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Effects of ergonomics intervention on work accidents in the construction sector and their effect on productivity



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ABSTRACT

Construction services are one of the most important and strategic sectors supporting the achievement of development in Indonesia. Through this sector, Indonesia can experience stable economic growth. In 2020, accidents in the construction sector were the highest cases compared to other sectors, with a death rate of more than 60,000 cases annually. The role of Occupational Health and Safety (OHS) Management and the application of its requirements when working at heights is crucial to protect against the dangers of work accidents due to high risk. This study aims to determine the relationship between the factors that affect work accidents in the construction sector and their effect on Productivity moderated by ergonomics. This research was conducted by analyzing surveys from work-at-height workers in the construction sector, with 107 respondents from projects in Jakarta. The data analysis method used is Structural Equation Modeling (SEM) based on non-covariance, namely Partial Least Square (PLS). Data analysis using Smart PLS 3.0 software. The results show that Ergonomics has no direct effect on Productivity, with p-value 0.313. Work Accidents do not directly affect Productivity with p-value 0.333. OHS Management does not directly affect Work Accidents with p-value 0.013. OHS Management has a direct effect on Productivity with p-value 0.000. Application of OHS Requirements has a direct effect on Work Accidents with p-value 0.527. Application of OHS Requirements has a direct effect on Productivity with p-value 0.001 and Application of OHS Requirements through Ergonomics has no direct effect on Productivity with p-value 0.000.

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1. INTRODUCTION

Construction is one of the infrastructure development activities which results in a building [1]. The construction sector is the most crucial part of the country's development because it can indirectly increase economic growth. According to Badan Pusat Statistik (BPS), the construction sector

has a vital role in supporting economic growth in Indonesia, namely as a source of state income after the manufacturing and trade sectors. Developments in this sector will make the Indonesian economy increase every year. The rapid development of infrastructure in Indonesia includes toll road construction projects, railway facilities and

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infrastructure projects, airport revitalization, etc.

The construction sector is strategic and is significant in supporting the achievement of development in Indonesia. This strategic position can be seen in the relationship with other sectors [2], [3]. Based on International Labor Organization (ILO) data, more than 240 million workplace accidents have occurred, more than 160 million workers experienced occupational diseases, and 1.2 million workers have died [4]. Work accidents in construction projects are the most significant cases compared to other sectors, with a death rate of more than 60,000 cases annually [5]. According to ILO statistical data in Indonesia, there were 13,344 cases from 2005 to 2015, of which 30.1% occurred in the construction sector [6]. The cause of death in construction projects include workers being hit by heavy objects, electrocuted, falling from buildings, and being squeezed between parts of the project object [7], [8]. There are five causes of accidents: not applying OHS, not using PPE, inadequate safety instructions against potential hazards, equipment that is not standardized, and lack of knowledge and training from the workforce regarding the use of equipment [9-11]. According to the Ministry of Manpower USA, Muscle and Skeletal Disorders (MSDs) cause a 30% loss of working time. The construction sector accounts for the 5th highest loss of work time due to MSDs and costs companies \$33 billion in compensation claims

The effects of accidents on the construction sector result in lost working time, bad company reputation, worker psychology, medical costs and, of course, reduced productivity [12]. According to Dozzi and AbouRizk [13], productivity is a measure that can state how efficient the management of resources and their utilization is to achieve an optimal target. In contrast, Productivity is the ratio between inputs and expenditures. Factors that affect productivity in the construction sector include several categories, namely education and training of project workers, government policies, risk management, project conditions, and construction project market share [14]. Based on the high number of work accidents in the construction sector that impact decreasing productivity and other losses, it is necessary to analyze work accidents in the construction sector on the variables that affect work accidents, especially work at heights. According to the World Health Organization (WHO) [15], and accident is an incident that cannot be prepared in

advance, resulting in injury, illness or death [16]. Occupational Health and Safety (OHS), according to Government Regulation 50 of 2012, is all preventive measures against work accidents and occupational diseases for all workers related to work so that their safety and health are protected. According to the ILO, OHS is all about planning and controlling actions against hazards that arise in the workplace to prevent workers from experiencing accidents, illness and death due to work [17]. The correct action to prevent work accidents is to provide OHS training to workers. According to Zahoor et al. [18], OHS training is an activity to get a skilled, motivated workforce and a special understanding of occupational safety and health. The OHS policy shows management's willingness to provide a healthy and safe workplace [19]. Every work activity needs to be carried out in risk management to increase safety and reliability and minimize losses [20].

Based on previous research by Kaynak et al. [21], Dale et al. [22] and Ahmed [23] that to analyze the factors that influence work accidents can link OHS Management and the Application of OHS Requirements. Then the research by Damaj [24] analyzed the factors of work accidents by conducting ergonomic studies. According to the International Ergonomics Association (IEA), ergonomics is a science that studies the relationship between human factors and the workplace environment in terms of efficiency, health and safety aspects to create a healthy work movement [25]. Research by Chin et al. [26] and Zaira and Hadikusumo [27] analyzes the application of OHS to construction work only. At the same time, this study focuses on construction at heights, so it becomes a novelty in this study. Another novelty also adds ergonomic factors that affect productivity in construction projects. This research aims to determine the relationship between the factors that affect work accidents in the construction sector and their effect on productivity by ergonomics. This research was conducted only on work at heights because this section contributes the highest number of work accidents compared to other sections. It is a limitation of this study

2. RESEARCH METHODS

This study uses an explanatory research type, namely a study that explains the causal relationship between research variables and tests the formulated hypothesis. This study analyzes the causal relationship between OHS Management

variables, Application of OHS Requirements, Work Accidents, Ergonomics and Productivity. The object of this research focuses on work at heights. The sampling technique used is purposive sampling, meaning that all samples referred to in this study are the same at work at heights [21]. It measures the low productivity of construction work caused by the number of accidents falling from a height.

The research was conducted by analyzing a questionnaire of workers sampled at heights in the construction sector. It has an amount of 107 respondents. The number of samples calculation uses the Slovin formula from 137 respondents. One hundred seven samples were taken—using samples above 100 using the reference from Putri et al. [28]. The research questionnaire used a Likert scale of 1-5. There are primary and secondary data used in this research. Primary data in this study were generated from questionnaire input. At the same time, secondary data is obtained from company reports, such as the number of work accident cases. Other secondary data were obtained from articles in journals and institutional annual reports. This study consists of 5 variables which include the Application of OHS Requirement (X1), OHS Management (X2), Work Accidents (Y), Productivity (Z) and Ergonomics as intervening. Intervening on Ergonomic variables is intended to mediate the relationship between variables—application of OHS Requirements to productivity. Intervening is used to

measure the level of complaints of workers' bodies. Ergonomics is carried out by intervening because it does not directly affect workers (long-term effect). Ergonomics variables in this study are not intended to be applied practically but based on complaints obtained after doing work activities (MSDs complaints). The Application of OHS Requirement consists of 16 indicators, OHS Management consists of 19 indicators, Work Accidents consists of 15 indicators, Productivity consists of 29 indicators, and Variable Ergonomics consists of 28 indicators (Table 1). The data analysis method used is SEM based on non-covariance, namely PLS [29]. SmartPLS 3.0 software is used to process the data from the questionnaire results. Fig.1 shows the causality model in this research.

- H1: There is an effect of Ergonomics on Productivity
- H2: There is an effect of Work Accident on Productivity
- H3: There is an effect of OHS Management on Work Accidents
- H4: There is an effect of OHS Management on Productivity
- H5: There is an effect of the Application of OHS Requirements on Productivity through Ergonomics
- H6: There is an effect of the Application of OHS Requirements on Work Accidents
- H7: There is an effect of the Application of OHS Requirements on Productivity

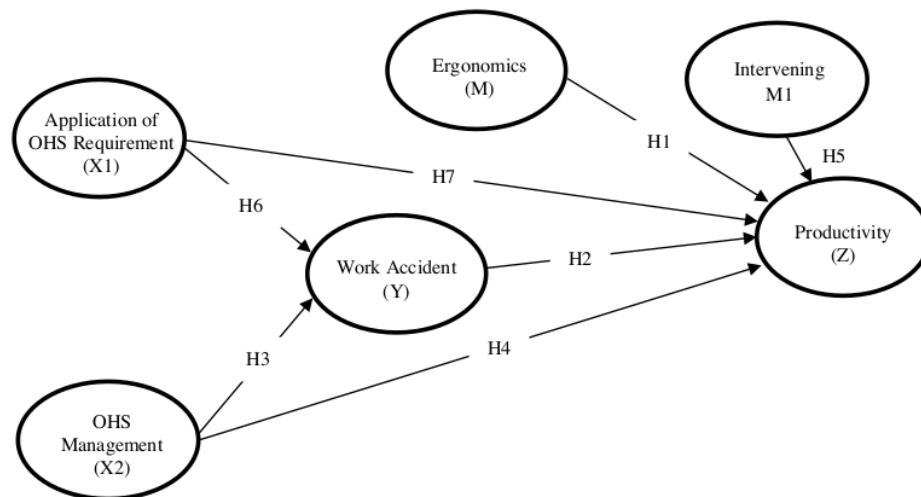


Fig. 1. Conceptual model

Table 1. Operational variable

Variable	Indicators	Source	
Application of OHS Requirement (X1)	<ol style="list-style-type: none"> 1. Job safety analysis 2. Risk assessment 3. Working method 4. Work Instructions 5. Safe working procedures 6. Safety line 7. Emergency response 8. Evacuation Path 9. Guardrail 	<ol style="list-style-type: none"> 10. Double hook 11. Personal protective equipment 12. Certified/licensed worker 13. Double overhead hook 14. Double hooks at different points 15. Danger forecasting movement 16. Consistency of using double hook 	[29], [30],
OHS Management (X2)	<ol style="list-style-type: none"> 1. Provision of PPE 2. OHS training 3. Controlling 4. OHS expert 5. Supporting facilities 6. Workload evenly 7. Adequate medical care 8. Granting of recovery time 9. Provision of accident insurance 10. OHS requirement 	<ol style="list-style-type: none"> 11. Safety Talk 12. Work Permit 13. Validation of medical devices 14. PPE according to standard 15. On-the-job training 16. Reporting of safety activities 17. Clean and safe environment 18. OSH policy 19. Worker certification 	[31], [32]
Work Accident (Y)	<ol style="list-style-type: none"> 1. Hit a stationary object 2. Lift excess objects 3. Hazardous chemical contact 4. Falling from a height 5. Hit a moving object 6. Trapped 7. Slip 8. Burns 	<ol style="list-style-type: none"> 9. Sprain 10. Scratched 11. Spinal injury 12. Bruises 13. Joint pain 14. Shocked 15. Suspension trauma 	[33], [34]
Ergonomics (M)	<ol style="list-style-type: none"> 1. Pain in the upper neck 2. Pain in the lower neck 3. Pain in the left shoulder 4. Pain in the right shoulder 5. Pain in the left upper arm 6. Pain in the back 7. Pain in the right upper arm 8. Pain in the waist 9. Pain in the hip 10. Pain in the lower back 11. Pain in the left elbow 13. Pain in the right elbow 14. Pain in the left forearm 15. Pain in the right forearm 16. Pain in the left wrist 	<ol style="list-style-type: none"> 17. Pain in the right wrist 18. Pain in the left palm 19. Pain in the right palm 20. Pain in the left thigh 21. Pain in the right thigh 22. Pain in the left knee 23. Pain in the right knee 24. Pain in the left calf 25. Pain in the right calf 26. Pain in the left ankle 27. Pain in the right ankle 28. Pain in the sole of the left foot 29. Pain in the sole of the right foot 	[26], [35], [36]
Productivity (Z)	<ol style="list-style-type: none"> 1. Job desk 2. Responsibility 3. Task success 4. Consistent 5. Fulfilment of tasks 6. Understanding of regulations 7. Job target 8. Hope 9. Work according to the rules 10. Jobs outside the job desk 11. Job as expected 12. Motivated 13. Punctuality at work 14. Nice to get feedback 15. The positive influence of the team 	<ol style="list-style-type: none"> 16. Negative influence from the team 17. Job by contact 18. Work dedication 19. Monthly performance report 20. Job presentation 21. Rest according to the rules 22. Work according to priority 23. Job acknowledgement 24. Performance keeps improving 25. The positive influence of OHS standards 26. Negative effects of OHS standards 27. Strict attendance 28. Work stress 29. Job dissatisfaction 	[38]

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3. RESULTS AND DISCUSSION

3.1. Characteristics of respondents

The determination of respondents in this study is aimed at construction project workers in the Jakarta area. The selection of respondents is based on workers who work at heights. Working at this height has the highest risk because it can create work accidents that cause death. The highest level of respondents is between 31 - 40 years, as much as 40.2%, with all construction project workers being male. Workers working 1-5 years dominate as much as 31.8% while Builders dominate the job position for respondents with a percentage of 42.9% (Table 2).

Table 2. Characteristics of respondents

Characteristic	Percentage (%)	
Gender	Female	0%
	Male	100%
Age (year)	<20	7.5%
	20-30	34.6%
	31-40	40.2%
	41-50	10.3%
	51-60	5.6%
	>60	1.9%
Work experience (year)	<1	10.3%
	1-5	51.4%
	6-10	28%
	11-15	31.8%
	16-20	3.7%
	>20	2.8%
	Position/ Skill	Craftsman
Technician		6.5%
HSE		5.6%
Supervisor		3.7%
Scaffolder		3.7%
Survey		2.8%
Others		32.7%

3.2. SEM Analysis

Data processing in this study was carried out

with smartPLS 3.0 software. The first data processing still found several invalid question items; the loading factor value was still below 0.7. The item is then removed from the model and further processed again. The results of the second data processing using smartPLS 3.0. The data processing results on each indicator have met the loading factor requirements, namely > 0.7. This value already meets the standard loading factor. The second model can be declared valid (Fig. 2).

The Average Variance Extracted (AVE) is used to perform measurements at the Convergent Validity test stage. The convergent validity test meets the requirements or is in suitable category if the AVE value is > 0.5. The AVE value for each variable is more than 0.5 (Table 3). This value follows the convergent validity standard. Therefore, it can be stated that the convergent validity conditions have been met.

Table 3. Convergent validity

Variable	Average variance extracted	Remark
Ergonomic (M)	0.593	Valid
Work Accident (Y)	0.538	Valid
OHS Management (X2)	0.674	Valid
Intervening Effect M1	1.000	Valid
Application of OHS Requirement (X1)	0.648	Valid
Productivity (Z)	0.567	Valid

Ensuring that each latent model is different from other variables is carried out at the discriminant validity test stage. Table 4 shows the discriminant validity of the model in this study by looking at the cross-loading value. Table 4 interprets that all variables are valid and can be declared discriminant validity. There is no problem.

Table 4. Discriminant validity

	Ergonomics (M)	Work accident (Y)	OHS management (X2)	Intervening effect M1	Application of OHS requirement (X1)	Productivity (Z)
Ergonomic (M)	0.770					
Work Accident (Y)	0.142	0.734				
OHS Management (X2)	0.140	0.088	0.821			
Intervening Effect MX1	0.546	-0.050	0.104	1.000		
Application of OHS Requirement (X1)	0.155	-0.137	0.784	0.108	0.805	
Productivity (Z)	0.183	-0.092	0.803	0.099	0.818	0.753

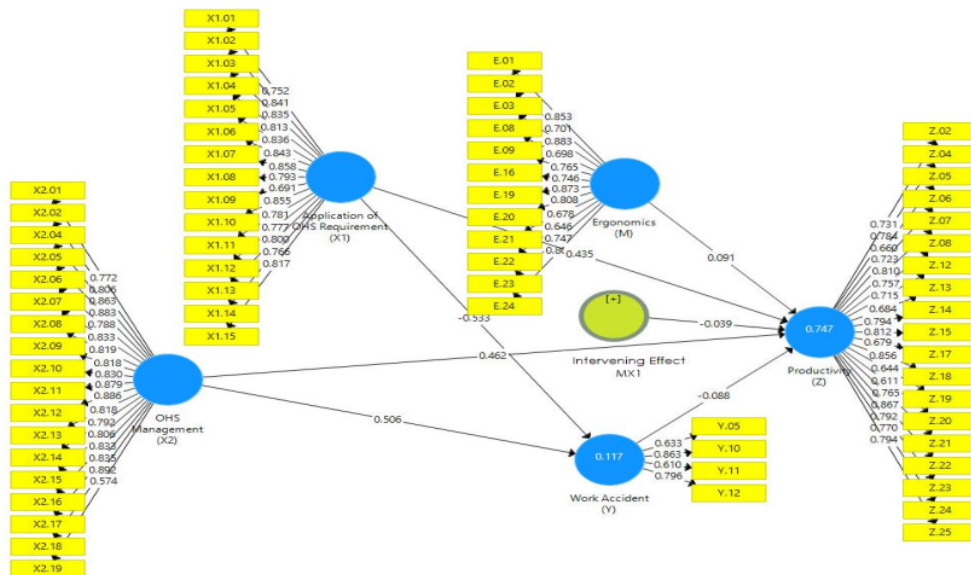


Fig. 2. PLS algorithm

In the formative model, the Multicollinearity test was measured using the Variance Inflation Factor (VIF). For this test, the VIF value must be less than 5. Based on Table 5, the VIF value is still above ten, so there is an indication of multicollinearity.

Table 5. Multicollinearity test

Variable	Tolerance	VIF
Ergonomic (M)	0.961	1.004
Work Accident (Y)	0.820	1.128
OHS Management (X2)	0.853	1.098
Intervening Effect MX1	0.867	1.049
Application of OHS Requirement (X1)	0.955	1.102
Productivity (Z)	0.948	1.110

Table 6. Composite reliability test

Variable	Composite reliability	Remark
Ergonomic (M)	0.946	Reliable
Work Accident (Y)	0.820	Reliable
OHS Management (X2)	0.974	Reliable
Intervening Effect MX1	1.000	Reliable
Application of OHS Requirement (X1)	0.965	Reliable
Productivity (Z)	0.961	Reliable

Composite Reliability (CR) or Cronbach Alpha can measure the reliability test. The

condition for a variable is considered reliable if it has a CR or Cronbach Alpha value greater than 0.7. Table 6 shows the results of the reliability test with composite reliability, and Table 7 shows the reliability test with Cronbach Alpha. The CR value and Cronbach's Alpha for each latent variable are more than 0.7. This value follows the Reliable Composite standard and Cronbach Alpha. Therefore, it can be stated that all variables are declared reliable.

Table 7. Cronbach alpha

Variable	Cronbach alpha	Remark
Ergonomic (M)	0.860	Reliable
Work Accident (Y)	0.776	Reliable
OHS Management (X2)	0.814	Reliable
Intervening Effect MX1	0.712	Reliable
Application of OHS Requirement (X1)	0.747	Reliable
Productivity (Z)	0.816	Reliable

The value of R-squared (R^2) is used to measure prediction accuracy. The requirement for the R^2 value is considered large if it is 0.75, moderate if the R^2 value is 0.50 and low if the R^2 value is 0.25. Table 8 interprets the estimated accuracy of the R^2 value for the Work Accident variable as 0.117. This value is still relatively low. At the same time, the estimated accuracy of the R^2 value for the Productivity variable is 0.747. This

value shows a large effect.

Table 8. R-squared (R²)

Variable	R Square	R adjusted square
Work Accident	0.117	0.100
Productivity	0.747	0.734

After all, assumptions are met, the next step is to analyze the path coefficients on the structural model. This analysis is used to determine the effect of significance between several variables. The test results interpret if the p-value < 0.05 is said to have a significant relationship and if the p-value > 0.05 is said to have an insignificant relationship. The results of the path coefficient analysis of the structural model will be shown in Table 9. The analysis can be obtained that:

1. The effect of Ergonomics on Productivity can be seen that the p-value of 0.313 > 0.05 means that Ergonomics has no significant effect on Productivity.
2. The effect of Work Accidents on Productivity can be seen in that the p-value of 0.333 > 0.05 means that Work Accidents have no significant effect on Productivity.
3. The effect of OHS Management on Work Accidents shows that the p-value is 0.013 > 0.05, meaning that OHS Management has no significant effect on Work Accidents. The path coefficient is positive so that better OHS Management will increase accidents.
4. The effect of OHS Management on

Productivity shows that the p-value is 0.000 < 0.05, meaning that OHS Management has a significant effect on Productivity. The path coefficient is positive. Better OHS Management will increase Productivity.

5. The effect of the application of OHS Requirements through ergonomics on Productivity can be seen as the p-value is 0.527 > 0.05, meaning that the application of OHS Requirements through Ergonomics has no significant effect on Productivity.
6. The effect of the application of OHS Requirements on Work Accidents shows that the p-value is 0.001 < 0.05, meaning that the application of OHS Requirements has a significant effect on Work Accidents. The path coefficient shows a negative value; the better the implementation of OHS, the Accident will decrease.
7. The effect of the application of OHS Requirements on Productivity can be seen that the p-value is 0.000 < 0.05, meaning that the application of OHS Requirements has a significant effect on Productivity. The path coefficient shows a positive value; the better application of OHS Requirements will increase Productivity.

In addition to the direct influence analysis, this study also conducted an indirect effect analysis. The aim is to determine the significant effect between latent variables. Table 10 shows the results of the indirect effect coefficient test in this study.

Table 9. Hypothesis test

Variable correlation	Path coefficient	P Values
Ergonomic (M) -> Productivity (Z)	0.091	0.313
Work Accident (Y) -> Productivity (Z)	-0.088	0.333
OHS Management (X2) -> Work Accident (Y)	0.506	0.013
OHS Management (X2) -> Productivity (Z)	0.462	0.000
Intervening Effect MX1 -> Productivity (Z)	-0.039	0.530
Application of OHS Requirement (X1) -> Work Accident (Y)	-0.533	0.001
Application of OHS Requirement (X1) -> Productivity (Z)	0.435	0.000

Table 10. Coefficient and indirect effect testing structural model

Variable correlation	Path coefficient	P Values
Application of OHS Requirement (X1) -> Work Accident (Y) -> Productivity (Z)	-0.045	0.404
OHS Management (X1) -> Work Accident (Y) -> Productivity (Z)	0.047	0.432

The Application of OHS Requirements to Productivity through work accidents has a p-value of $0.404 > 0.05$, meaning that the Application of OHS Requirements has no significant effect on Productivity through work accidents. The influence of OHS Management on Productivity through Work Accidents has a p-value of $0.432 > 0.05$, meaning that OHS Management has no significant effect on Productivity through Work Accidents.

3.3. Findings and discussion

H1: Ergonomics has no significant effect on Productivity. This correlation does not match with Damaj et al. [24], where Ergonomics can increase Productivity and reduce construction time and costs in Lebanon. This factor is influenced by age, where the average worker is 25-40 years old. This age factor states that the limb's pain has not been felt.

H2: Work Accidents have no significant effect on Productivity. This correlation does not match with Zairani et al. [8], where accidents due to falling from a height on a construction site can increase project costs resulting in Productivity. This factor is influenced by the fact that work accidents are only minor injuries such as being pinched or scratched, which means that this Accident does not eliminate working time.

H3: OHS Management has no significant effect on Work Accidents. This correlation does not match with Liu et al. [34] in Ghana that OSH management does not affect the incidence of Work Accidents, meaning that there is no significant correlation. This factor is influenced by the PPE used is not up to standard (Indonesian National Standard). It can be said that OHS Management is not optimal in preventing workplace accidents.

H4: OHS Management has a significant effect on Productivity. This correlation does not match with Choudhry [39] that implementing OHS Management increases OHS performance from 86% to 92.9% during project implementation. This factor is influenced by good safety talk from the leadership. Leaders are always concerned about the use of PPE, reminding them to always comply with work procedures.

H5: The application of OHS Requirements through Ergonomics has no significant effect on Productivity. This correlation does not match with Damaj et al. [24] at two construction sites in

Lebanon where a positive impact on ergonomic planning can affect Productivity. This factor is influenced by full-body harnesses, which make workers uncomfortable at work. The movement of workers is limited, which makes working time longer. In addition, this can be explained by the PPE factor used not meeting international standards so that workers do not choose to use PPE completely, which impacts accidents that cause Productivity to decrease.

H6: The application of OHS Requirements significantly affects Work Accidents. This correlation does not match with Liu et al. [40], where there is a negative relationship between the application of OHS Requirements and accidents and injuries in the workplace. Implementation of existing OHS Requirements is ineffective or does not have safety standards can create accidents. While this research is successful in reducing work accidents, namely the correct use of PPE and the worker's compliance with safety rules.

H7: The application of OHS Requirements has a significant effect on Productivity. This correlation does not match with Lyu et al. [41] and Martiano and Soekiman [42], where the research results show that Productivity is influenced by factors of worker skill, worker health and a safe work environment. While in this study, the factors supporting this relationship are identifying risks that can prevent work accidents from eliminating lost time

4. CONCLUSION

Based on the analysis in the previous chapter, it is known that Ergonomics does not directly affect Productivity. Work Accidents do not directly affect Productivity. OHS Management has a direct effect on Work Accidents, OHS Management has a direct effect on Productivity, Application of OHS requirements has a direct effect on Work Accidents, and the Application of OHS Requirements has a direct effect on Productivity. Meanwhile, applying OHS Requirements through Ergonomics has no direct effect on Productivity. Future research suggestions focus more on all parts of the construction project to find out the factors that cause work accidents.

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