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Organizational Factors That Drive to BIM Effectiveness: Technological Learning, Collaborative Culture, and Senior Management Support

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Abstract: Senior management support is a key dynamic capacity for design companies in the architecture, engineering, and construction (AEC) industry, given the fact that they must identify changes in the competitive environment, which are increasingly becoming more and more technological. In addition, senior management support is obliged to react in the most efficient and effective way. Currently, the project design teams that have adopted building information modeling (BIM) are subject to constant changes in the technological environment, of which the activity is influenced by the behavior of senior management support. This research focuses on this issue by analyzing the role played by the variables of technological learning, collaborative culture, and support provided by senior management as precedents of BIM technology effectiveness. The data set has been obtained from 92 AEC companies in Spain. Using partial least squares (PLS), this research finds evidence of the previously mentioned relationships and the existence of partial mediation effects generated by technological learning and collaborative culture within the support of senior management in BIM technology effectiveness. In addition, this model achieves an appropriate level of predictive validation to explain BIM technology effectiveness in engineering project designs. The results highlight that senior management support needs to promote a technological learning and collaborative culture to improve the technological capabilities. The contribution and original value of the paper is to provide empirical evidence that the effectiveness of BIM factors in project design teams is influenced by the behavior of top management support.

Keywords: senior management support; BIM effectiveness; technological learning; collaborative culture; PLS

1. Introduction

Design teams in the architecture, engineering, and construction (AEC henceforth) industry are subjected to highly dynamic, complex environments with technological uncertainty [1,2]. Technological advances have led certain companies in the construction industry to adopt and use building information modeling (BIM) technologies in the design of infrastructure projects [3,4], for both the vertical (buildings) and the horizontal (linear) infrastructure industries, such as roads, bridges, and pipelines.

The technology acceptance model (TAM) is one of the most effective and widely used theoretical frameworks for information systems to predict how it is accepted by users in different organizations [5–8]. The TAM studies the relationship between perceived utility, perceived ease of use, and future use of technology from a technology-user point of view. The TAM explains that user satisfaction is key to new technology adoption. Several studies have chosen the TAM in order to explain the acceptance of BIM in countries such as Korea [9,10], China [11], Ghana [12], United Kingdom [13], and Peru [14]. The BIM

adoption has significantly increased around the globe, particularly in developed countries, over the past years [15].

Among the BIM benefits, the following are highlighted: (1) improving the effectiveness and accuracy of existing conditions' documentation [16]; (2) simplifying design reviews leading to a sustainable design [17]; (3) enhancing energy efficiency [3]; (4) resolving design clashes earlier through visualizing the model [18]; and (5) enabling a faster and more accurate cost estimation [17]".

Nowadays, design projects in Spain are slowly and gradually starting to use BIM technology despite technological barriers not having been overcome by many companies in the AEC sector [19]. The main barriers that impede BIM technology acceptance are as follows: legal and intellectual property issues [20], cultural reasons and resistance to change [21], lack of the collaboration between those involved in the projects [22], lack of training [23], and problems with software and hardware [24]. Therefore, BIM acceptance and adoption is a complex phenomenon, affected by multiple industry-specific variables and remains an unsolved issue [25]. The literature evidences that AEC companies who adopt BIM improve their final project design, making them more competitive [3,4,15]. This study is focused on AEC companies who design projects with BIM as well as assessing how certain organizational factors can influence BIM effectiveness. The purpose is to provide empirical evidence that the effectiveness of BIM in project design teams is influenced by organizational cultures fostered by top management support.

In this regard, this study focuses on assessing the organizational factors that could influence BIM technology effectiveness in AEC companies. The technological capabilities are abilities required for the effective use of technological knowledge [26]. BIM is a tool for designing projects with different technological capabilities: virtual vision (3D), planning (4D), costs (5D), energy simulation (6D), and facility maintenance (7D). BIM is a technology that allows the integration of project information. AEC companies that carry out projects with BIM use it for different purposes. On the other hand, effectiveness is the ability to achieve the desired result. Therefore, in this research, the effectiveness of BIM is defined as the ability to properly use BIM by project teams for the objectives set.

In this study, the term "team members" refers to the company staff who work with BIM technology, and the term "project agents" includes the participants in the project who can use BIM information.

Key organizational factors included in this study are as follows: support offered by senior management, collaborative culture fostered by senior management and the encouragement of technological learning, and factors relating to the application of BIM methodology. This way, senior management in different companies who have adopted BIM technology show that, by encouraging certain organizational factors, it is possible to improve BIM technology effectiveness in engineering project designs. More specifically, this study aims to provide answers to the following research questions for companies that have adopted BIM:

(1) What are the links between senior management support, collaborative culture, technological learning, and BIM technology effectiveness?
(2) How does senior management support influence BIM technology effectiveness in the presence of relationships between the aforementioned variables?

Therefore, the goal of this research is to examine the impact that certain organizational factors, encouraged by senior management, have on BIM effectiveness in AEC companies who design their projects with BIM. In order to achieve this goal, Section 2 shows a review of the theory as well as the research model and the hypotheses raised. The next section includes a description of the research methodology, followed by data analysis performance results and the discussion of the results. The final section explains the conclusions, including contributions, limitations, and future research.

2. Literature Review and Research Hypotheses

2.1. BIM: Barriers and Factors

BIM is a design tool that enables the process of editing, creating and using digital models for design, construction, and maintenance of infrastructure projects throughout their whole life cycle [15,27]. BIM is not only a 3D digital representation of project designs, but also provides a lot of information about the model itself, such as the amount of needed material, cost estimates, and energy simulations. In addition, the coordination of BIM design connects with different disciplines (structures, facilities, energy efficiency, health and safety, etc.) through the industry foundation classes (IFC) information standard. In BIM, the IFC serves as a data exchange format between agents, processes, and applications, which is defined by the ISO 16739:2013 Standard. The IFC is a particular data format that allows the exchange of an informational model without loss or distortion of data or information. It is an open, neutral format, which is not controlled by software producers, and planned to facilitate interoperability between various operators [28]. The IFC has been designed to produce all the information about the project.

Therefore, the large amounts of information found in construction information models can be used for several purposes [29]. The potential application of BIM occurs throughout all phases of the infrastructure life cycle, so experience is key in these phases and also for further modifications and improvements of the model. Therefore, technological learning perception and experience using BIM are vital skills [30], because BIM experience contributes to a higher knowledge assimilation, through technological learning.

There are a number of contributions regarding the adoption and implementation of BIM [21,22,31,32]. These studies are important in order to represent the adoption of BIM in different phases of the project, as well as diverse countries. The existing technological barriers have been investigated with the general objective of identifying strategies to increase their adoption [1,2]. Several studies analyze BIM as an information system and have focused on assessing user satisfaction [33,34]. It is generally accepted that BIM is a technological tool and is needed so as to improve competitiveness while adding value to companies [3,4].

The theoretical framework of BIM aims to promote the understanding of this technology in the AEC sector. To be able to do this, BIM is analyzed by different research models from many different perspectives. In general, BIM is recognized as an effective tool to eliminate design errors and reduce cost and time [31,32]. Nevertheless, from a technological standpoint, some contextual organizational factors, equally or even more relevant than its actual adoption, have been neglected when researching BIM. As pointed out [10,35], there are few studies that promote the understanding of the technologies through variables of an organizational nature.

In addition, the literature revealed that barriers in BIM adoption are as follows: (1) a deficiency of capital, BIM benefits not outweighing implementation costs, unwillingness to start new workflows, and BIM being too risky from a liability perspective [36]; (2) the lack of client interest, insufficient expertise, lack of training, and unavailability of standardized tools, protocols, and issues related to data ownership [37]; (3) cultural resistance, longer processes, high investment costs, lack of awareness, and demand and uncertainly about return on investment (ROI) [38]; (4) the sub-contractors not having sufficient knowledge about BIM, clients' lack of awareness about BIM benefits, high cost of BIM implementation, high cost of training, and unwillingness to change current construction culture [39]; and (5) high initial costs, training issues, and cultural resistance [40].

Therefore, this paper explores BIM as a technological tool in the design phase, where its effectiveness may well derive from organizational factors. Several organizational factors (i.e., collaborative culture, technological learning, and support from senior management) are considered key to influencing BIM effectiveness. Collaborative culture is fundamental given the fact that BIM is a functional organizational structure, which adds value to collaboration from the early and subsequent phases of the life cycle [41]. Since both

technological learning and experience are essential to be able to use BIM to begin with, they must also be assessed [30].

2.2. BIM Technology Effectiveness

Nowadays, the concept of technological capabilities was interchangeable with other concepts used for the same purpose, such as technological effort [42,43] or technological ability [43,44], and it has become a widely accepted term. Previous contributions have developed several industry-level BIM maturity models to help the AEC sector measure the performance of its BIM effectiveness [45] and to be able to make comparisons of maturity models between countries. In the design phase, BIM implementation has made possible the decrease of design errors, which means reducing the cost of the project and the time spent on the design, as well as generating benefits for the designer, the contractor, and the owner [33,34].

In the BIM literature, as a high-tech information system, the term "dimension" is used to indicate the information-processing capability of this technology [46]. It has been demonstrated that BIM is ahead of CAD, as it is able to turn physical properties into virtual models. In fact, it has been named the 3D BIM construction model. The fourth dimension 4D BIM added on was time in order to carry out study plans. Then, 5D BIM added price as its fifth dimension with the aim to study the cost of projects [47,48]. Sustainability analysis was the sixth dimension to be added to 6D BIM, allowing energy and sustainable simulation studies to be carried out in projects [49]. Later on, 7D BIM added a seventh dimension in order to include any information or documentation that may be required for systems to be managed in the most suitable way [50]. Finally, 8D BIM was incorporated so as to carry out studies of labor risk prevention in models throughout the design phase [51].

BIM is a technology that allows the integration of project information. AEC companies that carry out projects with BIM use it for different purposes. On the other hand, effectiveness is the ability to achieve the desired result. Therefore, in this research, the effectiveness of BIM is defined as the ability to properly use BIM by project teams for the objectives set.

2.3. Senior Management Support

BIM can be understood as an information system, which an organization needs to maintain their ability to compete, will produce quality information and needs senior management as a key factor for its successful implementation [52]. In this study, senior management support is defined as the extent to which the manager engages with their team in order to succeed in technological projects [53], due to the fact that greater encouragement from the top management leads to increased BIM adoption benefits [54]. The specific ways in which managers behave in terms of supporting their team may vary [55,56], but they tend to set action plans and project progress, communicate project vision, obtain project resources, attend project meetings and establish any structural changes that may be needed in the organization [53].

Currently, design teams that work with BIM technology are subject to constant changes in the technological environment. Their performance is being influenced by different behaviors and by the support received from senior management. Therefore, this support can improve the performance or capabilities of the project team [57].

2.4. Technological Learning

For decades, researchers have shown that learning is a clear organizational factor in order to succeed, as learning affects the development of technology and industry [57,58]. Learning can be described as a variety of processes from which individuals gain knowledge and technical skills [43]. The concept of technological capabilities was interchangeable with other concepts used for the same purpose, such as technological effort [42,43] or technological ability [43,59], until it has nowadays become a widely accepted term. Learning has also been described as the ways in which companies build, complement and organize knowl-

edge and routines around their activities within their cultures, adapting and developing organizational efficiency, through the best use of general skills and those of their staff [32].

Technological capabilities are the set of resources required to generate and manage technical change, including skills, knowledge, and experience [60]. Technological capabilities are defined as the ability to make effective use of technological knowledge by assuming, using, adapting and changing existing technologies [61]. BIM is a technological and procedural change which requires a broad domain of knowledge within the AEC industry [62]. For other authors, BIM is considered a disruptive technology [63], which involves not only technological change, but also a change process in BIM [3] that forces AEC organizations who carry out their projects in BIM to adapt to new cultural changes.

2.5. Collaborative Culture

Some studies suggest that organizational factors such as company culture, leadership, and knowledge management can affect the creation of technological knowledge [64]. Culture is the character and personality of the organization. Positive workplace culture attracts talent, drives engagement, impacts happiness and satisfaction and affects performance. In addition, studies carried out in construction projects show that encouraging the team to work collaboratively in a positive way brings them much closer and as a result, the team becomes much more united [65,66]. If project success is to be studied in the construction industry, it is important for senior management to foster a suitable environment for people to collaborate so as to have a successful project [67]. In the construction industry, collaboration in technological environments is essential for people to manage technology at its fullest [68].

2.6. Research Hypothesis

This study examines whether senior management support can improve team performance [57]. It is suggested that technological capabilities depend on learning processes and the organizational culture such as the collaborative environment and the environment itself, which are influential factors regarding team productivity. Therefore, this study postulates the following hypotheses arising from the theoretical review carried out:

Hypothesis 1 (H1). *There is a positive link between senior management support and BIM technology effectiveness when carrying out design projects.*

Hypothesis 2 (H2). *The effect senior management support has on BIM effectiveness when carrying out design projects is positively mediated through technological learning.*

Hypothesis 3 (H3). *The effect senior management support has on BIM effectiveness when carrying out design projects is positively mediated through a collaborative culture.*

From these hypotheses, a research model were formulated. The variables were obtained from the literature exposed in the previous sections, and the indicators used to measure the variables are presented in Section 3.3. The proposed model (Figure 1) had an independent variable "senior management support" (SMS), two mediating variables "technological learning" (TL) and "collaborative culture" (CCU), and one dependent variable "BIM effectiveness" (BIME).
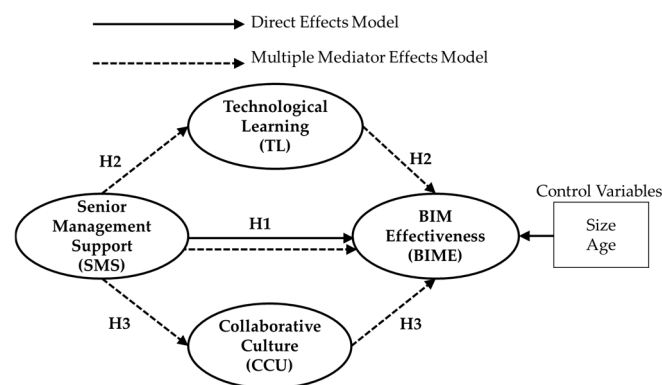
Figure 1. The research model and hypotheses.

Control variables were those variables which monitored the behavior of the dependent variable. The direct effect was used to test the model without the mediating variables, while multiple effects were used to test the model with mediating variables.

3. Research Method

3.1. Overall Approach

Once the literature were reviewed and the theoretical foundations were laid, the research method used in the study could be explained. First of all, the target population of this study and the selection of samples were explained. Next, the survey design as well as the empirical research and the data gathered for it was described as well as the variables to be studied and the equipment used in order to measure them. Subsequently, the statistical technique chosen for data analysis was justified.

This research follows an exploratory design [69], as it is used for the purpose of exploring the proposed research problem, which, given its characteristics, requires a predictive causal method. The research model is empirically contrasted using structural equations to explain its objective. Partial least squares (PLS) is suitable for this research for several reasons: (1) it is particularly useful, when mediating analysis is performed and the sample size is small [70]; (2) it is mainly intended for causal predictive analysis, where the problems explored are complex and previous theoretical knowledge is scarce [71]; (3) it is robust for small to moderate sample sizes [72]; (4) it does not require data distribution assumptions and uses a main component based on an estimation approach [73]; (5) it is adequate for formative constructions [74]; and (6) it is a predictive causal approach that emphasizes prediction when estimating statistical models of which the structures are designed to provide causal explanations [75]. PLS can be used for both predictive and exploratory research [76].

3.2. Sample and Data Collection

The target population of this study, on which the research hypotheses were tested, are companies in the AEC sector that carry out projects with BIM technology in Spain. The sample was made up of 92 architectural and engineering design companies. To collect data, a survey was used, which included components that gathered information about the company, as well as a series of questions related to the main variables of the model, which were grouped by topic. The questions related to the model variables were designed and adapted from previous contributors by the researchers (Table 1). The questionnaire was reviewed by academic experts, and then, a pilot study was conducted in five companies. Professional architect and engineer associations in Spain distributed the survey to the managers or CEOs of companies who used BIM in their projects. The researchers also contacted companies via telephone in order for the survey to be directly emailed to managers. Respondents were able to access the survey through a link (URL address) which was sent by email. According to [77], if the interest of the research is to link behavior variables of a company, key informants such as managers or high-level executives are able to provide

this information to researchers. On the other hand, studies that use organizational behavior information must take into account the different methods of bias that can influence the response process [78], which is previously taken care of in the research design [77]. The field work was carried out from November 2019 to April 2020. One hundred and six completed surveys were received and 92 were validated, as some of them were not appropriately completed.

Table 1. Variables (constructs)/indicators.

Senior Management Support	Supporting Contributions: [52,53,57].

SMS1: Project team members are rewarded for learning new skills.
SMS2: BIM effectiveness has promoted innovate mindsets and risk-talking.
SMS3: New ideas originated in project design by clients/promoter/contractor/are easy to implement. SMS4: Meetings where problems and alternative solutions are raised are frequently held.
SMS5: Show the approximate percentage of success in problems raised by the project team.

Technological Learning	Supporting Contributions: [26,60].

TL1: The project team has gained knowledge in BIM technology by attending external training courses.
TL2: Thanks to internally hiring experts, the project team gains knowledge in BIM technology.
TL3: Any knowledge gained from BIM technology is applied to all stages of the building or infrastructure life cycle (design, construction, and operation).
TL4: Indicate the number of years using BIM technology when carrying out projects.

Collaborative Culture	Supporting Contributions: [65–68].

CCU1: The project team supports and helps each other during the development of the project.
CCU2: There is a willingness to share responsibilities in the event of failure.
CCU3: The relationships between the different project agents have improved with the BIM methodology.
CCU4: The company tries to expand mutual collaboration with other design companies.
CCU5: Professional social networks (LinkedIn, etc.) are normally used to collaborate with other companies in carrying out projects.

BIM Effectiveness	Supporting Contributions: [46–49].

BIME1: The project team knows the functionality of BIM applications regarding 3D modeling and design.
BIME2: The project team knows the functionality of BIM 4D applications to carry out time planning.
BIME3: The project team knows the functionality of BIM 5D applications for cost and budget studies.
BIME4: The project team knows the functionality of BIM 6D applications for the study of energy efficiency and sustainability (energy savings).
BIME5: Tools are used to detect interferences between services and project facilities.
BIME 6: Indicate which dimensions of BIM you are using in the company.
BIME7: Indicate the approximate percentage of the project completion with BIM tools.

3.3. Variables

The proposed model contained the following constructs: SMS, TL, CCU and BIME. A previous review of the literature was needed to build the indicators used to measure the variables studied. All variables used in this study were measured by constructs with scales of measurement, which represented the manager's perception regarding the model variables. The indicators were established based on a five-item Likert scale (1 = totally disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = totally agree), except BIME5 which is dichotomous, except SMS5, TL4, and BIME7 which are ordinals and BIME6 which is categorical.

The following were included as control variables: age (measured by the number of years the company had been in the market since its foundation) and size (number of employees). This way, its effects on the dependent variable (BIM effectiveness) were neutralized. Table 1 shows the indicators for each variable in this study.

To conceptualize senior management support (from SMS1 to SMS5), questions were designed to assess how a project team's new skills, innovative mindset and risk-taking, as well as new ideas in the project design, manager performance in team meetings, and the percentage of solved problems, which had been raised by the project team [52,57]. On the other hand, a collaborative environment is understood to be adequate for people to collaborate so as to succeed in the project [67].

To conceptualize technological learning (from TL1 to TL4), questions were designed to assess information regarding gained learning, that is, the acquisition of new knowledge in BIM technology gained in different phases of the project and also assessing their experience with BIM [26,60].

To conceptualize collaborative culture fostered by management (from CCU1 to CCU5), questions were designed to assess support amongst team members and their willingness to share responsibilities, support offered by all those involved in the project, collaboration with other companies to carry out the project, and the use of professional collaboration networks [65,66,68].

Finally, to conceptualize BIM use effectiveness with regards to the project team (from BIME1 to BIME7), questions were designed to assess BIM effectiveness in terms of design, planning, costs, and energy efficiency throughout the different phases of the project (from 3D BIM to 6D BIM), the use of BIM tools for the study of interferences between facilities, and the percentage of the project carried out only with BIM tools [46–49].

3.4. Data Analysis

Relationships raised in the research model were assessed by the selected data, for which the chosen method of analysis was the modeling of structural equations through PLS. According to the characteristics of the model (predictive) and the sample (less than 250 observations), the minimum sample size depended on the number of relationships between variables in the research model [79,80]. In this case, at least 70 observations were suggested for 5 relationships. This sample complied with this condition, having a sample size of 92, which was suggested by G-Power software for a medium effect size (f2 = 0.15), at a power of 0.8 for an alpha level of 0.05.

This study used SmartPLS 3 software [81]. The estimation of the model was completed in two steps [82]. In the first step, the measurement model was analyzed, where the link between indicators and the variable they represent was verified. In the second step, the structural model was analyzed to examine how valid the relationships between the proposed variables in the model were. To test the measurement model in the first step, the nature of the direction of causality between the indicator and the construct should be analyzed. In our model, all variables had a formative specification, since the indicators directly helped create the variable. In other words, the direction of causality went from the indicators to the variable being measured or from the indicators to the construct. A variable with formative indicators implied that the indicators did not need to be highly correlated with each other, because each indicator collected different aspects of the variable which can occur independently [83].

For the structural model, relationships between the variables proposed in the research model were validated through the path coefficient (β) and their level of statistical significance with a Bootstrap test using 5000 subsamples and also illustrated the variance R^2 of the variables explained. In order to contrast the hypotheses of mediation, the first thing to be assessed were the direct effects caused to the model without introducing any mediating variables. After that, the mediating variables were introduced in order to assess the indirect effects the mediation relationships had on the mode to then calculate the VAF value.

4. Results

Table 2 shows the descriptive statistics of the sample. Companies that use BIM to carry out architectural and engineering projects have been examined. It should be noted that 68.1% of company samples are micro-companies, 63.4% of the sample had been using BIM for over three years, and 40.4% of the companies carry out more than 80% of their projects with BIM. As for the type of projects, approximately 50% of the companies carry out building projects, 30% engineering facilities, and 20% civil engineering and architecture.

Table 2. Descriptive statistics of the sample.

Type of BIM Company	Percentage	Number of Years Using BIM	Percentage
Architecture	48.9%	Under 1	9.7%
Engineering facilities	30.4%	1–2	16.1%
Civil engineering Architecture	20.7%	2–3	10.8%
Company Size	**Percentage**	Over 3	63.4%
Micro companies (under 10)	68.1%	**Project Fulfillment with BIM Tools**	**Percentage**
Small companies (11–50)	22.3%	Under 20%	8.5%
Medium companies (51–250)	8.5%	20–40%	12.8%
Big companies (over 250)	1.1%	40–60%	21.3%
Annual Turnover € Million (Euros)	**Percentage**	60–80%	17%
Under 2	80.4%	Over 80%	40.4%
2–10	15.2%		
10–50	3.9%		
Over 50	0.5%		

Table 3 shows the result of the measurement model with formative indicators, where the content validity of variable indicators, represented in weight and statistical significance, were assessed. To ensure the absence of the collinearity between the indicators and their construct, VIF (variance inflation factor) was assessed, needing its value to be less than 3 [84]. In our case, all VIF values obtained were under 3, except for CUB3 being 3.17, which was eliminated in order to avoid collinearity problems. The indicators that obtained weights very close to zero were also eliminated from the model, since they were not statistically significant, except for TT1 and BIME5 since they conceptually contribute to the construction of the variable they represent, despite not being significant. Control variables age and size were found not to be statistically significant due to β coefficients being very close to zero and also being eliminated from the study, although it is important as a previous step to use control variables to see their influence on the dependent variable to be explained BIM effectiveness.

Table 3. Measurement model results.

Senior Management Support	Weight	T-Value	VIF	Technological Learning	Weight	T-Value	VIF
SMS1	0.224 *	1.646	1.658	TL1	0.104 NS	0.904	1.126
SMS2	0.591 ***	3.882	1.660	TT2	-	-	-
SMS3	-	-	-	TT3	0.720 ***	5.798	1.062
SMS4	0.362 **	2.554	1.614	TT4	0.623 ***	4.828	1.148
SMS5	-	-	-				
Collaborative Culture	**Weight**	**T-Value**	**VIF**	**BIM Effectiveness**	**Weight**	**T-Value**	**VIF**
CCU1	0.530 ***	4.192	1.204	BIME1	0.255 *	1.754	1.812
CCU2	-	-	-	BIME2	-	-	-
CCU3	0.613 ***	5.423	1.233	BIME3	-	-	-
CCU4	-	-	-	BIME4	0.307 *	2.239	1.421
CCU5	0.211 *	2.154	1.033	BIME5	0.186 NS	1.398	1.570
				BIME6	0.235 *	1.943	1.205
				BIME7	0.427 ***	3.464	1.523

*** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$, NS: not significant (based on t (4999), one-tailed test), t(0.05, 4999) = 1.645; t(0.01, 4999) = 2.327; t(0.001, 4999) = 3.092.

Structural analysis assessed the strength of the relationships established between the different variables in the model. To do this, the level of statistical significance of the

"β" or path coefficients and the R^2 for the dependent variables were assessed. In Table 4, the results of the structural model and the results of the mediation analysis are shown. The control variables (size and age) were eliminated, as they were not significant for the dependent variable. To contrast the hypotheses of mediation, the direct effects model (Figure 2) between senior management support and BIM effectiveness was first assessed, which was certainly significant. Secondly, the model with mediated effects was evaluated (Figure 3), introducing the following mediating variables: technological learning and collaborative culture. Finally, the VAF (variance accounted for) value was calculated in the mediator model to determine the mediation strength.
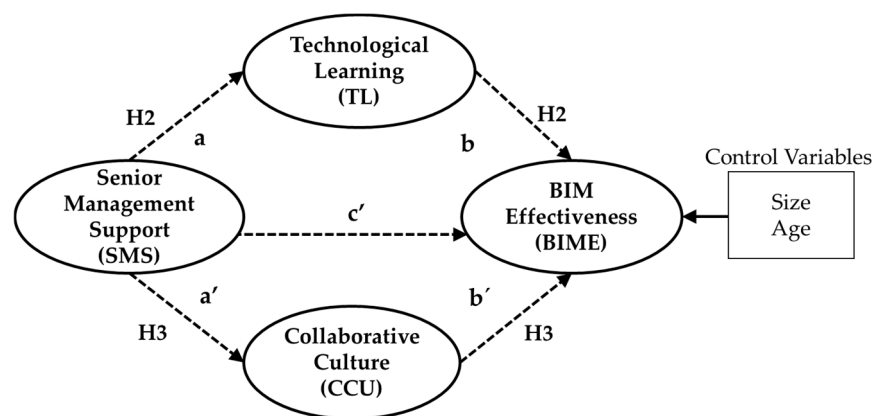
Table 4. Structural model results.

Direct Effects Model	Path Coefficient "β" (T-Value)
VIF (SMS → BIME) = 2.1263	C = 0.698 *** (14.959)
BIM Effectiveness	$R^2 = 0.487$
Mediated effects model	Coefficient Path "β" (T-valor)
VIF (SMS → TL) = 1.0000	A = 0.672 *** (11.325)
VIF (TL → BIME) = 1.6145	B = 0.310 ** (2.090)
VIF (SMS → CCU) = 1.0000	a′ = 0.592 *** (10.512)
VIF (CCU → BIME) = 1.9113	b′ = 0.418 *** (4.254)
VIF (SMS → BIME) = 2.1263	c′ = 0.213 NS (1.560)
Technological learning	$R^2 = 0.350$
Collaborative culture	$R^2 = 0.451$
BIM effectiveness	$R^2 = 0.648$

*** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$, NS: not significant (based on t (4999), one-tailed test), t(0.05, 4999) = 1.645; t(0.01, 4999) = 2.327; t(0.001, 4999) = 3.092.
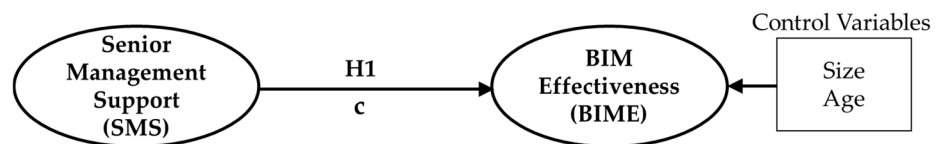
Figure 2. Direct effects model.

Figure 3. Mediated effects model.

Figure 3 represents the model of mediated effects to contrast hypotheses H2 (+) and H3 (+). Table 4 shows the results of the structural model with direct effects (Figure 2) and with mediated effects (Figure 3). Again, Table 4 shows that there was no collinearity between the variables of the model, since the VIF values were under 3. The results in Table 4 were obtained under a one-tailed Student's t test distribution, because the hypotheses with a (+) sign were stated. In addition, shown in Table 4 are the values of the path

coefficients "β" (T-value) for each path. To estimate the path coefficients, a Bootstrap resampling procedure was performed with 5000 subsamples. Table 4 shows the R^2 value for technological learning (R^2 = 0.350), collaborative culture (R^2 = 0.451), and BIM effectiveness (R^2 = 0.648). The higher the value of R^2, the more predictive power exists in the model. According to [85], R^2 values (0.67, 0.33, and 0.10) were considered as prediction reference values (substantial, moderate, and weak). According to [86], R^2 values (0.75, 0.50, and 0.25) were considered as values (substantial, moderate, and weak). Therefore, the values obtained are relevant to explain BIM effectiveness.

The model with mediated effects verified that H1 (+) was proved in the model with direct effects and H2 (+) and H3 (+) were demonstrated in the model with mediated effects. Table 5 shows the contrast of hypotheses for the model of mediated effects, and the VAF value was calculated to know the type of mediation. The strength of the mediation was calculated through VAF. According to [87], if the VAF value is greater than 80% it is complete mediation and if the VAF value is between 20% and 80% it is partial mediation. Therefore, as the VAF value was 68.15%, the relationship between senior management support and BIM effectiveness was a partially mediated relationship by technological learning and by the collaborative culture in a multiple way.

Table 5. Hypothesis testing and mediation analysis.

H2(+): SMS → TL → BIME			
β (SMS → TL) p = 0.0000	Percentile 95% confidence interval	β (AT → BIME) p = 0.0000	95% confidence interval
0.672 ***	(0.4533–0.6545)	0.310 **	(0.2399–0.5547)
H3(+): SMS → CCU → BIME			
β (SMS → BIME) p = 0.0000	Percentile 95% confidence interval	β (CCU → BIME) p = 0.0178	95% confidence interval
0.592 ***	(0.5280–0.7442)	0.418 ***	(0.0208–0.5076)
VAF = (Indirect effect/Total effect) × 100 = 68.15% Indirect effect = (a × b) + (a′ × b′) Total effect = direct effect + indirect effect = c′+ (a × b) + (a′ × b′)			

*** p < 0.001, ** p < 0.01, * p < 0.05, NS: not significant (based on t(4999), one-tailed test), t(0.05, 4999) = 1.645; t (0.01, 4999) = 2.327; t (0.001, 4999) = 3.092.

The direct effects model explained 48.7% of the variance of BIM effectiveness, and the model with mediating effects explained 68.4% of the variance of BIM effectiveness. Therefore, it is very important that management support not only technological projects, but also a collaborative culture and technological learning, as it has been demonstrated that, if management fosters both in the BIM team, the capacities to use this technology improve.

The results indicated that the proposed hypotheses were well supported, and the causal relationships among the postulated constructs in the model were analyzed. The model in our study provides an elaborated explanation of the key factors influencing BIM technology effectiveness when the manager engages with their team in order to succeed in technological projects.

5. Discussion

In the construction sector in Spain, digitalization has caused an increase in the demand for projects carried out with BIM both for public projects where its use is mandatory and private projects. Adopting BIM technology requires internal adjustment and corporate redesign, where improving employee productivity is a priority in the transformation from CAD to BIM [14].

According to recent research to investigate the reasons for low BIM adoption among architectural firms in India [10], it was concluded that top management support and BIM ex-

pertise promote BIM adoption but do not inquire about which variables can influence BIM effectiveness from top management support. In order to do this, senior management support must promote adequate culture and values, enhancing technological learning [26,60] and a collaborative culture amongst members of a project team [65,66,68]. For an effective BIM implementation to exist, senior management support must make decisions to improve the work process, defining objectives and establishing the responsibilities of each person involved. Senior management support must establish leadership throughout the BIM implementation process, which allows monitoring and coordinating all activities of a project team, avoiding errors and misunderstandings [33,34].

Finally, for BIM performance to be appropriate, it must have a well-defined hierarchical and collaborative structure, as well as fluid and determined work processes in addition to having adequate technological resources [26]. With all of the above, BIM effectiveness will be enhanced for competitive improvement and differentiation in the market.

6. Conclusions

From a theoretical perspective, the TAM validates the acceptance or use of new technology but did not inform on how to improve its technology. This study has shown that, once a new technology is accepted, its effectiveness can improve with senior management support. For that to happen, senior management support must promote both a collaborative culture and technological learning amongst members of a project team. It has been proven that senior management support exerts an influence with direct effects on BIM effectiveness ($R^2 = 0.487$). In the same way, evidence with indirect effects has been found, proving that technological learning and collaborative culture are mediating variables between senior management support and BIM effectiveness. These mediation effects improve the explanation of BIM effectiveness ($R^2 = 0.648$). It can be concluded that the development of technological capabilities depends on the learning processes and the environment, as established by the literature review, and it is proven that BIM technology is also met. Senior management support alone does not improve technological capabilities, and management must also promote both technological learning and the collaborative culture in a project team simultaneously. In this way, the ability to use BIM technology among team members is desired. It has been shown that the size of the company and its age do not influence BIM technology effectiveness. This is an advantage, as any manager can improve their competitiveness in the market by offering equal opportunities. Through these results, the following question can be answered: Why do companies who adopt BIM to carry out projects obtain different levels of effectiveness if they are being done at the same time? It can be seen that the answer is hidden in managerial behaviors and intangible organizational factors that explain the phenomenon. Therefore, BIM requests the need for theoretical frameworks that distribute knowledge to promote business strategies where senior management promotes better performance in project design.

A possible limitation of this study is that the survey was restricted to AEC design companies using BIM in Spain, which could raise questions about the extent to which the results can be generalized in other countries. Testing the external validation of the findings would require the replication of this study in other countries. The study also used a cross-sectional research design, which could be criticized for not capturing the temporary dynamics incorporated in the model. Thus, future work should consider a lengthwise design that provides insight into these relationships over time. It would also be interesting to undertake the same study analyzing BIM effectiveness by type of project design (architecture, civil construction, and industrial construction). Finally, it can be said that, from this study, future lines of research related to this topic are opened, creating the possibility of expanding the analysis with different variables or organizational factors that are not included in this research. For example, the role that organizational variables may cause from the perspective of employees, such as team entrepreneurship, needs to be investigated to analyze their influence on the ability to use BIM technology. The results of this study are intended to help managers and professionals gain a better understanding

of the importance of fostering technology learning and collaborative culture to ensure the potential benefits of technological capabilities.

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