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Article

Digital poverty in quantity surveying practice

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Abstract: Background: Digitalization has profoundly impacted the construction sector, offering tools and technologies that promise increased efficiency, accuracy, and collaboration. Nevertheless, the integration of these digital solutions, notably Building Information Modeling (BIM), can be impeded by a set of fundamental barriers known as enablers of digital poverty. These enablers encompass a range of challenges that quantity surveyors face in Lagos State when attempting to embrace BIM and other digital tools. Objective: The objective of this study is to pinpoint, classify, and assess the factors that enable digital poverty when it comes to implementing BIM within the community of quantity surveyors in Lagos State, Nigeria. By understanding these enablers, stakeholders can develop targeted strategies to alleviate digital poverty and promote digital inclusion in the field of quantity surveying. Methods: A quantitative research method was utilized, employing a questionnaire survey to collect information from quantity surveyors in Lagos State. The questionnaire used in the study was designed to collect demographic data and evaluate the factors contributing to digital poverty. The collected data were analyzed using the mean item score and subjected to exploratory factor analysis (EFA) to uncover hidden groups or patterns among these contributing factors. Results: The EFA exposed five distinct clusters of enablers of digital poverty: Exploration Enablers—Factors related to creating an enabling environment for digital adoption, including limited financial resources, inadequate institutional arrangements, and lack of awareness; Incognizant Enablers—Factors reflecting a lack of knowledge and awareness, such as erratic power supply and insufficient government support; Compliance Enablers—Factors associated with the challenges of complying with new digital practices, including resistance to change from traditional methods and the scarcity of BIM specialists; Infrastructural Enablers—Challenges linked to infrastructure, including high costs of investment and software/hardware upgrades; and Automation Enablers—Factors related to the adoption of automated processes, such as an unsupportive organizational culture, lack of experience and knowledge, and inadequate support from senior management. Conclusion: This research provides a comprehensive understanding of the enablers of digital poverty in BIM implementation among quantity surveyors in Lagos State. It highlights the multifaceted characteristics of these challenges and underscores the importance of addressing them to promote digital inclusion and leverage the advantages of digital technologies within the construction sector. The identified enablers can serve as a foundation for policymakers, organizations, and communities to develop targeted interventions aimed at reducing digital poverty and fostering a digitally inclusive environment for quantity surveyors in Lagos State.

Keywords: digital poverty; building information modeling (BIM); quantity surveyors; enablers; Lagos state; construction industry; exploratory factor analysis (EFA)

1. Introduction

As poverty assumes an increasingly complex and pervasive nature, the academic community has delved extensively into its multifaceted dimensions. Various forms of poverty, including ICT poverty, data poverty, poverty clock, economic poverty, and digital poverty, have been subjects of substantial research efforts. However, the field of digital poverty in the construction sector refers to the lack of essential equipment, infrastructure, education, and training required for effective use of digital technology, a topic that has received limited scholarly attention. The construction industry is undeniably a cornerstone of a country's economy, driving development, providing employment, and stimulating economic growth. In Nigeria, the construction sector contributes to roughly 3% of the nation's Gross Domestic Product (GDP), making it a vital sector for economic development [1]. However, despite its potential for growth and development, this industry faces several challenges, including productivity issues, building collapses, material shortages, unethical practices, and cost overruns [2]. Moreover, the construction industry has fallen behind when compared to other sectors in adopting digital technologies, which have transformed various aspects of modern life [3].

The COVID-19 pandemic in 2020, coupled with fluctuations in oil and gas demand, negatively impacted Nigeria's construction industry, resulting in a 7.7% drop [4]. However, there is optimism as the sector is anticipated to experience an annual growth rate of 3.2% from 2021 to 2025 [5]. To harness this growth and address longstanding issues, the construction industry is turning to digitalization.

Digitalization is ushering in a new era for the construction industry, revolutionizing how projects are planned, designed, constructed, and maintained. This transformation is being driven by a range of digital technologies, including BIM, 3D printing, augmented reality (AR), drones, virtual reality (VR), and the Internet of Things (IoT) [6]. These technologies promise to enhance productivity, collaboration, efficiency, and sustainability in construction.

This study explores the enablers of digital poverty within the construction industry, with particular emphasis on the quantity surveyors. It underscores how digitalization is reshaping the quantity surveying profession, providing tools and technologies that streamline processes, improve accuracy, enhance collaboration, and ultimately contribute to more efficient and cost-effective construction projects. Furthermore, this document explores the utilization of BIM within the field of quantity surveying, elucidating the profound impact of BIM technology on cost estimation, project budgeting, and construction management.

In a rapidly evolving construction landscape, embracing digitalization is not just a choice but an essential requirement for industry stakeholders to remain competitive, reduce risks, and create better-built environments for communities. This publication underscores the transformative power of digitalization in the construction sector and its significance in ensuring sustainable expansion and progress in the construction sector of Nigeria.

2. Literature review

The Nigerian construction industry (NCI) is a vital sector that significantly contributes to the nation's economy by providing employment opportunities, promoting industrialization, and stimulating economic activity [7]. However, despite its potential for growth and development, the industry faces several challenges, one of which is the persistent issue of digital poverty. Digital poverty in this context refers to the limited access and utilization of digital technologies and tools within the construction sector. This literature review explores the enablers of digital poverty in the Nigerian construction industry, shedding light on the factors that hinder the industry's full adoption of digitalization.

2.1. Overview of the Nigerian Construction Industry (NCI)

Ojo and Ebunoluwa [8] posited that the NCI comprises various stakeholders, including clients, government and zoning bodies, consultants, contractors, and subcontractors It encompasses a diverse range of professionals, tradesmen, and laborers who contribute to the construction of buildings, roads, bridges, dams, and other infrastructure projects. The industry is considered a cornerstone of economic growth, accounting for about 3% of Nigeria's GDP [1].

2.2. Digitalization challenges in the construction industry

Despite its economic importance, the Nigerian construction industry faces multiple challenges that have hindered its digital transformation. These challenges can be categorized into the following key enablers of digital poverty:

1) Lack of Digital Infrastructure: One of the primary enablers of digital poverty in the NCI is the inadequate digital infrastructure. The country's digital infrastructure, including access to high-speed internet and reliable power supply, remains limited, which hampers the industry's ability to fully embrace digital technologies [4].
2) Resistance to Change: Historically, the construction sector has been reluctant to embrace emerging technologies, according to Oke et al. [9], and this resistance to change has perpetuated digital poverty. Compared to industries like manufacturing and banking, which have readily embraced digitalization, construction has lagged behind.
3) Fragmentation and Inefficiency: The decentralized structure of the Nigerian construction sector has resulted in inefficiencies and a shortage of standardized procedures as posited by Khalfan and Anumba [2]. This fragmentation inhibits the uniform adoption of digital tools and practices across the sector.
4) Inadequate Funding: Limited financial resources and funding for infrastructure projects have constrained the industry's ability to invest in digital technologies as described by Idoro [10]. Many construction firms struggle to allocate funds for technology upgrades and training.
5) Regulatory Challenges: Inadequate government policies, regulations, and standards for quality control further exacerbate digital poverty in the construction sector as discussed by Idoro [10]. The absence of a conducive regulatory framework hinders the adoption of digital tools and practices.
6) Lack of Digital Skills: A shortage of skilled professionals who can effectively leverage digital technologies in construction projects contributes to digital poverty [11]. This includes a scarcity of quantity surveyors with the necessary digital skills.
7) Environmental Concerns: The construction industry's environmental impact, including excessive energy consumption and greenhouse gas emissions, poses a

challenge to its digitalization efforts [12]. Balancing sustainability goals with digitalization is a complex issue.

2.3. The quantity surveying profession and the role of quantity surveyors in mitigating digital poverty

According to the Canadian institute of quantity surveying, quantity surveyors (also known as construction cost consultants or cost estimators) play a critical role in construction and infrastructure projects, working for either the client or contractor, on-site or in an office [13]. They ensure accurate cost estimation based on project requirements and specifications and help maintain financial feasibility throughout the project lifecycle. Therefore, quantity surveying is a key discipline within the construction industry that centers on cost management, financial efficiency, and value optimization for projects.

Quantity surveyors play a pivotal role in addressing digital poverty in the NCI. They possess the expertise required to estimate costs, manage budgets, and ensure that projects are completed efficiently. Quantity surveyors can help bridge the digital divide by utilizing digital tools for cost planning, procurement, and cost control [14]; applying digital technologies such as BIM to enhance efficiency and accuracy in quantity surveying practices [15]; leveraging digitalization for improved risk management, contract administration, and project management [16]. BIM software like Cost X, Bluebeam Revu, PlanSwift, Revit allows quantity surveyors to extract precise quantity takeoffs directly from 3D models. This automates the traditionally manual process of measuring from 2D drawings, reducing errors and saving time. BIM also facilitates cost estimation throughout the project lifecycle by linking cost data to building components [17]. Drones equipped with cameras and photogrammetry software allow quantity surveyors to conduct site surveys quickly and accurately. These tools generate topographical data and measurements for planning and cost assessments, especially in large or remote areas [18].

2.4. Digitalization in the construction industry

Digitalization has the potential to transform the Nigerian construction industry by introducing advanced technologies that enhance productivity, collaboration, and efficiency. Key digital technologies and their impact on the industry include:

1) Building Information Modelling (BIM): BIM enables collaborative and data-driven project management, improving communication and decision-making [19].
2) Drones: Drones offer valuable data for surveying, site inspection, and progress tracking, enhancing project monitoring [6].
3) Virtual Reality (VR) and Augmented Reality (AR): VR and AR technologies improve visualization and decision-making during the design and construction phases [20].
4) 3D Printing: 3D printing reduces waste and costs while increasing construction efficiency [9].
5) Internet of Things (IoT): IoT devices enhance building performance, safety, and energy [21].

In conclusion, digital poverty in the NCI represents a significant obstacle to its full potential. The industry faces challenges related to infrastructure, resistance to change, fragmentation, funding, regulations, skills, and environmental concerns. Quantity surveyors can play a crucial role in mitigating digital poverty through their expertise in digital tools and practices. Embracing digitalization offers the industry opportunities for increased efficiency, sustainability, and overall growth, ultimately contributing to Nigeria's economic development.

2.5. Digitalization in quantity surveying practice

The adoption of digitalization in quantity surveying practice has brought about significant transformations. Some key ways in which digitalization has influenced quantity surveying include:

(1) Building Information Modelling (BIM): BIM technology has had a profound impact on quantity surveying. BIM models contain detailed information about building components, materials, and specifications, allowing quantity surveyors to generate precise cost estimates and bills of quantities. This has significantly reduced errors and increased efficiency in cost estimation [22,23].

(2) Cost Estimating Software: The development of cost estimating software has enabled quantity surveyors to generate cost estimates swiftly and accurately. These tools allow quantity surveyors to forecast project data and receive detailed estimates based on that data, improving the speed and accuracy of cost estimation [24].

(3) Digital Takeoff Software: Digital takeoff software enables quantity surveyors to measure and quantify building elements more swiftly and accurately than traditional manual methods. By using digital plans and drawings, quantity surveyors can calculate quantities and produce bills of quantities efficiently [25].

(4) Collaboration Tools: Digital collaborative instruments enable increased cooperation among quantity surveyors and other construction experts such as architects, engineers, and contractors. Real-time collaboration enhances communication, reduces errors, and results in better coordination and communication, ultimately leading to more efficient project delivery [26].

(5) Data Analysis: Digitalization has simplified data collection and analysis for quantity surveyors. This data can be utilized to identify trends, forecast costs, and pinpoint potential cost-saving measures. Consequently, project planning, cost estimation, and risk assessment have improved [27].

(6) Automation of Routine Tasks: Digital tools have made it possible to automate mundane tasks, such as measurement and quantity take-off. This automation reduces the time and effort required for these tasks, allowing quantity surveyors to focus on more complex and value-adding activities [28].

(7) Increased Accuracy and Efficiency: Digital tools have enhanced the accuracy and efficiency of various quantity surveying activities, including cost estimating, value engineering, and cost control. This has resulted in improved cost management, reduced project risk, and better project outcomes. Accurate quantity estimation benefits both small and large projects. In small projects, it reduces study time and improves cost accuracy. For large projects, it expedites

later study phases despite potentially longer initial modeling [29].

(8) Greater Flexibility: Digital tools have enabled quantity surveyors to work remotely and collaborate with professionals from different locations, providing greater flexibility and efficiency in project delivery [30].

(9) Improved Decision-Making: Digital tools furnish quantity surveyors with better data and insights, empowering them to make well-informed decisions. This, in turn, has led to improved project outcomes, reduced project risk, and enhanced cost management [31].

In summary, digitalization has transformed quantity surveying practice by enhancing data collection and analysis, improving collaboration, automating routine tasks, increasing accuracy and efficiency, providing greater flexibility, and enhancing decision-making. These benefits have elevated the role of quantity surveyors in the construction industry, allowing them to deliver accurate cost estimates, reduce errors, and enhance efficiency.

2.6. Building Information Modelling (BIM)

BIM is an acronym for Building Information Modelling, which represents a significant technological advancement that has reshaped the construction industry. It is characterized by its ability to offer a comprehensive digital representation of both the physical and operational characteristics of a building. BIM encompasses various definitions and interpretations, but at its core, it is a digital process involving the creation of a 3D model of a building and its components. BIM facilitates collaboration among architects, engineers, contractors, and other stakeholders, fostering a shared digital model of the building [22].

BIM technology empowers stakeholders with the tools and the information necessary for effective planning, designing, constructing, and overseeing buildings and infrastructure [22]. It virtually eliminates human errors in drawing production, estimation, and quantity take-off, thus revolutionizing traditional 2D drafting techniques [32].

Digitalization has brought about transformational changes in quantity surveying practice, offering a wide range of tools, technologies, and software that enhance accuracy, efficiency, and collaboration. Despite these advancements, several factors can limit the full implementation of digitalization in quantity surveying. Addressing these enablers of digital poverty is essential to fully harness the benefits of digitalization in the profession. By embracing digitalization and overcoming these challenges, quantity surveyors can continue to play a pivotal role in the construction sector, delivering accurate cost estimates, reducing errors, and increasing efficiency, ultimately benefitting clients and stakeholders alike.

Finally, research has explored the potential of BIM to address challenges such as cost overruns and project delays in the Nigerian construction industry. Investigation on BIM application is gaining attention as BIM can help resolve design conflicts and reduce errors during construction, which is particularly important in complex projects. Clash detection. In Nigeria, BIM was used in the land reclamation and urban development initiative in Eko Atlantic, Lagos. BIM was integrated to enhance project coordination and management. The use of BIM facilitated efficient design processes, improved collaboration among stakeholders, and streamlined construction workflows, contributing to the project's success. Recognizing the importance of BIM, Nigerian polytechnics are incorporating BIM technology into their curricula to promote digitalization in the built environment. This educational integration aims to equip future professionals with the necessary skills to implement BIM effectively in their practices, thereby enhancing the industry's overall productivity and efficiency [33].

2.7. Digital poverty

Poverty, in its various forms, remains a persistent global challenge, compelling nations worldwide to seek comprehensive strategies for its mitigation. Recent research efforts have shown significant advancements in understanding poverty, with a particular emphasis on addressing digital poverty in Asian countries [34]. Scholars have undertaken notable contributions, exploring poverty in its multifaceted dimensions. These investigations encompass a range of dimensions, such as ICT poverty [35], data poverty [36], poverty clock [37], economic poverty [38,39], and digital poverty [40–44].

"Digital poverty" in particular, has emerged as a significant concern, referring to the inability of individuals or communities to access or effectively use digital technologies due to socio-economic barriers. These barriers encompass factors such as the lack of access to internet connectivity, computers, devices, and digital skills. In the context of BIM—a digital technology used in the construction industry—digital poverty can present substantial obstacles to its adoption, particularly in developing countries and low-income communities.

Digital poverty, as a concept, has been variously defined in the literature. Barrantes [40] described digital poverty as "the absence of commodities and services based on Information and Communication Technologies (ICT). It is also a means of accounting for both connection and operation". This comprehensive definition of digital poverty incorporates three key dimensions: The demand dimension (inability to afford ICT services), the capability dimension (lack of skills to use digital services), and the supply dimension (absence of infrastructure to offer digital services). Finally, Beaunoyer et al. [41] elaborated on this definition by delineating digital poverty as the deficiency of tools, infrastructure, educational resources, and training, encompassing socio-economic disparities evident in the rural-urban divide. Digital poverty can therefore be defined as the inability to use information technology due to a lack of digital access or digital skills. Importantly, digital poverty is not limited to economically poor populations but can affect any group within a society.

2.8. The consequences of digital poverty in BIM

Digital poverty in the context of BIM can have profound consequences. It can lead to limited access to critical information and knowledge necessary for effective project management. The consequences may include reduced productivity, efficiency, and an increased potential for errors and project delivery delays. Addressing digital poverty is, therefore, essential to harness the full potential of BIM technology in the construction industry [45].

2.9. Enablers of digital poverty

Enablers of digital poverty are the underlying factors or drivers that facilitate the existence and perpetuation of digital poverty. Several studies have identified these enablers within the context of BIM adoption and digital technology utilization:

(1) Resistance to Change: One of the primary enablers of digital poverty in quantity surveying practice is resistance to change from traditional practices. Individuals or organizations may be hesitant to transition from familiar manual methods to digital technologies due to a lack of awareness of the benefits that the adoption of BIM can bring to organizations and construction projects. Without a clear understanding of these advantages, stakeholders may be reluctant to invest in BIM [46].

(2) Lack of BIM Specialists: In some regions, the scarcity of BIM specialists can hinder its adoption. The absence of skilled professionals may discourage organizations from implementing BIM [47,48].

(3) High Costs: High costs associated with training existing staff, software/hardware upgrades, and initial investments in BIM technology can deter its adoption [49,34].

(4) Lack of Experience and Knowledge: A shortage of experience and knowledge in working with digital technologies like BIM can enable digital poverty. This lack of expertise can impede the successful integration of BIM into construction practices [7].

(5) Lack of Confidence with Automation: Some individuals or organizations may lack confidence in automated processes, leading to resistance and digital poverty [47].

(6) Lack of Client Demand: When clients do not require or incentivize the use of BIM in construction projects, there may be limited motivation to overcome digital poverty [48].

(7) High Initial Investment: The high initial investment required for adopting digital technologies like BIM can be a significant barrier, especially for organizations with limited financial resources [50].

(8) Lack of Subcontractors with BIM Expertise: In construction projects, the absence of subcontractors who can effectively utilize BIM technology can hinder its widespread adoption [51].

(9) Infrastructure Challenges: Erratic power supply, unsupportive organizational culture, lack of support from senior management, and inadequate communications and power infrastructure can all contribute to digital poverty [51,52].

(10) Limited Access and Connectivity: Lack of devices, connectivity, and access to digital infrastructure, tools, education, and training can negatively impact opportunities and quality of life, perpetuating digital poverty [53].

Understanding the enablers of digital poverty is essential for crafting effective strategies to address this pervasive issue, especially in the context of BIM adoption within the construction industry. By recognizing and mitigating these enablers, policymakers, organizations, and communities can work collectively to bridge the digital divide, ensuring that the benefits of digital technologies are accessible to all, ultimately advancing social and economic development.

3. Methodology

This study employed a quantitative research approach to investigate the enablers of digital poverty in Building Information Modeling (BIM) implementation within the Lagos State, Nigeria construction industry. Data was collected through a structured questionnaire designed to gather information from practicing quantity surveyors.

Given the anticipated challenges in obtaining responses from the target population, a convenience sampling technique was utilized. Questionnaires were distributed via both online (Google Forms) and manual methods to enhance accessibility, with a total of 265 questionnaires distributed. Of these, 150 were completed online, and 115 were completed on paper. A total of 172 completed questionnaires were returned for analysis, representing a 65% response rate, deemed sufficient for the study based on the criterion that a response rate exceeding 30% generally indicates minimal bias [54].

The questionnaire comprised two sections: 1) Demographic information of the respondents; and 2) factors enabling digital poverty in BIM implementation. Data analysis involved descriptive statistics and exploratory factor analysis.

4. Data analysis

To fulfill the main objective of the study, which was to assess the accuracy of the instrument, data analysis was performed using an exploratory factor analysis. Following this, a validation and reliability assessment was undertaken to evaluate the questionnaires' validity and consistency.

Exploratory factor analysis (EFA)

EFA is a statistical technique used in research to identify the underlying structure of a set of variables or data. The goal is to explore and uncover hidden dimensions that explain the relationships between observed variables [55]. By reducing a large number of variables to a few easily understandable underlying factors, resulting in data that is simple to interpret and use. According to Hamed et al. [56], EFA analyzes a large dataset to determine whether the variables can be grouped into smaller, meaningful factors that reflect underlying patterns or themes. Each factor comprises a cluster of related variables that share a common variance. To ensure the validity of the analysis, statistical tests such as the Kaiser-Meyer-Olkin (KMO) measure and Bartlett's test are conducted to assess sampling adequacy. Additionally, key outputs like the rotated factor matrix, pattern, total variance explained, and scree plots are reported.

Once the factors are identified, they are named to represent the overarching concept or theme of the variables within each cluster. As Mvududu and Sink [57] emphasized the naming process as both an art and a science. Researchers must identify a unifying theme that ties the variables together, guided by theoretical and empirical literature. By drawing on existing studies, theories, and frameworks, researchers ensure the assigned names align with established knowledge in the field. This careful and thoughtful approach to naming enhances the interpretability and relevance of the factors.

This study employed the Statistical Package for the Social Sciences Version 23 (SPSS V23) to evaluate the validity and reliability of the selected variables. A key measure employed was Cronbach's alpha, as described by Tavakol and Dennick [58], which assesses a test or scale's internal consistency. This metric indicates the extent to which all items within a test measure the same underlying concept, reflecting their interrelatedness. A minimum acceptable Cronbach's alpha value is 0.7, with values above 0.8 being preferable for stronger reliability [59]. In this study, the Cronbach's alpha value was calculated at 0.914, demonstrating excellent internal consistency and surpassing the threshold of 0.70 [59]. In addition to reliability testing, EFA was conducted to examine the enablers of digital poverty in Building Information Modeling (BIM) implementation among quantity surveyors in Lagos State.

5. Results and discussion

All the eighteen (18) items composed in this study were further discussed below.

5.1. Descriptive analysis

Table 1 illustrates the descriptive analysis, which includes the mean and standard deviation of the enablers of digital poverty in BIM implementation. It was discovered that lack of experience and knowledge has the highest mean (M = 4.18), followed by high costs of software/hardware upgrades (M = 4.09) and high cost of training to the existing staff (M = 3.98). This corroborated the study by Eadie et al. [47] which emphasized that the lack of experience and understanding of digital technologies can create resistance to their adoption in construction organizations. Lack of experience and knowledge hinders individuals and organizations from effectively utilizing digital technologies. When there is a lack of familiarity and expertise in using digital tools and platforms, individuals may struggle to access, navigate, and leverage the benefits of technology, resulting in digital poverty. These rankings are based on the fact that the construction industry has undergone a paradigm shift from traditional practice to digitalization. Professionals lacking experience and knowledge in these technologies are left behind.

Table 1. Mean ranking for the enablers of digital poverty in BIM implementation.

Enablers of digital poverty in BIM implementation	Mean	SD	Rank
Lack of experience and knowledge	4.18	0.807	1
High costs of software/hardware upgrades	4.09	0.932	2
High cost of training to the existing staff	3.98	0.985	3
Limited financial resources	3.97	0.794	4
Inadequate ICT content in Quantity surveying courses	3.95	1.002	5
Inadequate institutional arrangements	3.94	0.866	6
Unsupportive organizational culture	3.92	1.015	7
Lack of client demand	3.88	1.033	8
Lack of encouragement from the government	3.84	1.075	9
Lack of BIM specialists in the region	3.82	0.822	10
High cost of investment	3.81	1.032	11

Table 1. (*Continued*).

Enablers of digital poverty in BIM implementation	Mean	SD	Rank
Shortage of ICTs facilities and skills	3.79	1.135	12
Lack of support from senior management	3.76	1.159	13
Erratic power supply	3.66	1.115	14
Resistance to change from traditional practices	3.61	1.131	15
Lack of confidence with automation	3.56	1.021	16
Unawareness of BIM benefits to the project	3.35	1.107	17
Unawareness of BIM benefits to the organization	3.32	1.163	18

5.2. Validity of data

Table 2 displays the results of the Kaiser-Meyer-Olkin (KMO) measure for sampling adequacy and Bartlett's test of sphericity, which were performed on the dataset to determine its suitability for EFA. The KMO measure for sampling adequacy yielded a value of 0.697, as presented in the table, surpassing the recommended threshold of 0.6. Additionally, Bartlett's test of sphericity returned a significant value of 0.000, which is lower than the suggested threshold of 0.5. Based on these assessments, it was concluded that the data met the requirements for conducting exploratory factor analysis, as recommended by Hair et al. [60].

Table 2. KMO and Bartlett's test for the enablers of digital poverty in BIM implementation in Lagos State.

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.697
	Approx.Chi-Square	2587.864
Bartlett's Test of Sphericity	Df	153
	Sig.	0.000

Results from the exploratory factor analysis (EFA) for the enablers of digital poverty in BIM implementation in Lagos State.

Table 3. Total Variance Explained (TVE) for the enablers of digital poverty in BIM implementation in Lagos State.

Factor	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total
1	7.460	41.445	41.445	7.460	41.445	41.445	4.984
2	2.115	11.751	53.197	2.115	11.751	53.197	3.886
3	1.469	8.160	61.357	1.469	8.160	61.357	3.474
4	1.400	7.779	69.136	1.400	7.779	69.136	3.710
5	1.157	6.427	75.562	1.157	6.427	75.562	3.181
6	0.995	5.530	81.093				
7	0.717	3.984	85.076				
8	0.593	3.296	88.372				
9	0.522	2.901	91.273				
10	0.367	2.039	93.312				
11	0.283	1.573	94.886				
12	0.259	1.437	96.323				

Table 3. (*Continued*).

Factor	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings
	Total	**% of Variance**	**Cumulative %**	**Total**	**% of Variance**	**Cumulative %**	**Total**
13	0.213	1.183	97.506				
14	0.160	0.887	98.392				
15	0.107	0.592	98.984				
16	0.086	0.479	99.463				
17	0.065	0.363	99.826				
18	0.031	0.174	100				

Extraction method: Principal component analysis.

Before performing the principal axis factoring, the suitability of the data for conducting EFA was assessed through the application of the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy and Bartlett's test of sphericity. The KMO measure demonstrated a value exceeding the recommended threshold of 0.6, while Bartlett's test yielded a significant value lower than the prescribed 0.5. Based on these results, it was confirmed that the data was suitable for EFA.

All 18 variables measured in the study underwent principal axis factoring with a direct oblimin rotation. The eigenvalue criterion, which involves retaining factors with eigenvalues greater than 1.0, was employed. Consequently, five factors with eigenvalues exceeding 1 were retained. These retained factors had eigenvalues of 7.460, 2.115, 1.469, 1.400, and 1.157, explaining 41.445%, 11.751%, 8.160%, 7.779%, and 6.427% of the variance, respectively. In total, these five clusters of factors accounted for 75.562% of the total variance, underscoring the significance of all 18 measured variables (as shown in **Table 3**).

Table 4. Pattern matrix (PM) for the enablers of digital poverty in BIM implementation in Lagos State.

S/N	Enablers of digital poverty	Component				
		1	**2**	**3**	**4**	**5**
	Exploration enablers					
	Limited financial resources	0.810				
	Inadequate institutional arrangements	0.697				
	Shortage of ICTs facilities and skills	0.695				
1	Inadequate ICT content in Quantity surveying courses	0.686				
	Lack of client demand	0.682				
	Lack of confidence with automation	0.661				
	Unawareness of BIM benefits to the project	0.622				
	Unawareness of BIM benefits to the organization	0.570				
	Incognizant enablers					
2	Erratic power supply		0.491			
	Lack of encouragement from the government		0.436			

Table 4. (*Continued*).

S/N	Enablers of digital poverty	Component				
		1	**2**	**3**	**4**	**5**
3	**Compliance enablers**					
	Resistance to change from traditional practices			0.663		
	Lack of BIM specialists in the region			0.517		
	High cost of training to the existing staff			0.452		
4	**Infrastructural enablers**					
	High cost of investment				0.630	
	High costs of software/hardware upgrades				0.420	
5	**Automation enablers**					
	Unsupportive organizational culture					0.435
	Lack of experience and knowledge					0.434
	Lack of support from senior management					0.420

Extraction method: Principal component analysis.

The analysis exposed a sharp decline in the values of the five components, falling below the threshold of 1.0. These five components represent the clusters intended for interpretation in this factor analysis and were subjected to direct oblimin rotation. The selection of direct oblimin rotation was made due to the intercorrelation among the 18 variables. The outcome of the direct oblimin rotation generated the pattern matrices, which are displayed in **Table 4**, revealing the variables categorized within each of the five components jointly identified through the total variance explained and scree plot.

The scree plot depicted for the dataset presents the eigenvalues corresponding to all 18 analyzed variables as shown in **Figure 1**. Within the scree plot, only five factors register values exceeding 1 on the eigenvalue axis. Upon closer examination of the scree plot, it becomes evident that the last significant discontinuity occurs at the fifth factor, affirming the extraction of five factors. The steeper segment of the slope signifies the major factors, while the gradual decline represents the remaining factors with eigenvalues below 1.

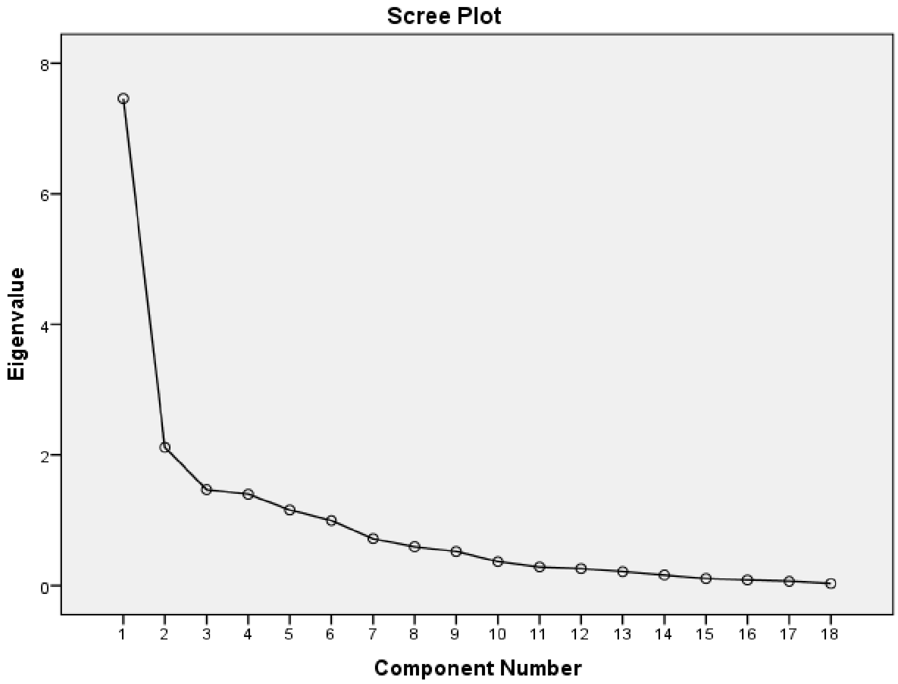

Figure 1. Scree plots the enablers of digital poverty in BIM implementation in Lagos State.

Factor cluster report for the enablers of digital poverty in BIM implementation in Lagos State.

The pattern matrix displays the coefficients representing the linear combination of the measured variables. Negative factor loadings suggest that the variables should be interpreted in the opposite direction, but this doesn't mean they are excluded from the constructs Pallant [55]. Each factor was given a name that encompasses all the variables it represents. In cases where selecting a suitable name posed challenges, the variable(s) with the highest factor loadings among all the variables grouped under a factor were used to name that specific factor. The report outlines the five factor groupings as follows:

1) Factor 1, as presented in **Table 4**, encompasses a total of eight (8) variables. These variables include limited financial resources, inadequate institutional arrangements, a scarcity of ICT facilities and skills, insufficient ICT content in quantity surveying courses, a lack of client demand, a lack of confidence in automation, a lack of awareness of BIM benefits to the project, and a lack of awareness of BIM benefits to the organization. This factor contributes to 41.445% of the total variance. It can be observed that all the mentioned variables within this cluster are associated with creating a conducive environment for exploration and enhancing productivity. Therefore, this cluster can be aptly referred to as "Exploration Enablers". As shown in **Table 4**, two (2) variables are loaded in cluster 2. These variables are erratic power supply and lack of encouragement from the government. The stated variables in this cluster relate to lack of knowledge and awareness. Therefore, this cluster can be named incognizant enablers. This cluster accounted for 11.751% of the total variance.
2) Cluster 3 contains three (3) variables, namely, resistance to change from traditional practice, scarcity of BIM specialists in the region, and the substantial training costs for existing staff. This cluster accounts for a total variance of

8.160%. The overarching term that adequately characterizes these variables is "Compliance Enablers".

3) Loaded in cluster four are two (2) variables, which are the high cost of investment and the high costs of software/hardware upgrades. These loaded variables in this factor are the most essential and prevalent, having a total variance of 7.779%. The general term that is common to the stated variables is infrastructural enablers.
4) Loaded in cluster five are three (3) variables, which are unsupportive organizational culture, lack of experience and knowledge, and lack of support from senior management. These loaded variables in this factor are the most essential prevalent enablers of digital poverty among quantity surveyors. The clusters have a total variance of 6.427%. The general term that is common to the stated variables is automation enablers.

6. Conclusions

The enablers of digital poverty highlight the complex challenges faced by quantity surveyors in adopting digital technology like BIM, which fosters digital poverty. The descriptive statistic indicated lack of experience and knowledge as the key enabler of digital poverty. Professionals with no experience may rely on intermediaries for digital tasks, leading to inefficiencies as many of the digital technologies require prior experience to adopt the technology effectively. Addressing these enablers is crucial to reducing digital poverty. The identified various enablers of digital poverty are categorized into five clusters, namely exploration enablers, incognizant enablers, compliance enablers, infrastructural enablers, and automation enablers.

Furthermore, the most prevalent exploration enablers of digital poverty among quantity surveyors include limited financial resources, inadequate institutional arrangements, shortage of ICT facilities and skills, insufficient ICT content in quantity surveying courses, lack of client demand, lack of confidence with automation, unawareness of BIM benefits to the project, and unawareness of BIM benefits to the organization.

Also, two significant incognizant enablers of digital poverty are erratic power supply and lack of encouragement from the government. Erratic power supply disrupts the use of digital devices, while government support is essential for digital infrastructure development. Additionally, digital poverty can arise from a lack of support and resistance to change from traditional practices, a shortage of BIM specialists in the region, and the high cost of training existing staff in BIM technology.

In addition, high costs of investment in digital technologies and expensive software/hardware upgrades act as barriers to digital inclusion, especially for low-income regions and marginalized communities. Finally, unsupportive organizational culture, lack of experience and knowledge, and the absence of support from senior management can hinder the effective adoption of digital technologies and contribute to digital poverty.

While this study provides valuable insights into the enablers of digital poverty among quantity surveyors in Nigeria, it is important to acknowledge that the findings may not be directly generalizable to other regions or contexts. The specific enablers and their relative importance may vary depending on factors such as economic development, technological infrastructure, cultural norms, and the specific characteristics of the construction industry in different locations.

Further research is needed to investigate the applicability and transferability of these findings to other regions and contexts. Comparative studies across different countries and regions can help identify common patterns and region-specific challenges in addressing digital poverty among construction professionals.

7. Recommendation

To mitigate digital poverty in Building Information Modeling (BIM) implementation among quantity surveyors in Lagos State, it is crucial to prioritize digital skills training to bridge knowledge gaps, launch awareness campaigns to educate stakeholders about BIM's advantages, invest in digital infrastructure development, especially in underserved areas, advocate for government support and the incorporation of BIM in public projects, establish standardized BIM training programs and collaborative platforms, encourage innovation and digital readiness within construction organizations, and provide financial incentives to promote BIM adoption. Finally, future studies should aim to employ stratified random sampling to enhance the representativeness of the sample and focus exclusively on a single response mode to eliminate variability.

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