The Effect of Isomorphic Pressure for Building Information Modelling in Hong Kong Construction Industry
同構壓力對建築資訊模型在香港建築業應用之影響

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IN HONG KONG CONSTRUCTION INDUSTRY

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# Table of Contents

Table of Contents ......................................................................................... II

List of Figures ................................................................................................. IV

List of Tables ................................................................................................. VI

Abstract .......................................................................................................... VII

1. Introduction ............................................................................................... 1

2. Theoretical Background and Research Model ........................................... 5
   2.1. Institutional Perspective on Project BIM Implementation .................... 5
   2.2. Role of Client/Owner Support ................................................................. 8
   2.3. Role of Coercive Pressures ................................................................. 9
   2.4. Role of Mimetic Pressures ................................................................. 10
   2.5. Role of Normative Pressures ........................................................... 11

3. Research Method ....................................................................................... 13
   3.1. Questionnaire Design and Measurement Development .................... 13
   3.2. Sampling and Data Collection .............................................................. 18
   3.3. Measurement Reliability and Validity Analysis .................................... 22

4. Data Analyses and Results ........................................................................ 25
   4.1. State of BIM Implementation Practices and Project Performance in the
        Hong Kong Construction Industry ......................................................... 25
   4.2. Impacts of Project Characteristics on BIM Implementation ............. 32
   4.3. Impacts of Isomorphic Pressures on BIM Implementation ............... 37
   4.4. BIM Implementation Motivations under the Impacts of Isomorphic
        Pressures .......................................................................................... 40
5. Policy Implications ................................................................. 46

5.1. Initiating a long-term plan to progressively facilitate the advancement of BIM in Hong Kong ......................................................... 46

5.2. Mandating the use of BIM in public projects to bring along the development of BIM in the private sector ...................................................... 49

5.3. Incentivizing the integrated use of BIM in complex projects to maximize BIM implementation benefits ................................................... 51

5.4. Establishing communication platforms for success stories to strengthen the influence of mimetic pressures for BIM implementation ......................... 52

6. Conclusions and Effectiveness of the Research Project ............... 55

6.1. Conclusions .................................................................................. 55

6.2. Effectiveness of the Research Project ........................................... 58

References ......................................................................................... 59

Appendices ......................................................................................... 66

Appendix A. Snapshots of the Online Survey Questionnaire ............ 66

Appendix B. The Email-based Survey Questionnaire (English Version) .... 67

Appendix C. The Email-based Survey Questionnaire (Chinese Version) ... 72
List of Figures

Fig. 1 Policies on BIM implementation in some typical regions ........................................2
Fig. 2 Research model of isomorphic pressures for BIM implementation ....................7
Fig. 3 BIM adoption year of the respondents’ employer organizations .......................21
Fig. 4 BIM use rate of the respondents’ employer organizations ................................21
Fig. 5 BIM implementation practices in different areas..................................................26
Fig. 6 Cost performance of the surveyed projects .........................................................28
Fig. 7 Schedule performance of the surveyed projects ...................................................28
Fig. 8 Quality performance of the surveyed projects .....................................................29
Fig. 9 Cost, schedule and quality performance in public and private projects .............30
Fig. 10 Association between BIM implementation and project cost performance ......31
Fig. 11 Association between BIM implementation and project schedule performance ..........................................................31
Fig. 12 Association between BIM implementation and project quality performance .32
Fig. 13 BIM implementation in different sizes of projects ..........................................34
Fig. 14 BIM implementation in residential and non-residential projects ...............34
Fig. 15 BIM implementation in public and private projects ........................................35
Fig. 16 Level of client/owner support for BIM implementation in different sizes of projects .................................36
Fig. 17 Perceived isomorphic pressures for BIM implementation ..........................37
Fig. 18 Results of PLS analysis for the research model ............................................39
Fig. 19 Results of PLS analysis for the alternative research model .......................40
Fig. 20 Motivations for BIM implementation under isomorphic pressures ..........41
Fig. 21 BIM implementation motivations of different project participating organizations........................................................................................................................................43
Fig. 22 BIM implementation motivations in different sizes of projects.......................44
Fig. 23 BIM implementation motivations in residential and non-residential projects ..................................................................................................................................................44
Fig. 24 BIM implementation motivations in public and private projects......................45
Fig. 25 Percentage of projects using BIM in surveyed organizations in HK, Shanghai and UK..................................................................................................................................................47
Fig. 26 BIM development plans and related promotion efforts in Shanghai..................48
Fig. 27 Comparison on BIM implementation in private and public projects...............50
Fig. 28 Comparison on BIM implementation and project performance in residential and non-residential projects............................................................................................................52
Fig. 29 Comparison on the impacts of different isomorphic pressures .......................53
List of Tables

Table 1. Measurement items of BIM implementation areas ........................................ 15
Table 2. Measurement items of client/owner support and isomorphic pressures ...... 17
Table 3. Demographic information of samples .................................................................. 19
Table 4. Measurement validity and construct correlations .................................................. 24
Table 5. Cross loadings of measurement items ..................................................................... 24
Table 6. Roles of project participants in BIM implementation process ............................. 27
Table 7. Results of ANOVA test for BIM implementation extent by project characteristics .......................................................................................................................... 33
Table 8. Results of ANOVA test for client/owner support by project characteristics . 36
Table 9. Summary of the objectives achieved in this research project ............................. 58
Abstract

Due to the great potential of BIM to address the performance problems rooted in traditional design and construction processes, in recent years government agencies in a wide variety of regions such as Denmark, Singapore, South Korea, the Chinese mainland, the UK and the USA have established related policies to facilitate the diffusion of BIM in the construction industry. While the deployment of BIM in Hong Kong could date back to more than a decade ago as pioneered by some public client organizations such as the Housing Authority, the advancement of BIM in the regional construction industry is still not widespread at present while compared with the leading practices worldwide.

Drawing on institutional theory, this study aims to assess how isomorphic pressures embedded within institutional environments affect the implementation of BIM in construction projects in Hong Kong and thus provide insights into how to facilitate the diffusion of BIM in the regional construction industry. Based on an empirical survey on BIM-based construction projects in Hong Kong, this study reveals that in the surveyed projects the in-depth implementation of BIM has been principally limited to visualization-related areas such as design authoring and 3D coordination, and that while the behaviors of project clients can significantly influence the extent of project BIM implementation, their overall support for BIM implementation in terms of paying for BIM costs, championing BIM utilization and supporting process and organizational changes is still relatively lacking at present. The study also provides evidence that performance problems are still relatively prevalent in construction projects (especially in public projects) in Hong Kong, with 30.43% of the surveyed
projects having suffered from cost overruns, and 31.30% having suffered from the problem of schedule slippages. This study further provides evidence that the extent of BIM implementation is positively associated with project performance, but the implementation of BIM generally has more substantial impact on project quality and schedule performance than on project cost performance at the current BIM development stage. With regard to the influences of institutional isomorphic pressures, this study provides evidence that that the three types of isomorphic pressures (i.e., coercive, mimetic and normative pressures) could only collectively explains a relatively small percentage (13.9%) of the variance in the extent of BIM implementation in the surveyed projects, and that the influences of mimetic pressures (i.e., influence from successful peer projects) on client/owner support and project BIM implementation extent are more substantial than those of coercive (i.e., formal or informal requirements from government agencies) and normative pressures (i.e., influence from professional bodies such as software vendors, industry consultants and industry associations). With regard to the motivations for BIM implementation under the impacts of isomorphic pressures, it is revealed that image motives (i.e, to portray a good image of technological sophistication) and cross-project economic motives (i.e., to conduct cross-project learning and capability building to gain long-term economic benefits in future projects) are currently the strongest reasons for designers and general contractors to implement BIM in construction projects in Hong Kong. By contrast, the influence of project-based economic motives (i.e., to improve design and construction performance in the current project) is found to be less substantial.

Based on these empirical findings, four aspects of policy suggestions are proposed to facilitate the advancement of BIM in the Hong Kong construction industry.
摘要

鉴于建筑资讯模型（BIM）技术在解决建造业绩效问题方面的巨大潜力，多地区（如丹麦、新加坡、韩国、中国大陆、英国、美国）的政府机构已制定各类政策推动其在行业内的应用。得益于房屋署等部分公共业主组织的尝试，香港地区的BIM应用可追溯至十余年前，但较之其他发达地区的BIM应用实践，目前BIM技术在香港建造业的应用仍远未普及。

基于制度理论，该项研究旨在系统评估制度环境中的各类同构压力如何影响香港地区建筑项目的BIM应用，从而为如何推动BIM技术在香港建造业的发展提供政策启示。通过香港地区BIM应用项目的调研，研究表明，目前香港建筑项目中BIM技术的深入应用仍主要局限在设计建模、三维协调及统筹等可视化领域；尽管业主方的技术应用行为可对项目BIM应用程度产生显著影响，从行业看，目前业主方在支付BIM应用成本、倡导项目BIM应用的正当性、推动相应的组织及流程变革等方面BIM应用支持行为整体仍处于较低水平。研究同时表明，当前香港建筑项目的绩效问题较为严重，在被调研BIM项目中，30.43%的项目存在成本超支问题，31.30%的项目存在进度拖延问题，相比私人项目，公共工程项目的绩效问题更为突出；而项目BIM应用程度与项目绩效存在正相关性，但相比对成本绩效的影响，BIM应用对质量及进度绩效的影响更加显著。关于各类制度性同构压力对BIM应用行为的影响，研究表明，制度性压力在香港地区的整体影响较弱，三类同构压力整体仅可在较小程度上解释项目BIM应用程度的方差（解释比例为13.9%，低于中国大陆地区的同类比例26.9%），而较之于强制性压力（来自政府部门的强制性要求）及规范性压力（来自软件开发商、顾问机构、行业协会等专业团体的影响），模仿性压力（来自同类型项目成功BIM应用行为的影响）对业主方支持行为及项目BIM应用程度的影响更为明显。关于同构化压力下项目参与方的BIM应用动机，研究表明，形象动机（维持组织在技术应用方面良好形象的动机）及跨项目效益动机（通过当前项目BIM应用为后续项目提供经验和资源支持的动机）是被调研项目中设计顾问及主承建商参与BIM应用的最主要原因，与之比较，项目效益动机（追求当前项目设计及施工绩效提升的动机）及被动动机（被动屈从于外部压力的动机）的影响相对较弱。

基于上述实证分析结果，该研究提出了四方面的政策建议，以推动BIM在香港建造业的发展。
1. Introduction

The construction industry worldwide has been long plagued by performance problems such as cost overruns and schedule slippages (Assaf and Al-Hejjii, 2006; Kaliba et al., 2009; Olawale and Sun, 2010) but widely criticized for being reluctant to embrace new technologies and processes to address these problems (Reichstein et al., 2005; Smyth, 2010). As an innovative model-based technology to parametrically create and integratively manage facility lifecycle data (Eastman et al., 2011), building information modelling (BIM) has been increasingly regarded during the past decade as one of the most promising technologies to address the performance problems widely rooted in traditional design and construction processes (Froese, 2010; Li et al., 2009). Based on its distinct characteristic of using parametric objects to model and manage project lifecycle information, BIM can be used in a variety of areas such as design coordination, cost estimation, phase planning and offsite fabrication throughout the project life cycle (CICRP, 2011; Eastman et al., 2011). It is claimed that BIM technology, if used appropriately, can facilitate a more integrated project lifecycle process and generate substantial benefits such as fewer design coordination errors, more energy-efficient design solutions, reduced production cycle time, lower construction cost, and higher design and construction productivity (Bryde et al., 2013; Cao et al., 2015). Based on these substantial benefits of BIM implementation, it is even claimed that BIM is currently “driving the most transformative evolution the construction industry has ever experienced” (Young et al., 2008).

Due to the great potential of BIM for the traditional construction industry, government agencies or their affiliated organizations in a wide variety of regions worldwide have established related policies to facilitate the diffusion of BIM in the
construction industry. In the United States, for example, BIM has gradually become part of the minimum requirements for the final submission as required by the General Services Administration since 2006. In Singapore, BIM implementation has also already become a mandatory requirement for all new project over 5000m² after 2015. Government supports in promoting and regulating the implementation of BIM also widely exist in other countries such as Denmark, Norway, Finland, Netherlands, South Korea and the Mainland China, with related policies in some of these regions being conceptually illustrated in Fig. 1. Largely benefiting from these policies and related supporting measures, the development of BIM in these regions have been relatively fast during the past decade. According to the Smart Market Survey in 2012 and the National Building Specification (NBS) International BIM Survey in 2015, for example, the adoption rate of BIM among industry practitioners has reached 71% in the USA in 2012 (Bernstein et al., 2012) and 78% in Denmark in 2015 (NBS, 2016).

Fig. 1 Policies on BIM implementation in some typical regions
As pioneered by some public client organizations such as the Housing Authority (HA), the deployment of BIM in the Hong Kong construction industry could date back to about a decade ago. In 2014, the Committee on Environment, Innovation and Technology of the Construction Industry Council (CIC) also published “A Roadmap for BIM Strategic Implementation in Hong Kong”, which plans to drive the adoption of BIM in the Hong Kong construction industry by collaborating closely with private and public clients. Despite these efforts, the diffusion of BIM in the construction industry at present is still not widespread while compared with the leading practices worldwide, and it is claimed that Hong Kong should be “strongly encouraged to keep up with the fast pace of the global adoption of BIM” (CIC, 2014, p.21).

Drawing on institutional theory (DiMaggio and Powell, 1983; Meyer and Rowan, 1977), this research project aims to comprehensively assess how factors embedded within institutional environments affect the implementation of BIM in construction projects in Hong Kong and thus provide insights into how to facilitate the diffusion of BIM in the regional construction industry. As stated in the submitted application proposal, the detailed objectives of this research project are as follows:

1) Empirically identify the influences of the following factors on the project-level implementation of BIM in the Hong Kong construction industry: coercive pressures, mimetic pressures, normative pressures; client/owner support; and other control variables such as project characteristics; and

2) Formulate strategies to improve the diffusion of BIM in the Hong Kong construction industry based on these factors.

The remainder of this research report is organized as follows. The next section
develops the theoretical model of isomorphic pressures for BIM implementation, and proposes the research hypotheses on the impacts of client/owner support and isomorphic pressures (including coercive pressures, mimetic pressures, and normative pressures) on the extent of BIM implementation in construction projects. Section 3 describes the empirical data collected in the Hong Kong construction industry from August 2016 to June 2017 which is used to test the model and hypotheses, and outlines the measurements used to operationalize the constructs related to the research model and hypotheses. Section 4 presents the data analysis process and results from the following four aspects: (1) State of BIM implementation practices and project performance in the Hong Kong construction industry; (2) Impacts of project characteristics on BIM implementation; (3) Impacts of isomorphic pressures on BIM implementation; and (4) BIM implementation motivations under the impacts of isomorphic pressures. Section 5 discusses policy implications of the research findings while Section 6 concludes this report.
2. Theoretical Background and Research Model

2.1. Institutional Perspective on Project BIM Implementation

Despite of the distinct increase of research interest in BIM during the past decade (Volk et al., 2014; Yalcinkaya and Singh, 2015; Zhao, 2017), much of the extant research on factors influencing BIM adoption/implementation has focused on identifying industry professionals’ perceived barriers to the development of BIM in the industry (Eadie et al., 2013; Howard and Björk, 2008), or on using theories such as the technology acceptance model to assess how technology characteristics and individual traits impact industry practitioners’ personal intentions to accept BIM (Lee et al., 2015; Son et al., 2015; Xu et al., 2014). While project is the basic unit of design/construction activities and in most cases the decision of BIM use is made at the project level, scant scholarly attention has been devoted to investigating how related BIM implementation decisions are made at the project level and how different types of factors embedded in external environments may influence the extent of BIM implementation in construction projects (Cao et al., 2014).

Distinct from transaction cost economics which posits that organizational decision making is based on an efficiency-seeking logic to rationally minimize the total production and transaction costs (Williamson, 1985), institutional theory proposes that isomorphic pressures in external institutional environments generally play a critical role in driving organizations to make structural and behavioral changes to obtain social legitimacy (DiMaggio and Powell, 1983; Meyer and Rowan, 1977; Scott, 2001). Through viewing organizations as open systems subject to the influence of particular environments, institutional theory has provided powerful explanations for
several behavioral and structural changes in organizations (Bhakoo and Choi 2013; Hertwig, 2012; Hsu et al., 2012; Liang et al., 2007; Liu et al., 2010; Sodero et al., 2013; Teo et al., 2003). These changes not only involve different industrial contexts such as the automotive industry (Hertwig, 2012), the healthcare industry (Bhakoo and Choi, 2013) and the high-technology industries (Sodero et al., 2013), but also involve a variety of national contexts such as China (Liang et al., 2007; Liu et al., 2010), Germany (Hertwig, 2012), Singapore (Teo et al., 2003), South Korea (Hsu et al., 2012), the UK (Ashworth et al., 2009) and the USA (Bhakoo and Choi, 2013). This study posits that the institutional perspective could also provide significant insights regarding how complex BIM solutions are implemented in construction projects in the “backward” construction industry.

For the implementation of BIM in construction projects, it is claimed that BIM is a relatively complex and systemic innovation whose successful implementation generally needs to be accompanied by substantial process and organizational adjustments (Cao et al., 2015; Eastman et al., 2011; Taylor, 2007). Although BIM, if used appropriately, has a potential to facilitate an integrated project lifecycle process and thus generate a variety of project benefits such as more energy-efficient design solutions and lower construction costs, much of the benefits brought by BIM is relatively intangible or not easily realizable at present (Bryde et al., 2013; Cao et al., 2015; Barlish and Sullivan, 2012; Eastman et al., 2011; Giel and Issa, 2013), with a relatively high percentage of industry practitioners already involved in BIM implementation practices having not yet perceived the positive value of BIM (Bernstein et al., 2012, 2015; Lee et al., 2012). The complexity and return-uncertainty of BIM implementation, together with some of the inherent characteristics of the construction industry which has been frequently criticized as being technologically
stagnant and performance backward (Smyth, 2010), may lead industry practitioners’ BIM implementation decision-making relatively sensitive to external institutional influences such as changes in government regulations, similar projects’ implementation activities and industry professionals’ normative suggestions.

Based on these discussions, this study aims to draw on institutional theory to comprehensively investigate how three types of institutional isomorphic pressures (i.e., coercive pressures, mimetic pressures, and normative pressures) exert influences on BIM implementation activities in construction projects within the specific institutional context of Hong Kong. As it is claimed that project clients have a penitential to substantially influence the adoption and implementation processes of other construction innovations (Ling, 2007) as well as BIM technology (Eastman et al., 2011), the variable of client/owner support is also included in the research model to examine how this factor mediates the impacts of institutional isomorphic pressures on the extent of BIM implementation in construction projects. Taking into account these possible influences, the research model is depicted in Fig. 2.

![Fig. 2 Research model of isomorphic pressures for BIM implementation](image-url)
2.2. Role of Client/Owner Support

The influences that clients / owners can make to a construction project during design and construction stages has been well documented in the extant literature (Winch, 2010). Previous studies indicate the importance of the client in adopting new technology and clients’ expectations and commitments are two major factors that will affect innovation adoption and implementation in a construction project (Ling et al., 2007; Manley, 2006; Nam and Tatum, 1997). Despite the importance of the role of clients, previous studies have also shown a lack of support to the implementation of innovative solutions in the past (Ivory, 2005; Taylor and Levitt, 2007).

According to Cao et al. (2014), a competent and supportive client/owner can facilitate the implementation of BIM in a construction project principally through the three following ways: (1) “paying for BIM costs” in order to cover or share the relatively high investment by design/construction service providers which generally compete with each other under price-based competitive mechanisms with relatively low profit margins; (2) “championing BIM utilization” in order to eliminate or mitigate the potential conflicts between project BIM implementation activities and traditional project cost or schedule goals; and (3) “supporting process and organizational changes” which is primarily related to the redesign of project processes and the redistribution of project participants’ risks and responsibilities. No matter whether BIM is advocated by project clients/owners for efficiency reasons or to gain legitimacy benefits, these three aspects of support from project clients/owners would substantially influence the extent to which BIM is to be implemented in related construction projects. Similar to the investigation conducted by the research team on BIM implementation on the Chinese mainland (Cao et al.,
2014), therefore, the first hypothesis of the present study is proposed as follows.

**Hypothesis 1 (H1). The level of client/owner support is positively associated with the extent of BIM implementation in a construction project.**

### 2.3. Role of Coercive Pressures

Coercive pressures are defined by DiMaggio and Powell (1983) as “formal and informal pressures exerted on organizations by other organizations upon which they are dependent” (p.150). Within the context of BIM implementation in Hong Kong construction projects specifically investigated in this study, coercive pressures at the current stage primarily stem from government agencies related to the management of industry-level design and construction activities. While the huge potential benefits of BIM have alerted government agencies or their affiliated organizations in several countries (e.g., Chinese mainland, Norway, South Korea, UK, USA) to regulate or plan to regulate mandatory use of BIM in public projects, Hong Kong has yet to establish any official BIM promotion or regulations mandating BIM use. However, government agencies could still directly or indirectly influence the adoption and implementation of BIM in specific projects through many other ways, such as requiring those highly influence projects to use innovative technologies like BIM to establish “showcase projects” or even “image projects” (Cao et al., 2014). These authoritative activities, whether in the form of public regulation or project-specific requirement, have a potential to substantially impact the BIM implementation decisions of both project clients and other participating organizations, and thus result in a greater extent of BIM implementation in related construction projects. These discussions lead to the following set of hypotheses.
Hypothesis 2a (H2a). The levels of coercive pressures (i.e., formal or informal requirements from government agencies) are positively associated with the level of client/owner support on BIM implementation in a construction project.

Hypothesis 2b (H2b). The levels of coercive pressures (i.e., formal or informal requirements from government agencies) are positively associated with the extent of BIM implementation in a construction project.

2.4. Role of Mimetic Pressures

Mimetic pressures refer to those forces that drive organizations to imitate the successful behaviors of other structurally equivalent organizations (DiMaggio and Powell 1983). This type of institutional isomorphic pressures primarily derives from uncertainty. Organizations tend to compare their behaviors with those of similar organizations to reduce associated risk (already taken by first movers) or to avoid lagging behind and lose legitimacy (Bhakoo and Choi, 2013) under uncertain environment, such as the contexts within which ambiguous goal or unproven innovation exists (DiMaggio and Powell, 1983). Compared with the implementation of many other design and construction technologies, BIM implementation generally involves more complex process and organizational changes in construction projects, and a large majority of industry practitioners have been struggling on how to conduct corresponding changes according to their specific project characteristics (Eastman et al., 2011). Moreover, the implementation of BIM also entails high investment cost and its project benefits are generally related to a number of factors such as project type, project construction goals, and project participant attributes (Bryde et al., 2013;
Giel and Issa, 2013). These characteristics may significantly increase the uncertainties of BIM implementation and thus lead related participating organizations to be more sensitive to the conduct of peer projects with similar project characteristics and participant attributes. Both project clients/owners and other participants has a potential to be subject to such influence of mimetic pressures, either for hedging against the associated risks, improving social image of the constructed projects or sustaining their competitiveness in future projects (Cao et al., 2014). These mimicking behaviors would then lead to higher extent of BIM implementation in their own projects. These insights lead to the following set of hypotheses of this research project.

**Hypothesis 3a (H3a).** The levels of mimetic pressures (i.e., influence from successful peer projects) are positively associated with the level of client/owner support on BIM implementation in a construction project.

**Hypothesis 3b (H3b).** The levels of mimetic pressures (i.e., influence from successful peer projects) are positively associated with the extent of BIM implementation in a construction project.

### 2.5. Role of Normative Pressures

According to DiMaggio and Powell (1983), normative pressures are principally generated from professionalization. Professional bodies usually define shared norms with their professions and expect related organizations in the professional domain to react to these norms based on their organizational characteristics (DiMaggio and Powell, 1983). Normative pressures could be exerted to organizations by professional
bodies through training, education, conferences and certification (Bhakoo and Choi, 2013; DiMaggio and Powell, 1983). Within the context of project-level BIM implementation in the Hong Kong construction industry, normative pressures can be generated from a variety of sources including industry associations such as the Hong Kong Institute of Building Information Modelling (HKIBIM), BIM soft vendors such as Autodesk, and industry consultants such as AECOM and InteliBuild. These associations or corporations have a potential to act as important vehicles for the definition and promulgation of BIM implementation norms in the regional construction industry through organizing industry workshops and publicly advocating the potential benefits of BIM. Through direct or indirect interactions with these industry associations, software vendors and consulting corporations, project participating organizations such as clients and general contractors could better understand the values and industry expectations regarding the BIM use in their specific projects, and thus adjust their specific project BIM implementation behaviors to meet external expectations. These discussions lead to the final set of hypotheses of this research project.

**H4a. The levels of normative pressures (i.e., influence from professional bodies such as software vendors, industry consultants and industry associations) are positively associated with the level of client/owner support on BIM implementation in a construction project.**

**H4b. The levels of normative pressures (i.e., influence from professional bodies such as software vendors, industry consultants and industry associations) are positively associated with the extent of BIM implementation in a construction project.**
3. Research Method

3.1. Questionnaire Design and Measurement Development

Due to its relative advantage to allow replicability of data collection and thus enable structured comparisons across different projects, a questionnaire survey was used as the main method of collecting data from BIM-based construction projects in Hong Kong to empirically test the theoretical model and research hypotheses. The design of the survey questionnaire and related measurement items were based on information gleaned from related literature as well as the similar empirical investigation previously conducted by the research team on the Chinese mainland (Cao et al., 2014, 2015). In order to assess the appropriateness of the survey questions in the context of Hong Kong, identify possible ambiguous expressions and preliminarily test the validity of related constructs, a pre-test involving 11 respondents from BIM-based projects in Hong Kong was first conducted through email and survey website https://www.surveymonkey.com/r/HKBIMSurvey during early August 2016 (two responses were collected through the e-mail, nine were collected through the online survey website; among these 11 responses, two were from project clients, five were from designers, and four were from general contractors). Based on the feedback from these respondents, the research team did not revise the content of any measurement item, but only slightly adjusted the format of the survey questionnaire and the expressions of some incorporated instructions.

The contents in the questionnaire associated with the present research project includes five primary parts. The first part obtains general information such as

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0 The questionnaire for the method of the online survey is conceptually illustrated in Appendix A,
project size and project type of the surveyed BIM-based project, as well as the roles of the key project participants in project BIM implementation. The second part concentrates on the general information (e.g., organization size, organization nature, the year of BIM adoption, and the percentage of projects that are using BIM at the time of survey) of the project participating organization in which the respondent was employed. The third part assesses the background (including the institutional isomorphic pressures and client/owner support) for BIM implementation in the surveyed project, as well as the motivations of the surveyed participating organization for project BIM implementation. The fourth part evaluates the extent to which BIM has been implemented in different areas in the surveyed project, while the fifth part assess the performance impacts of project BIM implementation.

Apart from project characteristic variables, organizational characteristic variables, BIM implementation motivations (including 11 measurement items) and project performance variables (including cost performance, schedule performance and quality performance), a total of six core variables have been measured in the questionnaire: the extent of BIM implementation in different areas (BIE), the roles of project participants in BIM implementation (BRP), client/owner support (COS), coercive pressures (CP), mimetic pressures (MP) and normative pressures (NP). The classification of BIM implementation areas was based principally on the categorization of BIM uses by CIC (2014). In order to simplify the survey questions and thus improve response rate, only 13 frequently implemented areas in design and construction phases were finally included in the questionnaire (see Table 1): design

while the questionnaire for the method of e-mail is presented in Appendix B (English version) and Appendix C (Chinese version), which both include other contents (e.g., project collaborative culture) which are not investigated in detail in the present research project.
authoring; design reviews; existing conditions modelling; site analysis; facility energy analysis; other engineering analysis; phase planning; site utilization planning, 3D control and planning; digital fabrication; as-built modelling; cost estimation and quantity take-off; 3D coordination. As the list of implementation areas is not exhaustive, one open-ended item was also included in the questionnaire for respondents to indicate other areas in which BIM had been implemented in the surveyed projects. Following Cao et al. (2014), the extent of BIM implementation in each area was measured on a three-point scale of "0" (not used), "1" (some use) and "2" (extensive use). To avoid misleading respondents into providing information with which they were not familiar, an alternative option of “not clear” was also provided for each area item. In order to improve the comprehensiveness of the implementation measurement and following Zhu et al. (2006), the extent of BIM implementation was measured as a summated factor based on the factor analysis results using the method of principal component analysis (PCA) on the listed areas.

Table 1. Measurement items of BIM implementation areas

<table>
<thead>
<tr>
<th>Project phase</th>
<th>Code</th>
<th>Area</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design phase</td>
<td>BIA1</td>
<td>Design Authoring</td>
<td>Utilize BIM software to design and three-dimensionally (3D) represent different building systems of the project</td>
</tr>
<tr>
<td></td>
<td>BIA2</td>
<td>Design Reviews</td>
<td>Related stakeholders review BIM models to provide feedbacks and to validate related details of the proposed design</td>
</tr>
<tr>
<td></td>
<td>BIA3</td>
<td>Existing Conditions Modelling</td>
<td>Develop a 3D model of the existing site conditions with the help of laser scanning or conventional survey methods</td>
</tr>
<tr>
<td></td>
<td>BIA4</td>
<td>Site Analysis in the Design Phase</td>
<td>Utilize BIM and GIS tools to evaluate a given site to determine the optimal location, position and orientation for the project</td>
</tr>
<tr>
<td></td>
<td>BIA5</td>
<td>Facility Energy Analysis</td>
<td>Utilize BIM models and energy simulation programs to conduct energy assessments for the proposed design</td>
</tr>
<tr>
<td></td>
<td>BIA6</td>
<td>Other Engineering Analysis</td>
<td>Utilize BIM models and analytical software to assess other performance (e.g., structural safety, acoustics) of the proposed design</td>
</tr>
<tr>
<td>Construction phase</td>
<td>BIA7 Phase Planning (4D Modelling)</td>
<td>Develop 4D models based on schedule information to visualize and analyze the sequence of construction activities</td>
<td></td>
</tr>
<tr>
<td>--------------------</td>
<td>----------------------------------</td>
<td>--------------------------------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td></td>
<td>BIA8 Site Utilization Planning</td>
<td>Utilize BIM models to graphically represent permanent and temporary on-site facilities to plan effective utilizations of the construction site</td>
<td></td>
</tr>
<tr>
<td></td>
<td>BIA9 3D Control and Planning</td>
<td>Utilize BIM models to create detailed control points for the layout of construction assemblies (e.g., walls) and the movement of equipment</td>
<td></td>
</tr>
<tr>
<td></td>
<td>BIA10 Digital Fabrication</td>
<td>Utilize digitized information in BIM models to facilitate the off-site fabrication of construction assemblies (e.g., walls, stairs)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>BIA11 As-Built Modelling</td>
<td>Create a post-construction record model to accurately represent the physical conditions, environment, and assets of the constructed facility</td>
<td></td>
</tr>
<tr>
<td>Design or construction phase</td>
<td>BIA12 Cost Estimation and Quantity Take-Off</td>
<td>Utilize BIM models to generate accurate quantity take-offs and cost estimates</td>
<td></td>
</tr>
<tr>
<td></td>
<td>BIA13 3D Coordination</td>
<td>Utilize clash detection software to identify and coordinate field conflicts by analyzing 3D models of different building systems</td>
<td></td>
</tr>
</tbody>
</table>

Note: The categorization of these areas are principally based on CIC (2014).

The roles of the key project participants were further examined within the questionnaire, with the roles being classified into two categories of “involved” and “not involved”. The construct of COS was assessed using items reflecting the three aspects of client/owner influences discussed in Section 2.2 (Cao et al., 2014). These three items originated from the measures of leadership involvement previously validated by Zhu et al. (2010), and were re-worded by Cao et al. (2014) to suit the context of BIM implementation in construction projects. These items were rated on a seven-point Likert scale of "1" (strongly disagree) to "7" (strongly agree).

Similar to COS, the three variables of isomorphic pressures (i.e., CP, MP, and NP) were also measured using reflective items rated on a seven-point scale of "1" (strongly disagree) to "7" (strongly agree), with their detailed measurement items
being shown in Table 2. Specifically, the item of CP was adapted from Cao et al. (2014) and Liang et al. (2007) to reflect the authoritative influences of government agencies on project BIM implementation. The construct of MP was operationalized in terms of the perceived success of BIM implementation by peer projects, with two items measuring the extent to which peer BIM-based projects had benefitted greatly and gained good reputations through BIM implementation. Similar items had previously been validated by Liang et al. (2007), Son and Benbasat (2007) and Teo et al. (2003) in other research contexts. Based on Cao et al. (2014), the construct of NP was operationalized to reflect how different professional bodies shaped the norms of BIM implementation in different types of construction projects. Based on the previous discussions, three items were used to measure the normative influences of software vendors, consultants and industry associations, respectively.

Table 2. Measurement items of client/owner support and isomorphic pressures

<table>
<thead>
<tr>
<th>Construct</th>
<th>Code</th>
<th>Measurement items</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Client/owner support (COS)</td>
<td>COS1</td>
<td>The project client had invested substantial resources in BIM use in this project</td>
<td>Cao et al. (2014); Zhu et al. (2010)</td>
</tr>
<tr>
<td></td>
<td>COS2</td>
<td>The project client regarded BIM use as a priority of project activities</td>
<td></td>
</tr>
<tr>
<td></td>
<td>COS3</td>
<td>The project client had put much effort in driving project participating organizations to collaboratively use BIM</td>
<td></td>
</tr>
<tr>
<td>Coercive pressures (CP)</td>
<td>CP1</td>
<td>Government agencies required this project to use BIM</td>
<td>Cao et al. (2014); Liang et al. (2007)</td>
</tr>
<tr>
<td>Mimetic pressures (MP)</td>
<td>MP1</td>
<td>Peer projects in Hong Kong had benefitted greatly through using BIM</td>
<td>Liang et al. (2007); Teo et al. (2003)</td>
</tr>
<tr>
<td></td>
<td>MP2</td>
<td>Peer projects in Hong Kong had gained good reputations in the industry through using BIM</td>
<td></td>
</tr>
<tr>
<td>Normative pressures (NP)</td>
<td>NP1</td>
<td>Software vendors strongly advocated the use of BIM in this type of projects</td>
<td>Cao et al. (2014)</td>
</tr>
<tr>
<td></td>
<td>NP2</td>
<td>Industry consultants strongly advocated the use of BIM in this type of projects</td>
<td></td>
</tr>
<tr>
<td></td>
<td>NP3</td>
<td>Industry associations strongly propagated the value of BIM in this type of projects</td>
<td></td>
</tr>
</tbody>
</table>
3.2. Sampling and Data Collection

Only Hong Kong construction projects involving the implementation of BIM were included in the sampling frame of this study. Targeted project respondents were identified as those most-informed senior and professional individuals directly involved in project BIM implementation processes. With the help of the Construction Industry Council (CIC) and the Hong Kong Institute of Building Information Modelling (HKIBIM), a diversified set of senior and professional individuals from clients, designers, general contractors and consulting organizations that have already been involved in project BIM implementation practices in Hong Kong were identified as potential project respondents. After being contacted through e-mails, respondents were asked to answer the survey questions based on the most recently accomplished BIM-based project which his/her companies participated in. It was expected that asking the respondents to select their most recently involved project would not only enable them to have a clearer recollection of the project BIM implementation process, but also help to reduce the possible response bias as many respondents might otherwise tend to select their most successful BIM-based project (Cao et al., 2017). Following Cao et al. (2017), the respondents were allowed to optionally report the name of the selected project to mitigate the potential impact of confidentiality issues on the response rate. In order to minimize the possible overlap between the surveyed projects and thus improve the representativeness of the sample, the research team attempted to distribute the questionnaire to diversified respondents which come from different organizations.

The contacted respondents were allowed to participate in the survey either through
the online survey website [https://www.surveymonkey.com/r/HKBIMSurvey](https://www.surveymonkey.com/r/HKBIMSurvey) or through returning the word-based questionnaire via e-mails. About 370 respondents were contacted through e-mails or personal visits (via industry BIM seminars such as the 2017 Digital Built Britain Level 3 BIM Strategic Plan Forum) during August 2016 and June 2017. After about eight months of data collection, 93 responses were collected through the survey website, 43 responses were collected through e-mails and personal visits. This resulted in a total of 136 responses and a response rate of 36.76%. After the further omission of responses with incomplete information, a total of 115 valid project-based responses were ultimately included in the analysis. Among the 115 valid project cases, 74 were collected through the survey website, 41 responses were collected through e-mails and personal visits. Demographic characteristics of these project cases and related respondents are shown in Table 3.

**Table 3.** Demographic information of samples

<table>
<thead>
<tr>
<th>Project demographics</th>
<th>N</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project size</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Below HK$50 million</td>
<td>6</td>
<td>5.22</td>
</tr>
<tr>
<td>HK$50-200 million</td>
<td>19</td>
<td>16.52</td>
</tr>
<tr>
<td>HK$200-1000 million</td>
<td>38</td>
<td>33.04</td>
</tr>
<tr>
<td>Above HK$1000 million</td>
<td>52</td>
<td>45.22</td>
</tr>
<tr>
<td>Residential</td>
<td>31</td>
<td>26.96</td>
</tr>
<tr>
<td>Commercial</td>
<td>26</td>
<td>22.61</td>
</tr>
<tr>
<td>Educational</td>
<td>9</td>
<td>7.83</td>
</tr>
<tr>
<td>Transportation</td>
<td>29</td>
<td>25.22</td>
</tr>
<tr>
<td>Industrial</td>
<td>5</td>
<td>4.35</td>
</tr>
<tr>
<td>Others</td>
<td>15</td>
<td>13.04</td>
</tr>
<tr>
<td>Project type</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project type</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project nature</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Private</td>
<td>63</td>
<td>54.78</td>
</tr>
<tr>
<td>Public</td>
<td>52</td>
<td>45.22</td>
</tr>
<tr>
<td>Respondent demographics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Variable</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Category</td>
<td></td>
<td></td>
</tr>
<tr>
<td>N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project participating type</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Client</td>
<td>21</td>
<td>18.26</td>
</tr>
<tr>
<td>Designer</td>
<td>28</td>
<td>24.35</td>
</tr>
<tr>
<td>General contractor</td>
<td>41</td>
<td>35.65</td>
</tr>
<tr>
<td>Consultant</td>
<td>24</td>
<td>20.87</td>
</tr>
<tr>
<td>Subcontractor</td>
<td>1</td>
<td>0.87</td>
</tr>
<tr>
<td>Organization nature</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Multinational a</td>
<td>40</td>
<td>34.78</td>
</tr>
<tr>
<td>Local b</td>
<td>75</td>
<td>65.22</td>
</tr>
<tr>
<td>Project participating role</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project manager c</td>
<td>28</td>
<td>24.35</td>
</tr>
<tr>
<td>BIM manager</td>
<td>54</td>
<td>46.96</td>
</tr>
<tr>
<td>BIM engineer</td>
<td>25</td>
<td>21.74</td>
</tr>
<tr>
<td>Other engineer</td>
<td>8</td>
<td>6.96</td>
</tr>
</tbody>
</table>

Notes: a Multi-national company; b Local company/organization in Hong Kong; c Including project manager, project director and construction manager.
It is evident from Table 3 that the surveyed projects are diverse in terms of project size, project type and project nature. Most respondents are senior and professional individuals with knowledge of the BIM implementation processes of their organizations in the surveyed projects, with 24.35% being project managers, project directors, construction managers or chief project engineers, 46.96% being BIM managers, 21.74% being BIM engineers, and the remaining 6.96% being other types of engineers also directly involved in the implementation of BIM in the surveyed projects. In order to formally examine whether the responses were impacted by the project participating types and positions of the respondents, a series of analyses of variance (ANOVA) were then conducted to examine the differences in the means of the core variables (including BIE, COS, CP, MP, and NP) for the responses from different types of respondents. The comparison results reveal that none of the differences is significant at the 5% level (the p-values range from 0.146 to 0.711 for the comparison for project participating type), indicating that the participating type of the respondents have not caused substantial survey biases.

The distribution of the years around which BIM was firstly used in the respondents’ employer companies/organizations is shown in Fig. 3, while the distribution of the percentages of projects in the employer companies/organizations that were using BIM at the time of survey is show in Fig. 4. It is evident from Fig. 3 that around 15.65% of the employer organizations had started to use BIM in or before 2007, and that 2011 is the year seeing the largest proportion (18.26%) of related organizations in Hong Kong to adopt BIM. It is also evident from Fig. 3 that 2014 also saw a distinct increase of organizations to adopt BIM, probably due to related BIM promotion of related industry agencies (e.g., release of the “Roadmap for Building Information Modelling Strategic Implementation in Hong Kong’s Construction
Industry” by the CIC) in that year. With regard to the BIM use rate, Fig. 4 shows that the majority (59.13%) of the respondents’ employer companies/organizations used BIM in less than 30% of their projects during the time of survey, while only 22.61% used BIM in more than 50% of their projects.

**Fig. 3** BIM adoption year of the respondents’ employer organizations

Note: BIM use rate is calculated as the percentage of projects that were using BIM in the surveyed organizations at the time of survey.

**Fig. 4** BIM use rate of the respondents’ employer organizations
3.3. Measurement Reliability and Validity Analysis

Partial least squares (PLS), as implemented in the SmartPLS 2.0 M3 program, was chosen as the structural equation modeling (SEM) technique to validate the measurements and test the hypothesized research model of the impacts of isomorphic pressures (see Fig. 2). Compared with covariance-based SEM techniques such as LISREL, PLS as a components-based technique is considered to be advantageous in analyzing research models with single-item constructs and processing data with non-normal distributions (Hair et al., 2012). As for the sample size requirement for using PLS, the most commonly cited rule is the “10 times rule”, which suggests that the sample size should be at least ten times the largest number of structural paths directed at a particular latent construct in the structural model (Hair et al., 2012). The latent construct with the largest number of directed structural paths in the present study are the variable of BIE (number of paths is 5), and the sample size (N = 115) satisfactorily meets the “10 times rule”. Apart from using the PLS technique to assess the measurements and test the research model for the impacts of isomorphic pressures on project BIM implementation, a series of descriptive and comparative analyses were also conducted in the SPSS Statistics programme 24 to illustrate the state of BIM implementation in construction projects in Hong Kong and assess the impacts of project characteristics on project BIM implementation.

The validity of the measurements was assessed in terms of internal consistency (which reflects the homogeneity of the measurement items), convergent validity (which measures the extent to which the items underlying a particular construct actually refer to the same conceptual variable) and discriminant validity (which assesses the degree to which different constructs diverge from one another). Internal
consistency was assessed through the estimate of composite reliability. As reported in Table 4, the composite reliability values of the examined constructs all exceed the recommended criterion of 0.70 (Fornell and Larcker, 1981). Following the study of Zhu et al. (2006) on other technologies, the extent of BIM implementation was measured as a summated factor based on principal component analysis (PCA) based factor analysis and, therefore, its reliability and validity measures were not calculated in the PLS-based model validation process. Instead, the internal consistency of the summated factor was further tested in SPSS Statistics 24 and an acceptable Cronbach’s Alpha of 0.792 was yielded. Convergent validity measures the extent to which the items underlying a particular construct actually refer to the same conceptual variable. The first evidence of convergent validity is provided by the values of average variance extracted (AVE). As shown in Table 4, each AVE is above the threshold of 0.5, indicating that at least 50 percent of the variance in the measurement items can be accounted for by their respective construct. Further evidence of convergent validity is obtained by estimating the factor loadings of the measurement items. As shown in Table 5, the standardized factor loadings of the items on their respective constructs are all above the threshold of 0.7 and are significant, and there exists no cross-loading problem (Hulland, 1999). Overall, the measurement model could be considered as having acceptable convergent validity. Discriminant validity assesses the degree to which different constructs diverge from one another. It is shown that the square roots of the AVE (values on the diagonal of the correlation matrix in Table 4) are all greater than the absolute value of inter-construct correlations (off-diagonal values), suggesting that the constructs possess satisfactory discriminant validity (Fornell and Larcker, 1981).
Table 4. Measurement validity and construct correlations

<table>
<thead>
<tr>
<th>Construct</th>
<th>Mean</th>
<th>SD</th>
<th>CR</th>
<th>AVE</th>
<th>COS</th>
<th>CP</th>
<th>MP</th>
<th>NP</th>
<th>EA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Client/Owner support (COS)</td>
<td>4.40</td>
<td>1.45</td>
<td>0.93</td>
<td>0.81</td>
<td>0.90</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coercive pressures (CP)</td>
<td>4.03</td>
<td>2.21</td>
<td>NA</td>
<td>NA</td>
<td>0.14</td>
<td>NA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mimetic pressures (MP)</td>
<td>4.25</td>
<td>1.28</td>
<td>0.92</td>
<td>0.85</td>
<td>0.27</td>
<td>0.20</td>
<td>0.92</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normative pressures (NP)</td>
<td>4.85</td>
<td>1.20</td>
<td>0.83</td>
<td>0.63</td>
<td>0.26</td>
<td>0.21</td>
<td>0.41</td>
<td>0.79</td>
<td></td>
</tr>
<tr>
<td>Extent of BIM implementation (BIE)</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>0.42</td>
<td>0.16</td>
<td>0.33</td>
<td>0.27</td>
<td>NA</td>
</tr>
</tbody>
</table>

Note: * Single-item construct, related measures are not applicable for this construct; b Values are calculated based on PCA analysis, related measures are not applicable for this construct; c Bold values on the diagonal represent the square root of AVE; SD = standard deviation; CR = composite reliability; AVE = average variance extracted.

Table 5. Cross loadings of measurement items

<table>
<thead>
<tr>
<th>Construct</th>
<th>Measurement items</th>
<th>Factor loadings</th>
<th>Mean</th>
<th>SD</th>
<th>T-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Client/Owner support (COS)</td>
<td>COS1</td>
<td>0.871</td>
<td>0.179</td>
<td>0.266</td>
<td>0.231</td>
</tr>
<tr>
<td></td>
<td>COS2</td>
<td>0.923</td>
<td>0.129</td>
<td>0.241</td>
<td>0.265</td>
</tr>
<tr>
<td></td>
<td>COS3</td>
<td>0.911</td>
<td>0.070</td>
<td>0.220</td>
<td>0.201</td>
</tr>
<tr>
<td>Coercive pressures (CP)</td>
<td>CP1</td>
<td>0.137</td>
<td>1.000</td>
<td>0.203</td>
<td>0.213</td>
</tr>
<tr>
<td>Mimetic pressures (MP)</td>
<td>MP1</td>
<td>0.279</td>
<td>0.255</td>
<td>0.929</td>
<td>0.386</td>
</tr>
<tr>
<td></td>
<td>MP2</td>
<td>0.211</td>
<td>0.116</td>
<td>0.917</td>
<td>0.370</td>
</tr>
<tr>
<td>Normative pressures (NP)</td>
<td>NP1</td>
<td>0.205</td>
<td>0.191</td>
<td>0.339</td>
<td>0.757</td>
</tr>
<tr>
<td></td>
<td>NP2</td>
<td>0.272</td>
<td>0.131</td>
<td>0.297</td>
<td>0.900</td>
</tr>
<tr>
<td></td>
<td>NP3</td>
<td>0.088</td>
<td>0.239</td>
<td>0.401</td>
<td>0.710</td>
</tr>
</tbody>
</table>

Note: Bold values represent standardized factor loadings of the items on their respective constructs, and T-values are for these loadings.
4. Data Analyses and Results

The collected project-based data will be analyzed in the section from the following four aspects: (1) State of BIM implementation practices and project performance in the Hong Kong construction industry; (2) Impacts of project characteristics on BIM implementation; (3) Impacts of isomorphic pressures on BIM implementation; and (4) BIM implementation motivations under the impacts of isomorphic pressures.

4.1. State of BIM Implementation Practices and Project Performance in the Hong Kong Construction Industry

The state of the surveyed projects’ BIM implementation practices in different areas\(^\circ\) is illustrated in Fig. 5, showing that there are varying degrees of implementation frequency among the listed BIM application areas. The most frequently implemented areas are 3D coordination in the design or construction phase (95.65%, 57.39% for extensive use and 38.26% for some use), and design reviews (92.17%, 49.57% for extensive use and 42.61% for some use) and design authoring (87.83%, 53.04% for extensive use and 34.78% for some use) in the design phase. Facility energy analysis in the design phase (35.65%), site analysis in the design phase (45.22%) and digital fabrication in the construction phase (48.70%) are the three least-frequent application areas. Only a relatively small minority (6.09%) of the surveyed projects are reported to have attempted to extensively implement other non-listed areas such as 3D printing. From Fig. 5, it is also evident that the extensive implementation of BIM is principally limited to the visualization-related areas such as 3D coordination (57.39%) and design authoring (53.04%), while the deep implementation of BIM in

\(^\circ\) Detailed explanations of different BIM implementation areas are presented in Table 1.
those analysis-related and management-related areas such as facility energy analysis (6.09%) and digital fabrication (14.78%) is still quite limited.

![Fig. 5 BIM implementation practices in different areas](image)

The roles of key project participants in BIM implementation are profiled in Table 6. It is evident that the most frequently involved participants in the implementation of BIM in the surveyed projects are general contractors (86.09%) and clients (73.91%), which are followed by designers (73.04%). Despite of the relatively frequent involvement of project clients in project BIM implementation process, Table 4 shows that the mean score of client/owner support (COS) in the surveyed projects is 4.40 (Standard Deviation = 1.45), which is a relatively neutral value for a seven-point Likert scale. This result suggests that while considering clients/owners’ behaviors in the aspects of paying for BIM costs, championing BIM utilization as well as supporting process and organizational changes to drive project teams to collaboratively implement BIM, their overall support for BIM implementation is still
relatively lacking in the Hong Kong construction industry at present.

**Table 6. Roles of project participants in BIM implementation process**

<table>
<thead>
<tr>
<th>Participant</th>
<th>Involved</th>
<th>Not involved</th>
</tr>
</thead>
<tbody>
<tr>
<td>Client</td>
<td>85 (73.91%)</td>
<td>15 (26.09%)</td>
</tr>
<tr>
<td>Designer</td>
<td>84 (73.04%)</td>
<td>31 (26.96%)</td>
</tr>
<tr>
<td>General contractor</td>
<td>99 (86.09%)</td>
<td>16 (13.91%)</td>
</tr>
<tr>
<td>Subcontractors</td>
<td>44 (38.26%)</td>
<td>71 (61.74%)</td>
</tr>
<tr>
<td>BIM consultant</td>
<td>77 (66.96%)</td>
<td>38 (33.04%)</td>
</tr>
</tbody>
</table>

Note: Values outside parentheses are project frequencies and values inside represent percentages (totals may not add to 100.00% due to rounding).

The cost, schedule and quality performance of the surveyed projects were also examined, with the cost and schedule performance being rated on a seven-point scale (“1” = increased more than 20%; “4” = stayed the same; “7” = decreased more than 20%), the quality performance being rated on a five-point scale (“1” = significantly below expectations; “3” = meeting expectations; “5” = significantly exceeding expectations). The distributions of these performance indicators for the surveyed projects are shown in Fig. 6, Fig. 7 and Fig. 8, respectively. It is evident from Fig. 6 that about 30.43% of the surveyed projects have suffered from the problem of cost overruns, with the actual construction cost having increased more than 20% as compared with the original construction contract in 6.69% of the surveyed projects, and increased 11–20% in 17.39% of the surveyed projects. Fig. 7 similarly shows that nearly one third (31.30%) of the surveyed projects have suffered from the problem of schedule slippages, with the actual construction duration in 8.70% of the surveyed projects have increased more than 20% as compared with the planned project construction duration. Compared with the cost and schedule performance, the quality performance seems to be less unsatisfactory, but there are still 20.00% of the surveyed projects reported to have suffered from quality performance problem (i.e., the overall quality of the finally delivered facility has not met the client’s
expectations). Taken together, these results provide clear evidence that performance problems (especially the problems of cost overruns and schedule slippages) are still relatively prevalent in construction projects in Hong Kong, even in those projects having already been involved in the use innovative technologies like BIM.

![Cost performance of the surveyed projects](image1)

**Fig. 6** Cost performance of the surveyed projects

![Schedule performance of the surveyed projects](image2)

**Fig. 7** Schedule performance of the surveyed projects
Further comparisons on the cost, schedule and quality performance in public and private projects are illustrated in Fig. 9. It is evident that while the difference in the quality performance between public and private projects is not distinct, the cost and schedule performance in public projects is obviously lower than that in private projects, with the mean scores of cost (mean = 3.52) and schedule performance (mean = 3.38) being both below the neutral score of 4.00 (i.e., “stayed the same”). In order to quantitatively characterize these differences, a series of analyses of variance (ANOVA) tests were further performed using the IBM SPSS 21.0. The results illustrate that the difference in quality performance between private and public projects is not significant at the 5% level (p = 0.616), but the differences in cost and schedule performance are both statistically significant (p = 0.040 for cost performance, p = 0.044 for schedule performance). These results provide clear evidence that, compared with private projects, public projects are suffering more obvious performance problems of cost overruns and schedule slippages in the Hong Kong construction industry at present.
The associations between BIM implementation and project cost, schedule as well as quality performance are plotted in Fig. 10, Fig. 11 and Fig. 12. In order to quantitatively characterize the associations, the extent of BIM implementation in each surveyed project was measured as a summated factor based on the factor analysis results using the method of principal component analysis (PCA) on the 13 listed BIM implementation areas (see Table 1). It is shown that the extent of BIM implementation is positively associated with all of the three examined performance indicators, providing clear evidence for the potential of BIM to address the performance problems rooted in traditional design and construction processes. Compared with the association between BIM implementation and project cost performance ($R^2 = 0.0268$, $p = 0.081$), the associations for project schedule performance ($R^2 = 0.0517$, $p = 0.015$) and quality performance ($R^2 = 0.0845$, $p = 0.002$) are more significant. These results tend to suggest that the implementation of BIM generally has more substantial impact on project quality and schedule performance than on project cost performance at the current BIM development stage.
Fig. 10 Association between BIM implementation and project cost performance

Fig. 11 Association between BIM implementation and project schedule performance
Fig. 12 Association between BIM implementation and project quality performance

4.2. Impacts of Project Characteristics on BIM Implementation

In order to compare BIM implementation practices in different kinds of projects, a series of ANOVA tests were performed to identify how the extent of BIM implementation are associated with project characteristic factors including project size, project type and project nature, and the results of these tests are presented in Table 7. It is unexpected that project type is illustrated to be significantly associated with the dependent variable (i.e., the extent of BIM implementation), with the extent of BIM implementation in non-residential projects being significantly lower than that in residential projects. With regard to project size and project nature, it is shown in Table 7 that the associations between these two project characteristic variables and the extent of BIM implementation are both non-significant at the 5% level (p = 0.452 for project size, p = 0.735 for project nature).
### Table 7. Results of ANOVA test for BIM implementation extent by project characteristics

<table>
<thead>
<tr>
<th>Variable</th>
<th>Category</th>
<th>N</th>
<th>Mean</th>
<th>SD</th>
<th>SSa</th>
<th>F-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project size</td>
<td>Below HK$50 million</td>
<td>6</td>
<td>-0.31</td>
<td>0.85</td>
<td>2.66</td>
<td>0.88</td>
<td>0.452</td>
</tr>
<tr>
<td></td>
<td>HK$50-200 million</td>
<td>19</td>
<td>0.04</td>
<td>0.82</td>
<td>111.34</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>HK$200-1000 million</td>
<td>38</td>
<td>0.19</td>
<td>1.03</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Above HK$1000 million</td>
<td>52</td>
<td>-0.12</td>
<td>1.05</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>115</td>
<td>0.00</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project type</td>
<td>Residential</td>
<td>31</td>
<td>0.49</td>
<td>1.03</td>
<td>10.17</td>
<td>11.07</td>
<td>0.001</td>
</tr>
<tr>
<td></td>
<td>Non-residential</td>
<td>84</td>
<td>-0.18</td>
<td>0.93</td>
<td>103.83</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>115</td>
<td>0.00</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project nature</td>
<td>Private</td>
<td>63</td>
<td>0.03</td>
<td>0.92</td>
<td>0.12</td>
<td>0.12</td>
<td>0.735</td>
</tr>
<tr>
<td></td>
<td>Public</td>
<td>52</td>
<td>-0.03</td>
<td>1.10</td>
<td>113.88</td>
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</tr>
<tr>
<td></td>
<td>Total</td>
<td>115</td>
<td>0.00</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: * SS = sum of squares.

Further illustrations on the associations between project characteristics and BIM implementation in the 13 detailed areas, as plotted in Fig. 13, Fig. 14 and Fig. 15, also validate the statistical analysis results presented in Table 7. While there is no regular tendency for BIM implementation practices to vary among different sizes of projects (see Fig. 13) as well as between public and private projects (see Fig. 15), it is evident that the level of BIM implementation in all of the 13 listed areas except design authoring (BIA1) is higher in residential projects than in non-residential projects (see Fig. 14). This result substantially diverges from that of Cao et al. (2015), which illustrates that the extent of BIM implementation in non-residential projects are substantially higher than that in residential projects on the Chinese mainland. This could be largely attributed to the facts that a relatively high percentage of residential building projects in Hong Kong are public projects and that the Housing Authority (HA) as the client of these projects has been relatively active in implementing BIM.

* Among the 31 residential projects surveyed in this research, 17 (54.84%) are public projects.
Fig. 13 BIM implementation in different sizes of projects

Fig. 14 BIM implementation in residential and non-residential projects
In order to statistically compare the extent of client/owner support for BIM implementation in different kinds of projects, a series of one-way ANOVA tests were also performed to assess the association between COS and related project characteristic factors, and the results of these ANOVA tests are presented in Table 8. The mean difference of COS across different categories of project size, which is also illustrated in details in Fig. 16, provides evidence that there is a general trend of clients/owners to provide more support for BIM implementation with larger projects. Although the mean values presented in Table 8 also indicate that the extent of client/owner support for BIM implementation is higher in residential projects (mean = 4.53) than in non-residential projects (mean = 4.35), and higher in private projects (mean = 4.49) than in public projects (mean = 4.29), neither of these differences is statistically significant at the 5% level.

**Fig. 15** BIM implementation in public and private projects
Table 8. Results of ANOVA test for client/owner support by project characteristics

<table>
<thead>
<tr>
<th>Variable</th>
<th>Category</th>
<th>N</th>
<th>Mean</th>
<th>SD</th>
<th>SS</th>
<th>F-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project size</td>
<td>Below HK$50 million</td>
<td>6</td>
<td>3.72</td>
<td>1.47</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>HK$50-200 million</td>
<td>19</td>
<td>3.46</td>
<td>1.63</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>HK$200-1000 million</td>
<td>38</td>
<td>4.58</td>
<td>1.36</td>
<td></td>
<td>25.19</td>
<td>4.34</td>
</tr>
<tr>
<td></td>
<td>Above HK$1000 million</td>
<td>52</td>
<td>4.69</td>
<td>1.31</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>115</td>
<td>4.40</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project type</td>
<td>Residential</td>
<td>31</td>
<td>4.53</td>
<td>1.20</td>
<td></td>
<td>0.71</td>
<td>0.34</td>
</tr>
<tr>
<td></td>
<td>Non-residential</td>
<td>84</td>
<td>4.35</td>
<td>1.54</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>115</td>
<td>4.40</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project nature</td>
<td>Private</td>
<td>63</td>
<td>4.49</td>
<td>1.49</td>
<td></td>
<td>1.12</td>
<td>0.53</td>
</tr>
<tr>
<td></td>
<td>Public</td>
<td>52</td>
<td>4.29</td>
<td>1.40</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>115</td>
<td>4.40</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: * SS = sum of squares.

Fig. 16 Level of client/owner support for BIM implementation in different sizes of projects
4.3. Impacts of Isomorphic Pressures on BIM Implementation

The perceived levels of different isomorphic pressures on BIM implementation in the surveyed projects are reported in Fig. 17. It is evident that the most substantial pressures perceived by the respondents at the time of survey are normative pressures (i.e., influence from professional bodies such as software vendors, industry consultants and industry associations), which are followed by mimetic pressures (i.e., influence from successful peer projects). By contrast, coercive pressures (i.e., formal or informal requirements from government agencies) are perceived to be the lowest level of institutional forces on BIM implementation in the surveyed projects.

![Fig. 17 Perceived isomorphic pressures for BIM implementation](image)

With regard to the impacts of these institutional pressures on project BIM implementation practices, as illustrated in Section 3, partial least squares (PLS) implemented in the SmartPLS 2.0 M3 program was chosen as the SEM technique to test the hypothesized relationships (see Fig. 2). Similar to the research setting of Cao et al. (2014), project size was also employed as a control variable to check for other
potential influences on BIM implementation. Due to the skewness in the size distribution for the surveyed projects (see Table 3), natural logarithms of the project size (“1” = Below HK$50 million; “2” = Between HK$50 and HK$200 million; “3” = Between HK$200 and HK$1000 million; “4” = Above HK$1000 million) were used in the data analysis process. A bootstrapping procedure with 5000 resamples was performed to compute standard errors and thus test the statistical significance of path coefficients in the research model.

The results of the bootstrap-based PLS analysis of the research model are presented in Fig. 18. The R² value of the dependent variable, extent of BIM implementation, is 0.280, suggesting that relatively substantial variances in the construct are explained by the research model. As illustrated in Fig. 18, the influence of COS on the extent of BIM implementation is highly statistically significant (β = 0.366, p < 0.001), thus Hypothesis 1 is supported. It is also shown that the MP-COS link (β = 0.185, p < 0.1) are statistically significant at the 10% level, providing evidence for Hypotheses 3a. However, neither of the CP-COS link (β = 0.063, p > 0.1) and the NP-COS link (β = 0.168, p > 0.1) is found to be significant, hence Hypotheses 2a and 4a are not supported. The results further indicate that while the influences of CP and NP on COS are both statistically nonsignificant, the influence of normative pressures on the behaviors of project clients at the current stage is still much stronger than that of coercive pressures. With regard to the relationships between isomorphic pressures and the extent of BIM implementation, while the effect of COS is included in the research model, the influences of MP is found to be statistically significant (β = 0.192, p < 0.1) at the 10% level, but the influences of CP and NP are both found to be statistically non-significant. As for the control variable, project size is also found to exert no significant influence on the extent of project BIM implementation while the
influences of isomorphic pressures and COS are considered.

![Fig. 18 Results of PLS analysis for the research model](image)

In order to better understand the mechanisms of how institutional isomorphic pressures impact BIM implementation practices in construction projects, an alternative model without the intermediate construct of COS was further tested with the collected data. The results of the PLS analyses on this alternative research model are presented in Fig. 19. While the intermediating effect of COS is excluded, as is evident in Fig. 19, the $R^2$ value of the dependent variable (i.e., the extent of BIM implementation) decreases substantially from 0.249 to 0.139, but the direct influence of MP on the extent of BIM implementation becomes more significant ($\beta = 0.253$, $p < 0.05$), hence Hypothesis 3b is supported. Combined with the results of the original full model shown in Fig. 18, this result provides evidence that client/owner support plays a partial mediating role in the influence of mimetic pressures on the extent of project BIM implementation. With regard to two other types of isomorphic pressures, the direct influences of CP ($\beta = 0.081$, $p > 0.1$) and NP ($\beta = 0.153$, $p > 0.1$) are still both non-significant at the 10% level. Taken together, these model testing
results tend to suggest that while compared with coercive pressures (i.e., formal or informal requirements from government agencies) and normative pressures (i.e., influence from professional bodies such as software vendors, industry consultants and industry associations), mimetic pressures (i.e., influence from successful peer projects) are currently playing a more substantial role in driving the development of BIM in the Hong Kong construction industry.

**Fig. 19** Results of PLS analysis for the alternative research model

4.4. BIM Implementation Motivations under the Impacts of Isomorphic Pressures

In order to further reveal the underlying logic of how BIM implementation activities in construction projects are influenced by external institutional pressures, this study has further examined the internal motivations of related project participating organizations for BIM implementation in the surveyed projects. As shown in Fig. 20, a total of 11 motivation items were examined which can be categorized to four

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* Only designers and general contractors are examined.
different motivation types: image motives (i.e., intrinsic desires to proactively adapt to the industry expectations and technology development trends and thus to portray a good image of technological sophistication); reactive motives (i.e., motivations to comply with the formal and informal requirements from external organizations); project-based economic motives (i.e., motivations to improve short-term design and construction performance in the current project); and cross-project economic motives (i.e., motivations to conduct cross-project learning and capability building to gain long-term economic benefits in future projects).

Fig. 20 Motivations for BIM implementation under isomorphic pressures

For detailed explanations on the categorization, please refer to a publication of the research team which is accomplished partly based on this funded research project: Cao, D., Li, H., Wang, G., Huang, T. (2017). Identifying and contextualising the motivations for BIM implementation in construction projects. *International journal of project management*, 35(4), 658-669.
It is evident from Fig. 20 that motivation items in the categories of image motives and cross-project economic motives have the highest mean values, suggesting that these two categories of motivations are currently the strongest reasons for designers and general contractors to implement BIM in construction projects. The mean values of the three motivation items related to project-based economic motives are also at relatively high levels, suggesting that seeking instant economic benefits in the focal project is also an important motivation for project participants to involve in project-level BIM implementation activities. Although ranked lowest among all of the examined motivation items, the mean values of the three items of reactive motives are still larger than the neutral value of 4 for a seven-point Likert scale\(^\circ\). Together with the relatively large standard deviations of these three motivation items (1.907 for M3, 1.688 for M4 and 1.743 for M5) compared with those of other motivation items, this result indicates that reactively responding to formal or informal requirements from other organizations is also a reason for some designers and general contractors to involve in project-level BIM implementation activities.

Fig. 21 further compares the BIM implementation motivations of two different types of project participating organizations (i.e., designers and general contractors). It is revealed that while the differences in the image motives, reactive motives and project-based economic motives (except the motivation items M6), the mean values of the cross-project economic motives (i.e., motivation items M9-M11) of designers are higher than those of general contractors. This result suggests that compared with general contractors, designers generally have more obvious motives of conducting cross-project learning and capability building to gain long-term economic benefits in

\(^\circ\) The p-value of the T test for the mean value of the construct of reactive motives (calculated as the average of the three related motivation items) is lower than 0.001.
future projects while involving in BIM implementation activities.

**Fig. 21** BIM implementation motivations of different project participating organizations

With regard to the impacts of project characteristics on project-level BIM implementation motivations, Fig. 22 illustrates that while there is no regular tendency for the associations of project size with image motives, reactive motives, and project-based economic motives (measurement items M1-M8), the cross-project economic motives (measurement items M9-M11) of designers and general contractors are generally higher in those smaller projects. Closely related to the associations between project type (i.e., residential or non-residential) and the extent of BIM implementation illustrated in Table 7 and Fig. 14, it is shown in Fig. 23 that the image motives, reactive motives, and project-based economic motives (measurement items M1-M8) of designers and general contractors are generally more obvious in residential projects than in non-residential projects.
Fig. 22 BIM implementation motivations in different sizes of projects

Fig. 23 BIM implementation motivations in residential and non-residential projects

Fig. 24 further illustrates the associations between project nature and project-level BIM implementation motivations of designers and general contractors. It is evident
that while the differences in image motives (motivation items M1-M2) and project-based economic motives (motivation items M6-M8) is not distinct, the reactive motives (motivation items M3-M5) are generally more obvious in public projects than in private projects. It is also evident, by contrast, that the cross-project economic motives (motivation items M9-M11) are generally weaker in public projects than in private projects. While the associations between project nature and reactive motives are attributable to the more substantial coercive pressures from government agencies on BIM implementation in public projects, the more obvious cross-project economic motives in private projects may derive from the fact that private projects are generally smaller in size than public projects.

![Pie chart showing BIM implementation motivations in public and private projects](image)

**Fig. 24** BIM implementation motivations in public and private projects

Among the 115 investigated projects in this research, the mean value of project size for public projects is 3.33 while the mean for private projects is 3.06.
5. Policy Implications

Based on the empirical investigation results, the following four aspects of policy suggestions are specifically proposed to facilitate the development of BIM in the Hong Kong construction industry.

5.1. Initiating a long-term plan to progressively facilitate the advancement of BIM in Hong Kong

As pioneered by some public client organizations such as the Housing Authority (HA), the deployment of BIM in the Hong Kong construction industry could date back to more than a decade ago, but the diffusion of the technology among industry practitioners is still not widespread at present. While this empirical study does not provide related data on the overall BIM adoption rate in the Hong Kong construction industry, only 22.61% of the respondents having already been involved in BIM implementation indicated that their companies/organizations had used BIM in more than 50% of their projects (see Fig. 25), which is obviously lower than the similar rates reported in the UK (NBS, 2017) and Shanghai (COHURDM and BIMPJC, 2017). Even for those projects that have already used BIM, it is reported that the deep implementation of the technology is principally limited to the visualization-related areas such as 3D coordination, while the deep implementation in those analysis-related and management-related areas such as digital fabrication is still quite limited (see Fig. 5). It is also evident from the empirical results that the reason for industry organizations to implement BIM in the surveyed projects is more related to image

15.65% of the respondents in this study indicated that the companies/organizations they worked in had started to use BIM in or before 2007.
matters (i.e., to portray a good image of technological sophistication) and cross-project economic motives (i.e., to conduct cross-project learning and capability building to gain long-term economic benefits in future projects) than project-based economic motives (i.e., to improve design and construction performance in the current project) (see Fig. 20). Taken together, these results tend to collectively suggest that the advancement of BIM in the Hong Kong construction industry in still in a relatively primitive stage at present.

Because of the potential benefits of BIM, government agencies in several countries/regions have initiated related plans to facilitate the diffusion of BIM in the construction industry (Cheng and Lu, 2015). In Singapore, for example, the Building and Construction Authority (BCA) released the first BIM roadmap in 2010, initiating...
a set of strategies to progressively achieve the aim that all new building projects of a size greater than 5,000 square meters meet architecture & engineering BIM e-Submissions requirement by 2015 (Cheng, 2012). In 2015, the BCA released the second BIM roadmap and initiated another set of strategies to further drive the collaborative BIM implementation in the industry (Andalis, 2015). Since 2014, the Shanghai Government has also initiated a set of plans to progressively promote the development of BIM and began to mandate the use of BIM in all large-scale projects (investment larger than 100 million RMB or building area greater than 20000 square meters) in 2017 (see Fig. 26). Other official BIM implementation plans include the BIM implementation roadmap released by the Korean Ministry of Land, Transport & Maritime Affairs (MLTM) and the Government Construction Strategy in the UK which establishes the aim of all centrally funded projects to implement Level 2 BIM by 2016. Benefiting from these BIM development plans and related promotion efforts, the advancement of BIM in these regions have been relatively fast during in recent years (COHURDM and BIMPJ C, 2017; NBS, 2017; Andalis, 2015).

**Fig. 26** BIM development plans and related promotion efforts in Shanghai
Aware of the problems of BIM development in Hong Kong, the Construction Industry Council (CIC) has released the “Roadmap for Building Information Modeling Strategic Implementation in Hong Kong’s Construction Industry” in 2014, which has valuably identified the major concerns that need to be addressed for BIM development in the Hong Kong construction industry. In order to further accelerate the advancement of BIM in the industry, the government could take a step further to initiate a long-term BIM development plan with measurable development aims at different stages in the next 5-10 years and the timeline of detailed actions (such as standard establishment, pilot project fostering, and training program development). Follow the experience of other regions such as Singapore (which newly establishes the BIM Steering Committee to help steer the industry BIM development process) and Shanghai (which newly establishes the BIM Promotion Joint Committee to take charge of facilitating the development of BIM in the industry), a specific BIM promotion agency could be established to coordinate the efforts of different government departments and industry organizations and thus guarantee the successful implementation of the plan.

5.2. Mandating the use of BIM in public projects to bring along the development of BIM in the private sector

While the empirical results of this study provide evidence that the clients/owners in certain types of public projects (e.g., public residential projects) have played relatively active roles in implementing BIM and the extent of BIM use in these projects are generally higher than that of other project types, it is unexpectedly revealed that the means of BIM implementation extent (BIE) and client/owner

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*This will be discussed in more details in Subsection 5.3.*
support (COS) in public projects are both lower than those in private projects (see Fig. 27), although neither of these differences are statistically significant (see Table 7 and Table 8). The empirical results also reveal that, compared with private projects, public projects in the Hong Kong construction industry are suffering more obvious performance problems of cost overruns and schedule slippages at present (see Fig. 9). These results tend to collectively suggest that many clients/owners of public projects in Hong Kong have not been actively involved in BIM implementation to address related project performance problems, and that the potential of public projects to take the lead of industry BIM implementation practices has yet to be fully exploited.

![Fig. 27 Comparison on BIM implementation in private and public projects](image)

Note: More detailed comparison statistics are presented in Table 7 and Table 8.

**Fig. 27** Comparison on BIM implementation in private and public projects

By contrast, government agencies or their affiliated organizations in many other regions such as Singapore, South Korea, the Chinese mainland, the UK and the USA have mandated or plan to mandate the use of BIM in public projects\(^\text{\circ} \), which could

\[^\text{\circ}\text{In July 2017, the EU BIM Task Group which is co-funded by the European Union (EU) also released the “Handbook for the Introduction of Building Information Modelling (BIM) by the European Public Sector} -
help to demonstrate the benefits of BIM, foster BIM capability of industry participants and thus also bring along the deployment of BIM in other types of projects throughout the industry. Although some public project owners/clients such as the Housing Authority and the MTR Corporation has been playing a relatively active role in driving the implementation of BIM in their internal projects, no policy has been released to regulate the implementation of BIM in public projects at the industry level in Hong Kong. In accordance with the BIM promotion plan established in the 2017 Policy Address and following the experience of other regions, government agencies could initiate an industry-wide scheme of gradually mandating the use of BIM in public projects to strengthen the role of these projects in leading industry BIM implementation practices.

5.3. Incentivizing the integrated use of BIM in complex projects to maximize BIM implementation benefits

Another unexpected result of this empirical study is that the extent of BIM implementation in non-residential projects is revealed to be significantly lower than that in residential projects (see Fig. 28), which substantially diverges from the findings in other regions such as the Chinese mainland (Cao et al., 2015). It is also revealed that, as plotted in Fig. 28, the mean values of cost and schedule performance in the surveyed non-residential projects are significantly lower than those in the surveyed residential projects (p-values for these two differences are 0.028 and 0.007, respectively). While such a performance difference could be partly attributed to the difference in BIM implementation extent in these two types of projects, it might also be a result of the Strategic Action for Construction Sector Performance” to encourage the leadership of public projects in advancing the implementation of BIM in Europe.

More detailed discussions on this result and its possible reasons are presented in Subsection 4.2.
projects, this result also tends to suggest that non-residential projects in Hong Kong are generally suffering more obvious problems of cost overruns and schedule slippages than residential projects which are generally less complex in building structure and construction process. Since the benefits of BIM are generally more substantial for complex projects such as industrial and transportation projects, and the benefits of BIM is not related to whether BIM is adopted but largely depends on how BIM is implemented in specific projects, government agencies could follow the experiences of Singapore and Shanghai to establish a specific BIM fund to incentivize industry organizations to deeply implement BIM in the life-cycle of complex projects.

![Fig. 28 Comparison on BIM implementation and project performance in residential and non-residential projects](image)

### 5.4. Establishing communication platforms for success stories to strengthen the influence of mimetic pressures for BIM implementation

Among the three types of isomorphic pressures investigated in this study, it is revealed that mimetic pressures (i.e., influence from successful peer projects) have the strongest influence on project BIM implementation extent (see Fig. 29), with the influence coefficient being statistically significant at the 5% level. While prior studies on other construction innovations (e.g., study on administrative safety innovations in
the USA by Esmaeili and Hallowell (2012), study on CAD technology in Turkey by Kale and Arditi (2005), and study on collaborative technologies in Greece by Nikas et al. (2007) have generated relatively conflicting results regarding the influence of mimetic pressures on innovation implementation intentions or behaviors, the result in the present study is consistent with that on the implementation of BIM on the Chinese mainland investigated by Cao et al. (2014). Such a consistence could be largely attributed to the particular nature of BIM which may be different from that of many other innovations in the construction industry (Cao et al., 2014). As for complex and radical innovations like BIM, the implementation process often not only involves project process change, high investment cost and intangible benefits, but could also exert considerable social influence due to the widespread industry interest in the innovations. Compared with those on other innovations with less ROI uncertainty and social influence, implementation decisions on these innovations tend to be more easily impacted by the behaviors of peer projects.

![Diagram](image.png)

**Fig. 29** Comparison on the impacts of different isomorphic pressures
Such a difference in the influence of different isomorphic pressures tends to suggest that the advancement of BIM in the industry should not principally rely on the advocating of the potential trend towards BIM practices by industry professional bodies. In order to more effectively facilitate the diffusion of BIM in the construction industry, by contrast, related BIM communication platforms such as industry BIM seminars, online BIM project demonstration portal and official BIM awarding schemes could be established or upgraded to exhibit the best practices and successful experiences of project BIM implementation in the industry.
6. Conclusions and Effectiveness of the Research Project

6.1. Conclusions

This research aims to empirically assess how factors embedded within institutional environments affect the implementation of BIM in construction projects in Hong Kong and to provide insights into how to facilitate the diffusion of BIM in the regional construction industry. The major empirical findings are as follows.

(1) Among the 13 BIM implementation areas investigated in this research, the most frequently implemented areas in the surveyed projects are 3D coordination, design reviews and design authoring, and the in-depth implementation of BIM in those analysis- and management-related areas such as facility energy analysis and digital fabrication is still quite limited. With regard to the roles of project participants in BIM implementation, general contractors are reported to have surpassed designers as the participants most frequently involved in the BIM implementation activities in the surveyed projects. While project clients have begun to more frequently participate in project BIM implementation processes, their overall support for BIM implementation in terms of paying for BIM costs, championing BIM utilization and supporting process and organizational changes is still relatively lacking at present.

(2) 30.43% of the surveyed projects have suffered from the performance problem of cost overruns, with the actual construction cost having increased more than 20% as compared with the original construction contract in 6.69% of the surveyed projects, and increased 11–20% in 17.39% of the surveyed projects. Similarly, 31.30% of the surveyed projects have suffered from the problem of schedule slippages, with the
actual construction duration in 8.70% of the surveyed projects have increased more than 20% as compared with the planned project construction duration. Compared with the cost and schedule performance, the quality performance seems to be less unsatisfactory, but there are still 20.00% of the surveyed projects reported to have suffered from quality performance problem. Taken together, these results provide clear evidence that performance problems (especially the problems of cost overruns and schedule slippages) are still relatively prevalent in construction projects in Hong Kong, even in those projects that have already been involved in the use of innovative technologies like BIM. It is also revealed that, compared with private projects, public projects are suffering more obvious performance problems of cost overruns and schedule slippages in the Hong Kong construction industry at present. It is further revealed that the extent of BIM implementation is positively associated with all of the three examined performance indicators, but the implementation of BIM generally has more substantial impact on project quality and schedule performance than on project cost performance at the current BIM development stage.

(3) BIM implementation practices, in terms of both the extent of BIM implementation across different application areas and client/owner support for BIM implementation, are significantly associated with project characteristic factors including project type and project size. While it is unexpectedly revealed that the extent of BIM implementation in non-residential building projects are significantly lower than that in residential projects, the empirical results also provide evidence for a general trend of clients/owners to provide more support for BIM implementation with larger projects.

(4) With regard to the influences of institutional isomorphic pressures, the three
types of isomorphic pressures (i.e., coercive pressures, mimetic pressures and normative pressures), together with the variable of project size, collectively explains a total of 13.9% of the variance in the extent of BIM implementation, which is lower than the equivalent value (26.9%) identified in a similar investigation on the Chinese mainland conducted by the research team. This result indicates that the overall influence of isomorphic pressures on BIM implementation is relatively weak in the Hong Kong construction industry at present. The results also reveal that, compared with coercive pressures (i.e., formal or informal requirements from government agencies) and normative pressures (i.e., influence from professional bodies such as software vendors, industry consultants and industry associations), mimetic pressures (i.e., influence from successful peer projects) generally have a stronger influence on project BIM implementation activities.

(5) With regard to the motivations for BIM implementation under the impacts of isomorphic pressures, it is revealed that image motives (i.e, to portray a good image of technological sophistication) and cross-project economic motives (i.e., to conduct cross-project learning and capability building to gain long-term economic benefits in future projects) are currently the strongest reasons for designers and general contractors to implement BIM in construction projects in Hong Kong. By contrast, the influence of project-based economic motives (i.e., to improve design and construction performance in the current project) is found to be less substantial. The empirical results also provide evidence that BIM implementation motivations are closely associated with project characteristics, with the cross-project economic motives being generally higher in those smaller projects, and reactive motives (i.e., motivations to comply with the formal and informal requirements from external organizations) being more obvious in public projects than in private projects.
Based on these empirical findings, the following four aspects of policy suggestions are specifically proposed to facilitate the development of BIM in Hong Kong: initiating a long-term plan to progressively facilitate the advancement of BIM; mandating the use of BIM in public projects to bring along the development of BIM in the private sector; incentivizing the integrated use of BIM in complex projects to maximize BIM implementation benefits; and establishing communication platforms for success stories to strengthen the influence of mimetic pressures for BIM implementation.

6.2. Effectiveness of the Research Project

Table 9 summaries the research objectives achieved in this research project. Both of the two originally proposed objectives have been satisfactorily achieved.

<table>
<thead>
<tr>
<th>Code</th>
<th>Proposed objectives</th>
<th>Achievements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Objective 1</td>
<td>Identify the influences of the following factors to the adoption of Building Information Modelling in Hong Kong construction industry: a: coercive pressures, mimetic pressures and normative pressures (Isomorphic pressure); b: The support from client; c: The support from government / government body / organizations; d: Other control variables</td>
<td>Achieved. The research findings on these influences are presented in Section 4. Please note that the variables related to the support from government / government body / organizations have been incorporated within the three types of isomorphic pressures (i.e., coercive pressures, mimetic pressures and normative pressures).</td>
</tr>
<tr>
<td>Objective 2</td>
<td>Formulate strategies to improve the diffusion of BIM in Hong Kong construction industry based on these factors</td>
<td>Achieved. As shown in Section 5, a total of four aspects of strategies have been proposed.</td>
</tr>
</tbody>
</table>
References


Cao, D., Li, H., Wang, G., Huang, T. (2017). Identifying and contextualising the


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Liu, H., Ke, W., Wei, K. K., Gu, J., Chen, H. (2010). The role of institutional pressures and organizational culture in the firm’s intention to adopt internet-enabled supply chain management systems. Journal of Operations Management, 28(5),


Shanghai Municipal Commission of Housing and Urban-Rural Development Management (COHURDM), Shanghai BIM Promotion Joint Committee (BIMPJC). (2017). Shanghai BIM Technology Application and Development


Appendices

Appendix A. Snapshots of the Online Survey Questionnaire

Survey on BIM Implementation Practices and Performance in Construction Projects in Hong Kong

Instructions

Dear Sir or Madam,

As a milestone technology to parametrically model and integratively manage project lifecycle information, building information modeling (BIM) has drawn increasing interest from construction practitioners over the past decade, but its advancement in the industry still faces a variety of technological and managerial challenges. Financially supported by the Public Policy Research Funding Scheme from the Hong Kong government (Grant No. 2014.A6.054.15B), this investigation aims to empirically assess the practices and performance of BIM implementation in construction projects in Hong Kong. Given your expertise and experience related to BIM, you are cordially invited to spare your precious time to participate in our questionnaire survey.

Please select a recently accomplished BIM-based construction project which you participated in (Please do not intentionally select the most successful BIM-based project in your company/organization), and answer the questions based on the information of your company/organization and the selected project. It will take you about 15 minutes to complete the questionnaire. All of the collected data will be used only for academic purposes, and the information related to specific projects and respondents will be kept in strict confidence. If you are interested in the research result, we will send you an electronic copy of the research report upon the accomplishment of this research. We greatly appreciate your support for our research.

Yours sincerely,

Heng Li, Chair Professor
Dongang Cao, Postdoctoral Fellow
Tel: (852) 2766 5603 Fax: (852) 2964 9322
Construction Virtual Prototyping Lab, Z11025, Block 2
The Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong

Appendix A.1: Snapshot of Online Survey Questionnaire

Survey on BIM Implementation Practices and Performance in Construction Projects in Hong Kong

Part I: Project Characteristics 项目概况

1. Project Name 项目名称 (Optional 可不填写):

2. For this project, your company acted as 该项目中，贵司担当的角色：
   - Main contractor 主承建商
   - Designer 勘测
   - Client 客户
   - BIM consultant BIM顾问
   - Other please specify 其他（请注明）

3. For this project, you acted as 在该项目中，您担当的角色：
   - Project manager 项目经理
   - BIM manager BIM经理
   - Construction manager 项目经理
   - BIM engineer BIM工程师
   - Other please specify 其他（请注明）

4. Project type 项目的类型：

   - Residential
   - Commercial
   - Industrial
   - Other 其他
Appendix B. The Email-based Survey Questionnaire (English Version)

Survey on BIM Implementation Practices and Performance in Construction Projects in Hong Kong (English Version)

Dear Sir or Madam,

As a milestone technology to parametrically model and integratively manage project lifecycle information, building information modeling (BIM) has drawn increasing interest from construction practitioners over the past decade, but its advancement in the industry still faces a variety of technological and managerial challenges. Financially supported by the Public Policy Research Funding Scheme from the Hong Kong government (Grant No. 2014.A6.054.15B), this investigation aims to empirically assess the practices and performance of BIM implementation in construction projects in Hong Kong. Given your expertise and experience related to BIM, you are cordially invited to spare your precious time to participate in our questionnaire survey.

Please select a recently accomplished BIM-based construction project which you participated in,* and answer the questions based on the information of your company/organization and the selected project. It will take you about 15 minutes to complete the questionnaire. After completing the questionnaire, you could return it to Dr. Dongping Cao (dongping.cao@connect.polyu.hk) by email. All of the collected data will be used only for academic purposes, and the information related to specific projects and respondents will be kept in strict confidence. If you are interested in the research results, we will send you an electronic copy of the research report upon the accomplishment of this research. We greatly appreciate your support for our research.

Yours sincerely,

Heng Li, Chair Professor
Dongping Cao, Postdoctoral Fellow
Tel: (852) 2766 5803 Fax: (852) 2364 9322
Construction Virtual Prototyping Lab, ZN1002, Block Z
The Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong

* Please do not intentionally select the most successful BIM-based project in your company.
Part I: Project Characteristics

Project Name (Optional):

1. For this project, your company acted as:  
   A. Main contractor  B. Designer  C. Client  D. BIM consultant  E. Other

2. For this project, you acted as:  
   A. Project manager  B. BIM manager  C. Construction manager  
   D. BIM engineer  E. Other (please specify)

3. Project type:  
   A. Residential  B. Commercial (banks, office, retail buildings, etc.)  
   C. Educational (school, museum, etc.)  D. Sporting (stadium, gym, etc.)  
   E. Hospital  F. Transport Infrastructure (bridge, tunnel, subway, etc.)  
   G. Industrial (factory, warehouse, etc.)  H. Other (please specify)

4. Construction contract value of the project (in HK$):  
   A. Below 50 million  B. 50–200 million  C. 201–1000 million  D. Above 1000 million

5. Type of project client organization:  
   A. Public client  B. Private client

6. Organizations involved in BIM use in this project [Select all that apply]:  
   A. Client  B. Designer  C. Main contractor  D. Subcontractor  
   E. BIM consultant  F. Other (please specify)

Part II: Organizational Characteristics

1. Approximate number of full-time employees in your company/organization:  
   A. Below 30  B. 30–100  C. 101–500  D. Above 500

2. Organizational type of your company/organization:  
   A. Multi-national company  B. Local company/organization in Hong Kong

3. The year around which BIM was firstly used in your company/organization:

4. Approximate percentage of projects in your company/organization that are using BIM:  
   A. Below 10%  B. 10–20%  C. 21–30%  D. 31–40%  E. 41–50%  F. Above 50%

Part III: Project BIM Implementation Background

Please indicate the extent to which you agree with the listed statements using the following scale:

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strongly disagree</td>
<td>Disagree</td>
<td>Slightly disagree</td>
<td>Neutral</td>
<td>Slightly agree</td>
<td>Agree</td>
<td>Strongly agree</td>
</tr>
</tbody>
</table>
### Environmental context of BIM implementation in the project

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<tbody>
<tr>
<td>01</td>
<td>Government agencies required this project to use BIM</td>
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<tr>
<td>02</td>
<td>Peer projects in Hong Kong had benefitted greatly through using BIM</td>
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<tr>
<td>03</td>
<td>Peer projects in Hong Kong had gained good reputations in the industry through using BIM</td>
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<tr>
<td>04</td>
<td>Software vendors strongly advocated the use of BIM in this type of projects</td>
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<tr>
<td>05</td>
<td>Industry consultants strongly advocated the use of BIM in this type of projects</td>
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<tr>
<td>06</td>
<td>Industry associations strongly propagated the value of BIM in this type of projects</td>
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</table>

### Collaborative culture and client’s support for BIM implementation in the project

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<tbody>
<tr>
<td>01</td>
<td>Most project participating organizations (e.g., designer, contractors) are proud to be part of this project</td>
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<tr>
<td>02</td>
<td>Most project participating organizations (e.g., designer, contractors) feel fully responsible for maximizing the benefits of the overall project</td>
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<td>03</td>
<td>The project client had invested substantial resources in BIM use in this project</td>
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<tr>
<td>04</td>
<td>The project client regarded BIM use as a priority of project activities</td>
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<td>05</td>
<td>The project client had put much effort in driving project participating organizations to collaboratively use BIM</td>
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### Motivations for BIM implementation: Our company/organization used BIM in this project because …

(*Respondents from clients and BIM consultants could neglect this question*)

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</thead>
<tbody>
<tr>
<td>01</td>
<td>We wanted to maintain a good image for using advanced technologies</td>
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<tr>
<td>02</td>
<td>We did not want to lag behind industry counterparts in using BIM</td>
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<tr>
<td>03</td>
<td>We needed to comply with BIM use requirements from government agencies or other project participants</td>
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<tr>
<td>04</td>
<td>We had to promise to use BIM to improve our competitiveness in project bidding</td>
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<tr>
<td>05</td>
<td>We had to participate in using BIM as many other participants are/were using BIM in this project</td>
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<tr>
<td>06</td>
<td>We wanted to use BIM as a tool to solve related design and construction problems in this project</td>
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<tr>
<td>07</td>
<td>We wanted to use BIM as a tool to improve cost and schedule performances in this project</td>
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<td>08</td>
<td>We expected that the direct economic benefits of BIM use will outweigh its costs in this project</td>
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<td>09</td>
<td>We wanted to become more familiar with BIM implementation process through using BIM in the current project</td>
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<tr>
<td>10</td>
<td>We wanted to foster BIM expertise of our team members through using BIM in the current project</td>
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<tr>
<td>11</td>
<td>We wanted to better guide the implementation of BIM in future projects through using BIM in the current project</td>
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</tbody>
</table>
### Part IV: Project BIM Implementation Practices

Please indicate how BIM was implemented in the listed areas in the selected project using any symbol (such as “√”) to mark your response: "0" (not used), "1" (some use), "2" (extensive use). If you are not clear on the implementation status in a specific area, you could choose the option of “N” (not clear).

[For more detailed explanations of the listed areas, please refer to “CIC Building Information Modelling Standards (Phase One)” issued by the Construction Industry Council in September 2015.]

<table>
<thead>
<tr>
<th>Project Phase</th>
<th>BIM Implementation Areas</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design Phase</td>
<td></td>
<td>0 1 2 N</td>
</tr>
<tr>
<td>Design Phase</td>
<td><strong>Design Authoring</strong>: Utilize BIM software to design and three-dimensionally (3D) represent different building systems of the project</td>
<td></td>
</tr>
<tr>
<td>Design Phase</td>
<td><strong>Design Reviews</strong>: Related stakeholders review BIM models to provide feedbacks and to validate related details of the proposed design</td>
<td></td>
</tr>
<tr>
<td>Design Phase</td>
<td><strong>Existing Conditions Modelling</strong>: Develop a 3D model of the existing site conditions with the help of laser scanning or conventional survey methods</td>
<td></td>
</tr>
<tr>
<td>Design Phase</td>
<td><strong>Site Analysis in the Design Phase</strong>: Utilize BIM and GIS tools to evaluate a given site to determine the optimal location, position and orientation for the project</td>
<td></td>
</tr>
<tr>
<td>Design Phase</td>
<td><strong>Facility Energy Analysis</strong>: Utilize BIM models and energy simulation programs to conduct energy assessments for the proposed design</td>
<td></td>
</tr>
<tr>
<td>Design Phase</td>
<td><strong>Other Engineering Analysis</strong>: Utilize BIM models and analytical software to assess other performance (e.g., structural safety, acoustics) of the proposed design</td>
<td></td>
</tr>
<tr>
<td>Construction Phase</td>
<td><strong>Phase Planning (4D Modelling)</strong>: Develop 4D models based on schedule information to visualize and analyze the sequence of construction activities</td>
<td></td>
</tr>
<tr>
<td>Construction Phase</td>
<td><strong>Site Utilization Planning</strong>: Utilize BIM models to graphically represent permanent and temporary on-site facilities to plan effective utilizations of the construction site</td>
<td></td>
</tr>
<tr>
<td>Construction Phase</td>
<td><strong>3D Control and Planning</strong>: Utilize BIM models to create detailed control points for the layout of construction assemblies (e.g., walls) and the movement of equipment</td>
<td></td>
</tr>
<tr>
<td>Construction Phase</td>
<td><strong>Digital Fabrication</strong>: Utilize digitized information in BIM models to facilitate the off-site fabrication of construction assemblies (e.g., walls, stairs)</td>
<td></td>
</tr>
<tr>
<td>Construction Phase</td>
<td><strong>As-Built Modelling</strong>: Create a post-construction record model to accurately represent the physical conditions, environment, and assets of the constructed facility</td>
<td></td>
</tr>
<tr>
<td>Design or Construction Phase</td>
<td><strong>Cost Estimation and Quantity Take-Off</strong>: Utilize BIM models to generate accurate quantity take-offs and cost estimates</td>
<td></td>
</tr>
<tr>
<td>Design or Construction Phase</td>
<td><strong>3D Coordination</strong>: Utilize clash detection software to identify and coordinate field conflicts by analyzing 3D models of different building systems</td>
<td></td>
</tr>
<tr>
<td>Design or Construction Phase</td>
<td>Others (please specify: )</td>
<td></td>
</tr>
</tbody>
</table>
Part V: Performance Impacts of Project BIM Implementation

1. Please indicate the extent to which you agree with the listed statements regarding the overall impact of BIM implementation on the project (“A” = Strongly disagree, “D” = Neutral, “G” = Strongly agree):

<table>
<thead>
<tr>
<th>Statement</th>
<th>Disagree</th>
<th>&gt;</th>
<th>Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>01 BIM use has substantially increased the frequency of communication among project participating organizations (e.g., client, designer, contractors)</td>
<td>A</td>
<td>B</td>
<td>C</td>
</tr>
<tr>
<td>02 BIM use has substantially improved the quality of the design/construction information exchanged among project participating organizations</td>
<td>D</td>
<td>E</td>
<td>F</td>
</tr>
<tr>
<td>03 BIM use has substantially improved the effectiveness of project participating organizations to collaboratively analyze design/construction problems</td>
<td>G</td>
<td></td>
<td></td>
</tr>
<tr>
<td>04 From the perspective of this project, the benefits of BIM use outweigh the costs</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2. **Cost Overrun**: Please indicate the level of the actual construction cost as compared with the original construction contract value in this project: ( )
   - A. Increased more than 20%
   - B. Increased 11–20%
   - C. Increased 1–10%
   - D. Stayed the same
   - E. Decreased 1–10%
   - F. Decreased 11–20%
   - G. Decreased more than 20%

3. **Schedule Overrun**: Please indicate the actual construction duration as compared with the planned construction duration (as specified in the construction contract) in this project: ( )
   - A. Increased more than 20%
   - B. Increased 11–20%
   - C. Increased 1–10%
   - D. Stayed the same
   - E. Decreased 1–10%
   - F. Decreased 11–20%
   - G. Decreased more than 20%

4. **Quality Performance**: Please indicate the extent to which the overall quality of the finally delivered facility has met the client’s expectations in this project: ( )
   - A. Significantly below expectations
   - B. Slightly below expectations
   - C. Meeting expectations
   - D. Slightly exceeding expectations
   - E. Significantly exceeding expectations

End of the questionnaire. Thanks a lot for your support for our research!

If you are interested in the research results, please write down your email address, we will send you an electronic copy of the research report upon the accomplishment of this research. You could also write down your suggestions on our research here:

__________________________________________________________________________

__________________________________________________________________________
建築項目 BIM 應用行為及績效調查研究

尊敬的先生/女士：

作為一項強調對建築全生命週期信息進行集成管理的創新性技術，建築信息模擬 (BIM) 在過去十年已引起建造業從業人員越來越廣泛的關注，但其在行業內的有效應用仍面臨諸多技術及組織障礙。受香港政府“公共政策研究資助計劃（項目編號：2014.A6.054.15B）”的資助，本次調研旨在評估香港地區建築項目 BIM 技術應用的現狀及績效。基於您在 BIM 技術領域的經驗及專業知識，我們誠摯邀請您拔冗參與我們此次問卷調查。

請選擇您最近參與的一項 BIM 應用項目（已完工項目），根據項目及您所在公司/組織的實際情況填寫問卷。問卷填寫過程預計會花費您 15 分鐘的時間。完成問卷後，您可通過電郵將其發送至曹冬平博士（dongping.cao@connect.polyu.hk）。本次調查僅出於學術研究目的，我們對所獲得的項目及被調研人員信息將嚴格保密。如果您有興趣了解調查結果，我們會在研究完成後及時與您分享我們的研究報告。

誠摯感謝您對我們研究的支持！

李 恆，講座教授
曹冬平，博士後研究員
香港理工大學建築虛擬模型實驗室
電話: (852) 2766 5803 傳真: (852) 2364 9322
香港九龍紅磡香港理工大學 Z 座 ZN1002 室

請避免刻意選擇 BIM 應用效果較好的建築項目。
第 I 部分：項目概況

項目名稱 (可不填寫):

1. 在該項目中，貴公司擔任的角色（）
   A. 主承建商   B. 設計顧問   C. 業主   D. BIM 顧問   E. 其他

2. 在该项目中，您擔任的角色（）
   A. 項目經理   B. BIM 經理   C. 建造經理
   D. BIM 工程師   E. 其他 (請註明)

3. 該項目的建築/設施類型（）
   A. 住宅   B. 商業（銀行、辦公樓、商場等）
   C. 教育（學校、博物館等）   D. 體育（體育場、體育館等）
   E. 醫療   F. 交通設施（橋樑、隧道、公路等）
   G. 工業（工廠、倉庫等）   H. 其他 (請註明)

4. 該項目的建造合約金額【單位：港幣】（）
   A. 低於 0.5 億   B. 0.5–2 億   C. 2.01–10 億   D. 高於 10 億

5. 該項目的業主類型（）
   A. 公共業主   B. 私人業主

6. 在該項目中，參與了 BIM 應用的組織包括【可多選】（）
   A. 業主   B. 設計顧問   C. 主承建商   D. 分包商
   E. BIM 顧問   F. 其他 (請註明)

第 II 部分：企業/組織概況

1. 企業/組織的全職員工數（）
   A. 少於 30 人   B. 30–100 人   C. 101–500 人   D. 多於 500 人

2. 企業/組織的區域類型（）
   A. 跨國企業   B. 香港本地企業/組織

3. 企業/組織開始應用 BIM 的年份:

4. 目前企業/組織各類項目中應用 BIM 的項目所佔比例（）
   A. 低於 10%   B. 10–20%   C. 21–30%   D. 31–40%   E. 41–50%   F. 高於 50%
第 III 部分: 項目 BIM 應用背景

請採用以下量表來反映您對各類表述的同意程度:

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
</tr>
</thead>
<tbody>
<tr>
<td>非常不同意</td>
<td>不同意</td>
<td>有點不同意</td>
<td>中立</td>
<td>有點同意</td>
<td>同意</td>
<td>非常同意</td>
<td></td>
</tr>
</tbody>
</table>

【您可在方框中填入任意符號（如“√”）標明您的選項】

該項目進行 BIM 應用的外部環境

| 01 | 政府機構要求該項目應用 BIM |
| 02 | 香港地區同類項目的 BIM 應用取得了很好的實際效果 |
| 03 | 香港地區同類項目的 BIM 應用取得了很好的行業聲譽 |
| 04 | 軟體開發商積極引導我們這類項目應用 BIM |
| 05 | 各類顧問機構（如 BIM 顧問）積極引導我們這類項目應用 BIM |
| 06 | 行業協會積極宣傳 BIM 在我們這類項目中的應用價值 |

該項目的協作文化及業主對項目 BIM 應用的支持

| 01 | 項目的絕大多數參與方（設計顧問、承建商等）以能參與該項目為榮 |
| 02 | 項目の絕大多數參與方對提升項目整體績效具有高度的責任感 |
| 03 | 項目業主為該項目的 BIM 應用投入了大量資源 |
| 04 | 在項目設計施工過程中，項目業主將 BIM 應用作為一項優先工作 |
| 05 | 在推動項目各參與方合作應用 BIM 方面，項目業主做了大量工作 |

BIM 應用動機：我們公司在該項目應用 BIM 是因為... [來自業主及 BIM 顧問的調研對象無需回答問題]

| 01 | 我們希望在應用先進技術方面維持良好的形象 |
| 02 | 我們不希望在應用 BIM 技術方面落後於同行 |
| 03 | 我們需要滿足政府機構或項目其他參與方的強制性 BIM 應用要求 |
| 04 | 為了提高在項目投標過程中的競爭力，我們不得不承諾應用 BIM |
| 05 | 項目的其他主要參與方都在應用 BIM，我們不得不參加 |
| 06 | 我們期望通過應用 BIM 來有效解決該項目在設計施工過程中的主要問題 |
| 07 | 我們期望通過應用 BIM 來明顯提升我們在進度、成本等方面的績效 |
| 08 | 我們期望在該項目中應用 BIM 的直接經濟效益會明顯高於 BIM 應用成本 |
| 09 | 我們希望通過該項目進一步熟悉 BIM 技術的應用流程 |
| 10 | 我們希望通過該項目培養一批掌握 BIM 技術的人員 |
| 11 | 我們希望通過該項目更好地指導將來其他項目的 BIM 應用 |
第 IV 部分：項目 BIM 應用概況

請根據以下量表反映該項目在各 BIM 應用領域的實際應用情況："0" (沒有應用), "1" (初步應用), "2" (深入應用)。在填寫過程中，您可在方框中填入任意符號（如“√”）標明您的選項。如果對某具體領域的 BIM 應用情況並不具有足夠了解，您亦可選擇 "N"(不清楚) 選項。【關於各 BIM 應用領域的具體解釋，您亦可參考香港建造業議會於 2015 年 9 月發佈的《建築信息模擬標準(第一期)》】

<table>
<thead>
<tr>
<th>項目階段</th>
<th>BIM 應用領域</th>
<th>應用情況</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0 1 2 N</td>
</tr>
<tr>
<td>設計及設計階段</td>
<td>設計建模：使用 BIM 軟體進行各設施系統（建築系統、結構系統、屋宇設備系統等）的設計及三維建模</td>
<td></td>
</tr>
<tr>
<td></td>
<td>設計檢討：項目相關持份者檢視 BIM 模型，提供反饋意見並驗證設計方案的具體細節（如設計方案是否滿足業主要求、三維空間佈局是否合適）</td>
<td></td>
</tr>
<tr>
<td></td>
<td>現行狀況建模：藉助激光掃描、攝影測量學或傳統測量方法，對項目地盤的現行狀況創建三維模型</td>
<td></td>
</tr>
<tr>
<td></td>
<td>設計及設計階段的工地分析：使用 BIM 及 GIS（地理信息系統）工具評估項目地盤，以確定擬建項目的最佳地點、位置及方位</td>
<td></td>
</tr>
<tr>
<td></td>
<td>設施能源分析：使用 BIM 模型及建築能源模擬程式對項目設計方案進行能源評估，以優化設計及降低生命週期能耗成本</td>
<td></td>
</tr>
<tr>
<td></td>
<td>其他工程分析：使用 BIM 模型和相關模擬程式對項目設計方案進行其他性能（結構安全、聲學、採光、安全疏散等）的評估及優化</td>
<td></td>
</tr>
<tr>
<td>施工階段</td>
<td>階段規劃（4D 建模）：基於項目進度信息創建 4D 模型，以展示及優化施工地盤的施工工序</td>
<td></td>
</tr>
<tr>
<td></td>
<td>工地利用規劃：使用 BIM 模型形象展示地盤在各施工階段的永久和臨時設施，結合空間佈局及工序要求對地盤的有效利用進行規劃</td>
<td></td>
</tr>
<tr>
<td></td>
<td>三維控制與規劃：藉助 BIM 模型創建控制節點，對建築元件（墻體、樓梯等）的施工位置及設備的移動進行精確控制</td>
<td></td>
</tr>
<tr>
<td></td>
<td>數碼建造：使用 BIM 模型中的精確數碼信息，實現建築元件（墻體、樓梯等）的工廠化建造</td>
<td></td>
</tr>
<tr>
<td></td>
<td>運工模型創建：在施工完成後，創建 BIM 模型對已建設施的物理條件、周邊環境、構件細節進行精確記錄</td>
<td></td>
</tr>
<tr>
<td></td>
<td>成本估算及工料測量：使用 BIM 模型進行精確的工料測量，並以此對項目成本進行估算</td>
<td></td>
</tr>
<tr>
<td></td>
<td>三維協調及統籌：使用衝突檢測工具，對各設施系統（建築系統、結構系統、屋宇設備系統等）三維模型之間的衝突進行識別及協調</td>
<td></td>
</tr>
<tr>
<td></td>
<td>其他領域（請註明： ）</td>
<td></td>
</tr>
</tbody>
</table>
第 V 部分: BIM 應用對項目績效的影響

1. 关于 BIM 應用對該項目的整體影響，请給出您對下列表述的同意程度 (“A” = 非常不同意, “D” = 中立, “G” = 非常同意):

【您可在方框中填入任意符號(如“√”) 標明您的選項】

<table>
<thead>
<tr>
<th>不同意</th>
<th>&gt;</th>
<th>同意</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>B</td>
<td>C</td>
</tr>
<tr>
<td>D</td>
<td>E</td>
<td>F</td>
</tr>
<tr>
<td>G</td>
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</tr>
</tbody>
</table>

01 BIM 應用明顯提高了項目各參與方（業主、設計顧問、承建商等）之間的交流頻率
02 BIM 應用明顯提高了項目各參與方（業主、設計顧問、承建商等）之間交流信息的質量
03 BIM 應用明顯提高了項目各參與方（業主、設計顧問、承建商等）共同分析設計/施工問題這一過程的有效性
04 整體來看，BIM 應用給該項目帶來的直接收益高於 BIM 應用的成本

2. 成本超支情況: 與早期建造合約中約定的建造成本相比，該項目的實際建造成本（ ）
   A. 增加 20%以上  B. 增加 11-20%  C. 增加 1-10%  D. 基本維持不變
   E. 減少 1-10%    F. 減少 11-20%  G. 減少 20%以上

3. 進度拖延情況: 與早期建造合約中計劃的建造工期相比，該項目的實際建造工期（ ）
   A. 增加 20%以上  B. 增加 11-20%  C. 增加 1-10%  D. 基本維持不變
   E. 減少 1-10%    F. 減少 11-20%  G. 減少 20%以上

4. 質量績效: 與業主方的期望相比，該項目最終交付產品的整體質量（ ）
   A. 明顯低於期望  B. 略微低於期望  C. 剛剛滿足期望
   D. 略微超出期望  E. 明顯超出期望

問卷到此結束。衷心感謝您對我們研究的支持！

如果您有興趣了解調查結果，您可留下您的 E-mail，在研究完成後，我們會及時與您分享我們的研究報告。您也可在此留下您對我們研究的寶貴建議:

___________________________________________________________________________
___________________________________________________________________________