VIRTUAL REALITY TECHNOLOGY TO RAISE AWARENESS OF OCCUPATIONAL HAZARDS ON CONSTRUCTION SITES

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Abstract

Safety is of utmost importance to the Abu Dhabi City Municipality, particularly for those working in the construction sector. Given the high-risk and critical nature of activities in this industry, it is essential to provide proper training to increase awareness and promote safety among the workforces. This paper aims to test the hypothesis that "VR Training on Construction Sites is an effective tool to prevent accidents and undesirable events" by comparing its effectiveness to traditional training methods in terms of coaching construction workers and improving their abilities to identify and assess risks. The framework in this paper includes understanding the root causes of incidents through the analysis of historical incident data. Based on this analysis, 15 training scenarios were developed using virtual reality technology to provide workers with an engaging and interactive training experience that enables them to visualize site risks better and effectively understand safety precautions. After the VR training sessions, participants were asked to evaluate their training experience through a short questionnaire to measure the effectiveness of VR technology in safety training. In addition to the training assessment, "incident trend analysis exercises" were carried out after delivering the VR training courses to measure the effectiveness of the VR training and its impact on the safety culture, overall workers' hazard identification, and awareness of work site risks. The study showed a positive attitude among participants toward VR safety training and a tangible reduction in the number of undesirable events recorded over a certain time span. These findings suggest that VR technology can be a valuable tool for promoting safety and preventing accidents in the construction industry.

Keywords: *virtual reality, safety, incident, awareness*

1. INTRODUCTION

According to Bureau of Labor Statistics (BLS) in 2021 construction work had the second most occupational deaths in USA [3]. one in five deaths among US labors is in the construction sector [2]. The main causes of fatality in construction are falls, being struck by equipment, being caught in or in between objects, and electrocution [6]. There is an urgent need to reduce fatal and serious injury incidents in the building and construction sector [1].

The analysis and study of incident root causes often reveal "a lack of adequate occupational safety training" as a significant contributing factor. It is therefore crucial to allocate resources and invest in delivering effective HSE training to workers. By doing so, organizations can improve their HSE culture, reduce accidents, and minimize the associated costs of such undesirable events. Construction companies usually spend more on the cost of injuries than they do on safety training [2]. The U.S. Occupational Safety and Health Administration (OSHA) provide support for HSE training as important aspect to ensure a safe and healthy working environment [5].

The virtual risk simulation project at construction sites demonstrates Abu Dhabi City Municipality's commitment to leveraging advanced technologies like Artificial Intelligence to enhance its services and support comprehensive development in the city. Inadequate training is a significant contributor to construction site accidents, highlighting the need for effective and suitable training methods [8]. Virtual Reality technology is an innovative solution that enables workers to experience and learn how to avoid potential hazards without physical harm. It can improve worker performance, reduce accidents, and create a safer work environment, particularly in the construction sector where compliance with HSE requirements can be lacking. Therefore, investing in effective training methods such as Virtual Reality is essential for organizations to foster a robust safety culture and protect their workers from harm.

Virtual Reality technology is currently among the most effective technologies used in creating simulated scenarios that can help enhance performance, prevent accidents, and improve the work environment. This technology enables the identification and understanding of potential risks in construction sites, thereby promoting their prevention and creating a safe working environment.

2. METHODOLOGY

This study examines the hypothesis that using virtual reality (VR) training on construction sites is an effective tool. The project aims to providing an effective learning and training by using VR and means to address safety risks and reduce the incidents in construction. and to what extent VR are addressing the established risk management process (i.e., risk identification, risk evaluation, risk response planning, and risk monitoring and control). This project reviews and analyses the body of the hazards proposing VR as an intervention to address safety risks in the Building & Constructions sector.

The framework of this paper involves a thorough understanding of the root causes of accidents that occurred at construction sites in Abu Dhabi city between 2016 and 2019. Building upon this analysis, a set of training scenarios were developed using Virtual Reality technology. Additionally, a proposal is made to create a multiplayer platform that aims to amplify the interaction between trainees, thereby providing substantial evidence for the advancement of safety training and accident avoidance in future construction projects. The approach involves utilizing an active safety game within a 3D virtual environment, allowing trainees to enhance their practical capabilities. To evaluate the training experience, a short questionnaire is administered, followed by an analysis of incidents upon completion of the training process to gauge the effectiveness of utilizing Virtual Reality technology. (See **Error! Reference source not found.**) illustrates the methodology of the paper.

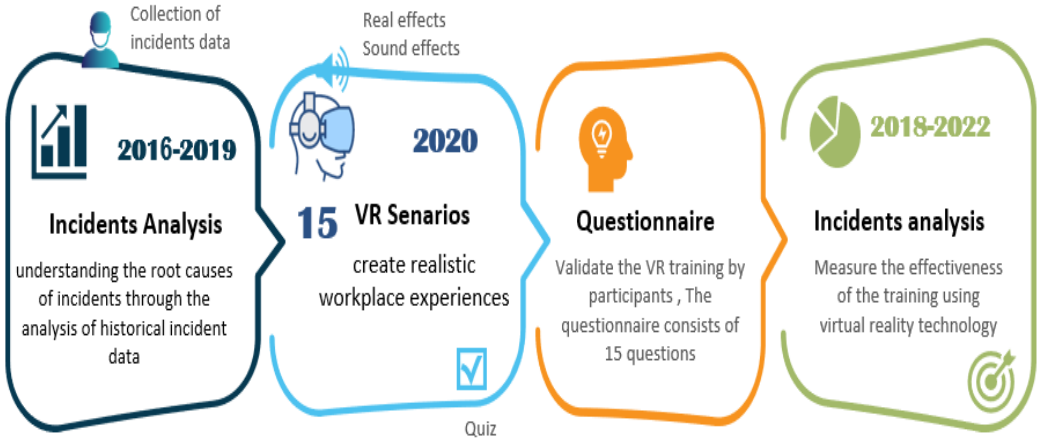

Fig. 1. Research methodology scheme

2.1. Incident analysis 2016-2019

A trend analysis of incident root causes during 2016-2019 identified "Fall from Height" and "Fall of Materials and Objects" as the primary causes of construction site accidents (See **Error! Reference source not found.**). To address this, a comprehensive training program has been established to promote HSE awareness and equip workers with essential knowledge to prevent accidents. The program aims to improve a safety culture within the construction sites, minimize accidents and injuries, and provide a safer and more productive work environment for all personnel.

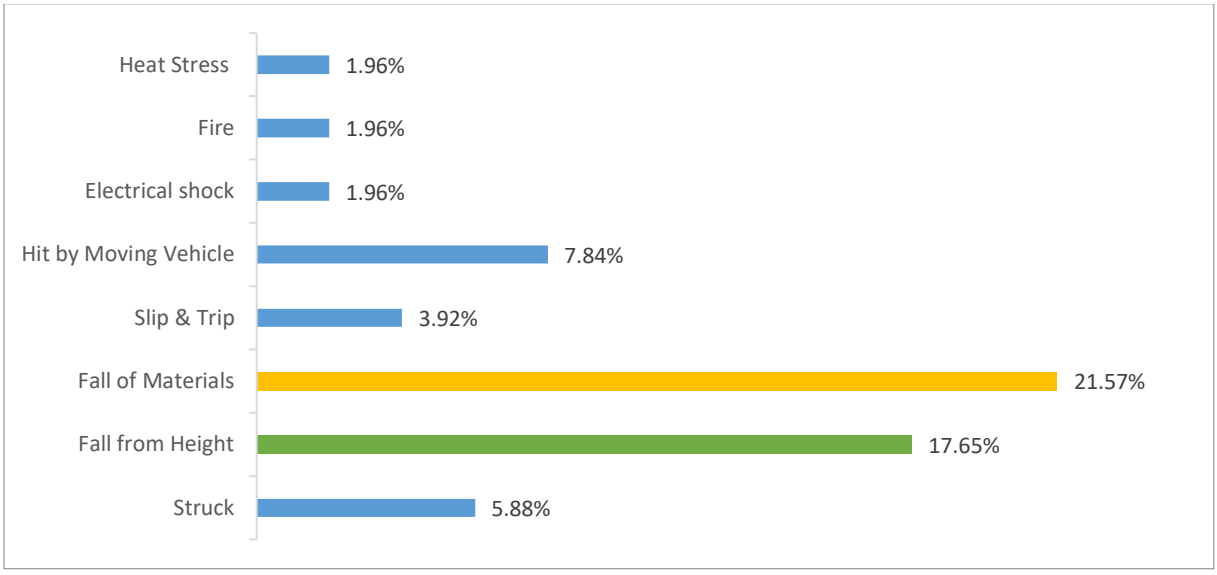

Fig. 2. Incident analysis before VR training.

2.2. Risk Management

The Risk Management Process includes four key phases: risk identification, risk evaluation, risk response planning, and risk monitoring and controlling [7]. These phases are implemented throughout the project lifecycle to identify and address potential hazards proactively, either eliminating or reducing the probability or impact of adverse events [4]. Risk identification is the first step, capturing and recording all potential causes of hazards. In the risk evaluation phase, the magnitude of each risk is assessed based on its probability of occurrence and impact, using qualitative or quantitative methods. The goal is to prioritize the risks, separating the acceptable from those requiring treatment. The results from the risk evaluation phase are used to develop measures at the risk response planning phase, employing a sequential hierarchy of measures that start with eliminating the risk, followed by reducing, isolating, controlling, implementing safe systems of work, or using personal protective equipment as a last resort. Finally, risk monitoring and controlling involves tracking and reviewing the effectiveness of the risk management plan, identifying, and responding to any new risks that may arise. By following the Risk Management Process, organizations can identify potential hazards and address them proactively, reducing the likelihood of adverse events and their associated impacts.

2.3. Virtual Reality (VR)

Virtual Reality (VR) systems use advanced hardware and software to create a simulated environment that can be interacted with by a user. The hardware components typically include a VR headset or display device, which contains screens or lenses that display the virtual environment. These headsets may use built-in sensors, such as gyroscopes and accelerometers, to track the user's head and eye movements, allowing the VR system to adjust the view of the virtual environment based on the user's position and orientation.

Other hardware components may include hand-held controllers and motion sensors, which enable the user to interact with the virtual environment. These controllers may use haptic feedback, simulating touch and other sensations to enhance the user's experience.

The software component of a VR system is essential to generate the virtual environment and enable the user to interact with it. This software typically includes specialized programs and applications that create a realistic virtual environment. These programs may also use algorithms and machine learning models to adapt the virtual environment based on the user's actions and movements, enhancing the overall user experience.

In this study, a VR system is being developed specifically for training workers in the construction industry on safety measures. The system will allow users to experience hazardous situations in a virtual environment and learn how to avoid accidents in real-world scenarios. The following Table 1. shows the main training course modules that are being prepared in this study.

Incident	Scenario
Fall from Height	Scaffolding, Fall Protection, unsafe working Platforms, Steel structure works.
Fall of Materials	Scaffolding, Unsafe Lifting Operations, Fall Protection, unsafe working Platforms, material handling & storage
Hit by Vehicle	Vehicles safety, Unsafe Lifting Operations
Struck	Material Handling and Storage, Vehicles safety, Concrete and Block work, scaffolding
Slip & Trip	Work Surface, excavation works, Unsafe access & egress, unsafe working Platforms
Electrical shock	Hand & power tools, Electrical Hazards
Caught In-between	Vehicles safety, Unsafe Lifting Operations, material handling & storage
Fire	Fire, Electrical Hazards, access & egress
Heat Stress	excavation works, Concrete and Block works
Collapse	Fall Protection, Scaffolding, unsafe working Platforms, Unsafe lifting operations & Excavation works

Table 1. Table Development of 15 training scenarios.

2.4. Develop Virtual reality (VR) training.

126 Abu Dhabi City Municipality employees, consisting of engineers, inspectors, and HSE officers, underwent VR training on 15 scenarios totalling 1,008 hours to address construction site needs and priorities. Moreover, the VR training program was extended to 70,000 laborers at building and construction sites, raising awareness of occupational hazards and promoting safe working practices. This achievement highlights the potential of VR technology to enhance occupational health and safety training in the construction industry.

2.5. Questionnaire

Following the VR training, a questionnaire was distributed to the participants, and 95% found the VR training to be effective, 5% held a neutral opinion, and only 0.5% disagreed, as illustrates (See **Error! Reference source not found.**). These results highlight the potential of VR technology for effective training in the construction industry.

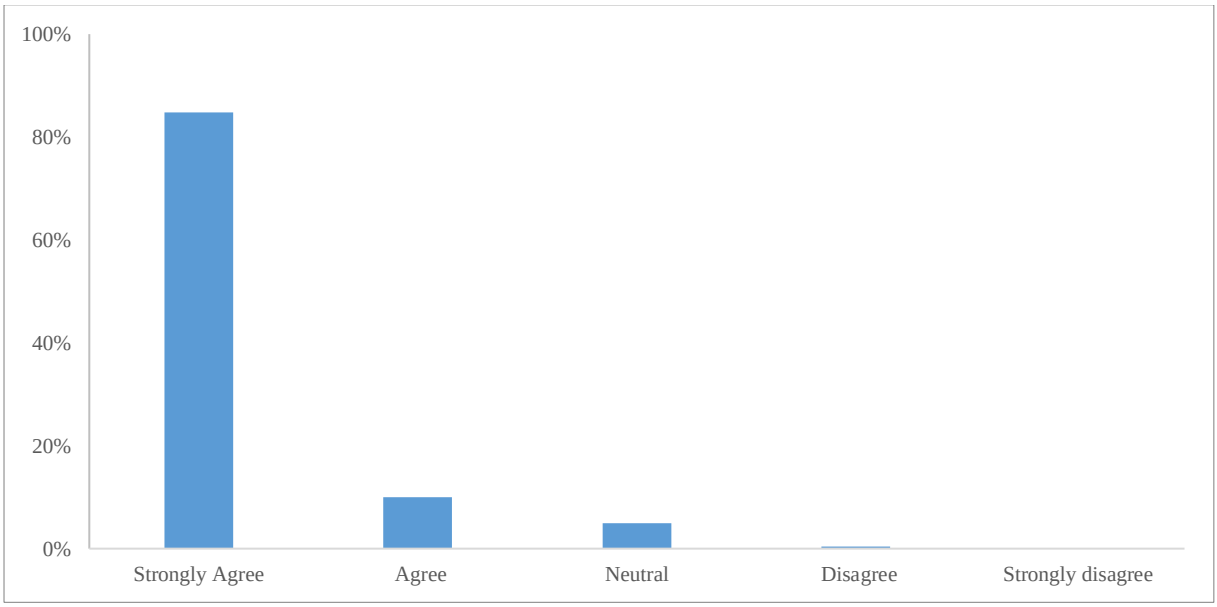

Fig. 3. Level of agreement with VR effectiveness for training.

2. INTERPRETATION OF THE RESULTS

The study showed positive attitudes among participants toward VR safety training, and a 20% reduction in accidents at construction sites in 2021 and a 16% reduction in 2022 were observed as a result of using virtual reality technology in training as illustrates (See **Error! Reference source not found.**). These findings suggest that VR technology can be a valuable tool for promoting safety and preventing accidents in the construction industry.

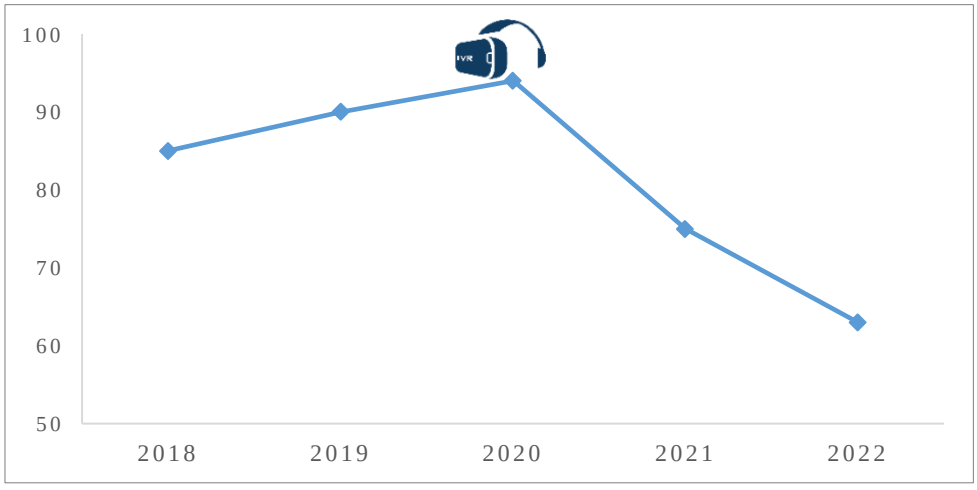

Fig. 4. Incident analysis after using VR training.

Virtual reality training is more effective than traditional methods in addressing the risk of material falls. The study found a 71% reduction in material fall injuries in the construction sector due to VR training. (See **Error! Reference source not found.**) illustrates the incidents analysis by type of incidents after using VR training.

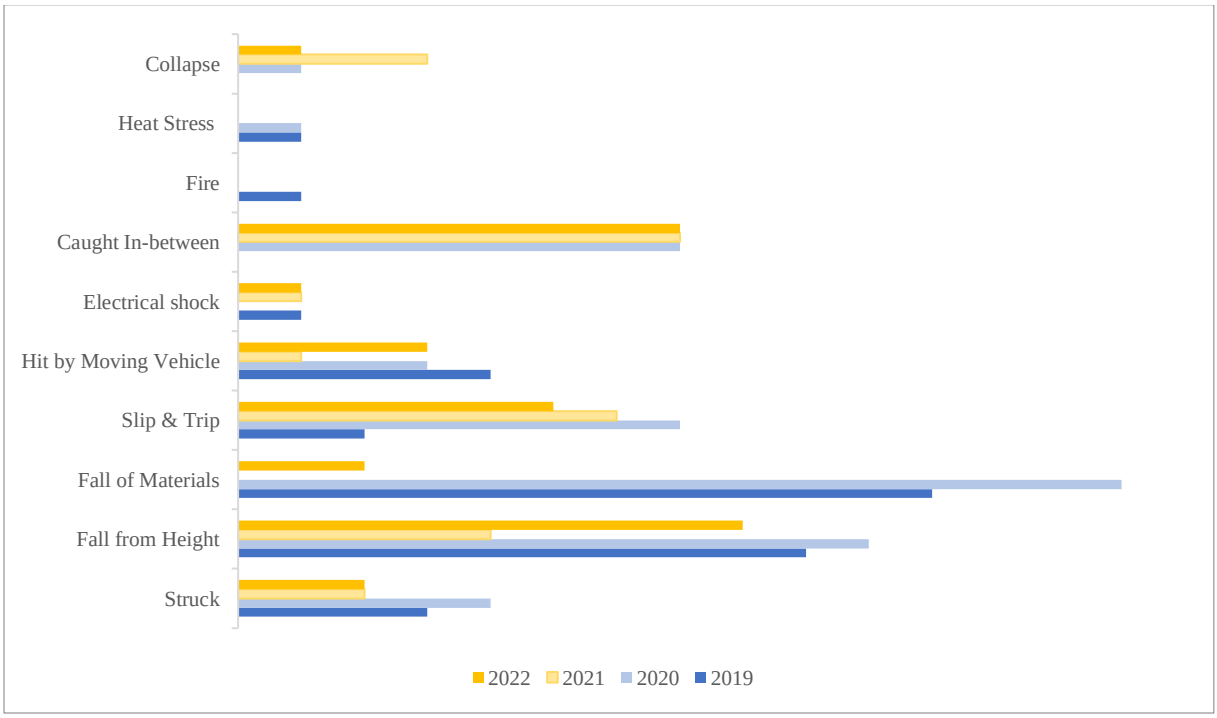

Fig. 5. Incidents type analysis after VR training.

These findings indicate that VR is a valuable tool for enhancing safety and preventing accidents in high-risk work environments like construction sites. Furthermore (See **Error! Reference source not found.**) illustrates the reduction in "Fall of Materials" incidents after using VR training.

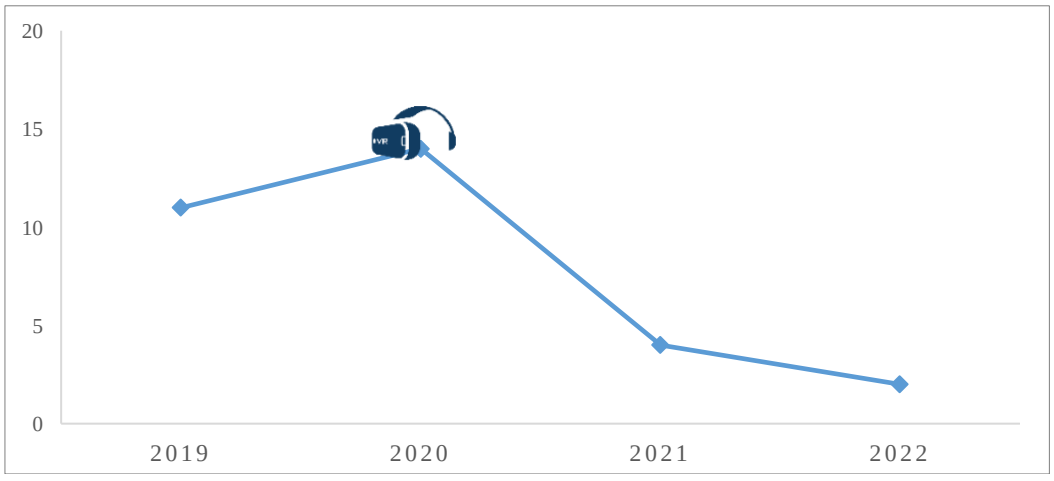

Fig. 6. Fall of Materials incidents reduction 70%.

Furthermore, using VR safety training showed that reduction of struck by hazard %50 and slip & trip Incidents %20 as show (See **Error! Reference source not found.**). Likewise, using VR safety training showed that reduction of Heat Stress causes to 0% during 2021-2022. While the Fall from Height Incidents showed 60% reduction in 2021 and only 20% in 2022.

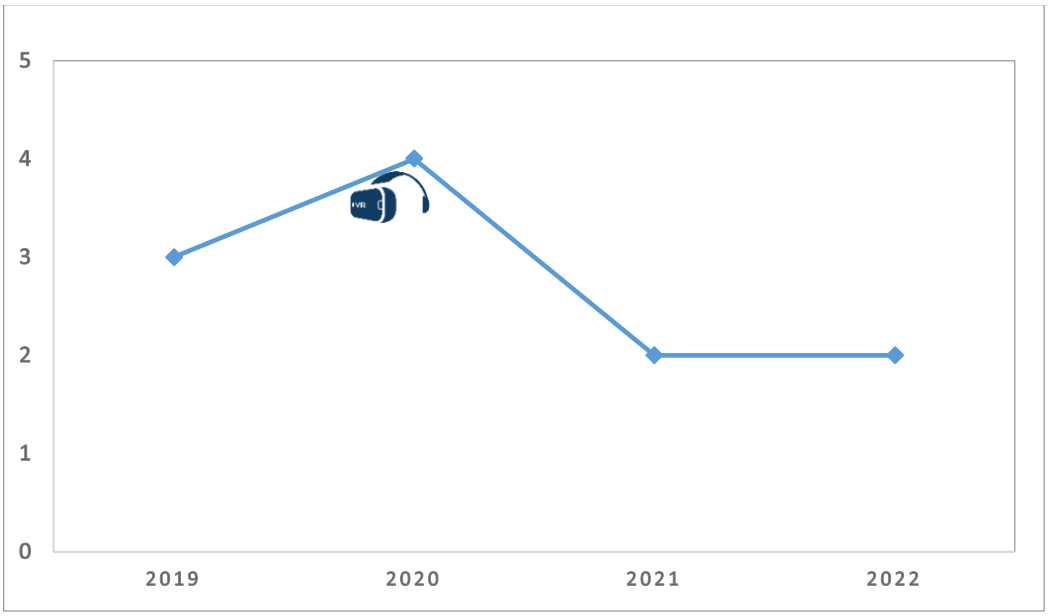

Fig. 7. Reduction slip & trip incidents 20%.

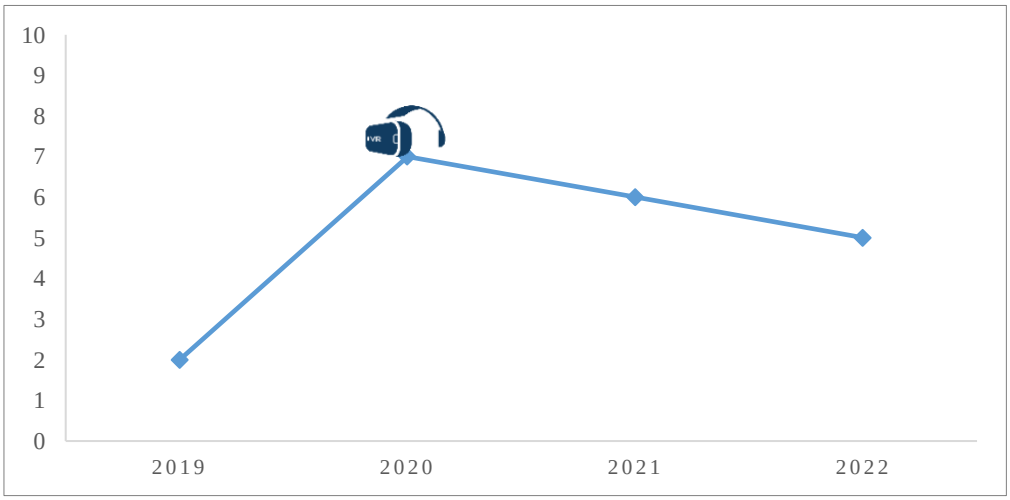

Fig. 8. Reduction of struck by hazard incidents 50%.

3. CONCLUSIONS

The study demonstrates that VR technology is an effective tool for promoting safety and preventing accidents on construction sites. The immersive and engaging training experience provided by VR enhances workers' hazard recognition skills and promotes safer working practices. The realistic environment simulated by VR closely resembles the actual work environment, enabling workers to gain practical experience in a safe setting. These findings emphasize the need to integrate VR technology into safety training for workers in the construction industry to improve their training experience and ultimately enhance the safety culture of the construction industry.

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