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Profile Characterization of Building Information Modeling Users

Eric Forcael [1,*], Carolina Puentes [1], Rodrigo García-Alvarado [2], Alexander Opazo-Vega [1], Jaime Soto-Muñoz [2] and Ginnia Moroni [2]

[1] Department of Civil and Environmental Engineering, Universidad del Bío-Bío, Concepción 4051381, Chile
[2] College of Architecture, Construction and Design, Universidad del Bío-Bío, Concepción 4051381, Chile
* Correspondence: eforcael@ubiobio.cl; Tel.: +56-41-3111200

Abstract: Nowadays, BIM (Building Information Modeling) has steadily been introduced into the construction industry as a promising methodology for managing projects. Therefore, it is necessary to study the users of its processes. Worldwide, there are already systems that classify companies according to how they use BIM, although only a few studies have been conducted on how individual users are classified. Hence, the present study sought to develop a model that characterized BIM users based on several parameters. The methodology employed defined variables based on a literature review, which experts subsequently validated. These variables made it possible to develop the measurement instrument: a structured questionnaire applied to construction professionals. The necessary parameters for the user characterization model were extracted using the Partial Least Squares (PLS) method. This model met the structural evaluation and measurement criteria, which confirmed that it was valid and reliable. It was found that three main aspects mainly characterized users: (i) their use and command of the software and the methodology, (ii) the experience and degree of adoption of the technology, and (iii) the individual's knowledge of process levels and standardization concerning BIM.

Keywords: Building Information Modeling; characterization; users; modeling; Partial Least Square

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1. Introduction

A building project involves a variety of participants from different specialties. Nowadays, digitalization has made it possible to improve the efficiency of this process, decrease the number of setbacks, and improve the predictability of costs and work deadlines. Digitalization includes tools such as BIM (Building Information Modeling), which enables a project to be managed throughout its life cycle by integrating architectural, engineering, facilities design, and construction company work [1,2]. The expression Building Information Modeling has multiple definitions that coincide in general terms, although there is no universal definition. The National BIM Standard-United States® (NBIMS-US™) defines BIM as a digital representation of a facility's physical and functional characteristics. It forms a reliable basis for making decisions during a facility's life cycle, from its beginning to its demolition [3].

Several authors, standards, companies, and experts, such as the European Standard for Building Information Modelling [4], Blankenbach and Becker [5], and Doan et al. [6], among others, agree that Building Information Modeling can be defined in two ways: (i) as the parametric digital representation of a construction product (examples are slabs, walls, columns, equipment, doors, windows, etc.) that includes its geometry and information, and (ii) as a methodology/process for developing and using BIM models to support design, construction, and operational decisions made throughout a project's life cycle, which implies that it can be used to integrate and manage the information provided and used by different project stakeholders.

These definitions explicitly specify that BIM is a methodology and software, a product and a process. As can be seen, the definitions attempt to advance toward an integrated working methodology that relies on IT-based tools. The information generated from files by one or more software programs is integrated into a process methodology for a multidisciplinary work team, with a bidirectional relationship that enables it to be updated [7]. Thus, the BIM methodology facilitates the initial virtual construction of a building. It anticipates possible interferences, conflicts, and inconsistencies; therefore, it can be used throughout the creation of a project and its subsequent use or operation.

However, in terms of standards, the authors of this paper found that no systematic investigation has been conducted to understand the characterization of BIM users through categorization parameters. Therefore, to fill this research gap, the general objective of this research was to develop a characterization model with BIM user categorization parameters. The specific objectives were: (1) to conduct a bibliographic exploration of BIM users' characteristics; (2) to obtain categorization variables; (3) to validate the variables through a panel of experts; (4) to create an instrument to measure the characterization parameters of BIM users and subsequently apply this to construction professionals, and (5) to analyze the results obtained using quantitative statistical tools and qualitative analysis to validate the parameters that characterize BIM users. Thus, this research produced information that can, on the one hand, be used to inform national BIM plans, allowing the necessary adjustments to achieve BIM maturity in a short time. On the other hand, this research gathered information that can help companies generate more suitable BIM methodologies in their workflow. Hence, through the implementation of BIM, companies can collaborate to achieve the expected goals of the construction industry.

2. Literature Review

2.1. BIM Context

The first recognized allusion to the concept of BIM was made by Charles M. Eastman (USA) during the 1970s. It criticized the lack of coherence in architectural information, which was not all in one single model, and proposed a "Building Description System" model [8]. Later, the architect Phil Bernstein began using the term BIM widely, while the analyst Jerry Laiserin popularized the term to represent the exchange of information about the digital representation of construction projects. Meanwhile, the Hungarian company Graphisoft developed the first BIM software, ArchiCAD, in 1987 [9].

Nowadays, certain countries are leading the development of BIM and reaping great benefits and better quality in their construction projects. They include the UK, China, South Korea, Finland, and the Netherlands [10]. For example, Finland, a technologically advanced country with a small but flexible construction sector, has quickly adopted BIM [11]. In Europe, BIM has been incorporated in the national legislation of at least 23 countries, mainly for large-scale or infrastructure projects. Of these, Finland is considered a pioneer in its integration into the construction sector [12]. According to Ullah et al. [13], the US, the UK, Scandinavian countries, and Singapore are the countries that lead the adoption of BIM worldwide. For example, in the UK, since the beginning of 2016, Level 2 BIM has been mandatory for the controlled reduction of costs, energy, and project delivery times [14].

In China, knowledge and use of BIM are growing, even though the construction industry is fragmented, and the use of BIM needs to be evenly distributed [15]. Norway, Denmark, and Sweden share a high level of BIM development. As early as 1991, the Swedish Standards Institute began publishing guides for BIM promotion. Then in 2007, the governments of these Scandinavian countries began obligatory incorporation, mainly in public services, including the Norwegian Public Roads Administration, Norwegian National Rail Administration, Danish Defense Construction Service, and Swedish Transport Administration [16]. In Singapore, the Building and Construction Authority implemented several regulations to promote BIM; since 2013, they have requested that all public and private projects with a greater gross floor area of 20,000 m^2 must use BIM to deliver architectural plans; and since 2015, this has included all building plans for projects over 5000 m^2 [17].

Developing countries are also committing efforts to adopt BIM methodology in their local industries. Malaysia has been working towards adopting BIM since 2009, driven by the Construction Industry Transformation Programme 2016–2020 agenda. This has led to initiatives such as creating committees to monitor BIM activities and conducting seminars and workshops. In Mongolia, the efforts for BIM adoption are led by industry professionals working with the Ministry of Construction and Urban Development to put in place a program for its implementation. In 2016, Vietnam launched a framework for the application of BIM in the construction industry, mainly for project operations and management activities [18].

The integration of BIM into Latin America is heterogeneous. In countries such as Brazil, Colombia, and Peru, it is highly accepted in public projects, and many BIM professionals have been hired. However, in other countries, the movement towards BIM continues to be slow, considering that by 2020 the BIM market will increase by up to 11%. In Argentina, BIM has been tackled by gradually incorporating educational institutions into its use and dissemination. Costa Rica and Ecuador have implemented BIM at the level of private companies since there are no national policies or training centers for BIM [19,20]. Although recent studies show that 24.5% of building projects in Lima, Peru, use BIM, the Panamerican games held in 2019 showed its benefits for developing needed infrastructure in record time [21].

In the case of Chile, one of the most advanced developing countries for the implementation of BIM, the acceptance of BIM through organizations such as PlanBIM stands out; this has been driven by a Government Strategic Program to promote BIM use in public institutions as well as the private sector [22]. The use of BIM began in Chile several years ago, primarily for architectural modeling; that is, in the initial phases of a project. By the end of 2010, Architecture, Engineering, and Construction (AEC) companies were using BIM in several projects and specialties, and the Chilean government declared its interest in incorporating this technology [23]. Nonetheless, this did not occur until 2015 when the government program called PlanBIM was launched, where the skills and abilities of the roles detailed by this program were adapted to numerical parameters to quantitatively establish requirements for the different attributes and capabilities of professionals assuming a specific BIM role [24]. The government has declared its intention to require BIM in all public buildings by 2020. Its full implementation is expected by 2025 in the private sector, despite the need for more incentives and regulatory frameworks [25].

In the use of BIM, three fields of work are normally recognized—Technology, Processes, and Policy [10,26]—and have different members, requirements, and deliverables. Technology corresponds to the organizations and software intended for facility design, construction, and operation. Processes consist of people (owners, architects, engineers, contractors, etc.) and activities responsible for the procurement, design, construction, manufacture, use, management, and maintenance of infrastructure. Finally, Policy includes the people who fulfill contractual, regulatory, and educational roles in design, construction, and operations processes; they work in insurance companies, research centers, educational institutions, and regulatory bodies. These fields interact through information transfer and established relationships; they also overlap because of shared stakeholders and deliverables [26].

2.2. BIM Classification Systems and Process Measurement Models

In BIM, classification systems usually refer to the information that is handled and assigned to classes of objects to analyze and facilitate design management. This procedure consists of regrouping objects that have similar characteristics or components, such as windows, doors, etc. Classification also includes the general hierarchical nomenclature; for example, selecting a product by choosing a family of products, then a subfamily, and thus accessing its properties. Nomenclature and classification systems are often related to a market with specific details [27–29]; some examples are discussed below:

(a) OmniClass—Table 23, ISO Standard 12006-2—the United States

This classification system was developed by the construction industry, even though it is also used for the American COBie (Construction-Operations Building Information Exchange). Omniclass is employed in numerous applications, such as the organization of product libraries, documentation, project information, and electronic databases. It is based on classification by codes arranged in tables and according to function, form, stages, etc.

(b) Uniclass—the United Kingdom

This is a classification system that structures information throughout the project life cycle. It is approved by all professional institutions and construction organizations in the UK and establishes tables with codes by stage, arranged alphabetically.

(c) Uniformat II—ASTM—the United States

This classification system enables improved project management and reporting at each stage of the building life cycle: planning, scheduling, design, execution, operations, and demolition. UniFormat II provides order by assigning levels to building elements to evaluate different construction procedures. It organizes the information into nine categories.

(d) Masterformat—CSI and CSC—Canada

The information is organized into two large groups. The first focuses on the conditions, requirements, and relationships in the construction process. The second focuses on the tangible aspects of construction, such as equipment and construction sites.

Measurement models are generally used for the evaluation of organizational processes. Some such models are the Capability Maturity Model, which establishes a set of levels (Initial, Managed, Defined, and Optimized), as a group of activities that collectively help achieve business objectives [30]; the UK BIM maturity model, which has become the primary component of the BIM implementation strategy in the UK that links maturity levels and local standards [31]; and finally, the Matrix of CIC Research Program, which consists of six key elements of BIM planning (Strategy, Uses, Process, Information, Infrastructure, and Personnel/Staff) and a maturity scale that establishes the existence or use of planning elements [32,33].

Therefore, it is clear that a critical aspect for evaluating the adoption level of BIM methodologies in a company or organization is the so-called BIM maturity model, where several frameworks have been developed to assess and improve BIM maturity in organizations and projects [34]. The term “BIM maturity” was created by Bilal Succar and refers to the quality, repeatability, and levels of excellence of BIM services [10,33]. It attempts to identify and subsequently classify the abilities that companies in the BIM sector have, to allow them to develop and excel in the execution of tasks or provision of services. This index was created from other maturity models and is focused explicitly on BIM methodologies. It proposes five levels: Initial, Defined, Managed, Integrated, and Optimized. Generally, each stage classifies the company according to its services and process level, focusing on BIM implementation, policies, productivity impact, and strategic communication.

According to Edirisinghe et al. [35], the systematic adoption of BIM in organizations can be supported by maturity models. However, most models are limited by the need for more theoretical foundations, socio-technical dichotomies, and the inability to adequately consider a project’s complete life cycle. Dakhil et al. [36], looking at UK clients, identified their BIM organizational maturity competencies and role in the BIM implementation process, and identified a relationship between them. However, because of the relatively recent implementation of BIM, companies lack the measurement instruments or evaluation systems for assessing the skills or abilities of their professionals and allowing them to participate in a BIM project.

3. Methodology

This research was classified as a categorization study and mainly centered on the collection of bibliographic information and the analysis of exploratory information on the experiences of construction professionals, considering both the academic and professional fields. As an exploratory study, it is important to emphasize that the review of the literature was non-systematic; rather, it was a content analysis of 28 pertinent articles published in scientific journals from 2017 onwards. The selection of these articles was based on the relevance of their content concerning perspectives on BIM adoption. In addition, while conducting the literature review, it was considered necessary to take into account the maturity models and their conditioning factors as part of the characterization of BIM users. Finally, to strengthen the bibliographic support, before building the model, the parameters considered in this study were bibliographically corroborated by examining a set of prior studies, as is shown in Section 4 (The Model Proposed).

3.1. Variables of the Model to Define the BIM Users' Profile

Once the literature review was conducted, the different variables that preliminarily comprised the analysis model that defined the profile of the BIM users were established and validated.

The process for defining the classification variables is described in the flow chart shown in Figure 1.

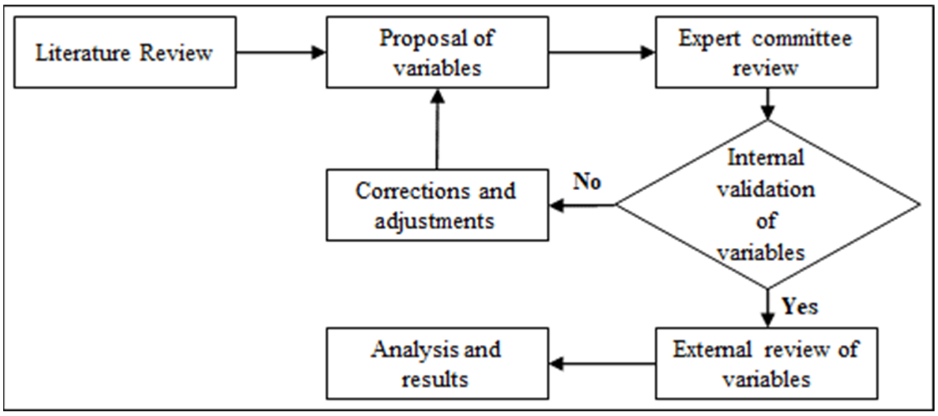

Figure 1. The process to define the classification variables.

Based on existing maturity models, it was determined that the multifunctional BIM model should be composed of measurable components organized in a hierarchical structure, with determined categories and subcategories. Therefore, the following parameters —first established by Kassem and Succar [10] as previously mentioned and later adopted by the existing maturity models—Technology, Process, and Policy, were adopted here. Given that the objective of this research was to characterize BIM users, a fourth parameter called personnel/staff was considered, which referred to variables that measure individual abilities and qualities.

After establishing the four parameters for the characterization model, they were defined:

(a) Technology: Refers to a series of techniques, skills, and processes used in BIM, mainly related to software (Revit-Autodesk, Bentley, Tekla) and hardware (computer, input/output peripherals).
(b) Process: Refers to companies' methods of developing or coordinating projects through the use of BIM.
(c) Policy: A series of contractual documents that take precedence over existing agreements, including requirements, coordination issues, conflicts, management models, etc.
(d) Personnel/Staff: Includes the skills, abilities, or specializations possessed by the individual BIM users participating in a project.

Next, based on the parameters that defined the BIM maturity models, the 17 variables shown in Table 1 were established; as explained in the next section, these were required to be validated by a panel of experts as.

Table 1. Definitive variables grouped by parameters or categories.

Technology	Process	Policy	Personnel/Staff
Software	Conflict analysis	Meetings	Expertise
Information maturity	Productivity	Roles for management	Experience
Interoperability	Workplan	Coordinator	Degree of adoption
Proper use of the software		Standardization	Work dedication
		Coordination of use	Project size

3.2. Validation of Obtained Variables

In this stage, based on the four categories considered, the 17 variables selected were reviewed to validate, correct, or eliminate them and thus better characterize BIM users. The review was carried out through a questionnaire applied to a panel of experts consisting of professors and researchers with knowledge of BIM methodologies. Through this review, the parameters and variables shown in Table 1 were analyzed and refined so that they could be validated, corrected, or eliminated.

In this sense, evaluation by experts involves presenting a series of questions to relevant people to receive from them a well-founded opinion about a measurement instrument [37], where the content validation by expert judgment corresponds to a knowledgeable assessment from people recognized by others as qualified specialists who can give solid feedback, evidence, judgments, and evaluations about a specific ambit [38]. While some methods are designed to consider the opinions of two experts [39], it is recommended a minimum of three and a maximum of 10 experts evaluate a questionnaire [40].

According to these precepts, the panel of experts was composed of recognized professors and professionals with more than 10 years of experience and knowledge of the use of BIM methodologies, as shown in Table 2.

Table 2. Panel of experts with knowledge and experience in BIM.

Academic Background	Area of Expertise
Civil Engineer, Master or Doctor of Engineering	Integrated Project Design
Architect, Master or Doctor of Architecture	Digitalization in the construction industry
Architect	BIM seminars and workshops
Architect, Master or Doctor of Architecture	Energy efficiency, environmental simulation, and conditioning
Doctor of Building Engineering	Environmental indicators applied to construction, operation phase, and maintenance of buildings

The questionnaire applied to the experts had six open-ended questions relating to the four categories considered (Technology, Process, Policy, and Personnel/Staff); one for each category for each variable, totaling four questions, plus two general questions to encompass the whole profile characterization of BIM users in terms of the categories taken into account in this study. As open-ended questions were used, a qualitative analysis was subsequently performed using the pattern-matching technique, which compares the expected behavior pattern of the dependent variables as a function of the independent ones, concerning the real pattern [41].

Results were analyzed using the data layout technique, which involves arranging the collected information by labeling all the text fragments with the same code to describe their content. Likewise, the information in the different questions was compared with text matrices. This manner of reordering and presenting is thoroughly addressed in Miles and Huberman's work [42] on the analysis of qualitative data. It involves creating a double-entry table housing textual information in the cell intersection of each row and column. In this case, this corresponded to questions and respondents, such that examination of the rows enabled comparison of the content of each question for different participants, and examination of the columns enabled comparison of data for a single respondent.

Pivot tables developed in spreadsheet software were necessary to create the text matrix, which yielded the following results:

1. 100% of the panel of experts surveyed agree with the grouping of variables into parameters, as there must be measurable and contrastable standardized indicators to characterize BIM users.
2. 80% considered that there should be a specific parameter to measure personnel/staff skills, whereas 20% believed there should be more than one parameter to measure personnel/staff skills.
3. 100% considered that the four parameters were sufficient to create a model that characterizes a single user; simultaneously, the experts thought the parameters were well-defined and delimited.
4. 80% considered it was effective to relate the software employed to the user level, while 20% thought they were not directly related and hence classification should not be based on software type but rather according to the user's real skills.
5. 80% believed the user level should be measured with the three parameters: Technology, Process, and Policy, although 20% suggested crossing them with the personnel/staff parameter.

In summary, the committee of experts consulted approved the categories and variables shown in Table 1.

3.3. Design, Validation, and Application of the Measurement Instrument

Once the tentative categorization was obtained, the measurement instrument was developed to collect the information that would enable the creation of the characterization model. The instrument chosen was a questionnaire, as it can be used to ask questions about one or more variables [43]. In addition, Oppenheim [44] suggests using questionnaires in studies where it is necessary to generalize the results. Here, the instrument used was a structured questionnaire with 22 questions: 19 close-ended questions and three open-ended questions (the questionnaire is available from the authors by request).

To develop the instrument, one question was included per variable (to reduce application time), with a Likert scale with seven response levels for each item. These values were associated with the question type and in general establish the degree of intensity (for example, from very bad at 1 to very good at 7), which provides greater statistical robustness upon evaluation [45]. Furthermore, this type of scale is easily assimilated by respondents, given its wide use in research and other subjects.

The questionnaire was structured by grouping the areas in the study, which included Technology (four questions); Process (four questions); Policy (five questions); and Personnel/Staff (six questions). Personnel/Staff had the largest number of questions due to the creation of this category specifically for this research, and the emphasis on measuring the skills of the professionals surveyed. Additionally, a section with three open-ended questions was included to gather opinions about its implementation in both public policies regarding BIM, and its teaching and use in the country. To process the data, this research used statistical software, with which it was also possible to evaluate the reliability and validity of the measurement instrument.

Before applying the questionnaire, a validation process of the measurement instrument was conducted. In this sense, diverse authors recommend verifying the accurate understanding of the designed survey and to make it self-explanatory by applying a series of tests to either executive-level individuals who were responsible for organization-level concerns or renowned researchers in the construction industry [43,44,46]. Similarly, Taherdoost [47] suggests that as a validation method, the questionnaire be reviewed by a commission of professionals who are experts in BIM methodology in aspects such as the concordance of each item with the objectives of the research, writing difficulties, and adjustment of the language. Therefore, for this research, distinguished senior professionals and researchers reviewed the questionnaire and made relevant observations that helped improve its comprehension, repeating the process until the survey instrument was fully debugged.

Once the measurement instrument (questionnaire) was validated, it was applied as a case study to 340 expert professionals working for several large construction companies in Chile using the SurveyMonkey™ platform, reaching a response rate of 23.3%, which is not uncommon and acceptable in the construction industry [48–52]. Regarding the characteristics of the participants in the questionnaire, they were architects, civil engineers, and builders with at least five years of experience in BIM, which is more than the three years of experience considered by Ham et al. [53] when they evaluated BIM staff.

4. The Model Proposed for the BIM Users' Profile

4.1. Partial Least Squares as the Method to Build the Model

Partial Least Squares (PLS)—a structural equation modeling method that allows the evaluation of complex cause-effect relationships in path models—was used to analyze the results from the measurement instrument, specifically the closed-ended questions. PLS is a modeling technique based on the theory of structural equations, which utilizes a component-based estimation approach focusing mainly on predictive causal analysis supported by variance, through modeling between the parameters and their indicators.

The use of PLS requires two stages. First, the measurement model is evaluated, and it is determined whether the relationship between the observed variables and the theoretical concepts or constructs being measured is correct. The second step consists of the evaluation of the structural model, after which conclusions are drawn. This method has been demonstrated to be effective when used to analyze complex relationship models in diverse areas of the construction industry [54–56].

In terms of the software, SmartPLS (developed at the University of Hamburg, Germany) was used in this research. This works with a data matrix that facilitates information entry with statistical software while the output is delivered in HTML, Excel, or Latex format [57].

In terms of the model, it is important to differentiate between two concepts: on the one hand, the "Indicator" which corresponds to those observable variables that can be measured directly and that are represented in the model by rectangles, and on the other hand, the "Construct", which corresponds to non-observable latent variables that can only be measured indirectly through the indicators, which in this paper are called parameters or categories. Depending on the role they play in the model, the latter may be exogenous (if they do not depend on any other factor), or endogenous (if they are predictable from other constructs). They are represented schematically by circles in the model. Figure 2 schematically and conceptually shows the main components of a PLS model, which consists of several endogenous (η), exogenous (ξ) latent variables or constructs, and observable variables (x_n or formative, and y_n or reflexive).

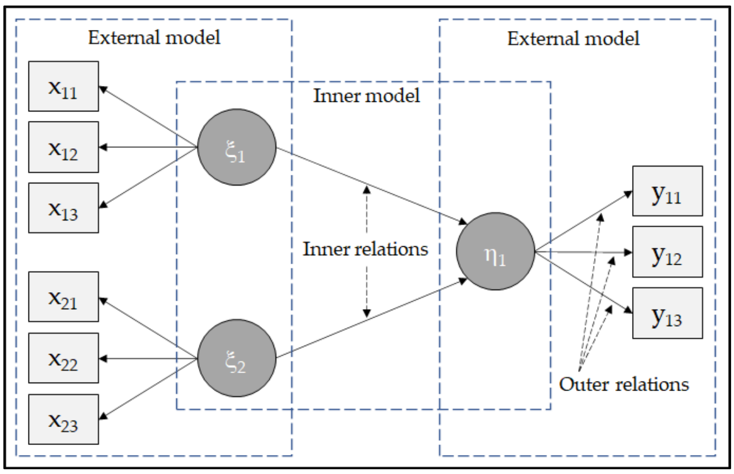

Figure 2. Conceptual PLS model (adapted with permission from [58]. Copyright 2022, Zoran Kalinic).

4.2. Evaluation of the Model

As mentioned above, the construction of the models began with the evaluation of the measurement model and continued with the evaluation of the structural model. This was conducted as follows:

4.2.1. Evaluation of the Measurement Model

The first step in the construction model was the reliability analysis, which measures the degree of consistency among the multiple values of a variable. Given a questionnaire with multiple questions that are grouped into a series of parameters, the items that form a construct must be highly correlated. Therefore, the following should be verified [59,60]:

- Correlation between the items of each construct: Measured with Cronbach's alpha (a). The generally accepted criterion for validating the results is a value equal to or greater than 0.7.
- Convergent validity: Confirms that the correlation between the items of each construct is significant. The constructs must have an average variance extracted (AVE) greater than 0.6, and this was used here. Moreover, the weight (or correlation) of the items on their constructs must also be greater than 0.6. Other authors point out that the AVE must satisfy an even more demanding condition, a recommended value of greater than 0.5.
- Discriminant validity: Verifies that there are no similar constructs in the model. Hence, the correlations between the different constructs must be low. This confirms that the square root of the construct's AVE is greater than the correlation between that construct and the others.
- Construct reliability: Analyzes the correlations between each item and its construct, and also the internal consistency of the construct. To be reliable, both Cronbach's alpha and the composite reliability must be greater than 0.7. Either can be used to determine this reliability.
- Composite reliability of the construct: Measures the integration between the indicators of the constructs. For a construct to be considered correctly integrated, the commonalities (the part of its variance that is explained by the construct) must have a value higher than 0.5.
- Individual item reliability: Assessed by examining the weights (or correlations) of the indicators with their respective construct. To consider the relationships to be strong, the measurements of these weights must be greater than 0.7.

4.2.2. Evaluation of the Structural Model

According to authors such as Hair [61], Benitez [62], and Collier [59], the structural model should be evaluated in two ways considering some recommended limit values, as indicated below:

- To evaluate the coefficient of explained variance R^2 of the endogenous construct, which is explained by the variables that predict it, the R^2 value should be greater than or equal to 0.1 since values below 0.1 indicate a low level of prediction of the dependent latent variable.
- To evaluate the path coefficient β, which indicates to what extent the predictive variables contribute to the explained variance of endogenous variables, the level of significance of the relationships between the constructs is evaluated. To be considered significant, the coefficients must at least reach a value of 0.2 and ideally be above 0.3.

In summary, the criteria adopted for the evaluation of the proposed model are shown in Table 3:

Table 3. Model evaluation parameters according to the literature.

	Evaluation of the Measurement Model				Evaluation of the Structural Model	
	Reliability of the item	Construct reliability	Convergent reliability	Discriminant reliability	R^2	β
Criteria	>0.7	$\alpha > 0.7$	AVE > 0.5	$\sqrt{AVE} > CORREL$	>0.1	>0.2

4.3. Parameters to Use in the Model

As mentioned previously, the BIM parameters for the characterization model were based on existing maturity models. These include Technology, Policy, and Process [10,26] and establishing the relationship between the stakeholders and deliverables in a project.

Although there was a single parameter added to the model called Personnel/Staff, once the results of the questionnaire were obtained, it was decided to separate this into two parameters (Adaptation and Experience). This was due to a large number of Personnel/Staff variables and so the two parameters would be better assimilated and distributed in the model.

For this purpose and utilizing the analyses mentioned above, the parameters or categories used in the characterization model are defined below, which were bibliographically corroborated considering diverse prior studies:

(a) Technology: Refers to a series of techniques, skills, and processes used in BIM, mainly related to software. In other words, the individual is evaluated according to his or her performance and relationship with the software used, at different stages. Its variables are the type of software, information maturity, interoperability, and proper software use. This is consistent with what was established by Khudhair et al. [63], Sun et al. [64], Wan et al. [65], and Kim and Kim [66].

(b) Process: Refers to company methods for developing or coordinating projects through BIM, for the delivery of information and project development as well as interferences that may occur between specialties. Its variables include productivity, conflict analysis, and work plans. The aspects that make up this parameter coincide with what has been stated by Lokshina et al. [67], Zaker and Coloma [68], and Boton and Forgues [69].

(c) Policy: A series of contractual documents that take precedence over existing agreements. It includes requirements, coordination issues, conflicts, and the management model, etc. at different stages of the project, and whether there are meetings, who is in charge, etc. Its variables are meetings, BIM management roles and coordinators, standardization, and coordination of use. This is in line with the statements of Xie et al. [70], Yuan et al. [71], Awwad et al. [72], and Li and Mao [73].

(d) Adaptation: Refers to the degree of adaptation of the individual to the use of the software or to the methodology itself, and is directly related to the advances, complications, disadvantages, etc. of the individual as such. The associated variables include the degree of BIM adoption and job dedication. The findings related to this parameter are according to what has been established by Wu and Issa [74], Forcael et al. [7], and Othman et al. [75].

(e) Experience: Refers to the skills, abilities, or specialization that a BIM user possesses and has acquired from observation, participation, and experience that comes from working with BIM techniques or software. It is the knowledge that is collectively created due to the time and dedication employed. The associated variables are expertise, experience, and project size. This coincides with the findings of Jolanta and Pupeikis [76], Mandičák et al. [77], Sampaio [78], and Taban et al. [79].

For each of the previous parameters, several questions were developed as latent variables to build a model to characterize BIM users, as shown in Table 4.

Table 4. Latent variables considered in the model.

Parameters	Questions Related to Each Parameter (Latent Variables)
Technology	TEC1, TEC2, TEC3, TEC4
Process	PRO1, PRO2, PRO3, PRO4
Policy	POL1, POL2, POL3, POL4, POL5
Adaptation	ADAP1, ADAP2, ADAP3
Experience	EXP1, EXP2, EXP3

4.4. Characterization Model

Once the data obtained from the questionnaire was entered, a model was generated to search for variables that met all the criteria. For this reason, the model had to include the creation and evaluation of a series of preliminary models, with emphasis on the correctness of the relationships and parameters presented. That is to say, the relationships established between the parameters or constructs had to be positive and related. After several iterations, the results from SmartPLS arising from the model are presented in Figure 3, where the causal links between the parameters or constructs can be seen.

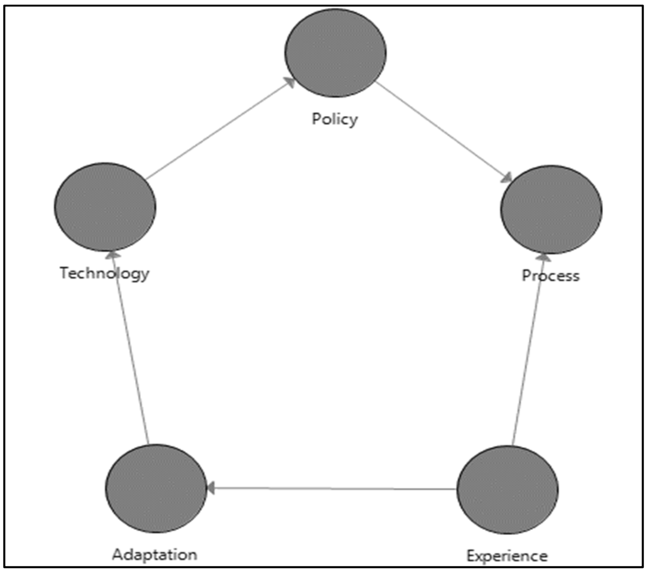

Figure 3. Interrelationships of parameters to characterize BIM users.

The interviews carried out in this study were separated by item and question. The information was entered into SmartPLS, from where the first model was obtained, and shown in Figure 4.

The correlations from this first analysis were unsatisfactory since when analyzing the individual reliability of each item by examining the values of the weights or simple correlations of the indicators with their respective constructs, negative values were obtained for questions TEC1 and TEC3, which means that these indicators did not represent their construct, Technology. These questions sought to identify the type of software used by the respondents and the use they subsequently made of it. The reason for these negative correlation values was the great variability in the responses.

In this sense, several authors [59,80,81] affirm that if there are values for the Path coefficient β, they do not represent the constructs and consequently do not contribute to the model. Therefore, the questions associated with these variables can be eliminated in a process called cleaning or debugging.

4.5. Validation of the Proposed Model

Once a model was created, it was necessary to carry out analyses to validate it. For this purpose, the parameters that were considered for validation, which are governed by the evaluation methodology, were calculated and are presented in Table 5.

Table 5. Values obtained from the analysis.

Constructs	Construct Reliability	Convergent Reliability	Discriminant Reliability	R^2
Technology	0.884	0.896	0.947	0.157
Process	0.766	0.567	0.753	0.425
Policy	0.732	0.651	0.806	0.626
Adaptation	0.813	0.673	0.820	0.323
Experience	0.727	0.638	0.798	

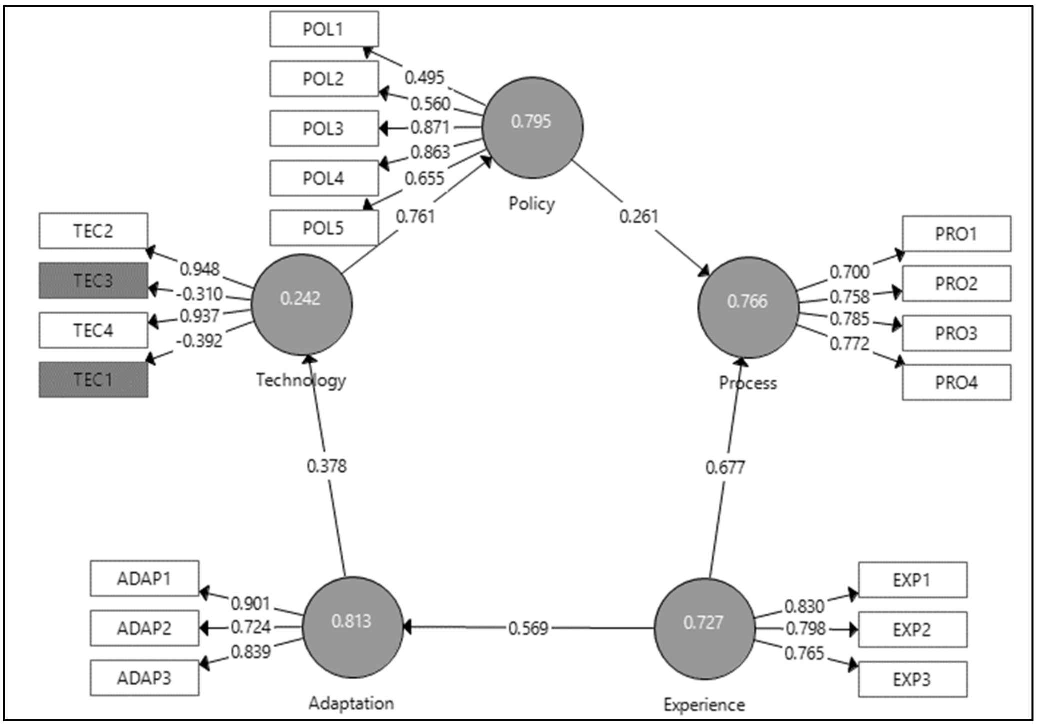

Figure 4. The first model obtained to characterize BIM users.

Firstly, the validity of the measurement model was analyzed and then the proposed relationships were validated. To evaluate the measurement model, the individual reliability of each item was first observed by examining the weights or simple correlations of the indicators. After cleaning, some indicators did not meet the condition of a weight greater than 0.7. These were: POL1 (0.536), POL2 (0.581), POL5 (0.662), PRO1 (0.693), and PRO4 (0.646). The questions POL1 and POL2 were far below the minimum value, so they had to be removed. This was not the case with POL5, PRO1, and PRO4, and a decision was taken to keep these since for values close to 0.7, the specialized literature suggests not eliminating the variable considered within the model [80–82].

The cleaning of the two variables that did not have individual reliability resulted in a new model, which is shown in Figure 5.

The same validation test was performed on the resulting model to assess the individual reliability of each item. It was observed that POL5 was below 0.7, but as mentioned previously, for values close to 0.7 (0.649), it is suggested they not be eliminated. Thus, the final characterization model was obtained, and its validation proceeded.

The second condition is internal consistency, which requires Cronbach's alpha to be greater than 0.7 [83]. As can be seen from Table 5, all reliability values per construct were above the required 0.7. Hence, it can be affirmed that the constructs were reliable.

As a third step, the validity of the scales used was evaluated (convergent validity). To this end, the average variance extracted was analyzed. Fornell and Larcker [60] recommend that this be greater than 0.5, thereby establishing that more than 50% of the variance of the construct is due to its indicators. As can be seen in Table 6, this was true of all the constructs used, with values ranging from 57% for the Process construct, to 90% for the Technology construct.

Finally, discriminant validity indicates the extent to which a construct is different from other constructs. One way to confirm this validation is through Fornell and Larcker's criterion, which considers that a construct's variance from its indicators (AVE) must be greater than that which the construct shares with others. Therefore, the square root of the AVE of each latent variable must be greater than the correlations with the rest of the variables; discriminant validity was achieved as the square root of a construct's AVE was greater than the correlation it had with any other construct, as shown in Table 6.

Alternately, the cross-factorial loads of the indicators of a latent variable must be compared with the indicator loads of the other latent variables, as seen in Table 7. Factorial loads must have a higher value with their variable than with the others evaluated in the model [80].

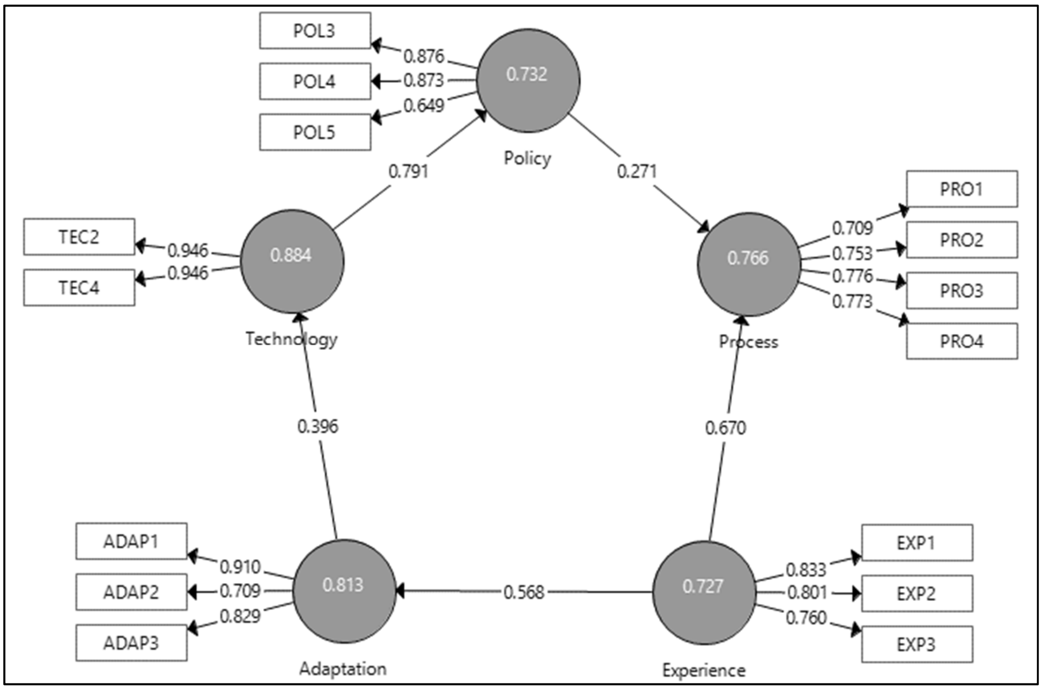

Figure 5. Proposed model for the characterization of BIM users.

Table 6. Discriminant reliability according to the criterium of Fornell and Larcker.

	Adaptation	Experience	Policy	Process	Technology
Adaptation	(0.820)				
Experience	0.568	(0.799)			
Policy	0.049	0.268	(0.806)		
Process	0.024	0.597	0.091	(0.753)	
Technology	0.395	0.299	0.791	0.418	(0.947)

Note: The square roots of the AVE values are shown on the diagonal in parentheses, the other data are correlations of the latent variables.

Furthermore, Henseler et al. [84], in their simulation studies, demonstrated that a lack of validity is better detected through the HTMT ratio. That is if the monotrait-heteromethod correlations (correlations between the indicators that measure the same construct) are greater than the heterotrait-heteromethod correlations (correlations between the indicators that measure different constructs) there will be discriminant validity. Thus, the HTMT ratio should be less than one—but for Gold et al. [85] that value is 0.90—and resampling or bootstrapping can also be used to test if the HTMT ratio is significantly different from one by using the confidence interval. According to the established criteria, the confidence intervals for the HTMT ratio were less than one, which makes it possible to validate this criterion, as shown in Table 8.

Given that all of the tests conducted previously met the proposed criteria, it was affirmed that the measurement model was valid and reliable. Consequently, the model in this investigation is evaluated below.

Table 7. Cross-factorial loads of the indicators of each latent variable.

	Adaptation	Experience	Policy	Process	Technology
ADAP1	**0.833**	0.400	0.127	0.595	0.525
ADAP2	**0.801**	0.288	0.353	0.251	0.045
ADAP3	**0.760**	0.585	0.463	0.476	0.066
EXP1	0.516	**0.910**	0.240	0.003	0.633
EXP2	0.343	**0.709**	0.399	0.206	0.184
EXP3	0.497	**0.829**	0.427	0.023	0.007
POL3	0.055	0.005	**0.876**	0.171	0.715
POL4	0.185	0.091	**0.873**	0.057	0.733
POL5	0.575	0.350	**0.649**	0.140	0.401
PRO1	0.542	0.012	0.231	**0.708**	0.513
PRO2	0.419	0.053	0.002	**0.753**	0.170
PRO3	0.500	0.121	0.238	**0.775**	0.098
PRO4	0.097	0.228	0.291	**0.772**	0.388
TEC2	0.307	0.307	0.482	0.454	**0.946**
TEC4	0.260	0.442	0.315	0.339	**0.946**

Note: The numbers in bold show those cross-factorial loads which have a higher value with their variable than with the others evaluated in the model.

Table 8. The HTMT ratio.

	Adaptation	Experience	Policy	Process	Technology
Adaptation					
Experience	0.6308				
Policy	0.7058	0.6196			
Process	0.6959	0.4332	0.3687		
Technology	0.3489	0.4494	0.8500	0.4641	

5. Analysis of Results

5.1. Evaluation of the Proposed Model

Once the model was validated, the proposed causal relationships were evaluated. How much of the endogenous variables' variance was explained by the constructs that predicted them was observed.

Firstly, Table 5 shows R^2 values greater than 0.1 for the latent dependent variables. Hence, all the parameters were highly predictive. Furthermore, these R^2 values indicated that the model strongly explained the variance of the constructs. In this sense, it can be asserted that 63% of the variance of the Policy variable was directly determined by the Technology variable, just as the Process construct was 43% determined by the Policy and Experience parameters, confirming that they are all linked. Therefore, the total can be attributed to these three parameters.

It can also be added that, unlike the other parameters, Experience had an R^2 value of zero because it was an exogenous variable. Therefore, Experience was a latent variable that was not observable (they are referred to in this way because they could not be measured directly and acted as predictive variables of endogenous constructs).

Concerning the paths between constructs, the significance values obtained must be above 0.3 (0.2 was accepted as a minimum value). Figure 5 shows that all the paths exceeded the suggested 0.3 value, except for the Policy-Process relationship, which was at 0.271. This value had a level of significance slightly below the minimum. Therefore, although the Policy parameter explained the Process parameter, it was not considered to be a main parameter in the model because it contributed to a lesser extent than the other parameters.

For the parameters analyzed, the following can be mentioned:

- Technology: The use and command the user has of the software and tools they are using are strongly related to the formalization of the work methodology. This was reflected in the model with a β of 0.8 in Policy.

- Process: This variable was 70% explained by the Experience value. Thus, it was possible to infer that thanks to specialization or acquisition of skills in BIM, the user continued to correctly use information by adhering to BIM standards or standardizations.
- Policy: This analysis strengthens the policies or contractual documents governing a project. This information was supported by the results obtained, in which Technology had a relevant R^2 value of 0.63 for Policy.
- Adaptation: When working with software or new methodology, the user must go through a period of adaptation, acquiring skills and specialization. This was reinforced in the model where Experience explained 57% of the Adaptation variable.
- Experience: The skills, abilities, and specializations that an individual acquires with repeated use of the methodology are significant for his or her categorization because they influence the Process and Adaptation parameters. This was reflected in the model with β of 0.7 and 0.6, respectively.

5.2. Qualitative Analysis

There were three open-ended questions in the applied questionnaire. One, answered by 75% of the respondents, was about the public policies related to BIM. Participants agreed that although well formulated, the questions could be more realistic in terms of completion time due to the low-intermediate level of implementation and lack of training of professionals in BIM.

The second question was related to the use of BIM, where 100% of the answers agreed that this is still weak. This was because, even though there are expert professionals in the field, they are scarce and concentrate on modeling. In addition, there is a lack of professionals with more knowledge in management, programming, and simulation with this methodology since most use it in the preliminary design and design stages of a project.

In question three on the teaching of BIM, 100% of the participants indicated that the teaching is in its infancy, and professionals graduate with relatively little knowledge of BIM. Although there are a variety of courses and training, they are still expensive, and respondents are unfamiliar with the quality or expertise of the educators. Education is focused on software and disregards the methodology. It is essential to mention client requirements since 70% responded that clients request projects in 2D, while the remaining 30% reported that although BIM is used, clients still request projects in 2D.

Finally, because of the exploratory nature of this study, the data obtained with the questionnaire may evidence some bias as they were applied to a small group of BIM users only, who are limited to the scope of working in a developing country. Therefore, to better understand the actual use of BIM, it is necessary to consult a larger universe of professionals in the future.

5.3. Comparison with Other International Studies

The results are consistent with similar studies. For instance, Murguia et al. [21] conducted a study about BIM adoption in Peru, concluding that resources and support for users in the first adoption stage are relevant. Furthermore, they suggested that a specialized BIM team can be created to help adapt other user groups. This relates to the acquisition of skills and specialization identified by the current investigation.

In another study by Hatmoko et al. [86] about BIM adoption in the Indonesian construction industry, they noticed that most projects request 2D documents. This makes the use of BIM optional for the professionals involved, which is consistent with the reported results from this research.

Finally, a study conducted by Yuan and Yang [87], identified that government policies and subsidies for the diffusion and implementation of BIM effectively encourage its adoption across the construction industry. This relates to the users' perceptions of unrealistic policies and the slow adoption of BIM in this research. It is also consistent with the results on BIM policies, representing an essential factor in promoting this methodology.

In a global framework [3–5], this study is coherent with the plans considered, disaggregating the characteristics of users measured by parameters linked to the implementation criteria. Furthermore, this work is also coherent with the concept of "BIM maturity" [26], nurturing it with a national characterization, similar to other studies in different countries, and enriching its approach. Besides, the development of the model is consistent with the definition of parameters previously used [8] and previous national surveys [21].

Thus, this comparison reinforces the results of the present research and, therefore, some interesting lessons learned have arisen, which may be useful for the state of the art of BIM practice, as shown below.

6. Discussion

6.1. Lessons Learned

It is important to highlight some lessons learned and link them to previous studies:

- The characterization of BIM users can enable companies that work with this methodology to identify the profiles of the professionals involved. Olbina and Elliot [88] studied the contributing project characteristics and the benefits of successful BIM implementation and determined that one key aspect is to improve teamwork and collaboration. Moreover, knowing the profiles of BIM users within a company would make it possible to relate the manner of use with the results obtained and improve the team organization and its communication.
- The literature review established that the categories defined as Technology, Process, Policy, and Personnel are the basis of the existing maturity models related to BIM users and their deliverables. Siebelink et al. [89] researched the barriers to implementing BIM and its relationship with maturity levels and established that the motivation and capabilities of the staff, from top management to the project level, are key characteristics. Other conditions were the defined or implemented open standards within the company and the processes applied for the development of projects. They also found that the technological infrastructure of the company was an important feature for the correct implementation of BIM. Likewise, for Kim and Kim [66], as new technologies are emerging rapidly, several are suitable for integration with BIM and thereby increasingly improve decision-making in the construction industry. Currently, according to Li and Mao [73], the legal and regulatory framework, as well as the texts of the contracts for the application of BIM have not yet been formulated or perfected, which implies possible difficulties in the division of responsibilities in BIM projects and no clear basis for addressing disputes arising from the use of the BIM methodology. Something similar was presented by Faisal Shehzad et al. [90], who also categorized BIM adoption based on technology, policies, and personnel factors.
- This research reinforces the idea that BIM is not a tool or software but a collaborative work methodology. Lokshina et al. [67] also highlighted this approach, like several national plans worldwide, considering that the integrated BIM work clearly demands that users must be well-organized to apply BIM in projects.
- The characterization of BIM users enhances the studies on the role of BIM and its standards, which establishes user roles and responsibilities. As mentioned by Liu et al. [91] regarding user satisfaction, and evaluated by Ham et al. [53], this is feasible by adding a more detailed profile of the functions involved.
- The defined variables can be used as indicators, which allow the measurement of user skills in different BIM fields. Just like Siebelink et al. [89] and Faisal Shehzad et al. [90], who presented the main aspects that influenced BIM maturity levels, this study could allow assessing its implementation at different levels within an organization.
- The analysis revealed that BIM users are strongly focused on modeling. Therefore, it is necessary to train professionals in management, programming, and the application of methodologies, to carry out BIM projects under a holistic view.

6.2. Limitations

Although this study was conducted in one of the most advanced developing countries implementing BIM, i.e., Chile, a limitation exists regarding the context and sample used. This is because the implementation of BIM consists of a transfer process that affects the global construction industry in different phases and ways. Besides, the BIM implementation is also influenced by each country's development, along with cultural, political, and even geographical reasons. Another limitation may be the rapid and vertiginous technological changes experienced in recent years in the construction industry, where the present model is just a "snapshot image" that can change later, partially altering the characterization performed in this study. Similarly, the size of the companies, the building processes used, and the local regulations may directly affect the characteristics of the jobs and functions of the staff. However, the conceptual approach presented in this research can evolve to adapt progressively to different constructive contexts or technologies and redefine the BIM profiles to face future scenarios.

6.3. Implications

The characterization of the BIM user's profile carried out in this work, based on consultations within the construction industry in Chile, along with a solid statistical validation, has great relevance for applying the results to different construction companies worldwide. In this sense, based on the model proposed in this research, local BIM plans or the specific BIM programs of diverse companies can provide the information needed to identify the characteristics of their BIM users, taking into account the five categories (Technology, Process, Policy, Adaptation, and Experience) and the 17 variables defined here and following the same methodology originally proposed with just slight adjustments.

7. Conclusions

BIM technology has established itself in many countries, including Norway, Finland, the UK, Sweden, and the US. In these countries, BIM is an accepted practice in construction thanks mainly to the coordination and development of organizations, common platforms, public policies, and open international standards.

Concerning the objective of this research, it was first necessary to define and approve a series of variables to measure BIM users. These were based on a literature review and then validated by a panel of experts. Afterward, a total of 17 variables remained and were used to review a questionnaire applied to construction professionals who use this methodology. Subsequently, an analysis was conducted with quantitative tools, and the variables were grouped into the following parameters: (1) Technology, (2) Process, (3) Policy, (4) Adaptation, and (5) Experience. Finally, the Partial Least Square method was used to evaluate the cause-effect relationships in different path models before converging to a characterization model of BIM users based on the parameters mentioned.

The proposed model met the structural and measurement evaluation criteria, thereby confirming its validation and reliability. In addition, the model presented a causal correlation between parameters, which enabled its degree of influence on the characterization of BIM users to be established.

To conclude, the model developed made it possible to analyze the level of BIM users based on the defined parameters. Therefore, users can be characterized and classified in levels based on software use, the kind of software employed, or the degree of development the user can achieve. Thus, their level of technology command is measured. However, the user must also know about the use of documents, standardization, or active participation in BIM format meetings (Process and Policy). This suggests that to carry out a complete analysis of a user, it is necessary to know and measure the experience acquired and the degree of adaptation the participant has in BIM projects.

From the qualitative analysis, it can be seen that the methodology was strongly focused on the draft design and final project design. Although multiple factors may be responsible for this, these are likely to be the stages where the software has the most significant potential to generate visualization models, and because the professionals have more knowledge to use the tool in such stages. In later stages, for example, while the generation of documentation is being conducted, the use of BIM software begins to decrease sharply, and the use of CAD-type software can begin.

Finally, in general terms, it is clear that BIM is attainable only if teamwork occurs and everyone shares their skills, knowledge, and experience. In this way, the construction industry will be strengthened, which creates growth opportunities.

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