



# PREDICTING BEHAVIOURAL RESISTANCE TO BIM IMPLEMENTATION IN CONSTRUCTION PROJECTS: AN EMPIRICAL STUDY INTEGRATING TECHNOLOGY ACCEPTANCE MODEL AND EQUITY THEORY

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Received 11 August 2019; accepted 13 December 2019

**Abstract.** Despite its great potential to streamline design and construction processes, the implementation of building information modelling (BIM) in many projects has failed to achieve expected benefits due to user resistance. Grounded in the technology acceptance model and equity theory, this study proposes a model of factors predicting resistance behaviours to BIM implementation during the post-adoption stage in construction projects. The model is tested with partial least squares modelling on survey data collected from design engineers in BIM-based construction projects in China. The empirical results provide evidence that after controlling for related individual, organizational and project characteristics, efficiency and equity perceptions play prominent but independent roles in determining behavioural resistance to BIM implementation, and that these perceptions are differently associated with contextual factors at individual, team and project levels. Apart from the independent contextual factors conceptualized in the model, control factors such as individual age and organization nature are also found to be significantly associated with resistance behaviours. As an exploratory effort to examine resistance behaviours to BIM implementation in construction projects, this study contributes to deepened understandings of the complexity of innovation resistance behaviours in the context of construction projects and offer suggestions for how to manage such behaviours.

**Keywords:** building information modelling (BIM), resistance behaviours, technology acceptance model, equity theory, construction projects, partial least squares modelling.

## Introduction

Despite its great potential to address the performance problems rooted in traditional design and construction processes (Eastman et al., 2011; Hartmann et al., 2008), the advancement of building information modelling (BIM) in many regions worldwide remains in an initial stage, with a large proportion of construction projects still sitting on the sidelines of BIM adoption (Bernstein, 2015; Samuelson & Björk, 2014). Even for those organisations that have already adopted BIM in their projects, relatively high percentage has not derived expected benefits from their implementation practices. According to the Smart-Market survey in 2015, for example, only 40% and 45% of the surveyed organizations in China report positive returns on the investment (ROI) from their BIM implementation practices (Bernstein, 2015).

Particularly salient among the reasons resulting in unexpected BIM implementation performance is resistive behaviours towards the changes related to BIM use (Cao et al., 2015; Eadie et al., 2013; Jin et al., 2017). After the decisions to adopt BIM in a specific project are made at the management level, either out of internal efficiency needs or driven by external isomorphic pressures (Cao et al., 2017a; Juan et al., 2017), it is the individual project participants as the ultimate technology users who concretely integrate the technology with their design and construction processes to improve project performance. While user resistance is asserted to be at the root of the unsuccessful implementation of many complex information technologies in other types of organisations (Ali et al., 2016; Kim & Kankanhalli, 2009), the implementation of

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BIM in construction projects as a complex process requiring substantial organisational changes and individual responsibility redistribution (Cao et al., 2015; Eastman et al., 2011) is also frequently accompanied with salient individual resistance. For example, among the eight top-ranked inhibitors to project-level BIM implementation identified in investigation by Eadie et al. (2013) in the UK construction industry, three are directly related to individual resistance behaviours.

While the vast majority of extant studies on BIM have focused primarily on technical issues such as the identification of potential areas in which BIM could be beneficially used, recent years have also witnessed increasing efforts to empirically investigate individual intentions and behaviours related to BIM adoption and implementation (e.g. Jin et al., 2017; Son et al., 2015). To date, this stream of empirical investigations has primarily focused on using the technology acceptance model to assess how factors like technology attributes and individual characteristics influence practitioners' intentions of adopting or accepting BIM, especially during pre-implementation stages (Son et al., 2015). These investigations have contributed to deepened understandings of how individual BIM acceptance and adoption intentions are influenced by related factors through efficiency beliefs (i.e., perceived ease of use and perceived usefulness) on the technology. However, user resistance as a complex phenomenon is not only different from adoption decisions which are principally made by the management level in organisations, it is also conceptually non-equivalent to non-acceptance and has its specific underlying decision-making mechanisms (Kim & Kankanhalli, 2009; Oreg et al., 2018). Despite the importance of understanding and managing user resistance for successful BIM implementation, scant scholarly attention has been devoted to directly investigating resistance behaviours to BIM implementation during the post-adoption stage and providing explanations of how and why these behaviours occur in the context of construction projects.

Grounded in the technology acceptance model (Davis, 1989) and equity theory (Adams, 1965), this study aims to develop and empirically test a model of factors leading to behavioural resistance towards BIM implementation during the post-adoption stage in construction projects. Apart from incorporating efficiency perceptions as direct determinants of behaviours as suggested by the technology acceptance literature, the developed model also examines the influence of equity perception on resistance behaviours considering the substantial process change and responsibility redistribution associated with project-level BIM implementation. The model is empirically tested with data collected from design engineers involved in BIM-based construction projects in China. Taking into account the hierarchy of project organisational contexts within which individual design engineers are embedded, the model further incorporates a set of individual-, team- and project-level contextual factors as antecedents

of efficiency and equity perceptions. The remainder of this paper proceeds as follows. The next section develops the theoretical model and proposes the research hypotheses on the impacts of different perception and contextual factors. Section 2 presents the measurements and data used to test the hypotheses. Section 3 presents the data analyses and results. This is followed by the discussions of the results in Section 4.

## 1. Research model and hypotheses

### 1.1. Theoretical background and research model

There are three primary types of innovation adoption or rejection decisions that occur in a social system (Rogers, 1995): optional decisions in which choices to adopt or reject an innovation are made by each individual independent of the decisions of other members in the system; collective decisions in which adoption or rejection choices are made based on the consensus of the members in the system; authority decisions in which adoption or rejection choices are made by only a small proportion of individuals in the system who are powerful or technically competent. Similar to the adoption of many other innovative technologies in project design and construction processes (Hedgren & Stehn, 2014; Mitropoulos & Tatum, 1999), the adoption of BIM in a construction project is generally based on authority decisions, either made by the management team of the project client/owner or by the managers of the design or construction teams (Cao et al., 2015). For this type of innovation adoption process, after the adoption decisions are made at the management level, individual project members may exhibit different responses towards the implementation of the adopted innovations. An important form of these responses is resistance, which can exhibit multiple dimensions such as cognition, affection and behaviour (Piderit, 2000). Behavioural resistance is the primary dimension of resistance, which is conceptualised in the innovation management and information systems literature as behaviours expressing opposition to the changes associated with the introduction of innovations such as information systems.

As an adaptation of the theory of reasoned action (Fishbein & Ajzen, 1975), the technology acceptance model (TAM) is the most widely applied theoretical model for understanding users' acceptance and usage of innovative technologies including information systems (Venkatesh, 2000). TAM proposes that two specific perceptions, i.e., perceived ease of use and perceived usefulness, determine one's behavioural intention to use a technology, and that the effect of contextual factors on the technology usage behaviours is mediated by the two perception constructs (Davis, 1989). With this proposition, TAM has proven to be powerful in predicting related usage variables, especially acceptance and adoption intention in pre-implementation stages, for a diversity of technologies in different types of contexts (Liu et al., 2018; Son et al., 2015). Despite its predictive power, TAM as a parsimonious model only

incorporates two key perception constructs that reflect cognitions about technical efficiency from an individual gain/loss perspective and fails to take into account the influences of potential conflicting interests among different individual users, which is suggested to be a salient phenomenon in the implementation of many technologies in organisational contexts (Joshi, 1990).

As an attempt to integrate the insights of cognitive consistency theory, psychoanalytic theory and exchange theory (Walster et al., 1978), equity theory proposed by Adams (1965) suggests that individuals involved in social activities seek to maintain equity between their inputs and outcomes against the perceived inputs and outcomes of referent others. In using this theoretical perspective, either explicitly or implicitly, extant literature has interchangeably utilised the terms “equity”, “fairness” and “justice” to refer to the same concepts (Joshi, 1989). The concept of equity proposed by Adams (1965) is primarily related to distributive equity which refers to the perceived fairness of outcome distributions. Through viewing changes in human behaviours as a result of intentions to restore fairness, equity theory can serve as a complementary perspective to TAM for understanding technology usage behaviours, especially behaviours such as resistance during post-adoption stages.

Integrating the theoretical perspectives of TAM and equity theory, and taking into account the characteristics of BIM implementation processes in construction projects, this study proposes that user resistance to BIM implementation during the post-adoption stage in a construction project could be influenced not only by the economic-rational assessment of technical efficiency but also by the perceived inequity during the implementation process. Drawing on TAM (Davis, 1989), perceived ease of use and perceived usefulness are specifically examined as the two efficiency perception constructs directly impacting behavioural resistance to BIM implementation. With regard to equity perceptions, this study focuses on examining the impact of perceived distributive equity,

not only due to its central role in Adams’ (Adams, 1965) equity theory but also because it is mostly related to the context of implementing innovative technologies like BIM in construction projects. Taking into account the hierarchy of project organisational contexts within which individual project participants are embedded, this study further examines how the following five contextual factors at different levels exhibit as antecedents of the efficiency and equity perceptions and thus indirectly impacting behavioural resistance to BIM implementation: self-efficacy and personal innovativeness at the individual level, team management support at the team level, and client/owner support and colleague opinion at the project level. In order to isolate the variation in the dependent variable (i.e., behavioural resistance to BIM implementation) caused by other contextual factors, this study also incorporates the following five control variables in the research model: individual’s gender, individual’s age, organisation nature (i.e., the ownership type of the design or construction firms in which individual project participants are employed), project nature and project size. The research model characterising the impacts of these factors is shown in Figure 1.

### 1.2. Impacts of efficiency and equity perceptions

With regard to the two efficiency perception constructs, perceived ease of use reflects the extent to which an individual believes that performing the behaviour of interest would be free of effort, whereas perceived usefulness reflects the extent to which an individual believes that performing the behaviour of interest would enhance his or her job performance (Davis, 1989). These two types of perceptions have been validated to be important determinants of usage variables, especially acceptance and adoption intention in pre-implementation stages, for a diversity of technologies in different types of contexts (Venkatesh & Davis, 2000). As a fundamentally new way to model, share and utilise project life-cycle data (Eastman et al., 2011), BIM is relatively technologically complex and its implementation benefits in construction projects are relatively

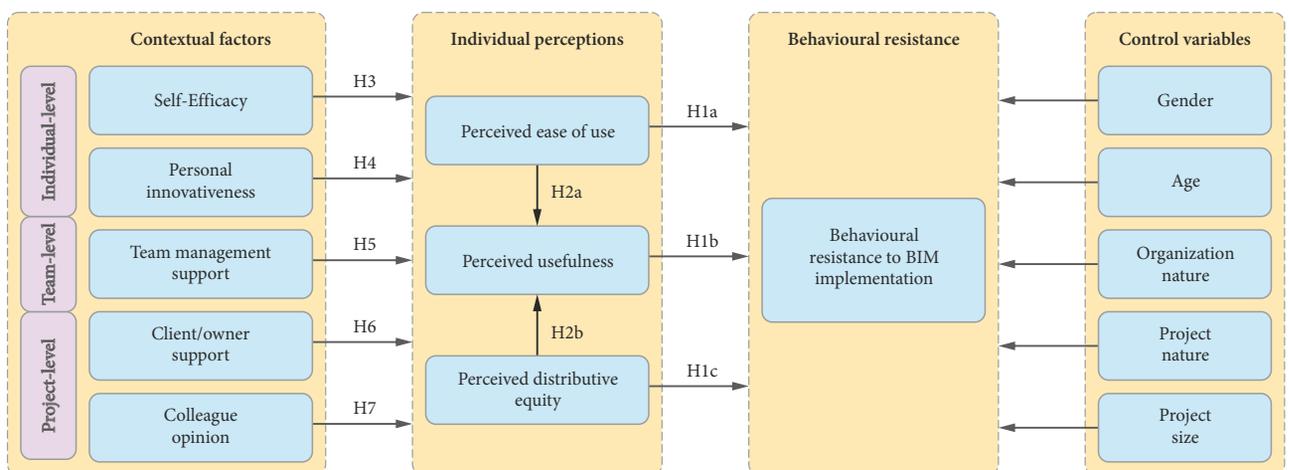


Figure 1. Research model

intangible or not easily realisable at present (Giel & Issa, 2013). Perceived ease of use and usefulness of BIM, therefore, is likely to influence not only whether project managers adopt the technology but also how design and construction engineers concretely implement the technology (e.g. whether express opposition to the changes associated with the usage of the technology) after it is adopted. Apart from the intangibility and uncertainty of its benefits, BIM implementation also involves substantial process changes, with the appropriate redistribution of responsibilities and benefits among different project participant individuals and teams being claimed to be a critical success factor for the implementation process (Cao et al., 2015; Dossick & Neff, 2010; Oraee et al., 2017; Taylor, 2007). Although not closely related to adoption or acceptance intention during pre-implementation stages, therefore, perceived distributive equity (i.e., perceived fairness of outcome distributions) also likely impact how design and construction engineers concretely implement BIM (including whether exhibit resistance behaviours) after it is adopted by project managers. The above considerations lead to the following set of hypotheses:

*H1a. Project participants' perceived ease of use of BIM is negatively associated with their behavioural resistance to BIM implementation.*

*H1b. Project participants' perceived usefulness of BIM is negatively associated with their behavioural resistance to BIM implementation.*

*H1c. Project participants' perceived distributive equity in the technology implementation process is negatively associated with their behavioural resistance to BIM implementation.*

Apart from directly impacting resistance behaviours, different efficiency and equity perceptions might also be impacted by each other. When project participants perceive BIM to be easy to use, they are also likely to regard the technology as having larger capacity to be productively applied to related design or construction activities and thus provide higher performance. Consistent with the theoretical arguments underlying TAM (Davis, 1989), therefore, it is anticipated that there is a direct impact of perceived ease of use on perceived usefulness. Moreover, as whether project participants perceive BIM would enhance their design or construction performance is closely related to how BIM implementation efforts and benefits are distributed among different project participants, it is also anticipated that there is a direct impact of perceived distributive equity on perceived usefulness associated with project-level BIM implementation. These discussions lead to the following set of hypotheses:

*H2a. Project participants' perceived ease of use of BIM is positively associated with their perceived usefulness of the technology.*

*H2b. Project participants' perceived distributive equity in the BIM implementation process is positively associated with their perceived usefulness of the technology.*

### 1.3. Impacts of individual-level contextual factors

The individual-level contextual factors examined in this study include self-efficacy and personal innovativeness, which are two individual traits widely examined as predictors of technology-related perceptions and behaviours in the information systems literature (e.g. Lewis et al., 2003). Self-efficacy refers to an individual's confidence in his or her own capability to perform a specific behaviour (Bandura, 1995). Self-efficacy tailored to the information technology context has been validated as an important determinant of a variety of user perceptions of technologies (e.g. Kim & Kankanhalli, 2009; Lewis et al., 2003). As an innovative information modelling technology in the construction domain, BIM is relatively technologically complex, and the lack of skilled personnel has been a key barrier to BIM implementation in many countries (Eadie et al., 2013). As such, individuals with high self-efficacy for information technology are more likely to be confident in mastering the complex BIM technology and leveraging the technology to improve their design or construction performance. In other words, they are more likely to perceive BIM to be useful and easy to use. These arguments lead to the following set of hypotheses:

*H3a. Project participants' self-efficacy in the domain of information technology is positively associated with their perceived ease of use of BIM.*

*H3b. Project participants' self-efficacy in the domain of information technology is positively associated with their perceived usefulness of BIM.*

As a concept derived from innovation diffusion theory, personal innovativeness is conceptualised by Rogers (1995) to reflect the degree to which an individual is relatively earlier in adopting new ideas than the other members of a system during the diffusion process. On the basis of this concept, individuals in a system can be categorised into different groups such as "innovators", "early adopters", "early majority", "late majority" and "laggards" (Rogers, 1995). In a re-conceptualisation of personal innovativeness, Agarwal and Prasad (1998) suggest that in order to predict individual behaviour toward an innovation, the concept need to be further operationalised as a domain-specific construct which can be explicated clearly and measured directly. Specifically, they re-conceptualise the construct in the domain of information technology and define it as "the willingness of an individual to try out any new information technology" (Agarwal & Prasad, 1998, p. 206). After the re-conceptualisation by Agarwal and Prasad (1998), personal innovativeness has been increasingly examined in the technology implementation literature and received increasing empirical support for its role as a key predictor of technology-related perceptions and behaviours (e.g. Lewis et al., 2003). BIM as an innovative information technology is a typical systemic innovation (Slaughter, 1998), its effective implementation in a construction project not only requires substantial process and cultural changes (Dossick & Neff, 2010; Eastman

et al., 2011) but also places newer requirements on the technical capability of related project participants (Cao et al., 2017a; Eastman et al., 2011). As such, project participants with higher personal innovativeness in the domain of information technology are expected to develop more positive beliefs regarding BIM, including not only perceived ease of use but also perceived usefulness. Based on these considerations, the following set of hypotheses is proposed:

*H4a. Project participants' personal innovativeness in the domain of information technology is positively associated with their perceived ease of use of BIM.*

*H4b. Project participants' personal innovativeness in the domain of information technology is positively associated with their perceived usefulness of BIM.*

#### **1.4. Impacts of team- and project-level contextual factors**

Apart from being associated with individual-level contextual factors, technology-related perceptions could also be shaped by organisational contexts providing facilitating conditions or exhibiting social influence, within which management support and colleague opinion are two relatively salient factors (Kim & Kankanhalli, 2009; Lewis et al., 2003). While colleague opinion is examined in this study at the project level as a whole, management support is examined at two different levels through taking into account the organisational hierarchy of construction projects: client/owner support at the project level and team management support at the team level (i.e., support from managers in the team to which an individual design or construction engineer belong). At the team level, the support from team managers (i.e., team management support) for BIM implementation can manifest in the form of recognising the value of BIM, encouraging BIM implementation efforts and providing BIM-related training and resources (Samuelson & Björk, 2013; Son et al., 2015). This form of support could not only reduce the difficulty for team members to adapt to and efficiently utilise BIM, but also help to prevent the absent or insufficient reimbursement for related BIM implementation efforts in the team. Therefore, the following set of is proposed:

*H5a. Team management support is positively associated with project participants' perceived ease of use of BIM.*

*H5b. Team management support is positively associated with project participants' perceived usefulness of BIM.*

*H5c. Team management support is positively associated with project participants' perceived distributive equity in BIM implementation.*

As an adaptation of the concept of top management support in the information systems literature, client/owner support of BIM implementation reflects the extent to which project clients/owners understand the importance of BIM and the extent to which they facilitate the project BIM implementation process. As construction projects

are generally operated through the production-to-order system, clients/owners can exert substantial influences on project design and construction activities, including the implementation of innovative technologies like BIM. Specifically, the support from project clients/owners for BIM implementation can manifest in the form of establishing execution plans to guide BIM implementation, paying for BIM cost, championing BIM implementation and driving different teams to collaboratively implement BIM (Cao et al., 2014; Eastman et al., 2011). Similar to team management support, this form of support from clients/owners could also reduce the difficulty for individual design or construction engineers to adapt to and efficiently utilise BIM. While team management support could help to prevent the absent or insufficient reimbursement for related BIM implementation efforts in a team, client/owner support in the form of paying for BIM cost and driving different teams to collaboratively implement BIM is closely associated with the distribution of responsibilities and benefits among different teams and, therefore, could also influence perceived distributive equity of project participants. These considerations lead to the following set of hypotheses:

*H6a. Client/owner support is positively associated with project participants' perceived ease of use of BIM.*

*H6b. Client/owner support is positively associated with project participants' perceived usefulness of BIM.*

*H6c. Client/owner support is positively associated with project participants' perceived distributive equity in BIM implementation.*

Colleague opinion is defined in the information systems literature as the perceived extent to which colleagues favours the changes related to the implementation of new information technologies (Kim & Kankanhalli, 2009). This construct has been considered as a salient social norm that shapes beliefs and behaviours in working environments (Kim & Kankanhalli, 2009). For individual design or construction engineers involved in BIM implementation activities in construction projects, colleagues' favourable opinions toward the BIM-related change could also serve to reduce their perceived difficulty in using BIM and amplify their perceived usefulness of BIM. Favourable colleague opinion could also serve to nurture a collaborative culture for BIM implementation in corresponding projects, which in turn could alleviate the "free-rider" problem in project-level BIM implementation processes and thus improve the perceived distributive equity of involved project participants. These considerations lead to the following set of hypotheses:

*H7a. Colleague opinion is positively associated with project participants' perceived ease of use of BIM.*

*H7b. Colleague opinion is positively associated with project participants' perceived usefulness of BIM.*

*H7c. Colleague opinion is positively associated with project participants' perceived distributive equity in BIM implementation.*

## 2. Measurements and data

### 2.1. Measurement development

This study is designed principally based on a positivist epistemology. In contrast to the interpretive epistemology which rejects the possibility of an objective account of events, positivist asserts the existence of a priori fixed relationships within phenomena that could be structurally identified and tested through hypothetico-deductive logic (Orlikowski & Baroudi, 1991). In the spirit of this assertion, positivist studies are generally characterised by the formulation of hypotheses or causal relationships among variables, the use of quantitative measures, the deployment of large-scale sample surveys or controlled laboratory experiments, and the presentation of objective and value-free interpretation from researchers (Creswell, 2013; Orlikowski & Baroudi, 1991). With its intrinsic advantage of allowing replicability and achieving results with statistical power, a questionnaire survey method was used the primary data collection method to empirically test the proposed hypotheses in the research model. Specifically, a survey questionnaire was designed to collect data from engineers involved in BIM-based construction projects.

Following Eisenhardt (1989) and National Academies of Sciences, Engineering, and Medicine [NASEM] (2016), a mix of other data collection methods, including interviews and direct observation, was also used in order to gain more detailed information on the resistance behaviors and related management contexts in some of the surveyed projects. The measurement items in the survey questionnaire were initially developed based on a comprehensive review of the related literature as well as a semi-structured interview with 11 engineers and managers from BIM-based construction projects in China. After the measurement items were initially developed, a pre-test involving 25 design engineers and 40 construction engineers in BIM-based projects was conducted through a Chinese online survey system (Sojump) between June and August 2017 to keep questions simple and avoid ambiguous expressions.

The finalised questionnaire was structured into three sections. The first section obtains general information related to the surveyed project engineer, the organisation in which the engineer was employed, and the BIM-based project the engineer selected to answer the questions. The second section assesses the perception and resistance behaviours of the surveyed engineer related to BIM implementation in the surveyed project. The third section comprises questions on the five examined contextual factors. Apart from control variables such as individual's gender and age, a total of nine core variables were measured in the questionnaire: behavioural resistance (BRE), perceived ease of use (PEU), perceived usefulness (PUS), perceived distributive equity (PDE), self-efficacy (SEF), personal innovativeness (PIN), team management support (TMS), client/owner support (COS) and colleague opinion (COP). These nine variables were all operationalised as reflective constructs with multiple items on seven-point Lik-

ert scales, anchored with "strongly disagree" to "strongly agree". Their measurement items are shown in Table 1.

The operationalisation of BRE was based on the work of Kim and Kankanhalli (2009) on behavioural resistance in other contexts. According to the information further gleaned from the interviews and the pre-test, a total of five items were adopted to measure the construct in the context of BIM implementation in construction projects. The four measurement items of PEU and the four items of PUS were derived from the work of Davis (1989) and Venkatesh and Davis (2000) and reworded to suit the context in this study. The measurement of PDE was adapted from Joshi (1989), with five items measuring the perceived fairness of outcome distributions during the implementation of BIM in construction projects. The measurement items of SEF were derived from Kim and Kankanhalli (2009) and reworded to suit the domain of information technology. The construct of PIN was measured using the items in the domain of information technology developed by Agarwal and Prasad (1998) and further validated by Lewis et al. (2003). The development of the measurement items of TMS was based on the work of Son et al. (2015), with four items measuring the support from team managers in the aspect of regarding BIM as a strategic resource, recognising the value of BIM, providing BIM-related resources and encouraging BIM implementation efforts. The measurement items of COS were derived from Cao et al. (2014), with four items measuring the support from project clients/owners for BIM implementation in the aspects of establishing execution plans to guide BIM implementation, paying for BIM cost, championing BIM implementation and driving different teams to collaboratively implement BIM. The measurement items of COP were derived from the work of Kim and Kankanhalli (2009) conducted for the context of enterprise system implementation in IT service companies and reworded to suit the context of BIM implementation in construction projects.

The control variables include two variables related to individual characteristics, one variable related to the characteristics of the organisation in which the respondent is employed, and two variables related to project characteristics. With regard to individual characteristics, gender was measured with a dichotomous variable which takes the value of 0 for male and 1 for female respondents, whereas age was operationalised as an ordinal variable with four categories (1 = below 25 years; 2 = 25–35 years; 3 = 35–45 years; 4 = above 45 years). With regard to organisational characteristics, organization nature was operationalised as a dummy variable reflecting whether the firm in which the respondent was employed was state-owned enterprises or not (0 = yes; 1 = no). With regard to project characteristics, project nature was operationalised as a dummy variable indicating whether the surveyed project is public project or not (0 = public project; 1 = private project), whereas project size was measured by investment value of the surveyed project (1 = below ¥100 million; 2 = ¥100–500 million; 3 = ¥500–1000 million; 4 = above ¥1000 million).

Table 1. Measurement items

Construct	Code	Items	Sources
Behavioural resistance (BRE)	BRE1	I constantly do not comply with the change associated with BIM implementation in the project	Kim and Kankanhalli (2009)
	BRE2	I constantly use excuses to delay the implementation of BIM in the project	
	BRE3	I have expressed my objections regarding the change associated with BIM implementation to project managers	
	BRE4	I constantly complain to my colleagues about the change associated with BIM implementation in the project	
	BRE5	I constantly protest against the change associated with BIM implementation in the project	
Perceived ease of use (PEU)	PEU1	My interaction with BIM to support my work is clear and understandable in this project	Davis (1989); Venkatesh and Davis (2000)
	PEU2	Interacting with BIM does not require a lot of my mental effort in this project	
	PEU3	I find BIM to be easy to use in this project	
	PEU4	I find it easy to get BIM to do what I want it to do in this project	
Perceived usefulness (PUS)	PUS1	Using BIM improves my job performance in this project	Davis (1989); Venkatesh and Davis (2000)
	PUS2	BIM enables me to accomplish tasks more quickly in this project	
	PUS3	Using BIM enhances my effectiveness on the job in this project	
	PUS4	Overall, I find BIM useful in my job in this project	
Perceived distributive equity (PDE)	PDE1	During the implementation of BIM in this project, the resources my colleagues and I need are provided on a fair basis	Joshi (1989)
	PDE2	The benefit my colleagues and I get from BIM in this project is fair and equal	
	PDE3	The increase in workload due to BIM implementation has been reimbursed accordingly in this project	
	PDE4	The benefits that my colleagues and I received from BIM are fair comparing with the efforts we spend in BIM in this project	
	PDE5	The tasks assigned to my peers and me as part of the BIM implementation process in this project is fair	
Self-efficacy (SEF)	SEF1	Based on my own knowledge, skills and abilities, working with new information technologies would be easy for me	Kim and Kankanhalli (2009)
	SEF2	I am able to change to the new way of working with new information technologies without the help of others	
	SEF3	I am able to change to the new way of working with new information technologies reasonably well on my own	
Personal innovativeness (PIN)	PIN1	If I heard about a new information technology, I would look for ways to experiment with it	Agarwal and Prasad (1998)
	PIN2	Among my peers, I am usually the first to try out new information technologies	
	PIN3	I like to experiment with new information technologies	
Team management support (TMS)	TMS1	Mangers in our team regards BIM as a strategic resource	Son et al. (2015)
	TMS2	Mangers in our team are aware of the benefits that can be achieved with BIM	
	TMS3	Mangers in our team promise to provide necessary resources for BIM implementation	
	TMS4	Mangers in our team encourage me to use BIM in my job	
Client/owner support (COS)	COS1	Client/owner has established execution plans to guide the implementation of BIM in the project	Cao et al. (2014)
	COS2	Client/owner has invested substantial resources in BIM implementation in the project	
	COS3	Client/owner regards BIM implementation as a priority of project activities	
	COS4	Client/owner has put much effort in driving project participants to collaboratively implement BIM	
Colleague opinion (COP)	COP1	Most of my colleagues in this project think the change to the new way of working with BIM is a good idea	Kim and Kankanhalli (2009)
	COP2	My colleagues in this project are supportive of the change to the new way of working with BIM	
	COP3	Most people whom I deal with in my job in this project encourage my change to the new way of working with BIM	

## 2.2. Sampling and data collection

The survey questionnaire was administered to those design and construction engineers directly involved in BIM-based construction projects on the Chinese mainland as targeted respondents, but only the responses from design engineers were analysed in this paper for reasons of research scope. As one of the largest construction markets in the world, the construction output value in China has reached RMB23.51 trillion (about US\$3.42 trillion according to the exchange rate in December 2018) in 2018 (National Bureau of Statistics of China [NBSC], 2019). In recent years Chinese government has released a series of plans to advocate the adoption of BIM (Cao et al., 2014), but the advancement of BIM in the construction industry is still in an infant stage. Constrained by the still limited development of BIM in the Chinese construction industry, a completely random sampling method could not be used to elicit BIM-based projects and related project respondents from a specific project database. Instead, respondents for diversified kinds of BIM-based construction projects in different regions were identified through a variety of methods, including searching through related industry publications, obtaining information from nationwide online BIM communication communities, and contacting professionals participating in five BIM industry seminars held by Tongji University between 2009 and 2017. The identified respondents were then invited to answer the survey questions based on a BIM-based construction project in which they most recently involved. It was expected that selecting their most recent project would not only enable respondents to better recollect the information on BIM implementation activities and contexts in the project, but also help to mitigate social desirability biases as many respondents might otherwise tend to select their most successful BIM-based construction project (Cao et al., 2017a).

Responses were collected by means of e-mail, on-site visits and an online survey system from August 2017 to January 2018. About 430 design engineers from more than 120 BIM-based construction projects located in diversified regions were contacted through network-based channels (including emails and WeChat) and on-site visits, and 192 responses were collected. Among these collected responses, 17 responses containing incomplete information were discarded, leaving a sample size of 175 for subsequent analyses. Demographic characteristics of these 175 design engineers and their involved BIM-based construction projects are shown in Table 2. It is evident that the surveyed engineers have diverse backgrounds in terms of gender, age, industry experience and BIM experience. It is also evident that the involved BIM-based construction projects are diverse in terms of project size, project type and project nature. It is shown, however, that nearly half (48.57%) of the involved BIM-based projects are located in East China whereas a relatively small minority (1.14%) are in Northwest China. Apart from being related to the sampling problem, such an unbalanced dis-

Table 2. Sample characteristics

Variable	Category	Number	Percentage
Individual demographics			
Gender	Male	124	70.86
	Female	51	29.14
Age	Under 25	33	18.86
	Between 25 and 35	123	70.29
	Between 35 and 45	14	8.00
	Above 45	5	2.86
Experience in the construction industry	Under 5 years	95	54.29
	Between 5 and 10 years	62	35.43
	Above 10 years	18	10.29
Experience in BIM implementation	Under 3 years	114	65.14
	Between 3 and 5 years	41	23.43
	Above 5 years	20	11.43
Project demographics			
Project size	Below ¥100 million	39	22.29
	Between ¥100 and 500 million	42	24.00
	Between ¥500 and 1000 million	18	10.29
	Above ¥10000 million	76	43.43
Project type	Residential	17	9.71
	Commercial	72	41.14
	Cultural	21	12.00
	Hospital	3	1.71
	Transportation	29	16.57
	Industrial	20	11.43
	Others	13	7.43
Project nature	Public	80	45.71
	Private	95	54.29
Project location	North China	29	16.57
	East China	85	48.57
	South Central China	31	17.71
	Southwest China	28	16.00
	Northwest China	2	1.14

tribution of the locations of the surveyed projects could also be largely attributed to the unbalanced development of BIM among different regions in China at present (Cao et al., 2015). Among the 175 valid responses, 79 (45.14%) were collected through email, 11 (6.29%) were through on-site visits and 85 (48.57%) were through the online survey system. In order to formally examine whether the responses were impacted by the data collection method, a series of chi-square tests were conducted to assess the associations between the data collection method and sample characteristics. The results revealed no significant difference in sample characteristics among the three types of data collection methods (p-values for gender, age, BIM experience, industry experience, project size, project type and project nature are 0.856, 0.067, 0.310, 0.618, 0.985,

0.518, 0.137 and 0.295, respectively), suggesting that the responses are not substantially influenced by the data collection method.

In order to better understand the factors impacting resistance behaviors towards BIM implementation, semi-structured interviews and direct observations were further conducted in four typical BIM-based projects to gain more detailed information on the resistance behaviors and related management contexts in these projects. These projects include an office building project (started in September 2015) in Jiangsu, an urban rail transit project (started in November 2014) in Shanghai, a laboratory building project (started in December 2016) in Shanghai, and an industrial building project (started in October 2016) in Jiangsu. A total of 13 professionals, including not engineers and directors from project design organizations but also managers from project owners, were interviewed. The interviewees were asked to indicate whether there are any resistance behaviours to BIM implementation, how these behaviours exhibit in daily design and construction activities, what are the factors resulting in these behaviours, and how these behaviors are specifically managed in their projects. The duration of each interview was 45 minutes to 1 hour, all interviews were audio recorded and transcribed verbatim. The authors also attended weekly project meetings and generally observe the interaction between participants on these projects to obtain more information related to resistance behaviors to BIM implementation. The information obtained through the interviews and direct observations in these projects were used to complement and validate the quantitative data collected through the questionnaire survey.

### 3. Data analyses and results

#### 3.1. Measurement validation

Based on the collected data, partial least squares (PLS) as a components-based structural equation modelling (SEM) technique was applied to validate the measurements and test the hypotheses. SmartPLS 2.0 M3 was used as the specific PLS analysis program. Compared with covariance-based SEM techniques like LISREL, PLS is considered to be advantageous in estimating complex structural models and have less strict assumptions of normal data distributions (Fornell & Bookstein, 1982). With regard to the sample size requirement for performing PLS analyses, it is suggested that the sample size should be at least ten times the number of structural paths aiming at the latent construct with the most incoming paths (Hair et al., 2012). The latent construct with the largest number of incoming paths in the present study is BRE (the number of incoming paths is 8 when the paths from the five control variables are included), and the sample size ( $N = 175$ ) satisfactorily meet the “10 times” requirement. Before using the PLS technique to test the proposed hypotheses, the measurements of the variables related to the hypotheses was first validated.

Except for the five control variables, all the variables examined this study were operationalised as multi-item reflective constructs. The measurements of these reflective constructs were validated through assessing internal consistency, convergent validity and discriminant validity. The internal consistency of the constructs was assessed through estimating composite reliability. As reported in Table 3, the composite reliability values of the examined constructs all exceed the recommended criterion of 0.70 (Fornell & Larcker, 1981), indicating that all the constructs exhibit satisfactory internal consistency. Convergent validity reflects the extent to which the items underlying a particular construct actually refer to the same conceptual variable. This was assessed by estimating the average variance extracted (AVE) values as well as the factor loadings of the measurement items. It is shown in Table 3 that the AVE values for all the constructs, except for BRE, are above the recommended threshold of 0.5. Although the AVE value for BRE (AVE = 0.49) falls below the recommended threshold, it is still above the acceptable threshold of 0.40 (Fornell & Larcker, 1981). It is further shown in Table 4 that most of the standardised factor loadings of the items on their respective constructs are above the threshold of 0.7 and are statistically significant (Fornell & Larcker, 1981). Although the loadings of BR2 (0.69), BR4 (0.70), PEU2 (0.62), PEU3 (0.60), TMS3 (0.64) are lower than 0.7, they are all above the criterion of 0.5 recommended by Hair et al. (2010), and none of them loads highly on any of the other constructs. Therefore, these values raise no concerns about convergent validity. Discriminant validity refers to the degree to which measures of theoretically distinct constructs diverge from each other. It is shown in Table 3 that the square roots of the AVE values (values on the diagonal of the correlation matrix in the table) are all larger than the absolute values of inter-construct correlations (off-diagonal values), suggesting that all the constructs have satisfactory discriminant validity (Fornell & Larcker, 1981).

#### 3.2. Hypothesis testing

A bootstrapping procedure with 5000 resamples was used to estimate the statistical significance of the path coefficients in the research model. The results of the PLS analyses based on the bootstrapping procedure are presented in Figure 2. The  $R^2$  value of the dependent variable, behavioural resistance to BIM implementation, is 0.520, indicating that more than half of the variance in the construct is explained by the research model. As shown in Figure 2, the influences of perceived ease of use ( $\beta = -0.432$ ,  $p < 0.001$ ), perceived usefulness ( $\beta = -0.213$ ,  $p < 0.01$ ), perceived distributive equity ( $\beta = -0.218$ ,  $p < 0.01$ ) on behavioural resistance are all negative and statistically significant, thus Hypotheses 1a, 1b and 1c are all supported. It is also shown that while all the influences of the three perception constructs on behavioural resistance are significant, the influence of perceived ease of use is stronger than those of the two other constructs.

Table 3. Measurement validity and construct correlations

Construct	Mean	SD	CR	AVE	Correlation matrix <sup>a</sup>									
					BRE	PEU	PUS	PDE	SEF	PIN	TMS	COS	COP	
Behavioural resistance (BRE)	3.49	1.05	0.83	0.49	<b>0.70</b>									
Perceived ease of use (PEU)	4.22	1.11	0.81	0.52	-0.62	<b>0.72</b>								
Perceived usefulness (PUS)	4.97	1.03	0.88	0.64	-0.46	0.35	<b>0.80</b>							
Perceived distributive equity (PDE)	4.16	1.04	0.89	0.61	-0.51	0.43	0.40	<b>0.78</b>						
Self-efficacy (SEF)	4.59	1.13	0.86	0.68	-0.26	0.35	0.46	0.14	<b>0.82</b>					
Personal innovativeness (PIN)	4.82	1.15	0.90	0.76	-0.36	0.39	0.36	0.24	0.48	<b>0.87</b>				
Team management support (TMS)	5.26	0.90	0.82	0.53	-0.48	0.37	0.38	0.40	0.24	0.33	<b>0.73</b>			
Client/owner support (COS)	4.64	1.22	0.90	0.70	-0.18	0.20	0.39	0.33	0.13	0.08	0.18	<b>0.84</b>		
Colleague opinion (COP)	4.89	1.09	0.88	0.71	-0.34	0.35	0.47	0.39	0.26	0.27	0.31	0.34	<b>0.84</b>	

Notes: SD = standard deviation; CR = composite reliability; AVE = average variance extracted. <sup>a</sup>Bold values on the diagonal represent the square root of AVE.

Table 4. Factor loadings for multi-item constructs

Construct	Items	Mean	SD <sup>a</sup>	Standardised factor loadings <sup>b</sup>									T-value
				BRE	PEU	PUS	PDE	SEF	PIN	TMS	COS	COP	
Behavioural resistance (BRE)	BRE1	3.60	1.33	<b>0.70</b>	-0.33	-0.32	-0.29	-0.18	-0.18	-0.28	-0.11	-0.13	15.17
	BRE2	3.56	1.65	<b>0.69</b>	-0.39	-0.23	-0.33	-0.21	-0.28	-0.34	-0.10	-0.25	15.63
	BRE3	3.55	1.63	<b>0.70</b>	-0.49	-0.29	-0.33	-0.17	-0.27	-0.28	-0.08	-0.26	15.09
	BRE4	3.87	1.43	<b>0.70</b>	-0.40	-0.40	-0.45	-0.18	-0.22	-0.44	-0.27	-0.33	17.51
	BRE5	2.90	1.48	<b>0.71</b>	-0.52	-0.35	-0.37	-0.19	-0.28	-0.33	-0.07	-0.21	15.27
Perceived ease of use (PEU)	PEU1	4.76	1.36	-0.57	<b>0.84</b>	0.37	0.40	0.29	0.32	0.38	0.16	0.30	27.84
	PEU2	3.79	1.79	-0.32	<b>0.62</b>	0.10	0.15	0.17	0.16	0.24	0.09	0.16	9.22
	PEU3	3.95	1.59	-0.26	<b>0.60</b>	0.10	0.25	0.22	0.25	0.17	0.13	0.16	8.02
	PEU4	4.38	1.36	-0.53	<b>0.80</b>	0.32	0.36	0.29	0.36	0.25	0.19	0.34	20.61
Perceived usefulness (PUS)	PUS1	5.23	1.44	-0.38	0.34	<b>0.83</b>	0.33	0.39	0.33	0.35	0.44	0.40	31.44
	PUS2	4.39	1.22	-0.35	0.21	<b>0.77</b>	0.29	0.37	0.26	0.26	0.31	0.35	20.45
	PUS3	5.04	1.27	-0.29	0.21	<b>0.75</b>	0.29	0.38	0.28	0.40	0.21	0.33	16.39
	PUS4	5.21	1.21	-0.45	0.35	<b>0.83</b>	0.36	0.32	0.29	0.22	0.28	0.41	24.69
Perceived distributive equity (PDE)	PDE1	4.50	1.38	-0.39	0.32	0.36	<b>0.82</b>	0.13	0.25	0.30	0.30	0.42	31.44
	PDE2	4.27	1.31	-0.40	0.37	0.28	<b>0.81</b>	0.15	0.22	0.32	0.28	0.32	25.31
	PDE3	3.63	1.35	-0.38	0.29	0.24	<b>0.72</b>	-0.02	-0.01	0.28	0.21	0.22	16.94
	PDE4	4.01	1.31	-0.34	0.21	0.29	<b>0.70</b>	0.12	0.12	0.29	0.19	0.12	15.33
	PDE5	4.42	1.33	-0.48	0.43	0.37	<b>0.84</b>	0.15	0.29	0.35	0.28	0.37	32.21
Self-efficacy (SEF)	SEF1	4.51	1.36	-0.23	0.36	0.33	0.04	<b>0.80</b>	0.35	0.18	0.06	0.20	18.84
	SEF2	4.37	1.46	-0.16	0.24	0.37	0.18	<b>0.84</b>	0.44	0.15	0.13	0.21	28.84
	SEF3	4.90	1.29	-0.25	0.25	0.43	0.13	<b>0.83</b>	0.40	0.24	0.12	0.24	21.80
Personal innovativeness (PIN)	PIN1	5.22	1.38	-0.36	0.38	0.34	0.21	0.45	<b>0.89</b>	0.33	0.11	0.24	42.63
	PIN2	4.26	1.24	-0.22	0.26	0.27	0.15	0.40	<b>0.79</b>	0.22	0.03	0.19	21.29
	PIN3	4.99	1.36	-0.32	0.37	0.33	0.25	0.41	<b>0.92</b>	0.29	0.07	0.26	61.41
Team management support (TMS)	TMS1	5.46	1.11	-0.44	0.34	0.30	0.30	0.20	0.31	<b>0.81</b>	0.05	0.31	20.43
	TMS2	5.54	1.17	-0.35	0.31	0.30	0.34	0.11	0.28	<b>0.75</b>	0.10	0.20	15.22
	TMS3	4.90	1.19	-0.27	0.22	0.28	0.19	0.26	0.19	<b>0.64</b>	0.23	0.20	8.20
	TMS4	5.13	1.43	-0.32	0.20	0.22	0.31	0.14	0.15	<b>0.71</b>	0.20	0.19	11.63

End of Table 4

Construct	Items	Mean	SD <sup>a</sup>	Standardised factor loadings <sup>b</sup>									T-value
				BRE	PEU	PUS	PDE	SEF	PIN	TMS	COS	COP	
Client/owner support (COS)	COS1	4.79	1.41	-0.16	0.12	0.32	0.31	0.07	0.06	0.07	<b>0.82</b>	0.31	24.24
	COS2	4.59	1.49	-0.10	0.16	0.33	0.25	0.10	0.03	0.19	<b>0.85</b>	0.29	33.13
	COS3	4.49	1.42	-0.11	0.18	0.28	0.21	0.16	0.04	0.13	<b>0.79</b>	0.27	20.04
	COS4	4.69	1.48	-0.23	0.21	0.37	0.31	0.10	0.14	0.20	<b>0.90</b>	0.28	58.83
Colleague opinion (COP)	COP1	5.06	1.32	-0.35	0.32	0.46	0.33	0.19	0.24	0.22	0.27	<b>0.84</b>	27.78
	COP2	4.80	1.25	-0.23	0.28	0.41	0.32	0.27	0.22	0.29	0.37	<b>0.87</b>	37.84
	COP3	4.81	1.32	-0.28	0.29	0.30	0.32	0.21	0.21	0.27	0.22	<b>0.81</b>	25.14

Notes: Note: Bold values represent standardised factor loadings of the items on their respective constructs, and T-values are for these loadings. <sup>a</sup>SD = standard deviation. <sup>b</sup>All factor loadings are significant at the 0.1% level.

As for the associations between these perception constructs, the influences of perceived ease of use ( $\beta = 0.001, p > 0.05$ ) and perceived distributive equity ( $\beta = 0.141, p > 0.05$ ) on perceived usefulness are both found to be non-significant at the 5% level, hence Hypotheses 2a and 2b are not supported.

With regard to the influences of the two individual-level contextual factors, it was hypothesised that self-efficacy (Hypotheses 3a and 3b) and personal innovativeness (Hypotheses 4a and 4b) are both positively associated with the two efficiency perception constructs (i.e., perceived ease of use and perceived usefulness). It is shown in Figure 2 that, except for the association between personal innovativeness and perceived usefulness ( $\beta = 0.074, p > 0.05$ ), all these hypothesised associations are statistically significant. Therefore, Hypotheses 3a, 3b, 4a are supported while Hypothesis 4b is not. With regard to the influences of the team- and project-level contextual factors, it was hypothesised that team management support (Hypotheses 5a, 5b and 5c), client/owner support (Hypotheses 6a, 6b and 6c) and colleague opinion (Hypotheses 7a, 7b and 7c) are all positively associated with the three perception

constructs. It is shown in Figure 2 that out of these eight proposed relationships, only the association between team management support and perceived usefulness ( $\beta = 0.132, p > 0.05$ ) as well as the association between client/owner support and perceived ease of use ( $\beta = 0.068, p > 0.05$ ) are not statistically significant. With regard to the influences of the control variable, age ( $\beta = 0.107, p < 0.01$ ) and organization nature ( $\beta = 0.130, p < 0.01$ ) both exert significant influences on behavioural resistance whereas the influences of gender, project nature, project size are not found to be significant at the 5% level.

#### 4. Discussions, implications and future research

##### 4.1. Discussions of findings

This study proposes that resistance behaviours to BIM implementation during the post-adoption stage in construction projects, which are different from adoption or acceptance intentions during the adoption or pre-adoption stages, could be influenced by not only efficiency beliefs but also equity perceptions. As proposed in the hypotheses, the negative influences of the three examined perception

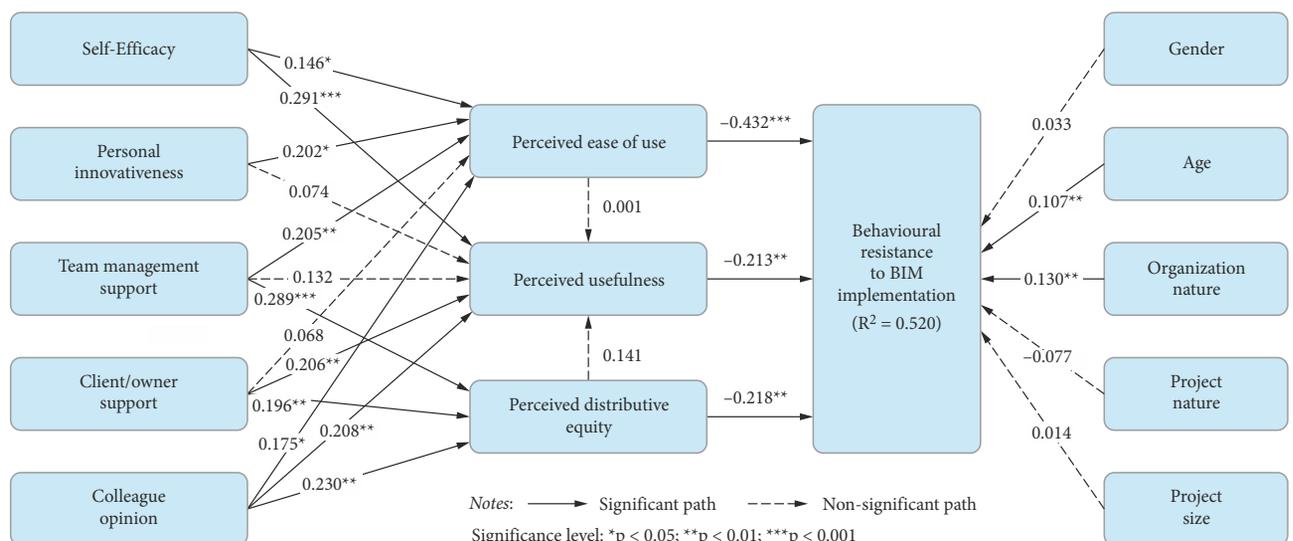


Figure 2. Results of PLS analyses for the research model

constructs (i.e., perceived ease of use, perceived usefulness, perceived distributive equity) on behavioural resistance to BIM implementation are all found to be significant. An unexpected result is that perceived usefulness is revealed to be statistically influenced by neither perceived ease of use nor perceived distributive equity. While the association between the perceptions of usefulness and ease of use has been relatively frequently suggested by the information systems literature based on the technology acceptance model (Venkatesh & Davis, 2000), the non-significant association between these two perception constructs ( $\beta = 0.001$ ,  $p > 0.05$ ) illustrated in the present study is consistent with the results of Son et al. (2015) investigation on BIM technology and Lewis et al. (2003) investigation on Web technologies. A plausible explanation for this non-significant association is that, for radical technologies like BIM which are relatively complex but widely claimed by professional communities to be advantageous over traditional technologies (Cao et al., 2014; Eastman et al., 2011), individuals' assessments of technological usefulness could be relatively independent of their ease of use perceptions to the technologies but is more influenced by contextual factors which could help to better exploit the potential benefits of the technologies.

Although having a higher path coefficient ( $\beta = 0.141$ ) than the association between the perceptions of usefulness and ease of use, the association between usefulness and distributive equity perceptions is also found to be non-significant. This result suggests that usefulness perceptions are also relatively independent of the cognitive resources related by distributive equity in BIM implementation. Paired-samples t-tests further reveals that the means of perceived ease of use and perceived distributive equity, which are close to the neutral of "4" for a seven-point Likert scale, are both significantly lower than that of perceived usefulness ( $p$ -values are both lower than 0.001). This results also tend to suggest that usefulness perceptions to BIM is relatively independent of the perceptions of ease of use and distributive equity, and that although the potential value of BIM has already been widely acknowledged by the sample design engineers, lack of skilled users and inappropriate distribution of responsibilities and benefits are still salient factors leading to resistance behaviours to BIM implementation. As the project manager of the owner in an urban rail transit project commented:

*"Due to the complexity of BIM tools and the lack of skilled engineers, the implementation of BIM in this project is very difficult ... We believe BIM can help us to digitally manage the facilities in the operation and maintenance stages. In the design stage, the designers need to transform their 2D drawings to BIM models. We know they could not benefit much from these activities. The implementation of BIM has redistributed the works and responsibilities of project participant teams. Many participants have not successfully adapted to these changes".*

With regard to the influences of contextual factors on the efficiency and equity perceptions, while most of

the proposed hypotheses are validated with the empirical data, the results also provide evidence that the impacts of the contextual factors are not invariant. It is noteworthy that the influence of personal innovativeness on perceived usefulness is not supported by the data. A plausible explanation for this result is that, due to the relatively wide media coverage and discussion of BIM (Cao et al., 2014), the usefulness of BIM has already been apparent to a large proportion of industry practitioners. As a consequence, the difference in the usefulness perceptions among the practitioners is primarily impacted by the contextual factors which could help to better exploit the potential value of BIM in corresponding projects, whereas the association between personal innovativeness and usefulness perceptions is rendered as non-significant. Another noteworthy result is that while perceived ease of use of BIM is found to be more substantially impacted by team management support, perceived usefulness of BIM is revealed to be more significantly associated with client owner support. This result tends to suggest that management support such as training provision at the team level and client/owner support such as driving inter-organizational collaborations for BIM implementation at the project level generally play different roles in shaping efficiency perceptions related to BIM implementation. A paired-samples t-test further reveals the mean score of team management support to be statistically higher than that of client owner support ( $t = 6.006$ ,  $p < 0.001$ ), suggesting that compared with insufficient management support at the team level, lack of client/owner support at the project level is a more obvious barrier for design engineers to actively participate in BIM implementation practices. This is also corroborated by the comment of a design engineer in an office building project involving BIM use:

*"(At present) we have not the ability to accomplish the design directly using BIM tools ... In this project the drawings are still accomplished based on traditional 2D CAD tools by design engineers and then transformed to BIM models by independent BIM engineers, which involves a large amount of additional works to establish and check BIM models. However, we haven't got sufficient support from the owners ... the design fees have not substantially increased according to these additional works, as it is difficult for us to bargain with the owners due to the competition environment. Frankly speaking, our designers have no intrinsic motivations to implement BIM in this project, we just plan to meet the minimum requirements of the project owner".*

In order to isolate the variation in the dependent variable (i.e., behavioural resistance to BIM implementation) caused by other contextual factors, this study has also examined the effects of five control variables in the research model. The empirical results provide evidence that age as an individual-level characteristic is positively associated with behavioural resistance to BIM implementation. A plausible explanation for this finding is that, in comparison with users from other age groups, older users tend

to be not only less flexible with changes but also more fearless in expressing different opinions (Ali et al., 2016). The empirical results also provide evidence that organization nature is significantly associated with behavioural resistance to BIM implementation, with design engineers from state-owned corporations are generally more behaviourally resistant to BIM implementation than engineers from non-state-owned corporations. This finding is closely related to the fact that state-owned design corporations have been playing more active roles in advancing BIM in the Chinese construction industry in recent years, not only because of their heavier social responsibilities to respond to public appeals and lead industry development, but also because they are generally large in scale and have more slack resources to facilitate the implementation of BIM in related projects (Cao et al., 2017a, 2017b). A design director in an industrial building project, who comes from a large state-owned design corporation in Shanghai, also commented:

*“The promotion of BIM is very challenging at present. In my opinion, the functions of current BIM software do not meet practical requirements, the exchange of data among different BIM software is also difficult ... The effective use of BIM needs substantial investment in both training and software. The top management team in our corporation quite supports the advancement of BIM... As our corporation has more and more BIM-based projects in recent years, we have established a separate BIM center to advance the implementation of BIM throughout the corporation”.*

#### 4.2. Implications

While recent years have witnessed increasing efforts to empirically investigate individual intentions and behaviours related to BIM adoption or acceptance during the adoption or pre-adoption stages (Son et al., 2015), this study represents an exploratory effort to directly examine the factors leading to resistance behaviours to BIM implementation during the post-adoption stage in construction projects. Through integrating the theoretical perspectives of TAM and equity theory, this study has comprehensively examined how user resistance to BIM implementation in a construction project is influenced by three different types of efficiency and equity perceptions. The results contribute to deepened understandings of how economic-rational assessments of technical efficiency and equity-oriented cognitions play distinct and complementary roles in shaping resistance behaviours during the implementation of innovative technologies like BIM. Through investigating how a set of individual-, team- and project-level contextual factors differently influence efficiency and equity perceptions and resistance behaviours during project-level BIM implementation processes, this study also provides insights into the complexity of individual behaviours in construction projects which are characterised as temporary and multi-organizational coalitions (Winch, 2010).

This study also has several practical implications. First, the empirical results provide evidence that efficiency and

equity perceptions play prominent but relatively independent roles in determining behavioural resistance to BIM implementation in construction projects. In order to alleviate user resistance in BIM implementation, therefore, project managers not only need to take measures (e.g. provide training) to improve the perceived usefulness and ease of use of BIM among project participants, special attention should also be paid to identify where distributive inequity might become an issue. Second, as colleague opinion proves to be a salient determinant of both efficiency and equity perceptions in BIM implementation, project managers could first persuade key project participants (especially opinion leaders) to accept the necessity, usefulness and appropriateness to implement BIM. These key participants can then serve as champions of BIM implementation to their project colleagues. Third, because of the importance of client/owner support in shaping BIM-related perceptions and its relatively low level as compared with the management support of BIM at the team-level, project clients/owners should play more active roles in project-level BIM implementation processes in terms of establishing execution plans to guide BIM use, paying for BIM cost, championing BIM use and driving different teams to collaboratively use BIM. Fourth, due to the significant influences of self-efficacy, personal innovativeness and age on BIM-related perceptions and resistance behaviours, project managers should be cognitive of these individual characteristics when managing BIM implementation processes.

#### 4.3. Limitations and future research directions

The findings of this study should be interpreted in light of the following limitations. First, due to its intrinsic advantage of allowing replicability and achieving results with statistical power, questionnaire survey was used to collect the data for model validation. However, the self-reported data collected through this method may be subject to the common method bias related to subjectivity and social desirability. As a statistical control technique, Harman's one-factor test was conducted on the nine multi-item constructs (including BRE, PEU, PUS, PDE, SEF, PIN, TMS, COS and COP) to assess potential biases (Podsakoff & Organ, 1986). It was revealed that the first factor only accounted for 25.72% of the variance in the measurements, suggesting that the common method bias tends to be less a problem for the results. Second, this empirical study was conducted with the sample of design engineers in the Chinese construction industry, in which the development of BIM is still in an infant stage. This may limit the generalisability of the results to other types of project participants within other market and cultural contexts. In order to validate the applicability of the analysis results in different contexts, future efforts can be devoted to conducting related cross-cultural and cross-national research which involves different types of project participants. Third, as an exploratory effort to directly examine resistance behaviours to BIM implementation during the post-adoption

stage in construction projects, this study focuses on examining the influences of related factors on resistance behaviours from a static perspective. Taking into account the evolutionary nature of individual behaviours, a natural extension of this study would be to conduct longitudinal investigations on resistance behaviours to BIM implementation from a dynamic perspective in the future.

## Conclusions

Grounded in the technology acceptance model and equity theory, this study proposed and tested a model of factors predicting resistance behaviours to BIM implementation during the post-adoption stage in construction projects. The empirical results provide clear evidence that after controlling for related individual, organizational and project characteristics, the three examined perceptions (i.e., perceived ease of use, perceived usefulness and perceived equity perceptions) play prominent but relatively independent roles in determining behavioural resistance in construction projects. The results also provide evidence that these perceptions are differently associated with contextual factors at individual, team and project levels. Apart from the independent contextual factors conceptualized in the model, control factors such as individual age and organization nature are also found to be significantly associated with resistance behaviours to BIM implementation. Taking into account these influences, the proposed model of factors explains a total of 51.9% of the variance in behavioural resistance to BIM implementation. As an exploratory effort to directly examine resistance behaviours to BIM implementation during the post-adoption stage in construction projects, this study contributes to deepened understandings of how efficiency- and equity-oriented cognitions collectively determine resistance behaviours during the implementation of innovative technologies like BIM, and how these cognitions and behaviours are shaped by different levels of contextual factors in construction projects.

## Acknowledgements

The authors gratefully acknowledged the assistance of Dan Tan at Tongji University in data processing.

## Funding

This work was supported by the <National Natural Science Foundation of China> under Grant [number 71802150, 71771172]; the <Shanghai Pujiang Talent Program> under Grant [number 18PJC110]; and the <Program for Young Excellent Talents in Tongji University> under Grant [22120180008].

## Author contributions

Guangbin Wang, Pengfei Wang and Dongping Cao collectively conceived the study and designed the structure of the paper. Pengfei Wang and Xiaochun Luo were responsible for data collection. Pengfei Wang and Dongping

Cao performed the partial least squares modelling using SmartPLS 2.0 M3 and obtained results. Dongping Cao wrote drafts of the paper, Xiaochun Luo revised the paper. Guangbin Wang and Dongping Cao are supervisors.

## Disclosure statement

No potential conflict of interest was reported by the authors.

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