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Barriers to Digital Technology Deployment in Value Management Practice

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Abstract: In the quest to promote constant value for money, value management (VM) has been proposed and adopted within the construction industry of countries across the world. To improve the VM process for a more effective outcome, pervasive digital technologies can be employed throughout a project and in the VM process. However, developing countries like South Africa are still lagging in using these emerging technologies. Therefore, this study assessed the digital technologies that can improve the VM process and the barriers hindering their usage within the construction industry. The study adopted a postpositivism philosophical stance with a questionnaire used to gather quantitative data from construction professionals that have participated in VM exercises within the South African construction industry. The data gathered were analysed using mean item score, standard deviation, the Kruskal-Wallis H-test, multiple linear regression and exploratory factor analysis. The study found with high predictive accuracy that digital technologies such as computer-based software, BIM, mobile devices, electronic meeting tools, cloud computing, augmented and virtual realities will significantly impact the overall success of VM practices. Furthermore, the barriers to the effective deployment of these technologies in the VM process can be categorised into (1) cost and awareness, (2) complexities of the VM and digital tools, (3) the construction industry's digital culture, and (4) the availability of technology and expertise. This study provides a theoretical backdrop for future studies exploring the use of digital technologies for VM practices—an aspect that has not gained significant attention in VM discourse in the construction industry.

Keywords: construction industry; digital technology; value for money; value management

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1. Introduction

Technological advancement is rapidly changing the way construction projects are being delivered in countries worldwide. Digital technology like building information technology (BIM) is changing how construction participants collaborate on projects with significant improvement in the performance of the construction projects being delivered [1]. Robotics and automation (R&A) are equally offering cost-effective construction by reducing labour and material costs as well as ensuring safety and improved construction workforce productivity [2]. In the same vein, while big data analytics (BDA) is helping in creating quick decision-making on projects, cloud computing and the internet of things (IoT), in conjunction with BIM, are rapidly improving the communication and collaboration on projects [2–4]. Based on the usefulness of these technologies, it is no surprise that studies have continued to focus on their use in the management of construction works [5–8].

However, one management aspect of construction that has seen less focus in terms of using digital tools is value management (VM).

VM was developed in the late 1940s to develop alternative approaches that will meet the required function of scarce resources [9]. Over the years, this approach has gained prominence in construction due to the need to deliver value for clients' limited budgets [10]. McGeorge and Palmer [11] described VM as the process of achieving value for money for construction clients through the delivery of quality products at a reasonable cost. Odeyinka [12] noted that through the careful management of a project's development from planning to completion using proper evaluation of all decisions against a value system outlined by the client, VM is able to maximise functional value in projects. However, the successful implementation of the VM process has not come without its challenges. Issues relating to poor communication among relevant stakeholders and within VM teams and poor technological advancement have been noted [13–16].

Construction participants stand a chance to deliver better value in projects through technology-driven VM processes. For instance, BIM, cloud computing and IoT can help improve communication and team collaboration among project teams—including VM teams [17]. There is also, through BIM, the opportunity for the VM team to detect any clash in designs that might have been overlooked by the project's design team early in the project. This will allow corrections to be made on time to avoid unnecessary cost, time and material wastage during construction [1]. Also, through BDA, the VM team can collect, store, and analyse data easily to make informed decisions necessary for the project's success [18,19]. Unfortunately, the use of digital technologies in the construction industry of developing countries like South Africa has been extremely slow due to several challenges facing the industry [2]. Evidently, this slow adoption of digital tools will also apply to diverse construction management practices, including VM. As a result, there is an absence of studies assessing the use of digital technologies in the VM process within the construction industry. A quick literature search using notable databases such as Scopus and Web of Science further affirms this assertion, as not a single related publication was found using VM and digital technologies together as keywords. This shows a knowledge gap in VM studies that needs to be filled. Much moreso, the success of the VM process in the construction industry of developing countries like South Africa has been hampered by the lack of use of technologies, and this has led to the industry's inability to deliver value for most clients [15,20]. Based on this understanding, the purpose of this research was to unearth the digital technologies that will improve the VM process and assess the issues that might serve as barriers to the use of these technologies in the quest for effective VM practices in the construction industry. This was done to improve the use of digital technologies to create value for construction clients and to improve the value delivery performance within the construction industry.

2. Review of Literature

2.1. Overview of Value Management

The concept of VM had evolved over the years since its introduction in the late 1940s when it was referred to as value engineering. The concept started off as an approach that involves using alternative methods rather than replacing scarce components required in the production system. Instead of searching for alternative components to meet production demand, value engineering proposed using new or alternative methods of fulfilling the function of those scarce components. Since the introduction of this concept, the removal of unnecessary costs and improvement in production using this analysis of functions has been noted [9,10]. VM has received several descriptions since its introduction into several fields (construction inclusive) [21]. Male and Kellye [22] described it as a proactive, creative, problem-solving or problem-seeking practice that maximizes the functional value by managing its development from concept to use. Padhye [23] described VM as a structured problem-solving practice that possesses tremendous solutions to customer dissatisfaction issues. This is because VM offers stakeholders (customer inclusive) the opportunity to be involved in the decision-making process of a project's delivery [24]. VM has been described as an approach that offers value for money and client satisfaction through delivering quality products at the most reasonable cost [11]. The VM practice involves conveying a VM workshop at several project stages. The purpose of these workshops is to bring together project stakeholders to brainstorm on the different approaches towards which value can be achieved on the project. The workshop follows several phases, which are mostly sequential in nature. First, functional analysis is conducted, and then comes the creative, evaluation, development and presentation phases [10,13]. In construction, VM allows the scrutiny of diverse design options and methods of construction. This, in turn, allows for improving designs and identifying possible problems that might affect the project's budget [10,24]. The inherent benefits offered by the VM process have led to its adoption in several developed and developing countries around the world. Countries such as Australia, Japan, the United Kingdom, Saudi Arabia, and Malaysia have all explored the use of VM in the delivery of public projects, and significant outcomes have been recorded [10,16,25].

Despite its significant benefits, the use of VM is challenged by several factors. These challenges include the absence of VM experts, lack of training, lack of management support, difficulties in stakeholders' co-ordination, obstruction from the VM team, poor technological advancement, lack of knowledge of the use of electronic VM systems as well as poor communication among the VM team [13–16]. Digital technologies can help address some of these identified VM challenges.

2.2. Digital Technologies in Construction

Ibem and Laryea [26] have noted that digital tools comprise software, methods, hardware, networks and networking systems, as well as intelligent systems that promote communication, collaboration, and teamwork. Several digital technologies are rapidly changing the way construction activities are being conducted, and the use of these digital tools can ensure the smooth and successful running of the VM process. For example, BIM, which involves using software models to simulate the design and delivery process of construction works [27], has proved effective for cost and time savings in construction projects. Furthermore, this tool has fostered positive collaboration on projects [28] and made it possible to deliver more sustainable designs within the industry [29]. In addition, IoT, which involves connecting objects using the internet with a pre-set protocol involving information sensors [30], has proven to improve communication among project participants [3,4]. Ikuabe et al. [31] also noted the importance of cyber-physical systems to the effective and efficient delivery of construction works.

Furthermore, BDA, which involves analysing complex and massive data to unearth the significant patterns and trends needed to make informed decisions [32], offers better predicting of future occurrences on construction projects [33]. Cloud computing has also been noted as a viable tool for successfully delivering construction works [2]. This technology allows computing resources to be shared among diverse participants [34]. Also, the use of visualisation tools such as augmented reality (AR) and virtual reality (VR), which provide a high immersive experience of the real world through the use of virtual data as well as a virtual experience, can significantly reduce errors in projects [35]. Studies have shown that VR offers the enhancement of site safety and productivity through the use of VR supported tools [36,37]. Also, AR help reduce on-site error and rework through the use of AR-based tools [38,39]. Other sensing and data gathering tools such as sensors, laser scanners, and drones can also effectively deliver construction projects. Drones can be integrated with BIM to achieve three-dimensional modelling data and create innovative technology applications [40]. Laser scanning can offer quality information delivery in projects because it can capture specific construction scenes, and the information can help create a virtual environment [41]. It can also offer quality detection of geometric deviation in construction, and this provides the benefits of comparing as-designed building information models with actual products [42]. Furthermore, blockchain technology can help achieve sustainable construction and ensure projects are delivered within limited budgets and schedules due to its different applicability [43,44]. The blockchain is a digital ledger, encrypted to allow transactions to be done in a shared manner, and its application is increasing in diverse sectors including construction [44,45].

2.3. Barriers to the Use of Digital Technologies for Value Management

Evidently, these digital technologies like BIM, BDA, cloud computing, IoT, and R&A all offer better collaboration, cost-effective construction, speedy decision making, as well as improved communication on construction projects. These benefits can also transcend into the VM process if these technologies are adopted. Unfortunately, the use of digital technologies in construction, just like VM, is constrained by several issues. The issue of the absence of well-trained personnel to handle digital tools has been noted within the construction industry. In the view of Sacks and Barak [46], to get these well-trained personnel, organisations must be ready to invest in the training and re-training of their workforce. Unfortunately, this comes with its associated cost, which most organisations are unwilling to incur [47]. Aside from the cost associated with training, the cost of acquiring and maintaining digital technologies has also been noted as a crucial deterring factor, especially in developing countries riddled with small and medium organisations that struggle financially [2,40,48,49]. The construction industry has, over time, been berated for its slow adoption of technologies required for the successful delivery of construction products [50].

Moreover, the digital culture of the industry is poor, and the support for the use of digital tools is not encouraging [2]. This is evident in the resistance to change by construction workers and the poor awareness and understanding of the inherent benefits of using digital technologies in construction [48]. Studies have revealed that the use of digital tools is seen as a threat to the jobs of construction workers; hence significant resistance to the introduction of these digital tools is faced by the workers and trade unions [2,47,49]. Therefore, sensitizing construction stakeholders on the inherent benefits of these technologies is important. This will also help construction clients and VM teams understand the potential benefits of using these digital tools for the entire VM process.

The complexity of both the VM process and digital technologies can also pose a significant challenge to digital tools. Golizadeh et al. [40] noted that some digital technologies are complex and require specific expertise to operate. When such expertise is unavailable, adopting these technologies can prove difficult. Also, the VM process involves information sharing, and as such, data security and privacy will be an essential element in determining whether a technology will be adopted or not. Past studies have signified that data insecurity and lack of privacy with information have been a deterring factor in the use of some digital technologies on construction projects [2,34,51]. This challenge is also related to the legal issues relating to information retrieval and usage that have hampered the use of digital technologies. This is because, worldwide, legislation on the use of digital technologies is still evolving, and as such, several issues might arise regarding how information is shared and used, especially for collaborative platforms like BIM and blockchain technology [40,52]. Drawing from the general challenges facing the use of VM as well as digital technologies within the construction industry, this study assessed the barriers to the use of digital tools in VM practices using fourteen barriers.

3. Research Method

The study adopted a postpositivist philosophical view which informed the use of a quantitative method with a questionnaire adopted as the instrument for data collection [31,53,54]. The choice of the questionnaire was premised on the notion that it allows a wider coverage within a short time frame [55]. The questions in the questionnaire were designed based on the literature review of VM and digital technology related works. The questionnaire is comprised of three sections—the first section harnessed information on the background of the respondents. The second section assessed the digital technologies that will impact the VM practice, while the third section assessed the barriers to using digital tools for effective VM. These second and third sections were assessed using a five-point agreement scale, with five strongly agreeing and one strongly disagreeing. The respondents to the survey were comprised of professionals that have been involved in VM workshops/practice within the South African construction industry. Past studies have noted that professionals that have participated in VM practice are few, as the practice is not common within the construction industry in most developing countries [10,20]. Therefore, to gather adequate responses, the snowball approach was adopted. The snowball approach has become popular among construction studies where the exact number of the target population is unknown from the initial stage of the research [56]. Using the snowball approach, stating the target population and the total number of questionnaire distribution becomes difficult, thus making the calculation of a response rate practically impossible. Based on the snowball approach adopted, a total of 80 professionals that have been involved in VM practices participated in the survey.

The data analysis was done using diverse statistical methods. For the data on the background of the respondents, frequency (f) and percentage (%) were employed. For the second and third sections, the reliability of the questions asked was tested using the Cronbach alpha (α) test. A cut-off of ≥ 0.7 was set for this test [57]. Based on the attainment of good reliability, the data from these two sections were then analysed using the mean item score ($\overline{X}$) to rank the different identified digital technologies and the barriers to their usage for effective VM. A Kruskal-Wallis H-Test (K-W) was used to test the significant difference in the view of the different respondents. This became important as the respondents were drawn from different organisation types (contracting, consulting and government). The K-W test gives a chi-square (χ^2) and a p-value that shows the significant relationship in the response of respondents from the different groups. Kendall's coefficient of concordance (Kendall's W) was also adopted to further confirm the relationship in the ranking of the variables by the respondents. Multiple linear regression (MLR) was also adopted to test the impact of the identified digital technologies on the overall success of VM. An exploratory factor analysis (EFA) was conducted based on the number of barriers assessed to regroup these barriers into more manageable subscales. Although studies have noted that large samples (over 100) are needed for this test to be conducted, others have noted that if the derived communalities for the variables are high (i.e., $\geq$ 50%), then less emphasis should be placed on the samples [58]. Pallant [59] further noted that communalities as low as 0.30 had been considered acceptable in some cases. Also, the Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy and Bartlett's test of sphericity (BTS) were used to ascertain the suitability of the data for EFA. Both tests gave acceptable values, thus allowing EFA to be conducted on the data gathered.

4. Findings and Discussion

4.1. Background Information of Respondents

The respondents for this study were drawn from contracting (49%, f = 39), consulting (25%, f = 20) and government organisations (26%, f = 21). These respondents comprised 62% (f = 49) construction and project managers, 12% (f = 10) architects, 12% (f = 10) engineers, and 14% (f = 11) quantity surveyors. The majority (55%, f = 44) of these respondents have a bachelor's degree, while 27% (f = 22) have national diplomas and 18% (f = 14) have master's degrees. For the years of experience, most of the respondents (65.1%, f = 52) have been in the South African construction industry for more than five years, with 16.3% (f = 13) having above 20 years of experience in the industry. Only 18.8% (f = 15) have below five years of working experience in the industry. Following these results, it can be said that the respondents to the study have a considerable understanding of happenings within the South African construction industry, and their response is based on their experience in VM shaped by their years of working experience in the industry.

4.2. Digital Technologies That Can Impact the VM Process

The result of the reliability test conducted to ascertain the reliability of the questions used in assessing the digital tools that might influence the VM process gave an α-value of 0.928. This implies that the questions asked were reliable and the variables had significant internal consistency. The result in Table 1 shows the different digital technologies that might influence the VM process if adopted on a project. From the result, it is evident that the respondents agreed that all the assessed digital tools will affect the VM process positively. This is because the all the assessed digital technologies revealed an $\overline{X}$ of above average of 3.0. Top among these digital tools is the use of computer-based software ($\overline{X}$ = 4.63, p-value = 0.068), BIM ($\overline{X}$ = 4.61, p-value = 0.013), and mobile devices ($\overline{X}$ = 4.60, p-value = 0.108). The K-W test revealed some disparity in how the respondent rated four out of the six assessed technologies. These four technologies gave a p-value of below 0.05. This implies that the respondents did not have a uniform view regarding the significance of these four technologies in improving the VM process. However, overall, Kendall's W gave a value of 0.34 at a degree of freedom (Df) of 9 with a calculated χ^2 of 243.7, which is above the 16.92 critical χ^2 derived from a statistical table. This result implies that, in a general view, the ranking by the respondents is related to each other within the groups, and that no disparity exists [60].

Table 1. Digital technologies that can affect the VM process.

Digital Technologies	$\overline{X}$	SD	Rank	K-W χ^2	K-W p-Value
Computer based software	4.63	0.919	1	5.364	0.068
Building information modelling	4.61	0.934	2	8.674	0.013 **
Mobile devices	4.60	0.936	3	4.460	0.108
Electronic meeting tools (zoom, Microsoft teams etc.)	4.58	0.978	4	4.445	0.108
Cloud computing	4.49	0.941	5	8.079	0.018 **
Augmented and virtual realities	4.46	0.954	6	7.821	0.020 **
Big data analytics	4.39	1.049	7	9.091	0.011 **
Blockchain technology	4.33	1.065	8	6.552	0.038 **
Digital twin	4.05	0.840	9	3.517	0.172
Internet of Things	4.04	0.834	10	2.075	0.354
Kendall's W	0.34				
Calculated χ^2	243.70				
Critical χ^2 from statistical table	16.92				
Df	9				
Asymp. Sig.	0.000				

Note: ** = p-value significant @ < 0.05.

In determining the impact of these digital technologies on the overall success of the VM process, further analysis was conducted using MLR. According to Pallant (2011), MLR is ideal for determining how well a group of factors predict an expected outcome. In this case, the ten digital tools were regressed against the success of VM practices. As a result, Table 2 shows a t-value of 44.760, which is greater than the 1.96 thresholds for a significant model at the conventional 95% confidence interval (p-value < 0.05). This result implies that the hypothesised relationship between the identified digital technologies and the overall success of VM once these technologies are adopted, is significant. Furthermore, R^2, which shows the predictive power of the model, was calculated. This analysis gave an R^2 value of 0.846, which implies that the developed model has a very high predictive power as the derived value is close to one [57]. Thus, it can be concluded that the identified digital technologies will significantly impact the success of VM processes if adopted.

Table 2. Summary of regression analysis conducted.

Model	β	Std. Error	*t*-Value	*p*-Value	R	R^2	Adjusted R^2	Std. Error of the Estimate
1	5.218	0.118	44.760	0.000	0.927 a	0.846	0.846	0.197

a. Predictors: (Constant), Ten assessed digital technologies.

4.3. Barriers to the Use of Digital Technologies in Value Management Practices

In assessing the barriers to the use of digital technologies for effective VM practice, the respondents were presented with 14 barriers to rank based on their level of agreement. These barriers revealed an α-value of 0.772, which is above the set cut-off of 0.7. This implies that the questions asked were reliable and that the variables had significant internal consistency. The result in Table 3 shows that the respondents agreed that lack of proper digital training is a major issue in deterring the application of digital tools in VM practice. This barrier was ranked first with an $\overline{X}$ value 4.40. This is followed by the high cost of maintaining digital technologies needed ($\overline{X}$ = 4.24, *p*-value = 0.516), failure to envisage the benefits of digital technologies to the VM exercise ($\overline{X}$ = 4.21, *p*-value = 0.260), resistance to change ($\overline{X}$ = 4.18, *p*-value = 0.033), and clients' unwillingness to incur extra cost associated with the use of digital technologies ($\overline{X}$ = 4.14, *p*-value = 0.291). The least ranked barrier is data insecurity with an $\overline{X}$ value of 3.26 and a *p*-value of 0.103. While this barrier might be considered the least critical issue, it has an $\overline{X}$ value above the average of 3.0. This means that issues surrounding the security of information when digital technologies are employed can be one deterring the use of digital tools in VM practices. The K-W test revealed that the respondents from the contracting, consulting and government organisations had a divergent view regarding two of the identified barriers. These two barriers (lack of proper digital training and resistance to change) had a *p*-value of below 0.05. However, there is no disparity in the view of the respondents in rating the remaining 12 variables, as a *p*-value of above 0.05 was derived. Overall, Kendall's *W* gave a value of 0.29 at a Df of 13 with a calculated χ^2 of 298.20 that is above the 22.36 critical χ^2 derived from a statistical table. This result implies that, in a general view, the ranking by the respondents is related to each other within the groups, and no disparity exists.

Table 3. Barriers to the use of digital technologies for VM practices.

Barriers	$\overline{X}$	SD	Rank	K-W χ^2	K-W *p*-Value
Lack of proper digital training	4.40	0.686	1	7.186	0.028 **
High cost of maintaining digital technologies	4.24	0.945	2	1.322	0.516
Failure to envisage the benefits of digital technologies to the VM exercise	4.21	0.807	3	2.693	0.260
Resistance to change	4.18	0.868	4	6.813	0.033 **
Clients' unwillingness to incur extra cost	4.14	0.882	5	2.470	0.291
Unavailability of needed digital technologies	4.03	0.224	6	0.494	0.781
Inadequate technical know-how among VM experts	4.00	0.159	7	2.894	0.235
Poor digital culture of the construction industry	3.94	0.431	8	3.018	0.221
High cost of acquiring needed digital technologies required VM process	3.86	0.725	9	1.128	0.569
Legal issues associated with the use of digital technologies	3.78	0.675	10	0.909	0.635
Lack of awareness of the needed digital technologies among VM experts	3.73	0.795	11	5.257	0.072
Nature of the VM exercise	3.44	0.613	12	4.636	0.098
Complexity of digital technologies	3.43	0.591	13	5.929	0.052
Data insecurity and privacy issues	3.26	0.497	14	4.547	0.103
Kendall's W	0.29				
Calculated χ^2	298.20				
Critical χ^2 from statistical table	22.36				
Df	13				
Asymp. Sig.	0.000				

Note: ** = *p*-value significant @ < 0.05.

Before conducting EFA, a preliminary analysis was conducted to ascertain the suitability of the data for factor analysis. First, the KMO measure of sample adequacy was assessed, and this gave a value of 0.712, which is above the 0.6 threshold (Pallant, 2011). Also, the BTS test gave a significant value of 0.000. furthermore, the result in Table 2 gave a communality of between 0.440 to 0.970, which is considered high enough for a good relationship between each variable [59]. Based on these outputs, it was concluded that the sample and data gathered are adequate for EFA to be conducted. Thus, EFA was conducted using principal component analysis (PCA), as it is the most suitable form of factor analysis that allows for the regrouping of variables into more manageable clusters [59]. After seven iterations, four principal components were derived with eigenvalues of above 1.0, as seen in the scree plot in Figure 1 and Table 4. These four components account for a cumulative variance of 81.1%.

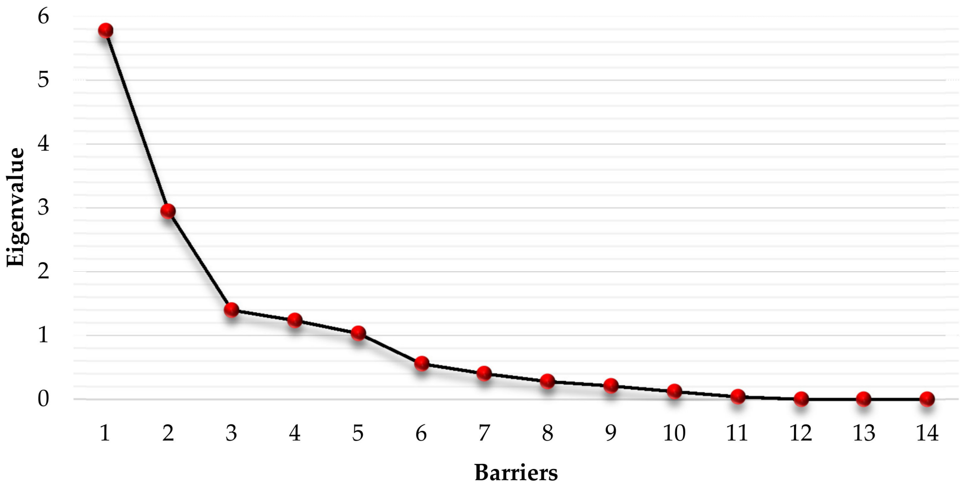

Figure 1. Scree plot.

Table 4. EFA of the barriers to the use of digital technologies for VM practices.

Barriers	Component				Comm.
	1	**2**	**3**	**4**	**Extract.**
Component 1 (41.3%)					
High cost of acquiring needed digital technologies	0.947				0.940
High cost of maintaining digital technologies needed	0.944				0.931
Lack of awareness of the needed digital technologies among VM experts	0.776				0.910
Legal issues associated with the use of digital technologies	0.692				0.751
Component 2 (21.0%)					
Nature of the VM exercise		0.947			0.953
Complexity of digital technologies		0.942			0.970
Data insecurity		0.797			0.861
Component 3 (10.0%)					
Poor digital culture of the construction industry			0.841		0.784
Lack of proper digital training			0.785		0.798
Resistance to change			0.720		0.827
Clients' unwillingness to incur extra cost			0.583		0.798
Failure to envisage the benefits of digital technologies to the VM exercise			0.515		0.627
Component 4 (8.8%)					
Non-availability of needed digital technologies				0.840	0.767
Inadequate technical know-how among VM experts				0.651	0.440

Note: comm. = communality extracted.

The first principal components account for 41.3% of the variance explained and have four variables. These variables are the high cost of acquiring needed digital technologies (94.7%), the high cost of maintaining digital technologies needed (94.4%), lack of awareness of the needed digital technologies among VM experts (77.6%), and legal issues associated with the use of digital technologies (69.2%). This component was renamed '*cost and awareness barriers*' based on the latent similarity in the rotated variables. The second extracted component accounted for 21% of the total variance explained and has three variables. These are the nature of the VM exercise (94.7%), the complexity of digital technologies (94.2%) and data insecurity (79.7%). This component was subsequently named '*complexity of VM and technologies barriers*'. The third component accounts for 10% of the total extracted variance and has five variables. These are lack of proper digital training (84.1%), clients' unwillingness to incur extra cost (78.5%), resistance to change (72%), failure to envisage the benefits of digital technologies to the VM exercise (58.3%), and poor digital culture of the construction industry (51.5%). This component was subsequently named '*construction industry digital culture barriers*'. The last extracted component accounts for 8.8% of the total extracted variance and has two variables: non-availability of needed digital technologies (84%) and inadequate technical know-how among VM experts (65.1%). The component was renamed the '*availability of technology and expertise barriers*'.

5. Discussion

Figure 2 gives a summary of the barriers to the use of digital technologies for VM. The findings of this study show that diverse digital tools will highly impact the success of VM practices within the construction industry. More specifically, computer-based software, BIM, mobile devices, electronic meeting tools, cloud computing, and augmented and virtual realities are all germane to the improvement of VM practices. However, the successful adoption of these tools to improve the VM practice is hampered by four main groups of factors: (1) cost and awareness barriers, (2) complexity barriers, (3) the construction industry's digital culture barrier, and (4) technology availability and expertise barriers.

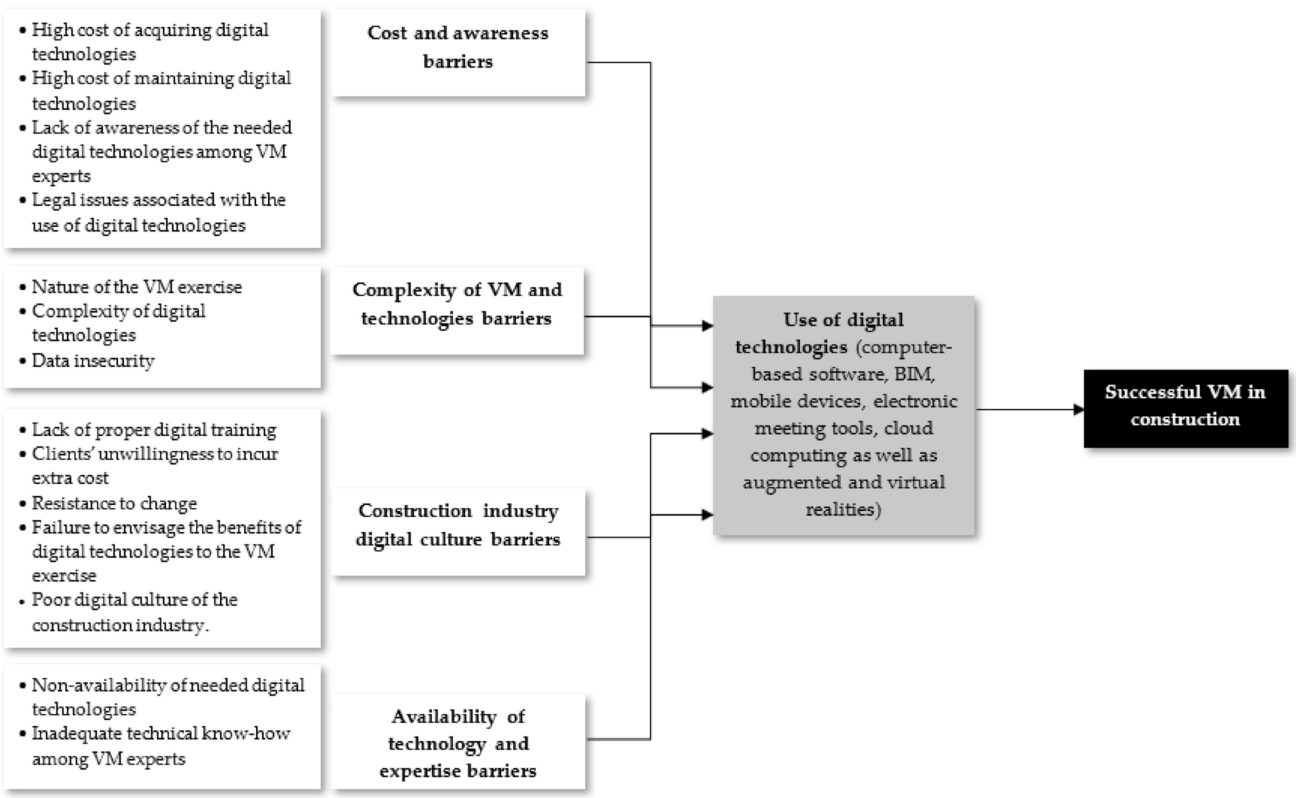

Figure 2. Summary of the barriers to the use of digital technologies for VM.

Cost and awareness barriers—This component comprised the high cost of acquiring needed digital technologies, the high cost of maintaining digital technologies needed, the lack of awareness of the needed digital technologies among VM experts, and legal issues associated with the use of digital technologies. The issue of the cost of acquiring and maintaining digital tools has been a recurring one for construction organisations, particularly in developing countries like South Africa where the industry is filled with small and medium organisations that struggle financially [2,61]. Evidently, adopting these technologies within these organisations and in the VM process might prove difficult. This finding is in line with the past submission that has noted that the cost of digital tools is a deterring element to the successful adoption of these technologies [40,48,49]. Furthermore, when there is little or no awareness of the need for these digital technologies in the VM process, adopting them becomes almost impossible. Thus, showcasing the usefulness of these technologies to the entire project and not only the VM process can help improve adoption.

Complexity of VM and technologies barriers—The component comprises the VM exercise's nature, the complexity of digital technologies, and data insecurity. The VM process requires the use of a workshop coordinated by a facilitator and requires the brainstorming and evaluation of ideas. This process can be considered complex, especially in the construction industry of developing countries where the knowledge of VM is limited [13]. This complexity, along with the complex nature of most digital tools, can hinder the use of the technologies in the VM process. This finding is in tandem with the study of Golizadeh et al. [40], who noted that some digital technologies are complex. These technologies require experts who are, in most cases, absent within the construction industry. Moreso, the issue of security of information shared within the VM process can deter the use of technologies, as noted in this current study. This is because past studies have affirmed that data insecurity and lack of privacy with information has been a deterring factor in the use of some digital technologies on construction projects [2,34,51,62]. Since the VM process is rooted in properly gathering and analysing information, ensuring that the information is safe and retrieved correctly is important. As such, the issue of data insecurity that has characterised most digital tools [29,50,62] can serve as a severe drawback for the deployment of these technologies in the VM process.

Construction industry digital culture barriers—This component comprises lack of proper digital training, clients' unwillingness to incur extra cost, resistance to change, failure to envisage the benefits of digital technologies to the VM exercise, and poor digital culture of the construction industry. Nguyen et al. [63] observed the importance of culture in adopting technologies. This culture is the belief and assumptions that shape the behaviour of the individuals and their understanding of the role of the technology being introduced [64]. Past studies have noted that the construction industry has a poor digital culture [50,62]. However, the improvement in the embrace of technological advancement within the industry as a whole will drive the use of digital tools in VM practices. This will lead to clients requesting the use of digital technologies in the delivery of their projects—an act that is currently deterring the use of digital tools within the construction industry [47,49]. Past studies have affirmed that the demand by clients for the use of digital technologies on their projects is crucial to technology adoption [2,65]. In most cases, clients are not ready to incur the additional costs that might arise with the use of VM or with extra technologies. This can emanate from the culture within the industry. If the use of technologies is a norm, embracing it for the VM process will come with little or no resistance [2,47,49]. Furthermore, studies have noted that when workers are not aware of the benefits they stand to derive from the use of technology, they tend to resist the use of such technology [48]. Some see emerging technologies as threats to jobs and the resultant effect of this perception is resistance; therefore, to ensure that digital tools are used to improve the VM process, there is a need to enlighten VM experts on the potential benefits of deploying these technologies. Showcasing the individual benefits of these technologies to the entire project and not only the VM process can help improve adoption.

Availability of technology and expertise barriers—This component includes the non-availability of needed digital technologies and inadequate technical know-how among VM experts. Evidently, adopting these technologies becomes an issue when they are not readily available. Baker [66] has earlier noted that the availability of these digital technologies is germane to the adoption process as they determine the scope and pace of technological change that will be attained. In South Africa, like in other developing countries, the ready availability of relevant digital technologies is a problem for the digital transformation of the construction industry [47]. This becomes a problem for diverse management activities that require the availability of these technologies for their success. More so, when these technologies are available, there is a need to have the right expertise that will handle them. The construction industry in developing countries including South Africa is challenged by a skill shortage [53,67–69], and this affects the effective adoption of technologies. This finding is in line with the submissions of Oke et al. [47] and Sacks and Barak [46], who have noted that the lack of well-trained personnel to handle digital tools is problem deterring technology adoption in most countries. As a result, there is a need for organisations to invest in in the training and re-training of their workforce to ensure that the right expertise is available. This can then lead to the embrace of digital tools for VM practices.

6. Conclusions

The study assessed the digital technologies required for improving VM practices in construction. Furthermore, the study unearths the barriers to the use of the identified technologies. Based on the findings, it is concluded that the use of digital technologies on a project will help improve the VM process significantly. Computer-based software, BIM, mobile devices, electronic meeting tools, cloud computing, augmented and virtual realities will have a significant impact on the success of the VM process. This result is based on the high predictive accuracy derived from the regression analysis conducted. However, the use of these technologies is constrained by key factors relating to cost and awareness, complexities of the VM and digital tools, the construction industry's digital culture, as well as technology availability and expertise. Thus, in the quest to provide construction clients with value for money through effective VM exercises, management in construction organisations needs to embrace the use of digital technologies on projects they handle. These digital technologies should be employed from the inception of the project and not necessarily for the VM exercise alone. Based on the impact of the use of these technologies on the VM process, it is also important to create awareness among VM experts on the need to adopt relevant technologies to improve the VM practice. Furthermore, client financial support will go a long way in promoting the use of these technologies. Creating workshops and seminars to sensitize experts on the use of these technologies, as well as to demonstrate their inherent benefits to the VM exercise, will help promote technology adoption in the VM process. These awareness programmes can be initiated by professional bodies and supported by the management of organisations responsible for delivering these technologies. Also, top management in construction organisations can help equip professionals in their organisations with the required training and retraining on digital technology usage. This will help them succeed in the use of digital tools when they are part of a VM exercise. Furthermore, there is a need for favourable legislation and regulations that support digital tools in construction projects. Through these policies, the digital culture within the industry can improve, and the fear of industry practitioners that might lead to resistance to change can be avoided.

The findings of this study have showcased the digital technologies that can be adopted on construction projects to help improve the management of such projects through an effective VM process. The findings offer clients, the management of construction organisations and professionals involved in the VM process insight into the challenges deterring the use of these technologies for effective VM. Furthermore, as a result of the absence of research on the role of digital technologies in the VM process, the findings of this study provide a significant theoretical contribution to the existing VM discourse. Theoretically, this study provides insight into the technologies that can be further explored in future works on successful VM driven by digital technologies. The barriers identified and further grouped in this study can serve as a bases for exploration in future works conducted in this area. Based on the limitation of the study, directions for the future are provided. For instance, due to the slow adoption of VM practice in South Africa and the rareness of VM participants, a small sample was used for this current study. Future works should consider including other project participants such as clients' representatives and end-users with knowledge of VM to get a wider view of the topic. In addition, a quantitative approach was used in this study. Further studies can be conducted using qualitative or mixed-method strategies, particularly in other countries where such a study has not been conducted.

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