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ADOPTION OF SURVEY METHODS AND FUTURE OF VIRTUAL REALITY IN CONSTRUCTION PROJECT AND MANAGEMENT

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ABSTRACT
Already during its introduction in the construction industry in the 1990s, VR was considered to have great potential in construction industry, providing new opportunities for improving the construction processes. However, it is only recently that VR has started to be adopted as an enabling technology in construction projects. Even though virtual reality today is primarily used for visualizing the final product, the potential as a universal interface application is high. This paper includes the methodology adopted to understand the industry vision for virtual reality in construction. The questionnaire shows the factors which affect most for the adoption of VR in the construction industry. And also, analysis of the result from the gathered data by using a quantitative methodology.

Keywords: Virtual Reality (VR), Visualization, Construction Management, Organizational Health and Safety (OHS), Virtual reality in construction.

INTRODUCTION

Virtual reality refers to an immersive multimedia or computer-simulated life, replicates an environment that simulates physical presence in places in the real world or imagined worlds. Virtual reality can recreate sensory experiences, which include virtual taste, sight, smell, sound, and touch (Luo, 2015). People gain 70 percent of information by vision, resulting in systems like HMDs that provide the visual component of immersion has been widely used to develop virtual environments. VR provides one of the best tools for accident reconstruction, training and hazard identification by immersing the trainee in an environment that is as real as possible. The use of high quality three-dimensional graphics, sound and dynamic simulation combine to form a uniquely engaging experience (Kizil and Joy, 2001).

Although the numbers of injuries in the construction industry have decreased significantly since the passage of the Occupational Safety and Health Act in 1970, several hundred workers still face fatalities every year. Addressing safety challenges remains a priority in every construction project as a result of this legislation. Safety managers now constantly attempt to enhance the effectiveness of training materials provided to workers (Bhoir and Esmaeili, 2015).

Current Virtual Reality (VR) technologies build upon ideas that date back to the 1960s and earlier. In 1968, Ivan Sutherland created the first head-mounted display that rendered simple wireframe models for the viewer's changing pose. This invention laid the foundations for the technologies we now call Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR), as defined by Milgram et al. in their reality-virtuality continuum. The term denotes a continuous scale ranging between the completely virtual and the completely real. VR is commonly described as computer-generated environments or realities that are designed to simulate a person's physical presence in an

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immersive and convincing environment. The purpose of VR is to allow a person to experience and manipulate the environment as if it were the real world. The VR subject experiences “hypes” at regular intervals, and they disappear shortly thereafter. With the advent of more powerful graphics hardware and innovative tracking technologies, the topic has been revisited in recent years. According to Gartner's hype cycle, VR has finally reached the “plateau of productivity”. The first applications can be found in the areas of gaming, marketing and advertising. For industrial applications, VR offers great potential that goes beyond just looking at virtual models. The idea of “Virtual Prototyping” (VP) or “Virtual Design Review” allows users to examine prototypes in a realistic way starting in the earliest design stages. Many companies conduct design reviews to detect errors in their products early on before the physical product is manufactured. Today, the classic design review process is often performed directly on the PC with the support of CAD software packages (Koskela, L., Ballard, G. and Howell, G.2003).

LITERATURE REVIEW

General

The literature review has been done by referring to various research papers and by gathering all the important information and findings required from those research papers. Aim of literature review was to identify and shortlist factors of VR in construction sector, current flows, and to find future scope of VR. In this section we studied literature review to understand different techniques and methods used for virtual reality in construction.

1. Safety participation with virtual reality in construction

This paper solve problems by providing a framework for systematic personal safety performance assessment and then developing a practical approach for personal safety participation assessment. This involved the development of a supporting multi-user platform to sharing safety-related information and also protecting the workers from danger sources through obtaining real-time locations (13).

The framework consists of the following three modules: Safety Knowledge Dissemination (SKD), Safety Knowledge Reflection (SKR), and Safety Knowledge Assessment (SKA). The system prototype was developed and evaluated with case studies to identify the system’s benefits and limitations. The results concluded that using mobile based VR+AR would improve construction safety & health effectively (14).

The paper provides a method of BIM based virtual environment with an intent to improve the safety training programs currently in practice in the construction industry. Through BIM models and VR tools a more proactive approach has been proposed to tackle safety issues (5).

2. Virtual reality in Education

This paper has focussed on the importance of teaching CAD systems at school, not only as a good instrument for “drawings” but mostly as a helpful tool to be used to develop research work and, as a professional support in their activity as engineers(8).

In this paper, we argue and present evidence from vast research that VR is an excellent tool in engineering education. Through our review, we deduced that VR has positive cognitive and pedagogical benefits in engineering education, which ultimately improves the students’ understanding of the subjects, performance and grades, and education experience(26).

The researchers collected student perceptions of the experience, and comparison of the two VR viewing options are analyzed and discussed in this paper. Overall, students’ attitudes were favorable about the use of VR as a substitute for the construction site visit and the data indicate that they preferred more immersive form factors for viewing the 360° panoramic photography. Lastly, students offered, through open-ended feedback, some ways in which the experience could be made more authentic(25).

3. Adoption of Virtual Reality for Site Layout

The purpose of this paper is to assess traditional practices for site layout planning and introduce the application of VR in construction jobsite organisations for site layout planning, collision detection, and evaluation of construction site layout scenarios. In this paper, two different construction jobsite scenarios for the structural phase of a construction are created and for optimisation purposes, Autodesk Revit software, SketchUp, and Lumion are used to develop the three-dimensional (3D) model(29).

The main objectives of this paper are to understand the industry trends in adopting AR & virtual reality technologies and identifying gaps within the industry. The identified gaps can lead to opportunities for developing new tools and finding new use cases. To achieve these goals, two rounds of a survey at two different time periods (a year apart)

were conducted. The findings demonstrate that older generations are significantly more confident about the future of AR & VR technologies and they see more benefits in VR utilization (30).

4. Analyzing the potential of Virtual Reality

The overall aim is to improve the competitiveness of the construction industry by developing a flexible, customer focused, efficient and reliable system of working throughout the design and operation cycle of a project. We believe that Virtual Reality techniques can be used interactively and can interface intelligently with other key existing IT systems for CAD, structural design, environmental design, costing and scheduling (27).

This paper presents a result of an experiment to integrate three different types of AEC digital modeling data and proposed workflows for IVR applications in construction, visualization and building performance analysis. The experiment deals with construction simulation, rapid generation of the VR scene for existing building and airflow visualization. Several workflows investigated game engine and VR tools have been used (28).

5. Investigating virtual reality Applications

This study revealed limited ability to interact with all the objects in the game. Future research intends to address this issue, expanding on the current research. Areas may include ability of the user to select the location of jobsite objects, i.e. the crane, materials, and tools. Additionally, giving the user the ability to operate operable objects such as the crane (31).

The research papers briefly describe the diverse avenues that have the scope of development or improvement under virtual reality. Collaboration and immersion are two aspects that are being explored in the field of design. With the complexities in design introduced by evolving time it becomes essential to manage this data in an efficient manner to seek maximum output (32).

METHODOLOGY ADOPTED

In this study, a quantitative approach was used to get factual information about the awareness of virtual reality use in the construction industry. The data is collected from the data an online questionnaire survey. The whole process is shown in below figure.

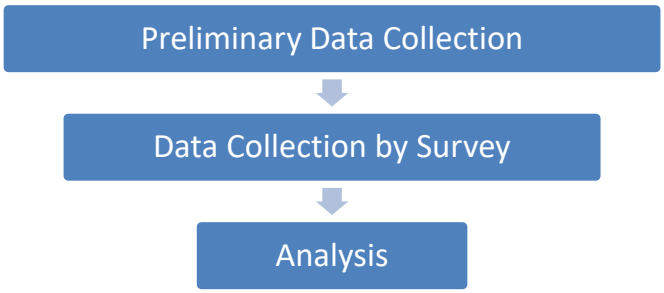

Figure No: 1. Methodology process chart

1. Preliminary Data Collection: The preliminary data for questionnaire design was taken by study current available literature review of research articles, paper published in various publications regarding VR in construction industry and understanding current scenario of technology enhancement and practicality in construction industry.

2. Data Collection by Survey: As mentioned earlier data collection was done by collecting data from online questionnaire survey using Google Forms. Prime focus of questionnaire was to take response of mainly construction professionals to understand and derive conclusion of the research. Professional Included in the study was in field of Architecture, Engineering, Developer and contractor and professors.

3. Data Analysis: After the data collection by the questionnaire survey, the analysis is to be done. In data collection, the opinion of professionals was collected through questions listed out in questionnaire form with help of Google forms. Here data analysis is accomplished with the data collected. Collected data is compared with one and all, and the percentage of responses is found out. Data analysis is done to determine the most affecting factors for use of VR in the construction industry.

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RESULTS AND DISCUSSION

General Respondent Information:

Overall, in both surveys, 71% (67% and 77%, respectively, in each survey) of the respondents were male and 29% were female (33% and 23%, respectively, in each survey). Respondent's age ranged from 25 to 60 with an average of 32 overall in both surveys. Approximately, 70% of the respondents were 30 years old or younger. Respondents were also asked about their roles in the industry. The survey categorized the respondents in four groups of engineer and designer (49% and 51%, respectively in each survey), researcher (21% and 32%, respectively in each survey), manager (29% and 17%, respectively in each survey), and owner (0%, respectively, in each survey).Professional experience is another important indicator of the expertise of the respondents.

Table no. 1 Experience of Participants

Options	Percentage
Less than a year	29%
1-5 years	57%
6-10 years	7%
More than 10 years	7%

Virtual reality Knowledge and Experience:

This section evaluates the adoption of VR technologies in the industry from by comparing the result of the first round of the survey with the result of the second round. The important questions and options that were selected by the experts. In each survey, the respondents were asked about their familiarity with VR equipment and whether they have used any related tools. This growth indicates that companies and professionals are becoming more familiar and interested in adopting VR tools.

Table No: 2. Virtual reality knowledge

Section	Option	Overall %
Usage of VR	Not at all	25%
	But I have seen	35%
	Yes	40%
Understanding and expertise in VR tools	Hardly at all	4%
	Not very well	12%
	Average	33%
	Very well	33%
	Extremely well	18%
VR usage on majority of the projects within 10 years	Definitely not	2%
	Probably not	9%
	Might or might not	20%
	Probably yes	39%
	Definitely yes	30%
Increase in end-users satisfaction rate by integrating VR	Significantly	54%
	Somewhat	34%
	Neutral	5%
	Not much	6%
	Not at all	2%

Visions of the Future virtual reality:

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This section was designed to determine the opportunities of VR in the industry. Respondents were asked to predict whether VR will be used on all or majority of the projects within the next 5 to 10 years. More than 70% of all respondents chose "probably yes" or "definitely yes," indicating a significant increase in the adoption of VR technologies. In addition, over the past year, the percentage of "definitely yes" and "probably yes" increased by 14%, indicating a rapid and positive change in the industry trend. Below table presents respondents' predictions on the VR usage in the AEC industry for the next 5 to 10 years.

The last question of this section asked for an optimal project size to which VR can be most beneficial. Large projects had the highest response, showing that large and mega projects can make the most out of VR technologies compared to small and medium projects.

Table no. 3. : VR usage on majority of projects within 10 years

Options	Percentage
Definitely not	2%
Probably not	9%
Might or might not	20%
Probably yes	39%
Definitely yes	30%

Table no. 4: Cost and time savings by utilizing VR during construction

Options	Percentage
I am not Sure	17%
Not much	8%
Slightly effective	21%
Noticeably by effective	40%
More effective	13%

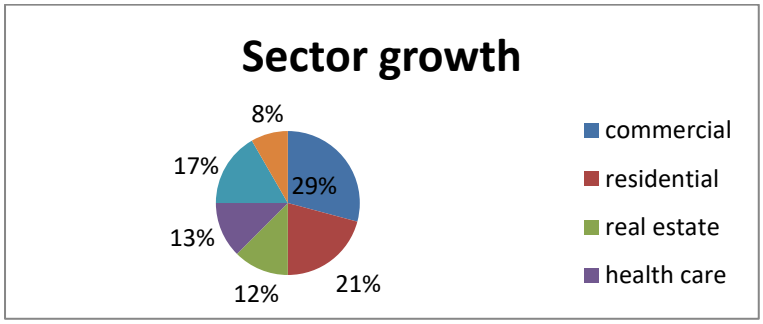

Figure 2: Sector growth in virtual reality

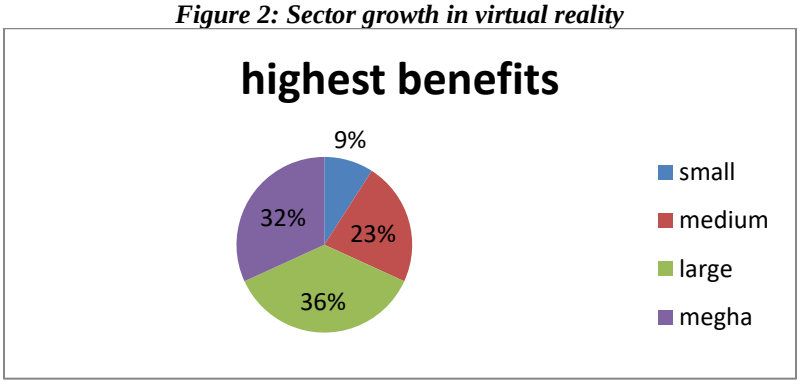

Figure 3: Project size achieve highest benefits

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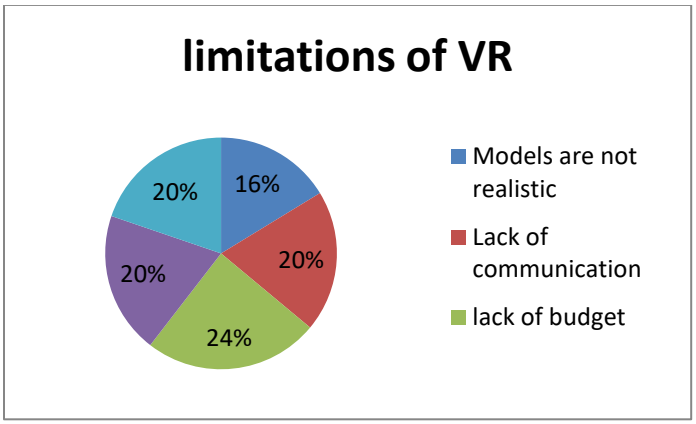

Figure 4: Limitations of VR

Analysis:

To measure the growth of confidence level of the respondents, the respondents' prediction on whether or not VR technologies will be used on the majority of the projects within the next 5 to 10 years was analyzed.

The result from unpaired t-test indicates that there was a significant difference in the scores (definitely not=0, probably not=1, might or might not=2, probably yes=3, definitely yes=4) of this question for First survey (M=2.63, SD=1.13) and Second survey (M=3.20, SD=0.76); p = 0.001. These 0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Survey 1 Survey 2 Not effective at all Not much (< 0.5% saving) slightly effective (0.5-1%) Noticeably effective (1-3%) More (>5%) 0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%.

Survey 1 Survey 2

Not effective at all

Not much :(< 0.5% saving)

Slightly effective :(0.5-1%)

Noticeably effective :(1-3%)

More effective :(> 5%)

22 results suggest that the confidence level of respondents about the future of VR technologies in the second survey is significantly higher than respondents in the first survey. This means that the experts are paying more attention toward the VR technologies. The increase in the number of employees with some level of expertise in VR technologies between the two surveys also supports this finding. In addition, although it seems that respondents who are relatively younger (i.e., less than 35 years old) believe that VR technologies will be used on the majority of the projects within the next 5 to 10 years, the survey results indicate that older generations are more confident about the future of these technologies.

The number of participants who are relatively young (less than 35 years old) is 78 and the participants from the older generations had a total number of 36. The rest of the participants were not interested in sharing their age so the authors ignored their answers for this analysis. These numbers shows that the authors had large enough samples to assume that the distribution of the data was normal. An unpaired t-test was conducted to compare younger (younger than 35 years old) and older (older than 35 years old) generations' idea about the future of VR. There was a significant difference in the scores for

Younger generations (M=2.86, SD=1.01) and

Older generations (M=3.29, SD=0.77); p = 0.025.

These results suggest that older generations' positive beliefs about the future of VR technologies are significantly higher than younger generations. Moreover, the increase in the number of employees with some level of VR expertise indicates the growth in utilization of such technologies. Performing unpaired t-test on survey data shows that there was a significant difference in the number of employees with some levels of VR expertise between the first survey (M=1.24, SD=2.99) and the second survey (M=3.55, SD=0.65); p = 0.015.

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These results suggest that there was a significant increase in employees becoming familiar with these technologies over the past year. Moreover, the authors used unpaired t-test and investigated the growth in employees expertise and there was a significant difference in the scores (hardly at all=0, not very well=1, average=2, very well=3, extremely well=4) of VR for the first survey (M=0.64, SD=1.18) and the second survey (M=1.27, SD=1.51); p = 0.009.

These results demonstrate that VR related expertise of the respondents in the second survey was significantly improved compared to the first survey. The results for the first survey (M=3.21, SD=6.7) and second survey (M=4.17, SD=10.97), p = 0.049 respondents' prediction about savings through VR was significantly increased in the second survey. (M=2.90, SD=2.94) and experts (M=3.80, SD=2.71); p = 0.033.

Using the survey results, lack of budget, lack of understanding of upper management about VR technologies, and lack of knowledge of design teams were the top three reported limitations for utilizing VR technologies. Also, an unpaired t-test on the survey results indicates that there was a significant difference in the VR expertise between engineers (M=0.76, SD=1.19) and managers (M=1.34, SD=2.71); p = 0.033.

These results suggest that although managers seem not experienced with VR related technologies, they are significantly more experienced than the engineers.

This suggests that the AEC industry needs more VR experts to fill this gap and overcome the limitations of utilizing VR technologies.

Additionally, 15% of respondents identified the lack of communication among software platform as one of the in survey 1; however, this number was significantly reduced (by 3%) in survey 2, indicating that algorithms and plugging are being developed that have improved this limitation.

Table 5: Analysis results on surveys with a significance level

Significance Factor	P-Value
1.Confidence level about the future of VR technologies significantly increased over the past year	0.001
2.Older generations are significantly more confident about the future of these technologies	0.025
3.The number of employees with VR expertise improved significantly over the past year	0.015
4.Employees expertise in VR significantly increased over the past year	0.009
5.Cost and time savings in design, construction, and operation by utilizing VR significantly improved over the past year	0.049
6.Savings by utilizing VR is predicted significantly different from Respondents	0.033

Discussion

It is clear from the recent researches that virtual reality technologies are the future of automotive construction management. Now, most of the construction management tools are integrating with virtual reality for increasing the output rate. Huge use of opportunities of VR in the construction management is pointed out earlier. For the effective and less time-consuming communication between different project participants, VR are proven technology.

Virtual reality also used for quality and defects management in the construction project. The effectiveness of virtual reality technology in quality management is recommendable for every construction project. Virtual reality technologies are hugely used in construction safety management and worker training for years. Many related researches proved that in training and safety management, virtual reality is the most effective and efficient tools in recent years. Project parametric model visualization and walk through into the project before the starting of the actual project with the feeling of the real world is another great characteristic of VR technology. For the visualization purpose, VR has a great contribution to the construction project from planning phase to maintenance phase.

Virtual reality already used in many construction companies effectively, and many are preparing to adopt these technologies to visualization, training, safety and progress tracking of projects. Even though VR technology seem to

be a vital tool in the construction industry, there are multiple drawbacks of these technology too. There are some limitations and drawbacks that appeared to implement the VR technology in the construction industry. The high cost of VR technology, lack of VR experts and technicians, unavailability of these technology and maintenance are the major limitations for any construction company to adopt VR-based construction management system. Many researchers believe that all the drawbacks and limitations will be quickly broken by the upcoming generations. Assuming VR technology will improve with safety, quality, visualization, workforce management and time management, it is far nearly sure that such technologies will play more important roles in construction for future years.

CONLUSION

Following important conclusions are drawn based on the survey results.

i. From the overall project study we came to know that current state, growth, and cost saving opportunities for virtual reality technologies in the industry is increased.
ii. A strong growth is seen in the use of virtual reality technologies over the next 5 to 10 years.
iii. Virtual reality in the industry shows a significant increase over the past years.
iv. There are some inherent limitations in adopting new virtual reality technologies, such as lack of budget, upper management's lack of understanding of these technologies, design teams' lack of knowledge.
v. Due to lower profit margins on construction projects, one major limiting factor that prevents the industry from adopting virtual reality technologies is the lack of availability of cost/benefit analysis.
vi. Owners and companies are not willing to invest their money without knowing the true costs and benefits (i.e., time and cost savings).
vii. There is a need for empirical studies that assess the true costs of implementing these technologies and reduction in costs and time from design to operation and maintenance phases. With regards to the other two major limitations, the results show that within the two surveys, the number of people within the respondents' companies that are familiar with VR technologies has significantly increased; this may indicate that upper management and designers/engineers will become more familiar with the capabilities of these tools in the near future as these tools become more accessible to the general consumer.

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