Analysis of environmental ergonomics in rice distribution center

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Abstract. Environmental ergonomics is dynamic effects of workplace environment to worker productivity. Rice distribution center is a value-added agro-industrial warehouse to support supply chain. Environmental ergonomics must be designed to achieve worker ergonomics and value-added of stored rice. The research objectives was to analyze effect of work capacity, workload and workplace environment to worker productivity. The samples were the 8 (Eight) workers in a sack-opening station. Work station capacity were 131.718 sacks per hour. Research hypothesis stated productivity could be influenced by 7 (Seven) variables as 1) age; 2) work experience; 3) workload; 4) workplace temperature; 5) relative humidity; 6) light intensity; and 7) noise. Based on test of independent variables, age, workload and temperature have significant relationship. 11 (Eleven) regression models were conducted to test the variables. The best model was selected based on adjusted $R^2$, standard error of the estimate, and value on $t$ statistical test. The research results indicated the best model of Hyperbolic with adjusted $R^2$ square of 0.754. It can be concluded that 75.4% productivity variation could be explained by all variables while 24.6% by other cause. This results confirmed our previous results that workplace environment influence the worker productivity in agro-industry.

1. Introduction
Environmental ergonomics is dynamic effects of workplace environment to worker productivity [1]. Environmental ergonomics could be concluded as a significant factors for the development of agro-industrial production systems [2,3]. Ushada et al. [2] have defined the relationship between workload, productivity and workplace environment. Some parameters of environmental ergonomics as temperature, humidity, light intensity, and noise was identified as significant for worker performance (Ushada et al., 2015)[2]. Sauian, et al. [4] have defined productivity is the performance parameters indicating size of the output produced from the number of inputs provided. Ushada et al. [2] have defined the relationship between workload, productivity and workplace environment. Sheikh, Ali and Adan [5] defined that a conducive work environment guarantees the welfare of the workforce that allows workers to exert all their abilities and strengths to get higher productivity. Ragab, et al. [6] concluded the effect of workload impact on productivity.
Rice distribution center (RDC) is a value-added agro-industrial warehouse to support supply chain. Warehouse is a special facility, designed to achieve service level targets with the lowest total cost. Worker productivity in the RDC has an important role as determinant of wages.

Some factors that affect labor productivity are carried out in a controlled room to simulate actual condition in the field. Ismail [7] indicated the influence of the environment on the productivity of temperature, humidity, and light intensity in the control room. In addition, there has not previous research that makes mathematical equations for labor productivity with work capacity factors, workload, and work environment in Indonesia. Environmental ergonomics must be designed to achieve worker ergonomics and value-added of stored rice. The research objectives was to analyze effect of work capacity, workload and workplace environment to worker productivity.

2. Methodology

2.1. Sample of rice distribution center
A sample of RDC in Bantul, Yogyakarta Special Region was analysed. There are two main activities in Rice Distribution Center, namely re-bag and lifting (“angkat-angkut”). Among the two activities, the routine activity of the workers is re-bag as repackage process from large sack to a smaller sack (50 kg sack into a 15 kg sack). The determination of workers wage are calculated based on the amount of rice tonnage distributed every day.

2.2. Environmental ergonomics parameters
In this study, the factors are analyzed are adjusted to the conditions in the sample of RDC. Firstly, the work capacity factor is evaluated. Ulfah [8] stated that components that affect other factors are gender and years of service. Because all workers are male, the factors that will be used are time and working period. Second, the workload factor. Tarwaka [9] defined workload can be defined as the difference between capacity or performance with the work that must be faced. In the RDC physical workload is a dominant workload with mental and social workload. Physical work is more dominant because Re-bags are carried out manually and every day workers have to do repack 500-600 sacks per day per worker with heavy loads processing between 15 to 50 Kg.

Third, environmental parameters are evaluated. The selection of these indicators considered the re-bag activity carried out in a rice warehouse, where the temperature standard for storing cereal temperature is 27 – 30° with 70% humidity [10]. Rahmillah [11] stated that a comfortable temperature for workers to get optimum work productivity is in the range of 24 to 26°C. The lighting indicator, inside the warehouse only uses sunlight without additional artificial light. The intensity cannot be adjusted and sometimes the light is blocked by a pile of rice sacks. The re-bag activity that uses equipment produces a sound comes from a sewing machine. Akbari, et al. [12] defined the noise level in the workplace has a negative effect on human productivity as a decreasing organizational productivity, quality and quantity of product service.

2.3. Selection of work station
This research was not conducted in all work stations because each station has specific process. Postural stress analysis is performed on workers who are conducting activities using the Ovako Working Posture Analysis System (OWAS) method.

There are six work stations that are assessed using OWAS, which are sacks dismantling, opening, placing, weighing, sewing, and structuring. The results indicated two work stations with the highest score after adjusting work time as sacks opening and sacks structuring with value category of two. The value indicated this attitude is harmful in the musculoskeletal system and required improvement in the future. Table 1 indicated two work stations which have highest score.
Table 1. OWAS score

| Stasiun Kerja | WS 1 | WS 2 | WS 3 | WS 4 | WS 5 | WS 6 |
|---------------|------|------|------|------|------|------|
| Score OWAS before time adjustment | 3    | 4    | 3    | 1    | 1    | 4    |
| Score OWAS after time adjustment   | 1    | 2    | 1    | 1    | 1    | 2    |

Subsequently, interview was conducted to workers. From the interview, the selected station is the sack opening due to not all workers can work in the work station and the hardest work element. Besides, the number of sacks opened at the work station is used as a calculation of the wage for workers every day. So, the more unproductive the work station is, the smaller wages will be received by the worker. The samples was pursued on 8 (Eight) workers who routinely carried out sack opening work. In determining the amount of wage, the foreman will calculate the tonnage that is processed on that day. The tonnage was multiplied by the wage cost and shared with all workers (including foreman).

2.4. Data acquisition

Data acquisition method was pursued once in an hour and was taken five times. Measurement of work capacity was conducted by direct interview. The data includes recent worker age and working period. The physical workload indicators was indicated from the heart rate of the workforce. Heart rate data was measured using a wrist pulse meter every hours, before-after working [2].

4 (Four) workplace environment parameters work environment was measured as light intensity, noise, humidity, and temperature of the RDC. Environment data was measured simultaneously with heart rate data collection. Workplace environmental parameters were measured the environmental meter. Finally, the worker productivity was measured by dividing output per hour with productive time (in hour). Productive time is defined as the time used to direct work. Observations were carried out every 1 (One) hour or there are 5 (Five) times in productivity cycle. The data was measured at 08.30-11.30 and continued at 13.00-15.00.

2.5. Calculation of physical workload and productivity

The classification of workload was determined based on an increase of working pulse compared to the maximum pulse due to cardiovascular load (cardiovascular load = % CVL) (Manuaba & Vanwonterghem (1996) in Tarwaka [13]). The amount of % CVL is calculated by the following equation:

\[
\% CVL = \frac{(100 \times (\text{working pulse} - \text{resting pulse}))}{(\text{maximum pulse} - \text{resting pulse})}
\]

The maximum pulse is (220-age) for men and (200-age) for women. Furthermore, the % CVL classification table is indicated in Table 2.

Table 2. CVL % classification

| %CVL | CVL % classification|
|------|----------------------|
| < 30 % | No Fatigue |
| 30 – < 60 % | Need Improvement |
| 60 - <80% | Work in minimum time |
| 80 - < 100% | Immediate action required |
| >100% | Activities not allowed |

Productivity was defined as the ratio between output and input. In other word, it was defined as the ratio of the result obtained to the resources used. The calculation was indicated in following equation [14].

\[
\text{Productivity} = \frac{\text{output}}{\text{input}}
\]
2.6. Data analyzing method

The data was processed and analyzed using SPSS. Statistical descriptive analysis was pursued to identify the company profile. In addition, the regression analysis was used to analyze the effect of work capacity, workload, and work environment on productivity.

3. Results and Discussion

3.1. Descriptive analysis

3.1.1. Age. From 8 respondents, four of them (50%) is in age 26–35 years old which is early adult. 25% of respondents is in late adult, and the rest of 25% is in early elderly category. All workers could be classified in productive category (15–64 years old).

3.1.2. Working period. According to Tulus (2003), working period can be categorized into three, namely early (<6 years); medium (6–10 years) and experienced working period (> 10 years). The result indicated that 37.5% of respondents work less than 6 years (early working period) while the rest 62.5% include in medium working period.

3.1.3. Workload. The result indicated that the average worker experienced workload of 31.96% ± 10.11. The workload experienced by workers ranged from 18.09 to 57.55%. Furthermore, the distribution of workload was indicated in Table 3.

| Data Retrieval | %CVL (<30%) | %CVL 30 – <60 % |
|----------------|-------------|-----------------|
| 1              | 100%        | -               |
| 2              | 37.5%       | 62.5%           |
| 3              | 37.5%       | 62.5%           |
| 4              | 62.5%       | 37.5%           |
| 5              | 75%         | 25%             |

The justified physical loading is a charge that exceeds 30–40% of the maximum workforce ability within 8 hours a day. This observation was based on the applicable working hour regulation. Heavier loading is permitted in a shorter period of time and coupled with an appropriate break to the load weight [15].

3.1.4. Temperature. The first workplace environment factor was temperature. Temperature data retrieval in this study uses environmental meter. In general, the temperature of RDC ranged from 29.3 to 33.4°C with an average temperature of 31.7°C. Furthermore, the conditions of the environmental temperature of the RDC Office was indicated in Figure 3. It showed that the highest temperature on 11.30 because of sunlight. According to research conducted by Ushada [3], optimal worker productivity at a temperature 30 °C so the environment temperature is quite suitable to achieve optimal productivity. Beside, it is difficult to adjust the temperature of the environment in the RDC considering adjusted workplace temperature to the standard for rice storage. If the temperature is not appropriate, it is feared that it will damage the rice.
3.1.5. **Humidity.** The humidity of work environment from RDC has the average humidity before production process was 80.63% ± 2.6%, and after production with the range from 71% to 75%. According to Industry Code of Practice on Indoor Air Quality the most comfortable humidity is 40 to 70%. This confirmation indicated that humidity was in accordance with the standard. However due to the high variability of humidity, the management should aware to discomfort felt by workers.

3.1.6. **Light intensity.** According to Grandjean [18], the not well designed lighting could cause visual disturbance or fatigue during work. The average light intensity in the RDC at the time of research was 1780.208 ± 250.93 with the range of 1139–2187 lux. The results obtained before work, the light intensity was approximately 1139–1655 lux. The intensity of light before production was 1372.75 ± 200.9 Lux. According to the results of Ismail [7], the level of light intensity to achieve optimal productivity is 500 lux. From the data above, the average lighting in the Warehouse of RDC was above 500 lux, so lighting confirmed the standard.

3.1.7. **Noise.** Noise is all unwanted sounds that are sourced from production process equipment and/or work tools that can cause hearing disorder. Noise level was measured using environmental meter. The result indicated 73.71 ± 11.96 with the range of 45.7 to 82.5 dB. The National Institute for Occupational Safety and Health (NIOSH) has recommended that workers noise exposures must be controlled below a level equivalent to 85 dB for eight hours to minimize work noise induced by hearing disorder. In the sack opening work station, the noise level had met the requirements with less than 85 dB.

3.1.8. **Productivity.** The workers have daily working hour from 08.00 to 16.00 WIB (local time). Approximately, they work not on the exact time due to borong (bulk) system and their average hour to work is from 08.30 to 11.30 then continue from 13.00 to 15.00. The remained time used for set up, break time, output counting and waiting for daily wage. Generally, the opening sack work station generate the output between 551-643 sacks with the average of 601.5 ± 31.5. In one hour observation, they can open 101-138 sack with average of 102.3 ± 9.86. Meanwhile, the worker’s productivity ranged from 108.21 to 131.718 with the average value of 131.718 ± 10.57. (Figure 1).

![Figure 1. Average productive time, output, and worker productivity in RDC](image)

3.2. **Hypothesis test**

Before the advance regression analysis is conducted, the hypothesis was tested by using linearity test and normality test as follow:
3.2.1. Linearity test. This test aims to know whether the relationship between independent and dependent variable is linear or not. If deviation from linearity is significant in more than 0.05, means the relationship between two variable is linear. The result of the test was indicated on Table 4.

| Variables     | Deviation From Linearity (Sig.) | Result |
|---------------|--------------------------------|--------|
| Age           | 0.075                          | Linear |
| Working periods| 0.000                          | Non Linear |
| Workload      | 0.873                          | Linear |
| Temperature   | 0.495                          | Linear |
| Humidity      | 0.092                          | Linear |
| Light Intensity| 0.107                         | Linear |
| Noise         | 0.561                          | Linear |

Table 4 showed that all variable has significant value with deviation from linearity more than 0.05 except the working period. It indicated non-linear relationship of variables to work productivity. Besides, age and humidity have value almost 0.05 so it is possible to make non-linear regression equation. Therefore, transformation on variables is highly required.

3.2.2. Transformation process. The transformation process was conducted to 11 non-linear regression equation models according to Sulaiman [17] and Siregar [18]. Table 5 indicated the transformation process of regression model.

| Model     | Equation                        | Linear Equation | Transformation |
|-----------|--------------------------------|-----------------|---------------|
| Linear    | $Y = a + bx$                    | $Y$             | $X$           |
| Quadratic | $Y = a + bx + cx^2$             | $Y$             | $X, X^2$      |
| Cubic     | $Y = a + bx + cx^2 + dx^3$      | $Y$             | $X, X^2, X^3$ |
| Logaritma | $Y = a + b \ln x$              | $Y$             | $\ln X$      |
| Inverse   | $Y = a + bx$                    | $Y$             | $1/X$         |
| Compound  | $Y = ab^x$                      | $ln Y = \ln a + x \ln b$ | $ln Y$        | $X$ |
| Growth    | $Y = e^{a + bx}$                | $ln Y = a + bx$ | $ln Y$        | $X$ |
| Exponential | $Y = a (e^{bx})$               | $ln Y = \ln a + bx$ | $ln Y$        | $X$ |
| Logistic  | $Y = (1/u + ab^x)^i$            | $Ln (1/Y - 1/u) = \ln a + x$ | $ln b$      | $1/Y$ | $X$ |
| Power     | $Y = ax^b$                      | $ln Y = \ln a + b \ln x$ | $ln Y$        | $Ln X$ |
| S         | $Y = e^{a+bt}$                  | $ln Y = a + b/t$ | $ln Y$        | $1/X$ |
| Hyperbolic| $y = \frac{1}{a + bx}$         | $\frac{1}{y} = a + bx$ | $1/Y$        | $X$ |

3.2.3. Normality test. The normality test was conducted to evaluate whether regression model, obstacle, or residual have normal distribution. The test was pursued by using One-Sample Kolmogorov-smirnov test. The result indicated that the data in normal distribution.

3.3. Choosing of the best model

11 (Eleven) regression models were conducted to test the variables. The best model was selected based on adjusted $R$ Square, standard error of the estimate, and value on t statistical test. In this regression
model, it will consider Adjusted $R$ Square, standard error of the estimate, and value on $t$ statistical test. This research conducted variable elimination automatically using backward method. Table 6 indicated the summary of regression result with 11 non-linear model and linear model. The table is sorted from the highest Adjusted $R^2$ to the lowest ones.

**Table 6. Summary of linear and non linear regression model**

| MODEL       | $R^2$ | ADJ $R^2$ | SEE | Sig. $T$ |
|-------------|-------|-----------|-----|----------|
| Cubic       | 0.909 | 0.873     | 3.7705 | 0.266 | - | 0.063 | 0.003 | - | 0.016 |
| Quadratic   | 0.905 | 0.858     | 3.9848 | 0.212 | 0.001 | 0.001 | 0.155 | 0.124 | 0.192 | 0.105 |
| Hyperbolic  | 0.785 | 0.754     | 0.0003 | 0.000 | 0.053 | 0.002 | 0.001 | 0.244 | - | - |
| Compound    | 0.784 | 0.753     | 0.0410 | 0.000 | 0.030 | 0.002 | 0.001 | 0.294 | - | - |
| Growth      | 0.784 | 0.753     | 0.0410 | 0.000 | 0.030 | 0.002 | 0.001 | 0.294 | - | - |
| Exponential | 0.784 | 0.753     | 0.0410 | 0.000 | 0.030 | 0.002 | 0.001 | 0.294 | - | - |
| Logistic    | 0.784 | 0.753     | 0.0410 | 0.000 | 0.030 | 0.002 | 0.001 | 0.294 | - | - |
| Linear      | 0.776 | 0.750     | 5.2828 | 0.000 | 0.008 | 0.005 | 0.000 | - | - |
| Power       | 0.747 | 0.709     | 0.0445 | 0.000 | 0.251 | 0.013 | 0.000 | 0.268 | - | - |
| Logarithmic | 0.743 | 0.705     | 5.7388 | 0.000 | 0.177 | 0.013 | 0.000 | 0.314 | - | - |
| S           | 0.718 | 0.686     | 0.0462 | 0.000 | - | 0.048 | 0.000 | 0.216 | - | - |
| Inverse     | 0.712 | 0.679     | 5.9858 | 0.000 | - | 0.045 | 0.000 | 0.228 | - | - |

$x_1$ = Age (th) $x_2$ = Working periods (Years) $x_3$ = Workload (%CVL) $x_4$ = Temperature (°C) $x_5$ = Humidity (%) $x_6$ = Light Intensity (Lux) $x_7$ = Noise (dB)

The best chosen model is Hyperbolic with 0.754 Adjusted $R^2$. The age, workload, and temperature factors have significant value less than 0.05 which means these factors affect the productivity. Besides, factor of working period and humidity have significant value more than 0.05 which means these factors not affect the productivity significantly.

The factor of light intensity and noise are omitted because the bias. These confirms our results [2,3]. Besides, the fact indicated light intensity and noise in the RDC is sufficient. The model choosing is also strengthened by the smallest of standard error value of estimate among other models. From ANOVA Test or $F$ Test of Hyperbolic model, the $F$ value is 24.852 with 0.000 of probability (Less than 0.05). The test indicated the hyperbolic model can be used to predict productivity or the factor of age, working period, workload, temperature, and humidity.

The $t$ significance test was conducted to test each independent variable affects to dependent variable partially. Variables of humidity and working period are not affect significantly, this can be seen from the value of significance probability for humidity (0.244) and working period (0.053), which the value is above 0.05. Whereas for age, workload, and temperature the significance probability value were 0.000; 0.002 and 0.001, respectively and were less than 0.5. This results indicated the labor productivity is affected by age, workload, and environment temperature.

$$Y = \frac{1}{4.016 \times 10^{-5}x_1 + 3.816 \times 10^{-5}x_2 + 2.144 \times 10^{-5}x_3 + 3.09 \times 10^{-4}x_4 + 2.616 \times 10^{-5}x_5 - 0.007}$$

$Y$ = Worker Productivity (sack/hour) $x_1$ = Workload (%CVL) $x_2$ = Age (year) $x_3$ = Temperature (°C)
In the model, $Y$ and $X_1$ value have reverse relation with $4.016 \times 10^{-5}$. The model indicated that the bigger age of worker, the smaller productivity value could be achieved in RDC. Mostly physical work reach optimum age between 20-50 years old and decreased by the increasing number of age (Lambert, 1996) [19]. The younger worker has higher probability of productivity rather than the older ones.

The $t$ value of workload is 0.002 indicated the significance to productivity (Less than 0.05). The temperature has larger significance to productivity rather than others. This results confirmed our previous results that temperature influence the worker productivity in agro-industry [3]. The relationship between temperature and work productivity is reversed. The increasing of temperature will decrease the productivity.

4. Conclusion

Based on test of independent variables, age, workload and temperature had significant effect to environmental ergonomics in rice distribution center. 11 (Eleven) regression models were conducted to test the variables. The best model was selected based on adjusted $R$ Square, standard error of the estimate, and value on $t$ statistical test. The research results indicated the best model of Hyperbolic with adjusted $R$ square of 0.754. It can be concluded that 75.4% productivity variation could be explained by all variables while 24.6% by other cause. This results confirmed our previous results that workplace environment influence the worker productivity in agro-industry.

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