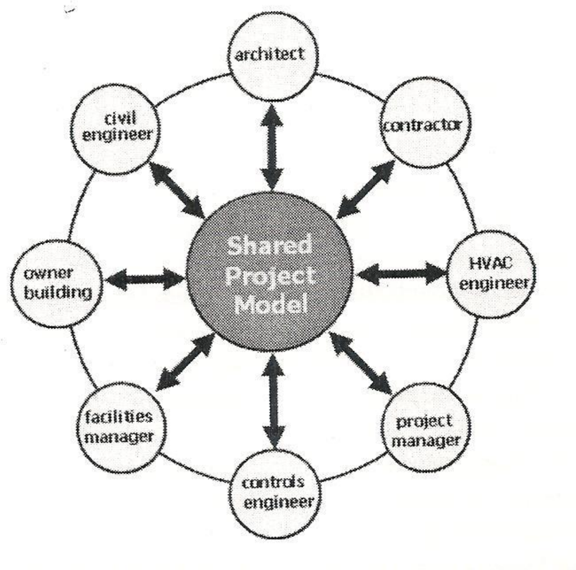

Figure 2.2. A Shared Project Model (Building Information Model) (Nederveen, et. al., 2010)

In order to encourage the construction industry to adopt the shared project model, various participants must be able to perceive the benefits of BIM. These benefits can be short term or long term, project based or city based, direct or indirect. If different stakeholders and participants are able to realize these benefits, the adoption of BIM in the society can be much faster and smoother.

HKCIC lists the benefits of BIM from project client's perspective in its *BIM: Fact Sheet*. Project clients include property developers, Government and public bodies.

(a) Provide multi-dimensional pictures and timely information of construction projects;
(b) Allow testing on models and quickly generating options for better decision making in respect of time, cost, process, and risk, etc, during the design phase to avoid site problems;
(c) Detect design faults (especially clashes) and minimize design change;
(d) Improve site safety management and education;
(e) Enhance financial risk management and minimize financial claims due to variation delay;
(f) Facilitate better project coordination by bringing all relevant disciplines of participants in the construction project at an early stage;
(g) Facilitate third party and even the public engagement by enhancing social awareness with a view to soliciting the support of the community at project planning stage.

(BIM: Fact Sheet, HKCIC 2013a)

Other than the project client, the benefits of BIM can be reviewed from three perceptions: owner's perception, AEC industry's perception and perception from society.

2.2.1 Owner's Perception

Richard Humphrey, senior director of Autodesk (2014) states that a BIM model-based process can achieve 30% more efficiency either through more productive or efficient design or through better coordination and collaboration. The 30% efficient is being interpreted by the potential owners (e.g. property developers) in the construction industry as 30% reduction in construction cost. Possible cost saving is definitely the primary motive for the adoption of BIM in the construction process by project owners.

Housing Department (HD), one of the pioneers in Hong Kong on the adoption of the BIM technology in HD's construction projects, reports to the Digital 21 Strategy Advisory Committee (2013) that the benefits of using BIM in construction projects includes better quality, coherent design, more effective construction cycle, reduction in construction waste and improved site safety. For the recent projects, Ir. Fung (2013), architect of Housing Department, discusses that HD used BIM as a visualization tool to understand the complex geological condition, a management tool to resolve complex site constraints and to reduce cost and time.

William Lichtig (2006), an attorney specializing in construction contracts, states that over the past one hundred years, the design and construction industry has become increasingly fragmented. Each specialized participant now tends to work in an isolated silo, with no real integration of the participants' collective wisdom. Project delivery methods developed over the years have not been able to satisfy the increase demands from project owners. Project owners have difficulties to visualize the project information based on the architectural design model and the contractor's 2D building plans. It would be even harder to realize if the project is able to meet the goals (e.g. energy efficient) set by the owners until the project is near its completion.

The BIM process creates an environment for the architect and contractors working together in the pre-construction stage on a virtual building model. Possible conflicts can be found and resolved in the model. Such a virtual design and construction process has the ability to communicate design intent by providing 3D view of the project models, which also helped the designer in the development of the project details (Kymmell, 2008). The capability of the software tools to generate 2D construction plans from the 3D models ensures last minute change in the model can be reflected in the construction documents. Project owners can have the comfort to believe "what you see is what you get". Furthermore, a geospatial BIM model, when linking to a GIS system, provides unlimited capabilities for environmental impact assessment.

In addition to the direct cost saving and 3D visualization capability, BIM process can reduce the risk of project delays and increase project participants' understanding of the details of a project. Other client benefits from the BIM process are listed below.

Project Benefits	Client Benefits
Reduction in the number of variation orders	Better cost and time control
Minimisation of construction waste	Becoming more environmental friendly
Enhancement of building project marketing presentation	Better perception from society

There is no doubt that project clients are very excited about the technology and their benefits are project based, immediate and direct. However, the successful adoption of BIM process in construction projects realizes heavily on the AEC industry's willingness to change and transform.

2.2.2 AEC's perception

As the BIM process tends to make the management process more transparent, project owners are able to visualize how their project goals are being achieved by the project team. Weaknesses and design problems of a project can easily be detected by processes and tools such as clash detection and 3D visualization. Unfortunately, the project team, which composes of team members from the AEC industry, would have a great difficult accustomed to this transparent environment. Jernigan (2008) states that convincing the construction industry to embrace new technology is a challenge – a cultural shift enormous resistance. Apparently, the AEC industry is unable to gain any direct benefits on the adoption of BIM in the construction process. Ironically, without the coordinated collaboration from the project team members, the full benefits of the BIM process cannot be realized. Apparently, "sticks" are given to the project team members but the project owners receive the "carrots".

To encourage a wider adoption of BIM in the industry, BCA Singapore setups a BIM fund (ENHANCED) to help firms adopt BIM technology into their work processes. Up to 50% of the supportable items costs at scheme levels, the firm level scheme and the project collaboration scheme, will be reimbursed. This BIM fund will certainly encourage AEC industry in Singapore to adopt BIM in the construction process. In UK, the Government will require fully collaborative 3D BIM on all centrally procured construction contracts by 2016. In another words, all AEC industrial players in UK will have to deliver all centrally procured public project information and documents at a minimum Level 2 BIM (refer to Section 2.4.2).

In both countries, the AEC industry has been pulled or pushed by their respective Governments to quickly adopt the BIM process.

While the project team members may not be able to benefit from the BIM process immediately during the pre-construction stage, indirect project benefits can be realized throughout the construction stage. Project risk can be reduced or eliminated through better communication and collaboration. Project cost can be reduced by the reduction of labor, pre-identification of construction conflicts and higher level of prefabrication via 4D BIM. Project time can be shortened with improved preconstruction planning and construction scheduling via 4D and 5D BIM (refer to Section 2.4.3).

2.2.3 Society's perception

Hugh public spending on infrastructure, shortage of labor in the construction industry, growing demands on green buildings and construction; and increasing demands on public project and government transparency are some of the drivers experienced by many developed countries such as US, UK, Singapore and The Netherlands to push the investment in BIM. Citizens and tax-payers would also be the beneficiaries.

With a potential of 15-20% saving on infrastructure cost as estimated by the Singapore and UK Governments, the benefit in term of value spending on infrastructure development can be perceived directly by the society. Accordingly to *Quarterly Construction Cost Review*, a quarterly report published by LangdonSeah (1st quarter, 2014), the tender price indices in Hong Kong have shown a high rate of increase. Both the Building Works Tender Price Index and Building Services Tender Price Index had gone up more than 43% and 64% respectively from end of 2009 to end of 2013. Shortage of construction workers continues to be one of the contributors to the increase in the indices. By adoption the BIM process, optimum level of workforce can be achieved and public spending on infrastructure development can be controlled.

Last year, a record high global CO_2 concentration sent a strong signal to the world. Buildings use about 40% of global energy and emit approximately one-third of the global greenhouse gas emissions (Zeiss, 2013). BIM has the potential to reduce unnecessary construction wastage by optimizing the construction lifecycle and create environmental friendly buildings which are sustainable and "green".

MTR recent announcement of a 2-year delay for the Hong Kong to Guangzhou express rail link project due to "unforeseen difficulties" shocked the local community. A 2-year delay in completion had pushed back the opening of the HK$67 billion line to 2017 and it would be billions of dollars over budget (SCMP, May 2014). With the advancement in wireless communication, popularity of mobile devices and change in the political culture, the demands for transparent public project and government spending have increased. Adopting the BIM process in this kind of project may not be able to shorten the project delay but can identify problems and resolve them in an early stage. With more timely and accurate information such as cost and schedule variations, the management would have a better control of the project and be able to manage the public expectation in a timely matter. Stewart (2014) explains that in large scale projects, it is common for the public to have a fear of the unknown because of a lack of understanding and knowledge of a project and its perceived impact on the locality. In the Homan high speed railway project in Korea (Cho et al. 2011), 3D BIM project model was developed not just for construction purpose but also public relations purpose as well. This is one of the indirect and intangible benefits using BIM.

2.3 Advantages of BIM

According to Kymmell (2008), the advantages of a BIM process can be organized under three words: visualization, collaboration, and elimination. Visualization addresses the benefits that are brought to individual so that the person has a better understanding of the project by using BIM; collaboration refers to cooperation among different parties that is facilitated by BIM; finally, elimination addresses the reduction of undesirable factors, such as conflicts, waste, time, and risk. Based on this framework, the advantages are to be introduced specifically in the following table.

Categories		Advantages	Brief Description
Visualization	✓ ✓ ✓ ✓ ✓	Better access to project information Easy to assess the constructability Easy to follow the construction stage Faster design plans and alternatives formation Improve design quality	People's understanding towards the projects is increased through the BIM process, as detailed information is visualized and 'seen' on the 3D model.
Collaboration	✓ ✓ ✓	Improved coordination and collaboration Avoid duplicated works Easier project management	The BIM process facilitates information exchange among different parties throughout the construction cycle.
Elimination	✓ ✓ ✓ ✓	Reduced risk Reduced cost Reduced time Reduced waste	Risk can be minimized by clash detection process; cost, time, and waste are reduced by better construction sequencing, optimization analysis, or reduction in re-works.

Table 2.1: The advantages of adopting BIM process under the classification method (Kymmell, 2008)

2.4 Misconceptions and Extensions of BIM

During the early stage of BIM adoption in the construction industry, there were a lot of misunderstandings and false expectations. Jernigan (2008) uses "BIM is not" as a way to clarify some of the misunderstandings of BIM. Table 2.2 summarizes his ideas and other misunderstandings in the industry.

BIM is "NOT"	Explanation
a single building model or a single database	BIM is a process with a series of interconnected models and databases
a replacement for people	People have to work smarter but not harder. People with different training and mindset are required.
automate you out of existence	BIM helps to streamline some processes with less effort but people still require gathering information, solving problems and communicating with project team members.
perfect	BIM is as good as the quality of the information entered into the system.
Revit (or ArchiCad, or Bentley)	BIM is not just a piece of software but a process. Software programs are essential tools but not the "BIM" solution.
just 3D or have to be 3D	3D models are essential in BIM. They helps project teams communicate and visualize problems effectively. Other standardized information can also be part of BIM, such as street addresses and zip code. This data can be imported into BIM and becomes part of BIM.
complete	There is no need to wait for all standards and tools are ready before BIM can be successful.
clash detection	Clash detection is one of the tools in BIM software but it is not BIM. Clash detection tools help design and construction engineers anticipate and avoid potential problems before construction begins, and minimize expensive delays and rework (Soni, et. al. 2011).
GIS	BIM is not GIS. Both technologies handles spatial data but BIM focuses on the microscopic view of a building and GIS may only concern with the macroscopic view of the same building. Both technologies should work in an integrated matter.

Table 2.2 Misconceptions of BIM – BIM is “NOT”

In fact, similar misconceptions happened in the land surveying profession when geographic information system (GIS) technology emerged and replaced the traditional manual map drafting and production processes. In the eighth decade of last century, a big wave of technological change catalyzed the creation of GIS, a significant product which has imposed strong impact in all fields that use geographic information, in resource management, land-use planning, transportation, marketing, and in many applications in the geosciences and elsewhere (Bonham-carter, 2006). With over twenty years of development, land surveyors fully understand that GIS can streamline some mapping processes and provide structured information for decision making but the system is not perfect. GIS is a decision supporting system and the quality of the information is as good as the quality of the information entered into the system.

2.4.1 3D Model vs 3D BIM Model

There have been a lot of misconceptions that "BIM is 3D modeling" and "3D model is BIM". As discussed before, a 3D model is probably the most important element in a BIM process but 3D model is not BIM. The 3D model referred is not just a geometric representative of a building or a project only. It is also an important platform allows members of the project team to share project information. While 3D models make valuable contributions, not all 3D models qualify as BIM models since a 3D geometric representation is only part of the BIM concept. In *the GSA BIM Guide Series 01* (2007), it further elaborates the differences that "3D geometric models contain very little intelligence. BIM models contain a high level of intelligence. A 3D model includes a three-dimensional geometric representation of the building, whereas a BIM is organized as a prototype of the building, in terms of building floors, spaces, walls, doors, windows and a wide array of information associated with each of these elements. A BIM can normally be viewed in 3D, but the model also includes information used by other building analysis applications, such as cost estimating, energy simulation, daylighting, computational fluid dynamics (CFD), and building code checking."

Kymmell (2008) states that two types of models, surface model and solid model are being used in BIM process but they have fundamental differences. Surface models consist only surfaces (that have no thickness) to give a 3D look to their hollow forms and generally use for visualization. Solid models are the actual representations of real objects in 3D space contained the correct dimensions, location, and other information such as materials, energy efficient factors, to be used for other qualitative analysis. 3D BIM model is the composite of surface model (geometric model) and solid model. In fact, surface model can be generated from solid model using BIM software tools (e.g. Navisworks) but not vice versa.

A 3D BIM model composes of many different components (objects) that are linked together geometrically via a local system with a model origin. Other than dimension and location information, each component (object) also stores parametric and linked information. Objects such as walls, slabs, roofs are some of the examples. Parametric information is very powerful in their flexibility and ease of use. Changes applied to the 3D BIM model can easily accomplish by editing the parametric information.

Geometric model is easy to build and is very useful for crash detection analysis. Accuracy of a geometric model will naturally improve through a construction lifecycle from the design stage to the as-built stage. On the other hand, intelligent of a solid model will depend on the levels of detail and accuracy of the information entered and stored in the objects within the model.

2.4.2 Levels of BIM

The BIM Industry Working Group devises a BIM maturity model and defines the maturity into 4 levels from 0 to 3 as illustrated in the following diagram. This BIM maturity ramp has been used to categorize the adoption of BIM by different entities such as a company, a project or a government organization. They are also being used as milestones for achievement as the case in UK.

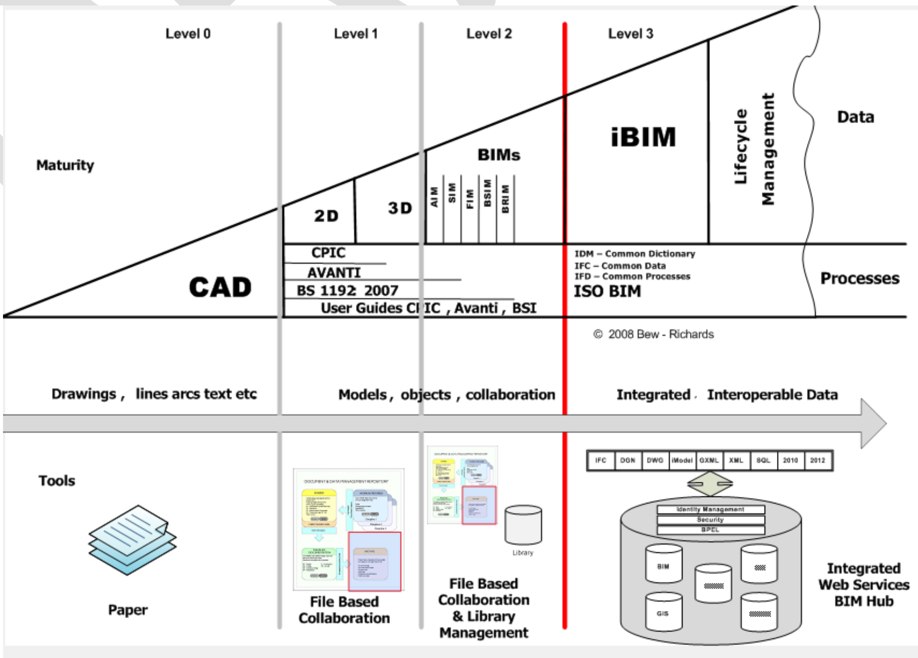

Figure 2.3. Levels of BIM (adopted from BIM Industry Working Group)

Level 0: lowest level of maturity with unmanaged CAD and rudimentary data exchange mechanism.

Level 1 CAD data in 2D or 3D format with a collaborative file based environment, possible with some data standards.

Level 2 a managed 3D environment with file based collaboration and library management, possible extensions to 4D and 5D.

Level 3 a fully open process with full data integration environment complaint with industrial standards and operated under a collaborative model server.

2.4.3 Dimensions of BIM

BIM is characterized by the availability and connectedness of all information that has become part of the project, such as its dimensionality – 2D, 3D, 4D (time-related), 5D (cost-related), and any other type of information (Kymmell, 2008). 3D models are extremely useful for visual communication within the project team and project marketing to the senior management and the public. 2D construction drawings or models are by-products of 3D models. These drawings are generated from 3D models created for the purposes to compile with local construction regulation or communicate with workers and engineers for construction coordination. 4D models include information that can inform, analyze and optimize project phasing, tenant sequencing, and construction scheduling. 5D models, combined 4D models with cost, can be used for cost benefit analysis and project budgeting optimization. Furthermore, BIM-based energy models allow project teams to conduct more efficient, accurate, and reliable energy simulations to predict building performance during facility operations (GSA, 2007).

3D model projected on a visualization tool is an excellent tool to coordinate all the various system components as the project evolves through the design development phase (Kymmell, 2008). Clash detection and multi-view visualization of the virtual buildings cannot be achieved without the 3D geometric model. BIM model is not just a geometric model with properties. In the BIM handbook compiled by Eastman C, et al (2011), it states that "it represents objects by parameters and rules that determine the geometry as well as some non-geometric properties and features. The parameters and rules allow objects to automatically update according to user control or changing contexts."

Through the BIM process, project schedule can be integrated with the 3D geometric model. Sequence of construction can be visualized via visualization and simulation tools (Figure 2.4). 4D models can be created to various levels of detail, from high-level zone analysis during the design phase, to detailed sub-contractor coordination during construction. The same model can be updated and maintained throughout the project based on the updated schedule and 3D model (The National 3D-4D-BIM Program, 2007).

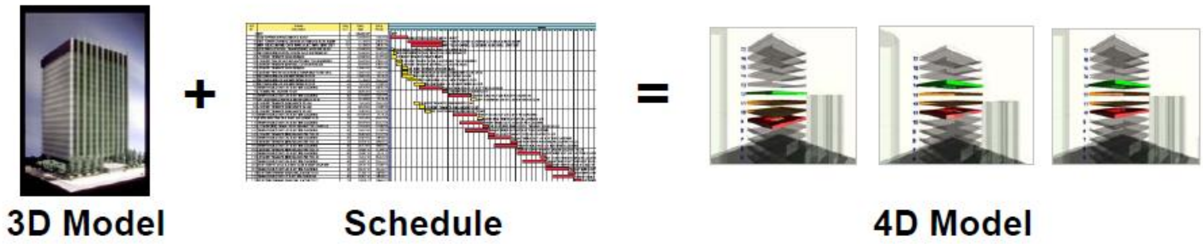

Figure 2.4. 4D models link 3D components with activities in the phasing schedule
(The National 3D-4D-BIM Program, 2007)

3 Technologies Driving BIM Development

Technologies play a very important role in the development of BIM. As discussed earlier, Autodesk has been the major driving force promoting the idea of BIM to the construction industry for many years.

Other than 3D modeling software tools, 3D laser scanning and Geographic Information System technologies are complementary to BIM modeling software tools. BIM modeling software provides the tools for the creation of virtual content-rich building models for new buildings or sites. 3D laser scanning technology has been used to create as-built surface building models and can also be used to monitor the construction process and play a major role in 4D BIM. GIS technology provides a common geo-referencing platform for the integration of BIM model and urban 3D city model. In the construction world, 3D modeling and mode-based design, which integrate BIM, GIS and survey, and laser-scanning (LiDAR) in a 3D visualization, are increasingly being used to improve the design and build phases of the construction process (Zeiss, 2013).

BIM is certainly the most important technology in the AECOO industry in the foreseeable future but vast majority of existing buildings were built before this BIM era. Creating a BIM model for an existing building is both time consuming and expensive. Capturing 3D point clouds data of existing structures using laser scanners is probably the most cost-effective approach to create as-built structures in 3D. 3D point clouds data (or the transformed building surface model) for existing buildings and the virtual 3D models for new buildings form the basic building blocks for a city information model.

3.1 Building Modeling and BIM Construction Management Tools

This section gives an introduction on the common software tools of BIM. In fact, many tools are being used in the entire construction lifecycle from the design stage to the as-built stage. The software tools provide capabilities such as 3D modeling, workflow simulation, rendering, performance analysis, collision check, visualization, scheduling, cost and material calculation, etc… Some of these tools offer functions specifically designed for professional disciplines such as MEP and structural analysis. Amongst all these tools, building modeling tools and BIM construction management tools are discussed in these sections.

BIM technology is becoming more mature and the BIM software markets are also evolving quickly. For examples, the popular point cloud data handling software, Pointools, were acquired by Bentley Systems in 2011 and the functions of Pointools are fully integrated with Bentley's software platform. Similarly, Autodesk completed the acquisition of Navisworks in 2007 to extend Autodesk's 3D software capability in the architecture, engineering, construction, shipbuilding and plan design industries. Trimble, one of the largest surveying and laser scanning equipment manufacturers in the world acquired Google Sketchup, Vico and Tekla during the last few years. Table 3.1 summarizes the product characteristics of BIM modeling tools offered by some of the BIM major vendors. Table 3.2 lists the BIM products which provide the project scheduling capability for BIM.

Manufacturer / Product(s)	Product characteristics
Autodesk / Architecture, Revit, MEP, Civil 3D	✓ A solid modeler addressed the needs of various disciplines ✓ A robust and reliable high-end product ✓ Operating with a centralized database ✓ Able to exchange scheduling information bi-directionally ✓ Has the ability to export its model quantities to cost-estimating software ✓ Augmented with other software to create specialty components in structure and MEP discipline.
Bentley / BIM Suite	✓ A solid modeler addressed the needs of various disciplines ✓ A robust and reliable high-end product ✓ Quite difficult to master ✓ Operating with a federated database
Trimble / SketchUp	✓ A surface modeler ✓ Components are collections of surfaces ✓ Originally not invented as a BIM modeler ✓ Very easy to use ✓ Limited type of data to be accepted

Table 3.1. A summary of BIM software tools from different companies (adopted and modified from Kymmell, 2009)

Manufacturer / Product(s)	BIM Use
Autodesk / Navisworks	✓ Clash Detection ✓ Project Scheduling
Bentley / ProjectWise	✓ Clash Detection ✓ Project Scheduling
Trimble / Vico, Tekla	✓ Structure-centric Model ✓ Schedule driven link ✓ Coordinate ✓ Eliminating

Table 3.2. BIM Construction Management and Scheduling Tools (adopted and modified from Reinhardt, 2009)

KIA (2013) has recently conducted a comprehensive review of BIM software packages based on assets management but information on the report is already out-of-date. The BIM software marketing is changing rapidly and more new functions are rolling. For more up-to-date information on the BIM software, it is a good idea to talk to the software manufacturers directly.

3.2 Scanning Tools

Low-cost 3D laser scanning technology may change the ways how land surveyors practicing professional surveying in the industry in the near future. A recent market research report published by MarketsandMarkets (2013) forecasts that the global LiDAR market will grow by more than 15% annually over the next few years, annualized market value reaching US$551.3 million in 2018. The total market composes of product types such as: airborne, terrestrial, mobile, and short range. The market growth will be driven by the increase demands from the construction industry using terrestrial scanning for monitoring design compliance and owners as as-built building records.

GSA (2009) also realizes the promises of 3D laser scanning and imaging in enhancing the accuracy and efficiency of documenting existing conditions of capital assets. In the *GSA BIM Guide Series* published by GSA, U.S., a special series 03 is exclusive documented for 3D imaging. 3D BIM scanned products deliverables, specifications, data quality controls and management processes are clearly defined. The guide has been prepared to assist the project teams in contracting for and ensure quality in 3D imaging contracts (GSA 2009).

3.2.1 Five Steps in Laser Scanning Project

There are five major steps in any laser scanning projects: project planning, data acquisition, data treatment, model creation and visualization. For the project planning step, depending on the size and complexity of the site, scanning process may have to be conducted in one or more scenes. Project planning is to ensure that the survey area (or object) can fully be mapped in both the horizontal plain and vertical plain (in 3D). During data acquisition, laser scanners are placed at the initial planned locations. The total project scanning time depends on the number of planned locations, the density of point cloud and the time required to complete one scanning scene (this is scanner dependent). A point cloud dataset is obtained after the scanning process. Each point in a point cloud dataset composes of 3D coordinates (x, y, z) and the intensity of the reflected signal. For a larger scale project, several point clouds have to be fused and registered in one coordinate system with the help of pass points or natural structures in the point clouds (Staiger, 2003).

In the data treatment step, any noise and unwanted points are eliminated. As large amount of raw data is required to be processed simultaneously, a powerful computer is needed to handle this task. An experience operator would be able to complete this task in a few hours. After that, depending on the project requirement, geometric model or component object models are created. The model or components created are only a surface model. The operator will have to input the semantic information (if available) to create the model intelligent. The model creation step is primarily a manual process. Researchers are still working on point cloud features extraction to automate the model recreation process (Nagel, Stadler, and Kolbe, 2012). The models created can be used to compare with a theoretical model for the same reality. The final step is visualization. The treated data can be visualized through multiple 3D viewing or the creation of a fly-through of the modeled scene.

3.2.2 Laser Scanning Applications

In the land surveying industry, LiDAR scanning technology has slowly been replacing the traditional aerial photogrammetric process to create urban 3D city models. It provides the most efficient means of defining the geometry and photo-realistic facades of a cityscape since it can define all sides of buildings and rooflines (Jonas, 2014). Recently, Hong Kong (Jonas, 2014) and London (DeVito, 2014) employed the technology to create their virtual 3D city models. The models can be used to support complex urban planning scenarios and wide variety of application areas such as urban planning, visualization, solar evaluations, urban analysis, line-of-sight and shadow analysis.

In the construction world, laser scanning to create final as-builts, managing inventory, and clash detection is thus expected to revolutionize the entire construction process (Rachenbach, 2014). Existing facilities near a construction site such as buildings and road infrastructures may need to be modeled in 3D space. If a 3D city model near the construction site is not available, survey can be conducted using laser scanners to build the model. This as-built model can be combined with the virtual BIM model of the project site to perform environmental impact analysis and clash detection. As laser scanning technology is becoming more reliable and cost effective, the speed of laser scanning easily rivals the traditional topographic survey techniques to document and monitor construction progress and site formation. Kymmell (2008) foresees that it can be used in new construction to document as-built conditions and compare them to the design model to check installation tolerances. Leica Geosystems recently announced an affordable entry-level scanner, Leica ScanStation, which can be used for as-built and topographic surveying.

The so-called “scan-to-BIM” technology is gaining popular recently. The following examples illustrate how the technology is being used for building renovations and cultural heritage preservation.

3.2.2.1 Building Renovation

Scan-to-BIM technique is being used for both internal and external building renovation. With the latest 3D scanning devices, scanning of an enclosed area in 360^{o} would only take approximately 10 minutes to complete. A photo-realistic 3D point clouds dataset will be available immediately for visualization. This technique is also very using to capture facilities with heavy MEP content. For example, the Shalford Project by Plowman Craven in UK (Bennett, 2009) adopted the technique to evaluate the condition and replace any old pipe and pump of the water treatment plant. Complicated piping networks are very difficult to measure precisely and existing MEP plan may not accurately reflect the latest installation. 3D scanning technique can be used to capture the details. Even though 360^{o} scanning may not be possible for all circumstances, partial 3D geometric information of the pipes and pumps would be sufficient for the engineer to re-create the 3D model using available specifications. Figure 3.1 shows the photographic view, the scanned point cloud view and the final 3D model view of the same water treatment plant pump.

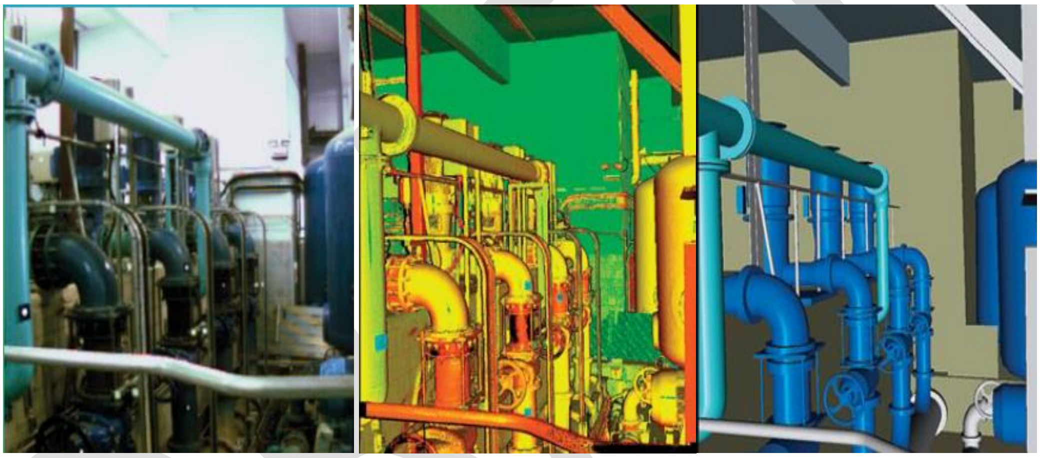

Figure 3.1. Laser Scans and resulting BIM model of a water treatment plant pump replacement (adopted from Bennett, 2009)

In fact, it is also common to apply this technique for renovation projects with accessibility constraints such as space, safety and operational constraints. Hospital and airport are places with many construction constraints. Figure 3.2 shows the renovation project of the Sutter General Hospital in America. The hospital must keep operating before the construction works start, so the as-built data must be recorded in a very limited of time.

Figure 3.2. Sutter General Hospital Renovation by Turner Construction in USA (adopted from Kymmell, 2008)

3.2.2.2 Cultural Heritage Preservation

Traditional terrestrial photogrammetry technique has been used to document archaeological structures using overlapping photographs and digital models created from stereo-pairs. Unfortunately, it would be very difficult to recreate the object models when the targets have irregular surface. 3D laser scanning technique would be able to collect high density point cloud data (x, y, z) completed with object texture and spectral information automatically and effectively. The capability of storing semantic inter-related information of BIM deserves attention in existing buildings renovation, especially in cultural heritage preservation (Garagnani and Manferdini, 2013). This non-contact based direct data acquisition method is ideal for the fields of archaeology and architecture. The demand for 3D models of historical objects is constantly rising (Karabork, et. al., 2007). Researches are looking into the development of Architectural Information Modelling (AIM) (Pauwels et.al, 2008) from the idea of BIM.

Cultural heritage preservation has different modeling requirements. A truthful photo-realistic 3D model with accurate geometric representation provides the solid foundation for archaeological investigation. Densely populated point cloud data depicts the reality with high accuracy and is able to document the status of the object (site) for future restorations (Figure 3.3). The effectiveness of this technique allows surveys to be conducted periodically for doing comparisons, monitoring, maintenances and even restorations. After the creation of a BIM model, a power documentation system is established for periodic checks, academic researches and future restorations as well. National Museums Liverpool has been using 3D laser scanning technique to document cultural artefacts for over 10 years (Rutland and Pensee, 2010). By combining laser scanning technique with latest 3D printer technology, the museum is able to create replica of the artefacts cost effectively for gallery demonstration and education purposes. It is anticipated that 3D modeling (not necessary BIM), 3D laser scanning and 3D printing techniques will soon be adopted by various disciplines for many different applications.

Figure 3.3. Sant' Apollinare Nuovo, the famous early Byzantine church (left image). The registered point cloud data colloected by3D laser scanning surveys (right image). (adopted from Garagnani and Manferdini, 2013)

3.3 Geographic Information System

GIS has been proven to be very useful technology for spatial data management. A spatial data model composed of geo-referenced information (spatial and aspatial) forms the core of the spatial data infrastructure of a city or a country. During the initial stage of GIS technology adoption, land surveyors had to go through a tedious and painful process to convert information from existing drawings and paper maps into digital form. Manual drafting tasks were gradually replaced by computerized digital mapping tasks and technical officers were re-trained to adopt the new technology and data processing environment. With over twenty years of development, land surveyors have become the experts of this technology.

Nowadays, GIS technology and geo-databases have been widely adopted by many different applications via various different wire/wireless computing platforms. 3D GIS data capture and visualization for city modeling is currently one of the hottest development topics thanks to the emerging of technologies such as 3D city modeling software, LIDAR and laser scanning. Campbell (2014) states that the boundaries between what is clearly BIM, CAD, GIS and visualization, are becoming less distinct.

It is not necessary to define GIS in this report. The three words, *Geographic Information System*, clearly outline the characteristics of this technology. Bonham-carter (2006) states that the first character represents *geographic*, which implies the locations of the data are concerned, and can be accurately expressed in coordinates. The second character stands for *information*, suggesting that a pool of useful knowledge is gathered, organized, and manipulated into different forms (pictorial, graphical, or tabularized) to cope with interactive queries. The last character means *system*, which gives a direct impression that GIS composes of a group of related parts working together. A GIS system composes of many functions to facilitate data capture, input, manipulation, organization, transformation, visualization, spatial query and analysis, modelling and output. Rajan (2012) comments that the most significant strength of a GIS is the ability to work at any scale and this is the reason that it is gaining importance in the BIM and Facilities Management space. GIS provides a platform to bring spatial objects together under a common geo-referencing framework despite of their size, dimension (2D/3D) and above ground/sub-surface. The detailed design elements embedded in a BIM building model are very important for construction but only the 3D shapes of building or building components are required for GIS systems (at least for the current GIS applications). While BIM might focus on the microscopic view of a building, GIS may only concern with the macroscopic view of the same building.

3.3.1 GIS vs BIM

GIS and BIM are the terms that easily trigger association of one another whenever one of them is mentioned. If GIS stands for a system developed to manage spatial data, one can say that BIM is developed to manage built features (Underwood & Isikdag, 2010). Information embedded in objects of both GIS and BIM are vital for the successful adoption of the technologies in their respectively industries. However, there are some fundamental differences between them. Understanding their differences would help to take advantage of the inherent spatial relationships in Geographic Information System allows building information (BI) to be aggregated at all scales and integrated with other management systems throughout the building lifecycle (Wallis, 2012). Table 3.3 summarizes the differences between them.

	GIS	***BIM***
Modeling Environment	*Focuses mainly on outdoor environment and extend to underground.*	*Focuses mainly on indoor environment, and 3D modeling of site utilities and terrain modeling are also possible.*
Reference System	*Spatial Objects are defined with global coordinate system or map projections. True coordinates are concerned.*	*Building Objects are defined in their own coordinate system and have a reference to a global coordinate system. Relative coordinates are often more valued.*
Level of Details	*Focuses on a large place (e.g. a district, or a city) in smaller scale with lower level of details.*	*Focuses on one or one group of structure in larger scale and with higher level of details.*
Application Area	*Focuses on not just urban areas but sub-urban and rural areas.*	*Focuses on a project site.*
3D Modeling	*Models in simple 2D shapes and 3D objects.*	*Models in full 3D environment.*
Feature Representation	*Represents in both vector and raster formats.*	*Represents in vector format only.*

Table 3.3 A comparison between GIS and BIM (Adopted and modified from Irizarry and Karan, 2012)

There have been a lot of discussions about the potential merging of GIS and BIM technologies. Or otherwise, a new system, City Information Model (CIM), will emerge to handle all city related information in one single platform. From the technology point of view, CIM is definitely on the horizon. In fact, enterprise GIS systems can be considered as the elementary level of CIM but buildings and infrastructures are not yet represented in 3D and detail semantic of buildings are not available. Rich and Davis (2010) comments that a GIS does not replace or compete with CAC or BIM, but it is used to complement and extend their capabilities on an enterprise level. They further elaborate that interoperability between GIS and BIM enable harvesting of information from a variety of data sources to create systems that platform well at large geographic scale, and yet link back to the source systems when highly detailed information is necessary for specific requirements.

3.3.2 BIM-GIS Integration

Combining GIS with BIM serves as a perfect canvas on which a city's planners and engineers can answer the two fundamental questions of building a sustainable future: are we doing the right projects; and, are we doing the projects right (Sharkey and Young, 2014)? Figure 3.4 illustrates that BIM and GIS are used throughout the entire facility lifecycle. During initial planning stage, GIS is being used to conceptualize the preliminary design and to plan and visualize how the planned facility fitting into the surrounding environment in term of transportation, utilities, land management, etc. Typically, GIS will be used throughout 50-60% of design phase, before moving into detailed design (McElvaney, 2013). In the operation and management stage, GIS can be used to visualize how the new facility connects and interacts with the neighborhood and the environment. In the design, engineering and construction stage, BIM plays a more important role for coordinated collaboration among all project team members in the project. The curve between GIS and BIM may shift up or down depending on the scale of the project from the realms of a single building, a site with multiple buildings, a large scale infrastructure or an entire city. The importance of GIS for the project increases as the project scale increases (curve will shift downward).

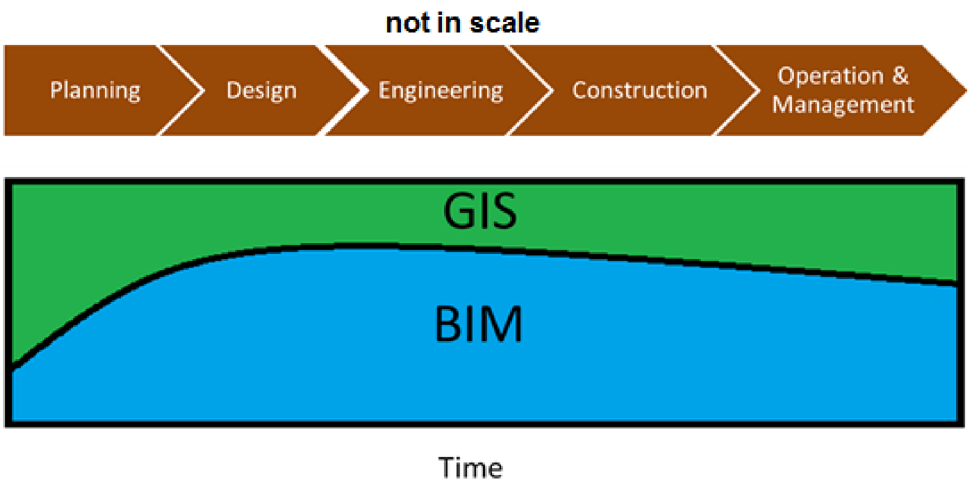

Figure 3.4. GIS and BIM involvement in a Construction Project Lifecycle

With 80% of urban information could be geo-referenced, seamless integration would not only benefit the construction industry but also urban management. The above figure may not be able to illustrate the importance of the integration between the two technologies during the operation and management stage and benefits to urban management beyond the project lifecycle. In the present, implementation of BIM is primarily focused on inside features at one place and little analysis has been done on the whole locality. In order to achieve real integration, it is necessary to bring the benefits of both technologies together into a single and comprehensive model. In that case, GIS is responsible for spatial analysis on the locality to complement the lack of this capability in BIM; BIM should take charge of creating the building information to mend the "holes" in GIS. The utilization of the two technologies together makes the value of both to be maximized (Irizarry and Karan, 2012).

Real integration between the two technologies cannot be achieved without addressing the interoperability issue. Standards must be defined to achieve seamless information flow on different data levels. One of the truly fascinating aspects of how GIS uses BIM technology and data to design and manage the built environment is that the interoperability standard, Industry Fountain Class (IFC), promulgated by US National BIM standard (NBIMS US) has proved to be a format that readily works with the data models and relational database technology power by GIS (Wallis, 2012).

3.3.3 IFC and CityGML for Interoperability between GIS and BIM

IFC has been published by the buildingSMART alliance as an International Organization for Standardization (ISO). The latest version of IFC4 was released in March 2013. The Industry Foundation Classes (IFC) data model developed by buildingSMART is an open, international and standardized specification for Building Information Modelling (BIM) data that is exchanged and shared among software applications used by the various participants in a building, construction or facilities management project (buildingSmart, 2014). Figure 3.5 outlines the various domains that IFC intended to be served. To facilitate information exchange, a machine readable modeling language, such as XML, is used to define various conceptual and abstracted objects, materials, geometry, assemblies, processes and relations, among other things. IFC is intended to address all building information for the entire building lifecycle and facilitate information exchange among all project team members. Definitions of building components (objects) such as walls, windows, stairs, doors can be defined clearly using IFC. This is the AEC standard for BIM models. More information on IFC can be found in www.buildingsmart.org.

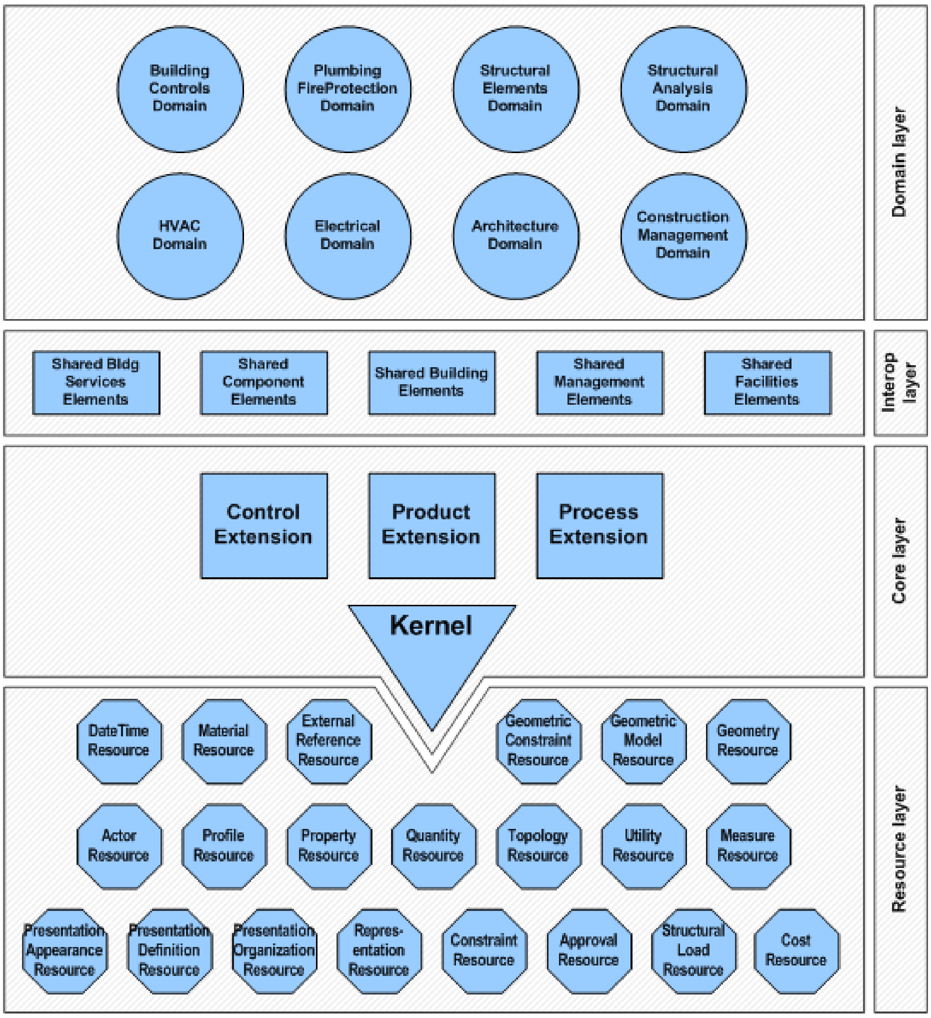

Figure 3.5. IFC Data schema architecture with conceptual layers (adopted from buildingSmart 2014)

In the GIS community, the Open Geospatial Consortium (OGC) has developed CityGML in conjunction with the buildingSMART alliance to meet the goal of modeling building exteriors at a neighborhood to regional scale (Rich and Davis, 2010). CityGML is defined as

"a common information model and XML-based encoding for the representation, storage, and exchange of virtual 3D city and landscape models. CityGML provides a standard model and mechanism for describing 3D objects with respect to their geometry, topology, semantics and appearance, and defines five different levels of detail. Included are also generalization hierarchies between thematic classes, aggregations, relations between objects, and spatial properties."

(www.citygml.org, 2014)

The latest version of CityGML (version 2.0.0) was released on April, 2012 with significant changes compared with version 1.0.0. As described in the CityGML website (www.citygml.org), CItyGML does not only represents the graphical appearance of city models but especially takes care of the representation of the semantic representation, thematic properties, taxonomies and aggregations of digital terrain models, sites (including buildings, bridges, tunnels), vegetation, water bodies, transportation facilities, and city furniture. The underlying model differentiates five consecutive levels of detail (LoD), where objects become more detailed with increasing LoD regarding both geometry and thematic differentiation. The five consecutive LoDs are (Kolbe, 2006):

- LoD0: a two and a half dimensional digital terrain model (DTM), over which an aerial image or a map may be draped.
- LoD1: block models, without any roof structures or textures.
- LoD2: buildings have differentiated roof structures and textures. Vegetation objects may also be represented.
- LoD3: detailed architectural models with wall and roof structures, balconies, bays and projections. High-resolution textures can be mapped onto these structures. In addition, detailed vegetation and transportation objects are components of a LoD3 model.
- LoD4: "walkable" architecture model with LoD3 modeling features plus interior structures like rooms, interior doors, stairs, and furniture.

Models with different LoDs can be used for different applications. The integration with BIM starts from LoD1 where buildings can be represented in the models in their simplest form. The following table lists the different LoDs can be applied in different application areas.

Application Area	**Model LoD**
Urban Planning	LoD0-LoD3
Noise Pollution	LoD1-LoD3
Disaster Management	LoD3, LoD4
Traffic Management	LoD1
Air pollution	LoD0-LoD3

Table 3.4 Model LoD for different applications (adopted from Navaratil, 2010)

Figure 3.6 illustrates the relationship between different BIM objects and their corresponding

LoD in the CityGML model. When defining these standards, it is clear that AEC industry could not stay within its own knowledge world (Mommers, 2014).

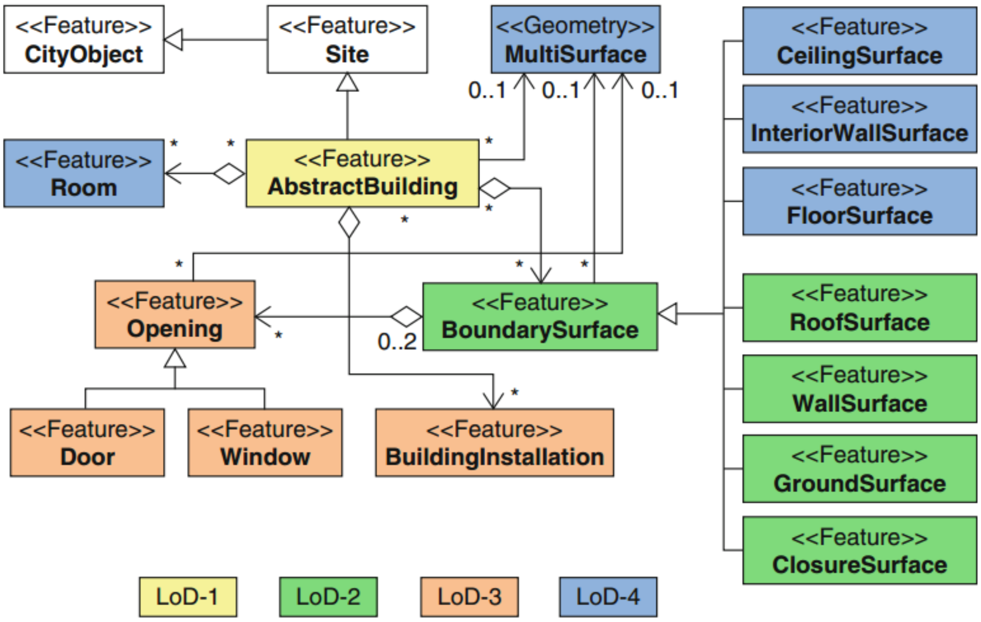

Figure 3.6. CityGML building Model (adopted from El-Mekawy et al., 2011)

Defining the proper standards is important for the future development of BIM and GIS integration. Open Geospatial Consortium (OGC), buildingSMART and software vendors will continue to enhance the standards interoperability between IFC and CityGML. El Meouche et al. (2013) has conducted some trial conversions to import IFC formatted BIM data into ArcGIS using ArcGIS Data Interoperability extension. Both geometric and semantic information were converted and integrated to the GIS system. The Hong Kong Housing Authority also piloted the integration of GIS and BIM (Fung A, 2013). Method 1 was to export Revit BIM data to IFC, then to 3D GIS CityGML and covert to ArcGIS environment using FME. Method 2, BIM data was first exported to IFC and ArcGIS Data Interoperability extension was used to import the data into Geo-database. However, to be able to perform this conversion, a full understanding of the IFC schema is required so that user can extract the required information correctly. More researches on the study of the interoperability between IFC and CityGML can be found in the *Advances in 3D Geo-Information Science* edited by Kolbe, et al. (2011).

4 BIM Development in Hong Kong

In the BIM@CIC Conference 2013 organized by the Construction Industry Council, Mr. Lee Shing-see (Chairman of Construction Industry Council), in his welcome remarks, comments that "… BIM is now being discussed a lot more but Hong Kong is still lagging behind many of its counterparts in the adoption of BIM. ….. Innovation is a new way, and BIM is the way to go…." In the same conference, the keynote speaker, Mr. CHAN Mo-po, Paul, Secretary for Development, Development Bureau, HKSAR, further addresses that "… it is important for Hong Kong to keep pace with the global trend in BIM…. Task now is to establish a local BIM standard. …" Ms. Ada Fung, Deputy Director of Housing, Hong Kong Housing Authority also states that BIM will soon become a required technology, a trend that has been driven by Hong Kong Housing Authority.

The above three speakers have already highlighted the current status of BIM development in Hong Kong. During the last two years, many local conferences were organized with themes which were related BIM. The local AECOO industry is certainly aware of the emerging of BIM. Professional organizations such as The Hong Kong Institute of Surveyors (HKIS) hosted a BIM conference in 2013 and various CPD talks focused on BIM. The Hong Kong Institute of Building Information Modelling (HKIBIM), in working with academia from the tertiary education units, drafted the frameworks for BIM professional training and certification in Hong Kong. Furthermore, HKIBIM has been actively participated in compiling the first BIM Standard in Hong Kong. The draft version of the standard was recently released and can be downloaded from the www.hkibim.org.

Hong Kong is certainly moving into the right direction in the adoption of BIM in the construction industry but slowly. In Singapore, BIM is identified as a key driver technology to transform the construction industry. A BIM Steering Committee was set up in Singapore to provide strategic direction and to address implementation issues. The Building and Construction Authority (BCA) has given supporting fund up to SG$200,000 to help companies adopt and implement BIM. All these activities are to support the milestone set by the Singapore Government - from July 2015, architecture and engineering submissions for all new building projects more than 5,000 sqm must submit a BIM model to the government agency to get their plans approved.

During the development of this report, two important documents were published locally in Hong Kong. *The Final Draft Report of the Roadmap for BIM Strategic Implementation, version 1* (BIM Roadmap Report) published in September 2013 by the Construction Industry Council (CIC) outlines the current adoption of BIM in construction industry, the challenges for the adoption and the major concern to be addressed. Information from the CIC report is extracted and summarized in this report. The other document is the *Hong Kong BIM Standards, Building Information Model – Project Execution Plan (BIM PEP) Draft 1* published by HKIBIM on June, 2014. The standard is intended to be used to define the scope of work for a BIM process, the responsibilities of the project participants and the deliverables from the BIM Process for the overall benefit of the project and the owner (HKIBIM, 2014).

4.1 BIM Adoption in AEC Industry

According to the *BIM Roadmap Report*, Hong Kong is lagging behind majority of developed countries in the adoption of BIM. The evaluation was conducted by Dr. Calvin Kam, one of the Director of Stanford University's Center for Integrated Facilities Engineering, using the Virtual Design and Construction (VDC) evaluation system. The VDC Scorecard evaluates the maturity of Virtual Design and Construction in practice based on an industry performance rating framework, and measures the degree of VDC innovation in planning, adoption, technology, and performance (Stanford, n.d.). The overall score reveals the project's ranking among the others in the global market by a 5-level innovation ranking system, ranging from 'conventional practice' (without BIM) to 'innovative practice' (industry 'firsts').

The evaluation was based on the 10 award-winning project of 2012 Autodesk Hong Kong BIM award. The median scores of the four Areas (Figure 4.1) indicate that all four Areas were lagged behind the leading practice countries. In particular, the two Areas: Technology and Performance, the scores are below the typical practice category. Lower score in Technology indicates that BIM technology is not being used by AECOO industry throughout the entire project lifecycle for visualization, documentation, performance analysis and increased automation of design and construction tasks. Lower score in Performance indicates that there are no objective targets or measures in the industry to track how BIM contributes to the improved performance.

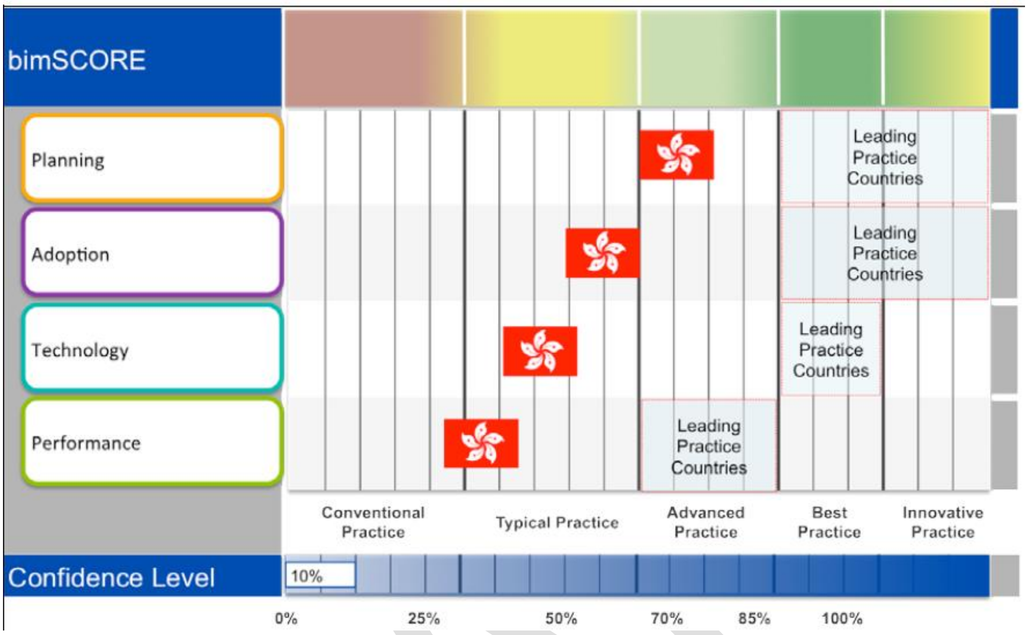

Figure 4.1: Comparison of Leading Practice Countries and Hong Kong Practice. (adopted from HKCIC 2013b)

The adoption of BIM by the industry might have been slow but Autodesk has been actively promoting the use of BIM in the construction industry in Hong Kong for more than a decade. Since 2007, Autodesk Far East Limited has been organizing the HK BIM Awards event annually. The event helps to bring industry professionals and educators together to drive the transformation of the building industry through the usage of BIM. The annual awards presentation ceremony helps to promote the best practice of BIM and a platform for the industry to share their experience. Amongst all the award winners, the Hong Kong Housing Authority (HA) has received many awards because of their commitments and innovations in using the technology to revolutionize their construction practice.

4.2 BIM Adoption by the Government

The Hong Kong Government has started using BIM technology since 2009. Highways

Department pioneered the technology in the Improvement to Tuen Mun Road project and in the Central-Wan Chai Bypass project. According to Mr. Paul Chan, the Secretary for Development, the Government has developed a specific strategy to adopt BIM in public works. The strategies include:

1. Extended trail of BIM technology for more public works projects such as bridges, tunnels, buildings and electrical and mechanical works in different construction stages,
2. Engaged and collaborated with various stakeholders including the CIC, software specialist consultants and contractors to explore the full potential of BIM in the construction industry, and
3. Launched a comprehensive staff training plan on BIM.

In the recent Digital 21 Strategy Advisory Committee meeting held in January 2014, BIM was identified as one of the strategies for transforming and integrating public services in Hong Kong. The Committee recommended that HA will implement BIM in all new projects starting from 2014-15 and the Government is also using BIM in some works projects.

The CIC has represented the construction industry since 2007 and has been actively promoting BIM technology to the construction industry in Hong Kong. In different events, the CIC comments that Hong Kong has to catch up with the fast pace of the global trend in the adoption of BIM in order to maintain the competitiveness of Hong Kong's construction industry in Asia Pacific Region and internationally in a long run. To purse industry-wide implementation of BIM in Hong Kong, 16 recommended initiatives in 9 areas were proposed in the BIM Roadmap Report. The three imminent actions are to:

1. compile local standards,
2. promote and increase the awareness of the programme, and
3. provide BIM training.

The CIC also named 2014 as the "BIM Year 2014" to promote BIM in the industry. A series of promotional activities has been prepared throughout the year of 2014. After the release of the *BIM Roadmap Report* last year, the CIC recently released the *BIM Standards (Phase One)* for Hong Kong practice in collaboration with the industry stakeholders. It is the first standard document prepared locally by the industry stakeholders and a very important milestone towards a wide scale adoption of BIM in Hong Kong. However, this document is not the first BIM related standard document published in Hong Kong. The Hong Kong

Housing Authority has prepared its in-house BIM standards, user guide, library component design guide and references since 2009. These documents are essential for HA and their partners to improve building quality by optimizing the designs, improving coordination and reducing construction through the implementation of BIM in their projects. Copies of the documents can be downloaded from the HA's website: http://www.housingauthority.gov.hk/.

4.2.1 Implementation of BIM by Hong Kong Housing Authority

The Hong Kong Housing Authority is a statutory body with the mandate to develop and implement a public housing programme to meet the housing needs of people who cannot afford private rental housing. HA owns and maintains the largest stock of public housing buildings in Hong Kong and continues to develop approximately 20,000 rental flats per year to meet the public demand. HA recognizes the inherited benefits of BIM and has started piloting BIM as early as 2006. According to Ms. Ada Fung, Deputy Director of Housing, HA has introduced BIM in its development of public rental housing projects for many years. More than 19 projects have already adopted BIM technology at various project stages, ranging from feasibility study to construction stage. HA has the role as a developer and also a facility manager. By adoption BIM, they can gain benefits in the entire building lifecycle and extend to the operational management stage. Based on the experience of HA (Fung A., 2013), they have used BIM for:

1. quick assembly of domestic blocks,
2. enhance quality of design,
3. enhance cost control and environmental protection,
4. better building services co-ordination,
5. optimize lighting design for energy saving,
6. improve site safety, and
7. better construction site planning.

Through the implementation of BIM, HA is able to optimize project designs, improve coordination and reduce construction waste. In addition, if BIM is fully implemented in the entire project lifecycle for their projects, HA will own the as-built models of the entire project sites which provide both the accurate 3D representation of all the facilities as well as the semantic information to facilitate the future operational and management of these facilities. As recommended in the Digital21 strategy, HA will implement BIM in all new projects starting from 2014-15.

4.3 Education of BIM

NATSPEC, an Australia not-for-profit organization that provides information to the Australian design and construction industry, recently published a *BIM Education – Global Report* summarized the current status of BIM education in a number of countries across the globe. In the executive summary, it states that

"…It would appear that the majority of BIM education available to date focuses on training in the use of particular BIM software packages. Training in openBIM concepts, BIM management and working in collaborative BIM environments, appears to still be in its infancy. …. tertiary education institutions, with the support of government and industry, need to fully incorporate BIM education into their curricula, to provide the AEC industry with the 'BIM-ready' graduates required for the collaborative BIM working environments to which they will be part of in the future."

(NATSPEC, 2014)

The above comment also reflects the current BIM education in Hong Kong. As the technology was driven by software vendors such as Autodesk and Bentley Systems, initial focus on BIM education has been in the use of BIM modeling software such as Revit, Civil3D, etc. Technicians in the construction industry, especially those who have been doing 2D CAD drafting, have received training in creating accuracy 3D models and the procedure to input the semantic information of different construction components. In addition to 3D modeling training, they also learned how to handle point cloud data captured from terrestrial laser scanning and perform cash detection analysis using tools such as Pointools and Navisworks.

Other than the software vendors, CIC and IVE also provide structure courses on BIM. CIC offers certificate course on Building Information Modeling Basic which introduces basic concept of BIM and its applications and with hand-on experience using Revit software to create models. IVE set up a BIM Training Centre at Morrison Hill since September, 2010.

BIM elements are incorporated in the curriculum of various Higher Diploma programmes in construction. Other tertiary education units have already incorporated BIM into their curriculum as listed in the Appendix A.

The Hong Kong Institute of Building Information Modelling developed three tiers BIM curriculum for the training of local HKIBIM Certificated Experts in different levels. The first tier, entry level course, covers the BIM basic knowledge and software operation. The second tier, the intermediate level, encompasses three courses: Structure, MEP and Revit Families. The third tier, the professional level, outlines the BIM knowledge as required for professional practitioners in various professional disciplines to become BIM experts. Here are the six courses in tier three:

- CEIII Architecture (Revit) Course
- CEIII Structure (Revit) Course
- CEIII MEP (Revit) Course
- CEIII Construction Management Course
- CEIII Cost Management Course
- CEIII BIM Management Course

Details of the proposed course outline can be found in the following http://www.hkibim.org/?page_id=80. The BIM curriculum outlines, in particular tier three, are not yet finalized and details of the curriculum are not yet completed. As HKIBIM do not offer the training courses, tertiary education units should work closely with HKIBIM to finalize the details and offer the professional trainings as needed.

5 Opportunities for Land Surveyors

While the roots of BIM are in architecture, the basic principle of working from and on accurate 3D digital models applies to nearly all infrastructure projects, including site work, subdivisions, bridges, highways and all the other things that surveyors routinely stake out (Bennett, 2009). All construction projects starts with the existing condition information in 3D and surveyors are the first to provide the essential information professionally for preliminary design and project plan. During the completion of construction projects, surveyors are there to conduct an accurate and up-to-date as-built survey for documentation, issuing final project payment and capturing the accurate 3D model data for the enterprise GIS system.

For a broader scope of land surveying industry in an urban environment, land surveyors involve in data collection, data processing, plans and maps creation, and data management in fields of land information management and construction/project data management. Traditionally, land surveyors have been recognized as the experts in collecting raw data such as distances and angles and transforming them to structured spatial data in the appropriate accuracy and map scale. GIS and geo-database technologies have further extended surveyors role to become spatial data managers to maintain, organize, classify and analyze data stored in geo-databases.

In a construction site, surveyors assume the data management roles responsible for the coordination all geometric data of site topography and facilities. In a citywide land information center, surveyors assume the data administration roles responsible for the coordination all urban spatial data. As BIM has created a buzz across AEC industry, its impacts on land surveying profession have started filtering in construction survey, as-built survey and 3D spatial data management.

5.1 Construction Surveys and BIM

For new construction projects, land surveyors are always the first arrived to the site to produce quality terrain models and accurate topographic models. Table 5.1 summarizes the duties of land surveyors during different stages of construction.

Construction Project Stages	Surveyor Roles and Duties	Purposes
Planning and Design Stage	Site reconnaissance; Control surveys; Preliminary site data collection: topography and existing as-built facilities.	Establish control networks; Provide site information to facilitate planning and design.
Construction Stage	Setting out; Create plan, profile and cross-section; Earthworks Calculation; Taking interim measurements of construction progress.	Confirm and monitor the construction process; Record and document the construction process; Quality control.
Completion Stage	As-built survey; Deformation survey (if needed).	Document and record the completed facilities; Verify the constructed with the original design.

Table 5.1. Land Surveyors' Duties in Construction Projects

Typical construction projects include roads construction, highway construction, sewer and tunnel construction, culvert construction, building construction and other heavy construction (such as dams, port facilities). As the scale and complexity of a project increases, roles of surveyors increase so as project duration.

Information collected from project sites such as earthwork volume is being used by contractors to monitor the project progression. To operate a construction project more efficiently, planning, scheduling, and supervising of earthwork operations are crucial. In addition, this information is also being used to determine partial payments based on the construction progress and final payment based on completion and acceptance of the works. Surveyors collect, calculate and record the information accurately with respect to dates, times, locations, quantities, methods of measurement, personnel, design changes, and so on.

In fact, in a construction site, land surveyors have long assumed the role as project data managers coordinating project information in collaboration with site engineers, owners and contractors. The role of land surveyors have not changed significantly but land surveying instruments and machine control systems are becoming more advanced and efficient. GPS, motor driven scanners and ICT help reduce times spent on data collection but at the same time, increase data volume and data processing time and efforts.

The introduction of BIM in a construction project has significantly changed how survey data should be managed by land surveyors using the new tools. These changes are in terms of quality and efficiency that more services can be delivered on the day-to-day activities with higher accuracy after combining the usual practice with BIM (Speed, 2012). These changes now require all stakeholders to both reassess the opportunities technology provides, and consider changes to traditional processes, if the maximum value is to be realized (Australian Institute of Architects, 2013). Traditionally, surveyors assume the project data manager role but with the introduction of BIM in a construction project, surveyors' role as project data managers cannot just be assumed but has to be endorsed by stakeholders. A project data manager in the BIM era may have a modern name called "BIM manager" but the roles of a BIM manager are more than that of a project data manager. BIM manager requires to have integrated knowledge of all professional disciplines participated in a construction project as well as ICT skills. Surveyors are responsible to ensure that all project information is well-coordinated in a collaborative matter. BIM provides a golden opportunity for land surveyors to take up a new and major role in a construction project.

5.2 As-built Survey and BIM

As-built surveys involve data collection and processing of the existing condition. Land surveyors have been doing as-built surveyors for mapping and cadastral survey purposes. 2D footprints and top view of buildings and infrastructures are captioned and stored in a geo-databases but not the completed 3D model as outputted from BIM. For cadastral survey, accurate and detail structure dimensions are presented clearly on cadastral plans. For conservation purpose, accurate 3D surface models of historical buildings and monuments are created. In some cases, both the interior and exterior structural surfaces are captioned and modelled in 3D space. Adoptive reuse, the process of adopting old structures for new purposes, is a very important concept and a coincidentally reached consensus in city planning community all over the world. Bennett (2009) further indicates that there is a change in consumer perception that people nowadays are inclined to live in an urban community where old buildings are kept and reused, rather than demolished.

In US, in order to fulfil the demand of the tremendous retrofit market, high accuracy three dimensional as-built data becomes a crucial component. For a retrofit construction project, it is almost essential to have as-built data in order to plan the design with consideration of the neighboring groups of buildings. After the retrieval of 3D as-built data, higher quality documentation can be achieved, which is much more accurate when compared to traditional 2D drawings. 3D digital models can be built for having a better visualization of the target structures and doing analytical works. By simulation on a 3D platform, designs are easier to optimize, facilitating the entire retrofit project.

In Hong Kong, retrofit construction project is not in high demand as the number of valuable historical buildings and monuments is limited. Nevertheless, the adoption of BIM and development of a complete CIM model bring positive impacts to the as-built survey market. In the process of developing a BIM model for a new construction project, 3D as-built model of buildings and infrastructures in the neighborhood are needed. To some extent, the emergence of BIM can be deemed as a remote cause for the great demand of 3D as-built data. A complete 3D representation of a project site (as-built 3D model and virtual 3D model) can be used for construction scheduling optimization, clash detection, cost estimation, feasibility analysis of construction workflow and environmental impact analysis, etc... With most of the as-built records are incomplete or missing, surveyors are going to be called upon to build that asset database. Land surveyors are spatial data collectors and suppliers and undoubtedly stand at the forefront of a construction project.

5.3 3D Spatial Data Management and BIM

Land surveyors' skills in spatial data handling have been recognized by many disciplines such as urban planning, transport planning, environmental protection, emergency response and rescue, etc… For example, the geo-database created and maintained by the Land Information Centre of the Surveying and Mapping Office in Hong Kong has been used by many Government departments, utility companies and land developers for various applications. Spatial data from varieties of data sources, in different data formats, is entered into the geo-database and then amalgamated and transformed into valuable information. Land surveyors' experience in managing GIS technology is an important asset in the construction industry when considering the adoption of BIM in the construction process. The following GIS skills are very valuable to surveyors:

- Data and project management,
- Data preparation and organization,
- Data quality checking, verification and analysis
- Information presentation and visualization,
- Information sharing and communication, and
- Applications development and deployment.

Owing to the similarity of the GIS and BIM, land surveyors' GIS skills are a valuable asset for the adoption of BIM in Hong Kong. Land surveyors with specialized skills in GIS can naturally assume the role as BIM managers to manage BIM data in the entire project lifecycle. Loh, the principle land surveyor at Housing and Development Board of Singapore, discusses that it is also imperative to present the accurate 3D survey data as accurate 3D models to a BIM-centric process as the land development industry embraces BIM. This is critically important that land surveyors have to be able to present, document and communicate the information as a 3D BIM model so that other members in the project team can work together in this shared BIM model.

In the last decade, CAD software manufacturers attempted to integrate GIS into CAD platform but the products were not accepted by either of the markets. It is uncertain if GIS and BIM will merge together to form one single integrated software platform with seamless boundary. The format and the level of integration will depend on the market demand, the benefits perceived by the markets and the commercial decision from software manufacturers. Others also worry that the present computing technology cannot keep pace with the huge data storage space and the complexity of functions; and seamless integration is unlikely to happen. In fact, the difficulties in data integration and data management make the coordination works done by land surveyors more significant.

As discussed earlier, popularity of scanning technology and the adoption of BIM in construction industry bring positive impacts to the as-built survey market. The initiative to develop an enterprise 3D geo-database from Government will also expand the use of geo-database and GIS technology in the construction lifecycle. With more existing buildings and infrastructures are being mapped as 3D objects, the role of land surveyors will also increase.

5.4 Opportunities and Challenges

There are great opportunities for land surveyors in this BIM era as discussed. Land surveying market in Hong Kong will expand as the maturity level of BIM adoption increases. To enable this to happen, land surveyors have an important role to ensure that the issue of interoperability between GIS and BIM must be resolved. Surveyors have to understand the IFC standard and if possible, assist the industry to localize the IFC standard. Efforts to enhance interoperability have been made in the AEC industry. For instances, Open Geospatial Consortium (OGC), an international voluntary consensus standards organization, gathers more than 360 commercial, governmental, non-profit and research organizations worldwide to form a 3D information management working group which focuses heavily on the convergence of AEC and geospatial trends and technologies (Underwood & Isikdag, 2010); buildingSMART Alliance has launched a project since 2010 with a major intention to provide the basis for an information relationship between the GIS and BIM environment and their underlying databases (NIBS, n.d.). Surveyors can certainly take a leading role in this process.

In using new technology, ones must examine our work processes and how they may change, and how those changes propagate downstream to the AEC ecosystem that relies on our spatial expertise (Bennett, 2009). Even though land surveyors have assumed the role as project data manager in a construction project, BIM and scanning technologies will certainly change the present workflow. Surveyors must sharpen their professional skills in using these technologies in the construction site and explore the integrated knowledge in the AECOO industry and BIM. The integrated knowledge covers engineering concept, ICT knowledge and construction knowledge. If land surveyors want to engage successfully in the BIM-centric process, they must confront with the challenges and learn the extra skills. In short, the role of surveyors in BIM may be expanding; it does not depend on what surveyors can do, but on what surveyors want to do.

6 The Steps Ahead

Loh Suat Yen, Principal Land Surveyor of Housing & Development Board in Singapore (Loh, 2013) addresses that "land surveyors may need to evaluate the combination of more than one survey techniques to measure the data and provide them in a format that best suits the requirements of a project after advising the client accordingly. It is also imperative to present the accurate 3D survey data as accurate 3D models to a BIM-centric process as the land development industry embraces BIM." Similar comment is shared by Bennett (2009) that laser scanning combined with a BIM-centric process required a rethinking of traditional processes. The demand for land surveyors to "think out of the box" is obvious. BIM provides a common environment for all information about construction, not just size, shape and coordinates, but includes design, time, costs, physical performance, logistics and more. Surveyors must keep up with modern technological trend and be able to transform 3D survey data to a 3D BIM model which can be used for communication amongst project team members.

BIM is about *digital databases*, *coordination* and *collaboration*. Land surveyors have over twenty years of experience in handling 2D and 3D geo-databases. Traditionally, surveyors have assumed the role as a project data manager to coordinate project data and collaborated with members in the project teams for project progress monitoring and scheduling, quality checking and payment endorsement. Adopting BIM in surveying profession might seem to be logical but as Bennett (2009) says clients may not realize that surveyors have the skills and desire to help them far more than they have previously and that surveyors are keen to do that. Surveyors certainly cannot take over the professional roles of other members in the project team but surveyors can be the BIM manager to coordinate information flow in a BIM-centric process.

BIM demands a steep learning curve and additional investment in staff training, new survey equipment, new software and powerful hardware are required. Surveyors also need to step up to learn more about the practices of the AECOO industry; to rethink the impacts of modern technology such as laser scanning on the traditional processes; to standardize/facilitate the seamless integration of BIM and GIS; and to market surveyors' skills, willingness and readiness to take up the challenge.

To address the above issues, the following possible actions are suggested:

Items	Major Issues	Possible Actions
Technologies	- Laser Scanning – use of laser scanning in BIM - GIS and BIM integration and interoperability	- Develop operational guide to govern the use of laser scanning technology with BIM and other surveying tasks - Investigate how GIS can be used in various construction stage - Explore the integrate between GIS and BIM based on standards, data transformation and conversion; applications and analysis
Education and Training	- Basic BIM and 3D modeling training - Basic knowledge of construction and engineering - Professional certification and recognition	- Receive BIM and 3D modeling training to understand the BIM process and the creation of 3D BIM model - Receive basic training in construction management and gain industry knowledge - Work with academic institutions to offer Postgraduate Programme in BIM/GIS Management - Collaborate with HKIBIM for professional recognition
Marketing and Promotion	- Promote BIM to land and engineering surveyors - Market land surveyors' expertise in project data management to AECOO industry and project owners - Participate in curriculum development with HKIBIM	- Offer CPD talks and seminars to professional land surveyors - Organize conference with theme BIM - Land Surveying and Data Management and invite industry stakeholders to attend - Work with HKIBIM to finalize the curriculum of BIM experts

Table 6.1 Recommendations for Follow-up Actions

The adoption of BIM technology in Hong Kong is only in its infancy stage. Opportunities for land surveyors to strengthen our professional roles in the construction industry are present.

While other professional bodies are still skeptical about the technology and reluctant to move the extra step to adopt BIM into their roles, land surveyors should move forward to embrace BIM into our profession. Surveyors have confronted with various technology challenges such as GIS, GPS, GSM and Remote Sensing in the last two decades but they were able to turn all these challenges into opportunities. BIM is certainly the technology that surveyors cannot overlook as it will transform the entire construction industry in these coming years. RICS (2012) states that “BIM is not going to go away, and so we must, therefore, learn to adopt and embrace or risk the threat of losing ground to other.”

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8 Appendix A: BIM Education Offered by Hong Kong Tertiary Education Units

School	Department	Class involve BIM	Short Description
CUHK	Department of Architecture	BIM LAB Summer Design Elective	Aims: Learn 'all' about BIM designing and practice, its tools and how to apply them; then use BIM in an design process Outcomes: BIM Software Skills, BIM Knowledge in Architectural Design and your own Design based on BIM.
HKU	Department of Civil Engineering	CIVL6059 Special Topic in Infrastructure Project Management -	
		Building Information Modelling (BIM): Theories, Development and Application	
	Department of Architecture	Introduction to Building Information Modeling and Management (BIM basic)	Students learn the basic concepts and workflows of BIM process in architecture through modeling and analyzing a project of their choice
		Building Information Modeling in Architectural Practice (BIM Advanced)	Students learn the advanced concepts of parametric modeling, project management and building analysis through three design exercises
		Construction Communication	The course focuses on the communication and documentation aspects of the BIM process and guides the students to produce a full schematic design documentation of a simple project
HKPU	Department of Building and Real Estate	Information Technology and Data Analysis	BIM in general; built up BIM models using Revit; NavisWork operations.
		Work Training and BIM	A BIM practicing and workshop training subject for the students to equip with more practical technical knowledge and skills
		Individual & Integrated Project	This new Integrated Project will be BIM orientated. Integrated Project for engineering discipline includes design review, method statement and planning. Integrated Project for surveying discipline includes measurement, cost planning and valuation of variations etc.
		Building Information Modeling	Understand the concept of BIM and the constituents of BIM models; Understand the functions and benefits of BIM in construction management; Use some typical software packages to build or operate basic BIM models; Apply BIM technology to building projects so as to solve some problems occurring in building projects.
		Information Management for Construction	BIM in general to advance; Build up model;4D/5D in BIM models using Revit and Navis Work; BIM in collaborative works.
	Department of Land Surveying and Geo-Informatics	Programme: BSc (Hons) in Geomatics/HD in Geomatics Subject: Mapping	Basic concepts of SDI and BIM, importance of SDI and BIM for modern urban development and construction
		Programme: BSc (Hons) in Geomatics/ HD in Geomatics Subject: Digital Terrain Modelling	Integrate BIM and DTM for 3D visualization and crash detection

		Programme: BSc (Hons) in Geomatics, Subject: Geomatics Project Management	International and local development BIM Technical, data, interoperability and policy issues of BIM Geo-referenced BIM platform to facilitate data integration in construction
Chu Hai College	Architecture	Building Technology II	Application of BIM into Design works and understanding of how building comes together
		Holistic Approach to Sustainability	Advanced application of BIM on Building Performance and associated
CUHK	Department of Civil and Architectural Engineering	Engineering Communication	The course aims at provide fundamental knowledge of visual and graphical communication methods and techniques used in engineering / building industry; introduce technique of report writing together with graphical presentation using computer aided drafting software; and provide the ability to locate, retrieval and apply technical information in fundamental engineering communications.
City U	Division of Building Science and Technology	BST11011 Communication Studies –Building Integrated Modeling	
HKUST	Department of Civil and Environmental Engineering	Construction Information Technology	Teaching Objectives:
			1. Understand the principles of building information modeling (BIM) and the current technologies and standards for BIM
			2. Leverage BIM software for engineering analysis and project management
			3. Model and represent various kinds of information in the construction industry
			4. Perform data processing and knowledge discovery
			5. Design a database system for managing information and supporting construction management
		Civil Engineering Drawing	Layout and development of multiple orthographic views,
			sectional views and dimensioning; Introduction to BIM
CIC	Management and Safety Training Centre	Building Information Modelling Basic course	Introduction of BIM concepts
IVE	Department of Construction	Higher Diploma in Civil Engineering Module: Building Information Modelling in Civil Engineering	Basic concepts of BIM for structural design
		Higher Diploma in Building Studies Module: Building Information Modelling for Building Works	Realize and identifies the important roles of BIM and its implication to building works; Create intelligent information-rich models and construction documentation.
		Higher Diploma in Surveying Module: Building Information Modelling for Surveying	Realize and identifies the important roles of BIM and its implication to building works; Create intelligent information-rich models and construction documentation for scheduling and quantity surveying.
		Higher Diploma in Building Technology with Interior Design Module: Building Information Modelling A	Create construction documentation, calculate and quantify materials, using such information to justify and evaluate the cost and integrity of design. Generate and evaluate multiple interior design schemes

		Higher Diploma in Building Technology with Interior Design Module: Building Information Modelling B	Manipulate and create user defined building components; Implement Design phase visualization
		Higher Diploma in Architectural Studies Module: Computer 3-D Visualization and Building Information Modeling	Convey architectural design concepts by accurately capture the parametric 3D model; Create construction documentation, etc.
		Enrichment Module to other Higher Diploma / Introduction to Building Information Modelling	Apply BIM software for preparation of construction documentation
		Introductory Workshop on Building Information Modelling (BIM)	Introduction to Building Information Modelling; Creating building design using Revit Architecture; Design Analysis and Construction Documentation
		Building Information Modelling(BIM) in Building System Design	Introduction to Revit MEP (Mechanical / Electrical / Plumbing) Basics; Working with MEP Family in mechanical, electrical, plumbing and fire protection system
			Drafting technique of tag, text, keynote, fill pattern and sheet
			Understanding Families/Libraries
		Building Information Modelling(BIM) in Structural Design	Revit Structure Basics; Drawing Production
			Scheduling Techniques: Beam Schedule, Column Schedule and Drawing List
			Project Coordination: Creating a Structural Model by Linking a Revit Architecture Model
			Applying the Analytical Model to the Design Process
		Introduction to Building Information Modelling (BIM) with ArchiCAD	Introducing the global BIM concept; BIM solution with ArchiCAD; Managing model data, collaboration
		Building Information Modelling (BIM) using Industry Foundation Classes (IFC) Standard	Introducing IFC; Global IFC concept; Open BIM™ Initiative and Building Smart etc.
		Higher Diploma in Architectural Design & Technology / 3D Computer Modeling	
		Higher Diploma in Architectural Design & Technology / Architectural Computer Visualization	
		Higher Diploma in Building Technology & Interior Design / Computer Aided Design II	
		Higher Diploma in Building Technology with Interior Design / Building Information Modeling	