

# Individual and Organisational Level Drivers and Barriers to Building Information Modelling

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**First submission:** 19 December 2019; **Accepted:** 12 August 2020; **Published:** 30 July 2021

**To cite this article:** Ensar Ademci and Selin Gundes (2021). Individual and organisational level drivers and barriers to building information modelling. *Journal of Construction in Developing Countries*, 26(1): 89–109. <https://doi.org/10.21315/jcdc2021.26.1.5>.

**To link to this article:** <https://doi.org/10.21315/jcdc2021.26.1.5>

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**Abstract:** The diffusion of building information modelling (BIM) has remained slow and the search for a solution to the problems that prevent technology acceleration continues. Although, there is strong evidence that user resistance is a major factor in delaying the adoption of new technologies, little attention has been paid to the drivers of BIM use in literature. Besides, majority of the studies on organisational barriers focus on large firms, despite strong emphasis laid on increased collaboration in the BIM. In the current study, the drivers of and barriers to BIM adoption and implementation are explored at both individual and organisational levels through a survey conducted on 905 industry professionals from the Turkish construction industry. This study further explores differences between groups of firm size in embracing BIM technologies to assess the extent and presence of digital divide. Results reveal that professionals place more value on performance enhancing factors rather than social influence for the adoption of BIM, indicating the role of improved performance as a driver for BIM. The most prominent barriers, on the other hand, appear to be related to the availability of expertise and skills, a problem that seems to exist not solely within companies but also further down the supply chain. Policymakers seeking to disseminate BIM use may address these concerns and consider these insights to revise policies and incentives.

**Keywords:** Building information modelling, Construction industry, Barriers, Drivers, Digital divide

## INTRODUCTION

Technological developments that took place in the 20th century had drastic impact on the ways different sectors operate. This effect has increased in line with the dissemination of technology culture and improved awareness on the benefits of information technologies. With rapid improvements in technology, all business areas are continuously searching more practical routes for their business processes (O'Brien and Marakas, 2011). Similarly, considerable efforts have been put in place towards addressing long-standing concerns over construction sector's poor performance and productivity (Love et al., 2013). In this background, building information modelling (BIM) is increasingly used all over the world and is at the top of agenda of many researchers, construction industry professionals and clients due its potential contributions to the construction industry (Construction Users Roundtable, 2006).

Eastman et al. (2008) defined BIM as "a modelling technology and associated set of processes to produce, communicate and analyse building models". McGraw-Hill Construction (2008) stated that BIM is "the process of creating and

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using digital models for design, construction and/or operations of projects". Gu and London (2010) defined BIM as "an IT enabled approach that involves applying and maintaining an integral digital representation of all building information for different phases of the project lifecycle in the form of a data repository". These definitions emphasise that BIM is not merely a technological development, but requires a deep focus on the human factor – the management of change and mindsets to fully exploit its advantages. Thus, a better understanding of individual perceptions, drivers and barriers to BIM implementation is crucial (Forsythe, 2014).

BIM implementation positively impacts project management areas, and constructive outcomes of its use can be observed in all phases of any project's life cycle and in the entire value chain. The benefits of using technology in the construction industry include quicker reduction of errors and clashes, faster project delivery processes, improved information and supply chain management (Demian and Walters, 2014; Eastman, 1999; Eastman et al., 2008). Organisations that have successfully adapted to the technological changes have succeeded in increasing their competitiveness through improved performance. However, for many other organisations, adapting technology systems and organisational knowledge base to ongoing developments has proven more challenging. Increased attention should be devoted to the problems encountered by the latter group as there is a paradigmatic shift in many countries towards the mandatory use of BIM in public projects and contractors and designers are increasingly faced with the challenge of quickly adopting and implementing BIM technology.

Accordingly, a number of articles dedicated to BIM adoption and associated challenges appeared in literature. However, the focus of research in this area has predominantly been the adoption barriers at aggregate level (i.e. industry, company or project) with no emphasis on individual level user resistance (Howard, Restrepo and Chang, 2017). Hossain, Munns and Rahman (2013), in their article, emphasised the significance of cultural barriers in BIM adoption including human-related obstacles such as user resistance. The authors suggest that technology itself is not only sufficient for success in BIM processes, but also important to "harness the diverse skills" for a synergistic effect.

Indeed, new technologies often fail to deliver intended benefits due to user resistance; negative beliefs and/or attitudes towards new technologies may lead to delays or impede their implementation (Davis, Bagozzi and Warshaw, 1989; Martinko, Zmud and Henry, 1996). Thus, user resistance has frequently been identified as the main barrier (ITtoolbox, 2004) and the most critical reason of failures in the implementation of information systems/information technologies projects (Kim and Kankanhalli, 2009). Looking at the issue from the BIM perspective, it is clear that there is a need to uncover user motivations, drivers and inhibitors in order to achieve intended objectives from BIM use.

Another important gap in the relevant literature relates to inadequate attention paid to the potential consequences of digital divide at organisational level, especially within the Turkish construction industry context. Digital divide theory stems from the observation that the benefits accrued from information and communication technologies (ICTs) are unevenly distributed among individuals, companies, countries and regions due to different socio-economic levels and abilities (Arendt, 2008; Dainty et al., 2017). Considering this aspect, it has been argued that the speed and the extent of technology adoption in companies operating within the architecture, engineering and construction (AEC) sector vary

as they face different types of organisational and financial barriers in the adoption and implementation of new technology (Ayinla and Adamu, 2018). For example, small- and medium-sized enterprises (SMEs) often lack digital capability and the necessary financial resources to invest in new technology (Dainty et al., 2017), which contribute to their disadvantaged position in exploiting the potential benefits of BIM compared to their larger counterparts. Considering that SMEs constitute a considerable number of construction firms (Forsythe, 2014), it is argued that actions and policies for improving the productivity of the sector should carefully take into account the specific motivations and the difficulties experienced in the adoption and implementation of new technologies (Dainty et al., 2017; Hong et al., 2016; Sexton, Barrett and Aouad, 2006). However, previous studies on BIM adoption have predominantly focused on large-scale companies, without sufficient attention paid to the needs of all groups (Hosseini et al., 2016). Hence, initiating top-down efforts to disseminate the use of BIM without a focus on the firm and individuals could only broaden discrepancies in the adoption of new technologies.

Based on these gaps in literature, the primary aim of the present research was to explore the drivers of and barriers to BIM adoption in the Turkish AEC industry by focusing both on individual and organisational levels. Besides providing an overall picture of BIM adoption in the industry, this study further explored differences between groups of firm size in embracing BIM technologies, which leads to a more complete picture of digital divide in the industry.

## **DRIVERS OF TECHNOLOGY ACCEPTANCE**

While the benefits of using BIM technology continue to remain on the agenda of BIM scholars and practitioners, it appears that the underlying reasons for use and potential benefits of BIM technology are still blurred for users (Lee, Yu and Jeong, 2015). This argument can be confirmed by looking at the actual levels of its use. He et al. (2017) documented that the expected diffusion rate of BIM among parties has remained lower than earlier expected. The authors explained this phenomenon by the uncertainty surrounding its potential value and effectiveness, which act as drivers of its acceptance by users. Indeed, research on the implementation of new technologies and in particular BIM, mainly focus on the factors occurring at the organisational or industry level (Howard, Restrepo and Chang, 2017). However, today it has been widely accepted that user acceptance at individual level is an important determinant of the adoption of new information technologies (Wu and Wang, 2005).

With the proliferation of computer technologies in 1980s, studies aiming to uncover users' behavioural intentions to accept and use IT/IS systems have expanded considerably. The Technology Acceptance Model (TAM) was developed to explain the drivers of technology acceptance by users based on "perceived usefulness" and "ease of use" (Davis, 1989). "Perceived usefulness" items in the model measure the extent to which individuals believe that the use of a particular technology enhances their job performance. On the other hand, "ease of use" items assess users' perceptions on the effort required to use the system. The TAM model has been tested and has undergone considerable modification since its initial proposal. Subsequent versions namely TAM 2 (Venkatesh and Davis, 2000) and TAM 3 consist of more constructs compared to the original TAM.

Since the initial development of the user acceptance models, considerable number of research activities on the acceptance of information systems and technologies have been observed. As a result, a number of competing models have been proposed and tested in numerous scholarly publications. Due to lack of a model based on proper consensus, Venkatesh et al. (2003) developed a unified model called "the unified theory of acceptance and use of technology" (UTAUT), a synthesis of eight prominent models in literature. UTAUT model explained technology acceptance and its use in organisations using performance expectancy, effort expectancy, social influence, attitude and facilitating conditions constructs. While performance expectancy construct items evaluate the extent to which users feel that the technology under question helps improve job performance, effort expectancy measures the ease of use of the system for individuals. Social influence construct reflects the influence of social pressures in adopting new technologies. Attitude construct reflects the evaluation of emotions about the experience with BIM use.

Since its introduction, UTAUT has been widely used in technology acceptance and use research including BIM. For example, Davies and Harty (2013) evaluated beliefs about consequences of BIM use in a survey of employees in the United Kingdom (UK) and found that "BIM is viewed as likely to improve job performance if it is compatible with existing ways of working". Mahamadu, Mahajoubi and Booth (2014) examined acceptance and use of BIM in the supply chain context based on the key constructs from the UTAUT model. Howard, Restrepo and Chang (2017) explored the reasons impeding the proliferation of BIM in UK using an extended version of the UTAUT model and found that expectations about improved job performance did not directly affect intention to use BIM, indicating that users perceive BIM as a hurdle that does not improve their performance at work.

### **Barriers Experienced to BIM Adoption and Implementation**

A vast amount of research offers solutions to the long-lasting problem of BIM adoption, yet policies and incentives fall short in convincing the industry to adopt BIM use on a large scale. This may be attributable to the lack of good understanding of the barriers faced in different contexts such as countries, which could lead to the emergence of unsatisfactory incentive policies. Thus, a thorough examination of the difficulties experienced in BIM adoption and use is essential. Table 1 exhibits the issues raised in previous literature. It is noteworthy that some technological and legal difficulties that are expected to occur during advanced level of BIM implementation are not included in the items.

Technical capabilities required for BIM use bring forth the need for training and formal education of employees. Firms often face difficulties in finding adequate number of educated or experienced professionals for implementation. The recruitment of personnel with poor knowledge and expertise about BIM leads to critical issues in implementation, such as design check problems and low data quality due to lack of regular updates and incorrect data entry into the BIM model (Zhao, Wu and Wang, 2018). Thus, one of the prominent barriers in BIM literature relates to the lack of skilled personnel (Ademci and Gundes, 2018; Arayici et al., 2009; Arendt, 2008). According to Gu and London (2010), one of the earliest steps for a company that considers using BIM for a specific project should be a thorough evaluation of current and potential capabilities of project participants in BIM use.

At this point, it is also important to consider whether the required level of BIM use for the project under question matches current levels. The outcomes of this assessment will then define the need for training-education, consultancy services and/or hiring new staff for BIM use.

Table 1. Literature Review on the Barriers to BIM

Code	Issues Raised in Previous Literature	Source
I-1	Issues related to the lack of skilled staff, labour efficiency, training/ education of existing employees, need for new employees	Arendt (2008), Arayici et al. (2009), Gu and London (2010), Sun et al. (2017), Young et al. (2009), Eastman et al. (2008), Yan and Demian (2008), Ademci and Gundes (2018), Gu et al. (2007), McGraw-Hill Construction (2008) and Ademci (2018)
I-2	Difficulties in finding BIM user/ experienced subcontractors, supply chain collaboration	Won, Lee and Lee (2008), Linderoth (2010), Eadie et al. (2014), Ademci and Gundes (2018) and Ademci (2018)
I-3	Clients awareness and knowledge, clients' support	Dakhil, Underwood and Alshawi (2019), Liao, Lin and Low (2019), McGraw-Hill Construction (2008), Eastman et al. (2008), Young et al. (2009), Ademci and Gundes (2018), Gu et al. (2007) and Ademci (2018)
I-4	Costs of investment	McGraw-Hill Construction (2008), Eastman et al. (2008), Young et al. (2009), Eadie et al. (2014), Arayici et al. (2009), Yan and Demian (2008), Ademci and Gundes (2018) and Ademci (2018)
I-5	Issues associated with the lack of tools and standards, guidelines, government support and policy initiatives	Eastman et al. (2008), Edirisinghe and London (2015), Young et al. (2009), Ademci and Gundes (2018), Ademci (2018), Gu et al. (2007), McGraw-Hill Construction (2008) and Cheng and Lu (2015)
I-6	Insufficiency of consultancy services	Ademci and Gundes (2018) and Ademci (2018)

Importantly, however, the access barriers to skills seem to disproportionately affect SMEs. Wages and job satisfaction are lower and training is not common in smaller firms compared to in larger firms (Atkinson and Storey, 2016; Rainnie, 2016). Thus, it often becomes more difficult for SMEs to attract needed talent for their ongoing or planned operations.

Moreover, training is considered to be a major cost component for organisations, thereby creating a major obstacle in efforts towards BIM use. Cost of investment for BIM includes cost of the software to be purchased, cost of suitable hardware, and cost of trainings for adapting to changes in workflows and technology. In numerous studies, costs and training issues have been identified as the greatest barriers to the implementation of BIM (Eadie et al., 2014; Eastman et al., 2008; McGraw-Hill Construction, 2008). In particular, smaller firms, which lack the financial capacity to invest in technological tools, are considered to be disadvantaged compared to the larger firms (Ritchie and Brindley, 2005).

Since companies feel that the benefits obtained from the implementation do not outweigh the implementation costs (Arayici et al., 2009), the cost issue is considered to be a major barrier to BIM use.

Apart from human resources issues within organisations, problems associated with skills may also manifest themselves in communication flows along the supply chain. For example, when a main contractor is obliged to use BIM in line with the contract terms, the contractor needs to identify subcontractors who are also capable of using BIM effectively. However, lack of subcontractors who can use BIM technology is an off-reported barrier in related literature (Ademci, 2018; Linderoth, 2010; Won, Lee and Lee, 2008). Indeed, subcontractors are often categorised as small firms and so such problems may be attributed to not only the lack of awareness and motivation, but also to disproportionate access to skills discussed earlier. The lack of BIM literate subcontractors has also been linked to the financial burden of investment in BIM software, which is a significant cost component for subcontractors (Eadie et al., 2014). Nevertheless, this barrier is understood to lead to longer tender periods, collaboration deficiencies in the supply chain and higher costs.

Construction clients are usually considered to be the "champions of BIM adoption and business-technology interface" required for successful BIM implementation (Brewer and Gajendran, 2010). By applying BIM, the clients can benefit from the optimisation of the design and construction processes and reduced lifecycle costs (Arayici and Aouad, 2010). Clients' awareness on these potential benefits likely to accrue from BIM use is expected to increase demand and thus to have a significant effect on the dissemination of this technology. Accordingly, lack of client demand and support appears to be one of the main barriers against the wider adoption and implementation of BIM (Dakhil, Underwood and Alshawi, 2019; Liao, Lin and Low, 2019).

While public sector clients are increasingly mandating BIM use on projects, those from private sector still lag far behind. In BIM adoption literature, resistance to change by private clients is often linked to extra costs of investment. Eastman et al. (2008) attributed clients' reluctance to use BIM to beliefs that the requirement of BIM use in contracts would negatively affect the competitive environment in bidding and thus prices would increase. Conversely, the use of BIM has the potential to reduce capital and operational expenditures, which together should motivate clients to adopt BIM technology. For example, according to Love et al. (2013), the use of BIM to level of development (LOD)/Detail 500 leads not only to lower capital expenditures due to reduced change orders and rework, but also to significant savings in the operations and maintenance stage resulting from labour utilisation savings provided by improved access to BIM objects by maintenance teams.

Finally, one crucial factor for a smooth transition to BIM in the industry appears to be government supports in the form of BIM programs and committees, activities, guidelines and standards (Cheng and Lu, 2015). The development of national standards in particular provides a solution to the inter-operability issues between various applications which further lead to collaboration problems between parties (Edirisinghe and London, 2015). While BIM standards and policies have long been established in a number of countries such as the United States of America (USA), UK and Singapore, many countries have not yet evolved uniform BIM standards. Eadie et al. (2015) found that while the most commonly used standard in the UK is BS 1192:2007, a considerable number of BIM experts use their own office standards,

a "concerning trend" as described by the authors. The negative consequences for the adoption of own standards by organisations include industry fragmentation and difficulties involved in collaboration. As collaboration is a key in the successful implementation of BIM, the need for a common industry standard becomes more evident.

## **METHODS AND DATA**

### **Design of the Questionnaire Survey**

The perceptions of users about BIM were obtained using questionnaire survey method. The target population comprised of architects, engineers, project managers, company owners and other professionals in the Turkish AEC industry. Questionnaires were frequently used in research to ascertain people's attitudes, behaviours, beliefs and knowledge (Boynton and Greenhalgh, 2004; Knight and Ruddock, 2008). Questionnaires are also known to be both time and cost-effective means of collecting information from respondents located in various locations (Gray, 2009).

The questionnaire survey instrument was prepared on the basis of previous surveys conducted in BIM research. The first section which aimed to collect general information from respondents consisted of questions designed for obtaining individual and organisational information. In the second part of the questionnaire, respondents were first asked if they had heard of BIM before. The survey was designed in such a way that respondents who had not heard of BIM before completed the entire survey as the remaining sections including detailed questions about BIM. Then, respondents were asked whether they used BIM to determine the BIM use rate in the sample survey.

To identify the drivers of BIM use, Likert-scale items about performance expectancy, usefulness and facilitating impacts were introduced in the next section. The items were based on the technology acceptance models provided in the literature section, which aim to explain the drivers of user acceptance of new technologies. The pool of questions used to measure the intentions were mainly retrieved from the study by Davies and Harty (2013) who adapted scale items used in mainstream information systems/information technologies technology acceptance research to BIM. However, in the current research, these items were screened by the authors after testing the initial survey instrument in the pilot phase, as participants raised concerns over some items in which word combinations were very close to each other. Thus, statements representing similar meanings were combined to enhance comprehension by participants and to ease completion. Moreover, the construct about effort expectancy was not included in the survey questionnaire as it was argued in previous studies (Davis, Bagozzi and Warshaw, 1989; Karahanna, Straub and Chervany, 1999; Bhattacharjee, 2001; Wu and Wang, 2005) that the effects of effort expectancy construct subside gradually and finally become insignificant in the post-acceptance stages. In this concept, the studies have noted that initial concerns about the effort required to use a technology in the pre-acceptance stages diminish as users gain experience over time. Thus, it is expected to be an initial determinant of acceptance. In the present research, as the part of the questionnaire regarding behaviours was submitted to only BIM users in the post-acceptance stage, effort expectancy construct items were not

included. The constructs, the definitions adopted in the present study and the final list of scale items used in the survey instrument are shown in Table 2.

The next section designed for assessing the difficulties experienced by the Turkish AEC Industry during BIM adaptation and implementation was evaluated on a 5-point Likert scale (from 5 = "Very Important" to 1 = "Not Important"). The items in this questionnaire were retrieved from previous studies that were presented in Table 1. Two barriers emerged from the I-1 item in Table 1. These are "Lack of trained professional staff" and "Need for additional staff". "Lack of subcontractors that can use BIM" barrier was placed in the questionnaire for supply chain collaboration issues mentioned in issue I-2 in Table 1. The next issue was "Clients' lack of awareness and knowledge" (I-3 in Table 1), followed by another item for cost concerns (I-4). Lack of standards and government support (I-5) were separately examined in the questionnaire. Finally, a barrier item about the insufficiency of consultancy services (I-6) was placed in the questionnaire.

Table 2. Construct Definitions and Scale Items

Construct	Definition	Code	Scale items
Performance Expectancy (PE)	The extent to which using BIM will provide benefits in job performance	PE1	Using BIM enables me to perform tasks more quickly
		PE2	Using BIM increases my job quality
		PE3	Using BIM processes would make my job easier
		PE4	BIM tools improve my effectiveness
		PE5	BIM provides greater control over my work
Social Influence (SI)	The extent to which individuals perceive that important others believe that they should use BIM	SI1	I would use BIM because of the high proportion of co-workers who use BIM
		SI2	The organisation that I work for supports the use of BIM
Facilitating Conditions (FC)	Users' perceptions on the support needed for the use of BIM	FC1	Guidance for the selection of BIM tools would be helpful
		FC2	A special training about BIM would be beneficial for me
		FC3	A consultant would be helpful to cope with BIM
Attitude (AT)	Individual's attitude toward using BIM	AT1	BIM would make my work more interesting

Source: Adapted from Venkatesh et al. (2003) and Davies and Harty (2013)



Once the initial questionnaire survey instrument was prepared, a construction project management firm and a design firm were asked to complete and comment on the survey design to identify potential problems. Survey questions were then once again sent to one architect and two civil engineers seeking their opinions. Consequently, revisions were undertaken based on the feedback obtained from the participants.

### **Data Collection**

Random sampling method was adopted in the selection of participants. Survey instrument prepared using the online survey hosting tool Survey Monkey was sent to member companies of the Turkish Contractors Association (TMB), The Association of Real Estate and Real Estate Investment Companies (GYODER), Turkish Chamber of Civil Engineers (IMO) Istanbul Branch, Chamber of Architects of Turkey (MO) Istanbul, Izmir, and Ankara Branches, Istanbul Project Management Association (IPYD), International Project Management Institute of Turkey (UPYE), Chamber of Electrical Engineers of Turkey Istanbul Branch (EMO), Chamber of Mechanical Engineers of Turkey Istanbul Branch (MMO), Turkish Architects-Engineers Association (TMMB), Turkish Employers' Association of Construction Industries (INTES), Architects Association 1927 (MD1927), Istanbul Freelance Architects Association (ISMD) and Turkish World of Engineers and Architects Association (TDMMB). As a result, a total of 905 responses were received.

### **Data Analysis**

The data were analysed using SPSS software version 26 (IBM Corp., New York, USA) and Microsoft Excel. First, frequencies and means for the whole sample population were obtained. It was necessary to check the normality of data in order to choose between parametric and nonparametric tests. For this purpose, Kolmogorov-Smirnov test was used. As the distributions were non-normal, the nonparametric Kruskal-Wallis test was conducted in order to see whether there were statistically significant differences between groups of firm size. Then, Dunn's test with Bonferroni adjustment post hoc test was performed to determine the source of significance.

## **FINDINGS AND DISCUSSION**

### **Descriptive Statistics**

Table 3 provides general information about respondents. As it can be seen from the table, the educational background of an overwhelming majority of respondents consisted of civil engineering (73.37%) and architecture (23.54%). In the next question regarding the working areas of participants, respondents could choose more than one option. Thus, the sum of the percentage rates exceeded hundred with 79.11% (716 respondents) out of the total of 905 working in the planning and costing field in which responsibilities included progress payments, quantity surveying, planning and cost control while 538 (59.44%) worked in the design and design management field, 497 (54.92%) in site management,

247 (27.29%) in contract management/procurement and 162 (17.90%) worked in the business development field.

There were several business types of the companies for which the respondents were working, 431 (47.62%) served as contractors for the private sector, 287 (31.71%) respondents noted that their company served as a contractor for public works, 269 (29.72%) were designers, 246 (27.18%) were consultants/project managers and the remaining 190 (20.99%) were client organisations.

Table 3. Demographic Profiles of Respondents

General Information	No. of Respondents	%
Educational Background		
Civil engineering	664	73.37
Architecture	213	23.54
Others	28	3.09
Working Area		
Planning and costing	716	79.11
Design and design management	538	59.44
Site management	497	54.92
Contract and procurement	247	27.29
Business development	162	17.90
Others	41	4.53
Business Type of Organisation		
Contractor (private)	431	47.62
Contractor (public)	287	31.71
Designer	269	29.72
Consultant – Project manager	246	27.18
Client	190	20.99
Number of Employees		
1 to 50	463	51.16
50 to 249	177	19.56
250 or more	265	29.28
Place of Operation		
Domestic markets	563	62.21
Domestic + international	342	37.79

The sample was quite well distributed across different groupings of firm size, which greatly contributed to observing the views of different groups. Out of 905 firms, 265 (29.28%) were large scale; 177 (19.56%) were medium scale; 463 (51.16%) were small scale forms. The majority of participants' firms in our sample (563 out of 905) carried out their operations only in domestic markets while 342 (37.79%) were active both in domestic and international construction markets.

## BIM Awareness and Use

In a question aiming to measure BIM awareness, the respondents were asked whether they had heard of BIM concept before. Out of a total of 895 respondents, 557 (62.23%) who responded to this question had heard of BIM concept, while 338 (37.77%) never heard of BIM. Those who had never heard of BIM were not allowed to respond to questions in the remaining parts of the questionnaire as their answers could disturb the consistency of results.

In the next question, the respondents were asked if they used BIM in the companies they were currently working for. Out of a total of 557 participants, 516 who had heard of BIM concept responded to this question. Analysis of responses to this question revealed that 334 (64.73%) respondents did not use BIM, while 182 (35.27%) actively used BIM. This question was posed to only those respondents who were aware of BIM. Thus, considering the total number of participants to be 895, it can be stated that the rate of BIM use was approximately 20.34% in our sample.

## Drivers of BIM Use: Perceived Usefulness, Social Influence and Facilitating Impacts

As mentioned in the "Methods and Data" section, the scale items aimed to identify drivers through the measurement of performance expectancy, social influence and facilitating conditions are constructed based on the scale items used by Davies and Harty (2013). To understand perceived advantages offered by the use of BIM and the factors that facilitate and encourage its use, the respondents were asked to evaluate eleven statements about the use of BIM on the Likert scale. Table 4 shows the frequency of responses, means, standard deviations (SD) and outcome of the Kruskal-Wallis tests.

Results revealed that an overwhelming majority of respondents either agreed or strongly agreed that BIM provides greater control over their work (PE5: 88.68%, mean = 4.26) and BIM use increases their job quality (PE2: 87.42%, mean = 4.30), indicating that improved control and job quality could be considered as a very strong drivers of BIM use. Respondents expressed relatively lower agreement on the remaining performance expectancy items, namely "Using BIM enables me to perform tasks more quickly" (PE1: 71.70%, mean = 3.95) and "BIM tools improve my effectiveness" (PE4: 74.84%, mean = 3.99). The view that BIM use makes job easier received the lowest support among performance expectancy items (PE3: 65.41, mean = 3.84), making it one of the last ranked statements in the list. These results suggest that performance advantages of BIM are quite well recognised by users, other than its performance enhancing effects through making tasks easier.

In BIM literature, management support in the form of BIM training for employees and adequate level of investment in software and hardware is considered to be critical for successful technology adoption (Won et al., 2013). In line with this argument, 85.34% of participants agreed that they needed consultancy services for coping with the difficulties of BIM (FC3: mean = 4.19); 81.76% felt that they needed guidance for the selection of BIM tools (FC1: mean = 4.06) and 72.96% believed that a special training about BIM would be beneficial for them (FC2: mean = 3.94).

Despite high expectations about training and guidance, users only moderately agreed that their organisation supports the use of BIM (SI2: 76.43%, mean = 3.97). Ding et al. (2013) obtained similar results and concluded that management support was not a key driver affecting architects' BIM adoption in China. One explanation regards the competitive advantage provided by BIM use, which motivates users to

Table 4. Performance Expectancy, Social Influence, Attitude and Facilitating Conditions

Code	Items	Frequency of Responses					Kruskal-Wallis Test			
		Strongly Agree (%)	Agree (%)	Neither Agree Nor Disagree (%)	Disagree (%)	Strongly Disagree (%)	Mean	SD	Chi-Square	Sig.
PE1	Using BIM enables me to perform tasks more quickly	35.22	36.48	18.24	8.18	1.88	3.95	1.017	6.652	0.036
PE2	Using BIM increases my job quality	47.17	40.25	8.80	2.52	1.26	4.30	0.831	8.128	0.017
PE3	Using BIM processes would make my job easier	29.56	35.85	25.78	6.92	1.89	3.84	0.990	3.799	0.150
PE4	BIM tools improve my effectiveness	35.85	38.99	16.35	5.66	3.15	3.99	1.019	2.055	0.358
PE5	BIM provides greater control over my work	40.88	47.80	8.18	2.51	0.63	4.26	0.765	4.964	0.084
SI1	I would use BIM because of the high proportion of co-workers who use BIM	13.21	23.27	32.07	25.16	6.29	3.12	1.122	1.369	0.504
SI2	The organisation that I work for supports the use of BIM	28.93	47.80	16.35	5.66	1.26	3.97	0.893	3.234	0.199
FC1	Guidance for the selection of BIM tools would be helpful	29.56	52.20	14.46	1.89	1.89	4.06	0.829	2.447	0.294
FC2	A special training about BIM would be beneficial for me	30.82	42.14	20.13	3.77	3.14	3.94	0.972	0.984	0.611
FC3	A consultant would be helpful to cope with BIM	38.37	47.17	10.69	3.14	0.62	4.19	0.799	0.490	0.783
ATI	BIM would make my work more interesting	33.96	35.22	22.01	5.03	3.78	3.91	1.048	1.627	0.443

learn and adopt BIM, with or without organisational support. The answers provided to the other social influence construct item about the incentivising role that co-workers play on the use of BIM showed very weak support, indicating the low power of this social influence item as a driver of BIM use (SI1: 36.48%, mean = 3.12). Finally, the view that BIM makes the work more interesting received only moderate support from users (AT1: 69.18%, mean = 3.91).

In order to see how perceptions change among individuals that work on firms with different size (small, medium, large), Kruskal-Wallis test was applied to the data. The last column on Table 4 shows the chi-square and significance ( $p$ -value) results of the Kruskal-Wallis tests. As it can be seen from the table, in nine out of total 11 items, the difference between size groups was not statistically significant, suggesting that behavioural intentions to use BIM depend more on individual attitudes rather than firm characteristics. Only two items, namely "PE1: Using BIM enables me to perform tasks more quickly" and "PE2: BIM use increases my job quality" were statistically significant at 5% level with  $p$ -values of 0.036 and 0.017, respectively. To determine which groups differ significantly, Dunn's Test with Bonferroni Adjustment was performed for post-hoc testing of these two items. Results for the PE1 item showed that there was a significant difference between responses obtained from participants working for small firms and those working for large firms ( $p = 0.086$ ), suggesting that individuals working for small firms more strongly perceive that using BIM enables them to perform tasks more quickly compared to those working for large counterparts. Thus, speed can be considered to be a stronger driver for smaller firms.

Dunn's test with Bonferroni adjustment applied to the second statistically significant item (PE2) demonstrated that significant difference occurred between medium and large groups ( $p = 0.031$ ). This finding indicated that participants who work for medium-sized firms place greater emphasis on the view that BIM use increases the quality of their job, again compared to their larger counterparts. These results suggest that some of the performance advantages provided by BIM are less recognised for the employees of large-scale organisations, hence a weaker driver of BIM use.

Looking at the general opinion of the total of 159 participants who responded to this question (as shown in Table 4), one can state that individuals put greater value on performance enhancing factors of BIM such as improved job quality, effectiveness and greater control over work, than on social influence represented by the stimulatory power of co-workers that use BIM. These results are to a great extent in line with the mainstream literature. For example, in a survey undertaken by site managers, Sezer and Bröchner (2019) noted that choices about the use of ICTs are mainly driven by perceived performance expectancy. However, findings of the present research partly contrast those of Howard, Restrepo and Chang (2017), who suggested that improved performance expectancy does not contribute to intentions to use BIM, whereas social influence has the greatest impact.

### **Non-Technical Barriers in the Adoption and Implementation of BIM**

In order to find out the significance of challenges related to organisational culture, people and government, survey participants were requested to rate nine barriers on a Likert scale. To this part of the questionnaire, 159 participants responded. Percentages representing frequency of responses and mean values were calculated (as shown in Table 5). The last column on the table shows the results

Table 5. Barriers to BIM Implementation

Code	Barrier	Frequency of Responses						Kruskal-Wallis Test		
		Very Important (%)	Important (%)	Moderately Important (%)	Slightly Important (%)	Not Important (%)	Mean	SD	Chi-Square	Sig.
B1	Lack of trained professional staff	23.27	57.86	11.95	5.66	1.26	3.81	1.032	2.147	0.342
B2	Lack of subcontractors that can use BIM	29.56	42.14	14.47	10.69	3.14	3.96	0.834	0.879	0.644
B3	Clients' lack of awareness and knowledge	26.42	44.65	15.09	11.32	2.52	3.52	1.036	0.675	0.714
B4	Need for additional staff to manage BIM	21.38	41.51	20.13	14.46	2.52	3.84	1.064	1.020	0.600
B5	Lack of national standard for the use of BIM	20.75	33.33	32.70	6.92	6.29	3.65	1.050	1.063	0.588
B6	Insufficiency of consultancy services	17.61	36.48	28.93	13.84	3.14	3.30	1.157	0.382	0.826
B7	Lack of government support	23.27	28.93	23.90	18.87	5.03	3.13	1.146	0.309	0.857
B8	Using BIM does not improve competitiveness	16.98	28.30	29.56	18.24	6.92	3.55	1.089	0.234	0.890
B9	Costs of BIM	15.09	19.50	35.85	22.01	7.55	3.47	1.184	0.234	0.890

of Kruskal-Wallis test conducted to determine whether there was a statistically significant difference in the barrier perceptions of participants working for different groups of firm size.

The most important barrier faced by respondents appears to be the difficulty experienced in finding technical staff with sufficient competence in BIM (B1: 81.13%, mean = 3.81). This finding was supported by the low rate of BIM use (20.26%), which became apparent in a previous question. Kruskal-Wallis test results for this item showed that there was no statistically significant difference observed between small, medium and large firms regarding this issue ( $p$ -value = 0.342). This finding is in contrast with the mainstream literature which suggests that SMEs more strongly suffer from lack of trained professional staff due to their inability in attracting personnel with skills suited to their needs. Thus, selecting the right technology also becomes problematic in smaller firms and outsourcing is preferred (Arendt, 2008). Thus, it appears that in Turkey, the "lack of skills" is not only a problem pertaining to SMEs, but it is also an industry-wide phenomenon.

The issue was further exacerbated by the need for additional staff in organisations, an item that was agreed by 62.89% of respondents (B4: mean = 3.84). Indeed the need for additional staff, which necessitates BIM user companies to change their existing organisational structure and to allocate additional resources for the new staff, has been cited extensively in the literature as a significant problem. In a survey by Eadie et al. (2014), undertaken on top 74 UK based main contractors, it has been shown that lack of trained staff with technical expertise was ranked 8th among a list of 10 barriers. Comparison of results further indicates that in the UK based study this barrier has received a quite lower mean value (2.26) than the mean of 3.81 obtained in the present study. Thus, it can be stated that the availability of technical expertise is perceived to be a much greater problem in the Turkish business environment.

As expected, a significant percentage of respondents agreed that they faced difficulties in finding subcontractors that use BIM (B2: 71.7%, mean = 3.96), followed by the clients' lack of knowledge and awareness which was supported by 71.07% of participants (B3: mean = 3.52). Together with the lack of trained professional staff, these barriers appear to be the most critical problems that BIM users face in implementation. In particular, lack of subcontractors who can use BIM is of significance in terms of collaboration. As BIM requires improved communication, BIM related capabilities of the parties further down the supply chain are extremely important. Without the alignment of the skills, systems and procedures adopted by the parties along the supply chain, collaboration and integration, which lie at the heart of BIM processes, are disrupted. Similarly, client's lack of awareness, knowledge and demand is also perceived to be a significant barrier as clients are considered to be the "champions" of technological innovations in construction.

The moderate support for the statement about the insufficiency of consultancy services (B6: 54.09%, mean = 3.30) further indicates the lack of expertise about BIM in the Turkish AEC industry. Existing expert manpower in consulting services is insufficient in number, however this finding revealed about some discontent about the services provided. Although individual-level analysis has shown that there is a strong need for consultancy services as a "facilitating impact". Such need still remains unfulfilled.

Government agencies may encourage the use of BIM through the enactment of required legislation and the formulation of the national BIM standards. Approximately half of respondents (52.20%) supported the view that lack of government support was a barrier against BIM (B7: mean = 3.13). Kruskal-Wallis test results did not show any statistically significant difference between groups of firms' size. "Lack of national standard for the use of BIM" is deemed either very important or important by approximately half of the participants (B5: 54.08%, mean = 3.65). According to the results obtained from the Kruskal-Wallis tests, the perceptions on the lack of national standards do not seem to be statistically different for small, medium and large firms ( $p$ -value = 0.588). Note that, although national BIM standards were prepared and made available many years ago in developed countries, many developing countries such as Turkey remained laggards in this respect.

One of the reasons for the slow adoption of BIM in organisations is that it does not provide the expected level of competitive advantage over rivals. 45.91% of respondents felt that the use of BIM did not provide benefits for their company in terms of improved competitiveness (B8: mean = 3.55%). Looking at the item results from the reverse side, it can be observed that only one fourth of participants (25.16%) believed that BIM contributes to competitiveness.

When respondents were asked to state the extent to which they perceived costs of BIM as a barrier, only 34.59% of them found costs either very important or important (B9: mean = 3.47), making it one of the last ranked items on the list. The high cost of investment has been identified as one of the major barriers in BIM adoption and implementation in previous literature. However, the findings of the present research reveal that cost is not perceived to be a very influential barrier in the Turkish AEC industry. Indeed, this result can also be attributed to the characteristics of the sample, predominantly composed of professionals working in the industry rather than of company owners that have to bear the capital and ongoing costs of technology investment.

## CONCLUSION

Previous research on the adoption and implementation of BIM mainly focused on the factors occurring at the organisational or industry level. However, there is an increasing evidence that user acceptance at individual level is an important determinant of the adoption of new information technologies. Thus, this article firstly looked for the drivers of BIM adoption using the items prevalent in technology acceptance research. We would like to document our findings as undermentioned.

Individuals placed great value on performance enhancing factors of BIM; in particular improved job quality, effectiveness and greater control over work, indicating the need for putting more emphasis on effectiveness and gains in job performance by the use of BIM for increased dissemination. However, improved job quality and work speed advantages provided by the use of BIM were less recognised by employees of larger firms.

Analysis of social influence factors indicated that co-workers' high level of use does not have an impact on the intentions to use BIM. Indeed, influence of social pressure on BIM use is far less important than all items about its performance enhancing effects.



Among facilitating conditions construct items, the need for consultancy services and for guidance on the selection of BIM tools have received considerable support. The need for training has received relatively less support among facilitating conditions construct items, implying that consultancy services and guidance for the selection of BIM tools is perceived to be more effective in resolving the difficulties encountered by users, at least in the current level of BIM use.

Main barriers faced during BIM implementations stemmed from the lack of availability of required expertise and skills, suggesting the need for improved training and education in the industry. In this respect, it seems that the few but increasing number of courses taught in architectural and engineering education are insufficient in satisfying present needs. The lack of knowledge and skills also manifests itself among parties across the supply chain as the "Lack of subcontractors who can use BIM" is perceived to be a very influential barrier. Indeed, this issue may be even more concerning for the functioning of the technology, considering the collaboration requirements of BIM. The gap between the level of skills that industry needs and that which new employees possess may be expected to widen still further with the progression from lower to higher BIM maturity levels. Thus, bridging this gap requires a more proactive and structured approach by policy makers and the academic community. In doing this, it should be recognised that developing the necessary digital skills comes also from actual usage, thus education and training programs should be designed to include learning through practice strategies. Overcoming the lack of skilled personnel barrier in SMEs may require a slightly different approach compared to their larger counterparts. As SMEs fall short in attracting skilled human resources, efforts to address labour shortages should primarily focus on the provision of training programmes for existing employees. However, such a strategy will further increase costs of BIM implementation, thus making its use questionable for SME owners.

Interestingly, cost concerns and related technology access problems fall behind many other issues for firms in the Turkish AEC industry. Indeed, this result can be attributed to the characteristics of our sample, which is mainly composed of employees working in the construction industry, rather than company owners who have to incur high initial and ongoing costs of technology investment.

As far as the digital divide debate is concerned, it appears that there are no differences between the degrees of barriers facing firms of different size. This finding is in contrast with the mainstream literature, which suggests that small, medium and large firms operating within the AEC sector face different kinds and degrees of organisational and financial barriers in the adoption and implementation of new technology. In particular, one would expect that the present study would provide additional evidence that barriers associated with costs and lack of skills are more prominent in smaller firms, as financial difficulties and skilled labour shortages in SMEs are frequently pronounced in literature. However, there were no clearly visible differences observed between groups even for these items.

Overall, the findings of this research are limited to cultural and institutional settings of Turkey. Thus, they should be interpreted with caution in different country contexts with advanced levels of BIM use, and in cultures with varying drivers of acceptance. It is suggested to conduct broader larger study spanning several geographies to confirm the findings and ascertain the BIM utility across larger corporates across the globe.

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