buildings

Article

A Multivariate Analysis of the Variables Impacting the Level of BIM Expertise of Professionals in the Architecture, Engineering and Construction (AEC) Industries of the Developing World Using Nonparametric Tests

Georgina Esi Takyi-Annan * and Hong Zhang *

School of Architecture, Southeast University, No. 90 Chengxian Street, Xuanwu District, Nanjing 210096, China
* Correspondence: georginaannan@outlook.com (G.E.T.-A.); zhangh555@aliyun.com (H.Z.);
Tel.: +86-180-147-44794 (G.E.T.-A. & H.Z.)

Abstract: Building information modeling (BIM) mandates are becoming more widespread because BIM allows design and construction teams to operate more productively and also enables them to collect the data they generate during the process for use in operations and maintenance tasks. As a result, professionals in the architecture, engineering and construction (AEC) industries are expected to possess excellent BIM expertise. Despite the fact that the developing world has largely not adopted BIM, many studies have been conducted on BIM usage, awareness, drivers and barriers with a focus on the developing world. Numerous studies have pointed to the professionals' lack of BIM expertise in the developing world's AEC sector as a major barrier to BIM deployment. Nevertheless, no research has been conducted to assess the variables impacting the level of BIM expertise among professionals. After a detailed review of the literature, the study developed five study hypotheses and created a conceptual model to help assess the variables impacting the level of BIM expertise of professionals in the AEC industry in the developing world. After that, a questionnaire survey was carried out to collect data from 103 seasoned professionals in the Ghanaian construction industry. Nonparametric tests, such as the Kruskal–Wallis, pairwise post hoc Dunn, Mann–Whitney, Pearson's correlation and the partial least squares structural equation modeling (PLS SEM) tests, were adopted to assess the relationships between the level of BIM expertise of professionals (BE) and the following variables: (1) profession (P), (2) the frequency of BIM use by professionals (BF), (3) the highest dimension of BIM adopted by AEC firms and companies (BD), (4) professionals' perception of BIM (PB) and (5) the BIM implementation barriers (BIMIBs). P, BF, BD and PB were found to have a substantial impact on the level of BIM expertise acquired by professionals. With regards to professionals' perception of the BIM software and process, only one (PB3–BIM is not useful to our company at the moment) out of ten of them was found to have a significant impact on BE, highlighting the impact of employers on the level of BIM expertise of professionals. In addition, the study discovered that any resolution made in an attempt to tackle the lack of/insufficient level of BIM expertise among professionals would prove futile without significant effort from the higher education sector (HES) of the developing world and the entire world at large. The study's conceptual, empirical, managerial and theoretical implications and findings would serve as a roadmap for researchers, professionals and academics in developing nations as they endeavor to seek more ways of increasing BIM expertise among their professionals and to encourage BIM usage throughout the project lifecycle.

Keywords: building information modeling; BIM expertise; the developing world; PLS SEM

check for updates

Citation: Takyi-Annan, G.E.; Zhang, H. A Multivariate Analysis of the Variables Impacting the Level of BIM Expertise of Professionals in the Architecture, Engineering and Construction (AEC) Industries of the Developing World Using Nonparametric Tests. *Buildings* **2023**, *13*, 1606. https://doi.org/10.3390/buildings13071606

Academic Editors: Daniotti Bruno and Mirarchi Claudio

Received: 19 May 2023
Revised: 13 June 2023
Accepted: 19 June 2023
Published: 25 June 2023

1. Introduction

The UN projects that there will be 9.7 billion people on the planet by the year 2050, hence, the worldwide AEC industry must seek smarter and more effective ways to design and build in order to not only meet the rising global demand, but also contribute to the creation of smarter and more resilient environments [1]. In the early 2000s, the phrase "Building Information Modeling", which first appeared at the tail end of the 20th century, became the accepted catchphrase for modeling and sharing information [2]. Building information modeling (BIM) is one of the most promising advancements the architectural, engineering, and construction sectors have made in recent years [3]. BIM can be defined as a set of tools, procedures and technologies that are made possible by digital and machine-readable documentation concerning a building's performance, design, construction and operation. Building Information Modeling (BIM) enables building design and construction choices to be virtually prototyped before construction starts, potentially increasing productivity, product quality and sustainability [4]. BIM is still a relatively new method for integrating multidimensional construction data into object-oriented modeling and in recent years, it has become more and more connected to the effectiveness and caliber of digital information exchanges that promote cooperation among building professionals [5].

BIM use has several advantages. The construction sector is predicted to benefit from increased collaboration and increased efficiency as a result of the organizational and technological changes that make up the BIM model [6]. Cloud-based models enhance BIM collaboration by providing a platform for project model sharing and planning coordination, ensuring that all project participants are aware of the project's status [6]. BIM, when used effectively, promotes a more integrated design and construction process that leads to high-quality buildings at a shorter project duration and lower project cost [7]. In addition, the possibility of combining the multiple discipline models into a common one permits a collision detection process and a common assessment of the project [7]. BIM also enhances site logistics and material deliveries because all building components can be bought online and supplied on time since the BIM model includes information about materials, quantities and even product models [7].

Furthermore, an accurate inventory of quantities and spaces helpful for cost assessment can be extracted using BIM technology, making it possible to obtain a thorough project budget and the financial repercussions of a design [8]. A number of projects that have used BIM for design and construction have experienced decreased project costs and duration [9]. BIM's potential for an early review reduces the need for costly and time-consuming modifications in the future [6]. Lastly, BIM has a lot of promise to enhance a building's sustainability, but to a large extent, that potential has yet to be realized [2]. Thermal and energy analysis can be conducted after a building model has been generated and at this point, design modifications can be applied quickly, and the analysis can be run again to ensure that the design works as efficiently as possible [2]. A facility can be examined using BIM for (1) its energy usage, (2) its effects on the generation of carbon during its life cycle and (3) assessments that can monitor environmental effects such as pollution and water use [2].

While the Finnish AEC sector leads the world in terms of BIM adoption, BIM adoption across the rest of Europe is largely similar to that of the US sector in that BIM is used by various businesses and projects, although it is still largely dispersed and poorly integrated [10]. Many government initiatives around the world have increased the significance of BIM expertise and knowledge among practitioners to support the efficient execution of BIM-related projects [11]. While many construction projects in the developed world are gradually implementing BIM, its implementation in the developing world is hampered by numerous challenges [12], with the lack of BIM expertise by professionals as a major hurdle [13–17]. After a review of 124 empirical studies on BIM implementation barriers (BIMIBs) in the developing world, the lack of awareness and understanding of BIM and its benefits, associated high cost (AHC), the lack of governmental support, a general resistance to change and the lack of BIM expertise (BE) were ranked as the top five BIMIBs that the developing world struggled with in implementing BIM. Even though 51 studies identified BE in the AEC industry as one of the major barriers, no study has been conducted to explore its root causes and find practical solutions to the problem, as has been accomplished with other BIMIBs, such as AHC [18].

Besides the numerous BIM benefits listed earlier, the promotion of the acquisition of BIM expertise by professionals in the AEC industry has been proven to increase the marketability of professionals immensely. For instance, findings from past research showed similar odds ratios from 0.741 to 1.175 between [having the title "project manager" or "BIM manager"] and [having BIM expertise] [19]. Different AEC industry segments are making deliberate efforts to expand BIM utilization. The education industry, for instance, has been looking into the best ways to include BIM into the curricula; however, in reality, professionals still lack various BIM expertise [19]. According to [10], the AEC industry is unable to transition to the BIM era because of a lack of knowledgeable practitioners. Finding professionals who have BIM expertise has become a hard nut to crack [20]. Such loopholes call for more in-depth research on the variables impacting the level of technical BIM expertise of professionals. To the best of our knowledge, no study has been conducted, hence the aim of this research, with a focus on the developing world.

1.1. BIM Expertise

Different studies have tried to classify BIM skills into different groups. A review by [11] classified the BIM skills that a professional can possess under technical and nontechnical BIM skills. Technical expertise refers to a person's ability to use BIM software tools and their knowledge of digital tools and the BIM standards [21,22]. According to [4], BIM skills can be divided into three categories: (a) soft skills, which refer to interpersonal and interpersonal communication abilities; (b) BIM-technical skills, which deal with the use of modeling and related software, BIM standards and frameworks, technical aspects of information exchange and management and (c) discipline-specific skills, which deal with the understanding of project, practice and construction processes and methods. It is important to note that, according to past studies on BIM expertise, software skills (technical) are the most preferred BIM skills that a professional can acquire [11]. Despite this fact, different professionals have stated that these skills are the least important and are useless without discipline-specific skills and soft skills [4].

There is no one tool that can create a BIM project all by itself; instead, one might require a number of tools that can be used for a variety of tasks [23]. Revit (Autodesk), Tekla Structures (Trimble), MicroStation (Bentley) and ArchiCAD (Graph iSOFT) can be considered as design authoring tools because they help with design and construction by producing data in 2D and 3D that may be used for a variety of purposes [23]. Navisworks can be considered as a scheduling and costing software. Solibri Model Viewer (Solibri), TeklaBIMsight (Trimble), Trimble Connect (Trimble), Rendra (Rendra O) and Dalux BIM Viewer (Dalux) are considered as model review software because they give the project team members the ability to examine, explore and query model information. Some of them also possess added features, such as the ability to detect clashes [23]. For 3D sketching, there are workflows that have been developed around SketchUp, Rhino and Bonzai to support BIM functionality [24]. Google SketchUp's fundamental ability is its simplicity in defining a 3D line and stretching it into a surface that lines up with other points in space, hence its support for simple and direct manipulations [24]. A 3D SketchUp model may be used to create dimensioned drawings using the free Layout 3 plug-in, as its Style Builder offers filters to customize a model rendering's drawing style. For professionals interested in 3D freeform modeling, such as architects, industrial designers, animators and jewelry designers. Rhino is a particularly alluring technology that offers a wide range of surface modeling features, including the ability to create, modify, view, combine and analyze basic or complex surfaces [24]. Rhino is known for editing curves and for the creation of a wide variety of intricate forms, such as building skins, concrete forms for casting, and other interior forms and fixtures [24].

1.2. Dimensionality in BIM

The first type of construction model is in 2D and consists of a straightforward X-axis and Y-axis [1]. Production information and statutory approval papers are both written using 2D BIM [1]. In addition, CAD standards are controlled in accordance with BS 1192:2007 [25], and electronic data sharing is performed through a common data environment (CDE), which is frequently run by the contractor [1]. Use-cases are also known as predefined, specified purposes. Use-case is a term used to describe how a BIM model might be put to use [26]. Certain parameters are added to BIM's already existing data in accordance with project stage requirements and project complexity and the term 'BIM dimensions' is used to express these enhancements of predefined BIM uses [26]. With the help of these dimensions, data from a model can be improved in order to share a deeper understanding of a construction project [26]. Any construction project's three most crucial components are quality, timing and cost, and a refined decision-making process is usually facilitated by timely, precise and multidimensional building information, which can decrease construction costs and increase construction quality [27]. Early on, BIM's 3D capabilities were heavily emphasized in an effort to claim that it was superior to CAD. Since it was primarily used to produce traditional 2D projections, such as floor plans, sections and elevations, the latter was wrongly presented as being only 2D [28]. Interestingly enough, these predictions were also true in BIM; however, BIM soon expanded beyond 3D and became nD [28]. The rate at which new dimensions flood in is unmistakably a sign of the informational capabilities of linked environments, such as BIM [28]. Each of the BIM dimensions (3D, 4D, 5D, 6D and 7D) has a specific usage and is helpful for determining a project's cost, schedule, completion date and level of sustainability [26]. According to [2], "BIM is a digital model of a building that houses project information and can be either 3D, 4D (integrating time), 5D (containing cost), or even 'nD' (which refers to any additional information)."

1.2.1. The Third Dimension of BIM

This is the most fundamental aspect of BIM, and its purpose is to provide building documentation that includes certain material takeoffs or other schedules. Three-dimensional BIM is not the same as CAD 3D. In 3D BIM, the building is broken down into functional components with specific attributes for BIM [29]. All of the spatial relationships, geographic data and geometry, such as the length, width and height of the building components, are contained in 3D BIM [3]. Design flaws caused by inconsistent 2D drawings are found and fixed by using a virtual 3D construction model [3]. Furthermore, models from other disciplines can be brought together and evaluated in order to look for any conflicts and constructability issues before they are discovered on the construction site [3]. The coordination between the many project participants is improved, and errors are greatly decreased by the use of 3D construction models [3]. As a result, the construction process is more cost-effective and less likely to result in legal issues [7]. Benefits of the 3D BIM dimension include complete transparency from the start due to fewer instances of rework and revisions, an improved 3D visualization of the entire project, a streamlined communication and sharing of design expectations and easier collaboration among numerous teams regardless of their area of expertise [26].

1.2.2. The Fourth Dimension of BIM

In order to mimic the construction process over time, 4D simulation involves connecting construction activities through the planning of 3D items in a building model [5]. Four-dimensional BIM, which stands for four-dimensional building information modeling, is utilized for all planning-related tasks on construction sites [30]. The word "4D" in BIM alludes to the fourth dimension, which is time, and its purpose is to expand the capabilities of 3D CAD or solid modeling by adding a fourth dimension of time to the 3D space of computer-aided design [29]. Scheduling is a labor-intensive manual task that frequently does not synchronize completely with the design and makes it difficult for project stakeholders to easily understand the schedule and its impact on the site logistics [3]. In order to address these flaws in the planning process, 4D technology was developed. BIM tools have made it possible for schedulers to develop, evaluate and modify 4D models more quickly, which has led to the adoption of more dependable and successful schedules [7]. Under 4D BIM, the creation date and, presumably, the date of destruction are recorded for each component in the model. By connecting the construction plan and 3D model in 4D BIM, it is possible to simulate the construction process and see how the building and site will look at any given point in time [3]. Planners may graphically discuss and schedule tasks in the context of time and geography using 4D tools [7]. The 4D model can also include information about production rate, allowing lines of balance schedule analysis, which consequently enables efficient task arrangement based on production rate and project location [3]. By using 4D modeling, the planned construction timetable may be evaluated and simulated, and the items in the building model are organized into groups based on the phases of construction and connected to pertinent tasks in the schedule of work [3]. The use of 4D simulations in the planning process helps project teams work more collaboratively and serves as a communication tool for spotting possible bottlenecks [7]. Despite the fact that 4D BIM is increasingly used in large-scale building and engineering projects, there have been a few positive results from its use in regular projects and it must be acknowledged that this technology is very new and needs to be adjusted to meet actual company needs [26,31].

1.2.3. The Fifth Dimension of BIM

A new development in the construction sector is 5D BIM, which integrates all the key data from the early stages of design through the completion of construction, after which, through the use of virtual design and construction (VDC), the combined information is organized and conveyed [27]. The cost of each task is disclosed through 5D BIM. Where cost estimation and budget analysis are necessary from the outset of any project, 5D BIM is useful because it makes possible the analysis of future expenditures in relation to project activities [26]. In order to anticipate and track the project cost during all phases of construction, 5D BIM mandates that project costs be integrated with the 3D model of the building [3]. Establishing budget areas at the beginning of the project is beneficial, and the cost of implementation of various design choices can be calculated at any step of the design phase as the model develops [3]. The budgetary requirements as well as changes in the scope, material, labor or equipment requirements can all be correctly predicted with the aid of 5D BIM, which makes it easier for the estimation of expenses related to a scenario, taking into account future adjustments along the process [26]. The cost information obtained from the 5D model can also be used to assess the project's financial performance while it is actually being built. In 5D BIM, how well the integration of the 3D model, time and cost works is significantly determined by the 'modelling effort, inter-operability, information output and limitation' [27]. Lee [27] is of the view that, although more than five dimensions of information can be included, it is foreseeable that too much information may increase the complexity in a way that is unfavorable to the adoption of BIM. Through the promotion of team collaboration, the improvement of project comprehension in terms of accurate cost and time estimations, the reduction in change orders, the boost in visualization of construction details and the linkage of 3D with time and cost, 5D-BIM benefits its users greatly [26,32].

1.2.4. The Sixth Dimension of BIM

Beyond the fifth dimension, there does not seem to be an agreement [33]. The sixth dimension of BIM has been referred to as project lifecycle, safety, energy, construction records (including quality, health and safety and contract information), procurement, facility management, as-built and as-is information [30,33,34]. Six-dimensional BIM takes into account a structure's various life cycles and guarantees a precise estimation of its energy consumption needs. During the project and operating stages, the 6D BIM dimension is used to assess energy efficiency [30]. Six-dimensional BIM incorporates precise information (such as a component's manufacturer, installation date, maintenance schedule, configuration specifics for best performance, energy requirement and decommissioning information) that can support facility management and operations in the future [26]. Benefits of the 6D BIM dimension include long-term energy consumption reductions, quicker and more accurate component installation decisions made during the design process, a thorough analysis of the effects of a decision on economic and operational aspects over the course of the decision's lifecycle and lastly, improved operational management of the building or structure following handover [26]. The primary goal of BIM 6D is to increase the effectiveness of FM practices, which overlap with the building's life-cycle performance and contribute to its sustainability [34].

1.2.5. The Seventh Dimension of BIM

Thus far, the final dimension (7D) relates to the use of the model for building maintenance, and as of right now, no software is able to offer such capabilities [29]. Over a building's lifetime, 7D is utilized to gather pertinent data regarding the operation, maintenance and state of the devices. Seven benefits of 7D BIM include a streamlined building maintenance procedure for contractors and subcontractors, optimized asset and facility management from the design phase to demolition, a simpler and easier replacement of parts and repairs anytime during the entire life of a building and lastly, simplified and easy maintenance process [26]. BIM application areas in facility management include (1) mobile localization of building resources, (2) digital assets with real-time data access, (3) space management, (4) renovation/retrofit planning and feasibility, (5) maintainability studies and (6) energy analysis and control [34]. Seven-dimensional BIM is a novel strategy in which the entire facility management process is gathered in one location within the building information model, which aids in raising the caliber of service delivery across a project's whole lifecycle [1]. Everything in a project is kept in top condition from the first day to the day a structure is demolished, thanks to the use of 7D BIM. BIM application areas in facility management include (1) mobile localization of building resources, (2) digital assets with real-time data access, (3) space management, (4) renovation/retrofit planning and feasibility, (5) maintainability studies and (6) energy analysis and control [34].

2. Materials and Methods

Of all the skill categories identified by researchers, only technical (software) skills are tangible and can be rated by professionals. The study carried out an in-depth examination of the variables impacting the level of technical BIM expertise of professionals in the AEC industry in the developing world. Based on the existing literature, the study adopted 5 major hypotheses, which are summarized in Table 1. In order to test the hypothesis of the study, data was collected using an online questionnaire created with Google Forms and distributed via email to over 600 professionals working in the construction industry of Ghana, after which nonparametric analysis methods, such as the PLS-SEM analysis and the one-way nonparametric ANOVA tests, were adopted for data analysis. The primary group of statistical tools that can be used to either define or confirm theoretical hypotheses based on empirical data analysis includes first-generation techniques such as regression-based methods (e.g., multiple regression analysis, discriminatory analysis, logistic regression and variance analysis) and factor or cluster analysis [35]. Figure 1 summarizes the data collection and analysis processes adopted by the study.

The following are the constructs the study adopted for PB [36,37]:

PB1: BIM is the future of project information.
PB2: BIM is needed in order to design sustainable buildings.
PB3: BIM is not useful to our company at the moment.
PB4: BIM has the ability to decrease waste and lower construction cost.
PB5: BIM has budget control and lean management abilities.
PB6: BIM has visualization and walkthrough abilities.
PB7: BIM improves project performance and quality.
PB8: BIM increases work speed and accuracy.
PB9: BIM has the ability to create new income and business opportunities.

PB10:BIM improves onsite communication and coordination among professionals.

Table 1. Study hypothesis.

Label	Hypothesis
1	There is a substantial correlation between one's profession (P) and degree of BIM expertise (BE).
2	There is a substantial correlation between the highest level of BIM dimension (BD) adopted by an AEC firm and the degree of BIM expertise (BE) of its employees (professionals).
3	There is a substantial correlation between professionals' perception of BIM (PB) and their degree of BIM expertise (BE).
PB	BIM usage frequency (BF) significantly affects the level of BIM expertise (BE) acquired by professionals.
5	BIMIBs significantly affect the level of BIM expertise (BE) of professionals in the AEC industry.

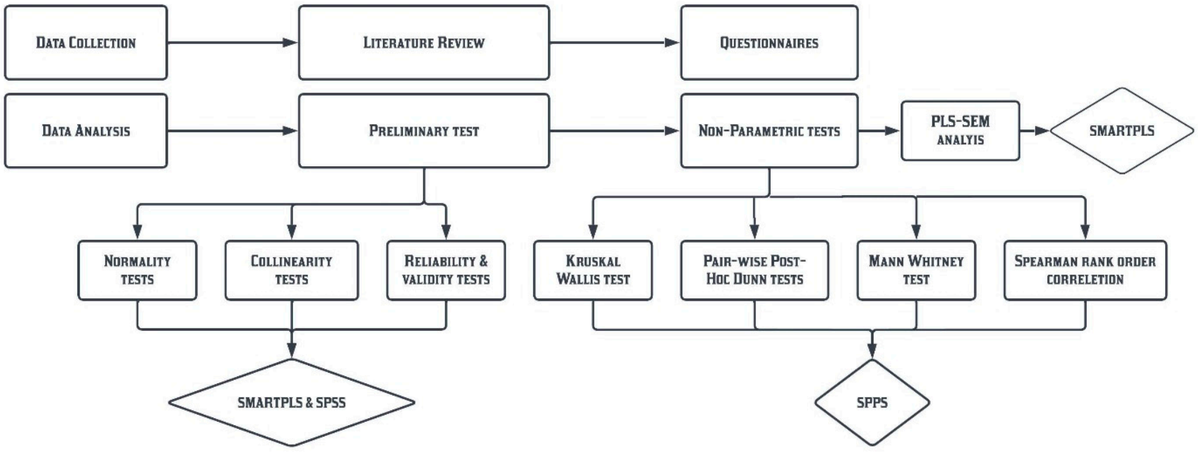

Figure 1. Summary of the data collection and analysis process.

The following are the constructs the study adopted for the BIMIBs:

B1: No/limited awareness and understanding of BIM, BIM benefits and BIM ROIs [38,39].
B2: Associated cost (high cost of software, hardware, etc.) [13].
B3: Lack of BIM experience and expert/skilled personnel [13].
B4: Lack of government support, regulations and incentives and lack of BIM standards [40].
B5: A general resistance to change due to the lack of executive buy in and client demand [16].
B6: Interoperability and compatibility issues [41].
B7: Lack of supporting technology/physical infrastructure/BIM training centers [42].
B8: Steep learning curve [40].
B9: Unavailability of contractual and legal framework [43].
B10: Data related problems [44].
B11: Collaboration and communication issues and unclear roles and responsibilities [45].
B12: BIM risks and the lack of dispute resolution mechanisms [46].
B13: Complex BIM software and tools and BIM process is time consuming and cumbersome [47].
B14: Lack of BIM studies in higher educational curricula and the lack of BIM research [48].

The PLS path modeling algorithm uses ordinary least squares regression to estimate different portions of the focused route model; therefore, the complexity of the overall model has little bearing on the required sample sizes [35]. In addition, PLS is a smooth SEM modeling technique with no assumptions about information allocation [35]. For partial least squares structural equation modeling (PLS-SEM), Smart PLS is one of the most used software programs [35]. Where the sample size is small, applications have limited theories, predictive accuracy is of utmost significance and lastly, it is impossible to guarantee an accurate model stipulation, PLS-SEM is quite useful. Since its release in 2005, the software has grown in popularity because of its user-friendly design, comprehensive reporting tools and ability to select formative or reflective learning. This is in addition to the fact that it is freely available to academics and researchers [35].

Smaller sample sizes can absolutely be used with PLS-SEM, but the characteristics of the population dictate the circumstances in which they are appropriate [49]. The more heterogeneous the population, the larger the sample size required to get an acceptable sampling error, if other situational features are comparable and findings are questionable [35] if basic guidelines for sampling theory are not followed [50]. Researchers should use power analyses that take into account the model structure, the expected meaning level, and the expected effect sizes to determine the sample size needed [51]. [52] proposed a minimum sample requirement guideline based on the maximum number of arrows pointing to a latent variable as specified in the structural equation model, which is dependent on the following 4 parameters: (1) the level of importance, (2) the strength of statistics, (3) the minimum determination coefficient (R values) used in the model and (4) the maximum number of arrows pointing to a latent variable [35]. This requirement is summarized in Table 2, where A represents the minimum sample size required and B represents the maximum number of arrows pointing at a latent variable [53].

Table 2. Sample size recommendations for a typical marketing study.

A	52	59	65	70	75	80	84	88	91
B	2	3	4	5	6	7	8	9	10

The conclusion on the matter of sample size is that, despite the fact that PLS is known for its capacity to handle small sample sizes, your objective should not be to only meet the minimal sample size requirement [54].

A total of 103 responses were collected within a period of 4 months. A total of 47.6% of the respondents were architects, 15.3% were surveyors and valuers, 14.6% were engineers and 3.9% were project managers. Other professions, such as contractors, educators and real estate developers formed a percentage of 19.4. A total of 84.8% of the respondents were 30 years old or older. There were no respondents below the age of 20. Only 32.6% of the respondents were female. The lowest educational level of the majority (82.6%) of the professionals is a master's degree. This is indicative of the level of knowledge and exposure the respondents of this survey have in their various fields of operation.

3. Results

3.1. Preliminary Tests for the Nonparametric Analysis

3.1.1. Normality Tests

It is impossible to dispute the significance of the normal distribution because it forms the basis for numerous statistical techniques, including t-tests, linear regression analysis, discriminant analysis and analysis of variance (ANOVA) [55]. When the premise of normality is broken, interpretations and conclusions might not be accurate or true [55]. In normality tests, the likelihood that the sample came from a population with a normal distribution is determined. The study adopted the use of the Shapiro–Wilk test because it has been proven to be the most powerful method for normality checks [55]. With p-values less than 0.05 (see Table 3), the Shapiro–Wilk test for normality showed that the majority of the data do not conform to the assumptions of normality, hence, the study adopted the use of nonparametric tests for data analysis.

Table 3. Test of normality—Lilliefors significance correction.

Independent Variables	Degree of BIM Expertise	Shapiro-Wilk		
		Statistic	df	Sig.
Profession (P)	Architect	0.900	47	0.001
	PM	0.971	4	0.850
	Engineer	0.669	14	0.000
	QS	0.630	4	0.001
	Others	0.851	21	0.004
	Valuer	1.000	3	1.000
	Land surveyor	0.828	8	0.056
Highest BIM dimension application (BD)	2D modelling	0.449	32	0.000
	3D modelling	0.885	64	0.000
	4D modelling	0.771	5	0.046
Length of BIM usage (BL)	1–3	0.880	44	0.000
	3–5	0.892	19	0.034
	above 5	0.747	17	0.000

3.1.2. Collinearity Tests

When there are numerous variables in a multiple linear regression analysis that have strong correlations, with both the dependent variable and each other, multicollinearity occurs and, as a result, some of the significant study variables become statistically insignificant [56]. The correlation coefficients, the variance inflation factor (VIF), and the eigenvalue method are all basic methods for determining multicollinearity among variables [56,57]. This study adopted the VIF, which is used to gauge how much the independent variables' correlation inflates the variance of the calculated regression coefficient [56]. In PLS-SEM, each block of indicators' relationships to its latent variables are specified by the outer model, sometimes referred to as the measurement model [51]. In collinearity tests, high correlations imply that the components of a construct are interchangeable, and this is preferable for constructs that are reflectively measured since indicators are used interchangeably, but it is not preferable for formative constructs because each item reflects a different part of a construct [58]. Collinearity can happen at lower VIF values between three and five; however, VIF values above five are indicative of likely collinearity difficulties among predictor constructs [59]. Higher-order constructs are a widely utilized solution when collinearity is an issue [50]. Table 4 shows the collinearity values obtained by this study for all independent variables are all well within an acceptable range (less than four). Hence, all variables are deemed statistically significant [57].

Table 4. Collinearity test -VIF.

Variables	**B1**	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**B8**	**BD**
VIF	1.896	2.242	1.861	1.808	1.987	2.480	1.773	1.499	1.636
Variables	**B9**	**B10**	**B11**	**B12**	**B13**	**B14**	**BE**	**P**	**BL**
VIF	1.464	1.740	2.627	3.201	2.043	1.241	1.000	1.228	1.810

3.1.3. Reliability and Validity Tests

In testing for composite reliability, greater values typically indicate higher reliability rates, as ratings between 0.60 and 0.70 are considered "acceptable in exploratory research", and values between 0.70 and 0.90 range from "satisfactory to good" [35]. Values of 0.95 and above are challenging because they suggest that the items are redundant, which reduces construct validity and can also be indicative of the possibility of unintended reaction patterns (such as straight lining), which leads to inflated correlations between the error terms of the indicators [60]. The study (see Table 5) obtained composite reliability values (rho_c and rho_c) of 0.922 and 0.921, respectively, which is good. The degree to which a construct converges in order to account for the variation of its indicators is known as convergent validity and the average variance extracted (AVE) for all indicators for each construct is the metric used to assess the convergent validity of a construct [61]. The grand mean value of the squared loadings of the construct-related indicators, or the sum of the squared loadings divided by the number of indicators, is used to define the AVE, hence, the commonality of a construct is equivalent to the AVE [61]. An AVE of 0.50 or greater implies that the construct explains 50% or more of the variation of the indicators that make up the construct, with 0.50 being the minimum admissible value [62]. The study obtained an AVE of 0.466, which is a little below the recommended level. However, according to [63], the AVE may represent a more conservative estimate of the measurement model's validity and "on the basis of P_n (composite reliability) alone, the researcher may conclude that the convergent validity of the construct is adequate, even though more than 50% of the variance is due to error". Hence, the internal reliability of the construct is adequate since the composite reliability of the construct is well above the acceptable level [64].

Table 5. Construct reliability and validity for the PLS-SEM analysis.

	Cronbach's Alpha	**Composite Reliability (rho_a)**	**Composite Reliability (rho_c)**	**Average Variance Extracted (AVE)**
BIMIBs	0.906	0.923	0.921	0.465

One of the most used reliability metrics in the social and organizational sciences is Cronbach's alpha [65]. Cronbach's alpha reliability refers to the reliability of a total (or average) of q measures, where the q measurements may reflect q raters, occasions, alternate forms or questionnaire/test items [65]. Researchers frequently use this statistic to show that scales and tests created or used for research projects are appropriate for the task at hand [66]. It is frequently used to represent internal consistency [67]. The Cronbach's alphas (CAs) for all the variables were between 0.858 and 0.922 (see Table 6), which are all well above the acceptable level of 0.70.

Table 6. Cronbach's alpha test.

Items	**B1**	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**B8**	**B9**	**B10**
Cronbach's alpha	0.911	0.908	0.911	0.910	0.910	0.907	0.911	0.913	0.916	0.912
Items	**B11**	**B12**	**B13**	**B14**	**BE**	**BF**	**P**	**BL**	**BD**	
Cronbach's alpha	0.907	0.906	0.909	0.922	0.907	0.911	0.922	0.858	0.861	

As part of the preliminary tests for the PLS-SEM analysis, the study tested the constructs for discriminant validity. The discriminant validity assesses how different a construct is from other constructs in the structural model empirically [61]. The Fornell–Larcker criterion, the HTMT criterion and cross-loading are the conventional assessment criteria for discriminant validity [68]. According to [69], the Fornell–Larcker criterion and the assessment of cross-loadings, the two commonly used methods to evaluate the discriminant validity in variance-based SEM, have an unacceptable low sensitivity, which indicates that they are often unable to identify a lack of discriminant validity [69]. As a result, [69] proposed the hetrotrait–monotrait ratio (HTMT) of correlations as a superior alternative for evaluating discriminant validity. The high sensitivity rates of the new HTMT criteria, which are based on a comparison of the heterotrait-heteromethod correlations and the monotrait-heteromethod correlations, show that they are successful at detecting a lack of discriminant validity [69]. The study obtained an HTMT value of 0.708 (see Table 7), which is less than the recommended 0.90 where constructs are similar and less than 0.85 if otherwise, suggesting the validity of the model [58].

Table 7. Fornell–Larcker analysis-HTMT.

	BD	BF	BIMIBS	BE	P
BD	1.000				
BF	−0.186	1.000			
BIMIBS	−0.064	0.585	0.682		
BE	−0.213	0.737	0.688	1.000	
P	−0.030	0.006	−0.053	−0.026	1.000

3.2. Nonparametric Analysis—The Kruskall–Wallis Test

Literally, a parametric statistical test is one that relies on presumptions regarding the parameters (defined characteristics) of the population distribution(s) from which one's data are derived, whereas a nonparametric test does not rely on any such presumptions [70]. Some of the typical assumptions of a parametric test include normality, homogeneity of variances, linearity and independence [70] After a test of normality as shown in Table 3, even though the majority of the *p*-values obtained were lower than 0.05, signifying statistical significance, we obtained a few values that deviated substantially from the normal. As a result, we performed the one-way nonparametric ANOVA test to ascertain the statistical difference between the groups in the independent variables (profession, BIM use experience and the highest BIM dimension used) when compared against the level of BIM expertise [71]. The study adopted the Kruskal–Wallis test in SPSS for its nonparametric analysis. The following situations make the Kruskal–Wallis test ideal for use: (a) when there are three or more conditions that you want to compare; (b) when each condition is carried out by a different group of participants, i.e., you have an experiment that involves design using independent measurements for three or more conditions; (c) when the data does not comply with the specifications for a parametric test. If the differences between the groups are so significant that they are unlikely to have happened by chance, the Kruskal–Wallis test will reveal this. Per the results of our analysis, as illustrated in Table 8, with *p*-values between 0.000 and 0.019, it is very unlikely that the results happened by chance, hence, one can conclude that there are some differences between the groups. Per the results, it can be concluded that the respondent's profession had a huge and substantial impact on their level of BIM expertise. It should be noted that the Kruskal–Wallis test only indicates that the groups differ in some manner; to determine how they differ specifically, one must look at the group means or medians in the results, there is sufficient data to infer that. There is a difference in the median test scores (and, consequently, the mean test scores). Note that the Kruskal–Wallis test results indicate if there are differences in the medians of some of the k groups, but unlike the Mann–Whitney U test, they do not indicate which groups differ from other groups.

Table 8. One-way nonparametric (Kruskal–Wallis) test (*p*-values) of significance for the level of BIM expertise.

Independent Variables	*p*-Values
Profession	0.019
BIM use experience	0.000
Highest BIM dimension used	0.000

Note: A *p*-value of 1 means we accept the null hypothesis as true. A *p*-value of 0 means we accept the null hypothesis as untrue. As we travel from a *p*-value of 1 to 0, the transition point between true and untrue is set at 0.05. The smaller the *p*-value the more confident we can be in rejecting the null hypotheses hypothesis.

3.2.1. Pair-Wise Post-Hoc Dunn Tests

In order to identify the groups in the independent variables (profession, BIM use experience and highest BIM dimension used) that had statistical relationships, a pairwise post-hoc Dunn analysis was carried out [71]. Within the inferential framework of the hypothesis test, performing many pairwise comparisons after an omnibus test redefines the meaning of α, which typically denotes the likelihood of incorrectly rejecting the null hypothesis of one test [72]. Dunn test is often used with multiple comparisons [72]. The Dunn's test can be viewed as a test for median difference if the data are supposed to be continuous and the distributions are assumed to be the same other than a shift in centrality, as in the rank-sum test [72]. By taking the mean rankings of the outcomes in each group from the previous Kruskal–Wallis test and basing inference on the differences in mean ranks in each group, the Dunn test approximates exact rank-sum test statistics [72]. Results from Table 9 revealed that the level of BIM expertise among the different professionals was significantly dispersed among architects and engineers (p = 0.006), architect and quantity surveyors (p = 0.010), engineers and land surveyors (p = 0.076) and quantity surveyors and land surveyors (p = 0.034) (see Table 9). Table 10 further describes the influence of BIM usage frequency on the level of BIM expertise, pairwise post hoc comparisons using Dunn's test revealed that the level of BIM expertise among the different professionals was significantly dispersed among professionals with BIM experiences of [o −1 year and 1–3 years], [0–1 year and 3–5 years], [0–1 year and above 5 years], [1–3 years and 3–5 years] and [1–3 years and above 5 years] with p-values of 0.000. 0.000, 0.000, 0.003 and 0.017, respectively. It was also discovered that (see Table 11), the level of BIM expertise among the different professionals was significantly dispersed among professionals with companies whose highest levels of BIM adoption were [2D and 3D] and [2D and 4D] with p-values of 0.000 each.

Table 9. Pair-wise post Dunn tests for BIM expertise—profession.

Independent Variables	Architect	Project Manager	Engineer	Quantity Surveyor	Land Surveyor	Valuer
Architect	N/A	0.338	0.006	0.010	0.916	0.266
Project manager		N/A	0.478	0.186	0.471	0.772
Engineer			N/A	0.354	0.076	0.806
Quantity surveyor				N/A	0.034	0.376
Land surveyor					N/A	0.358
Valuer						N/A

Table 10. Pair-wise post Dunn tests for BIM expertise—BIM experience.

Independent Variables	0–1 Years	1–3 Years	3–5 Years	Above 5 Years
0–1 years	N/A	0.000	0.000	0.000
1–3 years		N/A	0.003	0.017
3–5 years			N/A	0.685
Above 5 years				N/A

Table 11. Pair-wise post Dunn tests for BIM expertise—highest BIM dimension used.

Independent Variables	2D	3D	4D
2D	N/A	0.000	0.000
3D		N/A	0.309
4D			N/A

Note: None of the professionals use BIM for the higher dimensions, such as 5D, 6D and 7D.

3.2.2. Mann–Whitney U-Test

When two samples are compared over their mean value for some variable of interest, the t-test for independent samples is generally used and the Wald–Wolfowitz Run test, the Mann–Whitney U test, and the Kolmogorov–Smirnov two sample test are the nonparametric alternatives for this test [70]. This study adopts the use of the Mann–Whitney U-test. The Mann–Whitney U test makes comparisons between the sums of ranks of two independent groups [70]. In the Mann–Whitney U test, no assumptions are made, and the average rank of the tied observations is applied to the tied ranks. It is the independent-samples t-test's nonparametric equivalent, but unlike the t-test, it looks for variations in the overall distribution of data across groups rather than mean differences. Compared with the *t*-test, the Mann–Whitney U test is approximately 95 percent as powerful; however, where values deviate substantially from the normal, the Mann–Whitney U test is significantly more effective and powerful [73]. For the independent variable "professionals' agreement or disagreement with the BIM benefits", the one-way nonparametric ANOVA test was found to be inappropriate as the variables contained only two categories (a 'yes' or a 'no'); hence, the Mann–Whitney test was carried out to assess any statistical significance in the level of BIM expertise of the professionals [71]. After the Mann–Whitney U test, results from Table 12 revealed statistical significance ($p = 0.029$) between PB3 (BIM is not useful to our company at the moment) and BE. Other than that, there was no statistical significance between the BE and all nine (9) other perceptions of the usefulness of the BIM software and process.

Table 12. Mann–Whitney U test.

Null Hypothesis	*p*-Values
The distribution of BIM expertise is the same across categories of PB1	0.986
The distribution of BIM expertise is the same across categories of PB2	0.613
The distribution of BIM expertise is the same across categories of PB3	0.029
The distribution of BIM expertise is the same across categories of PB4	0.235
The distribution of BIM expertise is the same across categories of PB5	0.118
The distribution of BIM expertise is the same across categories of PB6	0.773
The distribution of BIM expertise is the same across categories of PB7	0.425
The distribution of BIM expertise is the same across categories of PB8	0.211
The distribution of BIM expertise is the same across categories of PB9	0.603
The distribution of BIM expertise is the same across categories of PB10	0.307

3.2.3. Spearman's Rank Order Correlation

When one or both of the variables are ordinal (as opposed to interval) and/or not normally distributed, or when the sample size is small, it is advisable to test whether there is a rank order relationship between the two quantitative variables, and this can be achieved using the Spearman's rank order correlation. In order to determine the statistical relationship between the frequency of BIM use and the level of BIM expertise that professionals possess, the Spearman's rank order correlation was used. or tap here to enter text. In the Spearman's rank order correlation, the closer the coefficient is to positive 1, the stronger the monotonic relationship [74]. A monotonic function is one that, when the value of its independent variable rises, never both grows and never lowers. The Spearman's rank order correlation is also considered a nonparametric statistic test since it requires no normality. In the Spearman's rank order correlation, the null hypothesis suggests that, in the population that the sample represents, there is no rank-order relationship between the variables and to reject the null hypothesis implies that the variables in the population have a rank-order relationship. The positive value of 0.795 (Table 13) is indicative of a positive correlation between the two variables (level of BIM usage expertise and BIM usage frequency). This implies that when one value increases, the other value also increases, or when one value decreases, the other value also decreases.

Table 13. Spearman's rank order correlation.

		BIM Usage Expertise	BIM Usage Frequency
BIM usage expertise	Correlation Coefficient	1.000	0.795
	Sig. (2-tailed)		0.000
	N	103	103
BIM usage frequency	Correlation Coefficient	0.795 **	1.000
	Sig. (2-tailed)	0.000	
	N	103	103

3.2.4. Partial Least Squares Structural Equation Modeling (PLS-SEM) Analysis

A PLS-SEM analysis was carried out to establish the relationship between three latent variables, which are: (1) the level of BIM expertise (BE), BIM usage frequency (BF) and the (3) BIM implementation barriers (BIMIBs). The PLS-SEM method has been adopted in many different domains because it makes it easier to conduct investigations using structural equations [75]. The CB-SEM and the PLS-SEM are the two main methodologies that have been used in SEM to date [76]. When evaluating a model, CB-SEM must adhere to the following criteria: data normality, sample size, reflective construct (i.e., the direction of indicator arrows pointing towards construct) and influential theory and it does this by allying with the empirical variance-covariance matrix [75]. Variance-based SEM, or PLS-SEM, is well known for being more approachable because it does not adhere to the same rigid standards as CB-SEM [75]. When CB-SEM assumptions are broken, PLS-SEM is crucial for resolving causality issues in the context of latent variables [75]. Studies using a common factor model should generally choose CB-SEM, while studies using a composite model should use PLS-SEM [75]. Generally, PLS-SEM is used to analyze latent social science constructs and due to its capacity to estimate models with composites and factors [75] and it is usually the preferred method [76]. Another remarkable difference between CB-SEM and PLS-SEM has to do with sample size. As implied by its name, PLS-SEM operates by partially estimating the structural model through the solving of the equations individually, and as a result, the minimal sample size needed to get model estimates depends on the model ramification of a specific equation, which is far less complex than the total model [75]. In the case of a small sample size, PLS performs better than its predecessor, CB-SEM [77,78]. It is vital to note that the independent latent variables in a structural equation model are the exogenous variables, while the dependent latent variables are the endogenous variables [76].

3.2.5. The Structural Model

Note that the preliminary tests for the PLS-SEM analysis have already been conducted in Section 4.1. Once it has been determined that the constructs measured are reliable and valid, the next step is to assess the structural model [69]. At this stage, the structural study theory is evaluated in accordance with prior empirical research, and the hypothesis is tested [75]. The process of evaluating a structural model entails determining the significance and applicability of the path coefficients, as well as the model's explanatory and predictive capabilities [79]. Bootstrapping is a nonparametric method for calculating the PLS estimates' precision [51]. Resampling techniques are used in bootstrapping to determine the importance of PLS coefficients [80]. In order to get N estimates for each parameter in the PLS model, N sample sets are made and typically, until the number of instances is the same as the original sample set, each sample is acquired by sampling with replacement from the original dataset [51]. Figure 2 shows the structural model after a two-tailed bootstrapping process was run on 5000 samples. On the influence of the prevalence of BIMIBs on the level of BIM expertise of professionals, a path coefficient of 0.688 was obtained. The t-values are represented in the outer models.

Testing the Structural Model

In order to assess the structural model, the study tested for the following: (1) the path coefficients and their significance levels, (2) effect size (f square), (3) coefficient of determination (R-square) and (4) the redundancy measure (Q square).

The significance and relevance of the path coefficients were tested. Strong positive relationships are shown by coefficients that are closer to +1, whereas strong negative relationships are represented by those that are closer to −1 and it should be noted that theoretically, values below −1 and beyond +1 are possible, for instance, when collinearity is quite high [81]. When PLS-SEM analyzes standardized data, the path coefficients, while maintaining all other predictor constructs constant, show changes in an endogenous construct's values that are related to standard deviation unit changes in one particular predictor construct [81]. The endogenous construct, for instance, will rise by 0.505 standard deviation units when the predictor construct increases by one standard deviation unit, according to a path coefficient of 0.505 [81]. When deciding whether the size of a route coefficient is significant, the research environment is crucial, hence, while analyzing the output of structural models, researchers should additionally include total impacts, which are calculated as the sum of any direct effects and any induced effects in the model connecting one construct to another [81]. A more complete picture of the relationships in the structural model can be obtained by looking at the total effects between constructs, including all of their indirect effects [82]. As shown in Table 14, all path coefficients obtained during the assessment of the structural model were between 0.50 and 0.8 (closer to positive 1), indicating a strong positive relationship.

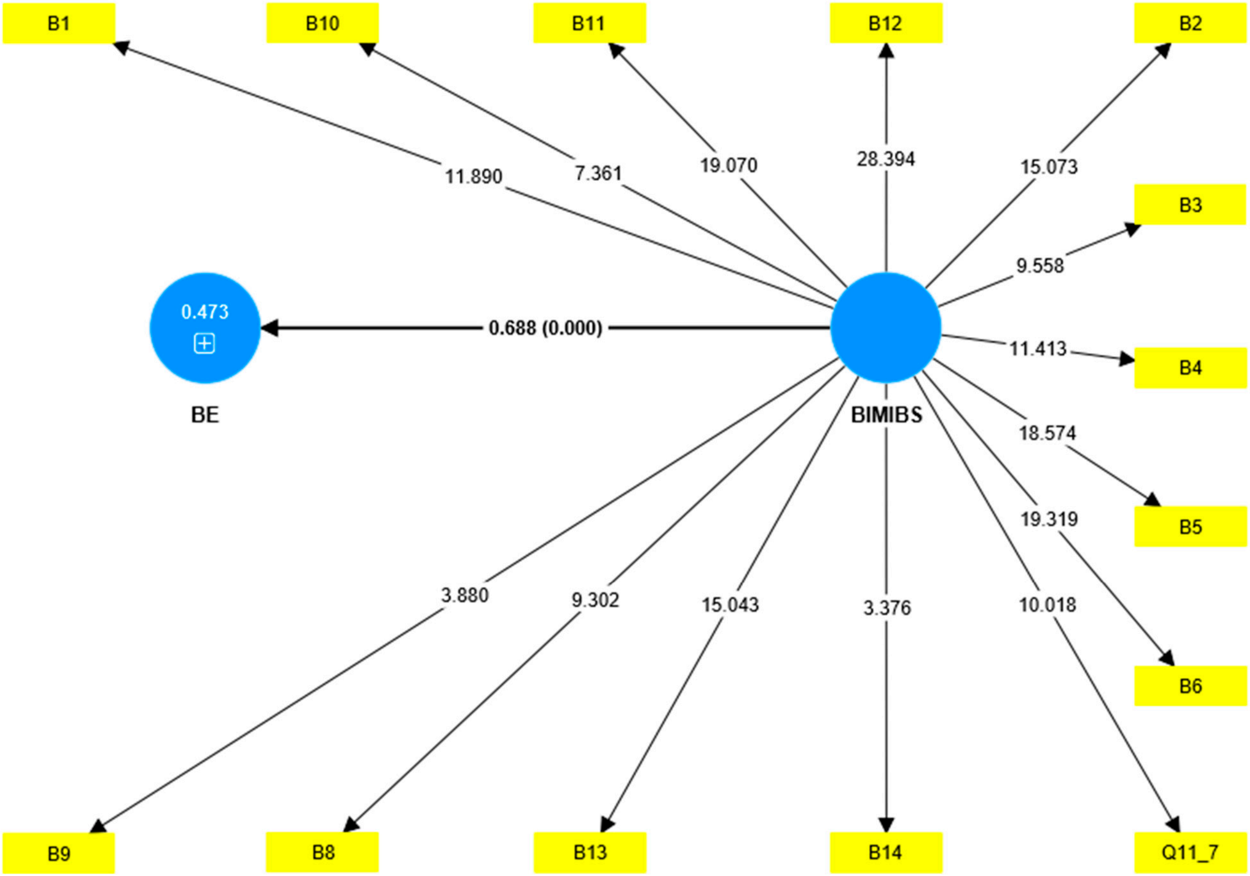

Figure 2. Final structural model.

Table 14. Bootstrapping results.

Nature of Relationship	Path Coefficients	T Values	*p*-Values
BIMIBS > BE	0.688	16.746	0.000

Next is the assessment of the endogenous construct's coefficient of determination (R-square). The R-square measures the explanatory power of the model and represents the variance explained in each of the endogenous constructs [83]. The R-squares for each dependent latent variable must be carefully examined when evaluating a PLS model, and this is necessary because the weight relations define the case values of the latent variables [51]. In order to determine whether or not a given independent latent variable has a significant effect on a dependent latent variable, it can be determined by examining the change in the R-square value [51]. Greater explanatory power is shown by higher values of R-square, which range from 0 to 1 [81]. R-square values of 0.75, 0.50 and 0.25, respectively, can be regarded as considerable, moderate, and weak, respectively, in several social science subjects as a general rule [78]. Table 15 shows the values recorded for R-squares and their adjusted versions, indicating fairly weak to moderate R-square values and per this study, the R-square values are perfect. According to [81], researchers should be aware that R-square is a function of the quantity of predictor constructs; the more constructs, the higher the R-square value. As a result, the R2 should always be understood in the context of the study and in light of the R-square results from related studies and models with a similar level of complexity [81].

Table 15. R-square, Q-square and PLS predict values.

	R-Square	F-Square	Q-Square	PLS Predict	PLS-SEM RMSE	PLS-SEM MAE	LM_RMSE	LM_MAE
BE	0.473	0.899	0.456	0.457	0.934	0.673	1.005	0.782

Furthermore, the R-square values of the study's endogenous constructs were evaluated in relation to the elimination of selected predictive constructs. This is known as the effect size. The effect size, represented as the F-square, takes into account the impact sizes of the links between the constructs, which is important to analyze the practical applicability of substantial effects [35]. Independent of sample size, the effect size is a way to quantify the size of an effect and F-square values between 0.020 and 0.150, 0.150 and 0.350 or greater than or equal to 0.350, respectively, indicate a weak, medium or large effect size [35]. An F-square value of 0.899 in the study is indicative of a substantial effect size.

It is important to note that R-square only represents the model's in-sample explanatory power and not its predictive capacity, which is a model's ability to predict future observations [84], hence the necessity for Q-square. One of the main reasons to choose PLS-SEM is to analyze predictive models [50], and in this regard, a key argument in PLS-SEM's recent developments is the distinction between a model's explanatory and predictive power [59]. Calculating the Q-square value aids in assessing the predictive accuracy of the PLS path model. This measurement is based on a blindfolding method that eliminates individual data points, replaces those points with the mean, and estimates the model's parameters [49]. To reflect the prediction accuracy of the structural model for a given endogenous construct, Q-square values for that construct should, as a general rule, be greater than zero, with values greater than 0, 0.25 and 0.50 representing the PLS-path model's small, medium and significant predictive importance, respectively [35]. After a blindfolding process, the study obtained q-values between 0.374 and 1 (see Table 1), representing a medium to significant predictive importance of the model. Recent research has recommended using the PLSpredict technique instead of Q-square from blindfolding to evaluate a model's predictive potential with PLS-SEM [83]; however, due to its novelty, only a few studies have applied it. PLSpredict execution entails estimating the model on a training sample and assessing its prediction effectiveness on a holdout sample [83]. Per the results of the study's PLSpredict analysis (see Table 1), it can be concluded that our model has a very high predictive power because, compared to the naive LM benchmark, every indicator in the PLS-SEM study had reduced RMSE (or MAE) values [83].

4. Discussion

4.1. The Influence of Profession on the Level of BIM Expertise

After the one-way nonparametric (Kruskal–Wallis) test, it was determined that the respondent's profession had a huge and substantial impact on their level of BIM expertise, with a p-value of 0.019. Pairwise post hoc comparisons using Dunn's test revealed that the level of BIM expertise among the different professionals was significantly dispersed among architects and engineers (p = 0.006), architects and quantity surveyors (p = 0.010), engineers and land surveyors (p = 0.076) and quantity surveyors and land surveyors (p = 0.034) (see Table 9). This finding is consistent with a past study where researchers determined a significant dispersion of BIM knowledge and expertise between architects, engineers and surveyors [71,85]. The top BIM tool used by all the professionals was identified as REVIT. Approximately 76.5 percent of professionals use Revit, followed by AutoCAD and Sketchup with percentages of 70.4 and 35.8, respectively. Due to numerous barriers that have accompanied BIM adoption in the developing world, it is, however, not surprising that the majority (77.5%) of professionals only employ BIM for 3D design purposes. For instance, due to a lack of understanding of how to use BIM software and a shortage of architects with BIM competence, architects have not yet made significant investments in BIM [10]. However, there is now a growing consensus among architects that the field of architecture needs to change to one that is more interconnected [10], and there is some evidence that the architecture industry is starting to feel the pressure to adopt BIM [86]. Practicing architects need to become more aware of the opportunities that BIM presents to them [10]. The biggest barrier, however, preventing structural engineers from using BIM more frequently is that there is no integration between them and the MEP designers [10]. Generally, all AEC stakeholders must agree on a broad BIM-based project delivery strategy that is backed by a regulatory framework in order to advance the industry as a whole [10]. Different professionals have different roles to play in the BIM process. Guides and guidelines for BIM implementation and practice have been published by numerous nations, industry groups, research coalitions and individual organizations and usually include definitions of the crucial roles needed for successful BIM implementation [87]. BIM adoption in firms is often started via a bottom-up process as a result of a single person pursuing a personal goal or advantage, leading to a restriction in BIM adoption by the organization as a whole [88]. Roles and procedures have consequently developed in an ad hoc manner, and standards developers have had to strike a balance between the necessity to create a consistent yet representative structure and the difficulty of describing processes and roles that are still changing in practice [87].

4.2. The Influence of the Highest BIM Dimensions Adopted by Companies on the Level of BIM Expertise of Professionals

With regards to the application of BIM in projects, the highest level of BIM dimension employed by 77.5% of the professionals is the 3rd dimension, followed by the 2nd and 4th dimensions, with percentages of 3.8 and 3.7, respectively. Even though 15% of the respondents had an idea of the BIM software and process, they do not use it since the companies or firms they work with have not adopted BIM usage in their projects. Pairwise post hoc comparisons using Dunn's test revealed that the levels of BIM expertise among the different professionals were significantly dispersed among professionals with companies whose highest levels of BIM adoption were [2D and 3D] and [2D and 4D] with p-values of 0.000 each (see Table 11). After the one-way nonparametric (Kruskal–Wallis) test, with a p-value of 0.000, it was determined that the highest BIM dimension employed by the companies in which the respondents worked had a huge and substantial impact on their level of BIM expertise. It is important to note that none of the professionals use BIM for the higher dimensions, such as 5D, 6D and 7D in their projects, hence no expertise in them.

The findings of this study are consistent with results from past studies. There are still barriers preventing 5D BIM and other higher dimensions from being fully embraced by estimating teams, despite the fact that they can offer numerous advantages from a value engineering and constructability perspective [89]. Many stakeholders, particularly those working in the construction business, still do not get how practical 5D BIM is [27]. Significant misconceptions among stakeholders sometimes lean to one of two extremes: either they see it as a simple "solution for all," or they see it as an overrated, makeshift computer aided design [27]. The construction sector perceives cultural opposition, the belief that their software is more accurate than 5D BIM, a lack of standards for coding items in building information models, and a shortage of employees with the necessary skills as impediments to the adoption of 5D BIM [27].

Many estimators adopting BIM would concede that the necessity for 2D plans is not going away any time soon [89]. This is because the 3D BIM software includes some 2D takeoff tools and it is generally acknowledged that these 3D tools do not yet offer the same degree of capabilities that estimators need for their work on 2D production estimation [89]. As a result, estimators are forced to use several disconnected 2D and 3D takeoff systems, which complicates things and raises the possibility of mistakes [89]. Another estimating concern with 3D models is the lack of specifications and from a designer's perspective (particularly for independent architects), there may be little value to putting specs into the model [89]. In fact, it may not be possible to build a model containing all the job specifications without impacting model size and performance and designers may attempt to resolve this issue by creating links in the model to external specification documents [89]. However, these links, which must be maintained by different stakeholders, can easily break as specifications change throughout the project [89]. Kreaker [8] cited two key factors for why people continue to utilize 2D BIM: client demand and installation managers' lack of IT expertise and understanding, resulting in their inability to precisely extract what they require from 3D models. In addition, they further stated that there is never the right amount of 3D information made available to make the installation process easier.

Although the creation of 2D graphics can now be reduced by over 90%, it cannot be completely avoided [8]. The current generation of leaders may be mostly responsible for the dominance of 2D drawings since the top managerial roles in the construction industry are typically held by a highly experienced workforce that depends more on their work experience and conventional methods of functioning [8]. BIM technology is considered to be a relatively recent technology and because of this, any change in the way they do things at work will be in direct opposition to what they see as a productive and beneficial manner of doing things [8]. Although many consequences are anticipated from the introduction of BIM, which has just emerged as a new paradigm in the construction sector, 2D-based products cannot be simply replaced with BIM [90]. Therefore, the simultaneous 2D and 3D activities that designers and contractors must complete will result in higher construction prices and workloads [90]. Hence, [90] suggests a BIM-based development and product supply strategy for the current situation in which 2D and 3D drawings coexist. Most importantly, the building industry also needs to investigate the possibility of skipping the creation of 2D drawings in order to attain BIM's full potential as a working technique [8].

4.3. Influence of Perception and BIM Usage Frequency on Level of BIM Expertise

As per Table 12, there is a statistical significance (u = 596, p = 0.029) between PB3 (BIM is not useful to our company at the moment) and the level of BIM expertise of professionals. In addition, there is no statistically significant difference between the level of BIM expertise of professionals and all nine (9) other perceptions of the usefulness of the BIM software and process. This implies that, other than Perception 3, the lack or possession of BIM expertise by professionals is independent of these perceptions about the usefulness of the software. The findings imply two things: (a) the inclusion or exclusion of BIM tools and processes in company activities would significantly affect the level of BIM expertise of professionals and (b) despite the low level of BIM expertise recorded among professionals, the majority (85.4%) of them agree with the usefulness of BIM within the AEC industry of the developed world. With regards to how often professionals use the BIM software and process, the majority (30.5%) of the respondents stated that they rarely did. Only 18.3% had an experience of more than 5 years. Additionally, 18% never use it, regardless of having a certain level of expertise. In order to determine the influence of BIM usage frequency on the level of BIM expertise, pairwise post hoc comparisons using Dunn's test revealed that the level of BIM expertise among the different professionals was significantly dispersed among professionals with BIM experiences of [0 −1 year and 1–3 years], [0–1 year and 3–5 years], [0–1 year and above 5 years], [1–3 years and 3–5 years] and [1–3 years and above 5 years] with p-values of 0.000. 0.000, 0.000, 0.003 and 0.017, respectively (see Table 10). Per the Spearman's rank order correlation results in Table 1, we observed that with a correlation coefficient of 0.795, there is a positive and very significant correlation between the level of BIM expertise and BIM usage frequency. However, according to [91], in Spearman rank order correlation, 'correlation is not the same thing as cause and just because there is a relationship between two sets of variables it does not mean that one thing causes the other'. After a one-way nonparametric (Kruskal–Wallis) test, it was determined that the length of the respondents' BIM use experience had a huge and substantial impact on their level of BIM expertise, with a *p*-value of 0.000. The level of BIM expertise was higher in instances where professionals used the adopted BIM process very often in their construction activities and vice versa when professionals seldomly adopted the BIM process.

4.4. Influence of BIMIBS on BIM Expertise

With a path coefficient value of 0.688, the PLS–SEM analysis determined that the existence of BIMIBs has a great and positive influence on the level of BIM expertise acquired by professionals. This implies that BIMIBs are a major obstacle impeding BIM skills development among professionals in the AEC industry of the developing world and hence, overcoming these BIMIBs would lead to a significant increase in the level of BIM expertise of professionals. This finding is supported by various studies. Cost-related barriers have been listed by many researchers as a major barrier affecting BIM skill adoption. BIM adoption frequently entails the purchase of new software and improved hardware in order to run the processing-intensive software, which is a financial challenge for firms in the developing world [92]. They identified the lack of knowledge of the value added by BIM, a lack of BIM expertise, cultural opposition and contract-type delivery methods as a group of interrelated BIMIBs that impede developing countries such as Bahrain's easy adoption of BIM [93]. In some instances, the lack of BIM standards and knowledge has been cited as one of the greatest BIMIBs [94]. In addition to the fact that achieving the various BIM levels will require significant effort on the part of professionals in the developing world, the degree of complexity and interoperability has become a technological and social barrier for many [95]. Other studies have identified the unavailability of BIM training centers, the lack of client demand, a general resistance to change and the complexity of implementation as major BIMIBs in the developing world [96–98]. Where it was found that professionals had a solid understanding of BIM, the absence of governmental support and guidance was noted as a significant BIMIB factor delaying the adoption rate of BIM [99], hence expertise. In recent years, research on the barriers to BIM adoption in the developing world's AEC sector has proliferated, highlighting the urgent need for workable solutions. In the examination of BIMIBs in the developing world, professionals in the AEC sector would not only be able to comprehend the key reasons behind its slow adoption, but also, the increased knowledge would put them in a better position to adopt BIM, to come up with tactical ideas that positively influence its wider acceptance, and to get rid of process inefficiencies [92]. In addition, governmental agencies and legislators would be able to implement more effective policy frameworks that would create enabling environments where BIM expertise would be more widely sought after and acquired with ease among construction professionals in the developing world. Liu [100] recommended managerial training for top management staff and employees of government agencies in addition to technical training for entry-level employees. According to [100], BIM training could be offered by public and private universities along with BIM-experienced business representatives. A variety of BIM education or training sessions can be provided, including but not limited to seminars, in-person or online workshops and a series of modules to achieve different levels of BIM skills [100]. Additionally, certain BIM policies should be implemented to accommodate smaller AEC organizations in order to foster the growth of BIM within them.

4.5. Implications of the Study on the Higher Education Sector

A significant advancement in computer hardware-related technologies over the past ten years has paved the way for the emergence of potent software applications in the industrial sector. How BIM is currently being taught in undergraduate curricula around the world has been the topic of considerable discussion, and there have been questions on whether BIM should be included as a stand-alone subject in a curriculum or as an overarching theme throughout the degree [101]. Others have conducted research on theories of practice for how BIM education should be structured [101]. The academic world is under increasing pressure to develop top-notch students who are prepared with the digital know-how to address the emerging difficulties of the industry as a result of information technology's ever-increasing engagement in today's industrial environment [20]. A balanced curriculum that may match this requirement for technology with courses to provide an in-depth grasp of the topic is being scrutinized by the academic community [20]. Currently, in some academic institutions, Students studying architecture, construction, computer graphics, and engineering now have access to a wider range of techniques thanks to BIM [20].

Proven impacts of BIM inclusion in the curriculum of different departments in academia include: (1) the production of high-quality drawings and generated images, (2) the provision of a new career path for two students to pursue as students had rapid training and employment offers from the BIM divisions of all the major construction corporations searching for qualified students in this field, (3) accelerated sketching and rendering production, (4) more original and imaginative responses to engineering issues from students of civil engineering and (5) the development of novel, project-specific library features to facilitate modeling and simulation [20]. Numerous researchers have concluded that the shortage of BIM professionals with the necessary training is the primary obstacle to the adoption of BIM in the AEC sector [11]. Intensive BIM training integrated into university curricula can help graduates better comprehend the BIM process, enhancing their understanding of the technology and processes [102]. Due to this, some higher education sectors all over the world have taken the initiative to incorporate BIM into the curriculum by either including it in the requirements for undergraduate education or by offering it as an elective subject to students. This is commendable and is highly recommended for higher education institutions in the developing world to do the same.

In institutions where BIM has successfully been added to the curricula, the BIM courses are introduced right at the start of the program [103]. While some institutions have placed more emphasis on the design, others have improved the traditional cost estimation course by adding model-based quantity take-off, clash detection, and project planning through the BIM model to the existing curriculum [103]. A framework called IMAC was created to promote the adoption of collaborative education using BIM. The IMAC stands for illustration, manipulation, application, and collaboration. Students are made to receive instructions or lessons on the introduction of BIM in several fields at the illustration stage, whereas the manipulation stage teaches students how to interact with and modify BIM models that are already in existence [104]. Students are also made to master the fundamentals of using the necessary BIM software program at the manipulation stage, after which the knowledge and ability acquired are used to tackle problems associated with their chosen fields of study during the application stage [104]. Lastly, during the collaboration stage, students from several AEC disciplines collaborate and coordinate their work on a single project [104].

The AEC academic sector of the developing world and the world at large need to overcome the challenge of constantly opposing the implementation of new technologies in education. Prior to students learning about the "old ways" of working once they graduate and becoming swayed into embracing current practices in the industry, educators should be able to inculcate in undergraduates in the AEC professions the concepts of collaborative design and the full potential of BIM [101]. Providing instruction in computer technology at universities has previously encountered pushback from instructors [105]. BIM is still viewed by many educators as just another CAD program that students should learn at their own pace [101]. Some claim that utilizing CAD has no educational value and that it "threatens creativity" and that it is not the responsibility of universities to generate "CAD technicians" [106]. This standard method of teaching BIM prevents students from understanding how BIM tools let them collaborate with others in an efficient manner [101]. This argument, however, ignores the fact that BIM is not just a merely new CAD tool, instead, it represents a new paradigm and its advantages go much beyond simple visualization and just as student are not expected to "teach themselves structural engineering", they cannot be expected to "teach themselves BIM" or either [107].

The BIM process is collaborative at its core and in order to accomplish common objectives, collaborative teams must devise better and more effective working methods [23]. In the same manner, collaborative education is also strongly encouraged in the BIM curriculum. There is a need for collaboration among the current organizational structures of AEC faculties. After graduation, the workplace is usually where graduates of each AEC subject are first introduced to working with team members from other disciplines [101]. It's critical for graduates to comprehend the responsibilities that other AEC professionals perform and how their choices affect projects as a whole, however, the fragmented way they are now being educated does not provide them with this understanding [101]. This is not only limited to the different departments within an academic institution. Different institutions must overcome the barrier of not sharing instruction across several academic silos if they are to generate graduates with the essential abilities for collaborative working with BIM (Shelburne). The ability of several project teams to interact, exchange, update, and use data is crucial to the success of collaboration [23]. No one can be a master of everything anymore due to the complexity of modern construction projects and technologies, hence, the information that each profession needs at various stages of a project is frequently not well understood [101]. As a result, time is lost stripping out and rebuilding models when it could have been saved by setting up the models more effectively at the beginning of the process and eliminating extraneous details before model exchange [101]. This amount of miscommunication will probably be eliminated in the future, and trust will likely increase, if students are taught to collaborate and to grasp the requirements of other disciplines before they graduate [101]. Therefore, our study strongly recommends that a bridge be built between the graduate skill sets and the evolving demands of the different professions in the AEC industry in the developing world. Cheng [108] could not have put it more succinctly, "Regardless of the magnitude of BIM's eventual of impact on the profession, its recent rise provides the ideal catalyst for rethinking architectural education. The level of experience required to intelligently design what BIM is significant, and serious consideration must be given to how it can be taught".

5. Conclusions

To maximize returns without compromising the standard, the idea of a successfully finished building project must be unambiguously carried out throughout the project life stages, hence the importance of the different BIM dimensions. BIM deployment is necessary in the developing world, particularly in Ghana, because the AEC sector faces difficulties including low efficiency and productivity caused by insufficient budgeting and corruption in the form of cost inflation, insufficient finance and credit services for contractors, design restrictions and job variance, insufficient planning and monitoring, and low computerization. The adoption of BIM in the developing world is still in its early stages, with the majority of professionals utilizing modeling-focused BIM software and only a small amount of collaborative or preconstruction tools. Additionally, the level of BIM expertise possessed by professionals in the developing world is very low. It is not surprising that the study discovered 3D BIM as the highest BIM dimension adopted by the of majority the companies and firms. The study also discovered that the predominance of BIMIBs, one's profession, the highest BIM dimension adopted by employers and how often and how long one uses BIM have a substantial impact on the level of BIM expertise possessed by professionals in the AEC industry of the developing world. In addition, the study provided information about the level of BIM competency among the various players in the construction industry. The created model highlighted the extent to which the level of BIM expertise possessed by professionals would greatly increase when the BIMIBs were tackled.

The study has conceived new concepts that can be added to the conceptual framework.

(1) Overcoming the critical BIMIBs would significantly improve the level of BIM expertise possessed by professionals.
(2) One's profession significantly affects their level of BIM expertise.
(3) The highest dimension of BIM adopted in a company/firm's processes significantly impacts the level of one's BIM expertise.
(4) To a large extent, there is no significant relationship between one's perception of BIM's importance and their level of BIM expertise in the developing world.

The BIM concept, technology and process are extensively being employed and are becoming more and more obvious that the developing world's AEC industry may benefit enormously from them. This elevates the study's importance. The study's significance lies in the fact that it is the first to fill in existing research gaps by shedding light on and providing insight into the extent to which the level of BIM expertise of professionals is influenced by external variables. The results of this study will make stakeholders in developing countries aware of the necessary steps to take that would directly improve the BIM skills of professionals at the different BIM dimensions if they were to fully benefit from BIM. Policymakers, institutions such as the higher education sector and other government agencies can use the study's findings to create an action plan that will boost the growth of BIM expertise in the AEC sector throughout the developing world and beyond. One of the study's main advantages is the inclusion of a wide range of reputable professionals (professionals in good standing) in Ghana's AEC industry. Even though one unique thing about the study is the conceptualization of the relationship between BIMIBs and the level of BIM expertise using PLS-SEM, it is highly recommended that future research on the developing world conduct this conceptualization with a different approach, such as the use of programs such as the Technology Acceptance Model and Innovation Diffusion Theory.

Author Contributions: Conceptualization: G.E.T.-A. and H.Z.; Methodology: G.E.T.-A. and H.Z.; Formal analysis and investigation: G.E.T.-A.; Writing—original draft preparation: G.E.T.-A.; Writing—review and editing: G.E.T.-A. and H.Z.; Resources: H.Z.; Supervision: H.Z. All authors have read and agreed to the published version of the manuscript.

Funding: The research was supported by the Research on Parts and Components Library and Building Information Model Sub-part, Coding and Labeling Standards (2022-K-069).

Data Availability Statement: Some or all data, models, or code that support the findings of this study are available from the corresponding author upon reasonable request.

Acknowledgments: We are grateful to Eyram Norgbey for proofreading our work.

Conflicts of Interest: The authors declare that they have no competing interest.

References

1. Sethia, S. Multidimensional BIM to Build Infrastructure Fast and Efficient—An Overview. 2012. Available online: https://www.ijedr.org (accessed on 21 April 2023).
2. British Standards Institution. *Constructing the Business Case of Building Information Modelling*; Building SMART UK Publishing: London, UK, 2010.
3. Tarar, M.; Dang, D.T.P. *Impact of 4D Modelling on Construction Planning Process*; Chalmers University of Technology: Goteborg, Sweden, 2012.
4. Davies, K.; McMeel, D.; Wilkinson, S. Soft skills requirements in a BIM project team. In Proceedings of the 32nd CIB W78 Conference 2015, Eindhoven, The Netherlands, 27–29 October 2015.
5. Boton, C.; Kubicki, S.; Halin, G. 4D/BIM Simulation for Pre-Construction and Construction Scheduling. Multiple Levels of Development within a Single Case Study. BIMetric View project Monumentum Project View Project 4D/BIM Simulation for Pre-Construction and Construction Scheduling. Multiple Levels of Development within a Single Case Study. 2015. Available online: https://www.researchgate.net/publication/279953595_4DBIM_simulation_for_pre-construction_and_construction_scheduling_Multiple_levels_of_development_within_a_single_case_study?channel=doi&linkId=559f8daf08ae8a0fbedc98e9&showFulltext=true (accessed on 21 April 2023).
6. Doan, D.T.; Ghaffarianhoseini, A.; Naismith, N.; Ghaffarianhoseini, A.; Zhang, T.; Tookey, J. Examining critical perspectives on Building Information Modelling (BIM) adoption in New Zealand. *Smart Sustain. Built Environ.* **2021**, *10*, 594–615. [CrossRef]

7. Eastman, C.; Teicholz, P.; Sacks, R.; Liston, K. BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers, and Contractors. 2011. Available online: https://www.EngineeringBooksPdf.com (accessed on 21 April 2023).
8. Kreaker, M.G.; Verdyguer, I.R. Bim-What Is Beyond 2d Drawings A Review of the Design Phase and the Perspective of an Industry without 2D Drawings. (Design and Construction Project Management). Master's Thesis, Chalmers University of Technology, Guttenberg, Sweden, 2019.
9. Fonseca Arenas, N.; Shafique, M. Recent progress on BIM-based sustainable buildings: State of the art review. *Dev. Built Environ.* **2023**, *15*, 100176. [CrossRef]
10. Hartmann, T.; Fischer, M. Cifecenter for Integrated Facility Engineering Applications of BIM and Hurdles for Widespread Adoption of BIM 2007 AISC-ACCL eConstruction Roundtable Event Report. 2008. Available online: https://stacks.stanford.edu/file/druid:wm995bw1706/WP105.pdf (accessed on 21 April 2023).
11. Fadzil, S.F.S.; Taib, N.; Ishak, N.A. Analysis of Skills Needs for Future Architecture Graduates of Building Information Modelling (BIM) in Malaysia: A Thematic Review Paper. *Int. J. Acad. Res. Bus. Soc. Sci.* **2021**, *11*, 759–773. [CrossRef]
12. Sinenko, S.; Hanitsch, P.; Aliev, S.; Volovik, M. The implementation of BIM in construction projects. *E3S Web Conf.* **2020**, *164*, 08002. [CrossRef]
13. Khodeir, L.M.; Nessim, A.A. BIM2BEM integrated approach: Examining status of the adoption of building information modelling and building energy models in Egyptian architectural firms. *Ain Shams Eng. J.* **2018**, *9*, 1781–1790. [CrossRef]
14. Ma, L.; Lovreglio, R.; Yi, W.; Yiu, T.W.; Shan, M. Barriers and strategies for building information modelling implementation: A comparative study between New Zealand and China. *Int. J. Constr. Manag.* **2022**, *23*, 2067–2076. [CrossRef]
15. Li, H.; Ng, S.T.T.; Skitmore, M.; Zhang, X.; Jin, Z. Barriers to building information modelling in the Chinese construction industry. *Proc. Inst. Civ. Eng. Munic. Eng.* **2017**, *170*, 105–115. [CrossRef]
16. Van Roy, A.F.; Firdaus, A. Building Information Modelling in Indonesia: Knowledge, Implementation and Barriers. *J. Constr. Dev. Ctries.* **2020**, *25*, 199–217. [CrossRef]
17. Ismail, E.D.; Said, S.Y.; Jalil, M.K.A.; Ismail, N.A.A. Benefits and Challenges of Heritage Building Information Modelling Application in Malaysia. *Environ. Behav. Proc. J.* **2021**, *6*, 179–184. [CrossRef]
18. Hamid, A.B.A.; Taib, M.Z.M.; Razak, A.H.N.A.; Embi, M.R. The Barriers and Causes of Building Information Modelling Usage for Interior Design Industry. In *IOP Conference Series: Materials Science and Engineering*; Institute of Physics Publishing: Bristol, UK, 2018. [CrossRef]
19. Rahman, R.A.; Alsafouri, S.; Tang, P.; Ayer, S.K. Comparing Building Information Modeling Skills of Project Managers and BIM Managers Based on Social Media Analysis. In *Procedia Engineering*; Elsevier Ltd.: Amsterdam, The Netherlands, 2016; pp. 812–819. [CrossRef]
20. International Association of Journals & Conferences. Joint International Conference on Engineering and Related Technologies (4 : 2014 : Orlando) and International Society of Agile Manufacturing. Joint International Conference on Engineering and Related Technologies (4 : 2014 : Orlando). In Proceedings of the 4th IAJC/ISAM Conference Proceedings, Orlando, FL, USA, 17 February 2014; IAJC: Guadalajara, Mexico, 2014.
21. Abdirad, H.; Dossick, C.S.; Dossick, C.S. BIM Curriculum Design in Architecture, Engineering, and Construction Education: A Systematic Review. 2016. Available online: http://www.itcon.org/2016/17 (accessed on 21 April 2023).
22. Gartoumi, K.I.; Zaki, S.; Aboussaleh, M. Building information modelling (BIM) interoperability for architecture and engineering (AE) of the structural project: A case study. *Mater Today Proc.* **2023**, *in press*. [CrossRef]
23. Kjartansdóttir, I.B.; Stefan, M.P.; Nowak, D.; Philp, J.T.S.; Politechnika, W.; Lądowej, W.I. *Building Information Modelling—BIM*; Civil Engineering Faculty of Warsaw University of Technology: Warsaw, Poland, 2017.
24. Lidelöw, S.; Engström, S.; Samuelson, O. The promise of BIM? Searching for realized benefits in the Nordic architecture, engineering, construction, and operation industries. *J. Build. Eng.* **2023**, *76*, 107067. [CrossRef]
25. Alizadehsalehi, S.; Hadavi, A.; Huang, J.C. From BIM to extended reality in AEC industry. *Autom. Constr.* **2020**, *116*, 103254. [CrossRef]
26. Koutamanis, A. Dimensionality in BIM: Why BIM cannot have more than four dimensions? *Autom. Constr.* **2020**, *114*, 103153. [CrossRef]
27. Lee, X.S.; Tsong, W.; Khamidi, M.F. 5D Building Information Modelling-A Practicability Review. *MATEC Web Conf.* **2016**, *66*, 00026. [CrossRef]
28. Rausch, C.; Nahangi, M.; Haas, C.; West, J. Kinematics chain based dimensional variation analysis of construction assemblies using building information models and 3D point clouds. *Autom. Constr.* **2017**, *75*, 33–44. [CrossRef]
29. Kacprzyk, Z.; Kępa, T. Building information modelling-4D Modelling technology on the example of the reconstruction stairwell. In *Procedia Engineering*; Elsevier Ltd.: Amsterdam, The Netherlands, 2014; pp. 226–231. [CrossRef]
30. Mesároš, P.; Smetanková, J.; Mandičák, T. The Fifth Dimension of BIM—Implementation Survey. In *IOP Conference Series: Earth and Environmental Science*; Institute of Physics Publishing: Bristol, UK, 2019. [CrossRef]
31. Boton, C.; Kubicki, S.; Halin, G. Designing adapted visualization for collaborative 4D applications. *Autom. Constr.* **2013**, *36*, 152–167. [CrossRef]
32. Hasan, A.N.; Rasheed, S.M. The Benefits of and Challenges to Implement 5D BIM in Construction Industry. *Civ. Eng. J.* **2019**, *5*, 412. [CrossRef]

33. Charef, R.; Alaka, H.; Emmitt, S. Beyond the third dimension of BIM: A systematic review of literature and assessment of professional views. *J. Build. Eng.* **2018**, *19*, 242–257. [CrossRef]
34. Nicał, A.K.; Wodyński, W. Enhancing Facility Management through BIM 6D. In *Procedia Engineering*; Elsevier Ltd.: Amsterdam, The Netherlands, 2016; pp. 299–306. [CrossRef]
35. Yahaya, M. Partial Least Square Structural Equation Modeling (PLS-SEM): A Note for Beginners Transaction Cost Analysis of the Nigerian Construction Industry in the Context of Public Procurement Act (2007) View Project Public Procurement in Construction View Project. 2019. Available online: http://www.casirmediapublishing.com (accessed on 21 April 2023).
36. Hergunsel, M.F. Benefits of Building Information Modelling for Construction Managers and BIM Based Users. 2011. Available online: https://www.academia.edu/download/32796045/BENEFITS_OF_BIM_for_Construction_Manager.pdf (accessed on 21 April 2023).
37. Azhar, S.; Hein, M.; Sketo, B. Building Information Modeling (BIM): Benefits, Risks and Challenges. 2008. Available online: https://www.semanticscholar.org/paper/Building-Information-Modeling{-}{-}(-BIM-)-%3A-Benefits-%2C-Azhar-Hein/f06d49120df6b73e1a43008edd3c89141e91dbe3#related-papers (accessed on 24 April 2023).
38. Bouguerra, K.; Yaik-Wah, L.; Ali, K.N. A Preliminary Implementation Framework of Building Information Modelling (BIM) in the Algerian AEC Industry. *Int. J. Built Environ. Sustain.* **2020**, *7*, 59–68. [CrossRef]
39. Enegbuma, W.I.; Ali, K.N.; Ologbo, A.C.; Aliagha, U.G. Preliminary study impact of building information modelling use in Malaysia. *IFIP Adv. Inf. Commun. Technol.* **2014**, *442*, 51–62. [CrossRef]
40. Kamal, Y.Y.; Esa, E.M. Building Information Modelling (BIM) Implementation: Challenges for Quantity Surveyors. *Int. Trans. J. Eng.* **2019**, *13*, 1–10. [CrossRef]
41. Marzouk, M.; Elsaay, H.; Othman, A.A.E. Analysing BIM implementation in the Egyptian construction industry. *Eng. Constr. Archit. Manag.* **2021**, *29*, 4177–4190. [CrossRef]
42. Zhang, L.; Chu, Z.; He, Q.; Zhai, P. Investigating the constraints to buidling information modeling (BIM) applications for sustainable building projects: A case of China. *Sustainability* **2019**, *11*, 1896. [CrossRef]
43. Rogers, J.; Chong, H.Y.; Preece, C. Adoption of Building Information Modelling technology (BIM): Perspectives from Malaysian engineering consulting services firms. *Eng. Constr. Archit. Manag.* **2015**, *22*, 424–445. [CrossRef]
44. Ismail, N.A.A.; Yousof, M.N.M.; Adnan, H. BIM Adoption in Managing Construction Risks Amongst Malaysian Quantity Surveyors: Current Practice and Challenges. *Int. J. Sustain. Constr. Eng. Technol.* **2021**, *12*, 166–175. [CrossRef]
45. Loyola, M.; López, F. An evaluation of the macro-scale adoption of Building Information Modeling in Chile: 2013–2016. *Rev. Constr.* **2018**, *17*, 158–171. [CrossRef]
46. Babatunde, S.O.; Ekundayo, D. Barriers to the incorporation of BIM into quantity surveying undergraduate curriculum in the Nigerian universities. *J. Eng. Technol.* **2019**, *17*, 629–648. [CrossRef]
47. Hamada, H.M.; Haron, A.; Zakiria, Z.; Humada, A.M. Factor Affecting of BIM Technique in the Construction Firms in Iraq. *Int. Symp. Civ. Environ. Eng.* **2017**, *103*, 03003. [CrossRef]
48. Shin, M.H.; Kim, H.Y. Facilitators and barriers in applying building information modeling (Bim) for construction industry. *Appl. Sci.* **2021**, *11*, 8983. [CrossRef]
49. Rigdon, E.E. Choosing PLS path modeling as analytical method in European management research: A realist perspective. *Eur. Manag. J.* **2016**, *34*, 598–605. [CrossRef]
50. Hair, J.F.; Risher, J.J.; Sarstedt, M.; Ringle, C.M. When to use and how to report the results of PLS-SEM. *Eur. Bus. Rev.* **2019**, *31*, 2–24. [CrossRef]
51. Chin, W.W. The Partial Least Squares Approach to Structural Equation Modeling the Proactive Technology Project Recovery Function: A Methodological Analysis View Project Research Methods View Project. 2014. Available online: https://www.researchgate.net/publication/311766005 (accessed on 21 April 2023).
52. Marcoulides, G.A.; Saunders, C. PLS: A silver bullet? *MIS Q. Manag. Inf. Syst.* **2006**, *30*, iii–ix. [CrossRef]
53. Hair, J.F.; Sarstedt, M.; Hopkins, L.; Kuppelwieser, V.G. Partial least squares structural equation modeling (PLS-SEM): An emerging tool in business research. *Eur. Bus. Rev.* **2014**, *26*, 106–121. [CrossRef]
54. Wong, K.K.-K. *Praise for Mastering Partial Least Squares Structural Equation Modeling (PLS-SEM) with SmartPLS in 38 Hours*; Iuniverse: Bloomington, IN, USA, 2019.
55. Razali, N.M.; Wah, Y.B. Power comparisons of Shapiro-Wilk, Kolmogorov-Smirnov, Lilliefors and Anderson-Darling tests. *J. Stat. Model. Anal.* **2011**, *2*, 21–33.
56. Shrestha, N. Detecting Multicollinearity in Regression Analysis. *Am. J. Appl. Math. Stat.* **2020**, *8*, 39–42. [CrossRef]
57. Daoud, J.I. Multicollinearity and Regression Analysis. *J. Phys. Conf. Ser.* **2018**, *949*, 012009. [CrossRef]
58. Russo, D.; Stol, K.J. PLS-SEM for software engineering research: An introduction and survey. *ACM Comput. Surv.* **2021**, *54*, 78. [CrossRef]
59. Becker, J.M.; Cheah, J.H.; Gholamzade, R.; Ringle, C.M.; Sarstedt, M. PLS-SEM's most wanted guidance. *Int. J. Contemp. Hosp. Manag.* **2022**, *35*, 321–346. [CrossRef]
60. Diamantopoulos, A.; Sarstedt, M.; Fuchs, C.; Wilczynski, P.; Kaiser, S. Guidelines for choosing between multi-item and single-item scales for construct measurement: A predictive validity perspective. *J. Acad. Mark. Sci.* **2012**, *40*, 434–449. [CrossRef]
61. Guenther, P.; Guenther, M.; Ringle, C.M.; Zaefarian, G.; Cartwright, S. Improving PLS-SEM use for business marketing research. *Ind. Mark. Manag.* **2023**, *111*, 127–142. [CrossRef]

62. Sarstedt, M.; Hair, J.F.; Pick, M.; Liengaard, B.D.; Radomir, L.; Ringle, C.M. Progress in partial least squares structural equation modeling use in marketing research in the last decade. *Psychol. Mark.* **2022**, *39*, 1035–1064. [CrossRef]
63. Fornell, C.; Larcker, D.F. Evaluating Structural Equation Models with Unobservable Variables and Measurement Error. *J. Mark. Res.* **1981**, *18*, 39–50. [CrossRef]
64. Lam, L.W. Impact of competitiveness on salespeople's commitment and performance. *J. Bus. Res.* **2012**, *65*, 1328–1334. [CrossRef]
65. Bonett, D.G.; Wright, T.A. Cronbach's alpha reliability: Interval estimation, hypothesis testing, and sample size planning. *J. Organ. Behav.* **2015**, *36*, 3–15. [CrossRef]
66. Taber, K.S. The Use of Cronbach's Alpha When Developing and Reporting Research Instruments in Science Education. *Res. Sci. Educ.* **2018**, *48*, 1273–1296. [CrossRef]
67. DeVellis, R. *Scale Development Theory and Applications*, 2nd ed.; SAGE Publishing: London, UK, 2003; Volume 26.
68. Hamid, M.R.A.; Sami, W.; Sidek, M.H.M. Discriminant Validity Assessment: Use of Fornell & Larcker criterion versus HTMT Criterion. *J. Phys. Conf. Ser.* **2017**, *890*, 012163. [CrossRef]
69. Henseler, J.; Ringle, C.M.; Sarstedt, M. A new criterion for assessing discriminant validity in variance-based structural equation modeling. *J. Acad. Mark. Sci.* **2015**, *43*, 115–135. [CrossRef]
70. Wohlin, C.; Runeson, P. Guiding the selection of research methodology in industry–academia collaboration in software engineering. *Inf. Softw. Technol.* **2021**, *140*, 106678. [CrossRef]
71. Acheng, P.O.; Kibwami, N.; Mukasa, T.J.; Odongkara, B.B.; Birungi, R.; Semanda, J.; Manga, M. Building information modelling adoption in Uganda's construction industry. *Int. J. Constr. Manag.* **2022**, 1–24. [CrossRef]
72. Dinno, A. Nonparametric pairwise multiple comparisons in independent groups using Dunn's test. *Stata J.* **2015**, *15*, 292–300. [CrossRef]
73. Plenkovic, M.; Civljak, M.; Puljak, L. Authors arbitrarily used methodological approaches to analyze the quality of reporting in research reports: A meta-research study. *J. Clin. Epidemiol.* **2023**, *158*, 53–61. [CrossRef]
74. Heinen, A.; Valdesogo, A. Spearman rank correlation of the bivariate Student t and scale mixtures of normal distributions. *J. Multivar. Anal.* **2020**, *179*, 104650. [CrossRef]
75. Fauzi, M.A. Partial least square structural equation modelling (PLSSEM) in knowledge management studies: Knowledge sharing in virtual communities. *Knowl. Manag. E-Learn.* **2022**, *14*, 103–124. [CrossRef]
76. Kazár, K. PLS Path Analysis and its Application for the Examination of the Psychological Sense of a Brand Community. *Procedia Econ. Financ.* **2014**, *17*, 183–191. [CrossRef]
77. Henseler, J.; Ringle, C.M.; Sinkovics, R.R. The use of partial least squares path modeling in international marketing. *Adv. Int. Mark.* **2009**, *20*, 277–319. [CrossRef]
78. Hair, J.F.; Ringle, C.M.; Sarstedt, M. PLS-SEM: Indeed a silver bullet. *J. Mark. Theory Pract.* **2011**, *19*, 139–152. [CrossRef]
79. Magno, F.; Cassia, F.; Ringle, C.M.M. A brief review of partial least squares structural equation modeling (PLS-SEM) use in quality management studies. *TQM J.* **2022**, *ahead-of-print*. [CrossRef]
80. Partial Least Squares (Pls-Sem) 2016 Edition. Available online: https://www.statisticalassociates.com (accessed on 21 April 2023).
81. Kante, M.; Michel, B. Use of partial least squares structural equation modelling (PLS-SEM) in privacy and disclosure research on social network sites: A systematic review. *Comput. Hum. Behav. Rep.* **2023**, *10*, 100291. [CrossRef]
82. Nitzl, C.; Roldan, J.L.; Cepeda, G. Mediation analysis in partial least squares path modelling, Helping researchers discuss more sophisticated models. *Ind. Manag. Data Syst.* **2016**, *116*, 1849–1864. [CrossRef]
83. Shmueli, G.; Ray, S.; Estrada, J.M.V.; Chatla, S.B. The elephant in the room: Predictive performance of PLS models. *J. Bus. Res.* **2016**, *69*, 4552–4564. [CrossRef]
84. Edeh, E.; Lo, W.-J.; Khojasteh, J. Review of Partial Least Squares Structural Equation Modeling (PLS-SEM) Using R: A Workbook. *Struct. Equ. Model.* **2023**, *30*, 165–167. [CrossRef]
85. Alemayehu, S. A multivariate regression approach toward prioritizing BIM adoption barriers in the Ethiopian construction industry. *Eng. Constr. Arch. Manag.* **2021**, *29*, 2635–2664. [CrossRef]
86. Arayici, Y.; Coates, P.; Koskela, L.; Kagioglou, M.; Usher, C.; O'Reilly, K. BIM adoption and implementation for architectural practices. *Struct. Surv.* **2011**, *29*, 7–25. [CrossRef]
87. Davies, K.; Wilkinson, S.; Mcmeel, D. A Review Of Specialist Role Definitions in Bim Guides and Standards a Review of Specialist Role Definitions in BIM Guides. 2017. Available online: http://www.itcon.org/2017/10 (accessed on 21 April 2023).
88. Samuelson, O.; Björk, B.C. Adoption processes for EDM, EDI and BIM technologies in the construction industry. *J. Civil. Eng. Manag.* **2013**, *19*, S172–S187. [CrossRef]
89. Jiang, F.; Ma, L.; Broyd, T.; Chen, K.; Luo, H.; Du, M. Building demolition estimation in urban road widening projects using as-is BIM models. *Autom. Constr.* **2022**, *144*, 104601. [CrossRef]
90. Seo, M.B.; Ju, K.B. A Study on the Interoperability between 2D Drawings and BIM-Based 3D Drawings. *Open. J. Soc. Sci.* **2013**, *1*, 10–14. [CrossRef]
91. The Spearman's Rank Correlation Test 2 QMUL School of Geography Resources for Schools. Available online: http://www.towerhamlets.gov.uk/lgnl/community_and_living/borough_statistics/borough_statistics.aspx (accessed on 21 April 2023).
92. El Hajj, C.; Montes, G.M.; Jawad, D. An overview of BIM adoption barriers in the Middle East and North Africa developing countries. *Eng. Constr. Archit. Manag.* **2023**, *30*, 889–913. [CrossRef]

93. Ahmed, S.H.A.; Suliman, S.M.A. Exploring the Adoption of Building Information Modeling in the Bahraini Construction Industry. In Proceedings of the 2020 2nd International Sustainability and Resilience Conference: Technology and Innovation in Building Designs, Sakheer, Bahrain, 11–12 November 2020. [CrossRef]
94. Matarneh, R.; Hamed, S. Barriers to the Adoption of Building Information Modeling in the Jordanian Building Industry. *Open. J. Civil. Eng.* **2017**, *7*, 325–335. [CrossRef]
95. Enshassi, A.; Abuhamra, L. Challenges to the Utilization of BIM in the Palestinian Construction Industry. In Proceedings of the 34th International Symposium on Automation and Robotics in Construction (ISARC), Taipei, Taiwan, 28 June–1 July 2017.
96. Matar, J. The Penetration And Impact of Bim Implementation in The Construction Industry in Lebanon. Ph.D. Thesis, The Faculty of Engineering at Notre Dame University-Louaize, Zouk Mosbeh, Lebanon, 2019.
97. Chen, Z.S.; Zhou, M.D.; Chin, K.S.; Darko, A.; Wang, X.J.; Pedrycz, W. Optimized decision support for BIM maturity assessment. *Autom. Constr.* **2023**, *149*, 104808. [CrossRef]
98. Bataw, A.; Kirkham, R.; Lou, E. The Issues and Considerations Associated with BIM Integration. In *MATEC Web of Conferences*; EDP Sciences: Les Ulis, France, 2016. [CrossRef]
99. Elyamany, A.H. Current practices of building information modelling in Egypt. *Int. J. Eng. Manag. Econ.* **2016**, *6*, 59. [CrossRef]
100. Liu, N.; Ruan, L.; Jin, R.; Chen, Y.; Deng, X.; Yang, T. Investigation of individual perceptions towards BIM implementation-a Chongqing case study. *Eng. Constr. Archit. Manag.* **2019**, *26*, 1455–1475. [CrossRef]
101. Piroozfar, P.; Farr, E.R.P.; Zadeh, A.H.M.; Inacio, S.T.; Kilgallon, S.; Jin, R. Facilitating Building Information Modelling (BIM) using Integrated Project Delivery (IPD): A UK perspective. *J. Build. Eng.* **2019**, *26*, 100907. [CrossRef]
102. Gamil, Y.; Rahman, I.A.R. Awareness and challenges of building information modelling (BIM) implementation in the Yemen construction industry. *J. Eng. Des. Technol.* **2019**, *17*, 1077–1084. [CrossRef]
103. Ismail, A.S.; Ali, K.N.; Mustaffa, N.E.; Iahad, N.A.; Yusuf, B.Y. Enhancing The Graduates' Employability And Career Development Through Building Information Modelling Intensive Training. *Int. J. Built Environ. Sustain.* **2019**, *6*, 91–99. [CrossRef]
104. Lassen, A.K.; Hjelseth, E.; Tollnes, T. Enhancing learning outcomes by introducing bim in civil engineering studies—Experiences from a university college in Norway. *Int. J. Sustain. Dev. Plan.* **2018**, *13*, 62–72. [CrossRef]
105. Gerber, D.J.; Khashe, S.; Smith, I.F.C. Surveying the Evolution of Computing in Architecture, Engineering, and Construction Education. *J. Comput. Civil. Eng.* **2015**, *29*, 04014060. [CrossRef]
106. Turk, Z. The pace of technological innovation in architecture, engineering, and construction education: Integrating recent trends into the curricula. *J. Inf. Technol. Constr.* **2011**, *16*, 411.
107. Engineers Australia, An Examination of an Industry Problem as It Applies to Queensland and Recommendations for Solutions and Actions. A Plan to Reverse Declining Standards in Project Design Documentation within the Building and Construction Industry ii. 2005. Available online: https://www.qld.engineersaustralia.org.au (accessed on 21 April 2023).
108. Cheng, A. *Report on Integrated Practice Suggestions for an Integrative Education 5 Renée Cheng AIA*; American Institute of Architects: Washington, DC, USA, 2020.