Measuring Virtual Reality (VR) Technology Application and Adoption in Chinese Construction Risk Management †

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Abstract: In recent years, the improvement of risk management and the Occupational Health and Safety (OHS) training process has become a hot topic. Virtual Reality (VR) technology is an efficient method to improve training efficiency and reduce accidents. Previous studies have validated its feasibility and usefulness in the construction industry. However, there is currently a lack of research on the adoption of VR technology in the Chinese construction industry. The present work explores the current applications of VR and the model for possible adoption by the Chinese construction companies using a mixed research methodology. Furthermore, this research has quantified the relationships between each adoption variable in China.

Keywords: Virtual Reality; risk management; Chinese construction industry; VR adoption; safety management; accident prevention

1. Introduction

The construction industry is a large, complex, and labor-intensive sector. It is also a high-risk environment where workers are more exposed to potential hazards than other industries. In particular, Chinese construction projects have shortcomings in risk identification, analysis, and evaluation aspects during the risk management process [1]. A previous study points out that an effective method to prevent accidents is to improve training efficiency regarding risk prevention and control [2]. Virtual Reality (VR) technology can effectively enhance knowledge absorption during construction risk management and training.

VR technology has been widely applied in entertainment, science, medicine, and other areas of knowledge [3]. In previous studies, the equipment has included helmets and motion capture systems to simulate tangible interactive 3D models [4]. Meanwhile, VR technology feasibility has been confirmed on construction risk management to prevent accidents and reduce construction reworks. However, it is still in the pilot stage, and it has not been widely applied in the Chinese construction industry [5]. Furthermore, there is a lack of systematic adoption of VR models to help stakeholders implement this technology in China. In light of these, this research report explores the application and adoption of VR technology in Chinese construction risk management to improve its application in the industry.

2. Material and Methods

2.1. Research Method

As shown in Figure 1, this research used a mix of research methodologies to achieve the established purposes, measuring the current application of VR technology in Chinese construction companies and emphasizing their adoption and attitudes towards this disruptive technology. An appropriate adoption model is established based on previous
similar research [6,7]. In addition, this research mainly considered collecting secondary data to analyze and summarize adoption variables in China from previous studies. As shown in Table 1, comparing each external factor’s degree and eigenvector value, the factors with more significant degree value mean they have more connections with other factors. Meanwhile, factors with more significant eigenvector values indicate that it is more important throughout the whole network. On the other hand, this research also employs the quantitative research method by an online questionnaire survey to measure the possible variables affecting the adoption and application of VR technology in the construction industry in China.

![Figure 1. Research Methodology flowchart.](image)

**Table 1. Ranking of the Influencing Chinese adoption factors by Ucinet.**

| NO. | Influencing Chinese Adoption Factors                        | Degree | Eigenvector |
|-----|-------------------------------------------------------------|--------|-------------|
| 1   | Government support/subsidies                               | 0.486  | 0.479       |
| 2   | Government regulation/Mandatory requirements               | 0.378  | 0.386       |
| 3   | Government strategies                                     | 0.378  | 0.382       |
| 4   | Management incentive by companies                          | 0.351  | 0.308       |
| 5   | Ease of use                                                | 0.324  | 0.274       |

Degree: Degree centrality assigns an importance score based purely on the number of links held by each node. Eigenvector: Measuring a node’s influence based on the number of links it has to other nodes within the network.

2.2. Formatting of Mathematical Components

This research used Cronbach’s alpha to measure the internal consistency and reliability of the received results. Then, this research used the Kruskal–Wallis test to explore whether professional experience or the participants’ occupations affect the variables of the Chinese VR adoption model. Moreover, to measure the relationship and correlation coefficient between each adoption variable in the Chinese construction industry, Spearman’s rank correlation coefficient formula would be used to analyze the collected data as the non-parametric method [8].

3. Result and Discuss

The questionnaire survey mainly used disagree/agree-type questions with a 5-point Likert scale to measure the Chinese stakeholders’ perceptions of VR technology in the construction industry. The results of Cronbach’s alpha $\rho_T$ is 0.876, which is above 0.8. It indicates that the received online questionnaire survey has good reliability and internal
consistency. Furthermore, according to the results of the Kruskal–Wallis test used in this research (Table 2), the significant values of VR adoption, adoption motivation, intrinsic motivation, and extrinsic motivation are 0.518, 0.637, 0.448, and 0.133, respectively, which are significantly above 0.05 or 0.01. Therefore, there is no significant difference between each professional experience group, and the professional experience would not significantly affect adoption variables. Moreover, the received results were quantitively analyzed using Spearman’s rank correlation coefficient method, commonly used in the non-parametric correlation analysis. The adoption of VR in the Chinese construction industry model is shown in Figure 2 with coefficients. A closer value of the correlation coefficient to −1 and 1 means powerful negative and positive correlation relationships between the variables, respectively.

Table 2. Kruskal–Wallis test—Professional experience variable.

| Test Statistics a,b | VR Adoption | Adoption Motivation | Intrinsic Motivation | Extrinsic Motivation |
|---------------------|-------------|----------------------|----------------------|----------------------|
| Kruskal–Wallis H    | 2.270       | 1.699                | 2.656                | 5.588                |
| df                  | 3           | 3                    | 3                    | 3                    |
| Asymp. Sig.         | 0.518       | 0.637                | 0.448                | 0.133                |

a Kruskal–Wallis Test; b Grouping Variable: Professional Experience Level.

Figure 2. VR adoption model with the correlation coefficient. * Correlation is significant at the 0.05 level (2—tailed); ** Correlation is significant at the 0.01 level (2—tailed).

4. Conclusions and Future Path

4.1. Conclusions

This research summarized the applications of VR technology in Chinese construction risk management and corresponding benefits and challenges. Furthermore, this research has established a possible model of adoption for the construction industry in China by collecting data from existing secondary data and questionnaire surveys. The Kruskal–Wallis test illustrates that the adoption variables are not significantly affected by the professional level of experience. In addition, Spearman’s rank correlation coefficient results indicated that intrinsic motivations strongly positively affect the adoption motivation. Meanwhile, the potential benefits and performance expectancy variables are also essential triggers for people accepting VR technology. Moreover, the specific external factors in China (e.g., government support, regulation, and strategies) positively affect the adoption motivation.
this research fills the research gap, which lacks a quantitative VR model of adoption, although the limited sample size constrains the generality of the study results.

4.2. Future Path

Further research will consider improving the limitations of this research about the sample size and sampling method. Furthermore, future research will explore the efficiency of construction risk management based on the different immersive experience levels. Moreover, the VR technology adoption model in China will also consider inserting the immersive experience level as the variable.

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References
1. Tang, W.; Qiang, M.; Duffield, C.F.; Young, D.M.; Lu, Y. Risk management in the Chinese construction industry. J. Constr. Eng. Manag. 2007, 133, 944–956. [CrossRef]
2. Li, X.; Yi, W.; Chi, H.-L.; Wang, X.; Chan, A.P.C. A critical review of virtual and augmented reality (VR/AR) applications in construction safety. Autom. Constr. 2018, 86, 150–162. [CrossRef]
3. Kloiber, S.; Settgast, V.; Schinko, C.; Weinzerl, M.; Fritz, J.; Schreck, T.; Preiner, R. Immersive analysis of user motion in VR applications. Vis. Comput. 2020, 36, 1937–1949. [CrossRef]
4. Steuer, J. Defining Virtual Reality: Dimensions Determining Telepresence. J. Commun. 1992, 42, 73–93. [CrossRef]
5. Huo, L.; Li, L.; Shen, L.; Meng, X. Analysis of the application prospects of VR technology in the construction industry. Times Financ. 2020, 18, 83–84.
6. Hong, Y.; Hammad, A.W.A.; Sepasgozar, S.; Akbarnezhad, A. BIM adoption model for small and medium construction organisations in Australia. Eng. Constr. Archit. Manag. 2017, 26, 154–183. [CrossRef]
7. Ghobadi, M.; Sepasgozar, S.M.E. An investigation of Virtual Reality Technology Adoption in the Construction Industry. In Smart Cities and Construction Technologies; Shirowzhan, S., Zhang, K., Eds.; Intechopen: London, UK, 2020.
8. Myers, J.L.; Well, A.D.; Lorch, R.F., Jr. Research Design and Statistical Analysis; Routledge: London, UK, 2013.