THE HONG KONG INSTITUTE OF SURVEYORS

Quantity Surveying Division

Research Project

for

BIM for Quantity Surveying: An Investigation into its Adoption and Education in Hong Kong

<u>Final Report</u>

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Abstract

Building information modelling (BIM) is an emerging technology in construction, and its adoption has evolved exponentially in recent years. BIM technology has dramatically transformed traditional practices within the industry throughout the project lifecycle. Because the quantity surveyor (QS) is one of the core project members, it is essential to recognise how BIM influences the profession of quantity surveying, the services it delivers and the sustainability of competent graduates. However, few studies have investigated the adoption level of BIM or diagnosed its deficiencies to improve quantity surveying practices in Hong Kong. To address this gap, this first-ever BIM study investigates the current status of BIM applications in QS practices and tertiary education in Hong Kong. Both qualitative and quantitative methods are used in this study. The results reveal that although a quantum leap in BIM engagement cannot yet be seen, most QSs show high awareness of BIM. In particular, consultant firms exhibit enhanced BIM adoption and involvement. Some clients are keen on BIM adoption, but some continue to only observe because they cannot realise benefits from BIM implementation. Contractor QSs are relatively passive in their use of BIM for their tasks in BIM projects. The results indicate that in general, the current model quality is not sufficient to support QS tasks. There is a pressing need in industry for well-recognised BIM standards and standard BIM conditions. The publication of a set of BIM practice notes may be expedient to assist QSs in the meantime.

The results further show that the current BIM education in quantity surveying is generally keeping pace with BIM development in the industry, but BIM courses at the advanced level and interdisciplinary student projects are not included in some tertiary institutions. To meet the market demand for BIM talent, local tertiary institutions are making efforts to integrate

BIM into their curricula. However, there are constraints to BIM teaching due to the stringent university graduation requirements and professional bodies' accreditation requirements. To ensure proper planning of integration of BIM in these courses, it is necessary to review the accreditation criteria by exploring which BIM competencies are required of the quantity surveying profession.

This study adds to the knowledge of BIM for quantity surveying and offers empirical evidence for the extent and level of BIM applications in QS practice and tertiary education in Hong Kong. A list of recommendations is offered in this study as a reference for the Hong Kong Institute of Surveyors. The proposed recommendations embrace a wide range of directions that can suit the Hong Kong Institute of Surveyors' strategic planning of BIM development and promotion. Finally, this study provides some suggestions for further research. The research framework developed in this study could pave the way for continuous study in this field.

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Chapter 1 – Introduction

1.1 Background

Cutting-edge computer technology has improved construction professionals' performance and efficiency in terms of project collaboration and team communication. One example of such technological advancement is building information modelling (BIM), which is an emerging technology in the built environment. The increasing adoption of BIM in many countries signifies the potential of such technology in the construction industry (McGraw-Hill, 2014). The government of Hong Kong has acknowledged this advanced technology in construction, and a recent policy shows positive signs of increasing BIM engagement in public works (DevB, 2018). With the increased demand for BIM in Hong Kong, every construction professional should keep pace with such technological changes.

The potential benefits of BIM, especially its benefits in financial terms, have been widely recognised (Bryde et al., 2013). According to a study conducted by the Centre of Integrated Facilities Engineering (CIFE) at Stanford University, BIM enables elimination of up to 40% of unbudgeted changes, cost estimation accuracy within 3% and reduction of up to 80% in the time required to generate a cost estimate (CIFE, 2007). As a result, the involvement of BIM in the practices of quantity surveyors (QSs) can improve job performance and add value to their traditional professional services (Raphael and Priyanka, 2014). However, the preliminary findings from an earlier study of BIM application in consultant QS firms (Keung, 2017) suggested that the implementation of BIM in quantity surveying still lags far behind its potential. Few studies in Hong Kong have shown a high degree of integration of BIM into current QS practice.

In recent decades, many BIM surveys have been conducted in countries such as the United States (McGraw-Hill, 2008), the United Kingdom (BCIS-RICS, 2011; NFB, 2014), New Zealand (CIL, 2013) and Malaysia (Harris et al., 2014). The purpose of these studies was to investigate the degree of adoption and diagnose deficiencies for improvement. Despite the popularity of BIM surveys, no similar studies have been done in Hong Kong, which indicates a pressing need for a survey of the current situation of BIM applications in quantity surveying and the potential barriers to its adoption. Because BIM provides a more integrated and collaborative approach to all phases of design and construction, BIM projects are most effective with the joint involvement of clients, consultants and contractors (Nawi et al., 2014). In this regard, an exploratory approach is adopted to examine the extent of BIM adoption from the perspective of QSs practicing in client organisations, consultant firms and contractor companies.

In contrast, the growing popularity of BIM has led to great demand for BIM talents in the construction market (Wu and Issa, 2014), and the supply of BIM-equipped graduates unfortunately falls short of this demand. Graduates from educational institutions currently provide strong support to BIM development (Ali et al., 2016), but it is challenging for educational institutions in Hong Kong to inject BIM courses into existing long-established curricula. The critical concern of BIM education in quantity surveying is whether BIM forms an intrinsic part of the whole surveying curriculum. In addition, BIM education requires resources in terms of staff (Ali et al., 2016), computer software and hardware (Barison and Santos, 2010) and support from government and professional bodies (Abdirad and Dossick, 2016). This study therefore extends the scope to cover current BIM education for QS training and the sufficiency of its coverage of current BIM practices.

This research study was funded by the Quantity Surveying Division (QSD) of The Hong Kong Institute of Surveyors (HKIS) in 2018. This study is the first-ever practical study of BIM in quantity surveying in Hong Kong. Unlike other BIM studies that focused upon a foreign country or a mixture of countries, this study is based purely on Hong Kong, so the results truly reflect the current situation of QSs' BIM adoption in client organisations, consultant firms and contractor companies in Hong Kong. The research scope is also extended to include the BIM curricula of the local educational institutions and matching them with the current QS practices in BIM adoption. Further insights into the sufficiency of the current BIM training in Hong Kong can thus be found. In summary, this study explores a broad spectrum of BIM for quantity surveying and contributes to the richness of the quantity surveying literature.

1.2 Research aims and objectives

This BIM study investigates current BIM applications in both QS practices and tertiary education in Hong Kong. The underlying goals of this project are to gain insights into BIM adoption in the field of quantity surveying and to assist the HKIS in formulation of effective policy for BIM development and promotion. Its research objectives were to

1. review the scope of BIM applications and education in the context of quantity surveying;
2. investigate the current BIM adoption level in various QS practices such as private developers, government departments, consultants and contractors;
3. examine the current BIM curricula of local tertiary educational institutions and their adequacy to meet the QS practices in BIM adoption; and

4. propose recommendations to the HKIS for strategic BIM development and promotion in Hong Kong.

1.3 Structure of the report

This report is divided into six chapters. Chapter One introduces the problem statement and the research aims and objectives. Chapter Two presents the concepts of the research subject in the form of an extensive literature review and critically appraises the main theories on offer. Chapter Three demonstrates the proposed method for achieving the study's objectives. Chapter Four reports on the data analysis and the results. Chapter Five discusses the key research findings and elaborates upon their implications, and the last chapter summarises and concludes the study.

Chapter 2 – Literature review

2.1 BIM and its development in Hong Kong

The concept of BIM was first introduced in the 1970s, and it fundamentally transformed the traditional practices of the construction industry. BIM technology dramatically changed the way project participants work and interact. A BIM is a computer model database of design, construction, management, operation and maintenance. BIM has matured from object-based parametric modelling (Kensek and Noble, 2014). Intelligent objects for various building elements constitute the BIM database. The database can generate plans, sections, and schedules, and any design changes made in the central model are automatically reflected in the resultant drawings, ensuring a complete and consistent set of documentation (Lee et al., 2005). BIM tools also help to reveal accidental conflicts earlier in the design process. Thus, BIM aims to improve efficiency throughout the project life cycle. Many positive outcomes have arisen from the use of BIM in construction projects.

The BIM bandwagon has already swept across the construction industry worldwide, and Hong Kong has been no exception. However, the adoption of BIM is still not very popular in Hong Kong, and some private developers, consultants and contractors remain only observers in BIM implementation. To boost BIM in the construction industry, the government of Hong Kong acknowledged the advanced technologies to change the innovation landscape for the construction industry (PCMO, 2018), and the use of BIM in government projects is one of the actions underway. According to the Development Bureau's Technical Circular on the adoption of BIM for government projects (DevB, 2018), BIM must be used on all capital works projects with a budget of HK$30 million or more. Moreover, the circular stipulated that most uses of BIM during the design and construction stages are mandatory. Such a government mandate is a positive step to motivate the entire to engage in BIM. The outcomes of government projects show the significant role of BIM in enhancing the quality of information and decision-making capability in construction time-and-cost monitoring, operation and maintenance planning and long-term asset management (PCMO, 2018). In addition, the Buildings Department is working on a roadmap to accept BIM for building submission. The issue of Practice Note for AP, RSE and RGE (ADV-34) and the development of an electronic submission hub provide strong evidence to encourage industry practitioners to adopt BIM in their building projects.

The Construction Industry Council (CIC) is a statutory body that serves as a communication channel between the government of Hong Kong and the construction industry. The CIC has contributed greatly to BIM promotion and development in Hong Kong; in 2015, it published the BIM Standards, the industry-wide standard designed to enable a client to specify, manage and assess BIM deliverables by architects, engineers, surveyors and contractors. These phase-one BIM standards provided a reference for practitioners to set up their BIM projects. The first draft of the phase-two BIM standards was published in 2019 and covers other aspects such as mechanical/electrical/plumbing (MEP) and underground utilities (UU). The lack of BIM capabilities by external stakeholders also influences the adoption of BIM in the private sector. Thus, the CIC introduced BIM certification and accreditation schemes to ascertain the competency of BIM personnel and the quality of local BIM training courses. Finally, the CIC was commissioned by the Development Bureau to act as the implementation partner of the Construction Innovation and Technology Fund (CITF). The HK$1 billion CITF encourages wider adoption of innovative constructive methods and new technologies in the construction industry. As a result, a financial subsidy for BIM adoption can be sought from CITF.

2.2 Goals of and barriers to BIM implementation

This section offers an extensive review of studies that identified the goals of and barriers to the implementation of BIM in the construction industry. These goals and barriers include some generic factors supported by the literature and are selected as variables to be incorporated into the questionnaire used in this study.

Using BIM in real-life construction projects can be advantageous to the project itself and to every participant in the construction industry. A wide range of potential benefits are associated with the use of BIM. Better team coordination that helps with visualisation, better accuracy and quality and cost savings are some top-rated examples. The key goals of BIM implementation include the benefits brought by the use of BIM that boost its adoption in the construction industry. According to Kubba (2012), BIM can lead to increased productivity and quicker project completion. A survey conducted by CIFE suggested that BIM can help reduce the total project time by 7% (CIFE, 2007), and it not only offers enhanced and accurate visualisation to aid the project team’s understanding of the design (Azhar, 2011; Stanley and Thurnell, 2014; Azhar, 2011), it also facilitates decision-making before and during construction (RICS, 2014). This constructability review provides the contractor with preconstruction support (Eastman et al., 2011, Lu et al., 2019) and minimises construction risks by reviewing complex details or procedures before the contractor visits the site (Ghaffarianhoseini et al., 2017). As a result, BIM enables faster and more effective processes via information sharing and production (Azhar, 2011). The design team can add value and make changes to the three-dimensional (3D) model, and the two-dimensional (2D) plans and drawings are updated accordingly and automatically. As a result, all design information produced by BIM will be consistent, which reduces the time needed for drawing production and the chances of errors and omissions (Kubba, 2012).

Moreover, the BIM platform allows integration of the separated architecture, structure and MEP models to detect conflicts. Reductions in cost and waste can be achieved via clash detection that leads to a reduction in abortive work and requirement changes. Cost can thus be saved and waste minimised. According to CIFE, the use of BIM can help attain savings of up to 10% of the contract value via clash detection (CIFE, 2007). In addition to clash detection, efficiencies can also be gained from improved coordination and scheduling (Kubba, 2012). The richness of information contained in 3D BIM models at the design stage lessens the risks borne by the main contractors and their sub-contractors because they can minimise the chances of errors and omissions and, hence, re-work (McGraw-Hill, 2014).

Higher-quality facilities can be built because BIM enables better interdisciplinary coordination (Eastman, 2011, RICS, 2014). Improvement of interdisciplinary coordination reduces potential errors and omissions and results in fewer coordination-based changes during the construction stage (Eastman, 2011). Also, the main contractor can provide constructability advice input during the design stage, thus enhancing the design’s feasibility (Kubba, 2012). Moreover, BIM offers a preview of the built environment, site planning, construction works and development of the method statement, improving the understanding of construction safety and accident prevention matters (CIC, 2014). Construction safety and security during operation can be improved by identification of the adequacy of various related equipment provided at early stages (CIC, 2014). Table 2.1 summarises the expected BIM goals.

Table 2.1 Expected BIM goals

Expected BIM goals	Eastman et al. (2011)	Kubba (2012)	CIFE (2007)	Azhar (2011)	RICS (2014)	McGraw-Hill (2014)	CIC (2014)	Stanley and Thurnell (2014)	Ghaffarianhoseini et al. (2017)	Lu et al. (2019)	Kaneta et al. (2016)	Total no.
Enhancing coordination	✓	✓			✓	✓		✓	✓	✓		7
Better visualisation	✓			✓				✓	✓	✓		5
Reducing errors and omissions	✓	✓		✓	✓	✓	✓					6
Constructability review	✓	✓					✓		✓	✓		5
Improving productivity	✓			✓			✓		✓	✓	✓	6
Reducing abortive works	✓				✓	✓				✓		4
Better predictability and cost control			✓	✓	✓	✓		✓	✓			6
Shortening overall project duration	✓	✓	✓	✓	✓	✓	✓		✓	✓		9
Improving accuracy in quantification of works	✓			✓				✓	✓			4
Lowering construction cost	✓		✓	✓	✓	✓			✓			6
Better documentation	✓			✓	✓		✓		✓	✓		6
Improving safety							✓		✓	✓		3
Expediting regulatory approval cycles				✓							✓	2

Despite the appealing benefits brought by the adoption of BIM, several significant barriers should be overcome to facilitate widespread use of BIM in the industry. One key barrier is the social and habitual resistance to changes in work process and mindset (Lindblad, 2013). Tremendous changes in the work process are necessary to adapt to BIM. Together with alterations in the development and flow of information to which BIM leads, the roles and responsibilities of each project team member are re-assigned. According to Arayici et al. (2009), the reluctance to initiate new workflows is a prime reason that contractors in the UK avoid adopting BIM. In addition to the resistance to change in the work process, practitioners in the construction industry tend not to vary their mindset towards BIM. Many of them do not appreciate its full value and benefits (Yan and Damain, 2008). As such, the government policies that dictate a systematic and standardised approach for the BIM implementation, together with some incentive schemes to the private sector, are used as BIM enablers (Koseoglu et al., 2019).

It would be more challenging for practitioners to embrace BIM and its associated changes without sufficient training to adapt to the new work process (Eadie et al., 2014). It is thus crucial for the individuals to be trained adequately to contribute to the new work process, mode and environment brought about by BIM (Arayici et al., 2009; Lindblad, 2013). Some studies have indicated that a lack of training and in-house BIM expertise are the most critical factors in rejecting BIM (Chan, 2014; RIBA, 2015). As a result, the lack of a BIM-savvy workforce is one of the greatest concerns in BIM implementation (RICS, 2014). In addition, other organisational challenges cause act as barriers to BIM implementation. The deployment of BIM changes a construction company's operational process and organisational structure. The establishment of an optimal organisational hierarchy that facilitates BIM adoption is unavoidable (Koseoglu et al., 2019; Lu et al., 2019).

Moreover, contractual incorporation of BIM into construction projects requires adjustments to contractual arrangements between contracting parties in BIM projects (RICS, 2014). According to the CIC (2014), there is a need for legal standards that reflect changes in data ownership, information confidentiality, risk allocation and procurement practices. However, Hong Kong's construction industry has no such standard contract conditions for BIM projects. Atop the uncertainties in a contractual arrangement, the lack of a submission requirement is also a key challenge for BIM implementation. Relevant government departments in Hong Kong do not accept BIM models as a valid means of building plan submission, nor do they provide any incentive schemes of its adoption in the private sector. A lack of direction from the government is a top barrier from the designers' perspective (Chan, 2014).

An organisation that begins to implement BIM must make capital investments into software, hardware and training (Eadie et al., 2014). The hefty front-end costs act as a barrier to the adoption of BIM because most participants in the construction industry are not willing to bear the initial outlays and productivity loss without sound proof of a positive return (Eastman et al., 2011). The stated costs impose a great amount of hesitation, especially to small and medium enterprises (RICS, 2014). Several practitioners in the construction industries in the United States and the UK believe that the need for their companies to allocate so much time and so many human resources to use BIM has become a strong demotivation (Yan and Damain, 2008). In addition to the capital investments, BIM software and tools require periodic updating, which further increases the financial burden of organisations who adopt BIM (Eadie et al., 2014). In contrast to those pessimistic views on BIM, 'overselling' or improper use can lead to disputes or other problems (RICS, 2014). The failed stories of BIM adoption may act as a significant mindset barrier to BIM implementation. The lack of vision of what successful BIM implementation can bring induces difficulties for senior management to make a return on investment calculations (Eadie et al., 2014). Yan and Damain (2008) suggested that companies in the construction industry are reluctant to invest in BIM because no real-life cases of financial benefits brought about by the use of BIM have been published.

Interoperability between software used by the various disciplines in a BIM construction project is necessary to ensure integration and effective information exchange (Lindblad, 2013). A lack of software interoperability fragments the BIM workflow and has been a primary reason for slow BIM implementation in the construction industry (Linlblad, 2013; RICS, 2014). Many organisations are not required to use BIM in data exchanges with external parties, which results in the difficulty in project team collaboration that is a key factor in BIM success. The CIC (2014) stated that the current challenges for BIM implementation in Hong Kong include a lack of common standards and protocol for data interoperability and management and a lack of capacity to ensure that every discipline in a project uses the same information based on the same standards, requirements and protocol. Designers in the Hong Kong's construction industry, like the CIC, view a lack of standards as a critical barrier to the adoption of BIM (Chan, 2014). In addition, Lindblad (2013) noted that the lack of a standards responsible for inaccuracies in BIM models, in particular, served as a roadblock. Table 2.2 summarises the barriers that lead to late BIM adoption.

Table 2.2 Factors that cause late BIM adoption.

Factors that cause late BIM adoption	Lindblad (2013)	CIC (2014)	Arayici et al. (2009)	Yan and Damain (2008)	Chan (2014)	Koseoglu et al. (2019)	Chien et al. (2014)	NBS (2018)	Eadie et al. (2014)	Eastman et al. (2011)	Lu et al. (2019)	Khaddaj and Srour (2016)	Total no.
The rush culture in the construction industry											✓		1
Lack of well-recognised industry BIM standard	✓	✓			✓		✓	✓			✓		6
Shortage of in-house BIM specialist			✓		✓		✓	✓					4
Lack of BIM expertise in the market			✓		✓	✓	✓						4
Shortage of successful BIM projects showcase			✓	✓					✓				3
Problem of interoperability amongst BIM software	✓						✓	✓		✓	✓		5
Extra cost for the appointment of BIM consultants		✓		✓					✓				3
Benefits of BIM adoption cannot be realised			✓	✓			✓	✓	✓				5
Staff refusal/reluctance to learn new technology	✓		✓							✓	✓		4
Restructuring of organisation to accommodate BIM						✓				✓	✓		3
High initial cost		✓		✓			✓	✓	✓		✓		6
Unforeseen positive return on investment on BIM			✓	✓			✓			✓	✓		**5**
Lack of government support and incentive					✓	✓		✓					3
Unsuitability of some projects for BIM adoption								✓				✓	2
Worried security of confidential data							✓				✓		2
Standard BIM contract is not available		✓					✓	✓		✓	✓		5

2.3 Effects of BIM on traditional QS practices

The QS is a key project team member and is mainly responsible for cost and contract management throughout the project's life span, from the feasibility and design stages to the final completion of a project. The profession of quantity surveying embraces subjects such as economics, law, accountancy, management, mensuration, information technology and construction, all within the framework of the construction industry. In Hong Kong and most

Commonwealth countries, the QS is a well-recognised professional who may choose to work for consultants, contractors or developers. However, even though they work in different organisations, QSs mainly provide conventional services that cover all aspects of procurement, contractual and project cost management. According to the HKIS's areas of specialisation, 14 core professional services are provided by QSs:

1. Cost planning
2. Life-cycle costing
3. Value management
4. Preliminary cost advice
5. Procurement methods
6. Contractual advice
7. Tendering
8. Valuation of construction work
9. Cost control and financial management
10. Financial claims and programme analysis
11. Dispute resolution
12. Insurance advice
13. Facilities management
14. Project management

Due to the increasing expectations of quality and performance from project clients, a QS must improve his or her services to solve a variety of financial and economic problems that confront the demanding construction market. Traditionally, QSs adopted a paper-based method based on human interpretation, but this approach was time-consuming and error-prone (Monteiro and Martins, 2013). BIM is seen to offer solutions because it consists of several cost management functions that could accelerate the traditional process of construction cost management. Ultimately, BIM can help QSs reduce errors, improve the quality of deliverables and add value across all processes throughout the project lifecycle. For example, its automation in quantity take-off is a key benefit for QSs (Monteiro and Martins, 2013; Nagalingam et al., 2013; Fung et al., 2014). BIM could significantly improve the efficiency and accuracy of quantity surveying services, including cost estimation (Lu et al., 2019; Smith, 2014; Stanley and Thurnell, 2014) and planning processes (Wu et al., 2014). Moreover, some BIM software automates processes to help accelerate the preparation of post-contract cost management tasks. By live linking with a cost database, 5D BIM technology can perform accurate and efficient valuations from BIM data and generate automatic cost advice for post-contract cost control purposes (Nagalingam et al., 2013; Fung et al., 2014; Stanley and Thurnell, 2014). In addition, with the integration of programme data in 5D BIM models, time-related cost management tasks such as cash flow forecasting and interim valuation can be efficiently performed by the QS (Yeung and Keung, 2012; Lu et al., 2019).

Some BIM software also offers the potential for QSs to assume a greater role within building projects, which allows QSs to delve more deeply into various parts of the cost management process than would have previous been possible. For example, more lifecycle data are available in the BIM environment at an earlier stage, which can facilitate more analysis, influence the choice of materials and change the construction costs (Pittard and Sell, 2016; Kim and Park, 2016). Furthermore, the visualised environment provided by BIM can facilitate faster and more accurate claims preparation (Koc and Skaik, 2014). Many organisations that engage in traditional construction projects fail to follow best practices and keep adequate site records to substantiate and present disputes for resolution purposes. BIM is recognised as a powerful visualisation and communication tool that can be fulfilling for forensic engineering and dispute resolution purposes (Dougherty, 2015; Lu et al., 2019). Table 2.3 summarises the potential tasks that can be performed by QSs in a BIM environment.

Table 2.3 Potential BIM QS tasks

BIM QS tasks	BIWG (2011)	Dougherty (2015)	Monteiro and Martins (2013)	Lu et al. (2019)	Smith (2014)	Stanley and Thurnell (2014)	Nagalingam et al. (2013)	Fung et al. (2014)	Pittard and Sell (2016)	Yeung and Keung (2012)	Kim and Park (2016)	Total no.
Cost planning	✓			✓	✓	✓	✓	✓	✓	✓	✓	9
Life cycle costing	✓								✓		✓	3
Value engineering	✓								✓	✓		3
Preliminary cost advice	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	10
Procurement advice	✓			✓			✓		✓			4
Contractual advice		✓		✓					✓			3
BQ measurement	✓		✓	✓		✓	✓	✓	✓	✓	✓	9
Valuation of variations				✓		✓	✓	✓	✓	✓		6
Interim valuation				✓						✓		2
Remeasurement of provisional items				✓				✓		✓		3
Financial report			✓	✓			✓			✓		4
Cash flow forecast	✓			✓						✓		3
Assessment of financial claims		✓		✓						✓		3
Dispute resolution		✓							✓			2

2.4 Concepts of BIM adoption in quantity surveying

BIM is a process of generating and managing building data during the project life cycle. The process typically uses 3D building modelling software to increase the productivity of consultants and contractors during design and construction. By using a BIM model instead of paper drawings, the take-offs, counts, and measurements can be generated directly by QSs from the underlying model. The information is always consistent with the design and when a change is made in the design, the change automatically ripples to all related construction documentation and schedules, as well as all the takeoffs, counts, and measurements that are used by QSs. There are several different approaches to get quantities and material definitions out of a BIM model and into a cost estimating software. The first approach is the Application Programming Interface (API) that creates a direct link between the costing system and the BIM authoring tool like Revit®. From within Revit®, the user exports the building model using the costing program's data format and sends it to the estimator, who then opens it with the costing solution to begin the costing process. This is the approach used by the program, such as Sigma Estimates®. The API integration between Revit® and Sigma Estimates® allows users to develop cost estimates based directly on the BIM model. The second approach is the Open Database Connectivity (ODBC) connection. This approach uses the ODBC export function in BIM authoring tools like Revit® to integrate cost estimating software with the building information model, so that the cost estimating software can link counts, attributes, and geometry from the building model with cost and pricing information. The program, such as CostX®, uses this approach. The third approach is the output of the BIM data to a spreadsheet program like Excel®. This method lets users create the schedule of material takeoffs in BIM authoring tools like Revit® and simply output the data to a spreadsheet, which is then used as input for adjustment and costing. Typically, BIM software for quantity take-off and estimating can open 2D drawings or 3D models created by BIM authoring tools for viewing and quantity extraction. Different BIM authoring tools produce models in different file formats. With the IFC or other neutral file formats, model information from one software can be exported and imported to another software platform for sharing and further use. Thus, information from a 3D model created by using a BIM authoring tool can be exported to another BIM tool for quantity take-off and estimating purposes. Table 2.4 lists some examples of the BIM software used for quantity take-off and cost estimating.

Table 2.4 Examples of BIM software for quantity take-off and cost estimating

	Software: (In alphabetical order)	*Source:*
1.	CostX #	https://www.exactal.com/en/costx/products/
2.	DimensonX #	http://www.dimx.co.za/index.php
3.	Glodon #	https://cubicost.com/TBQ/
4.	Innovaya Visual	http://www.innovaya.com/prod_ov.htm
5.	Italsoft	https://www.italsoft.net/software-bim-building-information-modeling/
6.	iTWO	https://www.itwo.com/en/
7.	Kreo	https://www.kreo.net/kreo-takeoff
8.	Lubansoft #	http://www.lubansoft.com/
9.	Revit # ^	https://www.autodesk.com.hk/products/revit/overview
10.	ROSS 5D	https://www.rlb.com/en/news/2018-12-10-rlb-bim-protocol-guide-for-clients-and-designers-released-today/?geolocation=americas
11.	Sigma Estimates	https://sigmaestimates.com/
12.	Solibri # *	https://www.solibri.com/our-offering
13.	Thsware	http://www.thsware.com/en/
14.	Vico Office #	https://gc.trimble.com/product-categories/vico-office-cost

BIM software used by QS in Hong Kong
^ *Revit is a model authoring tool that provides the function of quantities schedule*
* *Solibri is a model checking software that provides a feature of simple QTO*

The successful delivery of a BIM process requires comprehensive planning, detailed specifications, a defined set of procedures and methods for BIM implementation. A BIM process should be set out and agreed by the client with the consultants and the contractor at the beginning of a project. As such, BIM standards are essential for successful implementation because it establishes a BIM process and defines the scope of work, the responsibilities of each project participant and the deliverables for the overall benefit of a BIM project. For example, the CIC's BIM standards require the creation of a BIM Execution PlN (BEP) at the beginning of the project to incorporate the client directions on BIM implementation. The BEP outlines the mandatory BIM requirements that the consultants and the contractor must follow throughout the project (CIC, 2015). It is recommended that QSs be consulted in the production of the BEP (Smith, 2015; AIQS-NZIQS, 2018).

During the design stage, design team members such as the architect, structural engineer and building services engineer must meet the client's BIM requirements to produce BIM deliverables. As a professional of construction cost, the consultant QS is required to provide cost advice to the client based on the models received from the design team. This approach of models handoff shows the consultant QSs' dependency, and the models provided by other disciplines are the sole source of BIM data. This approach is popular in many countries such as the UK, Singapore, Australia and New Zealand (Smith, 2015; Seah, 2013; Smith, 2014; Stanley and Thurnell, 2014). In addition, the efficiency and accuracy of the QS functions depend upon the quality and sufficiency of the models. Quality assurance procedures are necessary to ensure that the QSs correctly interpret the information (Turner and Edwards, 2014). Upon awarding of the construction contract, the contractor begins the construction process by fulfilling the client's BIM requirements as stipulated under the contract. Any BIM databases, models and data are handed over by the design consultants to the contractor, and they agree on a process for incorporating design changes and revisions in the models after the handover date. Any cost implications that arise from variations should be measured and valued by the consultant QSs according to the contract. As a result, BIM data are exchanged occasionally during the construction stage between consultant QSs and contractor QSs for the purposes of VO settlement and final accounting. Figure 2.1 illustrates the conceptual model of the client's mandatory BIM adoption in a traditional procurement construction project. The conceptual model shows the client directions on the mandatory BIM requirements and the QSs' reliance upon the BIM data from the design consultants. This data reliance warrants that the information is always consistent with the design (Autodesk, 2007).

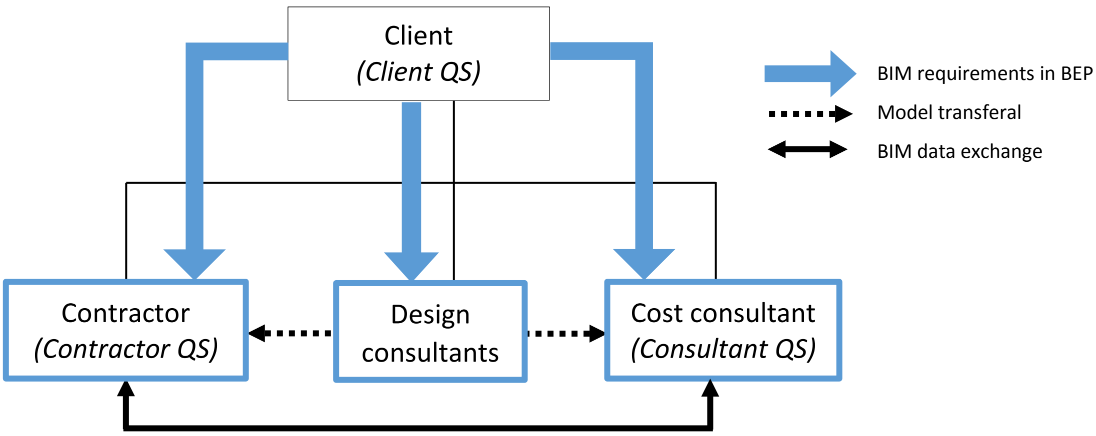

Figure 2.1 Conceptual model of mandatory BIM requirements and their effects on QSs.

2.5 Future development of quantity surveying on the BIM trail

Depending on how a BIM model is compiled, the information can either be useful and add benefit, or it can be generated in a way that does not complement the QS's working and measurement methods. BIM models require considerable upfront calibration amongst the QS and the design team members, such as inputting the correct coding, naming, and zoning and ensuring that the building is drawn as it should be built (Kim and Park, 2016; Smith, 2015; Turner and Edwards, 2014). Even after all that upfront work, the QS must still interrogate, interpret and extract the quantities and align them with standard methods of measurement. (Harrison and Thurnell, 2015; Stanley and Thurnell, 2014; Smith, 2014). These include concrete volumes with the same or a different mix, classification of formwork in stages, reinforcement bars and interior finished areas and can be classified as building works, architectural works, landscaping works and MEP works. The standard methods of measurement are currently based on traditional computer-aided design (CAD) drawing production. A tailor-made standard method of measurement (SMM) is required for BIM.

BIM provides many benefits for the construction industry but also raises many legal and contractual concerns that cause challenges. From a legal perspective, the challenges include ensuring that the risks are identified and allocated appropriately at the outset and that the BIM process can then be managed closely until satisfactory completion. BIM implementation requires a range of legal and contractual issues to be considered because multiple stakeholders are required to share their own assets and work together on combined assets (i.e., responsibility and authorship may become blurred). The need exists for a binding agreement that identifies BIM models that must be produced by the project team and establishes specific obligations, liabilities and associated limitations upon the use of those models. So far, no current construction contracts deal in any way with the use of BIM, and nothing mandates or prevents the use of BIM at any stage. Similarly, none of the existing standard consultancy agreements by the professional bodies refer to the use of BIM. Some leading countries in BIM, such as the United States, the UK and Singapore, have already published BIM contracts, and a BIM contract is urgently needed in Hong Kong.

2.6 BIM education and its importance

The Hong Kong government's BIM initiatives have stimulated the adoption of BIM in the construction industry. This boom has led to an increase in the demand for BIM talent, and BIM professionals have become difficult-to-find resources in the construction market. Effective implementation of BIM requires the inclusion of new professionals in the industry. Thus, BIM education is preparing a new generation of construction professionals, with the prime objective of equipping students with the necessary BIM skills. With the dramatic increase in the demand for BIM technology, the lack of sufficiently trained BIM talents is a significant constraint that hinders the adoption of BIM in the industry (Becerik-Gerber et al., 2011). As such, BIM education and training are important to foster future BIM talents to meet the market's needs. To satisfy industry demand for construction professionals with BIM skillsets, many universities or institutions in the United States have integrated BIM into their existing curricula (Barison and Santos, 2010; Becerik-Gerber et al., 2011).

Intelligent BIM includes multiple dimensions from 3D to nD that require a broad spectrum of BIM learning on various course levels. Students can design, visualise, simulate, analyse, estimate, schedule, collaborate and manage every construction project in a single integrated BIM system (Uddin and Khanzode, 2014). To ensure proper planning of the integration of BIM into a curriculum, it is necessary to determine which competencies students require, because no common understanding has been established regarding which BIM skills are required in industry or regarding the methods of BIM education (Sacks and Pikas, 2013). Construction professionals come from various disciplines, but students of these various disciplines are traditionally taught in separate departments with little or no integration or collaboration with the others (Macdonald, 2012). However, the use of BIM requires changes in the traditional roles, practices and skill sets among project members, and the construction industry is moving towards more collaborative working practices. Upon graduation, students are expected to be able to work in integrated teams in a BIM environment. As a result, in addition to individual discipline-focused BIM teaching, an interdisciplinary approach to BIM education is vital to address today's complex engineering and construction problems (Badrinath et al., 2016).

From a theoretical perspective, educational institutions should design courses that fit the industry's real-world practices. However, the construction market is dynamic, and technology changes rapidly. It is a great challenge for any educational institution to keep the BIM curriculum in line with industry needs (Becerik-Gerber et al., 2011; Lee and Hollar, 2013). Moreover, the lack of teaching resources, including competent faculty members, reference materials and computer software and hardware, presents another challenge to BIM education (Wong et al., 2011). BIM teaching requires a higher level of construction expertise based on practical experience. Faculty members without the relevant experience may have difficulty preparing the teaching materials for senior-level courses such as BIM applications and management skills. The variety of BIM software and the high technical requirements in computers also create further hurdles for educational institutions in financing new software and upgraded equipment.

2.7 BIM education in quantity surveying

Traditional quantity surveying education is paper-based, and students mostly learn about the law and economic subjects such as construction contracts, procurement, measurement and cost management. The use of BIM has grown significantly in the construction industry and has led to changes in the practices of construction professionals. In the BIM environment, the quantity surveying profession has embraced 5D, and QSs have become key players on the BIM team. 5D is about cost, and the 5D model enables the instant generation of cost budgets and financial representations of the model against time (e.g., cash flow forecasting). 5D BIM significantly reduces the time spent on manual quantity take-off and estimation and improves the accuracy of estimates (Smith, 2014). QSs can thus provide more value-added services to clients due to job efficiency. As a result, a new breed of QSs with technical expertise and skills in BIM is emerging in the industry. However, the shortage of QSs with BIM skills has become a significant constraint that restrains the use of BIM. Education has been identified as a solution for BIM adoption (Gu and London, 2010), as QSs have seen an increasing need for the appropriate knowledge and skills that allow them to participate in BIM-enabled processes.

To fulfil the market demand for BIM professionals, educational institutions are trying to integrate BIM within their curricula, especially in the field of quantity surveying. Ali et al. (2016) suggested a broad BIM education framework for quantity surveying students that comprises four key objectives: visualisation, quantification, planning and scheduling, and management. Quantity surveying students should acquire various BIM skills to achieve these objectives. For example, 3D model visualisation can be achieved with BIM authoring software that not only offers a design tool but also provides a scheduling function for quantification. As such, modelling skill can enhance the experience of model visualisation, and it is can be used to verify the model's integrity before quantity take-off. Quantity take-off skill can help quantity surveying students to efficiently abstract the quantities and information from the 3D model with the aid of BIM software. To integrate a construction schedule and costs with the 3D model, the post-contract cost management skill can help students perform 5D BIM tasks such as cash flow forecasting and interim valuation. BIM management skill is critical for the success of the BIM process, and students learn how the BIM project is planned and executed.

With a structured BIM curriculum, quantity surveying graduates are equipped with appropriate skills in project delivery via BIM (Ali et al., 2016). Many universities worldwide that offer quantity surveying degree programmes have begun to teach BIM and have established curricula to integrate BIM into their existing courses. Table 2.5 lists some overseas universities that offer a Bachelor's degree programme in quantity surveying, and their curricula include several BIM-related courses. Based on the syllabi of those BIM-related courses, the key BIM skills acquired by the quantity surveying students can be classified as i) modelling, ii) quantity take-off and estimation, iii) post-contract cost management and iv) BIM model management.

Table 2.5 Selected list of BIM-related courses for quantity surveying students in various countries

University (Country)	*Quantity Surveying degree programme*	*BIM-related courses*	*BIM skills*
University of Reading (UK)	BSc in Quantity Surveying	• Introduction to Quantification and Computerised Taking-off • Quantification and Costing • Digital Technology Use in Construction	• Modelling • Quantity take-off and estimating • Post-contract cost management
University of Salford (UK)	BSc (Hons) in Quantity Surveying	• QS Private and Commercial Practice • Multi-disciplinary Project	• Modelling • Quantity take-off and estimating
Massey University (New Zealand)	Bachelor's of Construction (Quantity Surveying)	• CAD and BIM • Measuring Systems • Construction Innovation and BIM	• Modelling • Quantity take-off and estimating • BIM model management
Queensland University of Technology (Australia)	Bachelor's of Urban Development (Quantity Surveying and Cost Engineering)	• Measurement for Construction • Advanced Measurement for Construction • Integrated Construction	• Modelling • Quantity take-off and estimating
University of South Australia (Australia)	Bachelor's of Construction Management and Economics	• Construction Communication • QS Practice • Construction Cost Planning • Construction Scheduling	• Modelling • Quantity take-off and estimating • Post-contract cost management • BIM model management
National University of Singapore (Singapore)	BSc in Project and Facilities Management	• Digital Construction • Measurement • Building Information Modelling	• Modelling • Quantity take-off and estimating • BIM model management
University of Malaya (Kuala Lumpur)	Bachelor's of Quantity Surveying	• Measurement of Construction Works • Integrated Project	• Modelling • Quantity take-off and estimating

2.8 BIM curriculum design

Construction involves professional training that adopts a long-established curriculum. As such, changes are needed to incorporate BIM into the existing curriculum. Abdirad and Dossick (2016) noted three strategies for BIM teaching in educational institutions. First, standalone BIM courses can be developed to cover various uses of BIM (Taylor et al., 2008; Lee and Hollar, 2013; Wong et al., 2011). Second, BIM teaching can be integrated into existing courses for a focus on specific BIM uses (Taylor et al., 2008; Abdirad and Dossick, 2016). Third, both strategies can be combined in addition to a BIM-enabled capstone course. Students can fully apply their BIM knowledge and skills in such a capstone course or in a research project (Lee and Hollar, 2013; Badrinath et al., 2016; Sacks and Pikas, 2013). The BIM courses can be offered as core courses and as electives in the curriculum (Azhar et al., 2010) to provide students with the opportunity to learn basic concepts and applications, and those who are interested can then acquire more in-depth BIM-related knowledge and skills. However, standalone BIM courses without follow-up courses do not support students' long-term BIM learning (Abdirad and Dossick, 2016) because the students cannot apply the BIM skills they have learned in higher-level courses and thus cannot maintain the skills.

Construction students should be equipped not only in basic BIM technology but also in the application of BIM processes that are vital for realising the value propositions of BIM (Sacks and Pikas, 2013). Barison and Santos (2010) stated that BIM could be introduced into a curriculum via a mixing approach with eight categories: digital graphic representation, workshop, design studio, BIM course, building technology, construction management, thesis project and internship. In the United States, for example, the predominant approach is to introduce BIM in a design studio and to teach BIM concepts and software in specific BIM courses. Wong et al. (2011) proposed the use of an application-based approach rather than an architectural design–based approach to teach BIM to construction students in Hong Kong. To meet the current cross-disciplinary trend, software and classroom equipment should be provided for students (Taylor et al., 2008; Abdirad and Dossick, 2016). Both software and hardware are essential in BIM teaching because students use them for modelling and for team communication to improve interaction. The integration of BIM into the curriculum requires significant upgrades in software and hardware infrastructure (Abdirad and Dossick, 2016), but such upgrading causes technology problems including BIM tool selection, BIM software licenses and the need for BIM laboratory facilities (Badrinath et al., 2016).

Barison and Santos (2010) classified the BIM courses into three teaching modes: single-course, interdisciplinary and distance collaboration. The single-course mode means that the BIM course is offered for an individual discipline. Students can learn the BIM concepts or the use of BIM software, such as how to create, develop and analyse BIM models. With this teaching mode, the courses are always provided to students in the same discipline, and no collaboration occurs amongst students from various construction disciplines. The interdisciplinary mode refers to offering the BIM courses to students from two or more construction disciplines. Students from various disciplines work together and learn to work cooperatively (Becerik-Gerber et al., 2011; Wong et al. (2011)). This cross-curriculum teaching mode can enhance students' understanding of the collaborative BIM applications (Lee and Hollar, 2013; Sacks and Pikas, 2013). Distance collaboration means that the BIM courses are expanded to create a BIM learning spectrum with various modes of collaboration (Badrinath et al., 2016). The collaboration can occur between two or more distant institutions or between industry and academia. This teaching mode not only provides excellent opportunities for students to exchange their BIM knowledge and skills but also connects institutions so that they can learn from each other regarding the enhancement of their own BIM courses and resources (MacDonald and Mills, 2013).

Lee et al. (2013) recommended that general BIM concepts and operations can be delivered to students during the early curriculum, whilst professional BIM uses, collaboration and integration of BIM skills should be left for senior-level courses. Likewise, Kymmell (2008) and Barison and Santos (2010) stressed the need to focus on individual skills in BIM applications during the first year. BIM implementation should then be expanded to teamwork and complex collaboration and further expanded to real-life projects in collaboration with other institutions or companies (MacDonald and Mills, 2013).

One problem that has led to the slow adoption of BIM education is the weak ties between industry and academia (Badrinath et al., 2016). According to Abdirad and Dossick (2016), industrial collaborations are needed to seek financial, technological and educational support from industry to accelerate the adoption of BIM in educational institutions. These external engagements can improve educational outcomes and are well received by students. Various forms of support were recommended in previous studies. For example, faculty members who teach BIM-related courses should actively participate in the BIM activities and engage with professional bodies so that their courses' content can reflect current industry practices (Lee and Hollar, 2013). Badrinath et al. (2016) suggested that BIM short courses and workshops can be delivered to the community outside the school as an effective strategy to facilitate BIM learning in industry via academia. Molavi and Shapoorian (2012) noted that collaboration with industry experts can develop professional relationships and provide internships for students. Based on these studies, the essential elements of BIM education are summarised in Table 2.6. These essential elements contribute to the BIM curriculum in various ways and support comprehensive BIM teaching in educational institutions.

Table 2.6 BIM education framework

Essential elements of BIM curriculum	Barison and Santos (2010)	Taylor et al. (2008)	Molavi and Shapoorian (2012)	Kymmell (2008)	Lee and Hollar (2013)	Badrinath et al. (2016)	Wong et al. (2011)	Abdirad and Dossick (2016)	MacDonald and Mills (2013)	Sacks and Pikas (2013)	Becerik-Gerber et al. (2011)	Total no.
BIM-related taught classes	✓	✓			✓	✓	✓	✓		✓	✓	8
Interdisciplinary students projects	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	10
Research projects	✓				✓			✓		✓	✓	5
Students learning activities	✓		✓							✓		3
Hardware						✓		✓				2
Software	✓	✓				✓	✓	✓			✓	6
Cross-institutional cooperation	✓								✓			2
Industrial support			✓		✓	✓		✓			✓	5

In contrast, the CIC published a roadmap for BIM implementation (CIC, 2014) whose key purpose was to propose a way forward for strategic BIM implementation in Hong Kong's construction industry. Not only does it summarise the benefits and constraints of BIM adoption, it also presents the industry's views and concerns regarding the current adoption of BIM in Hong Kong. The final recommendation included nine initiatives for the successful implementation of BIM: (A) collaboration, (B) incentive and proven benefit, (C) standard and common practice, (D) legal and insurance, (E) information sharing and handover, (F) promotion and education, (G) sufficient digital capability and vendor support, (H) risk assessment and (I) global competitiveness. With regard to the initiative of promotion and education, the perspective is to expedite the building up of BIM capacity and capability by enhancing BIM training in universities or training institutes in various aspects such as BIM management and research and development. Comprehensive and systematic new BIM courses can be added to the curricula for degree courses and diploma courses to meet industry's needs. The CIC (2014) recommended that suitable training programmes be designed and offered to cover the full BIM spectrum. Table 2.7 shows the three types of BIM training functions proposed by the CIC: BIM model development, the use of a built BIM model and BIM model management. Wong et al. (2011) noted BIM teaching should be gradually introduced to students at various stages of the curriculum. Basic model development courses are provided for first-year students, and the use of the built model, including estimation, scheduling and clash analysis, should be delivered in later years. This teaching approach can align BIM with the curriculum's existing structure.

Table 2.7 Three types of BIM training functions (Source: CIC, 2014)

Initiative No:	F.2
Perspective:	Promotion and education
Initiative:	To expedite the development of BIM capacity and capabilities
Activity:	Design and offer training covering three functions: (a) BIM model development (b) Using built BIM models (c) BIM model management

Chapter 3 – Research methods

3.1 Research framework

A study's methods depend largely upon its research framework and its objectives. Figure 3.1 illustrates the study's research framework, which comprises a series of research activities in a logical sequence. The goal of this study is to investigate current BIM development in Hong Kong from the QS's perspective. The status of BIM applications in QS practices and BIM education in local tertiary institutions are two core subject areas. To this extent, the extent to which BIM has been adopted in quantity surveying and in the BIM curricula of surveying programmes was investigated. The results provide insights into current BIM development in quantity surveying and assist in the establishment of recommendations for promotion of BIM in Hong Kong. Both quantitative and qualitative approaches are used in this study, including a literature review, questionnaire survey, semi-structured interviews and a case study.

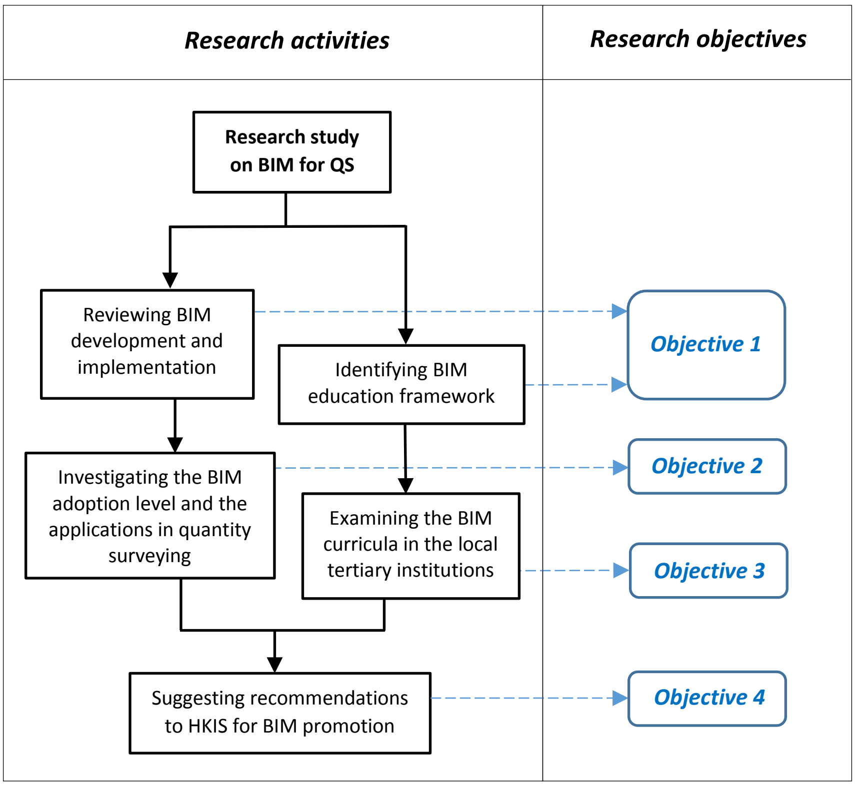

Figure 3.1 Research framework

3.2 Research methods

3.2.1 Questionnaire survey

A questionnaire framework was developed based on the theories and knowledge acquired from previous studies. Based on the research objectives, QSs employed with private developers, government offices, consultant firms and contractor companies were selected as the research samples for the questionnaire survey. Lists of the research samples are shown in the Appendices. Before dissemination of the questionnaires, draft versions were sent to BIM practitioners and professional QSs for review and feedback. Suggestions related to their appropriateness were received, and the draft questionnaires were amended based on the feedback obtained. The final version of the questionnaire consists of five parts. The first part contains questions about the background of the respondent's company. Information was also sought regarding the in-house BIM team and the appointment of BIM consultants. In the second part, the respondents are requested to state the number and the type of their BIM projects. In the third part, the respondents are requested to show details of the BIM implementation, such as model production, model contents and model uses. The fourth part evaluates the respondents' expectations of and satisfaction in their models. The final part of the questionnaire seeks the respondents' perceptions of barriers to the implementation of BIM. The respondents' personal opinions on the recommendations are also sought. Samples of the questionnaires are included in the Appendices.

The data analysis methods depend on the types of data collected in the questionnaire survey. For example, percentages were computed for frequencies, numbers and the yes/no answers obtained from the questions in the first three parts of the questionnaire, including the respondent's background, experience with the adoption of BIM, the number of quantity surveying staff involved in BIM projects, numbers of BIM projects, types of BIM projects and types of model elements. In contrast, for the questions in the last two parts of the questionnaire, the respondents were requested to rate on a 7-point Likert scale their agreement with the expected BIM goals and the factors that cause late BIM adoption, and the Statistical Package for Social Sciences (SPSS) was used for analysis.

The reliability of the scaling method adopted in the questionnaire was checked by Cronbach's alpha reliability coefficients, which are a popular indicator of a scale's internal consistency (Pallant, 2010). The alpha coefficient can range from 0 to 1. The higher the coefficient, the more reliable the groupings of the variables. An alpha coefficient of greater than 0.7 is regarded as 'good' in reliability testing (Sharma, 1996). An analysis of variance (ANOVA) was performed to examine whether the opinions of various groups of respondents were sufficiently consistent. The mean scores were recognised as having no significant difference when the significance level (*p*-value) was higher than 0.05. (Hair et al., 1998). In addition, the level of agreement between any two respondent groups on their rankings was measured with Spearman's rank correlation coefficient (r_s), which can only take on values from -1 to +1. The sign in front indicates either a positive linear correlation or a negative linear correlation. A correlation of 0 indicates no relationship between the two respondent groups on the variable (Albright et al., 2006). If the significance level (*p*-value) was lower than 0.05, the null hypothesis that no significant correlation exists between the two groups on the rankings can be rejected, which means that no significant disagreement was found between the two respondent groups on the ranking exercise (Chan et al., 2007).

3.2.2 Semi-structured interviews

Semi-structured interviews were conducted with QSs and scholars involved in BIM applications and education, respectively, in Hong Kong. The purpose of these interviews was to obtain professional insights about the research subject, and the acquired information was used to further explain and validate the research findings. The interviewees invited were esteemed QSs in the client organisations, consultant firms and contactor companies. In addition, academic staff from the educational institutions were interviewed. Finally, 12 interviewees were invited to participate in the interviews that were undertaken by the research team via a series of face-to-face meetings or telephone discussions. Table 3.1 lists the professional backgrounds and the company nature of the interviewees.

Table 3.1 List of interviewees and their background

No. of the interviewee	*Professional background of the interviewee*	*Nature of the interviewee's company*
Interviewee 1	Quantity Surveyor	Private developer
Interviewee 2	Quantity Surveyor	Private developer
Interviewee 3	Quantity Surveyor	Private developer
Interviewee 4	Quantity Surveyor	Consultant firm
Interviewee 5	Quantity Surveyor	Consultant firm
Interviewee 6	Quantity Surveyor	Consultant firm
Interviewee 7	Quantity Surveyor	Contractor company
Interviewee 8	Quantity Surveyor	Contractor company
Interviewee 9	Quantity Surveyor	Contractor company
Interviewee 10	Academia	Educational institution
Interviewee 11	Academia	Educational institution
Interviewee 12	Academia	Educational institution

The interviews are semi-structured, with the following pre-determined subject areas and open-ended questions.

For BIM adoption in QS practices

1) Company's current BIM adoption status

2) BIM process and QS tasks in BIM projects

3) Challenges of BIM adoption in QS practices

4) Recommendations to the HKIS for establishment of BIM promotion policy

For BIM education in quantity surveying

1) Perception of BIM education in the tertiary institution

2) Current BIM curriculum and its design

3) Challenges of BIM education

4) Recommendations to the HKIS for establishment of BIM promotion policy

3.2.3 Case study

With regard to the subject area of BIM education in quantity surveying, an exploratory case study approach was adopted to investigate the backgrounds of the academic departments in the educational institutions that offer BIM teaching to surveying students in Hong Kong and the curricula used for the BIM education. Zahra and Pearce (1990) concurred that case studies offer a promising approach to develop fieldwork-based research that encourages in-depth knowledge and understanding of an organisation and its processes. Other methods are also used in this study. Its purpose is to collect data from the academic departments of the local educational institutions and compare the results with the education framework developed from the literature review. This entails the collection of qualitative and quantitative data via interviews with key informants. The case study includes samples from local educational institutions in Hong Kong that offer a degree programme in surveying.

3.2.4 Achievement of the research objectives

Based on the research framework established in Figure 3.1, the four research objectives are achieved by conducting various research activities with various methods. Table 3.2 summarises how the research objectives match with the corresponding methods (i.e., literature review, questionnaire survey, case study and interviews) and their contributions to each report chapter.

Table 3.2 Achievement of the research objectives by the proposed research methods

Research objectives	Research methods	Purposes	Report chapters
Objective 1	Literature review	Review the previous research critically to offer a summary of the knowledge in the subject area and discover the research gap	Chapter 2
Objective 2	Questionnaire survey	Collect data for analysis of the current BIM adoption in various QS practices	Chapter 4
	Interviews	Acquire information to further explain and validate the research findings	Chapter 5
Objective 3	Case study	Collect data for review of the current BIM curricula of the local tertiary education	Chapter 4
	Interviews	Acquire information to further explain and validate the research findings	Chapter 5
Objective 4	Questionnaire survey	Solicit recommendations	Chapter 5
	Interviews	Solicit recommendations	Chapter 5

Chapter 4 – Data collection and analysis

This research study includes two parts. Part I concerns BIM adoption in QS practices, and Part II concerns BIM education in quantity surveying in Hong Kong. The following sections explain the process of data collection and the findings obtained after data analysis.

4.1 BIM adoption in QS practices

4.1.1 Data collection

Professional QSs who practice in client organisations, consultant firms and contractor companies were the target respondents of the questionnaire survey. A two-stage approach to data collection was adopted in this study. For the first stage, research samples were randomly selected from company lists representing the key property and construction businesses in Hong Kong, such as the member list of the Real Estate Developers Association of Hong Kong, the QS company list maintained by the HKIS and the list of Approved Contractors for Public Works under the Development Bureau of Hong Kong. Government departments involved in public works were also chosen to provide samples. The lists of the target respondents are attached to the Appendices. For the second stage, the questionnaires were disseminated throughout the industrial network with the aid of the professional institutions. Table 4.1 summarises the questionnaire distribution and return.

Table 4.1 Summary of the questionnaire distribution and return

Research samples	Total no. of questionnaire sent	Total no. of questionnaire received	
	N	N	%
Client organisations	30	12	40%
Consultant firms	20	15	75%
Contractor companies	100	33	33%
Total	150	60	40%

One hundred fifty questionnaires were distributed by hand or via e-mail, and 60 completed questionnaires were returned, yielding a response rate of 40%. Fellows and Liu (2003) stated that a useable response rate of 25% to 35% should be expected for questionnaires, so the questionnaire survey produced a meaningful response rate. Each of the returned questionnaires was in order and appropriate for data analysis.

4.1.2 Data analysis and results

The data collected from the questionnaire survey were analysed with the statistical tools mentioned in Chapter 3. The following sections report the results of the five core components of the questionnaire survey. Further in-depth discussions of the results can be found in Chapter 5.

4.1.2.1 Respondent background

Tables 4.2 to 4.6 show the results of the respondents' company background and the extent of the personnel involvement in their BIM projects. Table 4.2 displays the statistics related to the respondents' organisation types, and four respondent QS groups are categorised. Table 4.3 lists the frequencies and the percentages of quantity surveying staff involvement in the BIM projects for each type of respondent QS group. The numbers of quantity surveying staff members are also provided for each case for reference. Statistical data for the private developers and the government departments are listed separately due to the different types of construction projects in the private and public sectors. The differences in quantity surveying staff involvement in BIM projects in 2019 compared with data from the last BIM survey conducted amongst the consultant QS firms in 2017 are listed separately in Table 4.4. The results show an increase in quantity surveying staff involvement amongst the consultant firms, and the number of zero BIM adopters was significantly reduced. Table 4.5 shows the establishment and the size of the in-house BIM team for the four respondent QS groups, and Table 4.6 shows the situation of BIM consultant appointment on a project basis.

Table 4.2 Organisation types of the survey respondents

Type of organisation	Frequency N	Percentage %
Private developers	10	17%
Government departments	2	3%
Consultant firms	15	25%
Contractor companies	33	55%
Total	60	100%

Table 4.3 QS staff involvement in BIM project

QS staff involvement in BIM project	Private developers		Government departments		Consultant firms		Contractor companies	
	N *(QS no.)*	%	N *(QS no.)*	%	N *(QS no.)*	%	N *(QS no.)*	%
0%	5 *(0)*	50%	-	-	2 *(0)*	13.3%	25 *(0)*	75.7%
1-9%	1 *(4)*	10%	1 *(19)*	50%	2 *(4-30)*	13.3%	3 *(2-5)*	9.1%
10-19%	-		1 *(23)*	50%	3 *(20-80)*	20%	2 *(10-20)*	6.1%
20-29%	1 *(2)*	10%	-	-	-	-	-	-
30-39%	-	-	-	-	3 *(2-6)*	20%	-	-
40-49%	-	-	-	-	3 *(8-48)*	20%	-	-
50-59%	-	-	-	-	2 *(15-23)*	13.3%	2 *(40-65)*	6.1%
80-89%	2 *(5-7)*	20%	-	-	-	-	1 *(60)*	3%
≥90%	1 *(12)*	10%	-	-	-	-	-	-
Total	10	100%	2	100%	15	100%	33	100%

Table 4.4 Comparison of QS staff involvement in BIM project

QS staff involvement in BIM project	(2017 Survey) Consultant firms N (%)	(2019 Survey) Consultant firms N (%)
0%	10 (58.8%)	2 (13.3%)
1-9%	3 (17.6%)	2 (13.3%)
10-19%	1 (5.9%)	3 (20%)
20-29%	1 (5.9%)	-
30-39%	-	3 (20%)
40-49%	1 (5.9%)	3 (20%)
50-59%	1 (5.9%)	2 (13.3%)
Total	17 (100%)	15 (100%)

Table 4.5 Establishment of BIM team in the company

Establishment of in-house BIM team	Private developers N (%)	Government departments N (%)	Consultant firms N (%)	Contractor companies N (%)
Yes	5 (50%)	2 (100%)	7 (46.7%)	11 (33.3%)
No	5 (50%)	-	8 (53.3%)	22 (66.7%)
Total	10 (100%)	2 (100%)	15 (100%)	33 (100%)

Table 4.6 Appointment of BIM consultant on project basis

Appointment of BIM consultant on project basis	Private developers N (%)	Government departments N (%)	Consultant firms N (%)	Contractor companies N (%)
Yes	4 (40%)	2 (100%)	1 (6.7%)	25 (75.7%)
No	6 (60%)	-	14 (93.3%)	8 (24.3%)
Total	10 (100%)	2 (100%)	15 (100%)	33 (100%)

4.1.2.2 Status of BIM adoption

Table 4.7 to 4.14 show the results regarding the level of BIM adoption for each respondent QS group and the types of their BIM projects. First, Table 4.7 shows the BIM adoption experience of various organisations. The unexperienced cases of BIM are found amongst private developers (50%), consultant firms (13.3%) and contractor companies (66.7%). Second, Table 4.8 shows the timeframe of future BIM adoption for organisations with no experience in BIM adoption. Unfortunately, most currently have no timeframe for future

BIM use. Compared with the last BIM survey conducted amongst consultant QS firms, the differences in the BIM adoption experience of consultant firms between 2017 and 2019 are listed separately in Table 4.9. The statistics show that experience with BIM adoption in the consultant QS firms has increased significantly.

Table 4.7 BIM adoption experience

BIM adoption experience	Private developers N (%)	Government departments N (%)	Consultant firms N (%)	Contractor companies N (%)
Yes	5 (50%)	2 (100%)	13 (86.7%)	11 (33.3%)
No	5 (50%)	-	2 (13.3%)	22 (66.7%)
Total	10 (100%)	2 (100%)	15 (100%)	33 (100%)

Table 4.8 Timeframe of future BIM adoption

Time frame of future BIM adoption	Private developers N (%)	Consultant firms N (%)	Contractor companies N (%)
Within 1-2 years	-	-	5 (22.7%)
Within 3-4 years	-	-	-
No timeframe	5 (100%)	2 (100%)	17 (77.3%)

Table 4.9 Comparison of consultant firms' BIM adoption experience

BIM adoption experience	(2017 Survey) Consultant firms N (%)	(2019 Survey) Consultant firms N (%)
Yes	7 (41%)	13 (86.7%)
No	10 (59%)	2 (13.3%)
Total	17 (100%)	15 (100%)

Third, Table 4.10 lists the frequencies and percentages of BIM projects over the past 5 years for each type of respondent group. The numbers of BIM projects are also listed against each case for reference. Compared with the last BIM survey conducted amongst the consultant QS firms in 2017, the differences between 2017 and 2019 in the BIM projects over the past

5 years are listed separately in Table 4.11. The results show that QS consultant firms are increasingly involved in BIM projects.

Table 4.10 BIM projects over the past 5 years

BIM projects over the past 5 years	Private developers		Government departments		Consultant firms		Contractor companies	
	N *(Project no.)*	%	N *(Project no.)*	%	N *(Project no.)*	%	N *(Project no.)*	%
<10%	-	-	-	-	6 *(6-40)*	46.1%	-	-
10-19%	-	-	-	-	3 *(3-29)*	23.1%	1 *(4)*	9.1%
20-29%	-	-	1 *(41)*	50%	2 *(4-16)*	15.4%	-	-
50-59%	1 *(2)*	20%	-	-	-	-	5 *(3-15)*	45.4%
60-69%	1 *(6)*	20%	-	-	-	-	-	-
70-79%	3 *(5-11)*	60%	-	-	-	-	3 *(7-12)*	27.3%
80-89%	-	-	-	-	1 *(4)*	7.7%	-	-
≥90%	-	-	1 *(6)*	50%	1 *(3)*	7.7%	2 *(8-27)*	18.2%
Total	5	100%	2	100%	13	100%	11	100%

Table 4.11 Comparison of consultant firms' BIM projects over the past 5 years

BIM projects over the past 5 years	(2017 Survey) Consultant firms N (%)	(2019 Survey) Consultant firms N (%)
<10%	5 (71.4%)	6 (46.1%)
10-19%	1 (14.3%)	3 (23.1%)
20-29%	-	2 (15.4%)
50-59%	-	-
60-69%	-	-
70-79%	-	-
80-89%	1 (14.3%)	1 (7.7%)
≥90%	-	1 (7.7%)
Total	7 (100%)	13 (100%)

Fourth, statistics for the mandatory and voluntary BIM adoption for the consultant firms and the contractor companies are shown in Table 4.12. The results reveal no significant difference in the types of BIM adoption in consultant firms, but mandatory adoption is very common in the contractor companies (81.8%). Table 4.13 shows the percentages of various types of BIM projects in Hong Kong. Due to the differences in the nature of construction in the private and public sectors, statistical data are listed separately for private and public projects. Further statistics about mandatory and voluntary BIM adoption for various project types are provided and listed in Table 4.14. The results show that the three most popular project types (i.e., residential, commercial and infrastructure) in mandatory BIM adoption are the same as those in voluntary BIM adoption.

Table 4.12 BIM projects over the past 5 years (mandatory vs voluntary adoption)

BIM projects over the past 5 years	Consultant firms		Contractor companies	
	Mandatory N (%)	*Voluntary N (%)*	*Mandatory N (%)*	*Voluntary N (%)*
	6 (46.2%)	7 (53.8%)	9 (81.8%)	2 (18.2%)

Table 4.13 Types of BIM projects (private vs public sector)

Types of BIM projects	Private projects	Public projects*	
		A	*B*
Residential	20.6%	100%	7.3%
Office/commercial	17.5%	-	26.8%
Hotel	12.7%	-	-
Infrastructure	11.1%	-	-
Institutional	9.5%	-	7.3%
Industrial	7.9%	-	-
Medical	6.3%	-	9.8%
Recreational	6.3%	-	34.1%
Renovation / fitting out	4.8%	-	4.9%
Others	3.2%	-	9.8%
Total	100%	100%	100%

* A = Government department 'A'; B = Government department 'B'

Table 4.14 Types of BIM projects (mandatory vs voluntary BIM adoption)

Types of BIM projects	Mandatory adoption	Voluntary adoption
Residential	28.7%	49.4%
Office/commercial	20.7%	12.7%
Infrastructure	20.1%	11.4%
Recreational	10.3%	5.1%
Medical	5.7%	1.3%
Institutional	5.2%	3.8%
Renovation / fitting out	2.9%	5.1%
Hotel	2.9%	6.3%
Industrial	1.7%	2.5%
Others	1.7%	2.5%
Total	100%	100%

4.1.2.3 Sources and uses of models

This section shows the common sources of models and the popular types of models used by QSs. First, Table 4.15 shows the statistics of various sources of models to be received by QSs. The percentages show that independent BIM consultants are the major source of models (46.3%), followed by design team members (43.3%) and contractors (10.4%). Independent BIM consultants are not a part of the design team; they are consultant firms appointed directly by the client. In addition to these sources, 3D models produced by transforming 2D CAD drawings via proprietary quantity surveying software were found but were excluded from the statistics of this study because these models are used for quantity take-off only by QSs. Second, Table 4.16 shows the popular types of model production in both the private sector and the public sector. The statistics indicate that architectural models, structural models and MEP models are commonly produced. Third, Table 4.17 lists the popular types of model elements created in BIM projects. The model elements of MEP models are shown separately in Table 4.18. Fourth, Table 4.19 displays the popular types of models used by QSs who practice in consultant firms and contractor companies. According to the results, the level of model use by consultant QSs was relatively higher than that of contractor QSs.

Table 4.15 Sources of models to be used by QS

Sources of models	Percentage %
Independent BIM consultants	46.3%
Design team members	43.3%
Contractors	10.4%
Total	100%

Table 4.16 Types of model production (private vs public sector)

Types of model	Private projects %	Public projects %	Total (Av) %
Architectural model	100%	100%	100%
Structural model	100%	100%	100%
MEP model	88.2%	100%	89.5%
Site model	47.1%	-	42.1%

Table 4.17 Popular types of model elements

Types of model elements	Private projects %	Public projects %	Total (Av) %
Structural elements	100%	100%	100%
Non-structural elements	94.1%	100%	94.7%
Facades	70.6%	100%	73.7%
Windows & doors	70.6%	100%	73.7%
Finishes	49.5%	100%	57.9%
Steel & metal works	47.1%	100%	52.6%
Foundations	47.1%	100%	52.6%
Site formation	47.1%	0%	42.1%
External works	41.2%	100%	47.4%
Reinforcing bars	35.3%	50%	36.8%
Slope stabilisation	23.5%	0%	21.1%
Wood works	23.5%	100%	31.6%
Retaining structures	23.5%	50%	26.3%

Table 4.18 Popular types of model elements (MEP model only)

Types of model elements	Private projects %	Public projects %	Total (Av) %
Electrical	88.2%	100%	89.5%
Plumbing & drainage	88.2%	100%	89.5%
Mechanical	88.2%	100%	89.5%
Fire services	88.2%	100%	89.5%

Table 4.19 Popular use of models (consultant QSs vs contractor QSs)

Type of model	Consultant QSs %	Contractor QSs %	Total (Av) %
Structural model	100%	54.6%	76.9%
Architectural model	87.5%	40.3%	69.2%
MEP model	83.3%	10.2%	45.5%
Site model	66.7%	33.3%	50%

4.1.2.4 Expectation and scope of BIM adoption

This section indicates the expectations and the scope of BIM adoption on current QS practices. First, the respondents were asked to rate their degree of agreement with each of the statements regarding the sufficiency of model quality to achieve the expected BIM goals. The data collected were subject to reliability tests whose results show higher alpha coefficients (0.86) and *p* values (0.10 to 0.98) than the benchmark values, which indicates that the scaling method adopted was reliable in the surveyed sample and that no significant differences were found between the various respondent QS groups in terms of their views on variable significance. Table 4.20 shows the ranking based on the mean scores computed from the replies of all QS respondents. Tables 4.21 compares the rankings by each respondent QS group and reports the results of ANOVA. Further, the level of agreement amongst the three respondent QS groups on the ranking was tested with the Spearman's rank correlation coefficient (r_s). Based on the results shown in Table 4.22, the null hypotheses (H_0) that no significant correlation existed between the three pairs of QS groups on the ranking can be rejected. This means considerable agreement was found in the three respondent groups.

Table 4.20 Ranking of the achievement of the expected BIM goals (All QSs)

Expected BIM goals	Sufficiency of BIM model quality to support the expected BIM goals	
	*Mean**	*SD*
Enhancing coordination	5.63	1.02
Better visualisation	5.56	1.54
Reducing errors and omissions	4.94	1.34
Constructability review	4.88	1.36
Improving productivity	4.76	1.35
Reducing abortive works	4.67	1.19
Better predictability and cost control	4.50	1.61
Shortening overall project duration	4.46	1.56
Improving accuracy in quantification of works	4.40	1.35
Lowering construction cost	4.23	1.48
Better documentation	4.17	1.53
Improving safety	4.14	1.56
Expediting regulatory approval cycles	3.91	1.58

* Seven-point scale (1 = strongly disagree; 7 = strongly agree) .

Table 4.21 Comparison of the ranking on the expected BIM goals and the results of ANOVA

Expected BIM goals	All QSs		Client QSs		Consultant QSs		Contractor QSs		F	Sig. (p-value)
	Mean	*Rank*	*Mean*	*Rank*	*Mean*	*Rank*	*Mean*	*Rank*		
Enhancing coordination	5.63	1	5.00	3	5.83	1	6.25	2	0.45	0.65
Better visualisation	5.56	2	5.50	1	5.13	3	6.50	1	0.13	0.90
Reducing errors and omissions	4.94	3	4.80	4	5.00	4	5.00	5	0.46	0.64
Constructability review	4.88	4	5.20	2	4.67	6	4.80	7	0.75	0.43
Improving productivity	4.76	5	4.40	7	5.29	2	5.50	3	0.39	0.77
Reducing abortive works	4.67	6	4.50	5	4.86	5	4.60	10	0.68	0.59
Better predictability and cost control	4.50	7	4.20	8	4.40	9	4.95	6	0.71	0.47
Shortening overall project duration	4.46	8	4.00	9	4.25	10	5.25	4	2.14	0.15
Improving accuracy in quantification of works	4.40	9	4.40	6	4.20	11	4.75	9	0.05	0.98
Lowering construction cost	4.23	10	3.50	13	4.60	7	4.50	11	2.49	0.10
Better documentation	4.14	11	3.75	12	4.00	12	4.75	8	0.17	0.87
Improving safety	4.17	12	3.80	11	4.50	8	4.33	12	0.32	0.80
Expediting regulatory approval cycles	3.91	13	3.80	10	4.00	13	4.00	13	0.25	0.83

Table 4.22 Results of Spearman's rank correlation test for the three pairs of QS groups

Ranking of the QS groups	Spearman's rank correlation coefficient (r_s)	Significance
Pair 1: Client QSs and Consultant QSs	0.813	0.000
Pair 2: Client QSs and Contractor QSs	0.786	0.002
Pair 3: Consultant QSs and Contractor QSs	0.794	0.001
Result: Reject H_o at 1% significance level for pairs 1, 2 and 3.		

Second, Table 4.23 shows statistics regarding the audit policy of model compliance by the private developers and government departments. The results indicate that such an audit policy has not been commonly implemented to check model quality in either the private or public sectors right now. Third, Tables 4.24 and 4.25 show the popular BIM QS tasks accomplished by consultant QSs and contractor QSs, respectively. Further statistics regarding mandatory BIM adoption and voluntary BIM adoption are listed separately for comparison. The results show that more types of BIM QS tasks involve voluntary adoption. Fourth, Table 4.26 indicates the companies' provision of measures to facilitate the use of BIM by quantity surveying staff for QS tasks from the perspectives of consultant QSs and contractor QSs. The consultant firms appear to be generally supportive of their quantity surveying staff in the use of BIM. The types of those measures are shown in Table 4.27, and the results indicate that both consultant firms and contractor companies provide a variety of measures to facilitate the use of BIM by quantity surveying staff. The consultant firms are keen to arrange internal BIM experience sharing (100%) and produce a BIM practice manual (100%), whilst the contactor companies provide their quantity surveying staff with some simple internal guidelines (100%) and BIM software training (100%).

Table 4.23 Setting up audit policy of model compliance by the client

Audit policy of model compliance	Private developers N (%)	Government departments N (%)
Yes	1 (20%)	-
No	4 (80%)	2 (100%)
Total	5 (100%)	2 (100%)

Table 4.24 Consultant BIM QS tasks (mandatory vs voluntary adoption)

Consultant BIM QS tasks	Mandatory BIM adoption %	Voluntary BIM adoption %
BQ measurement	41.7%	75%
Cost planning	25%	66.7%
Preliminary cost advice	25%	50%
Valuation of variations	25%	50%
Cash flow forecast	16.7%	50%
Interim valuation	16.7%	41.7%
Re-measurement of provisional items	16.7%	41.7%
Value engineering	-	41.7%
Contractual advice	-	41.7%
Dispute resolution	-	41.7%
Financial report	-	33.3%
Life-cycle costing	-	33.3%
Assessment of financial claims	-	33.3%
Procurement advice	-	25%

Table 4.25 Contractor BIM QS tasks (mandatory vs voluntary adoption)

Contractor BIM QS tasks	Mandatory BIM adoption %	Voluntary BIM adoption %
Variations and claims	40%	40%
Tender preparation	-	33%
Payment application	33%	-
Progress report	20%	33%
Cost monitoring and control	-	20%
Value engineering	-	20%
Quantification of works for sub-letting/purchasing	-	20%
Arbitration and dispute resolution	-	13%
Risk management	-	13%
Life cycle costing	-	-
Project cash flow	-	-
Sub-contractors' payment preparation	-	-
Financial report	-	-

Table 4.26 Measures to facilitate the use of BIM by QS staff in QS tasks

Provision of measures to facilitate the use of BIM by QS staff in QS tasks	Consultant firms N (%)	Contractor companies N (%)
Yes	9 (69%)	3 (27%)
No	4 (31%)	8 (73%)
Total	13 (100%)	11 (100%)

Table 4.27 Types of measures to facilitate the use of BIM by QS staff in QS tasks

Types of measures to facilitate the use of BIM by QS staff in QS tasks	Consultant firms %	Contractor companies %
Internal BIM projects experience sharing	100%	67%
BIM practice manual	100%	33%
Simple guidelines for internal use	78%	100%
Software training by outsiders like software vendors or BIM consultants	67%	100%
Recruitment of BIM specialists	44%	67%
Software customisation for QS tasks like QTO	44%	67%
Develop standard approach of modelling to suit QS requirements	-	33%
Project-based BIM execution plan	-	67%

Fifth, Table 4.28 demonstrates the respondents' satisfaction level with the existing BIM conditions and specifications to deal with the contractual matters of their BIM projects. The results reveal a low ($\bar{x} \leq 4.6$) satisfaction level with the existing conditions and specifications. The level of the respondents' desire for the publication of new standard BIM conditions is also shown in Table 4.28. The high mean scores ($\bar{x} \geq 6$) represent the QSs' great desire for a new publication. Table 4.29 lists the likelihood of future adoption of the new standard BIM conditions from the perspective of QSs who work for private developers, government departments, consultant firms and contractor companies. The results show support for the future use of the new standard BIM conditions ($Y \geq 93.3\%$).

Table 4.28 Existing BIM conditions and publication of a new standard BIM conditions

BIM conditions/ specification	Private developers	Government departments	Consultant firms	Contractor companies	Total
	Mean	*Mean*	*Mean*	*Mean*	*Mean*
Existing BIM conditions/ specifications are effective	4.3	4.5	3.9	4.6	4.2
Publication of a new standard BIM Conditions	6.3	7.0	6.0	6.2	6.2

* Seven-point scale (1 = strongly disagree; 7 = strongly agree).

Table 4.29 Adoption of new standard BIM conditions

Adoption of new standard BIM conditions	Private developers N (%)	Government departments N (%)	Consultant firms N (%)	Contractor companies N (%)	Total N (%)
Yes	10 (100%)	2 (100%)	14 (93.3%)	32 (97%)	58 (97%)
No	-	-	-	-	-
Others	-	-	1 (6.7%)	1 (3%)	2 (3%)
Total	10 (100%)	2 (100%)	15 (100%)	33 (100%)	60 (100%)

4.1.2.5 Improvement of BIM adoption

This section shows the respondents' opinions about the factors that result in late adoption of BIM. The respondents were asked to rate the degree to which they agreed with each statement regarding the factors that lead to late adoption of BIM. The data collected were subjected to reliability tests, and the results show that the alpha coefficient (0.83) is higher than the benchmark values, which indicates that the scaling method adopted was reliable in the surveyed sample. However, the ANOVA results indicate that not all *p* values were higher than the threshold. The results suggest that significant differences existed amongst the respondent QS groups concerning their perceptions of 'High initial cost' (p=0.01), 'Restructuring of organisation to accommodate BIM' (p=0.02) and 'Benefits of BIM adoption cannot be realised' (p=0.04). Table 4.30 ranks the statements based on the mean scores computed from the replies from all QS respondents. Table 4.31 shows the rankings of the factors causing late BIM adoption. The overall ranking of the sixteen factors is listed based on the reply from all QS respondents. The overall ranking is the initial results showing the importance level of the factors in the perspective of all QSs. Individual rankings of the factors for the three QS groups are also listed separately. The results show that the rankings between the three QS groups are not similar, reflecting the existence of diverse views from different QS groups. As a result, ANOVA test was conducted and the results are displayed in Table 4.31 as well. Furthermore, the level of agreement amongst the three respondent QS groups on the ranking was tested with the Spearman's rank correlation coefficient (r_s). Based on the results shown in Table 4.32, the null hypotheses (H_0) that no significant correlation on the ranking exists amongst the three pairs of QS groups cannot be rejected, which means that apparent diverse perspectives from the three respondent groups were found.

Table 4.30 Factors that cause late BIM adoption (All QSs)

Factors causing late BIM adoption	Mean*	SD
The rush culture in the construction industry	5.76	1.48
Lack of well-recognised industry BIM standard	5.52	1.58
Shortage of in-house BIM specialist	5.48	0.91
Lack of BIM expertise in the market	5.04	1.52
Shortage of successful showcase of BIM projects	4.74	1.45
Problem of interoperability amongst BIM software	4.70	1.37
Extra cost for appointment of BIM consultants	4.70	2.07
Benefits of BIM adoption cannot be realised	4.61	1.65
Staff refusal/reluctance to learn new technology	4.61	1.74
Restructuring of organisation to accommodate BIM	4.57	1.53
High initial cost	4.57	1.74
Unforeseen positive return on investment on BIM	4.57	1.93
Lack of government support and incentive	4.45	2.10
Unsuitability of some projects for BIM adoption	4.39	1.44
Worries about security of confidential data	4.26	1.62
Standard BIM contract is not available	4.22	1.84

* Seven-point scale (1 = strongly disagree; 7 = strongly agree).

Table 4.31 Comparison of ranking on factors that cause late BIM adoption and results of ANOVA

Factors that cause late BIM adoption	All QSs		Client QSs		Consultant QSs		Contractor QSs		F	Sig.
	Mean	*Rank*	*Mean*	*Rank*	*Mean*	*Rank*	*Mean*	*Rank*		(*p*-value)
The rush culture in the construction industry	5.76	1	5.80	2	5.38	4	6.20	1	0.23	0.87
Lack of well-recognised industry BIM standard	5.52	2	5.90	1	5.88	2	5.80	3	0.20	0.91
Shortage of in-house BIM specialist	5.48	3	5.60	3	5.50	3	5.40	5	0.15	0.96
Lack of BIM expertise in the market	5.04	4	4.90	7	5.25	5	5.80	2	0.34	0.83
Shortage of successful showcase of BIM projects	4.74	5	5.10	4	4.50	10	4.80	8	0.45	0.80
Problem of interoperability amongst BIM software	4.70	6	4.80	8	5.25	6	4.00	13	0.64	0.77
Extra cost for the appointment of BIM consultants	4.70	7	4.10	15	4.75	8	4.20	12	0.75	0.64
Benefits of BIM adoption cannot be realised	4.61	8	5.00	5	4.13	12	4.60	9	0.87	0.04
Staff refusal/reluctance to learn new technology	4.61	9	4.90	6	3.63	15	5.20	6	0.84	0.52
Restructuring of organisation to accommodate BIM	4.57	10	4.30	13	4.13	13	5.60	4	0.95	0.02
High initial cost	4.57	11	3.50	16	6.13	1	3.20	16	2.17	0.01
Unforeseen positive return on investment on BIM	4.57	12	4.40	11	5.00	7	3.80	14	0.77	0.58
Lack of government support and incentive	4.45	13	4.20	14	4.75	9	4.40	10	1.12	0.23
Unsuitability of some projects for BIM adoption	4.39	14	4.60	9	4.38	11	5.00	7	0.98	0.35
Worries about security of confidential data	4.26	15	4.30	12	3.25	16	3.20	15	0.65	0.72
Standard BIM contract is not available	4.22	16	4.60	10	4.00	14	4.40	11	0.71	0.60

Table 4.32 Results of Spearman's rank correlation test for the three pairs of QS groups

Ranking of the QS groups	Spearman's rank correlation coefficient (r_s)	Significance
Pair 1: Client QSs and Consultant QSs	0.345	0.221
Pair 2: Client QSs and Contractor QSs	0.427	0.100
Pair 3: Consultant QSs and Contractor QSs	0.226	0.289
Result: Cannot reject H_0 at 5% significance level for Pair 1, 2 and 3		

4.2 BIM education in quantity surveying of Hong Kong

4.2.1 Data collection

The case study investigates the current status of BIM teaching at Hong Kong's educational institutions. In this study, educational institutions refer to local universities or tertiary institutions that offer a Bachelor's degree programme in surveying. Generally, the study mode (e.g., full-time or part-time) and the type of student admission (e.g., JUPAS or non-JUPAS) influence the curriculum of the degree programme. For example, the JUPAS applicants from secondary schools can apply to the full-time Bachelor's degree programme (e.g., a 4-year curriculum), whilst Associate's degree/higher diploma holders can apply to the full-time top-up Bachelor's degree programme (e.g., 2-year curriculum) or the part-time degree programme (4-year curriculum). In addition, some private institutions in Hong Kong offer self-financed top-up Bachelor's degree programmes in cooperation with overseas universities (e.g., a 15-month curriculum). To compare the surveying degree programme on the same basis, the local tertiary institutions that offer a 'full-time 4-year BSc in surveying' were selected as the research samples, including, in alphabetical order, i) the City University of Hong Kong (CityU), ii) the University of Hong Kong (HKU), iii) the Hong Kong Polytechnic University (PolyU) and iv) the Technological and Higher Education Institute of Hong Kong (THEI). According to the course accreditation information, the Bachelor's degree programmes in surveying offered by these four institutions are accredited by the HKIS in the stream of quantity surveying.

4.2.2 Data analysis and results

A variety of data were collected from the four tertiary institutions for analysis, and the results are further discussed in Chapter 5. First, the backgrounds of the academic departments that offer Bachelor's degree programmes in surveying were searched. The four academic departments in Hong Kong were founded at different times, and the academic fields of their college or faculty differ. For example, the Department of Architecture and Civil Engineering (ACE) of CityU is under a non-construction field college, whilst the Department of Real Estate and Construction (REC) of HKU and the Department of Building and Real Estate (BRE) of PolyU are under construction-related faculties. In contrast, the Department of Environment (ENV) of THEI is under a faculty that mixes the field of design with the environment. Moreover, the four academic departments offer more than one undergraduate and postgraduate programme. The BRE Department of PolyU offers the greatest number of taught programmes, whilst the ENV Department of THEI offers the fewest. Based on the overall taught programmes offered by each academic department, a variety of construction disciplines can be determined. The ACE Department of CityU includes the most of construction disciplines, including architecture, structural engineering, building services engineering, surveying and construction management. This unique composition covers almost all key disciplines in the construction industry. In contrast, the REC Department of HKU and the ENV Department of THEI have the fewest construction disciplines. The two disciplines of the REC Department are surveying and construction project management, whilst the two disciplines of the ENV Department of THEI are surveying and landscape architecture. Table 4.33 lists the results of our analysis of the backgrounds of the four local tertiary institutions. Second, the details of the BIM teaching in each academic department were investigated, and the results were mapped with the BIM education framework developed based on an extensive literature review. This mapping exercise can show the comprehensiveness of the scope of BIM teaching at each tertiary institution that offers Bachelor's degree programmes in surveying. The four tertiary institutions offer their surveying students a variety of BIM-related taught courses and final-year research projects. The ACE Department of CityU offers the most BIM-related courses, whilst the REC Department of HKU offers the fewest. Only the ACE Department of CityU and the BRE Department of PolyU provide interdisciplinary BIM projects for their surveying students. With regard to hardware and software support, the four academic departments provide computer centres or laboratories equipped with BIM software for surveying students. Moreover, the four academic departments offer a variety of student learning activities, such as seminars, conferences, internships and study tours. In addition, the four academic departments signed a memorandum of understanding with the CIC for enhancement and cooperation in BIM teaching. However, none of the tertiary institutions have cooperated at the academic level. Table 4.34 summarises the BIM teaching details of the four tertiary institutions according to the BIM education framework.

Third, BIM skills are categorised based on the syllabi of the BIM-related taught courses offered by each tertiary institution. For example, the syllabi of the five BIM courses offered by the ACE Department of CityU include four BIM skills: i) modelling, ii) quantity take-off and estimating, iii) post-contract management and iv) BIM model management (CityU, 2019). Likewise, the BIM skills of the remaining universities can be categorised by the same approach. The BRE Department of PolyU (PolyU, 2019) and the ENV Department of THEI (THEI, 2019) include three BIM skills: i) modelling, ii) quantity take-off and estimating and iii) post-contract management. The REC Department of HKU includes only two BIM skills: i) modelling and ii) quantity take-off and estimating (HKU, 2019). To obtain further results, the categorisations of the BIM skills are then mapped with the three BIM training functions recommended by the CIC (Table 2.6). This mapping exercise can show the extent to which the four academic departments have fulfilled the CIC-proposed training functions. Only the ACE Department of CityU can fully meet all three functions. The BRE Department of PolyU and the ENV Department of THEI can meet only two functions: i) BIM model development and ii) the use of built BIM models. The REC Department of HKU meets the function of BIM model development and partially meets the function of the use of built BIM models. Table 4.35 outlines the results of the BIM skills of each academic department and their mapping with the CIC's recommended BIM training functions. Fourth, the training of the BIM skills provided by each Bachelor's degree programme in surveying are further mapped with popular BIM applications in QS tasks. The popular BIM applications in QS tasks include the top ten BIM QS tasks identified in Chapter 4, and they are expected to be accomplished by the appropriate BIM skills. This mapping can evaluate the sufficiency of the current BIM teaching in Hong Kong's tertiary institutions. The graduates from the four tertiary institutions could acquire BIM skills for the top three pre-contract BIM QS tasks: bill of quantity/schedule of rate (BQ/SOR) preparation, cost planning and preliminary cost advice. However, not all of them can acquire BIM skills for post-contract QS tasks such as valuation of variations, cash flow forecast and interim valuation. In addition, only the graduates from CityU are equipped with the necessary BIM management skills that cover other topics like BIM contracts, value engineering and dispute resolution. Table 4.36 shows the mapping results of the BIM skills with popular BIM applications in QS tasks and compares the four tertiary institutions.

Table 4.33 Background of the academic departments of the local tertiary institutions

Items	Local tertiary institutions (in alphabetical order)			
	CityU	HKU	PolyU	THEI
Academic department (current name)	Department of Architecture and Civil Engineering	Department of Real Estate and Construction	Department of Building and Real Estate	Department of Environment
College/Faulty (current name)	College of Engineering	Faculty of Architecture	Faculty of Construction and Environment	Faculty of Design and Environment
Year academic department was established	1984 *(Department of Building and Construction)*	1950 *(Architectural Stream)* 1984 *(Building Stream)*	1937 *(Department of Building and Surveying)*	2012
Number of taught construction-related programmes offered by the academic department	• ASc in Architectural Studies • BSc in Architectural Studies • BSc in Surveying • BEng in Architectural Engineering • BEng in Civil Engineering • MSc in Construction Management • MSc in Civil and Architectural Engineering • Master of Urban Design and Regional Planning	• BSc in Surveying • MSc in Construction Project Management • MSc in Real Estate • MSc in Integrated Project Delivery	• HD in Building Technology and Management • BSc in Building Engineering and Management • BSc in Property Management • BSc in Surveying • MSc in Construction and Real Estate • MSc in Construction Law and Dispute Resolution • MSc in Project Management • MSc in International Real Estate	• BSc in Surveying • BA in Landscape Architecture
Summary of construction disciplines	• Architecture • Civil Engineering • Building Services • Surveying • Project/ Construction Management	• Surveying • Project/ Construction Management	• Building Engineering • Surveying • Property Management • Project/ Construction Management	• Landscape Architecture • Surveying
Source	CityU 2019	HKU 2019	PolyU 2019	THEI 2019

Table 4.34 Comparison of BIM teaching under the BIM education framework

Elements	Local tertiary institutions (in alphabetical order)			
	CityU	HKU	PolyU	THEI
BIM-related taught courses for surveying	• Engineering Communication • Measurement of Building Works • Surveying Studio • BIM for Capital Projects • Strategic BIM Management in Construction	• Construction Project Management	• Information and Data Analysis • Individual and Integrated Project • Information Technology and BIM for Construction	• Computer Aided Drafting & BIM • Surveying Studio
Interdisciplinary student projects	Integrated Building Project Development	Nil	Integrated Professional Workshop	Nil
Research projects	Final-Year Project	Dissertation	Capstone Project: Final-year dissertation	Graduation Project: Thesis report
Students learning activities	• BIM seminar/ conference • Summer internship	• BIM seminar/ conference • Overseas study trip	• BIM seminar/ conference • Summer internship	• BIM seminar/ conference
Hardware	BIM lab/ computer centre	BIM lab/ computer centre	BIM lab/ computer centre	BIM lab/ computer centre
Software	• Revit® • Navisworks® • CostX®	• Revit® • iTWO® • CostX®	• Revit® • Navisworks® • CostX®	• Revit® • CostX®
Cross-institutional cooperation	Nil	Nil	Nil	Nil
Industrial support	CIC MOU signed in 2018	CIC MOU signed in 2017	CIC MOU signed in 2018	CIC MOU signed in 2019
Source	CityU 2019	HKU 2019	PolyU 2019	THEI 2019

Table 4.35 Mapping of BIM skills with the CIC's BIM training functions

	Local tertiary institutions (in alphabetical order)			
	CityU	HKU	PolyU	THEI
BIM skills derived from the syllabus of the BIM courses	1. Modelling 2. QTO & estimating 3. Post-contract cost management 4. BIM model management	1. Modelling 2. QTO & estimating	1. Modelling 2. QTO & estimating 3. Post-contract cost management	1. Modelling 2. QTO & estimating 3. Post-contract cost management
BIM training functions:				
1. BIM model development	Met	Met	Met	Met
2. Using built BIM models	Met	Partially met	Met	Met
3. BIM model management	Met	Not met	Not met	Not met

Table 4.36 Mapping of BIM skills with the popular BIM QS tasks

		Popular BIM QS tasks#									
		Top 1	Top 2	Top 3	Top 4	Top 5	Top 6	Top 7	Top 8	Top 9	Top 10
Local tertiary institutions	BIM skills derived from syllabi of the BIM courses	BQ/SOR preparation	Cost planning	Preliminary cost advice	Valuations of variations	Cash flow forecast	Interim valuation	Re-measurement	Value engineering	Contractual advice	Dispute resolution
CityU	1. Modelling	✓	✓	✓				✓			
	2. QTO & estimating	✓	✓	✓				✓			
	3. Post-contract cost mgt				✓	✓	✓				
	4. BIM model management								✓	✓	✓
HKU	1. Modelling	✓	✓	✓				✓			
	2. QTO & estimating	✓	✓	✓				✓			
PolyU	1. Modelling	✓	✓	✓				✓			
	2. QTO & estimating	✓	✓	✓				✓			
	3. Post-contract cost mgt				✓	✓					
THEI	1. Modelling	✓	✓	✓				✓			
	2. QTO & estimating	✓	✓	✓				✓			
	3. Post-contract cost mgt				✓	✓	✓				

Popular BIM QS tasks reported in Chapter 4.

Chapter 5 – Discussions of the key research findings

This chapter offers in-depth discussions based on the results reported in Chapter 4 and the information acquired from the interviews. Recommendations for promotion of BIM in quantity surveying are also suggested at the end of this chapter for consideration by the HKIS.

5.1 Extent of BIM adoption and QS involvement in BIM projects

Four respondent QS groups completed the questionnaire survey in this study, including private developers, government departments, consultant firms and contractor companies. Generally, most respondents indicated a high degree of BIM project engagement. This is shown in the statistics that highlight the respondents' experience with BIM adoption and their BIM projects over the past 5 years. For example, the results show 100% (N=2) BIM experience in the government departments (Table 4.7), and half (N=1) were involved with 20% to 29% of BIM projects over the past 5 years, whilst the remaining half (N=1) had more than 90% (Table 4.10). According to the results, 86.7% (N=13) of consultant firms have adopted BIM (Table 4.7), and 38.5% (N=5) of those BIM-engaged firms were involved with 10% to 29% of BIM projects in the past 5 years (Table 4.10). The adoption level was significantly higher than in the last BIM survey conducted in 2017. Moreover, 50% (N=5) of the private developers have gained experience with BIM (Table 4.7), and 60% (N=3) of those BIM-engaged developers were involved with 70% to 79% of BIM projects (Table 4.10). One third (N=11) of the contractor companies have adopted BIM in their projects (Table 4.7), and more than 90% (N=10) of those BIM-engaged companies were involved with more than 50% of BIM projects (Table 4.10). These results indicate that BIM is becoming popular in the construction industry. Both private and public sectors are being influenced by the government's initiation of BIM, particularly those BIM-capable contractors who are required to use BIM in most public works. As project clients, private developers dominate the decision to adopt BIM and the extent of BIM use, resulting in a high adoption rate if BIM is opted-in their projects. In contrast, the results of quantity surveying staff involvement in BIM projects are not encouraging, particularly those of the QSs who practice in contractor companies and private developers. The statistics indicate that 75.7% (N=25) of contractor QSs and 50% (N=5) of client QSs have no BIM involvement (Table 4.3); however, better situations were found in the consultant firms and government departments. According to the statistics, 53.3% (N=8) of the consultant firms involve more than 30% of their quantity surveying staff in BIM projects (Table 4.3). For the government departments, half of the respondents (N=1) involve 10% to 19% of their quantity surveying staff in BIM projects (Table 4.3). Notwithstanding, it appears that the consultant QSs acknowledge the benefits to efficiency that arise from BIM, and they are keen to use this kind of technology to accomplish some of their tasks that are time-consuming and tedious in the extreme if the traditional method is used. This is shown by the statistics that involve the proportion of mandatory and voluntary BIM adoption (Table 4.12). According to the results, 53.8% (N=7) of BIM adoption by consultant firms is voluntary. Comparatively, voluntary adoption of BIM is not common for contractor companies, and 81.8% (N=9) of their BIM projects are mandatory and required under the contract. The results further reveal that, except for the government departments, more than half of the respondents have not established an in-house BIM team (Table 4.5). In this study, an in-house BIM team is defined as a section or department that aims to provide technical support for BIM implementation. The size of the BIM team varies greatly. The smallest team size (one staff member) was found in a private developer, whilst the largest team size (70 staff members) was found in a contractor companies. Furthermore, the appointment of a project-based external BIM consultant is popular amongst both government departments (100%, N=2) and contractor companies (75.7%, N=25), but moderate amongst private developers (40%, N=4) and uncommon amongst consultant firms (6.7%, N=1) (Table 4.6).

5.2 Types of BIM project and model production

The research results suggest that BIM covers a wide range of construction projects in Hong Kong. In the private sector, the three most popular types of BIM projects are residential (20.6%), commercial (17.5%) and hotel (12.7%) development (Table 4.13). The results are reasonably expected because they can reflect Hong Kong's major construction outputs. The statistics published by the Census and Statistics Department in 2019 indicate that the construction works in the top three in terms of gross value performed by main contractors over the past 5 years was in line with the top three BIM project types. Furthermore, the results show that the three most popular types of BIM projects under mandatory BIM adoption and voluntary BIM adoption are identical (Table 4.14). In other words, the project type is not likely to be the determining factor for voluntary use of BIM tools by QSs. In addition, the results indicate that 46.3% of models are produced by independent BIM consultants (Table 4.15). Independent BIM consultants are not part of the design team; they are individual consultant firms that provide BIM services such as model production. Normally, design team members provide 2D CAD drawings for independent BIM consultants, who then produce 3D models mainly for visualisation and project coordination purposes. This 'fake BIM' approach deviates from the traditional BIM approach, and it is unlikely that all of the information will find its way back into the 3D models. Eventually, QSs are discouraged from adopting BIM by the potential conflicts between the 2D drawings and the 3D models, as they are all produced separately by different people. The results show that the remaining percentages of model production by design team members and contractors are 43.3% and 10.4%, respectively (Table 4.15). As such, the statistics highlight that independent BIM consultants have an enormous impact on the production of models in Hong Kong.

BIM is widely adopted in building works, so the types of models typically created are architectural models, structural models and MEP models. The empirical results demonstrate the popular types of models to be produced (Table 4.16). In the private sector, 100% of BIM projects include an architectural model and a structural model, whilst 88.2% and 47.1% include an MEP model and/or site model, respectively. In the public sector, 100% of BIM projects contain an architectural model, a structural model and an MEP model. Interestingly, the extents of the model elements to be created in private projects and public projects are not the same (Table 4.17 and 4.18). In the private sector, the top-three model elements of architectural models are non-structural walls (94.1%), building façades (70.6%) and windows/doors (70.6%). Concrete structural elements are always (100%) created for the structural models. The MEP model incorporates electrical, mechanical, fire services, plumbing and drainage elements equally (all 88.2%). The results also reveal that finishes (49.5%), steel and metal works (47.1%), external works (41.2%) and wood works (23.5%) are not commonly produced. However, in the public sector, the elements contained in architectural, structural and MEP models are exhaustive. For instance, non-structural elements, facades, woodworking, finishes, steel and metal work, windows and doors are indispensable in architectural models (all 100%). The structural models always contain structural elements (100%) and foundations (100%), whilst the MEP models fully incorporate electrical, mechanical, fire services, plumbing and drainage elements (all 100%). These results reveal that the government departments' BIM perception influences the BIM process and model production, ultimately enhancing the opportunity for the use of BIM by the downstream QSs. Nevertheless, the statistics also indicate that some elements are not popular in either the private or public sector, such as reinforcement, retaining structures, site formation and slope stabilisation, which means that the use of these elements by QSs is not currently widespread.

5.3 BIM contract conditions

Hong Kong currently has no industry-wide standard BIM conditions. The usual approach is to prepare particular BIM provisions that are incorporated as part of the contract document in the principal agreement. Generally, those BIM provisions are contractual requirements for BIM implementation that are incorporated via a set of BIM specifications or particular BIM conditions. According to the statistics (Table 4.28), most respondents consider the current approach ineffective in dealing with the contractual matters of their BIM projects ($\bar{x}$=4.2). The vast majority of respondents strongly agreed that a set of standard BIM contract conditions should be published ($\bar{x}$=6.2) and supported its use in the future (Av. Y=97%) (Table 4.29).

5.4 Sufficiency of model quality to support QS tasks

According to the empirical results of the expected BIM goals to be achieved by the current model quality (Table 4.22), the null hypotheses were all rejected (H_o: no significant correlation between client QSs and consultant QSs, client QSs and contractor QSs, and consultant QSs and contractor QSs on the ranking of the expected BIM goals). These results explain that the three respondent QS groups held consensus views on the extent of achievement on the expected BIM goals (Table 4.21). From the perspective of the consultant QSs, the current model quality is sufficient to improve job productivity ($\bar{x}$=5.29, rank 2) and offer visualisation ($\bar{x}$=5.13, rank 3). In particular, most respondents agreed that the models could effectively reduce discrepancies amongst team members by enhancing design coordination ($\bar{x}$=5.83, rank 1). However, the current model quality is not sufficient to improve accuracy in the quantification of works ($\bar{x}$=4.20, rank 11). Likewise, the contractor QSs agreed that the current model quality could strongly support visualisation ($\bar{x}$=6.50, rank 1) and enhance coordination ($\bar{x}$=6.25, rank 2) while improving productivity ($\bar{x}$=5.50, rank 3). The same concern from the contractor QSs is that the model quality cannot enhance accuracy in works quantification ($\bar{x}$=4.75, rank 9). The client QSs offered similar views that the current model quality is acceptable for visualisation ($\bar{x}$=5.50, rank 1), constructability review ($\bar{x}$=5.20, rank 2) and design coordination purposes ($\bar{x}$=5.00, rank 3), but not in improving accuracy in the quantification of works ($\bar{x}$=4.40, rank 6). Several QS practitioners noted that not all necessary information is modelled or contained within the models. As such, extra effort should be made by QSs to identify the missed items. In addition, to align the BIM data with the prescribed measurement rules, some quantities must be derived using traditional or hybrid approaches. Thus, the data extracted from the models must be validated to avoid any potential errors created throughout the quantification process. The results further show that the audit policy of model compliance has not been commonly implemented to check model quality in either the private or public sectors (Table 4.23). A BEP should outline the BIM requirements and provide implementation details for the consultants and contractors to follow throughout the project. Thus, it is essential that QSs articulate what information they need and collaborate with the design team members to agree what will be included within the model. QSs' early input is imperative to ensure the model is set-up with proper geometry and contains key information for effective QTO is addressed in the BEP. The audit policy established in the BEP can be implemented by performing quality control checking to ensure appropriate checks on information and data accuracy against the requirements stated in the BEP. Each design team members shall be responsible for performing quality control checks of their design, dataset and model properties before submitting their BIM deliverables. As a result, a proper and well-planned audit policy enables the production of quality models and enhances QSs' job efficiency.

5.5 Variety of BIM applications in QS tasks

The statistics reveal that the adoption of BIM in pre-contract QS tasks is more popular than in post-contract QS tasks (Table 4.24). The most common BIM application for consultant QSs under mandatory BIM adoption is BQ measurement (41.7%). Some pre-contract QS tasks are also popularly accomplished with BIM, such as cost planning (25%) and preliminary cost advice (25%) during the early design stage. It was also found that the most common BIM application during the post-contract stage is the valuation of variations (25%). Furthermore, the results highlight no significant difference in the ranking between mandatory BIM adoption and voluntary BIM adoption in terms of the popular BIM QS tasks, but the task variety of voluntary adoption is wider than that of mandatory adoption. In contrast, only a few types of QS tasks are accomplished by the contractor QSs under mandatory BIM adoption (Table 4.25), including valuations and claims (40%), payment application (33%) and progress reports (20%). The results indicate that the client's BIM requirements for contractor QSs are not common and are restricted to only a few QS tasks. However, more BIM QS tasks are accomplished voluntarily by the contractor QSs, including submission of variations and claims (40%), tender preparation (33%), progress reports (33%), cost monitoring and control (20%), value engineering (20%) and quantification of works for subletting (20%). These results echo those of the client's influence on the extent of BIM adoption in quantity surveying. The potential BIM applications in QS tasks (on either the consultant or contractor side) may be limited in this way.

5.6 Barriers of BIM adoption in quantity surveying

As shown in the results of the factors that result in late adoption of BIM (Table 4.32), the null hypotheses cannot be rejected (H_o: no significant correlation between client QSs and consultant QSs, client QSs and contractor QSs, and consultant QSs and contractor QSs on the ranking of the factors that cause late adoption of BIM). These results reflect the apparent diversity of views amongst the three respondent QS groups (Table 4.31). From the perspective of client QSs, the barriers to BIM adoption include a lack of well-recognised industry BIM standards ($\bar{x}$=5.90, rank 1). This result is in line with the literature review, which acknowledges the lack of BIM standards as a barrier to BIM adoption. Several QSs considered that the use of the current first BIM standards published by CIC is not popular and that further consultation with industry is needed for the next version. Moreover, the client QSs considered that the rush culture of the industry causes hurried BIM adoption ($\bar{x}$=5.80, rank 2). The model may not be updated frequently to reflect the latest design changes made on site. They also considered that the market lacks BIM talents to take up the role of BIM manager ($\bar{x}$=5.60, rank 3). Furthermore, successful BIM business cases for BIM projects are needed to realise the benefits of BIM implementation ($\bar{x}$=5.10, rank 4). In contrast, cost is the key concern in BIM adoption of the consultant QSs. Thus, most of the respondents considered the high initial cost of software as the critical factor for late adoption of BIM ($\bar{x}$=6.13, rank 1). Some QSs acknowledged the CITF provided by CIC for the sponsorship of software purchases; however, the funding supports only 3 years, and the consultant QSs must pay the annual subscription by themselves in the long term. They also agreed that the market lacks well-recognised BIM standards ($\bar{x}$=5.88, rank 2). Due to the lack of BIM expertise in the market, the shortage of in-house BIM specialist is also a concern ($\bar{x}$=5.50, rank 3). From the perspective of the contractor QSs, the industry's rush culture is a significant cause of late adoption of BIM ($\bar{x}$=6.20, rank 1). Several practitioners considered that many sub-contractors are not yet BIM-ready because they are reluctant to take up the new technology. Due to tight construction schedules, it is difficult to synchronise the BIM deliverables from the contractor QSs and the sub-contractor QSs because their BIM levels are not the same. The results also show that the contractor QSs face manpower shortages due to the lack of BIM talent in the market ($\bar{x}$=5.80, rank 2) and the lack of well-recognised BIM standards in industry ($\bar{x}$=5.80, rank 3). An additional finding from the contractor QSs is that the organisation must be reconstructed to accommodate the use of BIM by contractor companies ($\bar{x}$=5.60, rank 4).

5.7 BIM education in quantity surveying and its challenges

The results highlight that the composition of construction professions in academic departments is a key factor that shapes the BIM curriculum in Hong Kong's tertiary institutions (Table 4.33). The ACE Department of CityU offers five undergraduate programmes and three postgraduate programmes supported by a group of multidisciplinary academic staff in areas such as architecture, structural engineering, building services engineering, surveying and construction management. This unique composition gives the academic department a good opportunity to offer interdisciplinary BIM courses that are vital in training the students about project coordination and team collaboration in the BIM environment. Thus, this interdisciplinary BIM approach gives the institution a teaching edge over others in BIM education. In contrast, this interdisciplinary BIM education approach cannot be found from the academic departments that are composed of a few construction disciplines. Furthermore, the results show that the BIM software taught in Hong Kong lacks variety (Table 4.34). It was found that the BIM software installed at the tertiary institutions is dominated by two software vendors. These two vendors offer free educational licenses to academic staff and students, which is the most likely reason that they are widely installed at the local tertiary institutions. In addition, the results indicate that the four academic departments are keen to tie up the industry to enhance their BIM education (Table 4.34). The invitation of the industrial speakers for BIM talks or seminars and the signing of a memorandum of understanding (MOU) with the CIC provide solid evidence. Under the MOU, the CIC will work with the local tertiary institutions to develop training materials for the incorporation into their BIM curriculum. In particular, the overwhelming applications of the CIC BIM Competition (tertiary student category) prove that the local tertiary institutions treasured this opportunity for their students to learn BIM through a collaborative and competitive approach. However, no cross-institutional cooperation in BIM education was found amongst the tertiary institutions (Table 4.34), which means that no interactive BIM activities are shared amongst the local tertiary institutions for the surveying students.

A variety of BIM-related taught courses, final-year research projects and student learning activities are currently provided by local tertiary institutions for surveying students (Table 4.34). For instance, the results indicate that elementary BIM courses are commonly offered by the four tertiary institutions. According to the BIM skills derived from the elementary

BIM courses, the core learning skills include modelling, quantity take-off and estimating. These skills are essential because the surveying students could be underpinned by the fundamental BIM applications. Modelling skills are particularly useful for students to check model integrity and abstract quantities and information efficiently with the BIM authoring tools. The same dataset used to determine the popular BIM QS tasks in the construction industry (Table 4.36) was also used to show that the core BIM skills not only cover the three most popular BIM QS tasks (i.e., BQ/SOR preparation, cost planning and preliminary cost advice), they also meet the two BIM training functions recommended by the CIC (i.e., BIM model development and use of the built BIM model). However, some advanced BIM courses, such as post-contract cost management and BIM model management, are not commonly offered to surveying students (Table 4.35). This finding is interesting because BIM has gained significant momentum in QS practices, which suggests that the relevant training should be provided to prepare future BIM talents. The reasons for the slowness of BIM adoption in the existing curriculum include insufficient capable academic staff to teach the advanced BIM courses and the resources (i.e., financial, technical or administrative support) to make necessary changes in the curriculum.

Moreover, there is no consensus regarding the explicit BIM competencies and the level to which they should be attained by Hong Kong surveying students. This causes further challenges for academic departments to properly plan to integrate BIM into their existing curricula. In addition, quantity surveying education is professional training that adopts a long-established curriculum that covers a great number of theoretical, practical and research-based subjects. There are thus further constraints in BIM teaching due to the heavy university graduation requirements and the surveying profession accreditation requirements. For example, due to the requirements for maintaining HKIS and RICS accreditation status, the Bachelor's degree programmes in surveying have limited ability to modify their curricula to match the speed of BIM advances in the industry.

5.8 Prerequisites of successful BIM applications in quantity surveying

Based on the research findings and recommendations received from the questionnaire respondents and the interviewees, two prerequisites to achieve BIM success in quantity surveying are discussed as follows. Afterward, recommendations for BIM adoption and education in quantity surveying are made based on the overall research findings of this study. According to the results of the questionnaire survey and the semi-structured interviews, the first concern raised by the respondents and the interviewees regarded the source of the models. The concept of BIM implementation is to cover the whole project life cycle from the beginning of the project. As a result, the models should be initiated and created by the design team (e.g., architect, structural engineer and building services engineer). By extracting data from the models for use in specific quantity surveying BIM software or spreadsheets, consultant QSs can provide cost advice based on the models produced by the collaboration of the design team during the design stage. Most respondents and interviewees considered that no projects could claim to have adopted BIM if the model was created by independent BIM consultants based on the 2D CAD drawings provided by the design team. Studies prove that the benefits of BIM cannot be maximised via this 'fake BIM' approach because the models cannot be updated in a timely fashion. In addition, some private developers ask the contractors to produce models for construction use based on the 2D CAD drawings transferred by the design team, which continues to use paper drawings to revise the project design during the post-contract stage. Such construction-stage BIM is not recommended because it not only blurs the design responsibilities but also creates difficulty in updating the models. As a result, updated construction costs cannot be easily determined if the models cannot reflect the latest project design. This also means that conflicts may occur between the 2D drawings and the 3D models because they are all produced separately. These conflicts continue to result in misunderstanding, delays, variations, cost overruns and disputes. Ultimately, client QSs will be disappointed with the failure of BIM adoption in cost management. Because the clients are the key driver for BIM implementation in industry, poor experiences from previous projects lead to clients' reluctance to make future attempts to use BIM.

The second prerequisite is the need for a set of standard modelling principles and information requirements for quantity take-off. The QS practitioners showed strong concerns about the modelling approach adopted by the modellers and the sorts of information contained in the modelled elements. Currently, well-recognised standard modelling principles are not available in Hong Kong's construction industry. BIM models are produced by modellers based on various modelling methods that commonly deviate from the QS requirements. Manual adjustments and validations are therefore necessary for the quantities extracted from the models. In addition, proper model checking by QSs is necessary to avoid modelling irregularities such as gaps and overlaps between modelled elements. As such, the practitioners have a consensual agreement that BIM modelling methods should be standardised to ensure consistency of data input and output. However, it is not practicable to compile a set of standard BIM modelling principles based solely upon the QS requirements. The modelling principles should be agreed with other disciplines and prepared to standardise a modelling process that enables greater multi-disciplinary BIM usage. For example, if contradictions exist between the current HKSMM4 and the industry's usual modelling practices, the existing measurement rules should be reviewed to accommodate universal BIM outputs rather than changing the BIM outputs to suit the existing measurement rules and descriptions.

5.9 Recommendations for BIM promotion policy

Most of the questionnaire survey respondents and the interviewees considered that the HKIS is taking up a strategic position to promote BIM adoption and education in quantity surveying. Based on the research findings and some suggestions collected from the questionnaire survey and the interviews, the following recommendations, which offer a wide range of directions, are proposed for the HKIS.

First, new publications by the HKIS are needed to support further BIM adoption by QSs. For example, some feedbacks from the consultant QSs regarding the need for a set of BIM practice notes that set out some basic principles, such as the role of the QS in a BIM project, the recommended BIM process, the awareness of contractual issues, the guidelines for practicing BIM tasks and the list for model checking. The practice notes establish the best practices to unify the current QS BIM practices and provide some quick guidelines for any QSs who need to advise their inexperienced clients. The Australian Institute of Quantity Surveyors (AIQS) and the New Zealand Institute of Quantity Surveyors (NZIQS) published similar best-practice guidelines in 2018 whose purpose was to provide an essential guide for their members involved with a project with BIM. In addition, a new SMM for BIM measurement was requested by most survey respondents. The current version of SMM, HKSMM4, was published in 2005, and it was not intended for BIM. With the consideration of the agreed BIM modelling principles mentioned earlier, a new SMM can be designed to fill the gap between HKSMM4 and the industry's usual BIM modelling practices. In particular, a coding system was recommended by the survey respondents as an essential element for 5D BIM implementation. Furthermore, standard BIM contract conditions are urgently needed because most survey respondents considered the current approach ineffective to deal with the contractual matters in their BIM projects. It is noted that the BIM Sub-committee of HKIS' QSD has already put effort into the preparation of BIM documents. For example, publication of the standard BIM conditions and the new SMM for BIM measurement is currently underway, and the formal release of these documents will be announced by QSD in due course.

Second, HKIS shall actively work closely with CIC and other stakeholders in the industry. CIC is the leading organisation to develop and promote BIM in Hong Kong. However, the current first BIM standards published by the CIC in 2015 are not highly recognised by practitioners, and it is expected that the next version should incorporate more industrial comments to support positive adoption in Hong Kong. Thus, the HKIS should raise its concerns to the CIC about the review of the standard BIM modelling principles and the consideration of QSs' information requirements in the next version of the BIM standards. Because the modelling principles and information requirements should be agreed with other disciplines, the HKIS can liaise with the HKIA and HKIE for collaboration so that the outcomes enable greater multi-disciplinary use of BIM. As such, a set of model information requirements must first be drafted by the HKIS. A similar contribution was made by the Singapore Institute of Surveyors and Valuers (SISV), who in 2018 published the QS BIM Attribute Requirements (QSBAR), a set of documents that explain the requirements of BIM in cost management; its purpose is to act as a guide for design consultants to model the BIM to the QS requirements. Furthermore, the joint effort from the three key professional institutions (i.e., HKIS, HKIA and HKIE) could effectively discuss with government officials the BIM adoption policy in the private sector, such as mandatory BIM submission to BD and a proposed incentive scheme for the private developers who adopt BIM. In addition, the HKIS should actively support Hong Kong's BIM professional bodies (e.g., HKIBIM, HKICBIM and bSHK) in BIM activities such as seminars and conferences and inform the QS members of these events. It is also noted that the BIM sub-committee initiated the communication with the CIC and the preparation of BIM model information requirements for the use of QTO.

Third, most of the questionnaire survey respondents acknowledged the BIM awareness seminar and hands-on software training arranged by the HKIS; they considered them necessary and thought that they should be continued. However, the research findings indicate that it is also necessary to change the mindset of some surveyors who continue to apply their traditional perceptions to BIM projects. BIM is not the sole use of BIM software in construction projects. It is a revolution of traditional project delivery, and much more effort is spent during the design stage. However, some PMs or client QSs from private developers are reluctant to use BIM due to the time and cost implications of BIM adoption and the unanticipated benefits it may bring BIM. Because many overseas cases show that effective BIM adoption should be client-driven, the HKIS is encouraged to develop a paradigm-changing strategy by organising more talks or seminars for senior surveyors in client organisations. The topic should focus on successful business cases in BIM implementation, and the speakers can be senior project managers, BIM managers or client QSs. In addition, it is suggested that HKIS provide other types of BIM training that can encourage the QS members to move ahead in their BIM journey. Some survey respondents requested that the HKIS invite newly CIC-certified BIM managers to deliver a talk to share their successful experience in the certification of the BIM manager.

Fourth, the HKIS is encouraged to review the current course accreditation policy with the local tertiary institutions. To encourage the local tertiary institutions to offer quality BIM courses for surveying students, the requirements for BIM teaching should be considered by the HKIS in accrediting the courses. BIM is not currently formally identified in the accreditation criteria, which adds to the difficulty of not having a more unified and comprehensive BIM adoption approach in Hong Kong's existing surveying curricula. Because no explicit criteria have been established regarding the appropriate level of BIM teaching in Bachelor's degree programmes in surveying, the HKIS is encouraged to explore the kinds of BIM skills that are needed in the quantity surveying profession and determine which competencies must be achieved by surveying students. The Board of Education of the HKIS can then review the existing BIM courses or require the academic departments to create new BIM courses to meet market needs. A list of qualified BIM courses can then be identified, and the HKIS can ask the academic departments to offer those qualified courses to their surveying students throughout the 4-year curriculum. In the future, the graduates who wish to apply for entry into the APC scheme (e.g., QSD) would need to complete the qualified BIM courses accordingly. In addition, the HKIS could adopt a role in linking with the local tertiary institutions that have no cross-institutional cooperation in BIM education. Studies demonstrate that strong ties between industry and academia can effectively enhance BIM development and education. As a result, the HKIS is encouraged to organise various activities to connect the staff members and students from different institutions, such as student BIM competitions, BIM scholarships, BIM internship schemes and any forms of BIM collaborative research.

Chapter 6 – Conclusions

6.1 Main research findings and conclusions

BIM is an emerging technology in the construction industry that offers new solutions for design, construction and operation throughout the project lifecycle. The QS is a key project team member involved throughout the project lifespan from the feasibility and design stages to the final completion, so BIM can be used to equip QSs with the technological tools to remain competitive in the construction market. As a result, it is essential to recognise how the implementation of BIM across the construction industry influences the quantity surveying profession and the services it delivers. Currently, both public and large private developers are increasingly engaging with BIM in their projects. The growing popularity of BIM has led to increased demand for BIM talent in the construction market. Graduates from the local tertiary institutions are major pillars to support BIM development in Hong Kong. However, the critical concern of BIM education in quantity surveying is whether BIM forms an intrinsic part of the whole surveying curriculum. Thus, this study aimed to investigate the current BIM applications in both QS practices and tertiary education in Hong Kong. The key findings follow.

First, polarised views of BIM were found from Hong Kong's client organisations. Some clients are keen on BIM adoption, but some keep observation as proven evidence that BIM success cannot be realised. The results also indicate that clients' perceptions of BIM influence the BIM process and the QS practices in BIM projects. In contrast, statistics show increasing adoption of BIM by consultant QSs and show that they are relatively active in BIM use, but their key concern regarding further adoption is the expenditure on BIM software, which is dominated by a few vendors in the market. Contractor QSs are comparatively passive regarding adoption of BIM due to a lack of company support and the need for organisational restructuring triggered by BIM.

Second, fake BIM cases are found in Hong Kong. The results indicate that the models built by independent BIM consultants are based on the design team's 2D CAD drawings. Independent BIM consultants are not a part of the design team, but statistics show that they are a major source of models. In addition, the current model quality is generally not sufficient to support QS tasks, but the audit policy for BIM compliance is not commonly implemented by project clients. The critical challenges of BIM adoption in quantity surveying are the absence of well-recognised BIM standards and standard BIM contact conditions. A shortage of BIM talent in the construction industry further worsens the development and adoption of BIM in quantity surveying in Hong Kong.

Third, the current BIM education in quantity surveying is generally keeping pace with BIM development in industry. BIM courses at the elementary level are commonly offered by local tertiary institutions, but advanced-level BIM courses and interdisciplinary student projects are absent from some institutions. The results suggest that an academic department that offers interdisciplinary programmes possesses a teaching edge over others in BIM education. A lack of resources and uncertain BIM competencies to be attained by students present challenges to the current BIM education, along with constraints in BIM teaching due to the extensive university graduation requirements and professional bodies' accreditation requirements. The local tertiary institutions also lack cooperation with each other in BIM education, and their engagement with the industry is quite low.

Based on the overall findings, the following short- to medium-term and long-term action statements are proposed for the HKIS's reference:

A) Short- to medium-term

1. Publish BIM practice notes for QSs
2. Publish standard BIM contract conditions
3. Organise joint events with the local tertiary institutions
4. Organise events of successful BIM project showcase for the senior surveyors working in the client organisations

B) Long-term

5. Publish SMM for BIM projects
6. Review current course accreditation and impose new requirements
7. Maintain a dialogue with the CIC for incorporation of QS's requirements in their updated BIM standards

In conclusion, the study's four research objectives are achieved. The underlying goals of this study not only provide insights into the adoption of BIM in quantity surveying but also help the HKIS to formulate effective policy for BIM development and promotion.

6.2 Limitations and implications for further research

The limitation of this study is the scope of the research samples. First, for the study about BIM adoption in QS practices, the research samples cover a substantial portion of professional QSs practicing in client organisations, consultant firms and contractor companies in Hong Kong. However, the samples remain limited to a small subset of QSs employed by the specialist sub-contractors in the construction industry. Second, for the study about BIM education in quantity surveying in Hong Kong, the samples were confined to full-time 4-year Bachelor's degree programmes in surveying in Hong Kong. Although the graduates from these programmes are the key market supply of the quantity surveying profession, graduates from other programmes, such as top-up Bachelor's degree or part-time distance learning programmes, can be studied. Thus, further investigations are recommended to use greater sample sizes for analysis.

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Appendix

Samples of the questionnaires

The Hong Kong Institute of Surveyors
Quantity Surveying Division – Research Project 2018

A Study on BIM Adoption in Quantity Surveying in Hong Kong (CLIENT QS)

Research background

The recent Hong Kong government policies demonstrate positive signs of increasing BIM engagement in public works. However, the results of the *Pilot Study on BIM Applications in Quantity Surveying in Hong Kong* conducted last year show that BIM adoption in consultant QS firms still lags far behind its potential. There is little evidence found in Hong Kong showing highly integration of BIM into the current QS practices. Thus, this research project aims to examine the use of BIM from another perspective and investigate project clients' intentions of using BIM and their expectations on BIM adoption in QS tasks.

All the data collected will be kept strictly confidential and used solely for research purposes. Should you have any questions about this research project, please contact the principal investigator Dr. Calvin Keung by phone (852 3442 2382) or by email (cwkeung@cityu.edu.hk).

Part 1 – Background of the respondent

This questionnaire survey is company based. Please state your answers in the boxes provided.

1.1 Company name (optional)	
1.2 Total number of client QS* in your company	
1.3 Number of client QS involved in BIM projects	
1.4 Is there any BIM team^ established in your company?	☐ Yes ☐ No (please go to 1.7) *(Please click the mouse to select)*
1.5 Year of the BIM team to be established	
1.6 Number of staff involved in the BIM team	
1.7 Has your company directly appointed BIM consultant on project basis?	☐ Yes ☐ No *(Please click the mouse to select)*

** Client QS refer to the employees of project client and the job duty is to monitor and liaise consultant QS.*

^ BIM team refers to a section or department that aims to provide BIM support to project client for BIM implementation.

Part 2 – BIM projects

Please check the appropriate boxes by clicking the mouse and state your answers in the boxes provided.

2.1 Has BIM been adopted in the projects of your company? ☐ A) Yes (please go to 2.3) ☐ B) No (please go to 2.2)			
2.2 Is there any time frame of BIM adoption in the future projects? ☐ A) Within 1-2 years (please go to Part 5) ☐ B) Within 3-4 years (please go to Part 5) ☐ C) No time frame (please go to Part 5) ☐ D) Others (please state) (please go to Part 5)			
2.3 Number of new projects in the past five years	HK:	PRC:	Others: (please state)
2.4 Number of new projects **using BIM** in the past five year	HK:	PRC:	Others: (please state)

Part 2 – BIM projects (Cont'd)

2.5 Types of the BIM projects mentioned in 2.4:			
Project types *(more than one project types can be chosen)*	*Number of BIM projects*		
	HK	*PRC*	*Others*
☐ A) Residential			
☐ B) Office/commercial			
☐ C) Hotels			
☐ D) Industrial			
☐ E) Institutional			
☐ F) Medical			
☐ G) Recreational			
☐ H) Infrastructure			
☐ I) Renovation / fitting out			
☐ J) Others (please state)			
	Total:	Total:	Total:

Part 3 – BIM adoption status
3.1 BIM implementation process
Please answer the questions under 3.1 based on <u>most BIM projects</u> of your company in the past five years.

3.1.1 Which project team members are usually responsible for the production of the BIM models?

Please state:

Please check the appropriate boxes by clicking the mouse.
3.1.2 What kinds of the BIM models are usually produced? More than one answers can be chosen.
3.1.3 What kinds of the model elements are usually incorporated in the respective BIM models?

3.1.2 BIM models	*3.1.3 Model elements (more than one elements can be chosen)*							
☐ Architecture model	☐ Facades	☐ Non-structural walls/ partitions	☐ Windows & doors	☐ Finishes	☐ Wood works	☐ Steel & metal works	☐ External works	☐ Others (pls state)
☐ Structure model	☐ Structural elements	☐ Reinforcing bars	☐ Foundations	☐ Retaining structures	☐ Others (pls state)	☐ Others (pls state)	☐ Others (pls state)	☐ Others (pls state)
☐ MEP model	☐ Electrical installation	☐ Plumbing & drainage	☐ Mechanical installation	☐ Fire services installation	☐ Others (pls state)	☐ Others (pls state)	☐ Others (pls state)	☐ Others (pls state)
☐ Site model	☐ Site formation	☐ Slope stabilization	☐ Others (pls state)	☐ Others (pls state)	☐ Others (pls state)	☐ Others (pls state)	☐ Others (pls state)	☐ Others (pls state)
☐ Others (please state)								

3.1 BIM implementation process (Cont'd)

3.1.4 What are the expected goals to be achieved from the BIM models?

3.1.5 Do you agree that the quality of the BIM models is sufficient to achieve the chosen goals? '1' represents strongly disagree whereas '7' represents strongly agree.

3.1.4 Expected BIM goals (more than one goals can be chosen)	*3.1.5 Degree of agreement*						
	1	*2*	*3*	*4*	*5*	*6*	*7*
☐ A) Better visualization	☐	☐	☐	☐	☐	☐	☐
☐ B) Improving productivity	☐	☐	☐	☐	☐	☐	☐
☐ C) Reducing errors and omissions	☐	☐	☐	☐	☐	☐	☐
☐ D) Reducing abortive works	☐	☐	☐	☐	☐	☐	☐
☐ E) Constructability review	☐	☐	☐	☐	☐	☐	☐
☐ F) Lowering construction cost	☐	☐	☐	☐	☐	☐	☐
☐ G) Better predictability and cost control	☐	☐	☐	☐	☐	☐	☐
☐ H) Improving accuracy in quantification of works	☐	☐	☐	☐	☐	☐	☐
☐ I) Better documentation	☐	☐	☐	☐	☐	☐	☐
☐ J) Enhancing coordination	☐	☐	☐	☐	☐	☐	☐
☐ K) Shortening overall project duration	☐	☐	☐	☐	☐	☐	☐
☐ L) Improving safety	☐	☐	☐	☐	☐	☐	☐
☐ M) Expediting regulatory approval cycles	☐	☐	☐	☐	☐	☐	☐
☐ N) Others (please state)	☐	☐	☐	☐	☐	☐	☐

3.1.6 Did your company set up any audit policy regarding model compliance with the specification?

☐ A) Yes

☐ B) No (please go to 3.1.9)

3.1.7 Who is/are responsible for carrying out the model audit?

Please state:

3.1.8 Do you agree that the aforesaid model audit is effective to ensure model compliance with the specification? '1' represents strongly disagree whereas '7' represents strongly agree.

1	*2*	*3*	*4*	*5*	*6*	*7*
☐	☐	☐	☐	☐	☐	☐

3.1.9 What is the usual delivery of the BIM models from design stage to construction stage?

☐ A) The design team members transfer the BIM models to the main contractors who receive and adapt the models for construction purpose

☐ B) The BIM consultants appointed by the client transfer the BIM models to the main contractors who receive and adapt the models for construction purpose

☐ C) No BIM models are transferred to the main contractors who shall create new models for construction purpose

☐ D) Others (please state)

3.1.10 What is the usual delivery of the BIM models from construction stage to occupation stage?

☐ A) The main contractors transfer the as-built models to the FM team

☐ B) No BIM model is transferred to the FM team

☐ C) Others (please state)

3.2 Contract conditions of BIM projects
Please answer the following questions based on <u>most BIM projects</u> of your company in the past five years. Please check the appropriate boxes by clicking the mouse.

3.2.1 Who is/are usually responsible to draft the BIM conditions/specifications in your BIM projects?

Please state:

3.2.2 Do you agree that the aforesaid BIM conditions/specifications are effective to deal with the contractual matters of your BIM projects? '1' represents strongly disagree whereas '7' represents strongly agree.

1	*2*	*3*	*4*	*5*	*6*	*7*
☐	☐	☐	☐	☐	☐	☐

3.2.3 Do you agree that a set of standard BIM contract conditions should be published? '1' represents strongly disagree whereas '7' represents strongly agree.

1	*2*	*3*	*4*	*5*	*6*	*7*
☐	☐	☐	☐	☐	☐	☐

3.2.4 Will you adopt the aforesaid standard conditions in your BIM projects if it is published?

☐ A) Yes
☐ B) No (please state the reason)
☐ C) Others (please state)

Part 4 – BIM QS tasks
Please answer the following questions based on <u>most BIM projects</u> of your company in the past five years. Please check the appropriate boxes by clicking the mouse.

4.1 Consultant QS tasks
4.1.1 What kinds of QS tasks are usually required to be accomplished by the consultant QS?
4.1.2 Do you agree that BIM can significantly improve the performance of the chosen QS tasks? '1' represents strongly disagree whereas '7' represents strongly agree.

4.1.1 Consultant QS tasks	*4.1.2 Degree of agreement*						
(more than one tasks can be chosen)	*1*	*2*	*3*	*4*	*5*	*6*	*7*
☐ A) Cost planning	☐	☐	☐	☐	☐	☐	☐
☐ B) Life cycle costing	☐	☐	☐	☐	☐	☐	☐
☐ C) Value engineering	☐	☐	☐	☐	☐	☐	☐
☐ D) Preliminary cost advice	☐	☐	☐	☐	☐	☐	☐
☐ E) Procurement advice	☐	☐	☐	☐	☐	☐	☐
☐ F) Contractual advice	☐	☐	☐	☐	☐	☐	☐
☐ G) BQ measurement	☐	☐	☐	☐	☐	☐	☐
☐ H) Valuation of variations	☐	☐	☐	☐	☐	☐	☐
☐ I) Interim valuation	☐	☐	☐	☐	☐	☐	☐
☐ J) Remeasurement of provisional items	☐	☐	☐	☐	☐	☐	☐
☐ K) Financial report	☐	☐	☐	☐	☐	☐	☐
☐ L) Cash flow forecast	☐	☐	☐	☐	☐	☐	☐
☐ M) Assessment of financial claims	☐	☐	☐	☐	☐	☐	☐
☐ N) Dispute resolution	☐	☐	☐	☐	☐	☐	☐
☐ O) Others (please state)	☐	☐	☐	☐	☐	☐	☐
☐ P) No BIM requirements on consultant QS tasks							

4.2 Contractor QS tasks

4.2.1 What kinds of QS tasks are usually required to be accomplished by the contractor QS?

4.2.2 Do you agree that BIM can significantly improve the performance of the chosen QS tasks? '1' represents strongly disagree whereas '7' represents strongly agree.

4.2.1 Contractor QS tasks (more than one tasks can be chosen)	*4.2.2 Degree of agreement*						
	1	*2*	*3*	*4*	*5*	*6*	*7*
☐ A) Tender preparation	☐	☐	☐	☐	☐	☐	☐
☐ B) Cost monitoring and control	☐	☐	☐	☐	☐	☐	☐
☐ C) Project cash flow	☐	☐	☐	☐	☐	☐	☐
☐ D) Value engineering	☐	☐	☐	☐	☐	☐	☐
☐ E) Quantification of works for sub-letting/purchasing	☐	☐	☐	☐	☐	☐	☐
☐ F) Payment application	☐	☐	☐	☐	☐	☐	☐
☐ G) Sub-contractors payment preparation	☐	☐	☐	☐	☐	☐	☐
☐ H) Variations and claims	☐	☐	☐	☐	☐	☐	☐
☐ I) Life cycle costing	☐	☐	☐	☐	☐	☐	☐
☐ J) Risk management	☐	☐	☐	☐	☐	☐	☐
☐ K) Financial report	☐	☐	☐	☐	☐	☐	☐
☐ L) Progress report	☐	☐	☐	☐	☐	☐	☐
☐ M) Arbitration and dispute resolution	☐	☐	☐	☐	☐	☐	☐
☐ N) Others (please state)	☐	☐	☐	☐	☐	☐	☐
☐ O) No BIM requirements on contractor QS tasks							

Part 5 – Improvement of BIM adoption

5.1 Do you agree that the following factors significantly cause late BIM adoption in your company? '1' represents strongly disagree whereas '7' represents strongly agree. Please check the appropriate boxes by clicking the mouse.

Factors of late BIM adoption	*Degree of agreement*						
	1	*2*	*3*	*4*	*5*	*6*	*7*
A) Lack of well-recognized industry BIM standard	☐	☐	☐	☐	☐	☐	☐
B) Standard BIM contract is not available	☐	☐	☐	☐	☐	☐	☐
C) Lack of government support and incentive	☐	☐	☐	☐	☐	☐	☐
D) Shortage of successful BIM projects showcase	☐	☐	☐	☐	☐	☐	☐
E) Benefits of BIM adoption cannot be realized	☐	☐	☐	☐	☐	☐	☐
F) Restructuring of organization to accommodate BIM	☐	☐	☐	☐	☐	☐	☐
G) Staff refusal/reluctance to learn new technology	☐	☐	☐	☐	☐	☐	☐
H) Unsuitability of some projects for BIM adoption	☐	☐	☐	☐	☐	☐	☐
I) High initial cost e.g. software, hardware, etc.	☐	☐	☐	☐	☐	☐	☐
J) Extra cost for the appointment of BIM consultants	☐	☐	☐	☐	☐	☐	☐
K) Unforeseen positive return on investment on BIM	☐	☐	☐	☐	☐	☐	☐
L) Shortage of in-house BIM specialist	☐	☐	☐	☐	☐	☐	☐
M) Lack of BIM expertise in the market	☐	☐	☐	☐	☐	☐	☐
N) Worried security of confidential data	☐	☐	☐	☐	☐	☐	☐
O) Problem of interoperability among BIM software	☐	☐	☐	☐	☐	☐	☐
P) The 'rush' culture in the construction industry	☐	☐	☐	☐	☐	☐	☐
Q) Others (please state)	☐	☐	☐	☐	☐	☐	☐

5.2 In order to facilitate efficient and best use of BIM models in QS practices, what **prerequisites** are required to be put forwarded to the BIM team in advance?

Please state:

Part 5 – Improvement of BIM adoption (Cont'd)

5.3 Do you agree that the **prerequisites** stated in 5.2 should be incorporated into the industry-wide BIM Standard to support BIM adoption in QS practices?

☐ A) Yes

☐ B) No (please state the reason)

☐ C) Others (please state)

5.4 Do you have suggestions to HKIS that can offer assistance in boosting BIM adoption in quantity surveying or the whole construction industry? Please state your answers in the box provided below.

For example Policy: Publication of standard documents: Training: Others:

- END -

Please return the completed questionnaire by email (cwkeung@cityu.edu.hk). Thank you for your participation in this survey.

The Hong Kong Institute of Surveyors
Quantity Surveying Division – Research Project 2018

A Study on BIM Adoption in Quantity Surveying in Hong Kong (CONSULTANT QS)

Research background

The recent Hong Kong government policies demonstrate positive signs of increasing BIM engagement in public works. However, the results of the *Pilot Study on BIM Applications in Quantity Surveying in Hong Kong* conducted last year show that BIM adoption in consultant QS firms still lags far behind its potential. There is little evidence found in Hong Kong showing highly integration of BIM into the current QS practices. Thus, this research project aims to conduct a holistic BIM study in the QS profession and extend the Pilot Study to cover different QS practices in Hong Kong (i.e. client, consultant and contractor). Thus, some new questions are added in the questionnaire for the purpose of comparing different QS practices in terms of the extent of BIM adoption.

All the data collected will be kept strictly confidential and used solely for research purposes. Should you have any questions about this research project, please contact the principal investigator Dr. Calvin Keung by phone (852 3442 2382) or by email (cwkeung@cityu.edu.hk).

Part 1 – Background of the respondent (consultant QS)

This questionnaire survey is company based. Please state your answers in the boxes provided.

1.1 Company name (optional)	
1.2 Total number of QS staff in your company	
1.3 Number of QS staff involved in BIM projects	
1.4 Is there any BIM team^ established in your company?	☐ Yes ☐ No (please go to 1.7) *(Please click the mouse to select)*
1.5 Year of the BIM team to be established	
1.6 Number of staff involved in the BIM team	
1.7 Has your company directly appointed BIM consultant on project basis?	☐ Yes ☐ No *(Please click the mouse to select)*

^ *BIM team refers to a section or department that aims to provide BIM support to consultant QS for BIM implementation.*

Part 2 – BIM projects

Please check the appropriate boxes by clicking the mouse and state your answers in the boxes provided.

2.1 Has BIM been adopted in the projects of your company? ☐ A) Yes (please go to 2.3) ☐ B) No (please go to 2.2)	
2.2 Is there any time frame of BIM adoption in the future projects? ☐ A) Within 1-2 years (please go to Part 5) ☐ B) Within 3-4 years (please go to Part 5) ☐ C) No time frame (please go to Part 5) ☐ D) Others (please state) (please go to Part 5)	
2.3 Number of new projects in the past five years in HK:	[ ] no.
2.4 Number of new projects **using BIM** in the past five year in HK:	
Mandatory BIM adoption (i.e. BIM adoption is required by the client)	[ ] no.
Voluntary BIM adoption (i.e. BIM is adopted voluntarily by the consultant QS)	[ ] no.

Part 2 – BIM projects (Cont'd)

2.5 Types of the BIM projects mentioned in 2.4 **(Mandatory BIM adoption)**:				
Project types (more than one project types can be chosen)	*Number of BIM projects*			
	Private			*Public*
	HK	PRC	Others (pls. state)	
☐ A) Residential				
☐ B) Office/commercial				
☐ C) Hotels				
☐ D) Industrial				
☐ E) Institutional				
☐ F) Medical				
☐ G) Recreational				
☐ H) Infrastructure				
☐ I) Renovation / fitting out				
☐ J) Others (please state)				
Total:				

2.6 Types of the BIM projects mentioned in 2.4 **(Voluntary BIM adoption)**:				
Project types (more than one project types can be chosen)	*Number of BIM projects*			
	Private			*Public*
	HK	PRC	Others (pls. state)	
☐ A) Residential				
☐ B) Office/commercial				
☐ C) Hotels				
☐ D) Industrial				
☐ E) Institutional				
☐ F) Medical				
☐ G) Recreational				
☐ H) Infrastructure				
☐ I) Renovation / fitting out				
☐ J) Others (please state)				
Total:				

Part 3 – BIM adoption status

3.1 BIM implementation process

Please answer the questions under 3.1 based on <u>most BIM projects</u> of your company in the past five years.

3.1.1 Which project team members are usually responsible for the production of the BIM models?

Please state:

3.1 BIM implementation process (Cont'd)
Please check the appropriate boxes in the following table by clicking the mouse:

3.1.2 What kinds of the BIM models are usually produced in your BIM projects?
3.1.3 What kinds of the model elements are usually incorporated in the respective BIM models?
3.1.4 Which model elements are usually used by the consultant QS to perform QS tasks?

3.1.2 BIM models (more than one models can be chosen)	*3.1.3 Model elements (more than one elements can be chosen)*	*3.1.4 Use of model elements (more than one answers can be chosen)*
☐ Architecture model	☐ Facades	☐
	☐ Non-structural walls/partitions	☐
	☐ Windows	☐
	☐ Doors	☐
	☐ Finishes	☐
	☐ Wood works	☐
	☐ Steel & metal works	☐
	☐ External works	☐
	☐ Others (please state)	☐
☐ Structure model	☐ Structural elements	☐
	☐ Reinforcing bars	☐
	☐ Foundations	☐
	☐ Retaining structures	☐
	☐ Others (please state)	☐
☐ MEP model	☐ Electrical installation	☐
	☐ Plumbing & drainage	☐
	☐ Mechanical installation	☐
	☐ Fire services installation	☐
	☐ Others (please state)	☐
☐ Site model	☐ Site formation	☐
	☐ Slope stabilization	☐
	☐ Others (please state)	☐
☐ Others (please state)		☐

3.1 BIM implementation process (Cont'd)
Please check the appropriate boxes in the following table by clicking the mouse:

3.1.5 What are the expected goals to be achieved from the BIM models?
3.1.6 Do you agree that the quality of the BIM models is sufficient to achieve the chosen goals? '1' represents strongly disagree whereas '7' represents strongly agree.

3.1.5 Expected BIM goals	*3.1.6 Degree of agreement*						
(more than one goals can be chosen)	*1*	*2*	*3*	*4*	*5*	*6*	*7*
☐ A) Better visualization	☐	☐	☐	☐	☐	☐	☐
☐ B) Improving productivity	☐	☐	☐	☐	☐	☐	☐
☐ C) Reducing errors and omissions	☐	☐	☐	☐	☐	☐	☐
☐ D) Reducing abortive works	☐	☐	☐	☐	☐	☐	☐
☐ E) Constructability review	☐	☐	☐	☐	☐	☐	☐
☐ F) Lowering construction cost	☐	☐	☐	☐	☐	☐	☐
☐ G) Better predictability and cost control	☐	☐	☐	☐	☐	☐	☐
☐ H) Improving accuracy in quantification of works	☐	☐	☐	☐	☐	☐	☐
☐ I) Better documentation	☐	☐	☐	☐	☐	☐	☐
☐ J) Enhancing coordination	☐	☐	☐	☐	☐	☐	☐
☐ K) Shortening overall project duration	☐	☐	☐	☐	☐	☐	☐
☐ L) Improving safety	☐	☐	☐	☐	☐	☐	☐
☐ M) Faster regulatory approval cycles	☐	☐	☐	☐	☐	☐	☐
☐ N) Enhancing your organization's image	☐	☐	☐	☐	☐	☐	☐
☐ O) Marketing new business	☐	☐	☐	☐	☐	☐	☐
☐ P) Offering new services	☐	☐	☐	☐	☐	☐	☐
☐ Q) Increasing profits	☐	☐	☐	☐	☐	☐	☐
☐ R) Maintaining repeat business	☐	☐	☐	☐	☐	☐	☐
☐ S) Reducing cycle time of workflows	☐	☐	☐	☐	☐	☐	☐
☐ T) Others (please state)	☐	☐	☐	☐	☐	☐	☐

3.2 Contract conditions of BIM projects
Please answer the following questions based on most BIM projects of your company in the past five years. Please check the appropriate boxes by clicking the mouse.

3.2.1 Who is/are usually responsible to draft the BIM conditions/specifications in your BIM projects?

Please state:

3.2.2 Do you agree that the aforesaid BIM conditions/specifications are effective to deal with the contractual matters of your BIM projects? '1' represents strongly disagree whereas '7' represents strongly agree.

1	*2*	*3*	*4*	*5*	*6*	*7*
☐	☐	☐	☐	☐	☐	☐

3.2.3 Do you agree that a set of standard BIM contract conditions should be published? '1' represents strongly disagree whereas '7' represents strongly agree.

1	*2*	*3*	*4*	*5*	*6*	*7*
☐	☐	☐	☐	☐	☐	☐

3.2 Contract conditions of BIM projects (Cont'd)

3.2.4 Will you adopt the aforesaid standard conditions in your BIM projects if it is published?

☐ A) Yes

☐ B) No (please state the reason)

☐ C) Others (please state)

Part 4 – BIM QS tasks

Please answer the following questions based on <u>most BIM projects</u> of your company in the past five years. Please check the appropriate boxes by clicking the mouse.

4.1 What kinds of QS tasks are usually performed by the consultant QS? Are these tasks accomplished under mandatory BIM adoption (Man) or voluntary BIM adoption (Vol)?
4.2 Do you agree that BIM can significantly improve the performance of the chosen QS tasks? '1' represents strongly disagree whereas '7' represents strongly agree.

4.1 Consultant QS tasks (more than one tasks can be chosen)	*Man*	*Vol*	*4.2 Degree of agreement*						
			1	*2*	*3*	*4*	*5*	*6*	*7*
☐ A) Cost planning	☐	☐	☐	☐	☐	☐	☐	☐	☐
☐ B) Life cycle costing	☐	☐	☐	☐	☐	☐	☐	☐	☐
☐ C) Value engineering	☐	☐	☐	☐	☐	☐	☐	☐	☐
☐ D) Preliminary cost advice	☐	☐	☐	☐	☐	☐	☐	☐	☐
☐ E) Procurement advice	☐	☐	☐	☐	☐	☐	☐	☐	☐
☐ F) Contractual advice	☐	☐	☐	☐	☐	☐	☐	☐	☐
☐ G) BQ measurement	☐	☐	☐	☐	☐	☐	☐	☐	☐
☐ H) Valuation of variations	☐	☐	☐	☐	☐	☐	☐	☐	☐
☐ I) Interim valuation	☐	☐	☐	☐	☐	☐	☐	☐	☐
☐ J) Remeasurement of provisional items	☐	☐	☐	☐	☐	☐	☐	☐	☐
☐ K) Financial report	☐	☐	☐	☐	☐	☐	☐	☐	☐
☐ L) Cash flow forecast	☐	☐	☐	☐	☐	☐	☐	☐	☐
☐ M) Assessment of financial claims	☐	☐	☐	☐	☐	☐	☐	☐	☐
☐ N) Dispute resolution	☐	☐	☐	☐	☐	☐	☐	☐	☐
☐ O) Others (please state)	☐	☐	☐	☐	☐	☐	☐	☐	☐
☐ P) No BIM requirements on consultant QS tasks									

4.3 Are there any measures to be adopted in your company to facilitate the QS staff to use BIM in QS tasks?

☐ A) Yes (please go to 4.4)

☐ B) No (please go to Part 5)

4.4 What kinds of measures have been adopted in your company to facilitate the QS staff to use BIM in QS tasks? More than one answers can be chosen.

☐ A) Software customization for QS tasks like QTO

☐ B) Software training by outsiders like software vendors or BIM consultants

☐ C) Recruitment of BIM specialists

☐ D) BIM practice manual

☐ E) Simple guidelines for internal use

☐ F) Internal BIM projects experience sharing

☐ G) Others (please state)

Part 5 – Improvement of BIM adoption

5.1 Do you agree that the following factors significantly cause late BIM adoption in your company? '1' represents strongly disagree whereas '7' represents strongly agree. Please check the appropriate boxes by clicking the mouse.

Factors of late BIM adoption		*Degree of agreement*						
		1	*2*	*3*	*4*	*5*	*6*	*7*
A)	Lack of well-recognized industry BIM standard	☐	☐	☐	☐	☐	☐	☐
B)	Standard BIM contract is not available	☐	☐	☐	☐	☐	☐	☐
C)	Lack of government support and incentive	☐	☐	☐	☐	☐	☐	☐
D)	Shortage of successful BIM projects showcase	☐	☐	☐	☐	☐	☐	☐
E)	Benefits of BIM adoption cannot be realized	☐	☐	☐	☐	☐	☐	☐
F)	Restructuring of organization to accommodate BIM	☐	☐	☐	☐	☐	☐	☐
G)	Staff refusal/reluctance to learn new technology	☐	☐	☐	☐	☐	☐	☐
H)	Unsuitability of some projects for BIM adoption	☐	☐	☐	☐	☐	☐	☐
I)	High initial cost e.g. software, hardware, etc.	☐	☐	☐	☐	☐	☐	☐
J)	Extra cost for the appointment of BIM consultants	☐	☐	☐	☐	☐	☐	☐
K)	Unforeseen positive return on investment on BIM	☐	☐	☐	☐	☐	☐	☐
L)	Shortage of in-house BIM specialist	☐	☐	☐	☐	☐	☐	☐
M)	Lack of BIM expertise in the market	☐	☐	☐	☐	☐	☐	☐
N)	Worried security of confidential data	☐	☐	☐	☐	☐	☐	☐
O)	Problem of interoperability among BIM software	☐	☐	☐	☐	☐	☐	☐
P)	The 'rush' culture in the construction industry	☐	☐	☐	☐	☐	☐	☐
Q)	Others (please state)	☐	☐	☐	☐	☐	☐	☐

5.2 In order to facilitate efficient and best use of BIM models in QS practices, what **prerequisites** are required to be put forwarded to the BIM team in advance?

Please state:

5.3 Do you agree that the **prerequisites** stated in 5.2 should be incorporated into the industry-wide BIM Standard to support BIM adoption in QS practices?

☐ A) Yes

☐ B) No (please state the reason)

☐ C) Others (please state)

Part 5 – Improvement of BIM adoption (Cont'd)

5.4 Do you have suggestions to HKIS that can offer assistance in boosting BIM adoption in quantity surveying or the whole construction industry? Please state your answers in the box provided below.

For example Policy: Publication of standard documents: Training: Others:

- END -

Please return the completed questionnaire by email (cwkeung@cityu.edu.hk). Thank you for your participation in this survey.

The Hong Kong Institute of Surveyors
Quantity Surveying Division – Research Project 2018

A Study on BIM Adoption in Quantity Surveying in Hong Kong (CONTRACTOR QS)

Research background

The recent Hong Kong government policies demonstrate positive signs of increasing BIM engagement in public works. However, the results of the *Pilot Study on BIM Applications in Quantity Surveying in Hong Kong* conducted last year show that BIM adoption in consultant QS firms still lags far behind its potential. There is little evidence found in Hong Kong showing highly integration of BIM into the current QS practices. Thus, this research project aims to examine the use of BIM from another perspective and investigate the extent of BIM adoption in contractor QS practices.

All the data collected will be kept strictly confidential and used solely for research purposes. Should you have any questions about this research project, please contact the principal investigator Dr. Calvin Keung by phone (852 3442 2382) or by email (cwkeung@cityu.edu.hk).

Part 1 – Background of the respondent (contractor QS)

This questionnaire survey is company based. Please state your answers in the boxes provided.

1.1 Company name (optional)	
1.2 Contractor group under the List of Approved Contractors for Public Works	☐ Group A ☐ Group B ☐ Group C ☐ Not applicable *(Please click the mouse to select)*
1.3 Total number of contractor QS* in your company	
1.4 Number of contractor QS involved in BIM projects	
1.5 Is there any BIM team# established in your company?	☐ Yes ☐ No (please go to 1.8) *(Please click the mouse to select)*
1.6 Year of the BIM team to be established	
1.7 Number of staff involved in the BIM team	
1.8 Has your company directly appointed BIM consultant on project basis?	☐ Yes ☐ No *(Please click the mouse to select)*

** Contractor QS refer to the employees of the Main Contractor (MC) and the job duty is to perform QS tasks.*
 # BIM team refers to a section or department that aims to provide BIM support to contractor project team for BIM implementation.

Part 2 – BIM projects

Please check the appropriate boxes by clicking the mouse and state your answers in the boxes provided.

2.1 Has BIM been adopted in the projects of your company? ☐ A) Yes (please go to 2.3) ☐ B) No (please go to 2.2)	
2.2 Is there any time frame of BIM adoption in the future projects? ☐ A) Within 1-2 years (please go to Part 5) ☐ B) Within 3-4 years (please go to Part 5) ☐ C) No time frame (please go to Part 5) ☐ D) Others (please state) (please go to Part 5)	
2.3 Number of new projects in the past five years in HK:	[ ] no.
2.4 Number of new projects **using BIM** in the past five year in HK:	
Mandatory BIM adoption (i.e. BIM adoption is mandatory under the contract)	[ ] no.
Voluntary BIM adoption (i.e. BIM is adopted voluntarily by the MC)	[ ] no.

Part 2 – BIM projects (Cont'd)

2.5 Types of the BIM projects mentioned in 2.4 **(Mandatory BIM adoption)**:		
Project types	*Number of BIM projects*	
(more than one project types can be chosen)	*Private*	*Public*
☐ A) Residential		
☐ B) Office/commercial		
☐ C) Hotels		
☐ D) Industrial		
☐ E) Institutional		
☐ F) Medical		
☐ G) Recreational		
☐ H) Infrastructure		
☐ I) Renovation / fitting out		
☐ J) Others (please state)		
	Total:	Total:

2.6 Types of the BIM projects mentioned in 2.4 **(Voluntary BIM adoption)**:		
Project types	*Number of BIM projects*	
(more than one project types can be chosen)	*Private*	*Public*
☐ A) Residential		
☐ B) Office/commercial		
☐ C) Hotels		
☐ D) Industrial		
☐ E) Institutional		
☐ F) Medical		
☐ G) Recreational		
☐ H) Infrastructure		
☐ I) Renovation / fitting out		
☐ J) Others (please state)		
	Total:	Total:

Part 3 – BIM adoption status

3.1 BIM implementation process

Please answer the questions under 3.1 based on most BIM projects of your company in the past five years.

3.1.1 If your company is involved at both design and construction stages, which project team members are usually responsible for the production of the BIM models?

Please state: (if not applicable, please go to 3.1.2)

3.1.2 If your company is involved at construction stage only, which project team members are usually responsible for the production of the BIM models?

Please state:

3.1 BIM implementation process (Cont'd)
Please check the appropriate boxes in the following table by clicking the mouse:

3.1.3 What kinds of the BIM models are usually produced in your BIM projects?
3.1.4 What kinds of the model elements are usually incorporated in the respective BIM models?
3.1.5 Which contractors are involved in developing those BIM models and model elements?
3.1.6 Which model elements are usually used by the contractor QS to perform QS tasks?

3.1.3 BIM models (more than one models can be chosen)	*3.1.4 Model elements (more than one elements can be chosen)*	*3.1.5 Model development (more than one answers can be chosen)*			*3.1.6 Use of model elements (more than one answers can be chosen)*
		MC	*NSC*	*DSC*	
☐ Architecture model	☐ Facades	☐	☐	☐	☐
	☐ Non-structural walls/ partitions	☐	☐	☐	☐
	☐ Windows	☐	☐	☐	☐
	☐ Doors	☐	☐	☐	☐
	☐ Finishes	☐	☐	☐	☐
	☐ Wood works	☐	☐	☐	☐
	☐ Steel & metal works	☐	☐	☐	☐
	☐ External works	☐	☐	☐	☐
	☐ Others (please state)	☐	☐	☐	☐
☐ Structure model	☐ Structural elements	☐	☐	☐	☐
	☐ Reinforcing bars	☐	☐	☐	☐
	☐ Foundations	☐	☐	☐	☐
	☐ Retaining structures	☐	☐	☐	☐
	☐ Others (please state)	☐	☐	☐	☐
☐ MEP model	☐ Electrical installation	☐	☐	☐	☐
	☐ Plumbing & drainage	☐	☐	☐	☐
	☐ Mechanical installation	☐	☐	☐	☐
	☐ Fire services installation	☐	☐	☐	☐
	☐ Others (please state)	☐	☐	☐	☐
☐ Site model	☐ Site formation	☐	☐	☐	☐
	☐ Slope stabilization	☐	☐	☐	☐
	☐ Others (please state)	☐	☐	☐	☐
☐ Others (please state)		☐	☐	☐	☐

MC: Main Contractor
NSC: Nominated Sub-contractor
DSC: Domestic Sub-contractor

3.1 BIM implementation process (Cont'd)

Please check the appropriate boxes in the following table by clicking the mouse:

3.1.7 What are the expected goals to be achieved from the BIM models?

3.1.8 Do you agree that the quality of the BIM models is sufficient to achieve the chosen goals? '1' represents strongly disagree whereas '7' represents strongly agree.

3.1.7 Expected BIM goals	*3.1.8 Degree of agreement*						
(more than one goals can be chosen)	*1*	*2*	*3*	*4*	*5*	*6*	*7*
☐ A) Better visualization	☐	☐	☐	☐	☐	☐	☐
☐ B) Improving productivity	☐	☐	☐	☐	☐	☐	☐
☐ C) Reducing errors and omissions	☐	☐	☐	☐	☐	☐	☐
☐ D) Reducing abortive works	☐	☐	☐	☐	☐	☐	☐
☐ E) Constructability review	☐	☐	☐	☐	☐	☐	☐
☐ F) Lowering construction cost	☐	☐	☐	☐	☐	☐	☐
☐ G) Better predictability and cost control	☐	☐	☐	☐	☐	☐	☐
☐ H) Improving accuracy in quantification of works	☐	☐	☐	☐	☐	☐	☐
☐ I) Better documentation	☐	☐	☐	☐	☐	☐	☐
☐ J) Enhancing coordination	☐	☐	☐	☐	☐	☐	☐
☐ K) Shortening overall project duration	☐	☐	☐	☐	☐	☐	☐
☐ L) Improving safety	☐	☐	☐	☐	☐	☐	☐
☐ M) Faster regulatory approval cycles	☐	☐	☐	☐	☐	☐	☐
☐ N) Enhancing your organization's image	☐	☐	☐	☐	☐	☐	☐
☐ O) Marketing new business	☐	☐	☐	☐	☐	☐	☐
☐ P) Offering new services	☐	☐	☐	☐	☐	☐	☐
☐ Q) Increasing profits	☐	☐	☐	☐	☐	☐	☐
☐ R) Maintaining repeat business	☐	☐	☐	☐	☐	☐	☐
☐ S) Reducing cycle time of workflows	☐	☐	☐	☐	☐	☐	☐
☐ T) Others (please state)	☐	☐	☐	☐	☐	☐	☐

3.1.9 What items were developed by your company to enhance the model quality and reliability? More than one items can be chosen.

☐ A) Develop custom 3D object libraries

☐ B) Software customization to suit the industry practices

☐ C) Interoperability solutions

☐ D) Augmented reality to visualize the model and existing conditions together

☐ E) Laser scanning during construction to validate compliance with the model

☐ F) Others (please state)

3.2 Contract conditions of BIM projects

Please answer the following questions based on <u>most BIM projects</u> of your company in the past five years. Please check the appropriate boxes by clicking the mouse.

3.2.1 Who is/are usually responsible to draft the BIM conditions/specifications in your BIM projects?

Please state:

3.2 Contract conditions of BIM projects (Cont'd)

3.2.2 Do you agree that the aforesaid BIM conditions/specifications are effective to deal with the contractual matters of your BIM projects? '1' represents strongly disagree whereas '7' represents strongly agree.

1	*2*	*3*	*4*	*5*	*6*	*7*
☐	☐	☐	☐	☐	☐	☐

3.2.3 Do you agree that a set of standard BIM contract conditions should be published? '1' represents strongly disagree whereas '7' represents strongly agree.

1	*2*	*3*	*4*	*5*	*6*	*7*
☐	☐	☐	☐	☐	☐	☐

3.2.4 Will you adopt the aforesaid standard conditions in your BIM projects if it is published?

☐ A) Yes
☐ B) No (please state the reason)
☐ C) Others (please state)

Part 4 – BIM QS tasks

Please answer the following questions based on most BIM projects of your company in the past five years. Please check the appropriate boxes by clicking the mouse.

4.1 What kinds of QS tasks are usually performed by the contractor QS? Are these tasks accomplished under mandatory BIM adoption (Man) or voluntary BIM adoption (Vol)?
4.2 Do you agree that BIM can significantly improve the performance of the chosen QS tasks? '1' represents strongly disagree whereas '7' represents strongly agree.

4.1 Contractor QS tasks (more than one answers can be chosen)	*Man*	*Vol*	*4.2 Degree of agreement*						
			1	*2*	*3*	*4*	*5*	*6*	*7*
☐ A) Tender preparation	☐	☐	☐	☐	☐	☐	☐	☐	☐
☐ B) Cost monitoring and control	☐	☐	☐	☐	☐	☐	☐	☐	☐
☐ C) Project cash flow	☐	☐	☐	☐	☐	☐	☐	☐	☐
☐ D) Value engineering	☐	☐	☐	☐	☐	☐	☐	☐	☐
☐ E) Quantification of works for sub-letting/ purchasing	☐	☐	☐	☐	☐	☐	☐	☐	☐
☐ F) Payment application	☐	☐	☐	☐	☐	☐	☐	☐	☐
☐ G) Sub-contractors payment preparation	☐	☐	☐	☐	☐	☐	☐	☐	☐
☐ H) Variations and claims	☐	☐	☐	☐	☐	☐	☐	☐	☐
☐ I) Life cycle costing	☐	☐	☐	☐	☐	☐	☐	☐	☐
☐ J) Risk management	☐	☐	☐	☐	☐	☐	☐	☐	☐
☐ K) Financial report	☐	☐	☐	☐	☐	☐	☐	☐	☐
☐ L) Progress report	☐	☐	☐	☐	☐	☐	☐	☐	☐
☐ M) Arbitration and dispute resolution	☐	☐	☐	☐	☐	☐	☐	☐	☐
☐ N) Others (please state)	☐	☐	☐	☐	☐	☐	☐	☐	☐
☐ O) No BIM requirements on contractor QS tasks									

4.3 Are there any measures to be adopted in your company to facilitate the contractor QS to use BIM in QS tasks?

☐ A) Yes (please go to 4.4)
☐ B) No (please go to Part 5)

Part 4 – BIM QS tasks (Cont'd)

4.4 What kinds of measures have been adopted in your company to facilitate the contractor QS to use BIM in QS tasks? More than one answers can be chosen.

☐ A) Develop Standard Approach of Modelling (SAM) to suit contractor QS requirements
☐ B) Software customization for QS tasks like QTO
☐ C) Software training by outsiders like software vendors or BIM consultants
☐ D) Recruitment of BIM specialists
☐ E) BIM practice manual
☐ F) Simple guidelines for internal use
☐ G) Internal BIM projects experience sharing
☐ H) Project-based BIM execution plan
☐ I) Others (please state)

Part 5 – Improvement of BIM adoption

5.1 Do you agree that the following factors significantly cause late BIM adoption in your company? '1' represents strongly disagree whereas '7' represents strongly agree. Please check the appropriate boxes by clicking the mouse.

Factors of late BIM adoption		*Degree of agreement*						
		1	*2*	*3*	*4*	*5*	*6*	*7*
A)	Consultants do not trust contractor-built BIM models	☐	☐	☐	☐	☐	☐	☐
B)	Unforeseen positive return on investment on BIM	☐	☐	☐	☐	☐	☐	☐
C)	The 'rush' culture in the construction industry	☐	☐	☐	☐	☐	☐	☐
D)	Lack of government support and incentive	☐	☐	☐	☐	☐	☐	☐
E)	Shortage of in-house BIM specialist	☐	☐	☐	☐	☐	☐	☐
F)	Lack of BIM expertise in the market	☐	☐	☐	☐	☐	☐	☐
G)	Restructuring of organization to accommodate BIM	☐	☐	☐	☐	☐	☐	☐
H)	High initial cost e.g. software, hardware, etc.	☐	☐	☐	☐	☐	☐	☐
I)	Extra cost for the appointment of BIM consultants	☐	☐	☐	☐	☐	☐	☐
J)	Shortage of successful BIM projects showcase	☐	☐	☐	☐	☐	☐	☐
K)	Benefits of BIM adoption cannot be realized	☐	☐	☐	☐	☐	☐	☐
L)	Staff refusal/reluctance to learn new technology	☐	☐	☐	☐	☐	☐	☐
M)	Unsuitability of some projects for BIM adoption	☐	☐	☐	☐	☐	☐	☐
N)	Lack of well-recognized industry BIM standard	☐	☐	☐	☐	☐	☐	☐
O)	Standard BIM contract is not available	☐	☐	☐	☐	☐	☐	☐
P)	Worried security of confidential data	☐	☐	☐	☐	☐	☐	☐
Q)	Problem of interoperability among BIM software	☐	☐	☐	☐	☐	☐	☐
R)	Others (please state)	☐	☐	☐	☐	☐	☐	☐

5.2 In order to facilitate efficient and best use of BIM models in QS practices, what **prerequisites** are required to be put forwarded to the BIM team in advance?

Please state:

Part 5 – Improvement of BIM adoption (Cont'd)

5.3 Do you agree that the **prerequisites** stated in 5.2 should be incorporated into the industry-wide BIM Standard to support BIM in QS practices?

☐ A) Yes
☐ B) No (please state the reason)
☐ C) Others (please state)

5.4 Do you have suggestions to HKIS that can offer assistance in boosting BIM adoption in quantity surveying or the whole construction industry? Please state your answers in the box provided below.

For example Policy: Publication of standard documents: Training: Others:

- END -

Please return the completed questionnaire by email (cwkeung@cityu.edu.hk). Thank you for your participation in this survey.