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# Managing critical drivers for building information modelling implementation in the Singapore construction industry: an organizational change perspective

Longhui Liao and Evelyn Ai Lin Teo

Department of Building, National University of Singapore, Singapore

**ABSTRACT**

Building information modelling (BIM) implementation has been mandated in the Singapore construction industry, but it is still plagued with challenges such as lack of contractor input in design models. Thus, the industry still needs changes in the BIM implementation. This study aims to identify critical drivers for change (CDCs) towards full BIM implementation, demonstrate the theoretical rational behind the CDCs, and formulate strategies to strengthen the CDCs. Conducting a questionnaire survey with 86 professionals, this study identified 31 CDCs, among which 'BIM vision and leadership from the management' was ranked top. The results indicated that these CDCs could be interpreted with an adapted organizational change framework in which process-related attributes were key to changing towards full BIM implementation. The identification of the CDCs and the strategies enables the project management team to obtain sufficient support for strengthening the positive influence from the CDCs and enhancing BIM implementation. Additionally, overseas construction practitioners can use the drivers and strategies identified in this study to prepare their customized lists of drivers and strategies.

**KEYWORDS**

Building projects; building information modelling; organizational change; driver; Singapore

## Introduction

In recent years, the value of implementing building information modelling (BIM) has been increasingly recognized among private and government owners globally. It is not uncommon today that governments encourage, specify, or mandate the use of BIM in publicly funded construction and building projects (Smith 2014). Such commitment on the BIM implementation enables the enlightened owners to empower design and construction firms to leverage BIM technologies to meet or even exceed their project goals. Cheng and Lu (2015) reported that as one of the leading countries in implementing BIM in Asia or even worldwide, Singapore has made substantial efforts to drive the industry-wide BIM implementation, such as mandating architectural and engineering e-submissions in BIM format for all new building projects with a gross floor area over 5,000 $m^2$ since July 2015. In addition, Singapore's Building and Construction Authority (BCA) has been driving the whole construction value chain to work collaboratively and optimize building designs for off-site manufacture (OSM) which are encouraged in full BIM implementation (BCA 2016).

In general, full BIM implementation requires that the relationships between the key participants in a project are bound with multi-party collaboration contracts and these participants are involved in the project very early, even before the design starts (El Asmar et al. 2013; Porwal and Hewage 2013). Despite the substantial efforts made, changing towards full BIM implementation is generally slow in most projects in the global construction industry due to the entrenchment in the traditional object-oriented computer-aided design (CAD) or wait-and-see attitude (Porwal and Hewage 2013; Juan et al. 2017). Therefore, BIM implementation in building projects needs to be enhanced. It is suggested that the best way to drive the projects to change towards full BIM implementation is to get the participants to understand the potential and the value of BIM over the traditional project delivery (Khosrowshahi and Arayici 2012). However, a holistic view of the critical drivers for change (CDCs) towards full BIM implementation in the construction industry has not been well established. In addition, full BIM implementation in the building project team can be conceptualized as a gradual organizational change (Azhar et al. 2014). This is because: the participating firms of the project can be seen as the business units of an organization which work for the same goals (Verdecho et al. 2012), and most firms tend to be accustomed to the traditional project delivery using the traditional CAD or using BIM lonely and thus should adapt to a new delivery process with the help of new technologies.

**CONTACT** Longhui Liao a0109736@u.nus.edu

The objectives of this study are to identify the CDCs towards full BIM implementation in building projects in Singapore, demonstrate the theoretical rational of the CDCs, and formulate possible strategies to strengthen the positive influence from these CDCs. In order to interpret full BIM implementation in building projects, this study adapted existing organizational change theories into a new organizational change framework with 29 organizational change attributes which fell into four groups, namely people, process, technology, and external environment aspects. The results of this study could be useful to project management teams which are facing difficulties in obtaining sufficient support from the owners and service providers for implementing the required changes towards full BIM implementation from the early design stage to the facility management stage. In addition, although this study focuses on the context of the Singapore construction industry, overseas construction practitioners can use the drivers and their corresponding strategies identified in this study to customize their own lists of drivers and strategies according to their project circumstances. Thus, it is believed that this study would contribute to the literature related to BIM implementation.

## Literature review

### Drivers for change towards full BIM implementation

Previous studies have reported that a number of factors could drive the change towards full BIM implementation in the global construction industry. In this study, two methods were used to identify the drivers for change towards full BIM implementation from the literature: (1) keyword search in peer-reviewed journals; and (2) expansion search through citation links. Two groups of keywords were used. The first group comprised of driver, success factor, and benefit; the second group included building information model and BIM. Articles that contain one keyword in the first group and one in the second group in the title/abstract/keywords were retrieved. In addition, extra articles were obtained through the citation links from the articles reviewed. Consequently, as shown in Table 1, a total of 32 factors driving for full BIM implementation were identified from the 26 previous studies related to BIM implementation in various countries. However, these studies usually examined only a few specific factors (see Table 1) that enhanced the BIM implementation in particular projects in various countries, and did not investigate these factors from an organizational change perspective in the project context. It would be difficult for firms to use BIM fully without considering all the identified drivers from the people, process, technology, and external environment aspects holistically. For instance, without the participation of downstream people such as key contractors in the design stage or effective data exchange between the contractors and designers, the repeated efforts by the designers and the contractors are inevitably needed to create design models in their own ways, respectively. This phenomenon is not uncommon both in Singapore (Lam 2014) and overseas (Sattineni and Mead 2013). Gao and Fischer (2006) focused on driving the collaboration between the contractors and the designers to create composite design models that fit for the downstream uses, but the involvement of facility managers in this process was rarely studied. Eastman et al. (2011) investigated the majority of the identified factors but did not study the critical role of governments (external political environment) in terms of their active participation during design to specify BIM use as well as their financial support such as subsidising training and consultancy costs. McFarlane and Stehle (2014) focused on the incorporation of new design and construction method, namely OSM into BIM processes. Other previous studies investigated even fewer factors driving for change towards full BIM implementation (see Table 1). Furthermore, the specific factors identified in these previous studies were not linked to all the people, process, technology, and external environment aspects which play critical roles in the organization-wide changes towards full BIM implementation. Therefore, this study intends to fill this gap by identifying the drivers with significant influence on changing towards full BIM implementation in building projects in Singapore and demonstrating the theoretical rationale behind these drivers from the organizational change perspective, extending the relevant literature.

### Organizational change

Organizational change is defined as 'an empirical observation of difference in form, quality or long-term state of an organizational entity, coming out of the deliberate introduction of new styles of thinking, acting or operating, looking for the adaptation to the environment or for a performance improvement' (Pardo-del-Val et al. 2012). Michel et al. (2013) advocated that organizations operating in a changing environment need sustainable organizational changes for their own survival and success. Among the number of organizational change theories, Leavitt's diamond theory was selected in this study because it assess the organization's current level of functioning and activities for designing better strategies of

**Table 1.** Drivers for change towards full BIM implementation.

| Code | Drivers for change towards full BIM implementation | References 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| D01 | BIM vision and leadership from the management | | √ | | √ | | | | | | | | | | | | √ | | | | | √ | | √ | | | | | √ | √ |
| D02 | Changes in organizational structure and culture | | | √ | √ | √ | | | | | | | | | | | √ | | | | √ | | | | | | | | √ | |
| D03 | Stakeholders seeing the value of adopting their own part of BIM | | | √ | √ | | | | | | | | | | | | | | | √ | √ | √ | | √ | | | | | √ | |
| D04 | Training on new skillsets and new ways of working | | | √ | √ | √ | | | | | | √ | | | | | √ | | | | √ | | | √ | | √ | | | √ | √ |
| D05 | Owner's requirement and leadership to adopt BIM | √ | | √ | | √ | | | | | | √ | | | | | | | | | | | | √ | | | | | √ | |
| D06 | Regulatory agencies' early participation to BIM use | √ | | | | | | | | | | | | | | | | | | | | | | √ | | | | | | |
| D07 | Gaining competitive advantages from full BIM use | | | √ | | | | | | | | √ | | | | | √ | | | | | | | | | | | | | |
| D08 | All disciplines sharing models in a 'Big Room' | | | | | | | | | | √ | | | | √ | √ | | | √ | √ | | √ | | | √ | | | | √ | |
| D09 | Government support such as subsidizing training, software, and consultancy costs | | | | | | | | | | | | | | | | √ | | | | √ | | | √ | | | | | | √ |
| D10 | Enabling subcontractors to use lower-skilled labor on site | | | | | | | | √ | | | | | | | | | | √ | | | | | | | √ | | | | |
| D11 | OSM lowering safety risks by controlling work in factory | | | | | | | | √ | √ | | | | | | √ | | | | | | | | | √ | | | √ | | |
| D12 | Alignment of the interests of all stakeholders | | | | | | | | | | | | | | | | | √ | | | | | | | | | | | √ | |
| D13 | Governance of BIM-related policies and standards | | | | √ | | | | | | | | | | | | √ | | | | | | | | | | | | | √ |
| D14 | Data sharing and access on BIM platforms | | | | √ | | | | | | | | | | | | √ | | | | | | | | | | | | √ | |
| D15 | Three-dimensional (3D) visualization enabling design communication | | √ | | | | | | | | | √ | | √ | √ | | √ | | √ | √ | | √ | | | | | √ | | | |
| D16 | Four-dimensional simulation before construction | √ | | | | | | | | | | √ | | √ | √ | | | | | √ | | √ | √ | | √ | | | | | |
| D17 | Design coordination between disciplines through clash detection and resolution | √ | √ | | | | √ | | | | √ | √ | | √ | √ | | √ | | √ | √ | | √ | √ | | √ | | √ | | √ | |
| D18 | Complex design analysis in sustainability, material selection, and constructability | √ | | | | | | | √ | | | √ | | | √ | √ | | | | √ | | √ | | | | √ | | | | |
| D19 | Project lifecycle costing | | | | | | √ | | | | | | | | √ | | | | | √ | | | | | √ | | | | | |
| D20 | Producing models and drawings for construction and fabrication | √ | | | | | √ | | | | √ | √ | | | √ | | √ | | | | | √ | | | | | | | | |
| D21 | High accuracy of model-based documentation | | | | | | | | | | | √ | | | √ | | | | | √ | | | | | | | | | | |
| D22 | More off-site fabrication and assembly of standard elements | | | | | | | √ | √ | | | | √ | √ | √ | | | | √ | | | √ | | | √ | √ | | | | |
| D23 | Automatic model updating and drawing production to deal with design changes and their implications | | | | | | | | | | √ | | | | √ | | | | | √ | | | | | | | | | | |
| D24 | Lifecycle information management improving facility management | | √ | | | | | √ | | | | | | √ | √ | | | | | √ | | | | | | | √ | | | |
| D25 | Increasing use of design-build and fast-track approach | | | | | | | | | | | √ | | | | | | | | | | | | | | | | | √ | |
| D26 | On-site work proceeds in parallel with off-site production | | | | | | | | √ | √ | | | | | | √ | | | | | | | | | √ | | | | | |
| D27 | OSM standardizes design and manufacturing processes, simplifying construction and testing and commissioning processes | | | | | | | | √ | √ | | | | | | | | | | | | | | | √ | √ | | √ | | |
| D28 | OSM produces building elements with better quality and consistency | | | | | | | | √ | √ | | | | | | | | | | | | | | | √ | | | | | |
| D29 | OSM reduces building wastes, especially on-site wastes | | | | | | | √ | √ | √ | | | | | | | | | | | | | | | √ | | | | | |
| D30 | Integrating model management tools with enterprise systems to exchange data | | | | √ | | | | | | | | | | | | | | | | | | | | | | | | | |
| D31 | Increasing complexity in buildings, project delivery, and marketplace | | | | | √ | | | | | | √ | | | | | √ | | | | | | | | | | | | √ | |
| D32 | New technologies such as Computer Numerically Controlled machines | | | | | | | | | | √ | √ | | | | | | | | | | √ | | | √ | | | | | |
| | Total number of drivers studied | 6 | 4 | 5 | 7 | 4 | 3 | 3 | 8 | 5 | 5 | 12 | 1 | 5 | 11 | 4 | 11 | 1 | 5 | 10 | 4 | 10 | 2 | 6 | 11 | 5 | 3 | 2 | 11 | 4 |

Notes: 1. American Institute of Architects, California Council (AIACC 2014); 2. Aranda-Mena et al. (2009); 3. Arayici et al. (2011); 4. Autodesk (2012); 5. Azhar et al. (2014); 6. BCA (2013); 7. Bernstein and Pittman (2004); 8. Blismas and Wakefield (2009); 9. Blismas et al. (2006); 10. Chua and Yeoh (2015); 11. Eastman et al. (2011); 12. Fischer et al. (2014); 13. Fischer (2008); 14. Gao and Fischer (2006); 15. Gibb and Isack (2003); 16. Juan et al. (2017); 17. Kent and Becerik-Gerber (2010); 18. Khanzode et al. (2007); 19. Khosrowshahi and Arayici (2012); 20. Kiani et al. (2015); 21. Kunz and Fischer (2012); 22. Li et al. (2009); 23. Liao et al. (2017); 24. McFarlane and Stehle (2014); 25. Ross et al. (2006); 26. Sattineni and Mead (2013); 27. Selvaraj et al. (2009); 28. Won et al. (2013); 29. Zahrizan et al. (2013). √ Indicates the inclusion of the specific driver in the reference.

implementing new technologies (Dahlberg et al. 2016), which is consistent with the Singapore government's encouragement to using BIM in the local industry.

Leavitt's diamond theory was developed to analyse the organization-wide effects when changes take place (Leavitt 1965). This theory identifies four interrelated factors: task, people, structure, and technology in an organization (system). 'Task' refers to what the organization tries to achieve and how things are being done. 'People' refer to the employees including their roles and responsibilities as well as characteristics, such as skills and knowledge. 'Structure' refers to the relationships, communication patterns, and collaboration between 'people'. 'Technology' enables 'people' to perform the 'task', such as software applications. Any change occurring in any factor will affect the entire organization; the organization can be thought of as maintaining a balance of the four factors. Thus, the theory can help organizations apply new technologies to the workplace in a way that lessens stress and encourages teamwork (Smith et al. 1992).

The theory has been widely recognized and applied in previous studies (Wigand 2007; Ranjbari 2013; Dahlberg et al. 2016) in novel and critical ways. For instance, Rockart and Scott Morton (1984) expanded Leavitt's diamond theory by incorporating Chandler's (1962) finding that 'changes in strategy would drive changes in structure' (see Figure 1). The expanded theory particularized Leavitt's diamond model by: (1) changing its generic 'task' into the broader concept of the organization's strategy since 'strategy' represents a summing of the organization's tasks; (2) adding 'corporate culture' to expand organization structure; (3) adding a box for 'management processes', such as meetings and plans creation; and (4) adding two forces in the external environment. Thus, it is crucial to find the link between strategic ideas and the implementation of new technologies. In addition, the expanded theory forms the foundation for MIT90s framework (see Figure 2) which was designed to encourage organizations to understand the dynamics of transformation and the acquisition of new technology (Scott Morton 1991; Mistry 2008). The major difference between the expanded Leavitt's diamond theory in Figure 1 and the MIT90s framework is the scope of organizational culture. The MIT90s framework regards organizational culture as an integral part of the organization rather than a dimension of organizational structure.

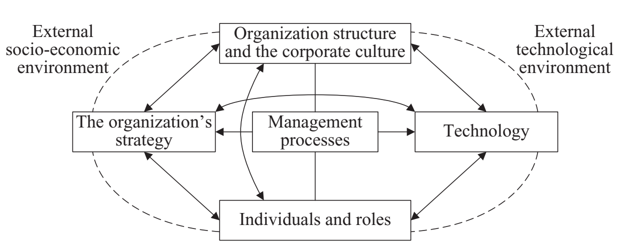


Figure 1. Expanded Leavitt's diamond model of technology impact (Rockart and Scott Morton 1984).

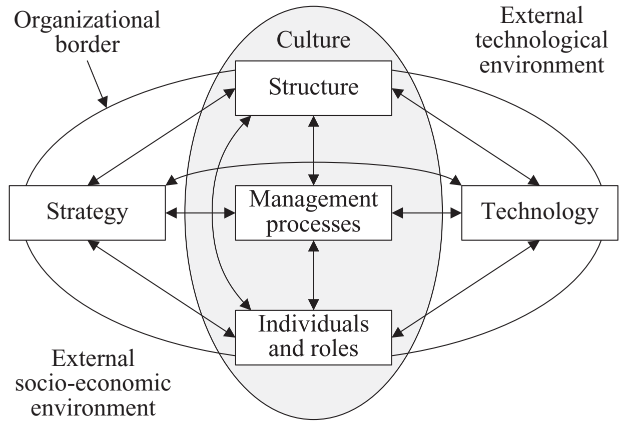


Figure 2. MIT90s framework (Scott Morton 1991).

Although the MIT90s framework focuses on individual enterprise contexts, its application in inter-organization context has been justified by conceptualizing the collaborative inter-enterprise context as an organization that pursues common objectives. For example, Verdecho et al. (2012) adapted the MIT90s framework to study the factors that influence inter-enterprise collaboration in the renewable energy sector. In the adapted framework, the enterprises need to manage and balance four groups of interrelated factors: strategy, organizational structure, culture, and business processes and infrastructure. The strategic factors are in an upper level because strategic aspects (such as the need of being competitive) drive the collaboration among enterprises.

Dahlberg et al. (2016) argued that the factors of Leavitt's diamond theory were generic and lack contemporary constructs, and modified the wording of some factors in the theory by: (1) replacing 'technology' with 'technology, IT services, and information'; (2) modifying 'structure' into 'strategy, business model, and governance'; and (3) replacing 'task' into 'tasks and processes' (see Figure 3). Such modifications were regarded as the updates of Leavitt's theory that reflect contemporary constructs, not as changes to the logic of the original

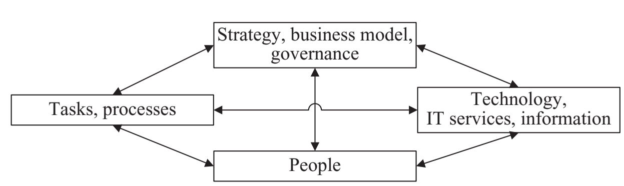


Figure 3. Modified Leavitt's diamond theory (Dahlberg et al. 2016).

theory. This modified theory was validated through interviews with 36 chief information officers (CIOs) within six industries and found that this theory could describe how technology and corporate strategy changes influence the CIOs' roles and tasks in a bidirectional way.

## An adapted framework for organizational change

Leavitt's organization theory was also applied in construction management studies. For example, Kasimu et al. (2012) adapted the theory's four interrelated factors to outline the key variables in the development of a knowledge management implementation framework for construction firms. Although Leavitt's diamond theory and the MIT90s framework have been applied to study the effects of information technology changes within individual organizations, little is known about the changes to inter-organization contexts when implementing BIM rather than the traditional CAD. A building project team is a collaborative inter-enterprise context, which can be thought of as a large organization in which multiple business units (project participants) pursue common goals within project constraints (Verdecho et al. 2012). In addition, the establishments of intra- and inter- organizational technology deployment are similar (Croteau and Bergeron 2009; De Haes et al. 2012). Thus, full BIM implementation in the building project team context is justified as an organizational evolution (Azhar et al. 2014), because individual participants tend to be stuck to the use of the traditional CAD approach or the use of BIM alone.

Lyytinen and Newman (2008) stated that Leavitt's theory's four-factor classification is good because it is simple, extensive, and sufficiently well defined; it can be, if needed, easily extended with other categories to obtain richer vocabulary. For example, Kwon and Zmud (1987) augmented the theory with the concept of an environment; while other studies have included also culture (Davis et al. 1992).

This study constructs a people, process, technology, and external environment framework by adapting the main factors of Leavitt's theory and the MIT90s framework to study the factors that drive the industry players to change towards full BIM implementation (see Table 2). First, 'people' represent the project participants and their employees. This includes: (1) 'inter-enterprise structure' (Leavitt 1965; Rockart and Scott Morton 1984; Verdecho et al. 2012) associated with the 'business model' (Dahlberg et al. 2016) to emphasize the collaboration between the participants; (2) the 'corporate culture' (Rockart and Scott Morton 1984; Verdecho et al. 2012) to describe the cultural issues in individual participants; and (3) the 'individuals and roles' (Rockart and Scott Morton 1984) to characterize the employees. Second, 'process' refers to various work processes with or without BIM use in the project lifecycle. This component consists of the 'management processes' (Rockart and Scott Morton 1984), the 'tasks' (Dahlberg et al. 2016), and the 'organization's strategy' (Rockart and Scott Morton 1984) because 'strategy' represents the summing of the organization' tasks. Thirdly, 'technology' is the BIM-related tools that are constantly improving. In addition, 'external environment' describes the external driving forces such as the policies that project participants must comply with. Table 2 also presents the attributes of each factor in the adapted framework. This modified classification echoes sentiments in previous studies (Teo and Heng 2007; Teo 2008) which focused on deploying automated quantity take-off system in terms of people, process, and technology in Singapore. Thus, this adapted framework expands the existing literature related to organizational change in the construction industry and can be appropriately used in the Singapore construction industry.

## Method and data presentation

In order to investigate the influence of the drivers on changing towards full BIM implementation in the Singapore construction industry, a questionnaire survey was carried out. The preliminary questionnaire was designed based on the literature review. In a pilot study, interviews were conducted with five BIM experts who were invited to comment on the relevancy, accuracy, readability, and comprehensiveness of the 32 drivers. All the experts had more than three years' experience of implementing BIM in the local construction industry. Among which, three were project manager, corporate BIM manager, and technical manager, respectively, of large construction and development firms with over 10 years' experience in this field, and the other two had over five years' work experience including one quantity surveying in charge from a general construction firm and one senior architectural associate from a large architectural firm. These interviews helped refine the questionnaire. Thus, the drivers presented in Table 1 were validated by the experts. In the final questionnaire, the research objectives and contact details were presented, followed by the first section to profile the respondents and their organizations. Then, the respondents were asked to rate the influence of the 32 drivers on the BIM implementation in one of their building projects, using a five-point Likert scale (1 = very insignificant; 2 = insignificant; 3 = neutral; 4 = significant; and 5 = very significant). According to the 'seven plus or minus two' principle

**Table 2.** Adapted organizational change framework for full BIM implementation in building project context.

| Components | Factors | Attributes | Code | References 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| People | Inter-enterprise structure | Contractual relationship | PE01 | | | | | | | | | | | √ | | | | | √ | | |
| | | Leadership | PE02 | √ | | | | | | | √ | | | | | | | | √ | √ | |
| | | Reward arrangement | PE03 | | | | | | | | | | | √ | | √ | | | | | √ |
| | | Involvement | PE04 | | | | | | | | | | √ | √ | | √ | √ | | | | |
| | | Risk allocation | PE05 | | | | √ | | | | | | | | | | | | | | |
| | | Conflict management | PE06 | | √ | | | | √ | | | | | | | | | | √ | | |
| | Corporate culture | Sharing | PE07 | | | | √ | | √ | | | | | | | | | √ | √ | | |
| | | Willingness to change | PE08 | | | | | | | | | | | √ | | | | √ | | | √ |
| | | Commitment on new ways | PE09 | | | | | | | | √ | | | √ | | | | | √ | | √ |
| | | Trust and transparency | PE10 | √ | | | | | √ | | | | | | | | | | √ | | |
| | Individuals and roles | Mindset and attitude | PE11 | | | | | | | | √ | | | | | | | √ | | √ | √ |
| | | Knowledge, skills and experience | PE12 | | | | | √ | | | √ | | | √ | | | | | √ | | √ |
| | | Training and education | PE13 | √ | | | | | | | | | | | | | | √ | | | |
| Process | Management processes | Communication | PR01 | | | | | | | | √ | | | | √ | | √ | | √ | √ | √ |
| | | Controlling and decision-making | PR02 | | √ | | | | | | | | | √ | | | | √ | √ | | √ |
| | Corporate strategy | Goals and requirements setting | PR03 | | | √ | | | | √ | | | | | | | | | | | |
| | | Vision and mission | PR04 | √ | | | √ | | | √ | | | | | | | | √ | √ | | |
| | | Top management support | PR05 | | | | | | | | √ | | | | | | | √ | √ | | |
| | | Processes alignment | PR06 | | | | | √ | | √ | | | | | | | | | √ | | |
| | Task | Coordination and simulation | PR07 | | | | | | | | | | | | | | | | √ | √ | √ |
| | | Documentation | PR08 | | | | | | | | | | | | | | | | | √ | √ |
| | | Production | PR09 | | | | | | | | √ | √ | | | | | | | | | |
| | | Model management | PR10 | | | | | | | | √ | | | | | | | | | √ | |
| Technology | Infrastructure | Hardware and software solutions | T01 | | | | | √ | | √ | | √ | | | | √ | | | | | √ |
| | Data exchange | Interoperability | T02 | | | | | | | | | √ | | √ | | | | | √ | | √ |
| | Construction method | Prefabrication | T03 | | | | | | | √ | √ | | | | | | | | | | |
| External environment | Socioeconomic environment | Policy | E01 | | | | | | | | | √ | | | | | | | | √ | |
| | | Changing market | E02 | | | | | √ | | | | | | | | | | | | √ | |
| | Technological environment | New technological solutions | E03 | | | | | √ | | | | | | | √ | | | | | √ | |

Notes: 1. Alshaher (2013); 2. Bikson and Eveland (1990); 3. Bobbitt and Behling (1981); 4. Croteau and Bergeron (2009); 5. Dahlberg et al. (2016); 6. Dahlberg (2016); 7. Higgins (2005); 8. Kasimu et al. (2012); 9. Lyytinen and Newman (2008); 10. Mitchell (2013); 11. Price and Chahal (2006); 12. Rockart and Scott Morton (1984); 13. Sarker (2000); 14. Smith et al. (1992); 15. Teo and Heng 2007; 16. Verdecho et al. (2012); 17. Wigand (2007); 18. Wilfling and Baumoel (2011). √ Indicates the inclusion of the specific attribute in the corresponding reference.

**Table 3.** Profile of respondents and their organizations.

| Characteristics | Categorization | N | % | Characteristics | Categorization | N | % |
|---|---|---|---|---|---|---|---|
| *Respondents* | | | | *Organizations* | | | |
| Discipline | Government agent | 2 | 2.3 | Main business | Architectural firm | 18 | 20.9 |
| | Developer | 5 | 5.8 | | Structural engineering firm | 5 | 5.8 |
| | Architect | 21 | 24.4 | | MEP engineering firm | 13 | 15.1 |
| | Structural designer | 8 | 9.3 | | General construction firm | 30 | 34.9 |
| | MEP designer | 9 | 10.5 | | Trade construction firm | 3 | 3.5 |
| | General contractor | 28 | 32.6 | | Facility management firm | 3 | 3.5 |
| | Subcontractor | 6 | 7.0 | | Others | 14 | 16.3 |
| | Supplier/Manufacturer | 2 | 2.3 | | | | |
| | Facility manager | 5 | 5.8 | | | | |
| Work experience | 5–10 years | 39 | 45.3 | Years of BIM adoption | 0 | 9 | 10.5 |
| | 11–15 years | 10 | 11.6 | | 1–3 | 40 | 46.5 |
| | 16–20 years | 8 | 9.3 | | 4–5 | 22 | 25.6 |
| | 21–25 years | 9 | 10.5 | | 6–10 | 13 | 15.1 |
| | >25 years | 20 | 23.3 | | >10 | 2 | 2.3 |

(Miller 1956), the scale of five was adopted in this study, which is convenient for respondents to make their judgments.

The population consisted of all the organizations in the Singapore construction industry. The sampling frame included the BCA, the Urban Redevelopment Authority, the Housing and Development Board (HDB), the building developers registered with the Real Estate Developers' Association of Singapore, the architectural consultancy firms registered with the Singapore Institute of Architects, the structural and mechanical, electrical, and plumbing (MEP) consultancy firms registered with the Association of Consulting Engineers Singapore, the contractors registered with the BCA, and the facility management firms registered with the Association of Property and Facility Managers. Among the contractors, it was considered logical to select only the large ones because they tend to have adequate resources for full BIM implementation. Thus, a total of 692 organizations were approached for this survey. The questionnaires were sent to them through emails or handed to them personally. Finally, a total of 86 completed questionnaires were received. The response rate was 12.43%, which was acceptable because it fell within the general response rate of Singapore surveys range of 10%–15% (Teo et al. 2007).

Table 3 shows the profile of the respondents and their organizations. The top three disciplines of the respondents were: general contractor (32.6%), architect (24.4%), and MEP designer (10.5%). The 14 organizations in the 'others' category included the BCA, the HDB, developers, precasters, and other consultancy firms such as multidisciplinary consultancy firms and a BIM consultancy firm. Thus, the responding organizations can represent the key BIM users in the construction value chain in Singapore. Moreover, since the mandatory BIM implementation took effect in July 2015, under half (43.0%) of the responding organizations had implemented BIM more than three years, implying that the local construction industry had been moving from the traditional project delivery into BIM-based project delivery and was shifting to full BIM implementation. Hence, the data collected are reliable.

As ordinal data, Likert scale ratings have been advocated to be analysed by parametric statistical methods in many studies, such as $t$-test (Binder 1984; Hwang et al. 2014; Zhao et al. 2016). Thus, the one-sample $t$-test was conducted in this study to check whether the respondents significantly agreed on the influence of the 32 drivers on changing towards full BIM implementation. The drivers that obtained mean scores above 3.00 and p-values below 0.05 were deemed critical (Zhao et al. 2014).

## Results and discussion

### CDCs towards full BIM implementation

The data of the respondents' perceptions on the influence of the drivers on changing towards full BIM implementation in building projects in Singapore received a Cronbach's $\alpha$ coefficient value of 0.968, implying high reliability of the data. Table 4 presents the one-sample $t$-test results. 31 out of the 32 drivers obtained mean scores above 3.00 and $p$-values below 0.05, indicating that the 31 factors were critical to changing towards full BIM implementation in building projects in Singapore. In addition, the overall mean scores of the drivers range from 2.90 to 3.99. These drivers were ranked according to their mean scores.

D01, 'BIM vision and leadership from the management', was ranked top (mean = 3.99). This result echoed Autodesk (2012) which found that the BIM implementation in a building project starts with a well-articulated vision that should be sponsored by the executives of the project team. Without the vision of implementing BIM and the executive leadership behind it, the effort to

**Table 4.** CDCs towards full BIM implementation in building projects in Singapore.

| Code | Mean | Overall rank | *p*-value | Classification | Rank within classification | Code | Mean | Overall rank | *p*-value | Classification | Rank within classification |
|---|---|---|---|---|---|---|---|---|---|---|---|
| D04 | 3.81 | 4 | 0.000* | PE | 1 | D13 | 3.57 | 15 | 0.000* | PC | 7 |
| D06 | 3.76 | 6 | 0.000* | PE | 2 | D21 | 3.56 | 16 | 0.000* | PC | 8 |
| D03 | 3.71 | 9 | 0.000* | PE | 3 | D23 | 3.49 | 18 | 0.000* | PC | 9 |
| D02 | 3.66 | 11 | 0.000* | PE | 4 | D16 | 3.43 | 20 | 0.000* | PC | 10 |
| D08 | 3.62 | 12 | 0.000* | PE | 5 | D18 | 3.43 | 20 | 0.001* | PC | 10 |
| D14 | 3.60 | 13 | 0.000* | PE | 6 | D28 | 3.31 | 24 | 0.008* | PC | 12 |
| D12 | 3.45 | 19 | 0.000* | PE | 7 | D24 | 3.29 | 27 | 0.009* | PC | 13 |
| D25 | 3.35 | 23 | 0.005* | PE | 8 | D26 | 3.28 | 28 | 0.010* | PC | 14 |
| D11 | 3.31 | 24 | 0.007* | PE | 9 | D27 | 3.26 | 30 | 0.024* | PC | 15 |
| D10 | 2.90 | 32 | 0.404 | PE | 10 | D19 | 3.23 | 31 | 0.034* | PC | 16 |
| D01 | 3.99 | 1 | 0.000* | PC | 1 | D30 | 3.59 | 14 | 0.000* | T | 1 |
| D17 | 3.92 | 2 | 0.000* | PC | 2 | D22 | 3.55 | 17 | 0.000* | T | 2 |
| D05 | 3.90 | 3 | 0.000* | PC | 3 | D29 | 3.27 | 29 | 0.030* | T | 3 |
| D07 | 3.78 | 5 | 0.000* | PC | 4 | D09 | 3.70 | 10 | 0.000* | E | 1 |
| D15 | 3.74 | 7 | 0.000* | PC | 5 | D31 | 3.40 | 22 | 0.001* | E | 2 |
| D20 | 3.74 | 7 | 0.000* | PC | 5 | D32 | 3.30 | 26 | 0.006* | E | 3 |

Note: *The one-sample *t*-test result is significantly higher than the test value (3.00).

adopt new ways of working will struggle and waste the dedicated resources. D17, 'design coordination between disciplines through clash detection and resolution', received the second position (mean = 3.92) in the overall ranking, substantiating the value of fully coordinated 3D data. Similarly, this result was in line with previous studies (Porwal and Hewage 2013; Sattineni and Mead 2013) which found that full BIM implementation would enable the design team to create a composite and fully coordinated design model for documentation and collaboration in the project. D05, 'owner's requirement and leadership to adopt BIM', was ranked third (mean = 3.90), indicating that the requirement and active participation of the owner would motivate its service providers to implement BIM. This result was consistent with the findings of Arayici et al. (2011) and Azhar et al. (2014) that without the requirement and support from the owner, the service providers may continue to deliver their scopes of work in their accustomed ways, hindering the project-wide BIM implementation.

## Interpretation of CDCs from the organizational change perspective

As mentioned above, it was justified that full BIM implementation in the project team context can be considered as an organizational change, this study interprets the CDCs towards full BIM implementation in building projects in Singapore from the perspective of organizational change. As shown in Figure 4, all the 29 attributes of the adapted organizational change framework can be applied to interpret some of the 31 CDCs.

### People

The relationships between the participating firms are crucial to organizational change in the building project context. The CDC 'increasing use of design-build and fast-track approach' (D25) is closely associated with 'contractual relationship' (PE01) in the attributes of the organizational change framework. As an organizational change, full BIM implementation requires close collaboration among the participants, such as the collaboration between the design team and construction team in design-build projects (Eastman et al. 2011; Azhar et al. 2014). The collaboration needs the participation of all the key participants (the owner, the architect, the engineers, key contractors, the supplier, and the facility manager), especially during the design stage, where they have to co-locate to develop and share digital design models. Thus, D08 can represent 'involvement' (PE04). Besides, since incorrect information providers may suffer from potential liability issues such as claims, the parties tend to be wary of providing information or advice to other parties. The pains and gains should be collectively shared in the team to remove the liability issues. Thus, the CDC 'alignment of the interests of all stakeholders' (D12) can be associated with 'reward arrangement' (PE03), 'risk allocation' (PE05), and 'conflict management' (PE06) in the organizational change attributes. In addition, in the context of mandatory submissions in BIM format in Singapore, regulatory agencies would provide high-level compliance information which leads the project team to design, build, and manage the building using BIM. Their involvement in the design process minimizes agency comments and required changes to the design as submitted for permit (AIACC 2014). Thus, the CDC 'regulatory agencies' early participation to BIM use' (D06) can represent 'leadership' (PE02).

Corporate culture also plays a critical role in organizational change. As mentioned above, the removal of the potential liability concerns would facilitate the direct and continuous sharing of information among the project team, thus D14 can be linked to 'sharing' (PE07). Nevertheless, people tend to respond to change in their

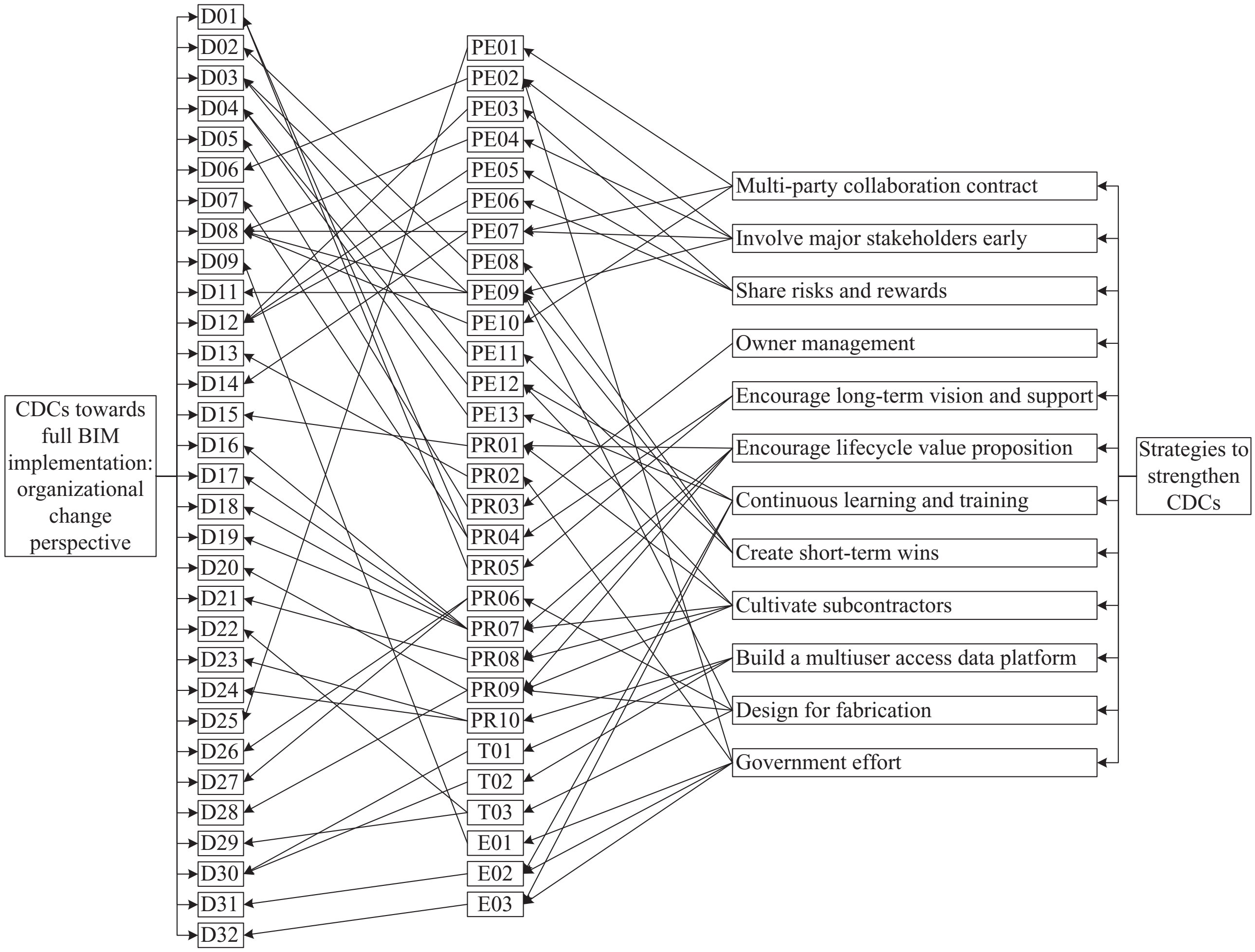


**Figure 4.** Linking CDCs towards full BIM implementation to attributes of the adapted organizational change framework.

accustomed ways when confronted with change (Low 1998). Such usual practice towards change could be influenced by their trust in and awareness of using the new ways of working such as implementing BIM along with OSM. Thus, D02 represents 'willingness to change' (PE08) in the attributes of the organizational change framework, while the CDC 'all disciplines sharing models in a 'Big Room'' (D08) motivates the 'sharing' (PE07), 'commitment on new ways' (PE09), and 'trust and transparency' (PE10) in the project team. Also, two significant CDCs (D03 and D11) related to the implementation of BIM and OSM can be linked to 'commitment on new ways' (PE09) in the organizational change framework.

In addition, when implementing an organizational change, the change agent must ensure that the relevant individuals are able to adapt to the change (Zhao et al. 2014). The implementers of a transformation are the staff working daily on the shop floor (Autodesk 2012). It is worth reiteration that people tend to harbour a biased view of change that fits most comfortably into a person's own perception of the reality (Low 1998). Such negative mindsets toward change may be changed by getting the individuals to understand the advantages of BIM work practices over the traditional drafting practices (Khosrowshahi and Arayici 2012). Thus, D03 could also be associated with 'mindset and attitude' (PE11). Nevertheless, the transformation needs new skills and new ways of working. The executives and staff would not actively participate in full BIM implementation or even undermine it if they lack the relevant expertise. Providing 'training on new skillsets and new ways of working' (D04) to both the management and the staff would equip them with knowledge and skills (Kiani et al. 2015), representing 'knowledge, skills, and experience' (PE12) and 'training and education' (PE13) in the organizational change attributes.

## *Process*

In order to hold together the project organization, management processes are necessary (Rockart and Scott Morton 1984). In the design stage, the use of detailed and accurate 3D models enables the service providers to communicate more clearly and effectively with each other, and with the owner. Fischer et al. (2014) found that it is not uncommon that many owners can only understand 3D models, because they have little or no experience building anything and cannot understand complex two-dimensional shop drawings. Thus, the CDC '3D visualization enabling design communication' (D15) can be associated with 'communication' (PR01). Meanwhile, D13 can be linked to 'controlling and decision-making' since the local BIM standards, guides, and best practices would help the team to control the project throughout the project.

In addition, organizational strategy also plays a critical role in organizational change because of its facilitative nature (Austin and Ciaassen 2008). It should be noted that no established standard fits the situation of every project and its participating firms due to the wide variety of project types and strategic goals. Such governance of standards is not adequate for full BIM implementation in every project. Thus, the 'owner's requirement and leadership to adopt BIM' (D05) is essential, representing 'goals and requirements setting' (PR03). Autodesk (2012) advocated that full BIM implementation is an organizational transformation which starts with executive vision and sponsorship. In order to avoid the pitfalls in a large-scale, radical change such as the change in the building project context, a solid vision should be built. One example of such vision is the long-term competitive advantages that full BIM implementation in this project can give to the service providers to win bids in the future market (Verdecho et al. 2012). Thus, D07 that drives the team to change towards full BIM implementation represents 'vision and mission' (PR04). Ideally, the BIM vision stems from the executives; however, it is common for the mid-tier management to strive to put BIM in the direct focus of the executives and seek for their sponsorship (Autodesk 2012). Therefore, the CDC 'BIM vision and leadership from the management' (D01) can be associated with 'vision and mission' (PR04) and 'top management support' (PR05). In the meantime, the performance improvement on the construction site would also benefit the project team, such as the reduced construction activities, site disruptions, hazard exposures, and site costs resulted from moving on-site activities to a factory environment (Blismas and Wakefield 2009; McFarlane and Stehle 2014). Hence, two significant CDCs (D26 and D27) related to the implementation of BIM along with OSM can be closely associated with 'process alignment' (PR06) in the organizational change attributes.

Although the organizational transformation begins with the vision supported by the management of the owner and the service providers, it is ultimately carried out through the effort on the shop floor by the individuals who would apply BIM in their day-to-day tasks (Autodesk 2012). The functions of digital information models and the management of the models facilitate the individuals to carry out the tasks, driving full BIM implementation in the project. Specifically, four CDCs (D16-D19) related to the development of optimal design models can be associated with 'coordination and simulation' (PR07). The project team can coordinate the models shared by specific disciplines and perform analysis for sustainability, material selection, constructability, operations, and so on (Eastman et al. 2011; Kunz and Fischer 2012; Chua and Yeoh 2015). Downstream parties can document the design intent and construction intent from the fully coordinated design models. Thus, D21 can represent 'documentation' (PR08). In the meantime, key contractors and manufacturers are able to use the design models shared by the design team as bases for producing their construction models and fabrication models as well as required drawings (Gao and Fischer 2006; Porwal and Hewage 2013). Thus, two CDCs (D20 and D28) can be associated with 'production' (PR09). Furthermore, D23 and D24 can be linked to 'model management' (PR10) which describes the functional and organizational relationships of design, construction, and facility management. Whenever changes (especially unexpected and late scope changes) take place, all these models can be easily updated. More importantly, the project lifecycle implications of the changes can be predicted in the digital models and thus better managed before changes would traditionally occur in the later stages of the project (Gao and Fischer 2006; Khosrowshahi and Arayici 2012).

### Technology

Successful organizational change needs constantly advancing technologies which help the participating firms in the project to work more efficiently (Azhar et al. 2014). 'Integrating model management tools with enterprise systems to share data' (D30) can be associated with 'hardware and software solutions' (T01) and 'interoperability' (T02) in the attributes of the adapted organizational change framework. This is because such integration not only facilitates the data sharing in individual parties, but also enables the parties to access the models and exchange data conveniently with each other. Meanwhile, D22 and D29 can represent 'prefabrication' (T03). OSM has emerged as a new construction method and has gained wide recognition in previous studies (Blismas and Wakefield 2009; McFarlane and Stehle 2014). Kunz and Fischer (2012) argued that the project may use automated method to carry out routine design tasks or to help fabricate more standard building products in a factory. On-site activities would be compressed and result in fewer workers and less waste on sites, reducing costs (McFarlane and Stehle 2014). Therefore, the CDC 'more off-site fabrication and assembly of standard elements' (D22) would motivate the project team to implement BIM fully.

### External environment

As mentioned above, the driving forces in the external environment can push the internal components (people, process, and technology) of the project organization into motion until reaching a new equilibrium (Rockart and Scott Morton 1984; Wigand 2007). As the construction market becomes increasingly complex and requires new skill sets and increasing specializations, the Singapore government has been offering the second BIM fund since July 2015 to the local construction industry to subsidize part of the initials costs in training, consultancy, software, and hardware, aiming to motivate BIM-ready firms to grow collaboration capabilities beyond just modelling (BCA 2016). Thus, D31 can be linked to 'changing market' (E02) and 'government support such as subsidizing training, software, and consultancy costs' (D09) can be closely associated with 'policy' (E01) in the attributes of organizational change. Meanwhile, since the technologies related to BIM have been constantly improving, more powerful hardware and a wide range of software applications can be selected to help the project participants to implement BIM fully. For example, computer numerically controlled machines can be used to automate the manufacturing of standard building products for field installation (Kunz and Fischer 2012), driving the team to change to increase the use of OSM. Hence, D32 can be associated with 'new technological solutions' (E03) in the organizational change attributes.

### Importance of organizational change attributes for full BIM implementation

Among the top 10 CDCs in the overall ranking of mean scores in Table 4, the aforementioned top three CDCs and overall six positions (D01, D17, D05, D07, D15, and D20) can be interpreted by some of the six organizational change attributes on process aspect, namely 'vision and mission' (PR04), 'top management support' (PR05), 'coordination and simulation' (PR07), 'goals and requirements setting' (PR03), 'communication' (PR01), and 'production' (PR09), respectively; three CDCs (D04, D06, and D03) are linked to 'knowledge, skills, and experience' (PE12), 'training and education' (PE13), 'leadership' (PE02), 'mindset and attitude' (PE11), and 'commitment on new ways' (PE09) on people aspect; D09 is associated with 'policy' (E01) on external environment aspect. It is notable that none of these CDCs represents the attributes on technology aspect.

Hence, the six organizational change attributes on process aspect are more critical areas in the successful change towards full BIM implementation in the Singapore construction industry. The project management team should prioritize their efforts and resources to these key areas. This result substantiated the argument of Eastman et al. (2011) that the most important driver would be the good information quality provided by the fully coordinated design and construction models. These models enhance visualization and design analyses, facilitate the use of standard building products, and allow for maintenance and operations.

Meanwhile, the project team should not neglect the five attributes (PE12, PE13, PE02, PE11, and PE09) on people aspect. In order to complete the project more efficiently, the owner has to build the knowledge and skills of its service providers such as by introducing training programmes, which facilitates them to adapt to the new ways of designing, building, and managing the building. In addition, the significant attribute 'policy' (E01) on external environment aspect would catalyse the more critical attributes on process and people aspects. It had been no more than five years since the building planning submissions in BIM format became mandatory in building projects in Singapore. Thus, many firms, especially small- and medium- sized enterprises, were still not experienced in delivering their scopes of BIM work (Kiani et al. 2015). So, more incentives from the local government would drive the industry to enhance BIM implementation.

Therefore, as Leavitt's diamond theory and the MIT90s framework indicate, the project team should understand that instead of separating the key areas identified on process, people, and external environment aspects, the interaction and integration between these areas would facilitate more successful changes towards full BIM implementation in the construction industry.

### Strategies to strengthen the CDCs

As shown in Figure 4, all the 31 CDCs were interpreted with some of the 29 attributes of the adapted organizational change framework. Based on these interpretation, a total of 12 possible strategies were identified to strengthen the positive influence from these CDCs from the organizational change perspective.

### *Multi-party collaboration contract*

Improving the contractual relationships among the project team is vital since the traditional contractual frameworks lead to adversarial working relationships in implementing BIM (Fischer et al. 2014). A multi-party collaboration contract in the project team enhances the collaboration among all the key participants since it allows and ideally incentivizes the information sharing among the key participants, beyond the design-build team (Kunz and Fischer 2012). Meanwhile, the enhanced relationship may contribute to build the trust in and respect for the other team members. Thus, such a contract can strength the model 'sharing' (PE07) and the 'trust and transparency' (PE10) in the project team as well as the collaborative relationships governed by the widely-used design-build framework (D25) associated with 'contractual relationship' (PE01) in the organizational change attributes.

### *Involve major stakeholders early*

The early involvement of the key stakeholders from the early design stage or even before facilitates the collaboration between the stakeholders and helps to create the optimal digital design models since key contractors and the facility manager can input their construction and operations expertise, respectively, and assist to create models in the design process (Gao and Fischer 2006; Kunz and Fischer 2012). In the early design stage, the regulatory agencies would provide high-level compliance information which leads the project team to implement BIM fully to design, build, and manage the building. Their involvement would significantly avoid the required changes to the design as submitted for permit (AIACC 2014). Thus, the early involvement of the government agencies (D06) enhance the 'leadership' (PE02) in the change towards full BIM implementation in the construction industry, while the other key participants' early involvement can strength the positive influence from the CDC 'all disciplines sharing models in a 'Big Room'' (D08) on 'involvement' (PE04), 'sharing' (PE07), and 'commitment on new ways' (PE09) in the attributes of organization change.

### *Share risks and rewards*

After the major stakeholders are bound by the interlocking collaboration contract, the sharing of risks and financial benefits can force them to be responsible for the whole project rather than trying to escape by shifting the blame to other parties in the project team when a problem occurs (AIACC 2014). This reduces all the stakeholders' anxiety to express their opinion which may help to solve significant project issues. Therefore, the shared risks and rewards can enhance the positive influence from the 'alignment of the interests of all stakeholders' (D12) on 'reward arrangement' (PE03), 'risk allocation' (PE05), and 'conflict management' (PE06) in the organizational change attributes.

### *Owner management*

It is the owner that makes decisions on whether or not to implement BIM and on the pace of changing towards full BIM implementation in the project organization. The lack of owner request or initiative would limit the interest and willingness of the service providers to implement BIM in practice (Arayici et al. 2011; Kunz and Fischer 2012; Zahrizan et al. 2013). Considering the first cost and apparent risk rather than the potential value as crucial selection criteria would limit the owner's insight into the BIM implementation in the project. Moreover, without the use of BIM in the design, owner-elected changes and their lifecycle implications tend to be costly. Therefore, the owner should rebuild its selection criteria when starting a new project, which strengthens the positive influence from the 'owner's requirement and leadership to adopt BIM' (D05) associated with 'goals and requirements setting' (PR03).

### *Encourage long-term vision and support*

Organizational change starts with executive vision and sponsorship. The senior management of the owner and the major stakeholders is very much encouraged to have the insight into the potential value of implementing BIM over the traditional drafting practices in the project (Khosrowshahi and Arayici 2012), because such value would give them a competitive edge that help win bids in the future market. Meanwhile, the solid vision of the project team can be built through the high-profile communication among all the major stakeholders, not only a few participating firms (Autodesk 2012). The significant CDC 'gaining competitive advantages from full BIM use' (D07) representing 'vision and mission' (PR04) can be strengthened by such a solid project vision. On the other hand, the top management needs to convey the vision to the staff working on the shop floor where the project vision is realized. Without the leadership and support from the top management, the staff cannot get the energy in the organizational transformation. This was consistent with the survey finding that the respondents cited the 'BIM vision and leadership from the management' (D01) as their top motivation. Thus, the long-term vision and support can enhance the positive influence from the top CDC (D01) associated with 'vision and mission' (PR04) and 'top management support' (PR05) in the attributes of organizational change.

### *Encourage lifecycle value proposition*

In the project organization, the architect, engineers, and contractors tend to be stuck to the cost minimization of delivering their scopes of work, but rarely try to maximize the value of their work (Kunz and Fischer 2012). Previous studies (Sattineni and Mead 2013; Lam 2014) noted that the project delivery currently adopted in the construction industry would cause many issues such as inefficient processes, repeated efforts, and liability anxieties; for example, it is common for the architecture and engineering team to create one design model, and for the main contractor and specialty contractors to develop their own model based on the information provided to them. This is because the design model is created without considering downstream uses and the contractors are not involved in the design process, which does not maximize the value of the design work. In contrast, full BIM implementation requires the architectural model to be shared with the engineers for creating their models on the same design; the key contractors are also involved in the design stage and get the design models as bases for creating their construction models (Gao and Fischer 2006; Porwal and Hewage 2013). This process would create constant value throughout the project. In addition, periodical project meetings can be arranged to enhance the BIM use in the day-to-day activities on the shop floor to realize the vision. Thus, this strategy can strengthen the positive influences from seven CDCs (D15-D21) associated with management processes and daily tasks, namely 'communication' (PR01), 'coordination and simulation' (PR07), 'documentation' (PR08), and 'production' (PR09) in the organizational change attributes.

### *Continuous learning and training*

Full BIM implementation in the project organization is a process of continual examination and improvement. It also requires continuous learning and testing of sometimes new and misunderstood BIM concepts (Autodesk 2012), so the project team needs continuous training to support the adoption of BIM into the daily work. As support from the management, project-wide training programmes can be arranged by the owner and in-house education by individual parties (Azhar et al. 2014; Kiani et al. 2015). Such programmes would motivate the participants and build up valuable intellectual capital in the organization. Thus, this strategy can strengthen the significant CDC 'training on new skillsets and new ways of working' (D04) pertaining to 'knowledge, skills, and experience' (PE12) and 'training and education' (PE13), and enhance the grasp of new technological skills (D32 and E03) and the adaption to the complex and changing market (D31 and E02).

### *Create short-term wins*

After the training and staggering start of implementing BIM in the project, creating milestones would help the project organization to overcome the initial paralysis of continually carrying out BIM practices (Autodesk 2012). Once accomplished, the short-term milestones can generate energy and motivate the major participants to implement their part of BIM in changing towards full BIM implementation in the project (Khosrowshahi and Arayici 2012; Kiani et al. 2015). The short-term wins can convince the management team and the staff that the BIM implementation in their project can add value rather than increase cost and risk (Teo and Heng 2007; Zhao et al. 2014). Therefore, this strategy drives the project organization to conduct cultural change to obtain advantages over the competitors (Arayici et al. 2011; Azhar et al. 2014; Kiani et al. 2015), strengthening the CDC 'stakeholders seeing the value of adopting their own part of BIM' (D03) representing 'commitment on new ways' (PE09) and 'mindset and attitude' (PE11) and the CDC 'changes in organizational structure and culture' (D02) associated with 'willingness to change' (PE08) in the organizational change attributes.

### *Cultivate subcontractors*

The large number of specialty contractors engaged in the project tend to lack adequate knowledge and skillsets to implement BIM and thus appear to still be happy to submit their drawings in traditional drafting format (Lam 2014). Thus, if the other stakeholders cultivate the subcontractors by spearheading the model development, visualization, coordination, and simulation for them, a number of management processes and daily tasks can be efficiently completed to truly realize the solid vision of implementing BIM fully in the project. For example, the MEP specialty contractors can contribute their construction expertise in the creation and coordination of MEP design models, which in turn guides their construction work on site (Khanzode et al. 2007). Thus, this strategy provides further evidence to enhance the positive influence from D04 representing 'knowledge, skills, and experience' (PE12) and from the seven CDCs (D15-D21) pertaining to four organizational change attributes (PR01 and PR07-PR09).

### *Build a multiuser access data platform*

In order to strengthen the information exchange and management, the project team may build a data platform that allows all the key participants to access and link it with their own data management systems. For instance, this platform would facilitate to upload submittals by the main contractor and specialty contractors, provide feedback by the owner and the design team, update the design models to deal with changes and their lifecycle implications, and retrieve the latest models and documents. Thus, the positive influence from two CDCs (D23 and D24) associated with ‘model management’ (PR10) and from the CDC ‘integrating model management tools with enterprise systems to exchange data’ (D30) pertaining to ‘hardware and software solutions’ (T01) and ‘interoperability’ (T02) can be enhanced by such a data platform.

### *Design for fabrication*

Changing the design philosophy that was based on traditional methods plays an important role in the organizational change (Blismas and Wakefield 2009). The early involvement of the contractors and suppliers facilitates the design for maximizing off-site production and assembly and leaving minimum assembly work on site (McFarlane and Stehle 2014). This would optimize manufacturing functions, standardize design and manufacturing processes, reduce safety risks in a factory environment, ensure maximum quality, and simplify construction processes (Belay 2009). Thus, this strategy would strengthen the positive influence from D11 associated with ‘commitment on new ways’ (PE09), from two CDCs (D26 and D27) representing ‘process alignment’ (PR06), from D28 associated with ‘production’ (PR09), and from two CDCs (D22 and D29) representing ‘prefabrication’ (T03) in the attributes of organizational change.

### *Government effort*

The lack of government involvement as well as national standards and guidelines for contractors is another concern (Zahrizan et al. 2013). Cheng and Lu (2015) observed that Singapore is a leading country for standards development in Asia because the local government had developed 12 out of the 35 BIM standards in Asia. For example, the second version of the Singapore BIM guide was released by the BCA in 2013 to outline the roles and duties of the major stakeholders in implementing BIM at different stages of the project (BCA 2013). Meanwhile, the Singapore government has incentivized the industry to adopt productive technologies such as prefab prefinished volumetric construction to manage the future requirements of the changing industry. A greater extent of OSM has been stipulated as part of the tender conditions for industrial government land sales sites (Ministry of Finance 2014). Hence, the continuous efforts made by the government will largely strengthen the ‘leadership’ (PE02) by the government (D06), the BIM governance of related policies and standards (D13) associated with ‘controlling and decision-making’ (PR02), the ‘government support such as subsidizing training, software, and consultancy costs’ (D09) representing ‘policy’ (E01), and two CDCs (D31 and D32) pertaining to ‘external economic and technological environment’ in the adapted organizational change framework.

## Conclusion and recommendation

This study has interpreted full BIM implementation in the Singapore construction industry from an organizational change perspective. Through the comprehensive literature review, 32 drivers for change towards full BIM implementation were identified. The questionnaire survey was performed in the Singapore construction industry to collect the data related to the influence of these drivers on changing towards full BIM implementation. The analysis results indicated that 31 drivers had significant influence. In addition, conceptualizing full BIM implementation in the building project context as an organizational change, this study interpreted the 31 CDCs with an organizational change framework adapted from existing organizational change theories. Specifically, all the 29 attributes in the adapted framework were linked to some of the 31 CDCs. It was found that while the attributes on process aspect are the most influential, the attributes on people and external environment should be considered in the meantime for the overall success of the organizational change in the building project context. Lastly, 12 strategies were identified to strengthen the CDCs towards full BIM implementation.

Although the objectives were achieved, there were some limitations to the conclusions. First, the 32 drivers identified from the literature review may not be exhaustive enough or continue to hold true as time passes. Second, the single-source data collected in the Singapore construction industry are likely to cause common method biases (Jiang and Wang 2014; Jiang and Jiang 2015), which is a common limitation of studies using questionnaire surveys (Zhao et al. 2016). In addition, the findings from this study were well interpreted in the Singapore context, which may differ from the context of other countries. Nevertheless, the theoretical and practical implications drawn from this study are not limited to the building projects in Singapore. It should be noted that the theoretical rational behind the CDCs can be used globally to interpret the drivers for change towards full BIM implementation in building projects. Additionally, overseas project teams can use the drivers and their associated strategies identified in this study to customize their own lists of drivers and strategies to strengthen the drivers, because other countries also tend to encourage or specify the BIM implementation in their construction and building projects (Smith 2014). In addition, since little research has been carried out to investigate full BIM implementation in the construction industry as an organizational evolution, this study interpreted the CDCs towards full BIM implementation with the adapted organizational change framework, thus expanding the existing literature related to BIM implementation.

Future publications for this study would conduct in-depth case studies that may disclose how project teams manage the positive influence from the CDCs to diminish the negative influence of the non-value adding activities carried out by the major stakeholders in the building projects in Singapore. Apart from the lack of contractor input in the design stage, plenty of other non-value adding activities exist in the current industry practices, such as no pre-agreed business interests sharing arrangements from the beginning and low proportion of building components being completed with OSM during construction. Non-value adding work holds a considerable portion in most construction processes and even exceeds 50% of the total work in some cases (Nikakhtar et al. 2015). Thus, a comprehensive checklist of the non-value adding activities in different project stages in the Singapore construction industry should be developed. Such activities usually cause detrimental inefficiencies such as design errors, requests for information, change orders, and reworks in the project lifecycle (Chelson 2010), significantly hindering the change towards full BIM implementation in the construction industry. A set of key inefficiencies for the local building industry should also be established. The identification of the non-value adding activities and inefficiencies would be valuable for evaluating the change performance in these case projects, which in turn would purposely and efficiently guide the project teams to change towards full BIM implementation. Using the outcomes, specific action plans would be identified to reduce the non-value adding activities.

## Disclosure statement

No potential conflict of interest was reported by the authors.

## ORCID

*Longhui Liao* http://orcid.org/0000-0003-2743-9104

## References

AIACC. 2014. Integrated project delivery: an updated working definition. Sacramento (CA): American Institute of Architects, California Council.

Alshaher AAF. 2013. The Mckinsey 7S model framework for e-learning system readiness assessment. Int J Adv Eng Technol. 6(5):1948–1966.

Aranda-Mena G, Crawford J, Chevez A, Froese T. 2009. Building information modelling demystified: does it make business sense to adopt BIM? Int J Managing Projects Bus. 2(3):419–434.

Arayici Y, Coates P, Koskela L, Kagioglou M, Usher C, O'Reilly K. 2011. BIM adoption and implementation for architectural practices. Struct Surv. 29(1):7–25.

Austin MJ, Ciaassen J. 2008. Impact of organizational change on organizational culture. J Evidence-Based Soc Work. 5(1):321–359.

Autodesk. 2012. A framework for implementing a BIM business transformation. San Rafael (CA): Autodesk.

Azhar N, Kang Y, Ahmad IU. 2014. Factors influencing integrated project delivery in publicly owned construction projects: an information modelling perspective. Procedia Eng. 77:213–221.

BCA. 2013. Singapore BIM guide version 2. Singapore: Building and Construction Authority.

BCA. 2016. Reaching new milestones with design for manufacturing and assembly. Build smart Singapore: Building Constr Auth.

Belay AM. 2009. Design for manufacturability and concurrent engineering for product development. World Acad Sci Eng Technol. 25:240–246.

Bernstein PG, Pittman JH. 2004. Barriers to the adoption of building information modelling in the building industry. Autodesk.

Bikson TK, Eveland JD. 1990. The interplay of work group structures and computer support. In: Galegher J, Kraut R, Egido C, editors. Intellectual teamwork: social and technological foundations of cooperative work. Hillsdale (NJ): Lawrence Erlbaum; p. 245–289.

Binder A. 1984. Restrictions on statistics imposed by method of measurement: some reality, much mythology. J Crim Justice. 12(5):467–481.

Blismas N, Pasquire C, Gibb A. 2006. Benefit evaluation for offsite production in construction. Const Manage Econ. 24(2):121–130.

Blismas N, Wakefield R. 2009. Drivers, constraints and the future of offsite manufacture in Australia. Const Innov. 9(1):72–83.

Bobbitt HR Jr, Behling OC. 1981. Organizational behavior: a review of the literature. JHigher Educ. 5:29–44.

Chandler AD. 1962. Strategic and structure: chapters in the history of American industrial enterprise. Cambridge (MA): MIT Press.

Chelson DE. 2010. The effects of building information modeling on construction site productivity. [Doctoral dissertation]. College Park (MD): University of Maryland, College Park.

Cheng JC, Lu Q. 2015. A review of the efforts and roles of the public sector for BIM adoption worldwide. J Inform Technol Constr. 20:442–478.

Chua DK, Yeoh JK. 2015. Understanding the science of virtual design and construction: what it takes to go beyond building information modelling. In: O'Brien WJ, Ponticelli S, editors. Proceedings of the 2015 International Workshop on Computing in Civil Engineering; 2015 Jun 21–23; Austin (TX):

Croteau AM, Bergeron F. 2009. Interorganizational governance of information technology. In: Proceedings of the 42nd Hawaii International Conference on System Sciences; 2009 Jan 05–08; Waikoloa (HI); Washington (DC): IEEE Computer Society.

Dahlberg T, Hokkanen P, Newman M. 2016. How Business strategy and technology impact the role and the tasks of

CIOs: an evolutionary model. IntJ IT/Bus Align Gov (IJIT-BAG). 7(1):1–19.
Dahlberg T. 2016. The creation of inter-organisational IT governance for social welfare and healthcare IT-lessons from a case study. Int J Netw Virtual Organisations. 16(1):38–71.
Davis GB, Lee AS, Nickles KR, Chatterjee S, Hartung R, Wu Y. 1992. Diagnosis of an information system failure: a framework and interpretive process. Inform Manage. 23(5):293–318.
De Haes S, Van Grembergen W, Gemke D, Thorp J. 2012. Inter-organizational governance of information technology: learning from a global multi-business-unit environment. Int J IT/Bus Align Gov. 3(1):27–46.
Eastman C, Teicholz P, Sacks R, Liston K. 2011. BIM handbook: a guide to building information modeling for owners, managers, designers, engineers and contractors. 2nd ed. Hoboken (NJ): John Wiley & Sons.
El Asmar M, Hanna AS, Loh WY. 2013. Quantifying performance for the integrated project delivery system as compared to established delivery systems. J Constr Eng Manage. 139(11):04013012.
Fischer M, Reed D, Khanzode A, Ashcraft H. 2014. A simple framework for integrated project delivery. In: Kalsaas BT, Koskela L, Saurin TA, editors. Proceedings of the 22nd Annual Conference of the International Group for Lean Construction; 2014 Jun 25–27; Oslo (Norway).
Fischer M. 2008. Reshaping the life cycle process with virtual design and construction methods. In: Brandon P, Kocatürk T, editors. Virtual futures for design, construction and procurement. Malden (MA): Blackwell Publishing Ltd; p. 104–112.
Gao J, Fischer M. 2006. Case studies on the implementation and impacts of virtual design and construction (VDC) in Finland. Stanford (CA): Stanford University, Center for Integrated Facility Engineering.
Gibb A, Isack F. 2003. Re-engineering through pre-assembly: client expectations and drivers. Build Res Inform. 31(2):146–160.
Higgins JM. 2005. The eight 'S's of successful strategy execution. J Change Manage. 5(1):3–13.
Hwang BG, Zhao X, Goh KJ. 2014. Investigating the client-related rework in building projects: the case of Singapore. Int J Project Manage. 32:698–708.
Jiang Z, Jiang X. 2015. Core self-evaluation and life satisfaction: the person-environment fit perspective. Pers Individ Differ. 75:68–73.
Jiang Z, Wang Z. 2014. Entrepreneurial intention and outcome expectancy: evidence from South Korea and China. Contemp Manage Res. 10:251–270.
Juan YK, Lai WY, Shih SG. 2017. Building information modeling acceptance and readiness assessment in Taiwanese architectural firms. J Civil Eng Manage. 23(3):356–367.
Kasimu MA, Roslan BA, Fadhlin BA. 2012. Knowledge management models in civil engineering construction firms in Nigeria. Interdiscip JContemp Res Bus. 4(6):936–950.
Kent DC, Becerik-Gerber B. 2010. Understanding construction industry experience and attitudes toward integrated project delivery. J Constr Eng Manage. 136(8):815–825.
Khanzode A, Fisher M, Reed D. 2007. Challenges and benefits of implementing virtual design and construction technologies for coordination of mechanical, electrical, and plumbing systems on large healthcare project. In: Proceedings of the 24th CIB W78 Conference; 2007 June 27–29. Maribor (Slovenia).
Khosrowshahi F, Arayici Y. 2012. Roadmap for implementation of BIM in the UK construction industry. Eng Constr Archit Manage. 19(6):610–635.
Kiani I, Sadeghifam AN, Ghomi SK, Marsono AKB. 2015. Barriers to implementation of Building Information Modeling in scheduling and planning phase in Iran. Aust J Basic Appl Sci. 9(5):91–97.
Kunz J, Fischer M. 2012. Virtual design and construction: themes, case studies and implementation suggestions. Stanford (CA): Stanford University, Center for Integrated Facility Engineering;
Kwon TH, Zmud R. 1987. Unifying the fragmented models of information systems implementation. In: Boland R, Hirschheim R, editors. Critical issues in information systems research. New York: John Wiley & Sons, Inc; p. 227–251.
Lam SW. 2014. The Singapore BIM roadmap [Internet]. Available from: http://bimsg.org/wp-content/uploads/2014/10/BIM-SYMPOSIUM_MR-LAM-SIEW-WAH_Oct-13-v6.pdf
Leavitt HJ. 1965. Applied organizational change in industry: structural, technological and humanistic approaches. In: March J, editor. Handbook of organizations. Chicago (IL): Rand McNally; p.1144–1170.
Li H, Lu W, Huang T. 2009. Rethinking project management and exploring virtual design and construction as a potential solution. Constr Manage Econ. 27(4):363–371.
Liao L, Teo EAL, Low SP. 2017. A project management framework for enhanced productivity performance using building information modelling. Constr Econ Build. 17(3):1–26.
Low SP. 1998. Managing total service quality: a systemic view. Manag Ser Qual. 8(1):34–45.
Lyytinen K, Newman M. 2008. Explaining information systems change: a punctuated socio-technical change model. Eur J Inf Syst. 17(6):589–613.
McFarlane A, Stehle J. 2014. DfMA: engineering the future. In: Proceedings of Council on Tall Buildings and Urban Habitat (CTBUH) Shanghai International Conference; 2014 Sept 16-19; Shanghai (China).
Michel A, By RT, Burnes B. 2013. The limitations of dispositional resistance in relation to organizational change. Manage Decis. 51(4):761–780.
Miller GA. 1956. The magical number seven, plus or minus two: some limits on our capacity for processing information. Psychol Rev. 63(2):81–97.
Ministry of Finance. 2014. Budget 2014 – opportunities for the future, assurance for our seniors. Singapore: Ministry of Finance.
Mistry V. 2008. Benchmarking e-learning: trialling the "MIT90s" framework. Benchmarking: Int J. 15(3):326–340.
Mitchell G. 2013. Selecting the best theory to implement planned change: improving the workplace requires staff to be involved and innovations to be maintained. Nurs Manage. 20(1):32–37.
Nikakhtar A, Hosseini AA, Wong KY, Zavichi A. 2015. Application of lean construction principles to reduce construction process waste using computer simulation: a case study. Int J Ser Operat Manage. 20(4):461–480.
Pardo-del-Val M, Martínez-Fuentes C, Roig-Dobón S. 2012. Participative management and its influence on organizational change. Manage Decis. 50(10):1843–1860.

Porwal A, Hewage KN. 2013. Building information modeling (BIM) partnering framework for public construction projects. Automat Constr. 31:204–214.
Price AD, Chahal K. 2006. A strategic framework for change management. Constr Manage Econ. 24(3):237–251.
Ranjbari M. 2013. A model in information management system using interior relation layers. Global J Sci Eng Technol. 5:108–113.
Rockart JF, Scott Morton MS. 1984. Implications of changes in information technology for corporate strategy. Interfaces. 14(1):84–95.
Ross K, Cartwright P, Novakovic O. 2006. A guide to modern methods of construction. Bucks: NHBC Foundation, IHS BRE Press.
Sarker S. 2000. Toward a methodology for managing information systems implementation: a social constructivist perspective. Informing Sci. 3(4):195–206.
Sattineni A, Mead K. 2013. Coordination guidelines for virtual design and construction. In: Proceedings of the 30th International Association for Automation and Robotics in Construction; 2013 Aug 11–15; Montreal (Canada).
Scott Morton M. 1991. The corporation of the 1990s: information technology and organisational transformation. Oxford: Oxford University Press.
Selvaraj P, Radhakrishnan P, Adithan M. 2009. An integrated approach to design for manufacturing and assembly based on reduction of product development time and cost. Int J Adv Manuf Technol. 42(1–2):13–29.
Smith C, Norton B, Ellis D. 1992. Leavitt's diamond and the flatter library: a case study in organizational change. Library Manage. 13(5):18–22.
Smith P. 2014. BIM implementation – global strategies. Procedia Eng. 85:482–492.
Teo AL, Heng PSN. 2007. Deployment framework to promote the adoption of automated quantities taking-off system. In: Zou PXW, Newton S, Wang J, editors. Proceedings of CRIOCM 2007 International Research Symposium on Advancement of Construction Management and Real Estate. 8–13 August 2007; Sydney (Australia).
Teo AL. 2008. Online survey: factors deterring the development of automated quantity taking-off system. In: Proceedings of CIB W055 – W065 Joint International Symposium; 2008 Nov 15–17; Dubai (United Arab Emirates).
Teo EAL, Chan SL, Tan PH. 2007. Empirical investigation into factors affecting exporting construction services in SMEs in Singapore. J Constr Eng Manage. 133(8):582–591.
Verdecho MJ, Alfaro-Saiz JJ, Rodriguez-Rodriguez R, Ortiz-Bas A. 2012. A multi-criteria approach for managing inter-enterprise collaborative relationships. Omega. 40:249–263.
Wigand D. 2007. Building on Leavitt's diamond model of organizations: the organizational interaction diamond model and the impact of information technology on structure, people, and tasks. In: Proceedings of the 13th Americas Conference on Information Systems; 2007 Aug 10–12. Keystone (CO).
Wilfling S, Baumoel U. 2011. A comprehensive information model for business change projects. In: Proceedings of the 17th Americas Conference on Information Systems; 2011 Aug 4–8; Detroit (MI).
Won J, Lee G, Dossick C, Messner J. 2013. Where to focus for successful adoption of building information modeling within organization. J Constr Eng Manage. 139(11):04013014.
Zahrizan Z, Ali NM, Haron AT, Marshall-Ponting A, Hamid ZA. 2013. Exploring the adoption of building information modelling (BIM) in the Malaysian construction industry: a qualitative approach. Int J Res Eng Technol. 2(8):384–395.
Zhao X, Hwang BG, Lee HN. 2016. Identifying critical leadership styles of project managers for green building projects. Int J Constr Manage. 16(2):150–160.
Zhao X, Hwang BG, Low SP. 2014. Enterprise risk management implementation in construction firms: an organizational change perspective. Manage Dec. 52(5):814–833.