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THE INFLUENCE OF THE OPEN ENVIRONMENT ON THE WORK PRODUCTIVITY OF CONSTRUCTION PROJECT WORKERS

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ABSTRACT: Work productivity is the amount of work achieved by workers in a certain time and place. It is an indicator of whether a construction project can run effectively. Therefore, this study aims to determine the influence of the open environment on the work productivity of construction project workers, namely: solar radiation temperature, project contours, safety, relative humidity, work layout, wind, weather conditions, light intensity, visibility distance, color scheme, and pollution. Data was collected using the purposive sampling method and analyzed using the Structural Equation Modeling (SEM) program. The results showed that the variables with a positive effect of 35%, 35%, and 22% on work productivity are security, weather conditions, and work layout. The factors that demonstrated a negative effect of -31.6% and -33.3% are solar radiation temperature and light intensity. Results also indicated that the security and weather condition variables have the highest influence on worker productivity, hence, they are the guarantor of workers' health and safety.

Keywords: *Work productivity, Project workers, Construction projects, Structural equation modeling (SEM)*

1. INTRODUCTION

Work productivity is the amount of work achieved by workers in a certain time and place. It indicates whether a project can run effectively and within the planned timeframe. When adequate attention is not given, the contractor will likely suffer losses in human and financial resources, materials, and equipment. Therefore, for maximum performance, the environment needs to be calm, safe, comfortable, and able to protect workers from the sun.

Fig. 1 Putting together the steel reinforcement on the second-floor plate

In Fig. 1, workers are weaving the steel to form the second-floor reinforcement of a building. Meanwhile, in Fig. 2, they are pouring and leveling the concrete for the second-floor plate.

The success of a construction project depends mainly on the management of highly correlated inputs, such as labor, material, and capital.

Fig. 2 Casting the concrete of the second-floor plate

Among these inputs, human resources are the most difficult to manage [1]. The presence of a highly productive workforce at every stage of project development plays an important role in its success [2]. Furthermore, knowledge of work productivity is important to cost estimation and control of work progress [3]. Its effect on the time and cost needed to complete different project performance measures has also been assessed. Following the model developed by Nasirzadeh & Nojedehi (2013), project managers can identify the root causes of productivity declines. Therefore, through the implementation of appropriate solutions, labor productivity can be increased. [2]. This factor is a measure of economic performance, which is negatively impacted by environmental management and moderated by quality management [4]. According to numerous studies, achieving maximum work productivity is not possible due to the various conditions experienced in the work environment. However, despite many obstacles, it has been concluded that the benchmark is a set of reliable indicators of project workforce performance [5]. Productivity and safety are important topics in the construction industry. Unfortunately, there is little information for project managers trying to determine management strategies designed to increase safety in an open environment [6]. Proper management of resources in a construction project can save time and cost [7]. Work productivity growth must be given serious attention because it is the key to success [8]. The occupational health and safety of construction project workers, including bodily harm caused by the sun's heat, must also be prioritized o maximize productivity [9]. The environment must be prepared properly before commencement to maximize productivity [10]. Unfavorable geographical conditions decrease woworkers'erformance compared to well-prepared conditions that are safe and comfortable [11]. Given the seriousness of the environmental impact of air pollution, special attention must also be paid to it to ensure it does not result in a reduction [12]. An objective and effective model for evaluating environmental performance is needed for controlling air pollution [13].

Many business organizations have successfully protected sensitive information by providing effective access control mechanisms that utilize information security technology. However, such security measures often reduce the work productivity of staff by requiring them to spend time on tasks not related to the project [14]. This means that attention must also be given to security mechanisms. Studies were also conducted on the impact of indoor environmental quality in open-plan research offices situated in universities [15]. In the absence of the right combination of characters and background colors, optimal performance of cognitive tasks is greatly affected, which, in turn, affects communication among operators [16]. A report on lighting and color schemes is accessible by non-professionals responsible for improving these strategies [17]. The layout of the previous building must be considered before planning for an extension of another [18]. Wind not only affects construction projects but also has the potential to impact the environment regarding the development of energy [19]. Therefore, ignoring its effects can result in an extension of the project duration by 5-20% [20].

Overall, results showed that a high-temperature environment exerts heat stress on the human body [21]. Other studies also showed ambient temperature, humidity, air pressure, CO2 sensors [22], wind strength, and intensity of night light [23]. The construction industry is one of the main sources of fine dust pollution with the occurrence of occupational hazards [24].

Based on the literature described above, several factors have been identified, however, the safety and visibility variables have not been examined. This study aims to determine the effect of solar radiation temperature, project contours or geographical conditions, security, relative humidity, work layout, wind, weather conditions, light intensity, visibility, color scheme, and pollution in an open environment.

2. MATERIAL AND METHODS

2.1. Population and Sample

This is a descriptive study that aimed to describe the influence of the open environment on work productivity of construction workers. The population was from all Java Islands, namely the Provinces of Special Capital Region, West Java, the Special Region of Yogyakarta, Central Java, and East Java, with the respondent percentage of 28%, 26.2%, 5.6%, 18,7%, and 21,5%, respectively.

2.2. Study Variables

In preliminary studies, the independent variables that influenced work productivity (Y) were nine, namely solar radiation temperature, project contours or geographical conditions, relative humidity, work layout, wind, weather, light intensity, color scheme, and pollution. This study included two new variables, namely security and visibility. Therefore, there are 11 independent variables, namely solar radiation temperature (X1), project contours or geographical conditions (X2), security (X3), relative humidity (X4), work layout (X5), wind (X6), weather conditions (X7), light intensity (X8), visibility (X9), color scheme (X10), and pollution (X11).

2.3. Hypothesis

The independent variables solar radiation temperature, project contours or geographical conditions, security, relative humidity, work layout, wind, weather conditions, light intensity, visibility, color scheme, and pollution are hypothesized to affect work productivity.

2.4. Data Collection Method

The questionnaire method was used to collect the data from construction workers in areas on Java Island.

2.5. Data Analysis Plan

Field data must be collected from a minimum of 100 respondents to be able to analyze the data using the Structural Equation Modeling (SEM) method [25]. The questionnaire used a scale of 1 to 5, hence, the initially qualitative data became quantitative. The numbers 1 to 5 are the weight values of the statements, indicating strongly uninfluential, uninfluential, no influence, influential, and strongly influential, respectively. The data obtained from respondents was essentially an exploration of the factors that affect the work productivity of construction project workers. It was used to determine the dominant factors identified using the SEM method.

3. ANALYSIS AND DISCUSSION

The SEM *analysis* proved the hypotheses. Before using SEM, several prerequisites must be met and used to fulfill the goodness of fit criteria. One of the main purposes of using Modification Indices *(*M.I) is to produce a better fit model. The results after employing the modification indices are as shown in Table 1:

Table 1 Goodness of fit index

The goodness of fit index	Criteria	*Cut of value*	Information
Chi-square	Must be small	63.447	Fit
Significant Probability	≥0.05	0.0520	Fit
RMS	≤0.08	0.025	Fit
GFI	≥0.90	0.924	Fit
CMIN/DF	≤2.00	6.345	Non fit
NFI	≥0.90	0.932	Fit
IF	≥0.90	0.942	Fit
CFI	≥0.90	0.938	Fit

RMSEA: The Root Mean Square Error of Approximation, GFI: Goodness of Fit Index, CMIN/DF: Relative x^2, NFI: Normed Fit Index, IFI: Incremental Fit Index, CFI: Comparative Fit Index.

The test results shown in Table 1 indicate that the majority of criteria are of the fit condition. Although one criterion is non-fit, the overall structural model is in good condition, and further analysis can be conducted. The data was then analyzed using the Full Model of the SEM method, which tests the models and hypotheses developed in this study.

This was carried out using the model suitability and the causality significance tests through the regression coefficient. The regression weight test was conducted along with the *t*-test to determine the regression weight and coefficient model. These tests are shown in Table 2 and Figures 3, 4, 5, 6, 7, 8, and 9.

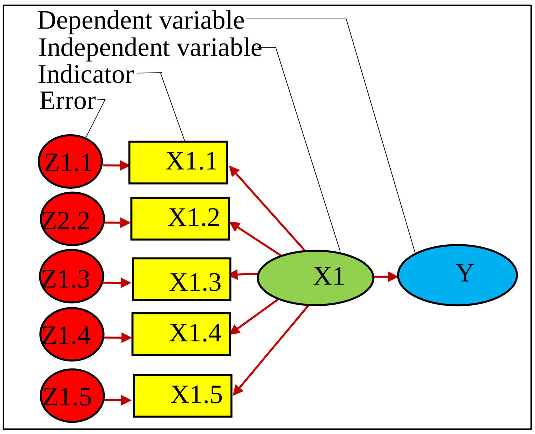

Fig. 3 Model of the relationship between X1 and Y

In Fig. 3, Y is the dependent variable used to denote work productivity, while X1 constitutes the independent with X1.1, X1.2, X1.3, X1.4, and X1.5 as indicators. The standard errors of each indicator are represented by z1.1, z1.2, z1.3, z1.4, and z1.5. Solar radiation temperature (X1) influences work productivity (Y) with a value of -0.306 and a probability of 0.003, smaller than 0.05, as shown in Table 2

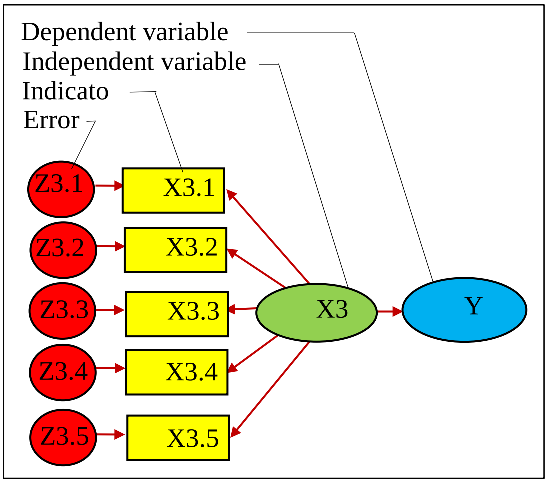

Fig. 4 Model of the relationship between X3 and Y

Fig. 4 presents a relationship model between security (X3) and work productivity (Y). X3 influences Y with a value of 0.388 and a probability of 0.003, smaller than 0.05, as shown in Table 2.

Variable X3 has five indicators, namely X3.1, X3.2, X3.3, X3.4, and X3.5, with corresponding standard errors of z3.1, z3.2, z3.3, z3.4, and z3.5.

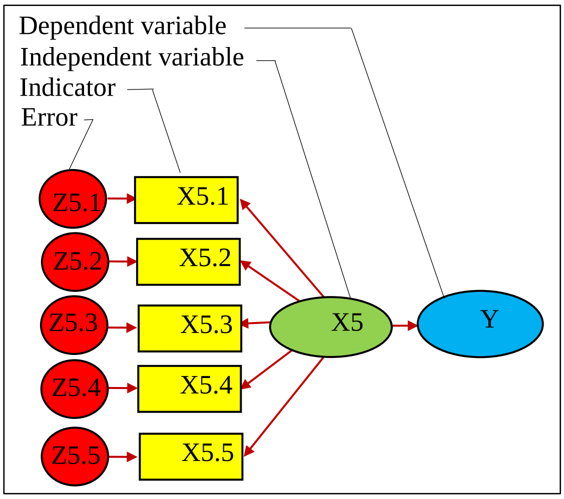

Fig. 5 Model of the relationship between X5 and Y

Fig. 5 shows the relationship between work layout (X5) and productivity (Y). X5 influences Y with a value of 0.269 and a probability of 0.045, smaller than 0.05, as shown in Table 2. X5.1, X5.2, X5.3, X5.4, and X5.5 are the indicators of the variable X1, with corresponding standard errors of Z5.1, z5.2, z5.3, z5.4, and z5.5.

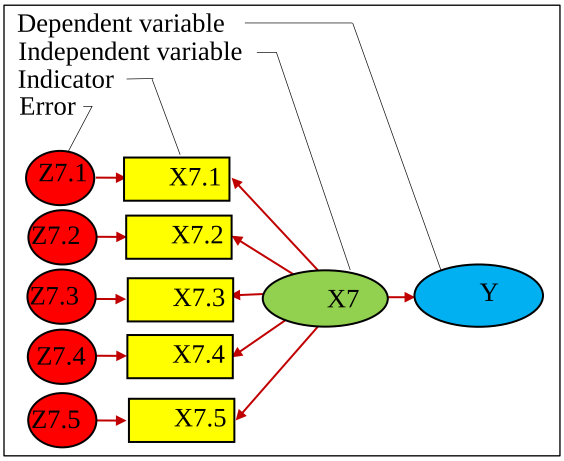

Fig. 6: Model of the relationship between X7 and Y

Fig. 6 shows the relationship between weather conditions (X7) and work productivity (Y). X7 influences Y with a value of 0.352 and a probability of 0.000, smaller than 0.05, as shown in Table 2. Variable X7 has five indicators, namely X7.1, X7.2, X7.3, X7.4, and X7.5, with corresponding standard errors of z5.1, z5.2, z5.3, z5.4, and z5.5.

Fig. 7 shows the relationship between light intensity (X8) and work productivity (Y). X8 influences Y with a value of -0.431 and a probability of 0.019, smaller than 0.05, as shown in Table 2. Variable X8 has five indicators, namely X8.1, X8.2, X8.3, X8.4, and X8.5, with corresponding standard errors of z8.1, z8.2, z8.3, z8.4, and z8.5.

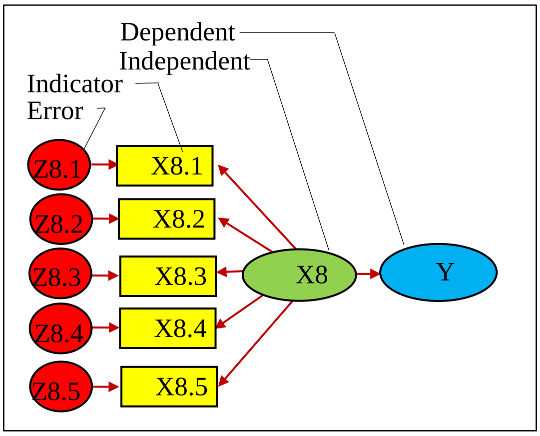

Fig. 7 Model of the relationship between X8 and Y

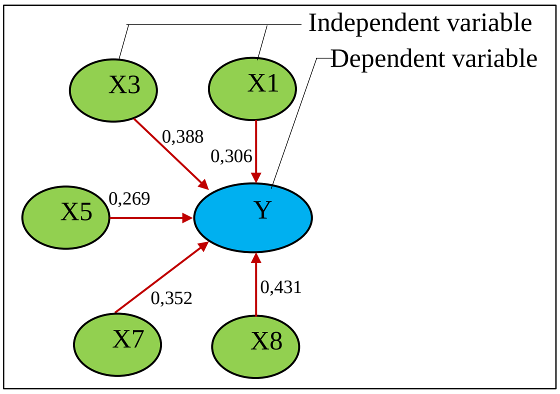

Fig. 8 Model of the relationship between the independent variable X that affects the dependent variable Y

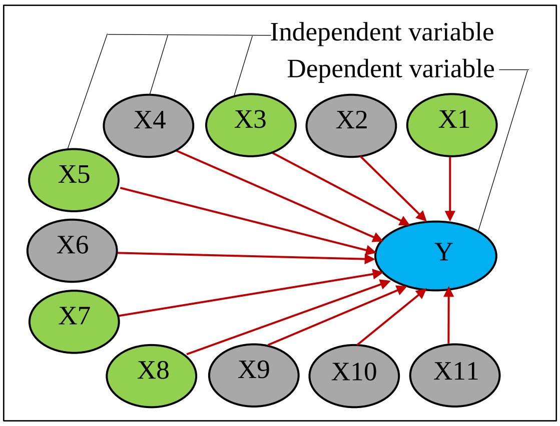

Fig. 9 Full model of the relationship between variables X and Y

Fig. 8 shows the solar radiation temperature between variable (X1) and productivity (Y). The solar radiation (X1), security (X3), work layout (X5), weather conditions (X7), and light intensity (X8) influence productivity (Y) with a value of 0.306, 0.388, 0.269, 0.352, and 0.431, respectively, as shown in Table 2.

Fig. 9 shows all the independent variables, namely solar radiation temperature (X1), project contours or geographical conditions (X2), security (X3), relative humidity (X4), work layout (X5), wind (X6), weather conditions (X7), light intensity (X8), and visibility (X9), color scheme (X10) and pollution (X11) influence the dependent work productivity variable (Y).

Table 2 and Fig. 9 show that the variables of solar radiation temperature (X1), security (X3), work layout (X5), weather conditions (X7), and light intensity (X8) affect work productivity (Y) because their probabilities are smaller than 0.05. The variables of project contours or geographical conditions (X2), relative humidity (X4), wind (X6), visibility (X9), color scheme (X10), and pollution (X11) do not affect the work productivity variable (Y), because their probabilities are greater than 0.05, as shown in Table 2.

Table 2 Results of the regression weight test

Dependent Variable		Independent Variable	Estimate	S.E.	C.R.	P	Label
Y	←	**X1**	**-0.306**	**0.102**	**-2.993**	**0.003**	**par_1**
Y	←	X2	0.167	0.111	1.500	0.134	par_2
Y	←	**X3**	**0.388**	**0.131**	**2.953**	**0.003**	**par_3**
Y	←	X4	-0.036	0.161	-0.223	0.824	par_4
Y	←	**X5**	**0.269**	**0.134**	**2.002**	**0.045**	**par_5**
Y	←	X6	-0.003	0.161	-0.018	0.986	par_6
Y	←	**X7**	**0.352**	**0.089**	**3.955**	*******	**par_7**
Y	←	**X8**	**-0.431**	**0.184**	**-2.344**	**0.019**	**par_8**
Y	←	X9	0,059	0.147	0.401	0.688	par_9
Y	←	X10	0.008	0.130	0.061	0.951	par_10
Y	←	X11	0.162	0.120	1.350	0.177	par_11

S.E. = Standard Error, C.R. = Current Ratio, P = Probability.

In this study, 11 hypotheses were proposed, which are outlined in the following sections:

Hypothesis 1 (H1): Solar radiation temperature affects worker productivity. Data processing shows that the CR and probability values are -2.993 and 0.003. These values show that solar radiation temperature affects worker productivity, therefore, H1 is accepted. The nature of the effect is negative, meaning that the higher the temperature of solar radiation, the lower the workers' productivity and vice versa. Therefore, workers need to be protected from harsh weather conditions, such as sunburn, through the provisions of an emergency roof. These findings are in line with the preliminary studies [21].

Hypothesis 2 (H2): project contours or geographic conditions affect worker productivity. Data processing shows that the CR and probability values are 1,500 and 0.134. These values indicate that project contours or geographic conditions do not affect workers, hence H1 is rejected. The finding stating that location does not affect workers is not in line with previous studies [22, 27].

Hypothesis 3 (H3): security affects worker productivity. Data processing shows that the CR and probability values are -2.953, and 0.003. These values indicate that security affects workers, hence, H3 is accepted. The nature of the effect is positive, meaning that the higher the level of security, the greater the outcome. Workers need to be protected from external influences by building a safety fence at the project site and providing guards to achieve such security. Other security measures include seat belts, appropriate footwear, safety gloves, etc. Safety equipment makes workers feel more comfortable and improves productivity. The security variable is a guarantor of the health and safety of workers and has not been reported in previous studies.

Hypothesis 4 (H4): relative humidity affects worker productivity. Data processing shows that the CR and probability values are -0.223 and 0.824. These values indicate that relative humidity has no effect, hence, H4 is rejected. This finding is not in line with previous studies by [22].

Hypothesis 5 (H5): work layout affects worker productivity. Data processing shows that the CR and probability values are -2.002 and 0.045. These values indicate that work layout affects workers, therefore, H5 is accepted. The nature of this effect is positive, meaning that the better the work layout, the greater the outcome. Work layout refers to the facilities that support the smooth running of activities within an organization. These include positioning the workplace near the materials warehouse, rest places, bathrooms and toilets, water sources, and transportation. This process allows the smooth running. These findings are in line with preliminary studies by [18, 27, 28].

Hypothesis 6 (H6): wind affects worker productivity. Data processing shows that the CR and probability values are -0.018 and 0.986. These values indicate that wind does not affect worker productivity, hence, H6 is rejected. This finding is not in line with previous studies by [28].

Hypothesis 7 (H7): weather affects worker productivity. Data processing shows that the CR and probability values are -3.955 and 0.000 thereby indicating that, H7 is accepted. The nature of the effect is positive, meaning that the clearer the weather, the greater their productivity and vice versa. To overcome the effects of bad weather, temporary tents need to be installed, and workers should be provided with raincoats. These findings are in line with preliminary studies by [9, 10].

Hypothesis 8 (H8): light intensity affects worker productivity. Data processing shows that the CR value for this variable is -2.344 and the P-value is 0.019. These values indicate that light intensity affects worker productivity, hence, H8 is accepted. The nature of the effect is negative, meaning that the higher the light intensity, the lower the worker productivity. The low intensity of light at night, or in dark areas also affects worker productivity, therefore, adjusting light must be installed. When working at night, the productivity of workers can still be increased. These findings are in line with preliminary studies [23]. The variables of project contours or geographical conditions, relative humidity, wind, color scheme, and pollution have a negligible effect on worker productivity. These findings are not in line with preliminary studies [17, 18, 22, 24, 26].

Hypothesis 9 (H9): visibility affects worker productivity. Data processing shows that the CR and probability values are 0.401 and 0.688. These values indicate that visibility does not affect worker productivity, hence, H9 is rejected. Visibility indeed does not affect work productivity. Visibility is a new variable that is suspected to affect worker productivity, after being proven by using statistics, it does not affect worker productivity.

Hypothesis 10 (H10): color scheme affects worker productivity. Data processing shows that the CR and probability values are 0.061 and 0.951. These values indicate that the color scheme does not affect worker productivity, hence, H10 is rejected. The color scheme indeed does not affect work productivity. This finding is not in line with previous studies [17].

Hypothesis 11 (H11): pollution affects worker productivity. Data processing shows that the CR and probability values are 1.350 and 0.177. These values indicate that pollution does not affect worker productivity, indicating H11 is rejected. Pollution indeed does not affect work productivity. This finding is not in line with previous studies [22, 24]. The visibility and security variables are new and were found to have a negligible and positive effect.

4. CONCLUSIONS

In conclusion, the factors with a positive effect on the work productivity of construction project workers are security, weather conditions, and layout, with percentages of 35%, 35%, and 25%. Meanwhile, the factors that negatively affect solar radiation temperature and light intensity, with percentages of 31.6% and -33.3%. The variables of project contours or geographical conditions, relative humidity, wind, visibility, color scheme, and pollution do not affect the work productivity of construction project workers.

The most dominant factors with a positive are security and weather conditions. These variables have the greatest influence on achieving the maximal effect, therefore, they need special attention during the implementation of a construction project.

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