The Influence of Occupational Safety, Health, and Security Standards on Increasing the Productivity of High-Rise Building Glass Cleaning Workers

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Abstract.

Occupational Safety and Health (OHS) is a crucial element in the modern workplace, particularly in high-rise building cleaning, as effective OHS implementation has been proven to reduce workplace accident rates and simultaneously increase workforce productivity. This study aims to analyze how the implementation of OHS management and VR-AR-based OHS training can affect workplace accident rates and ultimately impact low work productivity due to the high number of falls from height. This study uses a quantitative approach with the Partial Least Squares Structural Equation Modeling (PLS-SEM) method. The subjects in this study included employees who had worked for more than 4 months in the field of high-rise building cleaning in the West Jakarta area. To obtain an appropriate number of respondents, the data collection process was carried out through the distribution of online questionnaires using Google Forms. The instrument trial stage was carried out involving 30 respondents for the initial test, while the total data collected during the main questionnaire filing stage amounted to 130 respondents. The results of the study indicate that the Implementation of OHS Requirements, OHS Management, and VR-AR-Based OHS Training have an impact on Workplace Accidents. Meanwhile, the Implementation of K3 Requirements, VR-AR Based K3 Training, and Work Accidents have an impact on Productivity.

Keywords*: Implementation of requirements, productivity, OHS management, VR-AR-based OHS training, workplace accidents.*

I. INTRODUCTION

Occupational Safety and Health (OHS) is crucial for creating a safe and healthy work environment, particularly in high-risk jobs such as high-rise building maintenance using gondola lifts for painting, wall repairs, installing Aluminum Composite Panels (ACP), and window cleaning [1]. Despite meeting OHS standards, this work remains hazardous due to worker carelessness and external conditions such as strong winds [1].

Lack of management oversight of the use of personal protective equipment (PPE) is a major cause of workplace accidents [2]. Indonesia BPJS Ketenagakerjaan data shows a high number of workplace accidents in the construction sector, with 2,965 cases in 2023 [3].

Therefore, implementing effective OHS management is essential to reduce accident rates and increase company productivity [4]. Structured OHS training, including the use of PPE such as welding masks, gloves, leather jackets, and safety shoes, is crucial for workers working at heights to reduce the risk of serious injury or death [5][6].

Integrating OHS into company operations supports sustainability and increased productivity [7]. Technological developments such as Virtual Reality (VR) and Augmented Reality (AR) provide innovative OHS training methods with immersive and interactive simulations, improving workers' understanding of safety procedures and handling emergency situations [8].

Self-efficacy is a person's general belief when they demonstrate performance that leads to task completion, hope is the energy focused on personal goals and alternative ways that lead people to their goals [9].

This study develops previous studies by adding VR-AR-based OHS training variables and focusing on high-rise building window cleaners. The purpose of the study is to analyze the

relationship between reducing work accidents and increasing productivity through a mathematical model based on safety factors, as well as to test the effectiveness of the OHS management system and VR-AR hybrid training as a strategic basis for OHS risk management in the industry [10].

II. METHODS

This study used an explanatory method to examine the causal relationships between the variables of Occupational Health and Safety Management, Implementation of Occupational Health and Safety Requirements, Work Accidents, and Work Productivity, with the additional variable of Virtual Reality and Augmented Reality (VR-AR)-based OHS training. The study focused on working at heights, using a purposive sampling technique to ensure the sample consisted of workers in that field. The primary objective was to analyze the effect of OHS management and VR-AR training on reducing occupational accidents and increasing productivity.

Data was collected through a survey using an online questionnaire distributed via Google Forms. The questionnaire used a Likert scale of 1–5, with categories ranging from strongly disagree to strongly agree. Respondents were high-rise building cleaners in West Jakarta who had been working for at least four months. The number of respondents was determined based on the Lisrel SEM criteria, which was five times the number of questionnaire questions, requiring a minimum of 125 respondents.

The validity of the questionnaire was tested using the Average Variance Extracted (AVE), with a value of >0.5 as an indicator of convergent validity. Reliability was tested using Cronbach's Alpha and Composite Reliability (CR), with values >0.7 indicating strong consistency, but values between 0.60–0.70 are still acceptable for explanatory studies (Hair et al., 2017). Data analysis was performed using Partial Least Squares-Structural Equation Modeling (PLS-SEM), a method suitable for models with many latent variables and relatively small sample sizes and allows testing of causal relationships in complex models.

III. RESULT AND DISCUSSION

This study involved 130 high-rise building cleaners in West Jakarta Indonesia with at least four months of work experience. Respondents consisted of 68 women (52.3%) and 62 men (47.7%). This gender composition is influenced by the nature of the job, which demands precision and detail, particularly in glass cleaner positions on middle floors and in interior areas, which are predominantly filled by women. In terms of age, most respondents were in the young to middle productive age range, with the highest age being 28 (15.4%), followed by 25 (13.8%), 27 (13.1%), and 26 (10.8%). This age range reflects the nature of the job, which requires peak physical condition.

Before the instrument was distributed, construct validity and reliability were tested using a reflective approach. Convergent validity was tested using the Average Variance Extracted (AVE) value, with all constructs having an AVE ≥ 0.50, indicating convergent validity. The validity of the indicators also met the criteria, with loading factors ≥ 0.70 for all 25 indicators. Construct reliability was tested using Composite Reliability (CR) and Cronbach's Alpha (CA), all of which showed values above 0.70, indicating high internal consistency.

	AOR	OM	VBKT	WA	P
AOR					
OM	0.207				
VBKT	0.518	0.347			0.690
WA	0.570	0.480	0.606		0.767
P	0.651	0.560			

Fig. 1. Discriminant Validity

Therefore, the instrument is suitable for further analysis. Discriminant validity was tested using the Fornell-Larcker criterion, where the square root of the AVE of each construct is greater than the correlation between the other constructs, and cross-loading analysis showed the highest

correlation of the indicator with the measured construct. This confirmed strong discriminant validity.

Variables	Indicators	*Loading Factor*	CA	CR	AVE
Application of OHS Requirment	AOR1	0.855	0.914	0.9369	0.744
	AOR 2	0.876			
	AOR 3	0.851			
	AOR 4	0.868			
	AOR6	0.863			
OHS Management	OM1	0.871	0.910	0.933	0.735
	OM2	0.869			
	OM3	0.862			
	OM4	0.873			
	OM5	0.808			
VR-AR Based K3 Training	VBKT1	0.726	0.848	0.892	0.623
	VBKT2	0.810			
	VBKT3	0.836			
	VBKT4	0.783			
	VBKT5	0.790			
Work Accident	WA1	0.889	0.914	0.936	0.746
	WA2	0.883			
	WA3	0.808			
	WA4	0.824			
	WA5	0.910			
Productivity	P1	0.828	0.909	0.932	0.735
	P2	0.886			
	P3	0.820			
	P4	0.921			
	P5	0.825			

Fig. 2. Outer Model

Evaluation of the inner model using the R Square (R^2) value shows the model's predictive ability. The Work Accident variable has an Adjusted R^2 of 0.449, which means that 44.9% of the variation in work accidents can be explained by the Application of OHS Requirements, OHS Management, and VR-AR Based K3 Training variables. The Productivity variable has an Adjusted R^2 of 0.604, indicating that 60.4% of the variation in productivity can be explained by the Application of OHS Requirements, OHS Management, VR-AR Based K3 Training, and Work Accident variables.

	R-square	*Adjusted R-square*
Work Accident	0.462	0.449
Productivity	0.613	0.604

Fig. 3. R-Square

All hypotheses were tested using t-statistics and p-values at a 5% significance level. The test results showed:

- H1: Implementation of OHS Requirements has a significant positive effect on Workplace Accidents ($\beta = 0.333$; $t = 4.646$; $p < 0.001$).
- H2: OHS Management has a significant positive effect on Workplace Accidents ($\beta = 0.288$; $t = 4.067$; $p < 0.001$).
- H3: VR-AR-Based OHS Training has a significant positive effect on Workplace Accidents ($\beta = 0.298$; $t = 3.747$; $p < 0.001$).
- H4: VR-AR-Based OHS Training has a significant positive effect on Productivity ($\beta = 0.260$; $t = 3.758$; $p < 0.001$).
- H5: Workplace accidents have a significant positive effect on productivity ($\beta = 0.430$; $t = 4.940$; $p < 0.001$).

- H6: Implementation of OHS requirements has a significant positive effect on productivity (β = 0.255; t = 2.893; p = 0.004).

These results indicate that the implementation of OHS requirements, OHS management, and VR-AR-based training can significantly reduce work accidents, which then has a positive impact on increasing employee productivity.

	Original sample (O)	*Sample mean (M)*	*Standard deviation (STDEV)*	*T statistics (|O/STDEV|)*	*P values*
Application of OHS Requirement -> Work Accident	0.333	0.333	0.072	4.646	0.000
OHS Management -> Work Accident	0.288	0.293	0.071	4.067	0.000
VR-AR Based K3 Training -> Work Accident	0.298	0.294	0.079	3.747	0.000
VR-AR Based K3 Training -> Productivity	0.260	0.260	0.069	3.758	0.000
Work Accident -> Productivity	0.430	0.432	0.087	4.940	0.000
Application of OHS Requirement -> Productivity	0.255	0.255	0.088	2.893	0.004

Fig. 4. Path Coefficient

The f^2 analysis shows that the effect of work accidents on productivity has a value of 0.292, categorized as a large effect, indicating a significant contribution of workplace accidents to productivity changes. The variables Application of OHS Requirements, OHS Management, and VR-AR-Based OHS Training on work accidents have f^2 values of 0.162, 0.139, and 0.122, respectively, which are considered medium effects.

Similarly, the effects of VR-AR-Based OHS Training and Application of OHS Requirements on productivity have f^2 values of 0.116 and 0.115, respectively, also in the medium effect category. This confirms that workplace accidents are the dominant factor influencing productivity, while the implementation of OHS and VR-AR-based training make significant direct and indirect contributions.

Hypothesis	F^2	*Category*
Application of OHS Requirement -> Work Accident	0.162	*Medium effects*
OHS Management -> Work Accident	0.139	*Medium effects*
VR-AR Based K3 Training -> Work Accident	0.122	*Medium effects*
VR-AR Based K3 Training -> Productivity	0.116	*Medium effects*
Work Accident -> Productivity	0.292	*Large effects*
Application of OHS Requirement -> Productivity	0.115	*Medium effects*

Fig. 5. F2 Estimation

IV. CONCLUSION

This study shows that the implementation of OHS requirements has a positive and significant impact on workplace accidents, supported by workers' avoidance of the use of risky equipment. Worker awareness of hazard avoidance and direct experience with accidents are important factors in the effectiveness of OHS implementation.

OHS management also has a positive impact on workplace accidents, as high-risk exposure in work activities requires strict OHS management implementation [11]. Workers indicated that VR-AR-based OHS training has a positive impact on workplace accidents, increasing workers' understanding of risks and preventative measures [12]. Furthermore, workers indicated that VR-AR-based OHS training also has a positive impact on productivity, with increased risk understanding and technical skills leading to more effective performance [13]. Workplace accidents also have a statistically positive impact on productivity but can substantially reduce productivity through lost work time and decreased morale [14].

Finally, workers also confirmed that the implementation of OHS requirements has a positive and significant impact on productivity, with worker vigilance and optimal skill in using work equipment contributing to a safe and efficient work environment [15]. Overall, effective OHS implementation not only serves as an accident prevention measure but also as a driving factor for efficiency and quality work output, which is crucial in the high-risk construction industry [16][17].

Based on worker responses, managerial implementation can focus on five key areas to improve workplace safety and productivity. First, the implementation of OHS requirements needs to be improved through strengthening the discipline of safe work procedures, regular internal campaigns, ongoing education regarding potential hazards, and the establishment of a minor incident reporting system that encourages workers to report without fear.

Second, optimizing OHS management requires effective policy dissemination and active management involvement at all levels, as well as regular internal audits to assess the effectiveness of OHS policy implementation. Third, VR-AR-based OHS training should be integrated into the training curriculum for high-risk scenario simulations, with increased worker technological literacy and post-training evaluations to ensure its effectiveness.

Fourth, increased productivity can be achieved by focusing on preventing minor incidents that disrupt workflow and creating a safe and healthy work environment to boost worker motivation. Finally, strengthening workers' discipline and technical understanding through a clear K3 discipline program, needs-based technical training, mentoring systems, and effective field supervision will improve discipline, understanding, efficiency, and the quality of work results.

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We hope that the results of this study will contribute positively to improving occupational safety and health, as well as productivity in the high-risk construction industry. The authors would like to thank all researchers who contributed to the writing of this journal for their input and reviews, and Universitas Esa Unggul and the university staff for their invaluable suggestions.

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