Achieving leanness with BIM-based integrated data management in a building project

Abstract

Purpose: Various concepts and techniques have been introduced to the built environment to improve its efficiency, and the effectiveness of these initiatives in projects is of immense significance to building production. Among these initiatives, lean construction and building information modelling (BIM) are two mainstream endeavours that share a number of principles to enhance the productivity of the built environment sector. This study aims to explain and explore how BIM-based integrated data management (IDM) facilitates the achievement of leanness in a building project.

Design/methodology/approach: This study is conducted through an ethnographic-action research that relies on the design-science approach and case study through a collaborative research project. As participants of the project, the researchers of this study cooperate with the practitioners to design the project approach and production workflows. Research data and evidence are obtained via participative observation, including direct observation, informal interviews, document analysis, and reflections on the actual situations.

Findings: This study adopts both the project and production perspectives to clarify BIM-based IDM in building design and construction, and analyse how BIM facilitates the achievement of leanness in a building project. The developed BIM-based IDM framework helps to organise miscellaneous information and data, as well as enhance multidisciplinary collaboration throughout the project life cycle. Also, the role of the integrated BIM model as an information hub between the building design and building construction has been identified.

Research limitations/implications: The project and production views of building and construction are employed in this study because the research purpose is to link the BIM-based IDM to lean construction. Although this mixed perspective may undermine the theoretical foundation of this study, the comprehensive understanding of implementing lean construction with BIM in the building project can be gained.

Social implications: This study provides a mixed perspective to understand how BIM-based IDM realise lean construction and implications for implementing lean construction with BIM through IDM.

Originality/value: This study provides new insights into IDM in a building project and presents BIM-based frameworks for IDM to achieve lean construction with BIM.

Keywords: Building information modelling (BIM), Lean construction, Integrated data management (IDM), Project management, Virtual design and construction (VDC), Building production

Article Type: Research paper

Introduction

The production of facilities in the built environment is organised as projects. The project accommodates multiple production teams with various interests, responsibilities, and specialties , and involves numerous procedures and works. Accordingly, handling the information generated in the process of building production can be an arduous task to complete. This issue becomes more acute, with the segmented feature of the built environment sector (Dawood et al., 2002, Beatham et al., 2004, Egan, 1998).

To improve the efficacy of information management, a series of information and communication technologies (ICTs) have been introduced to the built environment. These ICTs have a profound influence on the building project from both technical and managerial perspectives (Froese, 2010, Adriaanse et al., 2010, Jacobsson and Linderoth, 2010). Yet, it is difficult to analyse such influence of ICT on the built environment in general as the adoption of ICTs involves a large volume of complex work embedded in various procedures (Leite et al., 2016).

Building information modelling (BIM) is one type of ICTs that affects the different levels of the building sector (Pour Rahimian et al., 2014). BIM is originally referred to as the 'building description system' by Eastman et al. (1974) and has developed for several decades along with its extensive practical application. BIM enables a digital simulation for building and construction, provides building information for project activities and facilitates the realisation of project objectives (Bryde et al., 2013, Azhar, 2011). In addition, BIM updates the context for the participants to work in regarding the different aspects of building projects (Succar, 2009, Wang et al., 2014, Wang and Chong, 2015). With regard to different aspects, BIM visualises a building product and simulates the building construction process from multiple dimensions (Yarmohammadi and Ashuri, 2015, Ding et al., 2014). However, the application of BIM in building projects is not limited to this scope.

The application of BIM in the built environment can contribute to lean construction. Several pieces of evidence on this point have been captured in the academic literature. Firstly, BIM and lean construction share a few common principles in their implementation, although they have developed from different backgrounds and foundations (Sacks et al., 2010a, Bhatla and Leite, 2012). Secondly, the simulation of the building production process through BIM facilitates the achievement of transparency in the project work, enables different participants to collaborate with one another and integrates the project process (Sacks et al., 2009). Moreover, BIM models can be applied as a "Kanban" for the production system to coordinate production planning in construction (Sacks et al., 2010b). The further exploration links BIM to the Last Planner System that allows dynamic project control based on visualisations of the building process (Bhatla and Leite, 2012). Although a few findings are presented in this area, the use of BIM to achieve leanness in the building project remains unexplained. In addition, lean construction is seldom associated with information management, especially integrated data management (IDM) in the building project. This area is worth further investigation.

From the perspectives of building production and building projects, this study clarifies the building design and construction process to explore a BIM-based approach to enable IDM in the building project. The following discussion focuses on how leanness in building design and construction is achieved with BIM and VDC in the project. BIM-based frameworks for IDM have been developed to handle miscellaneous information and data, as well as promote multidisciplinary communication and collaboration in building design and construction.

Key issues for IDM in the building project

Projects in the built environment are naturally expanding and becoming substantially complex (Baccarini, 1996, Williams, 1999, Chan et al., 2004, Lu et al., 2014). Handling massive information through the building life cycle is a fundamental issue encountered by numerous current projects. Moreover, the segmentation of building production (Baiden et al., 2006, Bouchlaghem et al., 2004, Jørgensen and Emmitt, 2009) aggravates this issue. Accordingly, it is difficult to realise IDM with fragmented procedures and various organisations of the building project. However, the building sector is updating its practice in handling information with the introduction of ICTs, especially BIM. Thus, a profound impact has penetrated the building sector; and construction management is shaping a new paradigm (Froese, 2010, Hyde, 2017, Khosrowshahi, 2017). At the meantime, the implementation of IDM remains to be clarified when ICTs are diffusing into the built environment.

One of the major IDM-related issues is information loss in different project stages. Figure 1 illustrates that the conventional practice in the building project is accompanied by loss of data and information at different stages of the building life cycle, which leads to loss of information value for following stages and an improved approach is needed to retain information value (Smith, 2008). Hence, one of the major requirements of IDM in the building project is to integrate building information and data through different stages and avoid loss of information value.

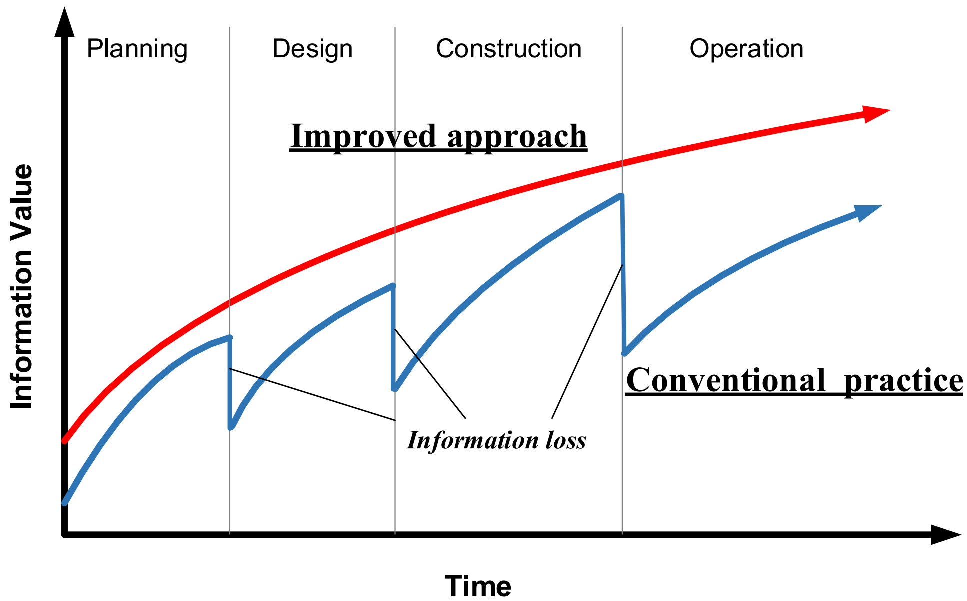


Figure 1. Information value: Conventional practice and improved approach (adapted from Smith, 2008)

Another key issue of IDM is information asymmetry. Sudarsan et al. (2005) explained that product lifecycle management (PLM) requires the integration of product information from all participants and organisations along the product life cycle. Xue et al. (2007) explained that the information asymmetry in the construction process can result in obstacles in communication and collaboration among the stakeholders. Thus, the systematic management and sharing of information and data are of immense significance due to the demand for multiple disciplinary collaboration (Bresnen et al., 2003, Caldas et al., 2002).

Lean construction with BIM-based IDM： From building production to building projects

Koskela and Dave (2008) suggest the efficiency of building production be enhanced with the effective integration of building process and information technology. Moreover, the integration of design and construction towards lean construction requires a lifecycle perspective of the building project (Jørgensen and Emmitt, 2009). Based on these perspectives, the research on building production to achieve lean construction with PLM and IPD and VDC to conceptualise the building project using BIM is investigated with a synthesised literature review.

Lean philosophy in construction

From a broad perspective, the concept of ‘leanness’ represents ‘a quest for structural flexibility involving restructuring, downsizing and outsourcing’ (Green and May, 2005). In further, ‘lean construction’ originates from lean production and introduces lean philosophy and techniques from the manufacturing sector to the built environment sector (Koskela, 1997, Howell, 1999). Without a standardised definition, however, the built environment sector needs to redefine ‘lean’ with reference to the building production system (Jørgensen and Emmitt, 2008). Ballard and Howell (1997) identify the two major principles in lean construction to achieve stable workflow and practice lean construction: structuring the upstream inflow and improving the downstream performance of the production process. Moreover, Salem et al. (2006) integrate theory to the practice of lean construction and develop four basic principles, namely, control of flow variance, process levelling, transparency in work and continuous improvement. Meanwhile, lean construction shall also focus on value creation as Koskela et al. (2002) point out that “‘lean’ is a way to design production systems to minimize waste of materials, time, and effort in order to generate the maximum possible amount of value" . The value creation of the building process and production also has different interpretations. The discrepancy between unified value in building design and construction, and customer-oriented value can lead to different theoretical frameworks and practical applications (Winch, 2006, Jørgensen and Emmitt, 2008).

PLM in building production an integrated lifecycle approach

PLM is a concept that advocates to manage the production with organised and structured lifecycle information of the product (Ameri and Dutta, 2005). Developed from product data management, the implementation of PLM relies on ICT systems and integration frameworks (Srinivasan, 2011, Abramovici, 2007). Apart from manufacturing, PLM has also attracted a few interests in building research, particularly when information management is concerned (e.g. Hartmann et al., 2009, Popov et al., 2010). As information handling is a prerequisite procedure for implementing building production, emerging ICTs in the built environment are the arms that extend the effort to achieve considerably efficient building production through an integrated lifecycle approach. Computer-aided information processing establishes an interactive human-computer collaborative environment to enable project organisations to render substantially reliable decision-making based on predictive information rather than descriptive information (Liston et al., 2003). The effective collaborative decision-making is significant to further execute a project in terms of improved coordinating disciplines, avoiding conflicts and eliminating rework. Moreover, a few requirements for effort in construction informatics include structuring the modelling of process and products, improving the quality of decisions and thoroughly maximising the application of modelling techniques (Tizani and Mawdesley, 2011).

Virtual design and construction: Visualising building projects with BIM

Virtual design and construction (VDC) gradually becomes a common practice in the built environment with the support of construction ICTs, particularly BIM. With lean principles, VDC can improve product value and avoid waste in building production (Björnfot and Jongeling, 2007). According to Popov et al. (2010), VDC provides sources for planning and decision-making to develop projects in an early stage. In addition, VDC is suggested as an effective tool to realise the lean IPD (Khanzode et al., 2006). The BIM models are commonly the vehicles of VDC, wherein the building product and process are simulated.

To conceptualise the project production, work breakdown structure (WBS) and product breakdown structure (PBS) are two fundamental categories to refer to. Globerson (1994) points out that WBS shapes the work packages of a project and a well-communicated WBS among project organisations is of great importance to collaborative efforts. At the meantime, the introduction of product breakdown structure (PBS) by Turner and Cochrane (1993) provides a clear view to analyse the building product. Some following studies indicate WBS is expanding from PBS (Chua and Godinot, 2006, Zhou et al., 2010). Sorting PBS out of WBS enables a product orientation towards the project and mapping their relations gives new insights to organise the project production.

Meanwhile, BIM is more adaptive to PBS than to WBS (Liu et al., 2015). Planning the package of construction work through BIM still has difficulties (Liu et al., 2016). Thus, one of the key objectives for applying BIM in building production is to visualise the product packages with PBS rather than the construction work. Additionally, BIM enables the modelling of the building product and simulation of the building process in advance, thereby further enabling project teams to have a considerable product-oriented view on the production (Watson, 2011, Kymmell, 2007).

Enabling IPD to achieve unified project value with BIM

As an empirical observation from the practice of building projects, the MacLeamy curve (The American Institute of Architects, 2007) illustrates that the IPD effort in the early stages of the building project can reduce changes, as well as possible rework and waste. As the early stage of the building project has substantial impact on cost and product functions, the IPD process leverages the project value by reversing the major coordination effort to an earlier stage. This process enables more effective value creation compared with the traditional design approach, thereby serves for the project to achieve unified project value.

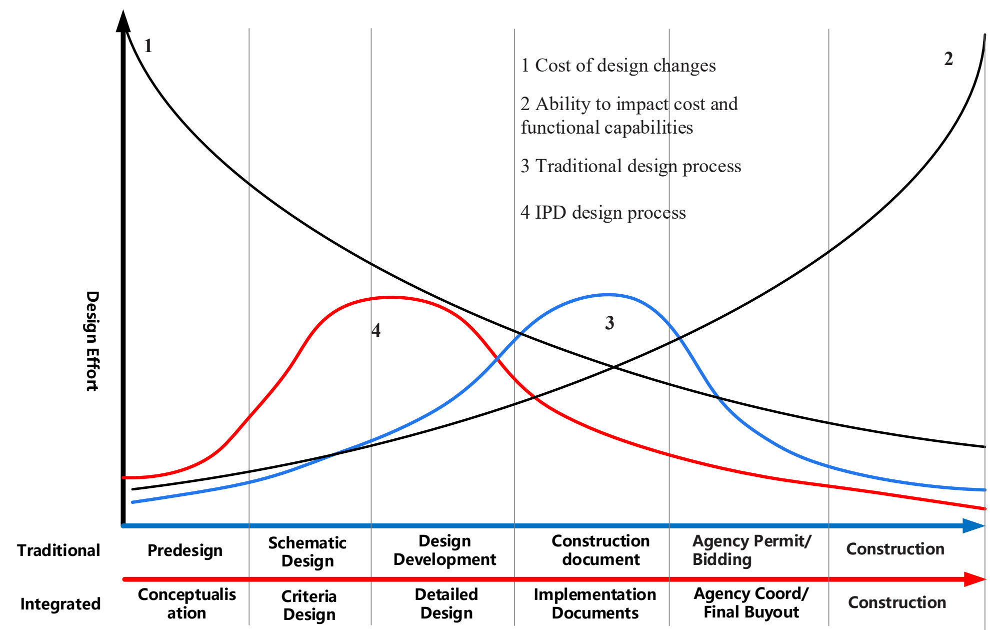


Figure 2. MacLeamy curve (Adapted from The American Institute of Architects, 2007)

The application of BIM in building construction mitigates the effects of information asymmetry (Forsythe et al., 2015). In one aspect, BIM is often regarded as a tool to support integrated project delivery (IPD) (Azhar, 2011, Succar, 2009, Bryde et al., 2013). In another aspect, BIM can enforce project management through information management, while the implementation of BIM with project management relies on information systems for support (Hartmann et al., 2009). Yet, the effects of BIM to alleviate information asymmetry may not be limited to the two aspects.

This implementation of BIM also serves as a propellant to the advance of the built environment sector and triggers the re-engineering of the building process in projects (Mihindu and Arayici, 2008, Jordani, 2008, Egan, 1998). The integration of BIM and PLM in a project requires a systematic effort from various teams and disciplines with problem-solving interactions through the project life cycle (Hartmann et al., 2009). According to Shou et al. (2017), capturing the structure of value chain and matching lean principles and with the appropriate arrangement of flows are critical to achieving the values. However, the changing of project approach and production workflows in this process has rarely been discussed. These issues require exploration, which is discoursed in the succeeding section of this research.

Research approach

The research project involves the development of an office building project owned by a local research institute in building design from Chengdu, China. As a building research institute, the owner has both practical and research interests for this project. The practical concern involves managing the project and achieving efficient production to further minimise cost and efforts. For the research purpose, the owner intends to explore a project management approach with the implementation of BIM, which is in agreement with the researchers of this study.

As a collaborative research project, the researchers served as consultants and collaborated with the owner to develop a BIM-based approach to manage the design and the related processes. The participation of the researchers in this project lasted until the end of the design stage. Due to this fact, the ethnographic-action research approach is adopted to implement the study. The ethnographic approach is applied in construction research to establish theories and collect data through observation and interaction with participation (Phelps and Horman, 2009, Pink et al., 2010) and action research probes into practical issues and develop theories in the relevant context (Azhar et al., 2009, Liu and Anita, 2015).

The researchers are primarily responsible for leading BIM process and directing BIM implementation in the project to generate actual value for the project. Through interactions in the project, the researchers compose the implementation strategies and measures together with practitioners. Research data and evidence are obtained via participative observation, including direct observation, informal interviews, document analysis, and reflections on the actual situation.

Research design

As an ethnographic-action research, the principal purpose of this study is to explore a lean production method with BIM-based IDM. Design science is employed as a research protocol to organise the ethnographic case study. The design science research guidelines (Dave and Koskela, 2009, Von Alan et al., 2004) have been followed accordingly to achieve robustness. The major steps of this part include conducting the case study, as well as collecting and analysing data and evidence (Yin, 2013). Table I presents the details of this research approach.

Table I. Design-science research approach in this study

Design science method guidelines	Corresponding procedures in the case study
1. Design as an artefact	The BIM models have been built in accordance with the building product information.
2. Problem relevance	BIM and lean construction have many common interactions; thus, realising lean construction with BIM solutions is a promising undertaking.

3. Design evaluation	The project plan has been evaluated by various participants of the project for its execution together with some external experts for the application of BIM.
4. Research planning and optimisation based on rigor and possible results	This research assesses the feasibility of the potential BIM solutions in a project, investigates the design process of a building, maps the necessary procedures in its construction and provides an effective reflection on the method of achieving lean construction.
5. Conducting the case study	The case study has been conducted with a few technical data and managerial evidence captured for interpretation.
6. Analysis of the findings	The findings have been analysed and discussed.

However, as the researchers have fairly strong influence in the project, the action research approach is followed in research planning and optimisation.

Design evaluation

Referring to two previously executed project plans, the execution plan for the current project was devised by the consultants in accordance with the project objectives of the owner and the requirements of BIM implementation. The newly compiled plan was evaluated by different project teams for its execution and external experts for the application of BIM. After a few meetings for the purpose of collaboration, the project plan was revised and eventually approved. Additionally, the scope of the BIM application was limited to a feasible and necessary level. The evaluation activities are as follows:

(1) initial discussion of the project objectives and requirements of the BIM application;
(2) evaluation of the project execution plan and application of BIM; and
(3) BIM model test and revision of the project plan to achieve project feasibility and efficiency.

Research planning and optimisation

The research interest of this project can be maximised as the owner is a research institute that is interested in the research on the implementation of BIM. During the project, the owner proposes the need for a collaborative information system; hence, a multidisciplinary platform has been outsourced from an application service provider. Thereafter, the BIM models with the multidisciplinary lifecycle information of the building are accommodated by the platform, serving as part of the information system. Accordingly, an action research approach that references Hartmann et al. (2009) has been adopted for the design of the integrated information system. The basic steps are as follows:

(1) employing knowledge to reflect on experience and observation;
(2) identifying the related work;
(3) developing the integrated information system with BIM;
(4) implementing the integrated information system within the project; and
(5) observing the implementation and running the iterative improvement.

This approach can substantially investigate the effect of BIM from a systematic review for project planning. Through this approach, moreover, interfaces have been achieved for the VDC process and the building production; and continuous improvements have been exerted to the entire production system. Finally, a holistic and dynamic view of the research project is also provided.

Findings and analysis for the ethnographic-action research

According to the design-science approach, the case and actions have been studied and analysed from the technical and managerial perspectives to investigate the application of BIM to project approach and production workflow.

Technical perspective: Modelling building products through PBS

The building information models are central to BIM. Thus, the analysis is developed from several building information models that are retrieved from a case of an office building. This case is a pilot project to systematically implement BIM with project management throughout the project life cycle. Different models had been established to visualise the product, and the relations of the models are identified.

Multidisciplinary global model and single-disciplinary models of the building

First, the multidisciplinary integrated model (Figure 3) of the entire building is built by incorporating the structure model (Figure 4) with the architectural model. However, due to the insufficient information in other disciplines (i.e., scaffold and building services) or aspects (i.e., schedule and cost) of later stages, the integrated model continues to encompass other forms of building information and expand through the building life cycle.

Figure 3. The multidisciplinary integrated model at an early stage of the building design

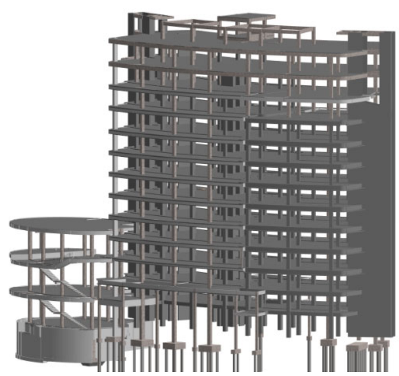
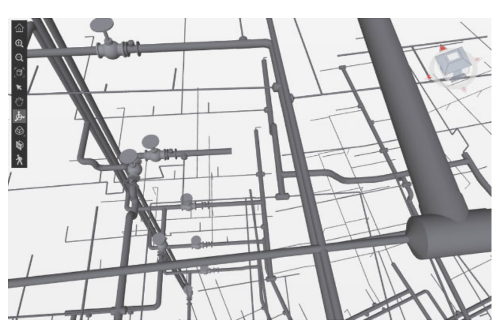


Figure 4. The designed structural model of the building

Models of the different disciplines of the building

The different disciplines have been individually modelled due to the specialised nature of the production work, which is similar to a line production. However, the disciplines are supposed to be



integrated during production to achieve synergy and avoid clashes since a building is a relatively large and complex product. Figure 5 provides the examples with the designed plumbing model. Figure 6 shows the designed ventilation model.

Figure 5. The designed plumbing model of the building

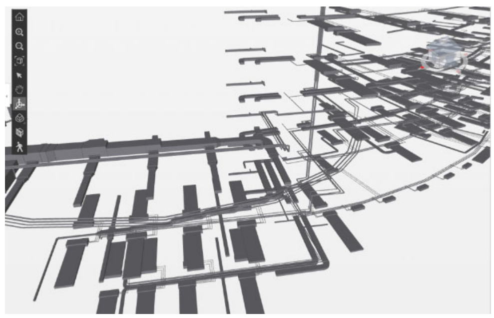


Figure 6. The designed ventilation model of the building

Models of the different parts of the building

Models that represent the different parts of a building have been utilised. Accordingly, constructing the building facility by parts is a typical practice since it is generally a giant block product. Figure 7 shows a model that represents an integrated substructure of a building with information on various disciplines. The models of the different building parts can be used to explicate the integrated project deliverables of different production teams for further collaborative undertakings because the production of different parts can have overlaps and conflicts. For example, Figure 8 shows the details of clash detection that had been previewed prior to the construction stage of this project.

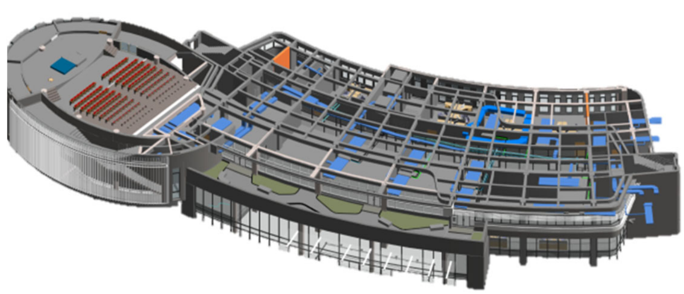


Figure 7. The model of a building part

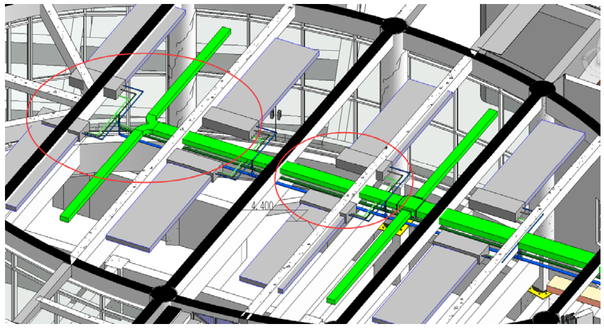


Figure 8. Clash detection

Managerial perspective: Managing IDM with integrated BIM model through the VDC approach

To manage the BIM models, an IDM perspective has been adopted to investigate the VDC approach. On the one hand, the modelling of building products during the design-oriented approach refers to building information by different disciplines according to the practice of design. On the other hand, the construction-oriented approach requires an integrated approach to visualise the information of the building process, but then to explicate building information for the real building construction. Although the modelling proceeds at the design stage of the project, the data that the model processes include the lifecycle information of the building based on VDC.

The design-oriented VDC approach: From separation to integration

As proposed by the owner, the demand for an integrated BIM model has been identified to integrate the segmentation of models from various disciplines, thereby enabling IDM. The analysis of the case indicates a framework for IDM with BIM in the building project (see Figure 9). An integrated model incorporates various disciplinary models used in the different stages of the VDC process, as well as explicates multidisciplinary building information for IPD. The single-disciplinary model abstracts product information from the original building design information based on PBS, which involves information handling for building design. WBS is barely considered until the models start to serve for the production purpose as WBS reflects the relationships shaped by the building production organisations and activities.

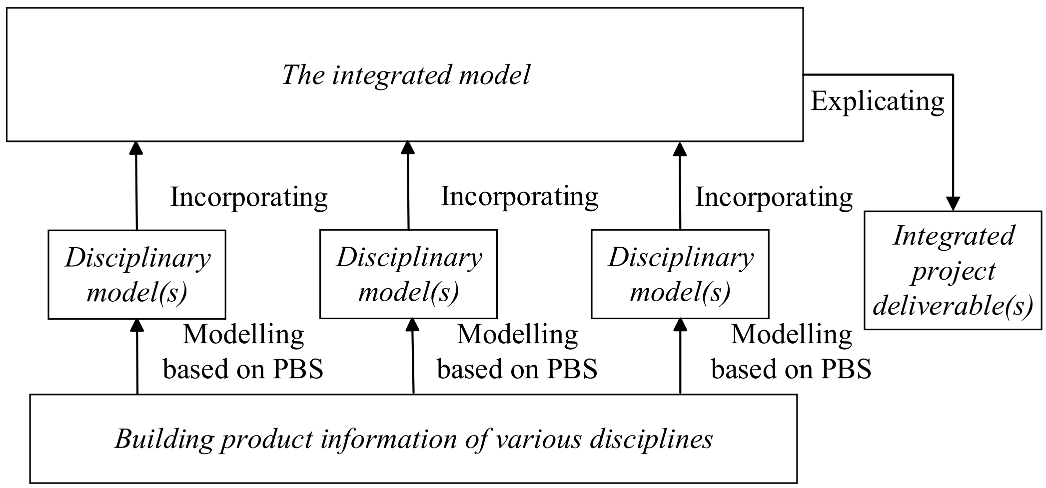


Figure 9. Framework for design-oriented VDC approach with the integrated model and BIM models of different disciplines

The construction-oriented VDC approach: From integration to separation

Meanwhile, managing models of different building parts follows a relatively different approach as presented in Figure 10. The segmented BIM models to represent local parts of the building, namely local models have been modelled and integrated from the product deliverables in the design approach to provide a full image of the designed building with the integrated model. Yet, in the construction approach, the product deliverables shaped by PBS are developed from the local models separated from the integrated model. This process is of primary importance to organize construction activities through defining WBS with the deliverables.

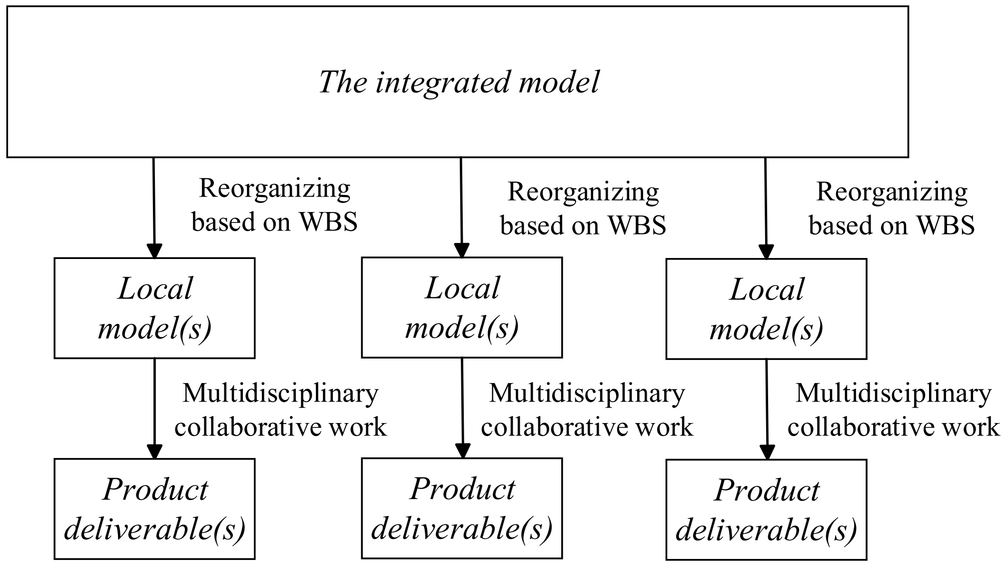
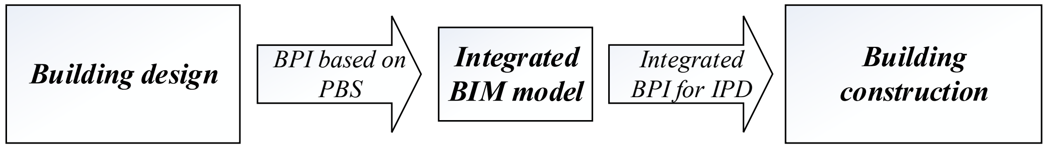


Figure 10. Framework for construction-oriented VDC approach with the integrated model and local BIM models

Summary of findings: the VDC approach with integrated BIM model

From the technical perspective, BIM advances building production by explicating building product information and PBS. It helps to achieve efficient information processing through a BIM-based approach. Whilst from the managerial perspective, BIM accommodates building information from different disciplinary teams to promote integrated project delivery and enables IDM through the building project life cycle for reliable decision making and project control. Both perspectives explain how leanness is achieved with the successful implementation of BIM in the process of building production.

To summarize the findings, the integrated BIM model serves as an information hub to bridge the gap between building design and building construction (illustrated in Figure 11). The key effect BIM has for lean construction is that it integrates building design and building construction and improves the information value. This in further restructures the workflow of the building production and eliminates the waste caused by segmentation in the design and construction process.



Note: BPI - Building product information

Figure 11. The integrated BIM model as an information hub that coordinates building design and building construction

Discussion

In this study, the VDC approach with the integrated model visualises product deliverables of multiple disciplines to promote synergy, resolve conflicts and achieve efficiency. The further interpretations of BIM in IDM explain how lean construction has been achieved.

BIM as a visualisation tool to coordinate the design and construction workflow

Firstly, the analysis reflects the function of BIM as a visualisation tool for product and workflow or 'Kanban' as demonstrated by Sacks et al. (2010b). The BIM models provide explicate building information to different participants in the design and construction processes. This approach is against information asymmetry and promotes a common understanding of the building product among the different stages of the project, thereby lowering the threshold for the collaborative effort of the project teams. This production method is consistent with the principles of lean construction and represents an implementable approach to achieve leanness with the BIM models incorporated in the process.

Th integrated BIM model as an information repository to retain information through

the building life cycle

In the second place, the integrated BIM model retains the building information through the building product life cycle. This model can serve as an information repository throughout the project life cycle to avoid the loss of information value and maintain a steady flow of information. The information from the BIM model can be employed to achieve effective planning and decision-making, as well as, to implement PLM in further (Popov et al., 2010). The introduction of the integrated BIM model leverages the information value across the different project stages. Given the lack of modelling and simulation processes in the past, poor planning and decision-making appear as design errors and are compromised with the revision of the design and rework that leads to waste. The BIM-based IDM eliminates this type of waste in building projects.

BIM-based IDM as a restructuring and re-engineering approach

Thirdly, compared with the conventional building production approach, the BIM-based IDM approach relies more on VDC to develop PBS and WBS. This approach is substantially product-oriented, thereby eliminating unnecessary work procedures and achieving lean construction. Consequently, the related project procedures will be restructured, and the production workflow will be re-engineered because the integrated BIM model directly links building design and construction. Moreover, virtual visualisation with multidisciplinary building information reshapes the mechanism of cooperation, reduces coordination work and avoids rework and waste in the production process.

Given discipline-specified convention in design practice and the requirement of IPD in construction work, BIM serves as a liaison process to bridge the discrepancy in handling the flows of information and work. BIM-based IDM enables the building information to be passed downstream and improved to avoid loss of information value. Furthermore, this process structures the information flow in the design stage and integrates the information from various disciplines to manage the production workflow. This analysis fits the fundamental principle for the implementation of lean construction to "reduce inflow variation and improve downstream performance" (Ballard and Howell, 1997).

Achieving leanness in building production with BIM-based IDM: Fiesta of related concepts

In summary, this study employs a few concepts all that contribute to explaining how leanness is achieved in building production with BIM-based IDM. Thereby, an illustration of their relations has been captured in Figure 12. The integrated BIM model with building product information and data from the disciplinary and local BIM models is a prerequisite to VDC to enabled IDM. Furthermore, IDM integrates building product information and data from different project stages and disciplines to realise PLM and IPD respectively. Finally, leanness is achieved in building production with BIM-based IDM.

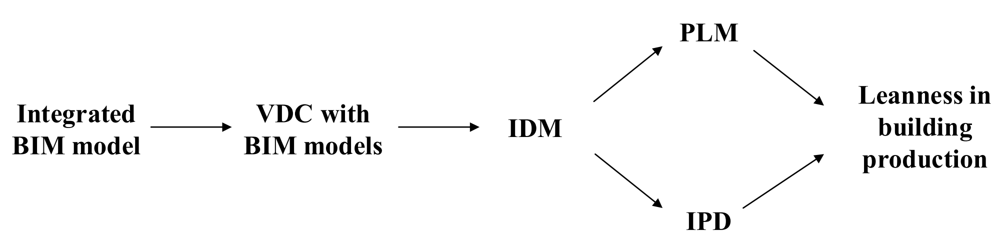


Figure 12. Achieving leanness in building production with BIM-based IDM

The design-oriented VDC approach synergizes building information of different disciplines for further multidisciplinary collaboration. The construction-oriented VDC approach establishes a virtual environment to simulate the building process, which leverages the availability of information of different project stages. Through VDC, IDM, PLM, and IPD can be partially realised although not exactly with the as-built information. And it can also help to exploit information value from an early project stage and achieve the MacLeamy curve.

Conclusions

This study adopts a mixed perspective and employs a number of related concepts to systematically discuss how leanness is achieved with BIM-based IDM in a building project. Meanwhile, BIM-based frameworks for VDC in the building project have been developed from the view of IDM. The project and production perspectives provide a holistic view of the proposed BIM-based IDM approach.

From an overview, BIM-based IDM coordinates the information management in building design and construction as the integrated BIM model can serve as an information hub between building design and building construction and even throughout the project life cycle. Furthermore, BIM-based IDM enables lean construction based on three aspects that fit principles of lean construction:

(1) BIM-based IDM reduces wastage in efforts to manage building lifecycle information through different project stages.

(2) The building information of different disciplines is integrated by BIM-based IDM to avoid conflicts and overlaps, and achieve project synergy that reduces rework and waste.

(3) This BIM-based production approach eliminates redundant procedures and coordination to provide an opportunity for continuous improvement.

This study has a few contributions to the body of knowledge for realising lean construction with BIM in the building project. Firstly, it maps a BIM-based IDM framework within the project context for lean construction through a case. The framework sketches a general image of data processing with BIM in building design and construction, and can provide implications for implementing lean construction with BIM and BIM platform in the building project. Secondly, the study distinguishes the different needs of information flows in building design and building construction, and identifies the role of the integrated BIM model as a hub to coordinate the two types of information flows. Thirdly, this study also contributes as a reference with process knowledge to achieve lean construction with the lifecycle integrated data management to realise PLM and IPD. Overall, the ethnographic action research establishes a BIM-based IDM framework, explicates the differences in organising information flows in building design and building construction, clarifies the critical role of the integrated BIM model, and integrates PLM and IPD into the production of a building project. All that helps to achieve leanness in the building project.

This study also partially explains how BIM promotes communication and enhances collaboration between the design and construction teams. However, no direct evidence supports this finding due to insufficient analysis of organisational systems. This can be a topic for future research. Moreover, the maturity of the BIM technology is a limitation for this type of application because BIM cannot be completely developed to support project management and production work. For an individual project, it may need to weigh whether the effort is worth the value of utilising BIM and VDC. It raises a further question that adopting BIM to what extent can add value to project production and help achieve leanness. In this study, the implementation of BIM is rationalised through the ethnographic-action approach with the proposed requirements of the owner and interaction between the practitioners and researchers. This production method is consistent with the principles of lean construction and represents an implementable approach to achieve leanness with BIM incorporated in the process. Thus, future research can focus on the examination of how BIM restructures the project system or the quantification of how the value of BIM can be maximised with the minimisation of effort in the process of installing BIM. These could be other research directions to help achieve leanness in BIM-based building production.

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