Innovation strategy or policy pressure? The motivations of BIM adoption in China’s AEC enterprises

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ABSTRACT
As a set of new technologies to enhance life-cycle construction management processes, Building Information Modelling (BIM) has been introduced to China’s Architecture, Engineering, and Construction (AEC) industries. Adopting the framework of Technology-Organization-Environment (TOE) and the theory of innovation diffusion, this study provides an empirical analysis of BIM adoption and its impact on corporation performance, using a time series panel sample of 1109 observations of AEC enterprises listed in China’s A-share stock market. This study reveals that the decision of BIM adoption could be driven by corporate innovation strategy and government policy pressure. Overall, BIM implementation brings positive financial performance to the BIM adopted enterprises, but the differences of BIM performance between innovation strategy-led and policy-driven adoption are only significant in enterprises of state-controlled. This paper contributes to the body of knowledge in enriching the TOE framework by adding innovation strategy motivations in the organization context and government policy forces to the environment context. In addition, the findings of this paper might help policy makers around the world improve the acceptance of BIM technology and evaluate the effects of BIM policy.

1. Introduction
Building Information Modeling (BIM) is generally understood as a set of technologies and solutions aiming to enhance interorganizational collaboration in the Architecture, Engineering, and Construction (AEC) industries (Ghafrarianhoseini et al. 2017). It helps owners, designers, contractors, and management teams to collaborate, visualize, and manage the construction work to achieve better outcomes (Azhar, Khalfan, and Maqsood 2012). These functions of BIM technology are generating project benefits in change control, decrease in repetition, energy efficiency, shortening construction time, and quality management (Doumbouya, Gao, and Guan 2016). Thus, BIM has been widely accepted for promoting efficiency and facilitating collaboration of projects in the AEC industries in many countries including the US, UK, and Europe countries (Jones and Bernstein 2012). BIM also becomes increasingly popular in projects in Asian countries like China, Singapore, Korea, and Japan (Cheng and Lu 2015). The Chinese government has emerged as a major force promoting BIM adoption by issuing an official guideline of BIM adoption in 2015 (MOHURD 2015). Yet, despite the strong encouragement and promoting efforts with government support, the adoption rate of BIM in Chinese AEC firms is lower than the expectation (Herr and Fischer 2019).

Researchers have explored engineers’ intentions to adopt BIM using behavior theories such as Technology Acceptance Model (TAM) and the Unified Theory of Acceptance and Use of Technology (UTAUT) (Ahmed and Kassem 2018; Baharuddin et al. 2021). Determine factors including BIM software characteristics (Yuan, Yang, and Xue 2019), project features (Barlish and Sullivan 2012), and perceived benefits (Hong et al. 2019) are analyzed under these behavior theories. BIM adoption at the corporate level is more suitable to be explored by theories of technology task fit model, innovation diffusion theory, and technology-organization-environment framework (TOE) (Ahuja et al. 2020). Based on this framework, the impacts of AEC firms’ characteristics such as enterprise size, learning capacity, and knowledge capability on BIM adoption are examined (Abbasnejad et al. 2020). Effects of management support, organizational readiness, and government policy have also been identified in the process of corporation BIM adoption and implementation (Yuan, Yang, and Xue 2019; Saka, Chan, and Siu 2020; Chen et al. 2019). The linkages between corporation innovation needs (Singh and Holmström 2015), innovation awareness (Gledson Barry and Greenwood 2017), and innovation characteristics (Ahmed and Kassem 2018) and BIM usage are explored. Yet, current findings of BIM adoption are mainly generated from surveys and interviews of experts, which have been
criticized for overemphasizing psychological effects (Ogrezeanu 2015). Validation of BIM adoption and its determinant theories and frameworks using actual corporate features, innovation strategies, and environmental changes is inadequate. In addition, although Yuan and Yang (2020) have proved that government efforts and subsidies are effective in driving BIM adoption, but their conclusion is based on theoretical derivation which requires further empirical evidence.

Therefore, questions could be raised: (1) what is the relationship between corporation innovation strategy and BIM adoption? (2) How does the BIM policy issued by the government impact on the innovation-driven BIM adoption model? To answer these questions, this paper explores the key influential factors of BIM adoption decisions in China’s AEC companies from the perspective of innovation strategy and policy promotion, and examines whether different motivations of BIM adoption would lead to divergence in BIM performance. Using a time series panel dataset from China’s A-share stock market, this study is among the first initiatives which tracks the changes of BIM adoption in China’s listed AEC enterprises. The findings of this study contribute to the knowledge of technology-organization-environment framework by adding internal innovation strategy motivations and external policy influencing mechanisms to the BIM adoption causal model. The implications of this study might improve the alignment between policy support and BIM adoption in AEC industries.

2. Literature review

2.1. BIM adoption and its influential factors

Scholars have studied the decision of BIM adoption from different perspectives, including technical, organization and management, and human aspects (Wang et al. 2020). From a technical perspective, Yuan, Yang, and Xue (2019) found that BIM software characteristics and ease of use were major considerations of BIM adoption. Lee, Eastman, and Solihin (2020) argued that latent data exchange issues and unexpected errors hindered the adoption and utilization of BIM-based technology in design, construction, and facility management. In addition, the perceived benefits brought by BIM implementation in construction projects (e.g., better scheduling management, time savings, cost reduction, facility management, and reduction in rework) are key incentives of BIM usage (Herr and Fischer 2019; Tan et al. 2019; Lin and Yang 2018). Apart from BIM benefits, project features such as size, team members’ BIM professionals, and the communication between them are key factors of BIM success (Barlish and Sullivan 2012).

From corporation management perspectives, BIM implementation enables more efficient communication and collaboration within the organization and with external stakeholders (Lindblad 2013; Chan, Olawumi, and Ho 2019). Thus, researchers have demonstrated that BIM adoption in construction industry is related to firms’ features such as availability of qualified staff (Ozorhon and Karahan 2017), inter-firm relationship network structure, and organizational competitiveness (Cao et al. 2018), cultural readiness and innovation strategic initiatives (Abbasnejad et al. 2020). Especially, Son, Lee, and Kim (2015) pointed out that top managers’ awareness, attitudes, and support were critical factors affecting companies’ intention to use BIM. Thus, a strategic approach at the organizational level of BIM adoption and implementation is preferred and suggested (Poireir, Staub-French, and Forgues 2015). Yet, high initial investment, costs and time required for BIM training, and low return on investment also hinder the intention of BIM usage (Tan et al. 2019; Hosseini et al. 2016), especially in small and medium AEC enterprises (Makabate Choewe et al. 2021).

Recognizing that BIM is an innovation which transforms the practices in the AEC industries, studies have investigated the link between BIM adoption and corporation innovation initiatives. For instance, Singh and Holmström (2015) found that BIM adoption was driven by organizations’ hierarchy ordering of innovation-related needs. Gledson Barry and Greenwood (2017) argued that BIM adoption was an authority-type decision made by organizational upper management with innovation awareness. Ahmed and Kassem (2018) developed a unified BIM adoption taxonomy and found that innovation characteristics, external environment characteristics, and internal environment characteristics were important drivers of BIM adoption. Moreover, the use of BIM could also improve the innovation capabilities in construction projects and organizations (Liu et al. 2020).

Furthermore, industry characteristics such as customer demand, shareholders’ willingness of collaboration, coordination, and communication also have positive impacts on BIM usage (Herr and Fischer 2019; Eadie et al. 2015). Studies from a macro-environment perspective, on the other hand, focus on the impact of legal standards as well as government support towards the adoption of BIM technology (Zhou, Yang, and Yang 2019; Ahuja et al. 2020). Evidence have shown that government-driven efforts significantly promote the awareness and uptake of BIM (Makabate Choewe et al. 2021). Human resource issues such as insufficient BIM technicians and lack of skilled and experienced personnel are major reasons for not adopting BIM (Ghaftarianhoseini et al. 2017; Zhao, Wu, and Wang 2018; Zhang et al. 2020). Therefore, measures such as government-led BIM education and investment in personnel training would help increase BIM awareness and promote BIM adoption (Ahn and Kim 2016; Zhang et al. 2020).
2.2. BIM adoption and decision theories

As a dominant enabler of construction innovation (Eastman et al. 2011), BIM adoption has been analyzed by various decision and innovation-related theories. At the level of individual’s BIM adoption intention and behavior, the theory of reasoned action, planned behavior, TAM and UTAUT are commonly adopted (Ahuja et al. 2020). For instance, Ahmed and Kassem (2018) analyzed BIM adoption in the UK using the TAM and defined three stages of BIM implementation, namely, awareness, intention, and adoption. Baharuddin et al. (2021) extended the TAM and tested the influence of training on BIM adoption. Hilal, Maqsood, and Abdekhadadeh (2019) integrated the model of technology task fit and unified theory of acceptance and use of technology to understand BIM adoption in facility management. Qin et al. (2020) further validated the impacts of environmental factors using the TAM-TOE (Technology-Organization-Environment) framework and found that government incentives played critical roles in BIM adoption in China. Yuan, Yang, and Xue (2019) also adopted the TAM-TOE framework to predict project owners’ BIM adoption behavior and found BIM technical features and government policies had a positive effect on the perceived usefulness of BIM.

Yet, although TAM and UTAUT and their extended models are widely adopted to analyze an individual’s technology adoption behavior, they have been criticized for overemphasizing the individual’s intention and psychological effects (Ogrezeanu 2015).

Ahuja et al. (2020) argued that the Innovation Diffusion theory (IDT) (Rogers 2003) and TOE framework (Tornatzky, Fleischer, and Chakrabarti 1990) were more suitable for analyzing technology adoption at the organization level, for these theories considering BIM adoption and implementation as an organization-wide process. Therefore, several recent studies have been devoted to explore the adoption of BIM in AEC enterprises within the TOE framework. For instance, Saka and Chan (2020) adopted the theory of IDT and TOE to explore the sociotechnical barriers of BIM adoption in small and medium enterprises. Mohammad et al. (2019) grouped BIM adoption challenges for contractor’s organizations into the TOE framework. Saka, Chan, and Siu (2020) further adopted the TOE framework to test the drivers of BIM adoption in the Nigerian construction SMEs and found that organizational readiness was of the utmost important. Chen et al. (2019) found that the advantages of BIM and management support were significant antecedents of BIM adoption in the TOE framework. Yet, it is worth noticing that most of the findings above are generated using data from questionnaire surveys collected with expert scoring methods, rather than the actual performance and managerial characteristics of AEC firms.

3. Research framework and methods

3.1. Research framework

The TOE framework is formed by three major contexts, namely, Technology, Organization, and Environment (Tornatzky, Fleischer, and Chakrabarti 1990). In the technology context, factors including complexity, compatibility, trialability, relative advantage, availability, and characteristics have been examined in BIM adoption studies of Ahuja et al. (2016), Ahuja et al. (2020), and Chen et al. (2019). Organizational elements of BIM determinants contain management support, organizational readiness, adequate financial resources, appropriate organization culture, and firm characteristics (Chen et al. 2019; Saka, Chan, and Siu 2020). Environmental context concerns the influences of competitor pressure, customer pressure, partner pressure, and government pressure on BIM adoption (Chen et al. 2019; Ahuja et al. 2016). According to Singh and Holmström (2015), the decision of BIM adoption could be an alignment with organizations’ innovation strategy. Regarding the BIM promotion policy issued by the government (MOHURD 2015), the application of BIM in some enterprises of China might also be out of the policy pressure. Therefore, the TOE framework adopted in this study examines the following contexts and elements: (1) Technology – corporate-level BIM performance; (2) Organization – corporate innovation strategy; and (3) Environment – government BIM policy.

According to the theory of “diffusion of innovation” (Rogers 2003) and the differences of individuals and enterprises in “technology readiness” (Parasuraman and Colby 2001), new technology adopters could be categorized into innovators, early adopters, early majority, late majority, and laggards in a hierarchy (Rogers 2003). Among which, innovators are risk takers, early adopters are enthusiasts and opinion leaders, while the early majority are pragmatists, and the rest are considered as conservative (Rogers 2003). Larger companies with less financial and socio-technical constraints are more likely to be among the early majority or innovators (Ainyin and Adamu 2018). Referring to the theory of Task-Technology Fit (TTF) (Goodhue and Thompson 1995) and the theory of innovation diffusion, this study further explores the diversification of BIM performance by different adoption motivations.

The research framework of this study is shown in Figure 1. To fulfill the aim of this study, we adjust the TOE framework in the following ways. First, we assume that the motivations of BIM adoption in AEC enterprises in China come from two major forces, namely, corporate innovation strategy (organization context) and government policy pressure (environment context). Instead of taking the perceived usefulness of BIM as a technology element which drives BIM adoption, this study uses the actual corporate performance...
to represent the benefit of BIM. Under this circumstance, BIM benefit becomes an outcome of BIM adoption, which is influenced by different motivations, referring to the theory of innovation diffusion. Other elements such as firm characteristics (e.g., nature, size, and location) and managerial characteristics are grouped as control variables in the framework.

3.2. Data and samples

The research sample of this study is the listed AEC enterprises in China’s A-share stock market, which contains 271 enterprises in total. The reasons of using secondary information from the stock market in this study are: (1) the time series panel data reports the actual adoption and changes of BIM adoption among listed AEC firms before and after the government promotion policy, (2) a firm’s innovation strategy could be measured by its R&D (research & development) investment to avoid subjective evaluations, and (3) the influences of managerial characteristics of firms and financial capability on BIM adoption could be controlled. Using “BIM” as a key word, we search the annual financial reports of 271 listed AEC companies in China and find that 258 reports document the adoption of BIM during their operation from 2013 to 2019. Then, we collect firms’ characteristics information and financial performance of the 271 AEC enterprises. After deleting the missing data, a panel sample of 1380 firm-year observations ranging from 2013 to 2019 is obtained. The data of this study is collected from the database of WIND and CSMAR.

Demographical information of the sample AEC enterprises is listed in Table 1. It could be seen that 99 of 271 AEC enterprises adopt BIM, indicating an adoption rate of 36.5% in China’s listed AEC enterprises. Majority of the AEC listed enterprises, about 63.5%, still haven’t applied BIM technology in their operations. About 26.3% of the adopters started to use BIM before the BIM policy, which could be defined as strategy-led adoption. The rest 73.7% of the adopters, however, adopted BIM after the BIM policy, which could be called policy-driven adoption. Other demographic features of the sample are also displayed in Table 1. It shows that 38% of the listed AEC enterprises are owned by the state, while more than 66% of them located in developed regions of mainland China. More than 90% of the sample companies are large in size, owing to the qualifications and requirements of China’s A-share stock market.

3.3. Research methods

We break down the analysis of this study into several steps. First, we test the influence of corporate innovation strategy and BIM promotion policy on the usage of BIM technology in AEC enterprises. We develop a logistic regression model to estimate the coefficient of innovation strategy on BIM adoption (Model 1 shown in Equation (1)). In Model 1, a company’s innovation strategy is measured by its R&D investment to total revenue ratio. The effect of policy promotion on BIM adoption is examined by the coefficient of Policy in Model 2 shown in Equation (2). The variable of Policy is designed as a dummy variable by breaking the time frame into before 2016 and from 2016, since the BIM policy was issued in mid-2015. We further test whether the BIM promotion policy changes the relationship between innovation strategy and BIM adoption by developing two sub-models in different time frames (before and after 2016) based on Model 1.

![Figure 1. Theoretical framework of BIM adoption.](image-url)

| Table 1. Demographical information of the sample enterprises. |
|-------------------|-------------------|-------------------|
| Factors           | Categories        | Frequency | Percentage |
| BIM adoption      | Never-adopted     | 172       | 63.5%    |
| Motivation of BIM adoption | Ever-adopted | 99       | 36.5%    |
|                   | Strategy lead adoption | 26       | 26.3%    |
|                   | Policy driven adoption | 73       | 73.7%    |
| Nature            | SOEs              | 103       | 38%      |
|                   | Non-SOEs          | 186       | 62%      |
| Location          | Developed regions | 179       | 66.1%    |
|                   | Less developed    | 92        | 33.9%    |
| Size              | Medium            | 25        | 9.2%     |
|                   | Large             | 246       | 90.8%    |
Table 2. Variable list.

| Variables         | Name             | Code                              | Calculations                                                                 |
|-------------------|------------------|-----------------------------------|------------------------------------------------------------------------------|
| Dependent variable| BIM adoption     | BIM                              | 1 = adopted 0 = not adopted                                                  |
|                   | Performance      | Profit                            | Gross profit                                                                 |
|                   | Innovation       | R&D                              | R&D expenditure/revenue                                                       |
|                   | Policy           | Policy                            | 0 = 2013–2015; 1 = 2016–2019                                                  |
|                   | Ever-adopted BIM | BIMever                          | 1 = ever adopted, 0 = never adopted                                          |
|                   | Motivation       | Motivation                        | 1 = first adoption before 2016, 0 = first adoption from 2016                 |
| Independent variable|                 |                                   |                                                                              |
| Control variables | Nature           | SOE                              | State-owned enterprise: 0 = Non-state-owned enterprise                       |
|                   | Firm size        | Size                              | Ln (number of staff)                                                          |
|                   | Location         | Location                          | 0 = higher developed regions, 1 = less developed regions                     |
|                   | Board size       | Board                            | Number of directors                                                          |
|                   | Management shareholding ratio | Mshare                        | Percentage of management shareholding                                         |
|                   | Board shareholding ratio | Bshare                       | Percentage of board shareholding                                              |
|                   | Year             | Year                              | Dummy variable of year                                                        |
|                   | Industry         | Industry                          | Dummy variable of industry                                                    |

logitBIM = α0 + α1Innovation + \sum aiControlsi + ε1  

logitBIM = β0 + β1Policy + \sum biControlsi + ε2  

Second, we test whether BIM adoption as well as different motivations of BIM adoption might lead to divergence financial performance, which could be referred to Model 3 in Equation (3) and Model 4 in Equation (4), respectively. In Model 3, the sample enterprises are grouped into ever adopted BIM and never adopted BIM, measured by a dummy variable BIMever. A company is grouped into the category of ever adopted (BIMever equals to 1) if it adopted BIM during 2013–2019, the adoption of which is not necessarily continuously. On the other hand, if a company does not have any observation of BIM adoption during 2013–2019, it is grouped into the never adopted category (BIMever equals to 0). The reason of using the variable BIMever instead of actual adoption observations to test the divergence of BIM performance is due to the fact that the reflection of BIM benefit should be considered from a longer-term perception (Won and Lee 2016). In Model 4, the BIM ever adopted enterprises are further divided into adopted before and from 2016 to represent their motivations of BIM usage (measured by the variable Motivation). If the first adoption of BIM in a company occurred before the BIM promotion policy, it could be considered as being motivated by its innovation strategy (Motivation equals to 1). On the other hand, if a company adopted BIM after the BIM policy, the motivation of adoption would be treated as policy-driven adoption (Motivation equals to 0).

regPerformance = γ0 + γ1BIMever + \sum yiControlsi + ε3  

regPerformance = λ0 + λ1Motivations + \sum λiControlsi + ε4  

Owing to the special link between the Chinese government and state-owned enterprises, sub-models differentiated by state-owned and non-state-owned enterprises are developed. For control variables, this study examines firm characteristics (firm size, nature, location) and management features including size of board, management shareholding ratio, and board shareholding ratio, referring to the study of Cao et al. (2017). The statistical software used in this study is SPSS v.25. The variables' definitions of this study are listed in Table 2.

4. Results

4.1. Motivations of BIM adoption

The impacts of different BIM motivations on BIM adoption in China’s AEC enterprises are shown in Table 3. First, model (1) in Table 3 examines the relationship between innovation strategy and the decision of BIM usage, which is referred to Equation (1). Tested by the Wald chi-square statistics, the coefficient of R&D of model (1) illustrates that innovation strategy is a significant predictor of BIM adoption (p < 0.01) in China’s AEC enterprises. The odds ratio of R&D in model (1) indicates that an increase of 1% in R&D investment would lead to 1.068 times higher in the probability that a company adopts BIM. The model evaluation indicators suggest that the prediction model of an enterprise’s innovation strategy towards BIM adoption is robust and significant at the 0.001 level. The Hosmer-Lemeshow (H-L) test yields a chi-square of 3.172 and is insignificant (p > 0.05), suggesting that the model fits to the data well. In addition, the test in model (1) generates an R-square of 0.361, indicating that the predictor and the control variables could explain 36.1% of the
decision of BIM usage. Models (2) and (3) are developed to test the differences between SOEs and non-SOEs in the prediction effect of innovation strategy towards BIM adoption. It is interesting to find that R&D investment fails to predict BIM adoption in SOEs (p-value of the coefficient of R&D in model (2) is higher than 0.1). Yet other control variables in model (2) appear to be robust predictors of BIM adoption in SOEs, for the overall model is significant (p < 0.001) with acceptable goodness-of-fit results (the χ² of H-L test equals to 2.094 with a p-value of 0.978 and Nagelkerke R² equals to 0.357). The decision of BIM usage in non-SOEs is significantly and positively linked to their R&D expenditures (the coefficient equals to 0.073 and is significant at the 0.01 level). The odds ratio for the predictor in model (3) indicates that an increase of 1% in a non-SOE’s R&D investment leads to 1.075 times higher probability that it would adopt BIM technology. The model evaluation and goodness-of-fit indicators of model (3) (displayed in Table 3) also suggest that the model is robust and well fitted to the data.

Second, the results of model (4) in Table 3 illustrate the impact of the BIM promotion policy on BIM adoption in China’s AEC enterprises (referring to Equation (2)). It shows that the BIM policy is acting as a major force that promotes BIM adoption for the coefficient of Policy on BIM adoption is 0.746 (p < 0.05). The odds ratio for the predictor of Policy proves that the BIM policy issued in 2015 remarkably increases the probability (2.108 times) of BIM usage in China. The likelihood ratio test results indicate that the prediction model of the BIM policy on BIM adoption is significant (p < 0.001) and well fitted with the data (χ² of H-L test is 4.284 (p = 0.831) and the Nagelkerke R² reaches 0.352). Yet, the results of models (5) and (6) show that the BIM policy promotes the usage of BIM in SOEs only. The adoption of BIM technology in SOEs of the AEC industries appears to be mainly driven by the BIM policy, as the coefficient of Policy in model (5) reaches 1.071 (p < 0.05), the odds ratio of which reaches 2.919. These results indicate that after the Chinese government issued the BIM policy, the probability of BIM adoption in SOEs increases nearly 3 times. Non-SOEs, on the other hand, do not follow the policy instructions as the coefficient of Policy in model (6) is insignificant. The model evaluation and goodness-of-fit indicators of models (5) and (6) (displayed in Table 3) suggest that these two models are statistically significant and well fit to the data.

Third, models (7) and (8) test the impact of BIM promotion policy on the links between innovation strategy and BIM adoption based on the TOE framework. In Model (7), the coefficient of R&D expenditure on BIM adoption before 2016 is 0.129 (p < 0.05). However, the coefficient drops to 0.057 (p < 0.01) from 2016 in Model (8). These results demonstrate that BIM adoption in China’s AEC industries is mostly driven by their innovation strategy before the promotion policy. Before the BIM promotion policy, an increase of 1% in R&D expenditure would lead to 1.138 times higher in the likelihood that an enterprise would adopt BIM (referring to the odds ratios in model (7)). However, from 2016, the relationship between innovation strategy and BIM adoption decisions is weakened by the BIM policy. An increase of 1% in R&D expenditure would only lead to 1.059 times higher in the probability that an enterprise would adopt BIM. Despite the changes of coefficients and odds ratios, innovation strategy is still a major predictor of BIM adoption in China’s AEC enterprises.

The assessment of the predicted probabilities of BIM adoption for models (1) – (8) is displayed in Table 4. It appears that the prediction for the AEC enterprises which are not adopted BIM is more accurate than that for those adopted in all models. The highest overall percentage of corrected ratio is in model (7), indicating that innovation strategy is the most powerful predictor of BIM adoption in Chinese AEC enterprises before the BIM policy. However, the BIM policy remarkably decreases the correction of predicted probabilities of BIM adoption led by innovation strategies from 2016, as the overall percentage corrected drops to 79.7% in model (8), which is also the lowest score in the prediction models in Table 4. The overall percentage corrected ratios for models (1) – (6) are quite similar, ranging from 83.8% to 84.1% and indicating a good prediction of BIM adoption by innovation strategy and BIM promotion policy.
4.2. BIM motivations and performance

In this section, we test whether BIM adoption would bring positive corporate performance to the AEC enterprises and whether different motivations of BIM adoption would lead to divergence of BIM performance. The results of Model (9), Model (10), and Model (11) in Table 5 (refer to Equation (3)) indicate that BIM adoption significantly brings about better financial performance to the corporations of both SOEs and non-SOEs. The gross profit of the BIM ever adopters is 1.96% higher than those never adopters in Model (9) (the coefficient of BIMever equals to 1.960, p < 0.05). For the SOEs, the adoption of BIM contributes 1.831% increase in gross profit, as shown by the coefficient of BIMever in model (10). Non-SOEs benefit more from implementing BIM technology, which brings about 2.421% increase in gross profit (shown by the coefficient of BIMever in model (11)). For the control variables, the results in Table 5 illustrate that enterprises of smaller size and higher management shareholding ratio have better profitability performance. Board shareholding ratio, on the other hand, has a negative impact on corporation performance. Particularly, the financial indicator in the SOEs is only related to corporation size (shown in Model (10)), while managerial characteristics such as management and board shareholding ratios are the major determinants of profitability in non-SOEs (refer to Model (11)).

The discrepancies of BIM performance of different BIM motivations are shown by the results of models (12) – (14) in Table 6. It is interesting to find that the divergence of BIM performance by different motivations is only existed in SOEs. The coefficient of Motivation on gross profit in Model (13) indicates that SOEs which adopted BIM before 2016 achieve 2.54% higher in gross profit (p < 0.1) compared to those adopted from 2016. This result implies that the innovation strategy led BIM implementation in SOEs has a greater contribution to corporate performance, compared to those of policy followers. In non-SOEs, however, BIM adoption motivations do not have a significant impact on corporations' financial performance as the coefficient of Motivation is insignificant in model (14).

| Model | Observed | Not adopted | Adopted | % Corrected |
|-------|----------|-------------|---------|-------------|
| Model (1) Predictor: R&D | Not adopted | 1063 | 58 | 94.8% |
| | Adopted | 171 | 87 | 53.7 |
| | Overall % corrected | 83.4 |
| Model (2) Predictor: R&D SOEs | Not adopted | 445 | 23 | 95.1 |
| | Adopted | 70 | 32 | 31.4 |
| | Overall % corrected | 83.7 |
| Model (3) Predictor: R&D Non-SOEs | Not adopted | 611 | 42 | 93.6 |
| | Adopted | 87 | 69 | 44.2 |
| | Overall % corrected | 84.1 |
| Model (4) Predictor: Policy | Not adopted | 1064 | 57 | 94.9 |
| | Adopted | 173 | 85 | 32.9 |
| | Overall % corrected | 83.3 |
| Model (5) Predictor: Policy SOEs | Not adopted | 446 | 22 | 95.3 |
| | Adopted | 71 | 31 | 30.4 |
| | Overall % corrected | 83.7 |
| Model (6) Predictor: Policy Non-SOEs | Not adopted | 614 | 39 | 94.0 |
| | Adopted | 32 | 64 | 41.0 |
| | Overall % corrected | 83.8 |
| Model (7) Predictor: R&D Before 2016 | Not adopted | 371 | 9 | 97.6 |
| | Adopted | 22 | 15 | 40.5 |
| | Overall % corrected | 92.6 |
| Model (8) Predictor: R&D From 2016 | Not adopted | 689 | 52 | 93.0 |
| | Adopted | 143 | 78 | 35.3 |
| | Overall % corrected | 79.7 |

**Table 4. Assessment of the predicted probabilities of BIM adoption.**

**Table 5. Impact of BIM adoption on corporation performance.**

| (9) | (10) | (11) |
|-----|------|------|
| All | SOEs | Non-SOEs |
| BIMever | 1.960** | 1.831* | 2.421* |
| Size | (2.211) | (1.777) | (1.814) |
| Location | −1.217*** | −1.767*** | −0.880 |
| | (−3.988) | (−5.303) | (−1.597) |
| Mshare | 0.832*** | 0.324 | 0.804*** |
| | (4.460) | (0.574) | (3.679) |
| Bshare | −0.685*** | −0.024 | −0.712*** |
| | (−3.501) | (−0.042) | (−3.121) |
| Board | 0.035 | −0.137 | −0.018 |
| | (0.260) | (−0.887) | (−0.058) |
| cons | 39.580*** | 42.240*** | 38.293*** |
| | (12.398) | (11.931) | (7.281) |
| Industry | Controlled | Controlled | Controlled |
| Year | Controlled | Controlled | Controlled |
| N | 1379 | 570 | 809 |
| Prob>F | 0.000 | 0.000 | 0.000 |
| Adj-R² | 0.252 | 0.421 | 0.182 |
5. Motivations of BIM adoption in China’s AEC enterprises

Follow the suggestion of Poirier, Staub-French, and Forgues (2015), this study analyzes BIM adoption at the organizational level from a strategic perspective. However, instead of exploring the psychological process underlying the motivation like Singh and Holmström (2015), this study is undertaken in a more objective way which measures a corporate’s innovation strategy by its actual R&D expenditures. Supplemented to the determinants of BIM adoption identified in previous studies such as software characteristics (Yuan, Yang, and Xue 2019), project features (Barlish and Sullivan 2012), organization demand (Singh and Holmström 2015), and legal standards and policies (Zhou, Yang, and Yang 2019), this study reveals that BIM adoption in China’s AEC listed enterprises is also motivated by corporation innovation strategy and government policy. As a new technology to redefine the life-cycle construction management process and enhance the productivity of AEC industries, early awareness of BIM and its benefits are essential to the decision of BIM usage (Othman et al. 2020). Yet, awareness of new technology is usually accompanied with organizations’ innovation culture and technology readiness (Ahmed and Kassem 2018). Thus, before the BIM promotion policy, the BIM adopters in China are mainly industry innovation leaders, of which the BIM adoption decision is positively influenced by their R&D expenditures.

In recognition of BIM benefits to the AEC industries, the Ministry of Housing and Urban-Rural Development of China issued a policy to officially promote BIM usage in 2015. Although Zhou, Yang, and Yang (2019) argued that insufficient government lead/support is still one of the most prominent barriers that hinders BIM implementation in China, this study illustrates that the BIM promotion policy dramatically increases the likelihood of BIM adoption in China’s AEC enterprises. This finding provides empirical evidence to the argument that government’s policy is an important force which encourages BIM usage in China (Qin et al. 2020; Yuan and Yang 2020). Apart from promoting BIM usage in China’s AEC industries, BIM policy also slightly weakens the effect of innovation strategy on BIM adoption. One possible explanation is that some less innovation intensive enterprises might join the BIM club due to policy pressure. For instance, the BIM policy requires that construction projects which plan to apply green building certification must implement BIM technology (MOHURD 2015). However, the significance of the impact of R&D expenditures on BIM usage after the BIM policy indicates that BIM adopters in China are still among the innovators and early adopters, according to the theory of “diffusion of innovation” (Rogers 2003).

5.2. Differences between SOEs and non-SOEs

The results of this study reveal that there is a divergence in the motivations of BIM adoption between SOEs and non-SOEs in China’s AEC industries. The linkage between innovation strategy and BIM usage is only existed in non-SOEs, while the BIM

![Table 6. Impact of BIM motivation on corporation performance](image)

| Motivation | (12) All | (13) SOEs | (14) Non-SOEs |
|------------|---------|----------|--------------|
| Size       | 1.376   | 2.540*   | -0.436       |
| Location   | -0.363  | -1.405***| 2.450***     |
| Mshare     | 2.925** | 0.535    | 8.468***     |
| Bshare     | 1.343***| 1.532**  | 1.225***     |
| Board      | -1.150***| -1.264  | -1.131***    |
| _cons      | 39.334***| 51.636***| 5.684        |
| Industry   | Controlled| Controlled| Controlled   |
| Year       | Controlled| Controlled| Controlled   |
| N          | 533     | 241      | 292          |
| Prob>F     | 0.000   | 0.000    | 0.000        |
| Adj-R²     | 0.531   | 0.602    | 0.546        |

Note:*** p<.01, ** p<.05, * p<.1
promotion policy only increases BIM implementation in SOEs. These findings imply that BIM motivation of non-SOEs is aligned with their innovation strategy, while the SOEs, however, are more likely to be followers of BIM policy. This phenomenon might be caused by the differences of corporate governance mechanism between SOEs and non-SOEs in China. Owned or controlled by the state, SOEs have the intrinsic duty to follow the government’s instructions (Xin, Bao, and Hu 2019). According to the guidelines in the BIM policy, it is required that “the proportion of integrated application of BIM in large and medium-sized buildings invested by state-owned funds should reach 90% by the end of 2020” (MOHURD 2015). Therefore, this study demonstrates that BIM usage in China’s SOEs is more likely to be reactive motives of government policy pressure. However, the BIM promotion policy does not set mandate targets for private enterprises but gives them high autonomy and a central role in BIM application (MOHURD 2015). Thus, BIM adoption in China’s non-SOEs, on the other hand, is more likely to be driven by their innovation strategies, which is agreed with the findings of Mitropoulos and Tatum (1999) and Gledson Barry and Greenwood (2017).

5.3. Motivations and BIM performance

This study provides empirical evidence from the perspective of corporate finance that BIM adopters achieve better performance, compared to those never adopted, which is agreed with the arguments raised by Herr and Fischer (2019), Tan et al. (2019), and Lin and Yang (2018). However, instead of calculating the return on investment ratio (ROI) of BIM implementation suggested by Walasek and Barszcz (2017), this study adopts corporation gross profit ratio to measure BIM benefits for ROI does not accurately reflect the real cost and benefits of BIM Love et al. (2013). Higher gross profit ratio indicates that a company might receive both an increase of sales and a reduction in cost from implementing BIM technology. By adopting BIM technology, enterprises could solve related problems to achieve cost reduction and time saving in construction projects, as identified by Azhar, Khalfan, and Maqsood (2012), Doumbouya, Gao, and Guan (2016), Chan, Olawumi, and Ho (2019), etc. In addition, BIM adoption could also “reflect and maintain a good image by using advanced technologies” for enterprises (Cao et al. 2017) to build up their competitive disadvantages in winning public project bids, which are featured as state funds invested and BIM applications required by the BIM policy (MOHURD 2015).

It is interesting to find that among the BIM adopters, the differences of BIM performance between innovation strategy-led adoption (adopted before the BIM policy) and policy-driven adoption (adopted after the BIM policy) are only significant in SOEs. That is, policy followers share the same level of benefits with innovation adopters in the private sector. These findings are opposite to the hypotheses based on the theory of diffusion (Rogers 2003). A possible reason is that to achieve the full capabilities of BIM requires effective collaboration among all project team members (Oraee et al. 2019). However, transforming into a new BIM-based collaboration is closely related to the width and depth of BIM implementation, which is not a short shift task and requires intensive support at the organizational level (Lindblad and Vass 2015). In SOEs, innovation-led BIM adoption is more likely to have management support, which is one of the critical factors for fully achieving the performance of BIM (Chen et al. 2019). Policy followers of SOEs, however, might consider BIM adoption as an administrative task and do not give full support to the implementation of BIM (Xin, Bao, and Hu 2019). Without organizational wide efforts of collaboration, it is hard to achieve the full capacity of BIM benefits in SOEs. Private AEC enterprises, on the other hand, have an urgent range of BIM investment costs recovering motivation to achieve better corporation performance, regardless the time of adoption. These findings support the argument that management awareness, attitudes, and support are key to the success of BIM (Son, Lee, and Kim 2015).

6. Conclusions

Using information of China’s listed AEC enterprises in the A-share stock market, this paper provides an empirical analysis on the decisions of BIM adoption and its impact on corporation performance. The findings conclude that: (1) BIM adoption in China’s AEC enterprises is motivated by corporation innovation strategy and government policy, among which the SOEs only respond to policy regulations while non-SOEs are triggered by their innovation strategies; (2) BIM policy weakens the link between innovation strategy and BIM usage but BIM adopters in China’s AEC industries are still among the innovators and early adopters; (3) BIM application brings about positive financial performance to the adopted enterprises, but the differences of BIM performance between innovation strategy lead and policy driven adoption are only significant in SOEs.

The findings of this study contribute to the body of knowledge by validating BIM adoption determinant model using actual corporate features, performance, and environmental changes. Especially, government promotion efforts in driving BIM adoption, which is theoretically deduced by Yuan and Yang (2020), are empirically proved in this study. In addition, this study adds two new elements to the TOE framework developed by Tornatzky, Fleischer, and Chakrabarti (1990). First, in the environmental context, government policy pressure appears to be an emerging force of BIM technology adoption, especially in state-controlled
enterprises. However, BIM adoption by policy pressure might not bring benefits if the implementation is formalistic and lack of organizational support. Second, in the organizational context, it is important to consider the influence of an enterprise’s innovation strategy on BIM adoption decisions and the effect of management support on BIM performance. Enterprises with innovation culture are more likely to adopt new technologies to facilitate their operation and obtain financial benefits.

As a set of new technologies and solutions to the AEC industries, BIM has been widely accepted around the world. Many countries have issued support policies to promote the adoption of BIM to enhance the efficiency and effectiveness of construction management. The experiences of BIM adoption among China’s AEC enterprises revealed in this study suggest that BIM usage promotion in other countries should start from enterprises with innovation culture, which are more willing to adopt new technologies. They are also more likely to achieve the benefits brought about by BIM technologies with organizational support, which would provide good examples and encourage more enterprises to become technology followers. In addition, policy makers around the world should pay attention to those policy reactive followers whose adoption might be formalistic due to policy pressure. Last, this study also suggests that it is important to measure corporation BIM performance in a longer-term perspective, for BIM requires high front-end investment which harms their short-term performance.

However, under the restrictions of data availability, this paper has the following limitations. First, BIM adoptions in unlisted AEC companies are not included in the analysis for their financial reports do not disclose publicly. Second, this study only analyzes whether or not an enterprise adopts BIM technology. The depth and width of BIM implementation are unable to measure based on financial information. Finally, although BIM adoption might bring cost reductions and revenue growth, a company’s gross profit ratio is an outcome of many other factors which are not completely captured in this study. Future studies could explore the BIM adoption model with more explicit measurements and investigations.

**Notation list**

The following symbols are used in this paper:

- **AEC**: Architecture, Engineering and Construction
- **BIM**: Building Information Modelling
- **R&D**: Research & Development
- **SDE**: State-Owned-Enterprises
- **TAM**: Technology Acceptance/Adoption Model
- **TTF**: Task-Technology Fit
- **UTAUT**: The Unified Theory of Acceptance and Use of Technology
- **TOE**: Technology-Organization-Environment
- **IDT**: Innovation Diffusion Theory

**Data availability statement**

Some or all data, models, or code generated or used during the study are available from the corresponding author by request.

**Disclosure statement**

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