MODELING THE LAST-MILE PROBLEM OF BIM ADOPTION

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Abstract: In recent years, the high expectation of Building Information Modeling (BIM) has increasingly attracted the attention of organizations in developing countries. To catch up with the leading BIM practice, those 'late mover' organizations tend to benchmark and adopt BIM practices that have been proven effective by global leaders. However, the uptake of BIM use is largely stuck by the "last-mile problem". While developers diffusing their standardized or generalized solutions to global users, organizations often find it difficult to adopt such solutions due to the contextual difference between such standardized and generalized BIM solutions and their use environments. This paper aims to firstly define the "last-mile" problem in BIM adoption and then, propose a conceptual model of such problem. In this paper, the last-mile BIM adoption is defined as "a decentralized process involving the linear diffusion of BIM solutions from its source developers to destination users". Synchronizing literature on BIM and last-mile problems in various domains, a last-mile BIM adoption model is proposed by identifying the model components and developing a design framework. This study has both academic and practical implications. It offers a set of formal language to systematically describe the last-mile problem of BIM adoption, leading to an improved understanding of the last-mile process and problems therein. For practitioners, the study facilitates them to analyze last-mile problems and develop strategies accordingly.

Keywords: Building Information Modeling (BIM), last mile, model, adoption, diffusion

1. INTRODUCTION

In recent years, Building Information Modeling (BIM) has been increasingly subscribed by the global architecture, engineering, and construction (AEC) industry to enhance construction productivity. Particularly, leading organizations in developing countries have started to show interests in BIM adoption. To minimize learning cost, one common strategy is to adopt the technology and related BIM practices that have been tested by the global leaders (Cao et al., 2014). For example, the majority BIM explorers in developing countries adopt mainstream technologies developed from the U.S. as their uppermost technical solutions (Herr and Fisher, 2019). Some authorities have developed localized BIM guidelines based on the early versions of U.S. and European countries.

During the course of BIM adoption, the late-mover organizations seem suffering from the "last-mile" problem. A major difficulty lies in adopting BIM from developed countries, considering the contextual differences between the environments where BIM is developed and used. This incurs huge efforts to adapt the given BIM practice to suit the specific organizational environment. While the BIM user organizations desire a set of tailor-made BIM solutions, software vendors hardly provide such a solution. From their point of view, such toolkits are against the massive production spirit, incurring higher development costs bringing inconvenience for maintenance. Similar concerns are also identified amongst international standardization bodies. In this regard, a feasible solution to bridge the last-mile BIM adoption should balance the concerns from different stakeholders.

The solutions to the last-mile problems have been widely discussed in telecommunications, e-commerce, logistics, and supply chain management studies. Although the last-mile problems vary in these domains, they shared a similar two-step solution: to formally describe the last-mile problems by identifying the its structural components and needs of different stakeholders therein, and find an optimal distribution structure that synchronizes the concerns of multiple stakeholders (Aized et al., 2015; Harrington et al., 2016; Wang and Odoni, 2014). However, in the context of BIM, the last-mile problems are still poorly theorized in literature. There lacks a rigorous language to clearly define the problems for further analysis and solution development.

The primary aim of this paper is to articulate the "last-mile" problem of BIM adoption by an organization. It does so by proposing a conceptual model comprising of a working definition, components, and a design framework. This paper takes the first step to provide a set of systematic language to describe the last-mile problem of BIM adoption. It enhances the understanding of last-mile process, and can be used to analyze the last-mile barriers for designing solutions. The remainder of the paper is organized as follows. Subsequent to this introduction is the research design of the study. Literature review is presented subsequently, focusing on last-mile studies in the telecommunication networks, supply chain management, and transportation planning, as well as BIM adoption literature. Then, the last-mile model is presented, including a working definition, the model components, and the design framework of last-mile BIM adoption. Discussions and conclusion are drawn in the last section.

2. RESEARCH METHODS

The research design of this study combines literature review and industry engagement. The former method facilitates to develop the definition, model, and design framework, while the latter enables to verify the outcomes using practical evidence from real-life cases. According to Fink (1998), literature review is a “systematic, explicit, and reproducible design for identifying, evaluating, and interpreting the existing body of recorded documents”. It facilitates identify conceptual contents in the domain by summarizing the conceptual patterns, themes, and issues of existing literature (Meredith, 1993). Even though there lack studies directly shed light on specific last-mile problems of BIM adoption, the last-mile problems in other domains and BIM adoption have been popular topics in the past twenty years.

Given this situation, relevant publications were searched and reviewed in two rounds. The first-round review concerns the literature on last-mile problems in the domains of telecommunication, supply chain management, and public transit. By doing so it is expected to identify the important conceptual elements for defining and articulating the last-mile problem in a general setting. Keywords for searching include “last mile”, “first mile”, “definition”, “model”, “framework”, and “dimensions”. One author quickly scanned the contents to determine the inclusion of the papers, while another author double checked to reduce potential bias. Following a similar process, the second-round selection focused on BIM adoption studies to contextualize the term “last mile” and its conceptual components in organization’s BIM adoption practice. Keywords used in this round include “Building Information Modeling OR BIM”, “adoption OR implementation OR use”, “process”, “practice”, “case”, and “barriers OR obstacles OR difficulties”. After selection, a detailed study was then conducted to critically analyze the selected papers, especially their arguments and scopes of applications concerning (1) BIM adoption stages, (2) BIM adoption barriers at each stage, (3) the stakeholders involving in ONE organization’s BIM adoption practice, and (4) the factors influencing BIM adoption.

The literature review findings allowed to propose the definitions and last-mile model of BIM adoption. Yet, the outcomes should be verified by empirical evidence to ensure its credibility. The last-mile model, especially its typology, should be also further explored in real-life cases. In this study, the two objectives were achieved through the author’s industry engagement. During the past two years, the authors constantly engaged with a cost consultant, a building client, a main contractor, and two software vendors. Working closely with the stakeholders, the researchers were able to offer advice and design strategies to help with BIM practice of each stakeholder. Meanwhile, the engagement enabled researchers to immerse, observe, and reflection from the real-life practice to verify the proposed last-mile model of BIM adoption. Data was collected through in-depth group discussions, informal interviews, reports, emails, and reflection of practical situations. Data was then analyzed by summarizing BIM adoption stages, the last stretch of the adoption process, the ways that BIM user organizations integrate BIM solutions with their own practice, and the methods that software vendors promote their BIM solutions. If the proposed model fails to consider all practical concerns, it will be modified accordingly; if the model contains some elements not identified in practice, it will be discussed with the AEC professionals to determine if the elements should be deleted or kept.

3. LITERATURE REVIEW

3.1 Last Mile and Last-Mile Problems in General

The term “last mile” originates from the telecommunication to denote the last leg of a wide area network that runs from the nearest aggregation point to users (Speta, 2000). Despite its seemingly short leg to the main backbone facilities, the last-mile connection is usually the most problematic one. It is usually the technological bottleneck that limits the bandwidth and consequently speed of data transfer to customers (Cotter and Taylor, 2001). It also incurs a huge amount of cost to install and maintain the last-mile connections, as these connections directly link to numerous users and their wider variety of equipment that a standardized service fails to support (Nandi et al., 2016). “Last mile” is now widely used as a metaphor to describe the problems in the last stretch of a network of service delivery in many domains, such as parcel delivery from centralized transits to geographically-dispersed users in supply chain management (Gevaers et al., 2011), and transportation planning that ships passengers from public transportation nodes to their final destination (Wang and Odoni, 2016). In a nutshell, “last mile”, in general, can be regarded as a decentralization process that delivers people, goods, products or service from a centralized point to a dispersed destination.

Underneath the last-mile problems is a need to coordinate the requirements of multiple stakeholders in the last-mile network. A typical example is the last-mile logistics, which usually involves manufacturers, retailers, deliverers, and customers (Niu et al., 2016) in the upstream and downstream flows of products, services, finances, and/or information (Mentzer et al., 2001). Hitherto, existing studies have identified many variables influencing the last-mile process. The variables can be classified based on the stakeholders involved, such as transportation operators (or *industry* level), public administrators (or *institutional* level), and end-customers (Russo and Comi, 2011; Taniguchi and Tamagawa, 2005). In some studies, merchandise-oriented variables are also included as one important level for analysis (Frederick et al., 2018; Harrington et al., 2016). The design variables can also be categorized into technical, social, economic and environmental dimensions, each contains smaller items (Gevaers et al., 2011; Harrington et al., 2016). The categorization into different levels and dimensions depends on the specific perspectives and requirements in analyzing the last-mile problem.

To find an optimal solution for the complex last-mile problem, a prerequisite is to describe the problem clearly, concisely and comprehensively. This makes it necessary to systematically model the last-mile network. For instance, Nandi et al. (2016) characterized the last-mile telecommunication network development in rural areas as the selection of suitable technologies and deployment methods considering the geographic locations, economic conditions, motivation and adoptability, and sustainable business framework (e.g., skilled workers and funding support). In the business to customer (B2C) delivery, the last-mile delivery is modeled by identifying its structural elements, typology of structures, hierarchical levels, and design framework (Aized et al., 2014; Frederick et al., 2018). Even though contextualizing in different scenarios, these models highlighted some conceptual elements in defining the last-mile model, e.g., start and end point, the "trunk" business to which last mile is attached, major stakeholders, last-mile structures and typology, and design variables. These should be addressed in defining the last-mile BIM adoption.

3.2 BIM Adoption

The definition of BIM adoption should be first clarified to develop a last-mile BIM adoption model. Despite numerous studies on BIM adoption, there still lacks a canonical definition. Indeed, BIM adoption tends to be used interchangeably with BIM implementation (e.g., Arayici et al., 2011, Ding et al., 2015), which blurs the distinctions between these two concepts. According to Rogers (2003), adoption is a "decision to make full use of an innovation as the best course of action available", while implementation is "a phase which occurs once an innovation has been put into use". In the BIM context, Succar and Kassem (2015) differentiate these concepts considering BIM implementation occurs at sub-organizational scales (e.g., individuals and groups), while adoption denotes a more generic term to overlay the connotations of implementation and diffusion (i.e., BIM use across the global construction industry). In another stream of literature (e.g., Papadonikolaki, 2018), BIM adoption and implementation are used in different levels – adoption of BIM by firms, and implementation in projects. Despite their nuances, these studies converge on a common understanding that adoption could be considered as a more holistic term than implementation (Ahmed and Kassem, 2018). In proposing the last-mile BIM adoption model, this study recognizes the need for a more holistic definition of adoption to cover more than just a specific phase or a milestone.

BIM adoption at organization level can be divided into several stages. According to Succar and Kassem (2015), BIM adoption can be achieved via a three-phased approach, namely *readiness* to BIM-based tools, workflow and protocols, *capability* built on willful experiments and implementation, and *maturity* as organizations gradually and continuously improving quality, repeatability, and predictability of BIM adoption. A critical leg here is the last stretch occurring after the point of adoption, at which organizational readiness transforms into organizational capability/maturity. In another stream of studies that follows Rogers' Innovation-Decision Model, BIM adoption is stretched to include an organization's exploration and decision-making process, e.g., awareness, intention and interest, point of adoption, implementation and confirmation (Ahmed et al., 2017; Hochscheid and Halin, 2019). In a broader sense, BIM adoption can be also portrayed as an iterative rather than a linear process, which can be modeled by multiple spiral cycles to diagnose the problems of adoption, plan executive strategies, execute plans, and evaluate the application results (Arayici et al., 2011). The model also highlighted the interactions amongst organizations and solution providers, who provide technical assistance for mutual adaptation of technology and organization practice for BIM adoption.

The explanations of the slow BIM uptake in organizations lie in various barriers of BIM adoption. A consensual typology of these barriers is yet to be agreed, but efforts have been paid to exploring it. Some widely mentioned hurdles include the attitudinal, technical, procedural, and economical (Azhar, 2009; Bryde et al., 2013; Chang, 2014; Niu et al., 2016). The attitudinal hurdles can influence the early stage BIM adoption as organization gaining knowledge and making decisions, while the effects of the rest can be prolonged to the later adoption stages. Lacking skillful staff is a significant factor hindering a scale-up BIM adoption, as identified in organizations of both BIM leading/following countries regardless of their sizes (Bui et al., 2016; Hosseini et al., 2016). Several researchers also attribute the slow uptake to the environment where BIM is adopted, e.g., internal management support, organization structures, external coercive/mimetic/normative pressures and the contextual differences between BIM developing and use environments (Ahmed and Kassem, 2018; Cao et al., 2014; Peansupap and Walker, 2005; Xu et al., 2014). These factors were further analyzed and modeled by Ahmed and Kassem (2018) into a holistic three-level hierarchy, namely BIM innovation characteristics, the external environment characteristics, and the internal environment characteristics. These factors should be taken into consideration in developing the last-mile BIM adoption framework.

4. THE LAST-MILE PROBLEM OF BIM ADOPTION

4.1 Definition

Organizations generally undergo a series of learning and decision-making process to adopt BIM (Figure

1). The journey starts with *awareness* of BIM, following a serious of information collection and knowledge acquisition to *evaluate* the cost and benefits of BIM adoption. If the evaluation is positive, organizations will *initiate* the BIM practice and *explore* feasible implementation strategies, e.g., suitable BIM toolkit, the BIM-related workflow, information standard, organization structure, staff training. These strategies may be tested in trial projects to identify their applicability in real-life cases. Once determined, organizations will *implement* the strategies for their existing practice. Notably, during the last stage, organizations will continuously interact with multiple stakeholders to acquire BIM solutions, including software vendors, technical developers, BIM consultants, policymakers and other BIM users. These solutions, however, may not be suitable for an organization's specific context, as the solution providers tend to develop, standardize, and promote its solutions to a larger portion of users worldwide. This leads to the last-mile problem.

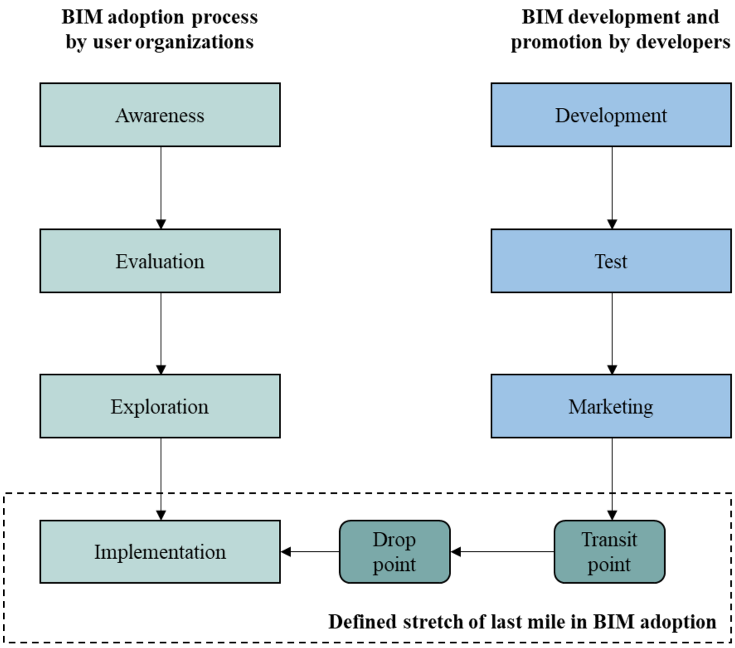

Figure 1. The stretch of last-mile BIM adoption

Synthesizing the previous studies on both last mile and adoption, this paper proposed a working definition of last mile in BIM adoption as follows:

The last mile is the last stretch in the BIM adoption process. It is a decentralized process involving the linear diffusion of BIM solutions from its source developer to destination users. It starts at the point when organizations determine/purchase BIM solutions to the point BIM is truly integrated into the organization practice.

4.2 Modeling the last-mile problems of BIM adoption

There are four conceptual components of the last-mile problem of BIM adoption, namely the product, transit point, drop point and destination (Figure 2).

(1) Product: BIM Innovations

Giving the real-life organization needs on BIM adoption, BIM solutions here should be pursued in a broader sense that includes not only technology, but its accommodating process and guidelines. These dimensions has been well categorized by Succar (2009), Liang et al., (2016), and various BIM ontological and implementation frameworks (e.g., Jung and Joos, 2011). Specifically, BIM technology refers to a collection of tools and techniques that support BIM's functionalities. It not only includes BIM data, software, and hardware, but also integral platforms to support effective communication and collaboration amongst different stakeholders. BIM process denotes a series of ordering work activities of BIM creation, management, and utilization to support the project tasks, while BIM policy can be regarded as a course of action adopted or proposed by a government, business, or individual as a reference to guide the BIM-based. An observation is that these solutions, mainly developed in U.S. and Europe, will be gradually diffused to other countries/regions and the organizations therein.

(2) Transit Point: The Point BIM Solutions Introduced to Users

The transit point denotes the state that a BIM solution is first removed from its original developing settings and introduced to the users. This is also the starting point of the last mile. At this point, the BIM solution may not be suitable to be used in the local organization settings, which may be conflicted to the embedded original/laboratory settings in the BIM solutions. Some common transit points include the in-house promotion department of the software vendors, the local subsidiary of a headquarter developer, and the third-party promotion by professional institutes, governments, and so on.

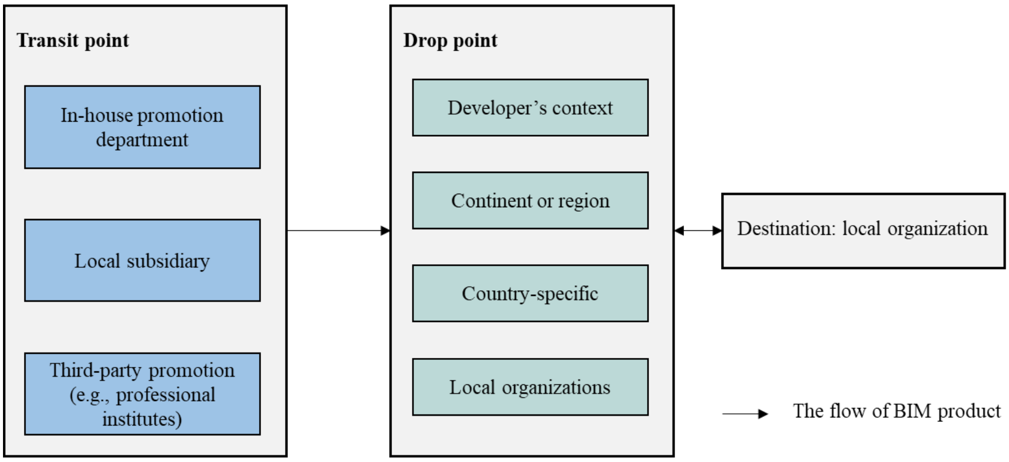

Figure 2. Modelling the last-mile problem of BIM adoption

(3) Drop Point: The Transfer Point of BIM Solutions

The drop point is where the BIM solutions are transferred. Technically, the drop point can be any point between the source developer and the final BIM adoption organization. Some typical examples include the developer's own context, a continent/region-wide market, a country/district, or specific local organizations. Currently, the selection of drop point is largely dominated by the mainstreaming BIM solution developers

(4) Destination: User Organizations

Organizations in AEC industries generally vary in attitudes and behaviors on BIM adoption. A small portion are actively embracing and explore the innovations with an aim to improve its existing business practice, while the majority are more hesitate and passive in adoption BIM. The organizational behaviors in the last mile can be attributed to its inherent characteristics, such as the scale, business nature, technical capabilities, human resources, financial resources, and culture. These will directly or indirectly influence an organization's attitude on BIM, and thus BIM expectations and implementation strategies. Notably, organizations are confined to specific local conditions, to which BIM solutions diffused from its origins may not be suitable to be applied. This makes it necessary for local agencies or BIM users to tailor the BIM solutions for the specific local regulation, economic, social, and cultural environment.

From the preceding section, a typology of the last-mile BIM adoption process can have three basic forms, namely the passive, active and mixed mode (see Figure 3). In the passive mode, BIM solutions are directly sent to fit the organization's specific context without much organization's involvement. In other words, BIM solutions are removed from its origin settings, customized and localized to meet the specific local requirements by agencies other than users. Examples include the country-specific versions of BIM software, local BIM software plug-ins, BIM specifications initiated by the local governments. In the active mode, BIM solutions are "fetched" by the user organization. It denotes a more active state that an organization constantly involves in the adaptation of BIM to suit its own requirements, e.g., in-house development of technology, regulation developed based on examples from other countries. The mixed mode is an intermediate state, in which developers provide BIM solutions customized to a certain degree, then users adapt the solutions to tailor their requirements, e.g., the customization sections in Industry Foundation Class (IFC) schema.

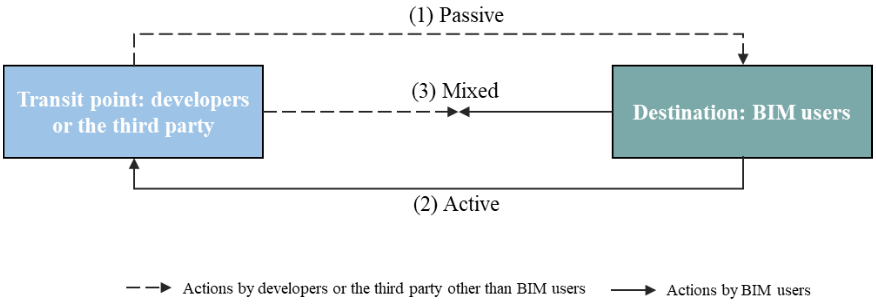

Figure 3. The typology of the mode of last-mile process

4.3 The design framework and variables for last-mile problems of BIM adoption

The design framework is a structural arrangement of variables that enables analyzing, optimizing, and designing a solution for the last-mile problem. Inspired by Lim et al (2018), the variables can be classified into structural variables and contingency variables (Figure 4). The structural variables are descriptive indicators describing the last-mile configurations, such as the geographical distance between the start point and end point, the geographical coverage concerning the geographic area of the group of local users, and the mode of last-mile process. Comparatively, contingency variables are factors influencing the permutations of structural variables. Contingency variables can be grouped into several dimensions based on different criteria. For example, they can be grouped according to components in the last-mile model, i.e., BIM dimension, organization dimension, developer dimension and industry dimension (e.g., the external environment of BIM adoption). The variable can be also categorized into technical, procedural, economic, and social dimensions. The selection of dimensions depends on the perspective of analysis, BIM expectations and requirements on the last mile.

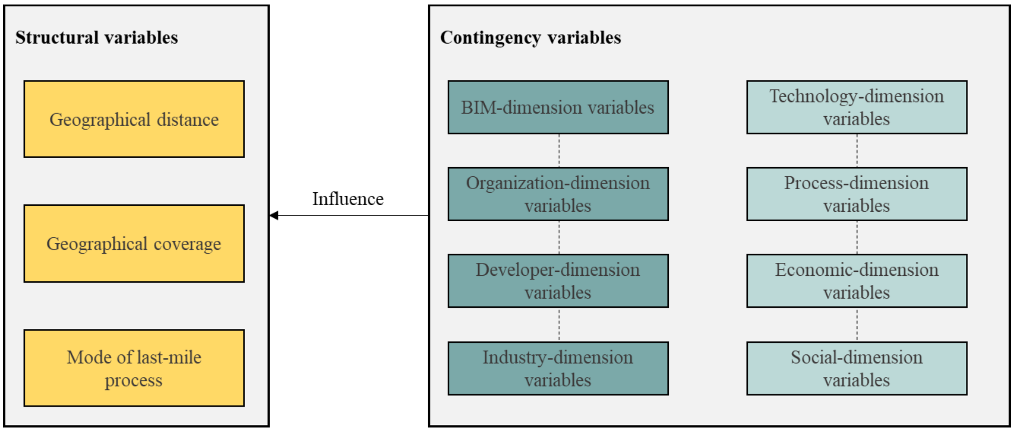

Figure 4. The framework for analysing the last-mile problems of BIM adoption

Properly harnessed, the framework can help different stakeholders to achieve their BIM objectives. For examples, based on the analytic framework, software vendors can set up product development and commercialization strategies to enhance market penetration. BIM users can analyze the critical barriers hindering the last-mile adoption in their existing organization practice, and thus adjust BIM adoption strategies. They may also identify the specific parts of BIM solutions to modify. The framework also assists policymakers or administrators to identify the weakest part in the local last-mile BIM adoption, and devise regulations, specifications, mandates, and incentive mechanism to further promote BIM adoption.

5. DISCUSSION AND CONCLUSION

Amidst the rapid diffusion of BIM in the AEC industry, an increasing number of organizations in the globe are willing to explore and adopt BIM. However, the existing BIM solutions, be they software, information hub, execution plan, and specifications, are dominated and led by a few countries such as the U.S and Europe. For the majority organizations, to catch up with the world-class practice, they tend to benchmark, select and follow the practices that have already been proven effective by global leaders.

The problems lie in the last mile, which is referred to as the period from the point of the determinant of BIM solutions until those solutions are integrated into organizational practice. For organization users, they find it difficult to dramatically change its mindset, practice, and culture to adopt BIM. The difficulties become larger when adopting BIM solutions from overseas countries due to the differences between the environments where the solutions are originated and adopted. This incurs huge efforts to adapt BIM solutions to a specific local setting. For software vendors, they hardly provide highly customized solutions targeting every market, in considering the high cost of development and maintenance. International standardization bodies and best-practice organizations also hold similar concerns. Thus, a critical problem here is how to synchronize and balance the different requirements of such a last-mile network.

This paper aims to take the first step by articulating the last-mile problem of BIM adoption. It does so by proposing a working definition, identifying the components and typology of the last-mile model, and devising a framework to analyze the problems in the last mile. Specifically, a last-mile model consists of three components – the BIM solutions to be diffused, a transit point where BIM solutions are first removed from its origins and introduced to users, and a destination organization in which BIM will be adopted. The last-mile process can have three forms, namely the active, passive and mixed mode based on the involvement of organizations in “fetching” and adapting BIM solutions based on their specific needs.

The proposed last-mile model can be used to analyze the last-mile BIM adoption barriers and design BIM strategies accordingly. For example, from a holistic point of view, the existing last-mile process is largely active; the majority of organizations tend to spend considerable efforts to adapt BIM technology, its accommodating organization practice and supporting specifications for their specific application scenarios. This costs less development efforts for software vendors. However, it incurs huge costs of BIM adoption especially for the early adopters of a locality and keeps a great number of organizations, especially the small- and medium-size organizations from even trying and exploring BIM. To solve the problem, incentives can be designed to encourage mainstreaming software vendors, local agencies, or BIM users to develop localized BIM solutions.

This study has both academic and practical implications. It offers a set of languages to systematically describe the last-mile problem of BIM adoption, which leads to an improved understanding of the last-mile process and problems therein. This also enables a deep dialogue among different stakeholders to work collaboratively to bridge the last-mile problem. For practitioners, this paper facilitates to analyze the last-mile problems of BIM adoption, and develop strategies accordingly – product development and commercialization strategies for software vendors, BIM adoption and adaptation guidelines for organizations, and incentive mechanisms or mandates for policymakers. Future research can work on evaluating the last-mile model in real-life practices, and exploring how the different contingencies influence the last-mile problem of BIM adoption at organizational level.

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