buildings

MDPI

Article

Immersive Technology Implementation in the Construction Industry: Modeling Paths of Risk

Adedeji Olushola Afolabi [1], Chukwuma Nnaji [2,*] and Chioma Okoro [3]

[1] Department of Building Technology, Covenant University, P.M.B 1023, Ota 112233, Nigeria; adedeji.afolabi@covenantuniversity.edu.ng
[2] Department of Civil, Construction and Environmental Engineering, The University of Alabama, 3043 HM Comer, Tuscaloosa, AL 35487, USA
[3] Department of Finance and Investment Management, University of Johannesburg, Johannesburg P.O. Box 524, South Africa; chiomao@uj.ac.za
* Correspondence: cnnaji@eng.ua.edu

Abstract: The purposes of this paper are to identify risk factors impacting the successful implementation of immersive reality technology (ImT) in the construction industry, analyze these risk factors (impact and probability), assess the relationships among different categories of risk factors, and provide recommendations to improve ImT implementation. A literature review, a pilot test based on expert interviews, and a questionnaire survey were used. First, the risk factors of ImT applications were identified by consulting the relevant literature on virtual reality, mixed reality, and augmented reality; these were subsequently grouped into five categories—technology, operation, individual/worker, investment, and external. Next, a questionnaire survey was designed and distributed to relevant construction practitioners in South Africa (usable response = 175). Twenty-one ImT implementation risk factors were identified, and risk criticality scores ranged from 2.02 to 3.18. High investment cost, the need for extensive worker training, and the possible introduction of new risks for workers were rated as significant risks. The present study confirmed three statistically significant hypothesized risk paths—namely, those between external issues and individual/worker's concerns, between external issues and investment limitations, and between individual/worker's concerns and technology concerns. The present study contributes to the literature regarding the adoption of construction technology by providing a list of critical risk factors that could be used to develop models and tools for assessing ImT adoption and guide practitioners involved in integrating ImTs.

Keywords: augmented reality; critical factors; immersive technologies; mixed reality; risk paths; virtual reality; innovation implementation

Citation: Afolabi, A.O.; Nnaji, C.; Okoro, C. Immersive Technology Implementation in the Construction Industry: Modeling Paths of Risk. *Buildings* **2022**, *12*, 363. https://doi.org/10.3390/buildings12030363

Academic Editors: Jurgita Antucheviciene and Audrius Banaitis

Received: 28 January 2022
Accepted: 10 March 2022
Published: 16 March 2022

1. Introduction

Within the construction industry, the position of a catalyst that accelerates the growth of a nation's economy has been assumed; thus, has often been referred to as the engine of a nation's development [1]. However, this industry's performance has been criticized for being poor compared to other sectors such as healthcare and manufacturing, particularly in terms of work productivity, delivery quality, safety, and system functionality [2,3].

A modernized construction system supported by technological development could reduce or eliminate the challenges of meeting expected construction performance [4]. Research has affirmed that digital technologies could significantly improve projects' cost, quality, and productivity [5–7]. Moreover, Nnaji and Karakhan [8] posit that applying technologies could reduce the number of accidents during construction projects, thereby improving the safety and health of workers. According to Ramilo and Embi [6], construction firms need to adopt and use emerging technologies because of their benefits, which enable organizations to be more competitive, secure more projects, and improve their financial results.

Recent advances in the construction industry have led to the deployment of technologies, such as building information modeling (BIM) for enhanced communication [9], drones for site inspections and surveys [10], wearable sensing devices for monitoring worker health and safety [11], laser scanning for improving coordination, and on-site single-task robots for assisting laborers and speeding up the construction process [12,13].

Another technology that has immense utility in the construction industry is immersive technology (ImT). ImTs extend reality or create new realities by leveraging the 360-degree space [14]. There are different types of ImTs, including virtual reality (VR), augmented reality (AR), and mixed reality (MR) [14]. Several studies have cited those substantial benefits can be derived from implementing ImTs. For instance, ImTs have been successfully used to enhance project communication [15], worker training [16], and coordination [17] in the construction industry. According to Noghabaei et al. [18], industry experts anticipate growth in the use of AR/VR technologies in the next five to ten years.

Despite the potential impact of ImTs in the construction industry, the implementation and adoption of emerging technologies such as ImTs have met strong resistance, especially in developing countries [15]. According to Ibem and Laryea [19] and Windapo [20], most construction companies in South Africa are resistant to change, insisting on conducting operations using traditional approaches (e.g., paper-based).

Substantial research has attempted to improve the implementation of emerging technologies by identifying the challenges to their adoption. For example, Sadeghi et al. [21] identified barriers to the use of blockchain in the construction industry. Without classifying the barriers, the study identified issues relating to infrastructure, applications, low customer demand, and taxation as the main barriers to the implementation of blockchain in the construction industry. Further studies classified the critical factors preventing the implementation of digital technologies in the construction industry as financial, technical, and organizational barriers [22]. Moreover, cultural, institutional, and technological challenges have also been identified as significant factors that impede the adoption of these technologies [23–25]. In addition, researchers have evaluated the critical factors that impact the adoption of technologies in the construction industry. Zhao [26] identified "inadequate relevant knowledge and expertise" and "poor information sharing and collaboration" as critical risks associated with the implementation of BIM in the construction industry. Furthermore, Nnaji and Awolusi [27] posited that poor training and a lack of information on effectiveness could significantly impact the extended use of wearable sensing devices in the construction industry. Meanwhile, Oke et al. [28] identified high costs and low awareness as significant risk factors impacting the use of robots in the construction industry.

While several researchers have generated valuable insights regarding adoption factors and emerging technologies in the construction industry, limited research has focused on factors impacting ImT implementation in the construction industry. Available studies on ImTs either focus on implementation trends [18], propose research paths [29], or solve specific research problems [30]. Moreover, limited information is available on ImT implementation in developing countries. Therefore, to successfully implement ImTs (both in developed and developing countries), and maximize the benefits associated with these technologies, the critical risk factors that impede their implementation must be identified and assessed.

The present study examines the factors influencing the implementation of ImTs. With this aim in mind, the present study: (i) identifies risk factors that prevent organizations from implementing ImTs; (ii) quantifies the likelihood and impact of these risk factors; (iii) assesses the relationships among these factors and identify risk paths; and (iv) provides ImT integration recommendations to organizations.

The following section provides a background to the use of ImTs in construction research and the construction industry. After that, the Methods section describes the research process, survey development, and the tested hypotheses. The findings obtained from the survey questionnaire are summarized in the Results section and expanded upon in the Discussion section. Finally, the Conclusions section provides insights on the key contributions and areas requiring further research.

2. Review of Related Literature

2.1. Application of Immersive Technologies/Extended Reality in AEC

The demand for extended reality—a collective term encompassing various immersive technologies [14] in the built environment—is increasing globally [31] in the construction industry as a response to challenges related to productivity, cost, safety, and quality [32]. According to Flavian et al. [33], immersion is a state of being present in an environment. ImTs have been employed, to some extent, in the built environment since the 1990s to aid the visualization of design, construction, and city operations [34]. ImTs help create distinct experiences by merging the physical world with digital or simulated reality. These technologies are essential to the built environment because this industry is naturally linked to the concept of three-dimensional space and imagery for communication [34,35]. ImTs comprise A.R., V.R., and M.R., which make up extended reality (Figure 1). The concept and application of these technologies are briefly explained below.

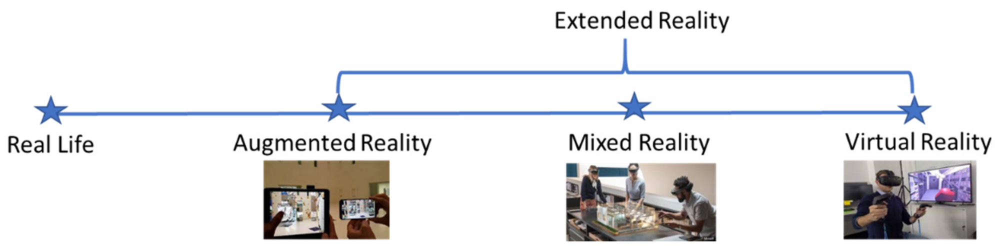

Figure 1. Extended Reality Spectrum.

Augmented Reality (A.R.): A.R. presents an enhanced real-life experience to the user by overlaying characters, animations, or general information onto a real environment by blending computer-generated information and the user's environment [29]. In the last decade, A.R. has received considerable attention from researchers in the architecture and construction industry [18]. Researchers use this technology to address many problems throughout a construction project—for example, project planning and coordination, design reviews, safety, and worker training [18,35,36].

Virtual Reality (V.R.): V.R. is a computer-created simulation of a realistic experience by which users can relate both virtually and physically with their environment [37]. V.R.-based simulations are designed to produce immersive realms in which users are given exclusive insights into how the digitally imagined world works [29]. The critical components needed to experience V.R. are respondents, content creators, hardware, and game engine software [12,38]. Examples of V.R. devices used in construction research include Oculus, H.T.C., and Samsung Gear.

Mixed Reality (M.R.): Similar to A.R., M.R. connects the physical and digital worlds. However, the level of immersion is increased in M.R. Unlike A.R., in M.R., digital content is not simply overlaid into the real world; it is embedded such that users can interact with the virtual content. The goal of M.R. is to create a new reality that blends components of V.R. (the digital environment) with A.R. (the physical environment). The most popular M.R. device used in the construction industry and research is the Microsoft HoloLens [39].

All forms of construction and all phases of the construction process can benefit from applying ImTs [40]. Examples of ImT implementation include using A.R. to detect on-site hazards and falls [41,42], simulating equipment operations in a controlled environment before deployment [43], and inspecting section dislodgment during tunneling [44]. These technologies are also utilized in commercial and residential construction projects. For instance, [45] used this technology to inspect steel columns, and [46] integrated V.R. with BIM to monitor on-site construction activities [46]. A.R. is also effective for worker training, construction project supervision, and collaboration [47]. During the maintenance or operation stage, integrating A.R. into BIM can increase the value of assets. For instance, concealed utilities in a structure can be revealed with a high level of precision [48].

ImTs are also applicable in the construction of roads and highways. For example, pavement-cracking assessments can be enhanced by ImTs [49]. Recently, Tedeschi and Benedetto [50] implemented A.R. and other technologies to detect and respond to vehicle intrusions in highway work zones. According to Delgado et al. [15], ImTs have six main applications in the architectural, engineering, and construction (A.E.C.) industry: stakeholder engagement, design support, design review, construction support, operations and management, and training. They are applied the most often for "stakeholder engagement" and the least often for "operation and management."

In summary, ImTs can be incorporated throughout a construction project and can support different types of construction projects [35]. Nevertheless, their implementation in construction projects is limited. Several factors impact the successful performance of ImTs in the construction industry, preventing stakeholders from utilizing them.

2.2. Factors Impacting the Implementation of ImTs in the A.E.C. Industry

As mentioned in Section 2.1, the application of ImTs has increased in various industries, including the construction industry, in the past [51,52]. Despite their recent development and potential benefits [42,53], the rate of adoption of ImTs is low in the A.E.C. industry [15]. Various risk factors individually and collectively influence the integration of emerging technologies [54]. The impacts of these risk factors can vary according to the technology type and the context [55]. According to Zhao [26], and Dossick and Neff [56], the risks associated with adopting and implementing technology in the construction industry could shape attitudes towards technology.

Therefore, researchers and practitioners must pay close attention to possible risks that could offset the benefits of ImTs in the A.E.C. industry and reduce stakeholders' willingness to use these technologies. The existing literature indicates that the barriers (risk factors) to the implementation of ImTs include: financial and usability concerns [25,57]; the required technical knowledge, data security [58,59]; and the availability of training, managerial support, resources, and incentives [60,61].

Table 1 summarizes the risk factors that could impact the successful implementation of ImTs in the A.E.C. industry. As shown in the table, the identified risk factors include those related to operational limitations, investment limitations, individual/worker's concerns, external issues, and technology concerns.

Table 1. Risk factors associated with immersive reality technology implementation.

Risk Categories	Risk Factors	Code	Sources
Technology concerns	ImTs having limited impact on error prevention	T1	[15]
	Data security is not guaranteed	T2	[58,59]
	Concerns regarding the durability of ImTs	T3	[62]
	ImT has limited functionality	T4	[63]
	The technology is complex to use	T5	[15,58,62,64]
	Concerns regarding the technical support available from the manufacturer	T6	[63–65]
	Limited opportunity(ies) to observe and try these technologies before adoption	T7	[66]
Operational limitations	Lack of central system for managing data captured during training	O1	[16]
	Lack of decision tools to support ImT integration	O2	[23–25]
	The difficulty associated with integrating these technologies into existing processes (interoperability)	O3	[57,60]
	Organization prefers using existing processes to manage safety	O4	[67–70]
Investment limitations	Lack of cost/benefit analysis and return on investment information	I1	[15,57,71]
	High investment (capital cost) cost	I2	[71–73]
	Extra maintenance costs associated with ImTs cannot be accommodated	I3	[73,74]

Table 1. *Cont.*

Risk Categories	Risk Factors	Code	Sources
Individual/worker's concerns	Need for extensive worker training before achieving optimum performance	W1	[60,62]
	Workers are not familiar with ImT	W2	[75–78]
	Workers will likely not take ImT-based safety training seriously (could be seen as unrealistic)	W3	[62,76]
	Could introduce new risks to workers (e.g., misrepresent severity of safety risk)	W4	[60,75]
External issues	Little or no known standards for operation	E1	[15,71]
	The decision to use ImTs varies significantly with the client (e.g., D.O.T.s, private entities, etc.)	E2	[77,79]
	Little or no government regulations for using ImTs	E3	[71,79,80]

Although existing studies have identified specific risk factors that could impact the use of ImTs, no study has synthesized or quantified these risk factors. Instead, studies have focused on individual risks while ignoring the interactions among risk factors, which has created a significant gap in the existing literature. Risks are dynamic and interdependent; thus, should not be managed individually [26,81]. Moreover, most studies on ImTs have focused on developed countries, while limited information is available to explain the implementation of ImTs in developing countries.

Therefore, the present study examines the risk factors influencing the effective implementation of ImTs in South Africa and models various risk paths. Quantifying these risk factors and developing a network of various risk paths representing their interactions will provide researchers and practitioners with invaluable insights into how risk assessments related to the use of ImTs should be conducted. This information could help: (i) direct the development of conceptual and theoretical models associated with technology acceptance or resistance; (ii) identify risks and the mechanisms underlying the interactions among risks; and (iii) provide fundamental metrics to support practitioners when assessing their organizations' readiness to implement ImTs.

3. Methods

The present study utilized a literature review and a quantitative research method—namely, a questionnaire survey—to address the aim of the present study. The research team developed a questionnaire and distributed it among construction stakeholders in South Africa to capture critical insights needed to meet the goal of the present study.

3.1. Literature Review

First, the authors conducted an integrative review of the existing literature to identify factors that could impact the successful application of ImTs in the construction industry. According to Nnaji and Karakhan [8], "an integrative review of literature is a comprehensive methodological approach of reviews that combines data from empirical and theoretical literature to develop a conceptual model, review evidence-based findings, and analyze concerns associated with a particular topic." Several construction-related studies have adopted this review process to identify important factors that affect decisions within the construction industry [8,82–84].

The review process implemented in the present study was adopted from [85]. It involved six phases: (1) preparing the guiding questions; (2) sampling the literature; (3) collecting data; (4) analyzing the included studies; (5) discussing the results; and (6) presenting an integrative review.

The review was guided by the following question: "What barriers could prevent companies in the construction industry from implementing ImTs?" The research team relied on Scopus as the primary database. However, several specific publishers, such as Elsevier, Taylor & Francis, Emerald, and the American Society of Civil Engineers, were considered when searching for useful publications. This search was conducted using keywords associated with the guiding question (e.g., "construction management," "virtual reality," "augmented reality," "mixed reality," "construction technologies," "implementation challenges," and "adoption risk factors").

First, the researchers probed these databases/sources for studies on ImT adoption and implementation in the construction industry. Subsequently, the same databases were searched to identify studies adopting and implementing emerging technologies (e.g., BIM, wearable devices, three-dimensional printing, and robotics). Finally, the researchers expanded the search to include studies on ImTs from other relevant industries to ensure the robustness of the list of included factors. The identified journals were screened, with a primary focus on titles, abstracts, and conclusions. A more detailed examination of the content was performed if a publication contained a discussion on:

i. The application of ImTs on a construction project;
ii. The challenges impacting the implementation of ImTs in occupational settings; or
iii. Risk factors impeding the adoption of emerging technologies in the construction industry.

Overall, 21 risk factors were identified and subsequently categorized into five groups, being operational limitation risk factors (four factors), investment limitation risk factors (three factors), individual/worker's concern risk factors (four factors), external issues risk factors (three factors), and technology concerns risk factors (seven factors), as presented in Table 1.

3.2. Survey Development

The survey consisted of three main sections. The first section focused on the demographic information of the respondents. Specifically, the questions in this section asked respondents about their roles in the A.E.C. industry, work experience, company size, and typical projects. The second section of the questionnaire asked respondents about their experience using ImTs. The third section assessed the risk factors identified during the literature review. This section examined the risk factors that prevent organizations from implementing immersive technologies. Table 2 shows the risk impact-probability matrix. Similar to previous studies [26,86], the risk factors were measured in terms of their likely occurrence (LO) and magnitude of impact (MI). Two 5-point Likert scales were used in the data survey. LO was rated as follows: 1 = extremely unlikely (<20%); 2 = unlikely (20% $\leq$ LO < 40%); 3 = neutral (40% $\leq$ LO < 60%); 4 = likely (60% $\leq$ LO < 80%); and 5 = extremely likely (LO > 80%). Meanwhile, MI was rated as follows: 1 = not at all impactful; 2 = slightly impactful; 3 = somewhat impactful; 4 = very impactful; and 5 = extremely impactful.

Table 2. Risk impact–probability matrix.

			Magnitude of Impact (MI)				
			1	**2**	**3**	**4**	**5**
			Not at All Impactful	**Slightly Impactful**	**Somewhat Impactful**	**Very Impactful**	**Extremely Impactful**
Likely Occurrence (LO)	1	Extremely Unlikely (<20%)	Low	Low	Low	Medium	Medium
	2	Unlikely (20% $\leq$ LO < 40%)	Low	Low	Low	Medium	Medium
	3	Neutral (40% $\leq$ LO < 60%)	Low	Medium	Medium	Medium	High
	4	Likely (60% $\leq$ LO < 80%)	Medium	Medium	Medium	High	High
	5	Extremely Likely (LO > 80%)	Medium	Medium	High	High	High

3.3. Survey Distribution

The survey was designed and distributed in Qualtrics, a widely used survey design and distribution platform. The survey was distributed to construction professionals across the construction industry in South Africa. The surveys were purposively distributed to personal contacts and the Council for Project and Construction Management Professions. The data was collected between May and July 2020. The researchers relied on an online data collection method because the data was collected during the COVID-19 pandemic. Before collecting the data, the research team calculated the sample size required to meet the research goal using Equation (1):

$$\mathrm{Ss} = \frac{\mathrm{Z}^2 \times \mathrm{P} \times (1 - \mathrm{P})}{\mathrm{Me}^2}, \tag{1}$$

where Ss = sample size, Z = z-value representing the data's confidence level, $P(1 - p)$ = response variance, and Me = margin of error or sampling error. The margin of error for this survey study was 10%, the Z-score was 1.96 (for a two-tailed alternate hypothesis at $\alpha = 0.05$), and the sample proportion was 50% for simple random sampling [87,88]. Therefore, the minimum sample size required to examine the risk factors associated with the use of ImTs was 97 respondents. Approximately 1500 construction professionals were contacted, of whom 215 agreed to participate. However, only 175 respondents answered most questions in the survey.

3.4. Statistical Analysis

3.4.1. Risk Quantification

As described earlier, the risk factors were quantified using two, five-point Likert scales (one for LO and one for MI). Since two rating scales were used to measure each variable, the study utilized a risk criticality (RC) index to gauge the dimension of each risk factor. The RC index was also used in previous studies [26,86,89,90]. The Equation of the RC index is represented in Equations (2) and (3):

$$\mathrm{RC}_j^i = \frac{\mathrm{LO}_j^i \times \mathrm{MI}_j^i}{\mathrm{N}} \tag{2}$$

and

$$\mathrm{RC}^i = \frac{1}{n} \sum_{j=1}^{n} \mathrm{RC}_j^i, \tag{3}$$

where LO_j^i = the LO assessment of risk i by respondent j, MI_j^i = the magnitude of impact assessment of risk i by respondent j, N = the five-point Likert rating scale, n = the total number of respondents in the survey, RC_j^i = the risk criticality of the risk i by respondent j, and RC^i = the risk criticality of risk i.

Next, the study assessed each risk factor to determine if they occurred to a significant extent during (or had a significant impact on) the implementation of ImTs. Similar to previous studies [26,27,91], a one-sample *t*-test was performed for this purpose. The hypothesized test value in the present study was set at the median value reported on the five-point Likert scale (3). The significance level for the one-sample test was set to 0.05. A *p*-value of < 0.05 and a mean value of >3.0 indicated that the risk factor is critical (i.e., likely to occur and significantly impacts ImT implantation). In contrast, a *p*-value > 0.05 indicated the factor is not critical (i.e., neither likely to occur nor has a significant impact on ImTs implementation).

3.4.2. Risk Path Analysis

The conceptual model of the network of risk criticality path for the adoption of ImTs was developed using partial least squares-structural equation modeling (PLS-SEM). Previous studies [92–95] have stated the importance of PLS in carrying out path analyses. Vinzi et al. [92] defined the PLS-SEM approach as a regression-based approach that applies the principal component factor analysis test in the path analysis. Meanwhile, David [94] showed that the PLS path model comprises the structural model and the measurement model, which are referred to as the inner and outer model, respectively.

The internal model helps define the relationship between the latent variables. These latent variables connect with observed indicators, and they are defined as the outer model [93]. PLS-SEM was used to explore the risk criticality factors that prevent organizations from implementing ImTs. Using the two phases specified by David [94], the relationship between latent variables and their observed variables was quantified. Afterward, a structural model depicting the relationship between the latent variables was presented. As described in Section 3.1, 21 variables were identified and subsequently categorized into five groups: operational limitation risk factors (four variables), investment limitation risk factors (three variables), individual/worker's concern risk factors (four variables), external issues risk factors (three variables), and technology concerns risk factors (seven variables).

The first four groups (operational limitation, investment limitation, individual/worker's, and external issues risk factors) are the endogenous latent variables, whereas technology concerns risk factors is the exogenous latent variable. Since the study is based on the risk factors influencing the implementation of ImTs, these factors are considered technology concerns (the exogenous latent variable) that can be affected by other endogenous latent variables (operational limitations, investment limitations, individual/worker's concerns, and external issues). The technology concerns of ImTs were considered by examining the influences of operational limitation, investment limitation, individual/worker's concern, and external issues.

The relationships among the risk factor groups are based on reviewed studies on factors impacting the use of emerging technologies in the construction industry [7,96,97]. Figure 2 shows the initial conceptual model for networking the risk criticality path in the implementation of immersive technologies. The researchers utilized the concept of risk path to describe the relationships among risk categories. The conceptual framework was developed based on the following proposed hypotheses (**H1–H10**):

H1. *External issues have a significant limiting effect on the individual/worker's concerns impact on the implementation of ImTs.*

H2. *External issues have a significant limiting effect on investment limitations' impact on the implementation of ImTs.*

H3. *External issues have a significant limiting effect on technology concerns' impact on the implementation of ImTs.*

H4. *Individual/worker's concerns significantly limit technology concerns' impact on the implementation of ImTs.*

H5. *Investment limitations have a significant limiting effect on individual/worker's concerns' impact on the implementation of ImTs.*

H6. *Investment limitations have a significant limiting effect on technology concerns' impact on the implementation of ImTs.*

H7. *Individual/worker's concerns significantly limit operational limitations' impact on the implementation of ImTs.*

H8. *Investment limitations have a significant limiting effect on operational limitations' impact on the implementation of ImTs.*

H9. *Operational limitations have a significant limiting effect on technology concerns' impact on the implementation of ImTs.*

H10. *External issues have a significant limiting effect on operational limitations' impact on the implementation of ImTs.*

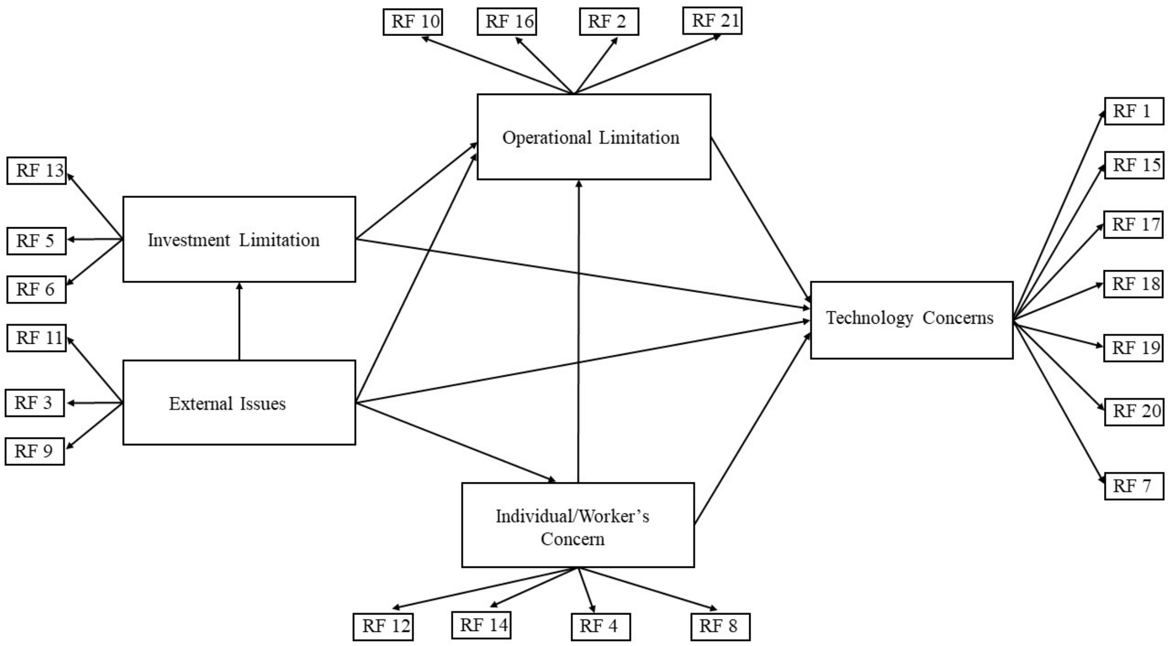

Figure 2. Initial conceptual model highlighting the networking of risk criticality paths in ImT implementation.

Figure 2 shows the interconnection between the endogenous latent variables and the exogenous latent variables. SMART-PLS version 3.2.3 was used to run the modeling path of implementing the risk criticality factors. First, the PLS algorithm was calculated to show the measurement model's evaluation, the discriminant validity of risk categories, and the cross-loadings. The assessment of the measurement model showed the construct reliability and validity of the loadings, Cronbach's alpha values, and the average variance extracted (AVE) ratings for the risk categories. The study by Hussain et al. [98] used this same process to evaluate the measurement model using PLS-SEM by indicating the internal consistency, reliability of individual indicators, estimation of the convergent reliability, the Fornell–Larcker criterion, and the discriminant validity. The suitability of the path model should be ensured when determining construct validity in PLS [99], and a loading of 0.7 is required when defining construct validity [100]. All values lower than 0.7 in the PLS algorithm calculations are eliminated because these variables have little explanatory power in the path model [100]. Therefore, variables with loadings higher than 0.7 are satisfactory for the path model [100,101].

4. Results

4.1. Demographics

This section describes the results obtained from the South African construction industry survey on ImTs. Table 3 shows the respondents' characteristics, including their roles in the A.E.C. industry, work experience, personal experience using ImTs, and duration of organizational use. Most of the respondents were consultants, and most of the companies they worked for had been operating for six to 10 years.

Achieving the goal of the present study requires firsthand knowledge of ImTs. Thus, only responses obtained from respondents who indicated they had used ImTs for construction projects were considered for the risk quantification and risk path model. Focusing on respondents with experience reduced bias and increased the confidence in the data.

Table 3. Personal characteristics of the survey respondents.

Demographic Information	Frequency	Percent	Cumulative Percent
Role in the construction industry			
General Contractor	46	26.3	26.3
Sub-Contractor	15	8.6	34.9
Consultant	59	33.7	68.6
Others (Owner, client, educator, health, safety officer, etc.)	55	31.4	100.0
Industry Work Years' Experience			
Less than 1 year	1	0.6	0.6
1 to 5 years	37	21.1	21.7
6 to 10 years	63	36.0	57.7
11 to 20 years	54	30.9	88.6
Above 20 years	20	11.4	100.0
Usage of Immersive Technologies			
Yes	67	38.3	38.3
No	108	61.7	100.0
Experience in Immersive Technologies			
More than 0 years but less than two years	23	34.3	34.3
More than two years but less than five years	9	13.4	47.7
More than five years	17	25.4	73.1
No response	18	26.9	100.0
Duration of Organization using Immersive Technologies			
More than 0 years but less than two years	18	26.9	26.9
More than two years but less than five years	14	20.8	47.7
Not Sure	17	25.4	73.1
No response	18	26.9	100.0

Each participant was asked if they had previous experience using ImTs via a binary closed question ("Yes" or "No"). Table 3 shows that 67 (38.3%) respondents had used ImTs in the construction industry, while 108 (61.7%) had not. Therefore, subsequent analyses on the use of ImTs focused on the responses of those 67 respondents. Table 3 shows that 23 (34.3%) of the ImT users had less than two years of experience using such technology. Most of the respondents were unsure how long ago their firms had adopted immersive technologies. Of those who were sure of this matter, most believed their firms had been using immersive technologies for less than two years.

Figure 3 shows the types of ImTs used by the respondents and the activities carried out. Figure 3 revealed that 30% of ImT users used Microsoft HoloLens, 23% used Google Glasses, 17% used Samsung Gear V.R., 13% used H.T.C. Vive, 11% used Lenovo Mirage, and 6% used other immersive technologies. Figure 3 also shows the activities for which immersive technologies are applied. The most common purpose for using ImT among its users was construction safety management (37%). Other uses of ImT include pre-construction planning (13%), construction sequencing (11%), facility management and design evaluation (10%), and on-site revisions (10%).

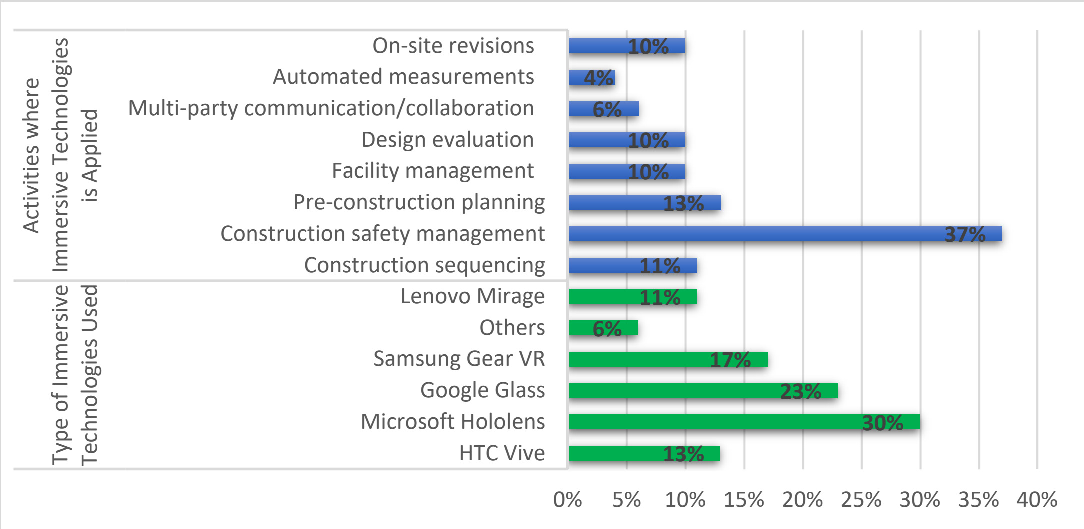

Figure 3. Type of immersive reality technologies (ImTs) used and the activities for which they are used (n = 67).

4.2. Risk Factors Preventing the Implementation of ImTs

As shown in Table 4, the main likelihood risk factors that could influence the adoption of ImTs are "W1: the need for extensive worker training before achieving optimum performance (3.94)", "I2: high investment (capital cost) cost (3.75)", "W3: workers will likely not take ImT-based safety training seriously (could be seen as unrealistic) (3.51)", "W4: could introduce new risks to workers", and "I2: lack of cost/benefit analysis and return on investment information". These risk factors had LO ratings between 60% and 80% regarding their influences on the implementation of ImTs in the construction industry.

Table 4. Risk factors preventing organizations from implementing ImTs (n = 67).

Risk Factors	Likely Occurrence (L.O.)			Magnitude of Impact (MI)			Risk Criticality (R.C.)	
	MS	*p*-Value	RI	MS	*p*-Value	RI	MS	RI
W1	3.94	<0.00 *	1st	3.71	<0.00 *	1st	3.18	1st
I2	3.75	<0.00 *	2nd	3.48	0.05 *	4th	2.87	2nd
W3	3.51	0.01 *	3rd	3.29	0.12	9th	2.54	6th
W4	3.49	0.01 *	4th	3.59	0.00 *	3rd	2.77	3rd
I1	3.47	0.03 *	5th	3.38	0.10	7th	2.54	6th
E3	3.45	0.03 *	6th	3.23	0.33	12th	2.49	9th
T6	3.45	0.02 *	6th	3.41	0.07	5th	2.59	4th
O3	3.35	0.03 *	8th	3.11	0.62	16th	2.25	12th
O2	3.34	0.03 *	9th	3.30	0.08	8th	2.50	8th
I3	3.32	0.07	10th	3.24	0.24	17th	2.22	14th
T7	3.32	0.08	10th	3.10	0.64	11th	2.36	11th
O4	3.30	0.17	12th	3.03	0.89	20th	2.19	15th
T3	3.26	0.13	13th	3.17	0.41	15th	2.18	16th
T5	3.25	0.14	14th	3.41	0.04 *	5th	2.57	5th
T4	3.19	0.29	15th	3.19	0.35	13th	2.25	12th
T2	3.14	0.48	16th	3.19	0.39	13th	2.18	16th
E2	3.12	0.43	17th	3.07	0.72	18th	2.02	21st
O1	3.11	0.62	18th	3.06	0.00 *	19th	2.17	18th
E1	3.11	0.54	18th	3.67	0.75	2nd	2.41	10th
T1	3.05	0.75	20th	3.29	0.08	9th	2.14	19th
W2	3.03	0.90	21st	2.93	0.79	21st	2.07	20th

* Significance level of 0.05 (two-tailed).

In terms of the MI, Table 4 shows that the risk factors that could have the greatest impacts are "W1: the need for extensive worker training before achieving optimum performance (3.71)", "O1: the lack of a central system for managing data captured during training (3.67)", and "W4: immersive technologies could introduce new risks to workers (e.g., misrepresent severity of safety risk) (3.59)". As depicted in Figure 4, all risk factors, with the exception of W2, are Medium to High Impact—Medium to High Likelihood risk factors.

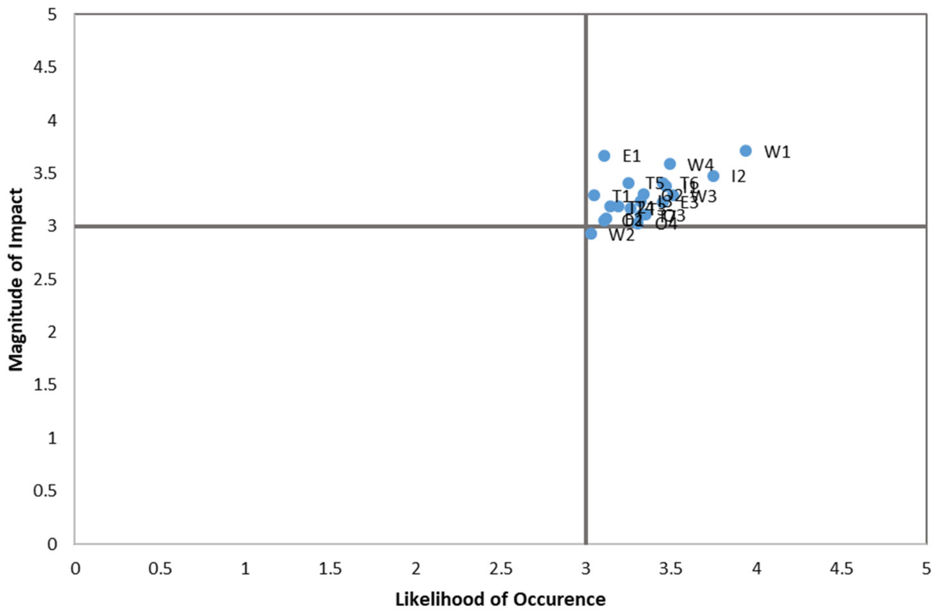

Figure 4. ImT implementation risk matrix.

Meanwhile, the main RC factors were "W1: the need for extensive worker training before achieving optimum performance (3.18)", "I2: high investment (capital cost) cost (2.87)", and "W4: immersive technologies could introduce new risks to workers (e.g., misrepresent severity of safety risk) (2.77)". Based on the benchmark established for critical risk factors (mean = 3) and the results shown in Table 4, nine significant risk factors (W1, I2, W3, W4, I1, E3, T6, O3, and O2) occurred when implementing ImTs. Only five risk factors (W1, I2, W4, T5, and O1) significantly impacted the implementation of ImTs.

4.3. Modeling Paths of Implementation Risks

Model Verification and Validity

Table 5 summarizes the measurement model used in this study to evaluate various risk categories. The "operational limitation" category and risk factors were eliminated from the initial conceptual framework, as can be observed in the final model for the networking of the risk criticality path for the implementation of ImTs (see Figure 5). All the risk factors in the operational limitation risk category loaded below 0.7. Therefore, O1–O4 were eliminated. The variables with loadings higher than 0.7 are also presented in the table, which shows the factor loadings, Cronbach's alpha values, composite reliability, and AVE ratings of the risk categories.

Table 5. Measurement model evaluation.

Risk Category	Risk Factor	Loadings	Cronbach Alpha	Composite Reliability	AVE
Technology concerns	T2 T3 T6	0.860 0.867 0.898	0.849	0.907	0.766
Individual/Worker's concern	W3 W2 W4	0.886 0.807 0.734	0.737	0.852	0.659
Investment limitations	I2 I1 I3	0.807 0.794 0.826	0.739	0.850	0.654
External issues	E2 E1 E3	0.726 0.901 0.870	0.792	0.873	0.698

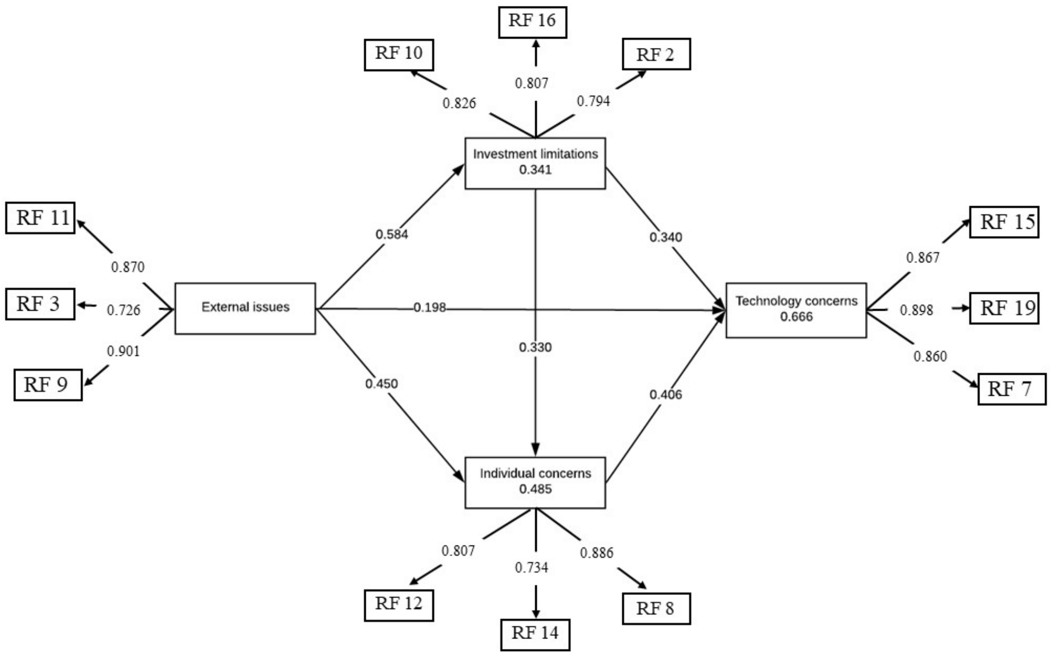

Figure 5. Final model for the networking of risk criticality path in the implementation of immersive technologies using PLS algorithm calculations.

All the factor loadings presented in Table 5 are higher than 0.7 and are, therefore, satisfactory. Regarding Cronbach's alpha values, George and Mallery [102] opined that it should be greater or equal to 0.7 in a PLS test. Table 5 showed that the Cronbach's alpha for technology concerns risk factors, individual/worker's concern risk factors, investment limitation risk factors, and external issues risk factors were higher than 0.7. Regarding measurements of the internal consistency of the construct reliability, Hock et al. [103] stated that the composite reliability should be greater than or equal to 0.6. In addition, Hair and Lukas [104] showed that the AVE should not be less than 0.5 in the convergent and validity test. Table 5 shows that technology concerns risk factors, individual/worker's concern risk factors, investment limitation risk factors, and external issues risk factors had composite reliability and AVE ratings higher than the recommended values.

Table 6 presents the results of the Fornell–Larcker criterion test for the risk categories in the path model. The values in the diagonal axis shown in Table 6 suggests that the square root of the AVE assumption was met. For instance, for the external issues risk factors, the square root of the corresponding AVE value (0.698) in Table 5 equals 0.836 in Table 6.

Table 6. Fornell–Larcker criterion test results.

Risk Category	External Issues	Individual/Worker's Concerns	Investment limitations	Technology Concerns
External issues	**0.836**			
Individual/Worker's concerns	0.643	**0.812**		
Investment limitations	0.584	0.593	**0.809**	
Technology concerns	0.658	0.735	0.697	**0.875**

Note: The bold values represent the highest loading value for each observable variable.

Regarding factor cross-loading in the PLS algorithm test, Chin [105] stated that the values signifying an indicator's relationship with the observed variables must be higher than the value generated considering other variables in the path model. Table 7 shows the factor cross-loadings of the risk categories in the path model. The highest relationship values were compared to other variables. The values obtained in the Fornell–Larcker criterion test and the factor cross-loadings (see Tables 6 and 7, respectively) confirm the discriminant validity of the variable observed in the model.

Table 7. Factor cross-loadings of the risk categories.

Risk Factor	Risk Categories			
	External Issues	Individual/Worker's Concerns	Investment Limitation	Technology Concerns
E1	**0.901**	0.626	0.543	0.604
E3	**0.870**	0.625	0.534	0.640
E2	**0.726**	0.239	0.337	0.318
W3	0.570	**0.886**	0.486	0.506
W2	0.628	**0.807**	0.462	0.593
W4	0.356	**0.734**	0.489	0.681
I3	0.409	0.600	**0.826**	0.692
I2	0.584	0.493	**0.807**	0.472
I1	0.425	0.297	**0.794**	0.503
T6	0.486	0.619	0.672	**0.898**
T3	0.469	0.560	0.487	**0867**
T2	0.732	0.726	0.645	**0.860**

Note: The bold values represent the highest loading value for each observable variable.

The model's predictive relevance (Q^2) was also determined by initiating blindfolding procedures and calculating the cross-validated redundancy [95]. The cross-validated redundancy measurement in Q^2 statistics is the preferred blindfolding output among various cross-validated measures because it focuses on the model fit of the PLS latent variable model [94]. Moreover, the Q^2 ensures that the conceptual model can predict the endogenous latent construct [98]. Its value must be greater than zero for it to be appropriate for measuring a specific endogenous construct; this is the case for the model generated in this study (Table 8).

Table 8. Construct cross-validated redundancy (Q^2).

Parameters (Risk Categories)	SSO	SSE	Q^2 (=1 − SSE/SSO)
External issues	201.000	201.000	
Individual/Worker's concerns	201.000	151.322	0.247
Investment limitation	201.000	160.378	0.202
Technology concerns	201.000	107.731	0.464

The final part of the PLS-SEM procedure provides the structural model assessment, which enables the path model to predict the relationships among the latent variables. SMART-PLS software was employed using the bootstrapping method via a resampling technique to measure the structural model assessment. Figure 6 presents the structural model assessment using a bootstrapping procedure. However, this assessment does not confirm the significance of the path in the hypothesis drafted for this study.

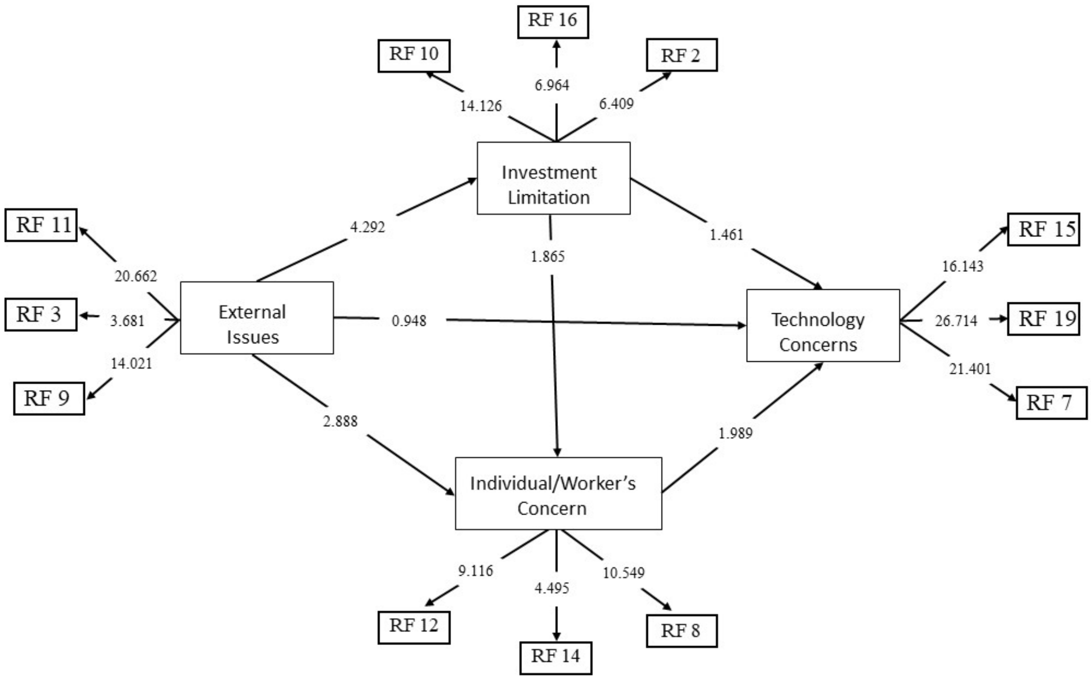

Figure 6. Structural model assessment using a bootstrapping procedure.

Taylor and Geldenhuys [106] noted that the bootstrapping approach helps validate the explanatory capacity of a path model. Meanwhile, to check the structural model assessment test, [98] itemized values such as the standard beta (β-value), standard deviation, T-statistics value, hypothesis significant values (*p*-value), effect size (f^2), and the predictive relevance of the model (Q^2). A structural model assessment showing the significant paths in the relationships of the exogenous latent variable with the endogenous latent is presented in Table 8.

The structural model assessment results suggest that three of the six hypothesized paths were significant. The data in Table 9 supports the alternate hypothesis for **H1**. This means that the path relationship is significant (β-value = 0.450, T-value = 2.888, *p*-value = 0.004). The results also indicate that external issues risk factors have a 45% effect on individual/worker's concern risk factors' impact on implementing ImTs.

H2, which predicted that external issues risk factors have a significant limiting effect on investment limitation risks' impact on ImT implementation, is supported (β-value = 0.584, T-value = 4.292, *p*-value = 0.000). According to the results, external issues risk factors have a 58.4% effect on investment limitation risk factors' impact on ImT implementation.

However, **H3**, which proposed that external issues risk factors have a significant limiting effect on technology concerns risk factors' impact on the implementation of ImTs, was not supported (*p*-value = 0.343, 95% confidence level).

H4 predicted that individual/worker's concern risk factors have a significant limiting effect on technology concerns risks' impact on the implementation of ImTs. This hypothesis was supported (β-value = 0.406, T-value = 1.989, *p*-value = 0.047). Individual/worker's concern risk factors had a 40.6% effect on technology concerns risk factors' influence on the implementation of ImTs.

Table 9. Structural model assessment indicating the path coefficients and significance values of the relationships among risk factors.

Hypothesis	Hypothetical Path	Standard Beta	Standard Deviation	T-Statistics	*p*-Values	Inference	f^2	Inference
H1	External issues risk–Individual/Worker's concern risk	0.450	0.156	2.888	0.004 **	Supported	0.259	Moderate
H2	External issues risk–Investment limitation risk	0.584	0.136	4.292	0.000 **	Supported	0.517	Large
H3	External issues risk–Technology concern risk	0.198	0.209	0.948	0.343	Not Supported	0.061	Small
H4	Individual/Worker's concern risk–Technology concerns risk	0.406	0.204	1.989	0.047 **	Supported	0.255	Moderate
H5	Investment limitation risk–Individual/Worker's concern risk	0.330	0.177	1.865	0.063	Not Supported	0.139	Moderate
H6	Investment limitation risk–Technology concern risk	0.340	0.233	1.461	0.145	Not Supported	0.201	Moderate

** Significant at a 5% level.

The remaining hypotheses were not supported. **H5** stated that investment limitation risk factors have a significant limiting effect on the individual/worker's concern risk factors' impact on the implementation of ImTs (*p*-value = 0.063). Meanwhile, **H6** predicted that investment limitation risk factors have a significant limiting effect on technology concerns risk factors' influence on ImT implementation (*p*-value = 0.145).

The T-values of all significant path models were higher than 1.96, which is the threshold value proposed by Ojelabi et al. [95]. Thus, these T-values confirm that the relationships corresponding to these paths are significant. Furthermore, the effect size—which indicates the effect of an independent construct on a dependent construct in a path model—was calculated for each significant relationship using SMART-PLS. It has also been stated that the effect size is evaluated by observing the change in the dependent construct when a predictor is omitted, which changes the coefficient of determination [95].

Per Cohen [107], the effect size is considered weak if the value is at least 0.002 but less than 0.15, moderate if it is at least 0.15 but less than 0.35, and substantial if it is equal to or greater than 0.35. The significant path models in this study's framework showed that external issues risk factors have a considerable effect ($f^2 = 0.517$) on investment limitation risk factors. Meanwhile, external issues risk factors have a moderate impact ($f^2 = 0.259$) on individual/worker's concern risk factors. Finally, individual/worker's concern risk factors have a moderate effect ($f^2 = 0.255$) on technology risk factors.

5. Discussion

This section presents a detailed discussion of risk quantification and the path of the risk model.

5.1. Risk Quantification

This study revealed risk factors that could arise when trying to implement ImTs in the construction industry. The results show that the need for extensive worker training to optimize performance, high investment (capital) costs, workers' tendencies to not take ImT-based safety training seriously, lack of cost/benefit analysis, and return on investment information have a 60% to 80% likelihood of occurring. The results also indicate that these risk factors are highly significant and should be considered when implementing ImTs in the construction industry.

Stakeholders hoping to implement ImTs must acknowledge individual/worker's concerns and investment limitations. In addition, the risk quantification was measured as the MI of each risk factor that occurred. The need for extensive worker training was found to be the most impactful risk factor. Other risk factors were somewhat impactful. After combining the LO and the MI associated with each risk factor, the RC indicates that the most significant risk factors are the need for extensive worker training, high investment (capital) costs, and the risks posed by immersive technologies (e.g., the misrepresentation of the severity of safety risks).

Delgado et al. [15] pointed out that technical limitations constitute a major impediment to the construction industry's adoption of ImTs. Such limitations, as identified in Yung and Khoo [108], include poor awareness about technology, usability issues, considerable time commitments, and the reluctance to integrate virtual substitutes into the construction industry. To increase ImT implementation, stakeholders must focus on training users how to take advantage of ImTs, as indicated in several studies [30,80,109]. However, such training has been lacking in the construction industry as compared to other industries, including aviation, defense, and medicine [74,110,111].

The use of ImTs is relatively new to the construction industry, even though several researchers have tried to apply ImTs in other construction-related processes. Ghobadi and Sepasgozar [78] concluded that most people experienced difficulties when using ImTs, although they hoped that this could be solved over time while arguing that others would continue to feel uncomfortable. The inadequate training of workers on the use of ImTs was also attributed to the high cost of training and the inadequate skill levels of trainers [80]. Examining the methods that have increased the implementation of other information communication technologies—such as BIM, web-based applications, and modeling-based applications—in the construction industry might increase the acceptance of ImTs within the construction industry.

Personnel training, the introduction of standards, and the development of feasible guidance have increased the implementation of these tools [112]. Nevertheless, there is still a need to develop training modules and immersive environments that can encourage construction workers' use of these tools. Large construction firms and the research community can contribute immensely in this regard. This is because large construction firms have adequate investment capital and resources to support the implementation of ImTs [15]. They can also fund applied studies focused on the use of ImTs in relevant construction applications.

In contrast, small and medium-sized construction firms are falling behind due to the high cost of ImT devices, in-house immersive content, and ImT technology teams. Large construction firms also need to collaborate with academia to quickly deploy ImTs. Delgado et al. [15] noted that even large construction firms have started collaborating with technology development companies to use ImTs. For example, Microsoft developed a HoloLens partnership program for large construction firms to build ImTs specifically for the construction industry [15]. Such partnerships can increase the training of construction workers needed to increase the implementation of ImTs in the construction sector.

5.2. Modeling the Path of Risk

This study showed three significant risk paths in the path of the risk model for implementing ImTs in the construction industry: external issues–individual/worker's concerns; external issues–investment limitations; and individual/worker's concerns–technology concerns. According to one risk path, eternal issues can influence individual/worker's concerns with implementing ImTs. Another risk path emphasized that external issues can influence investment limitations facing the adoption of ImTs. These two risk paths underline the importance of considering the influence of external issues.

External issues → individual/worker's concerns: The positive and significant relationship between risks associated with external issues and individual/worker's concerns confirms that external issues, such as standards for operation, client participation, and government regulations, can heighten the level of risk associated with workers' concerns when trying to implement ImTs in the construction industry. External issues can affect individidual/worker's concerns (e.g., the need for extensive worker training, familiarity with ImTs, level of seriousness related to using ImTs, and the introduction of new risks to workers).

Researchers have opined that workers should be encouraged to use ImTs through effective training [15]. However, standards for operating ImTs in the construction industry are needed to inform the development of practical and effective training for construction workers. Delgado et al. [15] stated that there is no standardized approach in converting ImT data into a format that can be used in the construction industry, which is a severe problem. For instance, data from ImTs are not compatible with the standard data formats used in the construction industry (e.g., industry foundation classes) [113]. The lack of compatibility makes integrating construction software packages and ImT software tools an immense challenge [15]. All these external challenges directly impact workers' intentions and abilities to use ImTs.

Another aspect of external issues that can influence individual/worker's concerns is client participation. It is well-known that the client is the most crucial stakeholder in the construction industry. This study asserts that clients can drive the use of emerging technologies, including ImTs. ImTs are beneficial to construction clients because they can improve coordination and communication across project phases [15]. ImTs have been praised as a mechanism that provides a realistic representation of a built asset to engage potential clients and generate informed feedback [15,114].

However, most clients do not request the use of ImTs due to several challenges [15]. For instance, clients have complained about user-unfriendly interfaces, the inability to share their ImT user experiences, and insufficiently accurate augmentation. Such factors lead clients to avoid using ImTs. When client involvement and support are absent, contractors will not have the motivation or resources needed to adequately train workers how to use ImTs. To increase clients' willingness to use ImTs and reduce individual/worker's concerns, technology developers should develop user-friendly systems that can be utilized easily throughout a project.

External issues—Investment limitations: External issues can affect investment limitations (e.g., the high cost of investment in ImTs, return on investment, and the extra maintenance costs of using ImTs). A lack of standards and government regulation increases costs, as end-users have to spend substantial amounts of time and money for testing and exploration. Moreover, limited interest and participation among clients increases the cost of implementing ImTs assumed by contractors because they cannot move the capital and operating costs upstream.

Various software tools have recently been developed to convert industry foundation classes to ImT formats [115,116]. This would increase the costs imposed on construction firms to acquire and maintain ImTs. Moreover, Qi et al. [82] cited the high costs of ImT hardware as a significant weakness of ImTs. Manikas and Hansen [117] concluded that the seamless integration of ImTs into the software systems used in the construction industry would create a robust technology ecosystem. However, clients have complained about the high cost of ImT software [80]. Although hardware costs have dramatically decreased in recent years and newer ImT versions are more accurate and user-friendly than ever, supporting software remains expensive and time-consuming to develop [74].

To increase purchases from clients while reducing investment risk, technology developers should create cost-effective hardware and software while supporting the development of operation standards. Before cost-effective standards of operation can be created, however, research is needed on software ecosystems and the best approaches for bringing together different ImTs and built-environment systems [118]. In the absence of such infrastructure and critical information, it is challenging to develop robust cost-benefit analyses or generate useful insights into the return on investments associated with ImTs.

The present study found that government participation in ImTs has been low. Although Moshood et al. [96] opined that government rules and regulations could improve the construction industry's performance in terms of innovation implementation, few government-facing studies have been conducted on the implementation of ImTs in the construction industry [79]. Governments can provide funding, tax incentives, mentorship programs, and practical support to foster the growth of ImT ecosystems in the construction industry. For instance, in the United Kingdom, the government provided immersive technology companies with £33 million in 2018 and 2019 [119]. In addition, in May 2018, 30% of immersive specialists in the United Kingdom benefitted from the tax incentives applied by the government [119].

Individual/worker's concerns—Technology concerns: The final risk path supported in this study confirmed that individual/worker's concerns affect technology concerns regarding ImT implementation. Specifically, worker-related concerns (e.g., the need for extensive training, low familiarity, resistance to change, and the potential introduction of new risks) can increase technology-related concerns when implementing ImTs in the construction industry. Workers who are not adequately trained to use ImTs are likely to question such technologies' functionality and benefits.

Users are critical to the implementation of ImTs in the construction industry. Therefore, users should be properly trained to ensure they have positive attitudes towards ImTs. Such attitudes will reduce workers' concerns about ImTs' functionality, the need for technical support, and fear of data security while fostering their appreciation for the ImTs' durability. Even though some resistance to change might arise, extensive training is expected to eventually lead construction workers to understand how to operate and extract benefits from ImTs.

In conclusion, the results suggest that external issues and individual/worker's concerns should be carefully monitored because they can influence other risk categories.

6. Conclusions

Research on immersive technologies has recently received significant attention from researchers and practitioners in the construction industry. Several studies have identified several potential benefits of using these technologies during different phases of a project. However, the A.E.C. industry has adopted and implemented these technologies at a slower rate than other industries. While several studies have highlighted different limitations that could impact the implementation of ImTs in the A.E.C. industry, no study has identified specific risk factors and conducted a risk assessment of ImT implementation.

Thus, this research team identified risk factors impacting the implementation of ImTs in the construction industry. Thereafter, the research team analyzed these risk factors (in terms of their impact and probability), modeled the paths of these risks, and provided recommendations for reducing their negative impact on ImT implementation. First, the risk factors of ImT applications were identified by reviewing the literature on V.R, M.R., and A.R. The 21 identified factors were subsequently categorized into five groups: technology risk, operation risk, individual/worker risk, investment risk, and external risk. Next, a survey questionnaire was designed and distributed to relevant construction practitioners in South Africa.

The risk criticality (RC) scores of the identified risk factors ranged from 2.02 to 3.18. High investment costs, the need for extensive worker training, and the possibility of introducing new risks to workers were rated as significant risk factors. The factor analysis results indicated 16 critical risk factors, which were re-categorized into four groups. The present study confirmed three significant relationships—namely, those between external issues and individual/worker's concerns, between external issues and investment limitations, and between individual/worker's concerns and technology concerns.

6.1. Contributions

The present study contributes to construction practice and knowledge, first by listing risk factors that could impede the implementation of ImTs in the A.E.C. industry. These factors could help develop theoretical and conceptual models for assessing ImTs' acceptance or resistance at the individual level in different countries. Second, the information on risk factors and their relationships could guide practitioners when integrating ImTs. Based on the results from the present study, practitioners will know what to prioritize during ImT integration (e.g., individual/worker-related risk factors). Third, the findings of the present study could serve as a foundation for guiding policymakers involved in creating ImT strategies and standards for the A.E.C. industry.

Finally, cost and training were ranked as critical risks impeding the implementation of ImTs. Therefore, organizations must develop and implement practical training modes that positively impact workers' attitudes towards ImTs. Moreover, there is an immediate need to develop insights into ImTs' returns on investment. Thus, researchers should prioritize investigating activities in which ImTs provide excellent financial value to organizations.

6.2. Research Limitations

Although the present study contributes to knowledge and practice, it has some limitations. First, the sample is relatively small and was drawn from only one country. To increase the generalizability of the results, researchers could consider larger samples and include workers from different countries. Second, the present study might have suffered from common method biases given the reliance on questionnaire surveys. Third, a non-probabilistic sampling method was used, which could have introduced some bias. Regardless of these limitations, the present study contributes to construction technology knowledge by providing helpful information about the risks associated with the implementing ImTs in the construction industry.

Author Contributions: Conceptualization, C.N.; methodology, C.N. and A.O.A.; software, A.O.A.; validation, C.N., A.O.A. and C.O.; formal analysis, A.O.A.; investigation, C.O.; resources, C.N., A.O.A. and C.O.; data curation, C.N. and A.O.A.; writing—original draft preparation, C.N., A.O.A. and C.O.; writing—review and editing, C.N. and A.O.A.; visualization, C.N.; supervision, C.N.; project administration, C.N. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki, and approved by the Institutional Review Board (or Ethics Committee) of The University of Alabama (protocol code 20-02-3383 and 10 April 2020).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

Acknowledgments: We are grateful to all the industry experts and the workers who enthusiastically participated in the presented research.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Ali, A.S. The performance measurement of construction projects managed by ISO-certified contractors in Malaysia Macmillan Publishers Ltd. 1479–1110. *J. Retail. Leis. Prop.* **2010**, *9*, 25–35. [CrossRef]
2. Zhou, N.; Ding, L.Y.; Chen, L.Y. Application of 4D visualization technology for safety management in metro construction. *Autom. Constr.* **2013**, *34*, 25–36. [CrossRef]
3. Bansal, V.K. Use of G.I.S. to consider spatial aspects in the construction planning process. *Int. J. Constr. Manag.* **2020**, *20*, 207–222.
4. McGeorge, D.; Zou, P.X.W. *Construction Management New Directions*, 3rd ed.; Wiley-Blackwell: Hoboken, NJ, USA, 2013.
5. Gambatese, J.A.; Halowell, M. Factors that influence the development and diffusion of technical innovations in the construction industry. *Constr. Manag. Econ.* **2011**, *29*, 507–517. [CrossRef]
6. Ramilo, R.; Embi, M.R.B. Critical analysis of key determinants and barriers to digital innovation adoption among architectural organizations. *Front. Archit. Res.* **2014**, *3*, 431–451. [CrossRef]
7. Chowdhury, T.; Adafin, J.; Wilkinson, S. Review of digital technologies to improve productivity of New Zealand construction industry. *J. Inf. Technol. Constr.* **2019**, *24*, 569–587.
8. Nnaji, C.; Karakhan, A.A. Technologies for safety and health management in construction: Current use, implementation benefits and limitations, and adoption barriers. *J. Build. Eng.* **2020**, *29*, 101212. [CrossRef]
9. Bradley, A.; Li, H.; Lark, R.; Dunn, S. BIM for infrastructure: An overall review and constructor perspective. *Autom. Constr.* **2016**, *71*, 139–152. [CrossRef]

10. 9 Construction Tech Trends to Watch in 2019. Available online: https://www.theb1m.com/video/9-construction-tech-trends-towatch-in-2019 (accessed on 17 December 2021).
11. Awolusi, I.; Marks, E.; Hallowell, M. Wearable technology for personalized construction safety monitoring and trending: Review of applicable devices. *Autom. Constr.* **2018**, *85*, 96–106. [CrossRef]
12. Careertrend.com. Available online: https://careertrend.com/facts-7524967-meaningconstruction-technology.html (accessed on 17 December 2021).
13. Delgado, J.M.D.; Oyedele, L.; Ajayi, A.; Akanbi, L.; Akinade, O.; Bilal, M.; Owolabi, H. Robotics and automated systems in construction: Understanding industry-specific challenges for adoption. *J. Build. Eng.* **2019**, *26*, 100868. [CrossRef]
14. Alizadehsalehi, S.; Hadavi, A.; Huang, J.C. From BIM to extended reality in A.E.C. industry. *Autom. Constr.* **2020**, *116*, 103254. [CrossRef]
15. Delgado, J.M.; Oyedele, L.O.; Demian, P.; Beach, T. A research agenda for augmented and virtual reality in architecture, engineering and construction. *Adv. Eng. Inf.* **2020**, *45*, 101122. [CrossRef]
16. Wang, P.; Wu, P.; Wang, J.; Chi, H.L.; Wang, X. A critical review of the use of virtual reality in construction engineering education and training. *Int. J. Environ. Res. Public Health* **2018**, *15*, 1204. [CrossRef] [PubMed]
17. Castronovo, F.; Nikolic, D.; Liu, Y.; Messner, J. An evaluation of immersive virtual reality systems for design reviews. In Proceedings of the 13th International Conference on Construction Applications of Virtual Reality, London, UK, 30–31 October 2013.
18. Noghabaei, M.; Heydarian, A.; Balali, V.; Han, K. Trend Analysis on Adoption of Virtual and Augmented Reality in the Architecture, Engineering, and Construction Industry. *Data* **2020**, *5*, 26. [CrossRef]
19. Ibem, E.O.; Laryea, S. E-tendering in the South African construction industry. *Int. J. Constr. Manag.* **2017**, *17*, 310–328. [CrossRef]
20. Windapo, A.O. Skilled labour supply in the South African construction industry: The nexus between certification, quality of work output and shortages. *South Asian J. Hum. Resour. Manag.* **2016**, *14*, 1–8. [CrossRef]
21. Sadeghi, M.; Mahmoudi, A.; Deng, X. Adopting distributed ledger technology for the sustainable construction industry: Evaluating the barriers using Ordinal Priority Approach. *Environ. Sci. Pollut. Res.* **2022**, *29*, 10495–10520. [CrossRef]
22. Sepasgozar, S.M.E.; Loosemore, M.; Davis, S.R. Conceptualizing information and equipment technology adoption in construction: A critical review of existing research. *Eng. Constr. Archit. Manag.* **2016**, *23*, 158–176. [CrossRef]
23. Azhar, S.; Behringer, A. A BIM-based approach for communicating and implementing a construction site safety plan. In Proceedings of the 49th A.S.C. Annual Conference, San Luis Obispo, CA, USA, 10–13 April 2013.
24. Abbas, A.; Choi, M.; Seo, J.; Cha, S.H.; Li, H. Effectiveness of Immersive Virtual Reality-based Communication for Construction Projects. *KSCE J. Civ. Eng.* **2019**, *23*, 4972–4983. [CrossRef]
25. Lin, J.; Zhu, R.; Li, N.; Becerik-Gerber, B. Do people follow the crowd in building emergency Evacuation? A cross-cultural immersive virtual reality-based study. *Adv. Eng. Infor.* **2020**, *43*, 101040. [CrossRef]
26. Zhao, X. A scientometric review of global BIM research: Analysis and visualization. *Autom. Constr.* **2017**, *80*, 37–47. [CrossRef]
27. Nnaji, C.; Awolusi, I. Critical success factors influencing wearable sensing device implementation in AEC industry. *Technol. Soc.* **2021**, *66*, 101636. [CrossRef]
28. Oke, A.E.; Kineber, A.F.; Albukhari, I.; Dada, A.J. Modeling the robotics implementation barriers for construction projects in developing countries. *Int. J. Build. Pathol. Adapt.* **2021**. [CrossRef]
29. Li, X.; Yi, W.; Chi, H.L.; Wang, X.; Chan, A.P. A critical review of virtual and augmented reality (VR/AR) applications in construction safety. *Autom. Constr.* **2018**, *86*, 150–162. [CrossRef]
30. Sacks, R.; Perlman, A.; Barak, R. Construction safety training using immersive virtual reality. *Constr. Manag. Econ.* **2013**, *31*, 1005–1017. [CrossRef]
31. Shibeika, A.; Harty, C. Diffusion of digital innovation in construction: A case study of a U.K. engineering firm. *Constr. Manag. Econ.* **2015**, *33*, 453–466. [CrossRef]
32. Xue, X.; Zhang, R.; Yang, R.J.; Dai, J. Innovation in construction: A critical review and future research. *Int. J. Innov. Sci.* **2014**, *6*, 111–126. [CrossRef]
33. Flavian, C.; Sanchez, S.I.; Orus, C. Integrating virtual reality devices into the body: Effects of technological embodiment on customer engagement and behavioral intentions toward the destination. *J. Travel Tour. Mark.* **2019**, *36*, 847–863. [CrossRef]
34. Whyte, J.; Nikolic, D. *Virtual Reality and the Built Environment*, 2nd ed.; Routledge: London, UK, 2002.
35. Okpala, I.; Nnaji, C.; Karakhan, A.A. Utilizing emerging technologies for construction safety risk mitigation. *Pract. Period. Struct. Des. Constr.* **2020**, *25*, 04020002. [CrossRef]
36. Omar, T.; Nehdi, M.L. Data acquisition technologies for construction progress tracking. *Autom. Constr.* **2016**, *70*, 143–155. [CrossRef]
37. Baeza, E. Applications of Virtual Reality in Construction. 2018. Available online: https://digitalcommons.calpoly.edu/cgi/viewcontent.cgi?article=1105&context=cmsp (accessed on 30 December 2021).
38. Moore, H.F.; Gheisari, M. A Review of Virtual and Mixed Reality Applications in Construction Safety Literature. *Safety* **2019**, *5*, 51. [CrossRef]
39. Somaiieh, R.; Sadeghi-Niaraki, A.; Choi, S.-M. A Review on Mixed Reality: Current Trends, Challenges and Prospects. *Appl. Sci.* **2020**, *10*, 636.
40. Rankohi, S.; Waugh, L. Review and analysis of augmented reality literature for construction industry. *Vis. Eng.* **2013**, *1*, 9. [CrossRef]

41. Jokkaw, N.; Suteecharuwat, P.; Weerawetwat, P.J. Measurement of construction workers' feeling by virtual environment (VE) technology for guard rail design in high-rise building construction projects. *Eng. J.* **2017**, *21*, 161–177. [CrossRef]
42. Eiris, R.; Gheisari, M.; Esmaeili, B. Using augmented 360-degree panoramas of reality for construction safety training. *Int. J. Environ. Res. Public Health* **2018**, *15*, 2452. [CrossRef]
43. Kim, B.; Kim, C.; Kim, H. Interactive modeler for construction equipment operation using augmented reality. *J. Comput. Civ. Eng.* **2012**, *26*, 331–341. [CrossRef]
44. Zhou, Y.; Luo, H.; Yang, Y. Implementation of augmented reality for segment displacement inspection during tunneling construction. *Autom. Constr.* **2017**, *82*, 112–121. [CrossRef]
45. Shin, D.H.; Dunston, P.S. Identification of application areas for augmented reality in industrial construction based on technology suitability. *Autom. Constr.* **2008**, *17*, 882–894. [CrossRef]
46. Wang, X.; Truijens, M.; Hou, L.; Wang, Y.; Zhou, Y. Integrating augmented reality with building information modeling: Onsite construction process controlling for the liquefied natural gas industry. *Autom. Constr.* **2014**, *40*, 96–105. [CrossRef]
47. Bosche, F.; Abdel-Wahab, M.; Carozza, L. Towards a mixed reality system for construction trade training. *J. Compt. Civ. Eng.* **2016**, *30*, 16. [CrossRef]
48. Liu, F.; Seipel, S. Precision study on augmented reality-based visual guidance for facility management tasks. *Autom. Constr.* **2018**, *90*, 79–90. [CrossRef]
49. Tedeschi, A.; Benedetto, F. A real-time automatic pavement crack and pothole recognition system for mobile Android-based devices. *Adv. Eng. Inform.* **2017**, *32*, 11–25. [CrossRef]
50. Sabeti, S.; Shoghli, O.; Baharani, M.; Tabkhi, H. Toward AI-enabled augmented reality to enhance the safety of highway work zones: Feasibility, requirements, and challenges. *Adv. Eng. Inform.* **2021**, *50*, 101429. [CrossRef]
51. Kim, D.; Ko, Y.J. The impact of virtual reality technology on sports spectators' flow experience and satisfaction. *Comput. Hum. Behav.* **2019**, *93*, 346–356. [CrossRef]
52. Vahdatikhaki, F.; El-Ammari, K.; Langroodi, A.K.; Miller, S.; Hammad, A.; Doree, A. Beyond data visualization: A context-realistic construction equipment training simulators. *Autom. Constr.* **2019**, *106*, 102853. [CrossRef]
53. de Klerk, R.; Duarte, A.M.; Medeiros, D.P.; Duarte, J.P.; Jorge, J.; Lopes, D.S. Usability studies on building early-stage architectural models in virtual reality. *Autom. Constr.* **2019**, *103*, 104–116. [CrossRef]
54. Wejnert, B. Integrating Models of Diffusion of Innovations: A Conceptual Framework. *Annu. Rev. Sociol.* **2002**, *28*, 297–326. [CrossRef]
55. Hartmann, T.; Meerveld, H.V.; Vossebeld, N.; Adriaanse, A. Aligning building information model tools and construction management methods. *Autom. Constr.* **2012**, *22*, 605–613. [CrossRef]
56. Dossick, C.S.; Neff, G. Organizational Divisions in BIM-enabled Commercial Construction. *J. Constr. Eng. Manag.* **2010**, *136*, 459–467. [CrossRef]
57. Neges, M.; Koch, C. Augmented reality supported work instructions for onsite facility maintenance. In Proceedings of the 23rd International Workshop of the European Group for Intelligent Computing in Engineering, Leuven, Belgium, 30 June–3 July 2019; pp. 1–10.
58. Fazel, A.; Izadi, A. An interactive augmented reality tool for constructing free-form modular surfaces. *Autom. Constr.* **2018**, *85*, 135–145. [CrossRef]
59. Hasanzadeh, S.; Polys, N.; Garza, J.M. Presence, Mixed Reality, and Risk-Taking Behavior: A Study in Safety Interventions. IEEE Transactions on Visual. *Comput. Graph.* **2020**, *26*, 2115–2125.
60. Zhao, D.; Lucas, J. Virtual reality simulation for construction safety promotion. *Int. J. Inj. Control. Saf.* **2015**, *22*, 57–67. [CrossRef] [PubMed]
61. Pereira, E.R.; Moore, H.F.; Gheisari, M.; Esmaeili, B. Development and Usability Testing of a Panoramic Augmented Reality Environment for Fall Hazard Safety Training. In Proceedings of the 35th CIB W78 2018 Conference: IT in Design, Construction, and Management, Chicago, IL, USA, 1–3 October 2018; pp. 271–279.
62. Golparvar-Fard, M.; Pena-Mora, F.; Savarese, S. 4ar–a 4-dimensional augmented reality model for automating construction progress monitoring data collection, processing, and communication. *J. Inf. Technol. Constr.* **2009**, *14*, 129–153.
63. Huang, L.; Kawamura, T.; Yamada, H. Operability of a control method for grasping soft objects in a construction teleoperation robot tested in virtual reality. *Int. J. Fluid Power* **2014**, *13*, 39–48. [CrossRef]
64. Albert, A.; Hallowell, M.R.; Kleiner, B.; Chen, A.; Golparvar-Fard, M. Enhancing construction hazard recognition with high-fidelity augmented virtuality. *J. Constr. Eng. Manag.* **2014**, *140*, 04014024. [CrossRef]
65. Chu, M.; Matthews, J.; Love, P.E.D. Integrating mobile Building Information Modelling and Augmented Reality systems: An experimental stcMMudy. *Autom. Constr.* **2018**, *85*, 305–316. [CrossRef]
66. Shi, Y.; Du, J.; Ahn, C.R.; Ragan, E. Impact assessment of reinforced learning methods on construction workers' fall risk behavior using virtual reality. *Autom. Constr.* **2019**, *104*, 197–214.
67. Fernandes, K.J.; Raja, V.; White, A.; Tsinopoulos, C.-D. Adoption of virtual reality within construction processes: A factor analysis approach. *Technovation* **2006**, *26*, 111–120. [CrossRef]
68. Ahmed, S. A Review on Using Opportunities of augmented reality and virtual reality in construction project management. *Organ. Technol. Manag. Constr.* **2019**, *11*, 1839–1852. [CrossRef]

69. Sampaio, A.Z.; Martins, O.P. The application of virtual reality technology in the construction of bridge: The cantilever and incremental launching methods. *Autom. Constr.* **2014**, *37*, 58–67. [CrossRef]
70. Du, J.; Shi, Y.; Zou, Z.; Zhao, D. Cloud-based multiuser virtual reality headset system for project communication of remote users. *J. Constr. Eng. Manag.* **2018**, *144*, 04017109. [CrossRef]
71. Wuni, I.Y.; Shen, G.Q. Towards a decision support for modular integrated construction: An integrative review of the primary decision-making actors. *Int. J. Constr. Manag.* **2019**, 1–20. [CrossRef]
72. Palmarini, R.; Erkoyuncu, J.A.; Roy, R.; Torabmostaedi, H. A systematic review of augmented reality applications in maintenance. *Robot. Comput. -Integr. Manu.* **2018**, *49*, 215–228. [CrossRef]
73. Mutis, I.; Ambekar, A. Challenges and enablers of augmented reality technology for in situ walkthrough applications. *J. Inform. Technol. Constr.* **2020**, *25*, 55–71. [CrossRef]
74. Renganayagalu, S.K.; Mallam, S.C.; Nazir, S. Effectiveness of VR Head Mounted Displays in Professional Training: A Systematic Review. *Technol. Knowl. Learn.* **2021**, *26*, 999–1041. [CrossRef]
75. Behringer, R.; Øhrstrøm, P. Persuasive Design in Teaching and Learning. *Int. J. Concept. Struct. Smart Appl.* **2013**, *1*, 1–5. [CrossRef]
76. Eynon, J. *BIM-ing the Team—Construction Manager's BIM Handbook*; John Wiley & Sons Ltd.: New York, NY, USA, 2016.
77. Elshafey, A.; Saar, C.C.; Binti, E.; Gheisari, A.M.; Usmani, A. Technology acceptance model for Augmented Reality and Building Information Modeling integration in the construction industry. *J. Inform. Techol. Constr.* **2020**, *25*, 161–172. [CrossRef]
78. Ghobadi, M.; Sepasgozar, S.M.E. An Investigation of Virtual Reality Technology Adoption in the Construction Industry. In *Smart Cities and Construction Technologies*; IntechOpen: London, UK, 2020; pp. 1–35.
79. Gontier, J.C.; Wong, P.S.P.; Teo, P. Towards the implementation of immersive technology in construction—A SWOT Analysis. *J. Inform. Technol. Constr.* **2021**, *26*, 366–380.
80. Khan, A.; Sepasgozar, S.; Liu, T.; Yu, R. Integration of BIM and Immersive Technologies for AEC: A Scientometric-SWOT Analysis and Critical Content Review. *Buildings* **2021**, *11*, 126. [CrossRef]
81. Chapman, C. Key points of contention in framing assumptions for risk and uncertainty management. *Int. J. Prof. Manag.* **2006**, *24*, 303–313. [CrossRef]
82. Qi, B.; Razkenari, M.; Li, J.; Costin, A.; Kibert, C.; Qian, S. Investigating US industry practitioners' perspectives towards the adoption of emerging technologies in industrialized construction. *Buildings* **2020**, *10*, 85. [CrossRef]
83. Schimanski, C.P.; Marcher, C.; Monizza, G.P.; Matt, D.T. The Last Planner® system and building information modeling in construction execution: From an integrative review to a conceptual model for integration. *Appl. Sci.* **2020**, *10*, 821. [CrossRef]
84. Karakhan, A.A.; Rajendran, S.; Gambatese, J.; Nnaji, C. Measuring and evaluating safety maturity of construction contractors: Multicriteria decision-making approach. *J. Constr. Eng. Manag.* **2018**, *144*, 04018054. [CrossRef]
85. Souza, M.T.D.; Silva, M.D.D.; Carvalho, R.D. Integrative review: What is it? How to do it? *Einstein* **2010**, *8*, 102–106. [CrossRef]
86. Hwang, B.-g.; Shan, M.; Supa'at, N.N.B. Green commercial building projects in Singapore: Critical risk factors and mitigation measures. *Sust. Cities Soc.* **2017**, *30*, 237–247. [CrossRef]
87. Al-Omari, A.I.; Benchiha, S.; Almanjahie, I.M. Efficient Estimation of the Generalized Quasi-Lindley Distribution Parameters under Ranked Set Sampling and Applications. *Math. Probl. Eng.* **2021**, *2021*, 1–17. [CrossRef]
88. Azeez, M.; Gambatese, J.; Hernandez, S. What do construction workers really want? A study about representation, importance, and perception of U.S. construction occupational rewards. *J. Constr. Eng. Manag.* **2019**, *145*, 04019040. [CrossRef]
89. Zou, P.X.W.; Zhang, G.; Wang, J. Understanding the key risks in construction projects in China. *Int. J. Proj. Manag.* **2007**, *25*, 601–614. [CrossRef]
90. Ke, Y.; Wang, S.; Chan, A.P.C.; Cheung, E. Understanding the risks in China's PPP projects: Ranking of their probability and consequence. *Eng. Constr. Archi. Manag.* **2011**, *18*, 481–496. [CrossRef]
91. Liu, J.; Zhao, X.; Li, Y. Exploring the factors inducing contractors' unethical behavior: Case of China. *J. Prof. Issues Eng. Edu. Pract.* **2016**, *143*, 04016023. [CrossRef]
92. Vinzi, V.E.; Trinchera, L.; Amato, S. PLS path modeling: From foundations to recent developments and open issues for model assessment and improvement. In *Handbook of Partial Least Squares*; Esposito Vinzi, V., Ed.; Springer: Berlin/Heidelberg, Germany, 2010; pp. 47–82. [CrossRef]
93. Rahman, I.A.; Memon, A.H.; Karim, A.T. Examining factors affecting budget overrun of construction projects undertaken through management procurement method using PLS-SEM approach. In Proceedings of the Evaluation of Learning for Performance Improvement Internet Conference, Kota Bharu, Malaysia, 25–26 February 2013.
94. David, G. *Partial Least Squares (PLS-SEM)*; Garson and Statistical Associates Publishing: Asheboro, CA, USA, 2016.
95. Ojelabi, R.A.; Oyeyipo, O.O.; Afolabi, A.O.; Omuh, I.O. Evaluating barriers inhibiting investors participation in Public-Private Partnership project bidding process using structural equation model. *Int. J. Constr. Manag.* **2020**, 1–10. [CrossRef]
96. Moshood, T.D.; Nawanir, G.; Sorooshian, S.; Mahmud, F.; Adeleke, A.Q. Barriers and Benefits of ICT Adoption in the Nigerian Construction Industry. A Comprehensive Literature Review. *Appl. Syst. Innov.* **2020**, *3*, 46. [CrossRef]
97. Yap, J.B.H.; Lee, K.P.H.; Wang, C. Safety enablers using emerging technologies in construction projects: Empirical study in Malaysia. *J. Eng. Des. Technol.* **2021**. *ahead-of-print*. [CrossRef]
98. Hussain, S.; Fangwei, Z.; Siddiqi, A.; Ali, Z.; Shabbir, M. Structural equation model for evaluating factors affecting quality of social infrastructure projects. *Sustainability* **2018**, *10*, 1415. [CrossRef]

99. Introduction to Structural Equation Modeling Partial Least Squares (SEM-PLS). Available online: https://www.slideshare.net/pallobby/introduction-to-structural-equation-modeling-partial-least-sqaures-sempls-61043221 (accessed on 17 December 2021).
100. Henseler, J.; Ringle, C.M.; Sarstedt, M. Using partial least squares path modeling in advertising research: Basic concepts and recent issues. In *Handbook of Research on International Advertising*; Okazaki, S., Ed.; Edward Elgar Publishing: Cheltenham, UK, 2012; pp. 252–276.
101. Memon, A.H.; Rahman, I.A. SEM-PLS analysis of inhibiting factors of cost performance for large construction projects in Malaysia: Perspective of clients and consultants. *Sci. World J.* **2014**, *2014*, 1–9. [CrossRef]
102. George, D.; Mallery, M. *Using SPSS for Windows Step by Step: A Simple Guide and Reference*; Allyn & Bacon: Boston, MA, USA, 2003.
103. Hock, C.; Ringle, C.M.; Sarstedt, M. Management of multi-purpose stadiums: Importance and performance measurement of service interfaces. *Int. J. Serv. Technol. Manag.* **2010**, *14*, 188–207. [CrossRef]
104. Hair, J.F.; Lukas, B. *Marketing Research*; McGraw-Hill Education: Sydney, Australia, 2014.
105. Chin, W.W. *The Partial Least Squares Approach to Structural Equation Modeling*; Lawrence Erlbaum Associates: Mahwah, NJ, USA, 1998.
106. Taylor, T.; Geldenhuys, S. Using Partial Least Squares to measure tourism students' satisfaction with work-integrated learning. In *Tourism–Perspectives and Practices*; Sabah, S., Ed.; IntechOpen: London, UK, 2019; pp. 1–8.
107. Cohen, J. *Statistical Power Analysis for the Behavioural Sciences*; Lawrence Erlbaum Associates: Hillsdale, NJ, USA, 1988.
108. Yung, R.; Khoo-Lattimore, C. New realities: A systematic literature review on virtual reality and augmented reality in tourism research. *Curr. Issues Tour.* **2017**, *22*, 2056–2081. [CrossRef]
109. Jeelani, I.; Han, K.; Albert, A. Development of Immersive Personalized Training Environment for Construction Workers. In Proceedings of the Computing in Civil Engineering, American Society of Civil Engineers, Reston, VA, USA, 25–27 June 2017; pp. 407–415.
110. Stansfield, S.; Shawver, D.; Sobel, A.; Prasad, M.; Tapia, L. Design and implementation of a virtual reality system and its application to training medical first responders. *Presence Teleoperators Virtual Environ.* **2000**, *9*, 524–556. [CrossRef]
111. Seymour, N.E.; Gallagher, A.G.; Roman, S.A.; O'Brien, M.K.; Bansal, V.K.; Andersen, D.K.; Satava, R.M. Virtual reality training improves operating room performance—Results of a randomized, double-blinded study. *Ann. Surg.* **2002**, *236*, 458–464. [CrossRef]
112. Sturts, D.C.; Sakagami, M. Implementing web-based project management systems in the United States and Japan. *J. Constr. Eng. Manag.* **2008**, *134*, 189–196.
113. Industry Foundation Classes Release 4 (IFC 4). Available online: https://standards.buildingsmart.org/IFC/RELEASE/IFC4/FINAL/HTML/ (accessed on 17 December 2021).
114. Grudzewski, F.; Awdziej, M.; Mazurek, G.; Piotrowska, K. Virtual Reality in Marketing Communication—The Impact on the Message, Technology and Offer Perception—Empirical Study. *Econ. Bus. Rev.* **2018**, *4*, 36–50. [CrossRef]
115. Lin, Y.C.; Chen, Y.P.; Yien, H.W.; Huang, C.Y.; Su, Y.C. Integrated BIM, game engine and V.R. technologies for healthcare design: A case study in a cancer hospital. *Adv. Eng. Inform.* **2018**, *36*, 130–145. [CrossRef]
116. Dris, A.-S.; Lehericey, F.; Gouranton, V.; Arnaldi, B. OpenBIM Based IVE Ontology: An Ontological Approach to Improve Interoperability for Virtual Reality Applications. In *Advances in Informatics and Computing in Civil and Construction Engineering*; Mutis, I., Hartmann, T., Eds.; Springer Publishing: Cham, Switzerland, 2019; pp. 129–136.
117. Manikas, K.; Hansen, K.M. Software ecosystems—A systematic literature review. *J. Syst. Softw.* **2013**, *86*, 1294–1306. [CrossRef]
118. Valenca, G.; Alves, C.; Heimann, V.; Jansen, S.; Brinkkemper, S. Competition and collaboration in requirements engineering: A case study of an emerging software ecosystem. In Proceedings of the IEEE 22nd International Requirements Engineering Conference, Karlskrona, Sweden, 25–29 August 2014; pp. 84–393.
119. Stagman, M. How UK Government Is Helping Virtual and Augmented Reality Flourish. Available online: https://www.inlinepolicy.com/blog/how-uk-government-is-helping-virtual-and-augmented-reality-flourish (accessed on 17 December 2021).