Optimization of Physical Working Environment Setting to Improve Productivity and Minimize Error by Taguchi and VIKOR Methods

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Abstract. The working environment is one factor that has contribution to the worker’s performance, especially for continuous and monotonous works. $L_9$ Taguchi design experiment for inner array is used to design the experiment which was carried out in laboratory whereas $L_4$ is for outer array. Four control variables with three levels of each are used to get the optimal combination of working environment setting. Four responses are also measured to know the effect of four control factors. Results shown that by using ANOVA, the effect of illumination, temperature, and instrumental music to the number of output, number of error, and rating perceived discomfort is significant with the total variance explained of 54.67%, 60.67%, and 75.22% respectively. By using VIKOR method, it yields the optimal combination of experiment 66 with the setting condition of $A_3\cdot B_2\cdot C_1\cdot D_3$. The illumination is 325-350 lux, temperature is 24-26°C, fast category of instrumental music, and 70-80 dB for intensity of the music being played.

Keywords: Working environment, illumination, temperature, music, ANOVA, Taguchi, VIKOR

1. Introduction

Physical working environment is one factor affecting productivity [1][2]. Physical working environment factors such as coloring in clean and clear working environment, good lighting and ventilation, music played, noise, and temperature are necessary to be well designed suits with the workers characteristics so that humans can perform work activities effectively and efficiently. But, if the workers are not comfort with their working environment, their performance will not be maximum. Even, it can make them faster to get bored and fatigue, moreover for continuous and monotonous works [3]. Activities which are categorized as monotonous job are sewing, typewriting, proofreading, office task, and visual inspection tasks in manufacturing settings. A task is monotonous when its stimulants do not change or the changes are predictable or there is a high type of repetition [4]. Headache and occurrence of accidents like needle-piercing because of the visual strain are caused by insufficient light at the working area [5].
Reference [5] stated that 42.5% of respondents in textiles and clothing sector felt of eye strain because of poor working condition. This data actually has similarities with the condition of workers in garment industry [6]. Scholar [2] had been done a research related with physical working environment and its influence to the civil servants in Malaysia while scholar [1] did the research to the workers in selected oil and gas industry in Nigeria. Questionnaire is used to collect the data and the result showed that there was significant relationship between physical environments (comfort level, temperature) with civil servants productivity [2]. Reference [7] found that human error is significantly affected by four major factors explored, which are stress, repetition, fatigue, and work environment by approximately 48.8%. A friendly physical working environment can be created through application of background music. Reference [8] has proved it by doing this research to the workers in garment manufacturing company in Sri Lanka. According to [9], the music should be only instrument; because if there was a lyrics, people will concentrate to the lyrics, not to the music; and it could be annoying. Even, the study [9] contributes to the field of utilizing music to influence human performance in the workplace.

The Taguchi method is a powerful method of solving quality problems in various fields of engineering. The Taguchi method can be utilized to find the sequence of dominant factors that contributed to the productivity of the operator at the specified production work station. Even, it can significantly reduce the time required for experimental investigation, as it is effective in investigating the effects of multiple factors on performance as well as studying the influence of individual factors to determine which factor has more influence, and which less. Research [10] was done in automotive components assembly factory, and examined environmental factors such as illuminance, humidity and WBGT while the response factor is production rate. The study reveals that the dominant factor that contributed to the productivity was humidity, followed by illuminance and WBGT.

The recent study aims at knowing the relationship among some factors such as temperature, illumination, beat of instrument, and intensity of music by using Analysis of Variance (ANOVA). The second objective is finding the optimum comfort level of sewing working environment setting by using VIKOR to improve productivity and minimize error by considering four responses which are number of output, average of eye blink, number of error, and rating perceived discomfort (RPD).

2. Research Method
The experiments were carried out in Climate Room of Work Design Analysis and Ergonomic Laboratory Universitas Islam Indonesia. The subject was asked to stitch beads in the veil during one hour experiment. They have to pass the training until reach certain amount of production so that the skilled and unskilled factor can be minimized to prevent bias. Eye blink and rating perceived discomfort are used to know when the fatigue happens. Those two kinds of measurements are used to mutually complete each other whereas the number of error is to indicate the accuracy level of the worker’s job. Before doing experiment, subject was asked about their healthy condition and RPD. That’s because the unhealthy condition can affect the experimental result. RPD is used to know whether the subject was in fresh eye condition or sleepless. The maximum score is 0.5, if the subject has more than 0.5, so that they asked to come at another day. Each of experiments was done for one hour. During the experiment, subject are not allowed to do other activities or talking with other people because it could affect the experiment result.

2.1. Data Requirement
The data required in this research are:
1. Number of output. It can be calculated from how many unit of beads that can be stitched in the veil during one hour experiment. This relates to the productivity of workers.
2. Average of eye blink. It is measured by direct observation and then make an average of the amount of eye blink for every 5 minutes of 0–5th minute, 5th–10th minute, 10th–15th minute, 45th, 50th minute, 50th–55th minute, and 55th–60th minute. Blinking is a common facial motion and
reflecting a person’s emotional or cognitive state [11]. There are many factors that can affect blink rate such as loud noises, flashing lights, tasks, and environment (room temperature and humidity) [12].

3. Number of error. It is calculated from the amount of error in stitching beads such as sewing result is not straight, the thread is not locked, and the beads sewed is unsymmetric.

4. Rating Perceived Discomfort (RPD) is based on Borg’s General Scale (Table 3). The subject is asked to mention the eye fatigue scale that is experienced after one hour experiment.

5. Working area temperature. First type (20°-22°C) is a cold comfortable working area where some jobs are good when it is done in this temperature; second type (24°-26°C) is the comfort zone for Indonesian climate is 24°-26°C [13][14], and third (28°-30°C) is the real condition.

6. Illumination. First type is 175-200 lux, second type is 250-275 lux, and third is 325-350 lux. Those all of intensity actually already fulfilled the requirement of illumination for sewing activity [14]. It is measured by using Luxmeter.

7. Beat of instrumental. First type is fast, second type is slow, and the third is middle.

8. Intensity of instrumental. It variates from 40-50 dB, 55-65 dB, and 70-80 dB. The good effect of background music can reduce wrong finger touch in typing task [9].

Table 1. Control factors and types

| No. | Control Factors   | 1                | 2                | 3                |
|-----|-------------------|------------------|------------------|------------------|
| 1   | Illumination      | 175-200 lux      | 250-275 lux      | 325-350 lux      |
| 2   | Temperature       | 20°C-22°C        | 24°C-26°C        | 28°C-30°C        |
| 3   | Beat of instrument| Fast             | Slow             | Middle           |
| 4   | Intensity of music| 40-50 dB         | 55-65 dB         | 70-80B           |

Table 2. Noise factor and type

| No. | Noise factor | 1              | 2              |
|-----|--------------|----------------|----------------|
| 1   | Age          | 18-25 years old| 26-33 years old|

Table 3. Borg’s General Scale [14]

| Score | Type of Fatigue                     |
|-------|-------------------------------------|
| 0     | Nothing at all                      |
| 0.5   | Extremely weak (just noticeable)   |
| 1     | Very weak                           |
| 2     | Moderate                            |
| 3     | Somewhat strong                     |
| 4     | Strong                              |
| 5     |                                     |
| 6     |                                     |
| 7     | Very strong                         |
| 8     | Strong                              |
| 9     |                                     |
| 10    | Extremely strong (almost maximal)   |

Table 4. Responses

| No | Response                                     |
|----|----------------------------------------------|
| 1  | Number of Output (Larger the Better)         |
| 2  | Average of Eye Blink (Smaller the Better)    |
| 3  | Number of Error (Smaller the Better)         |
| 4  | RPD (Smaller the Better)                     |

The data is collected by doing some experiments based on L9 design experiment from Taguchi as shown in Table 5 with twice replication. Then, SNR values for all responses are calculated. If the
combination experiment for all responses is different, then VIKOR is used to find the result. The next step is doing confirmation experiment to validate the result obtained.

| Table 5. Experimental Design using L9 Orthogonal Array |
|--------------------------------------------------------|
| L4 OA (Outer Array)                                    |
| E | 1 | 2 |
| L9 IA (Inner Array)                                    |
| A | B | C | D | Y1 | Y2 |
| Column Number                                         |
| Run | 1 | 2 | 3 | 4 |    |    |
| 1 1  1  1  1  |    |    |
| 2 1  2  2  1  |    |    |
| 3 1  3  3  3  |    |    |
| 4 2  1  2  3  |    |    |
| 5 2  1  2  3  |    |    |
| 6 2  3  1  2  |    |    |
| 7 3  1  3  2  |    |    |
| 8 3  2  1  3  |    |    |
| 9 3  3  2  1  |    |    |

2.2. Technique for Analizing Data

2.2.1. Signal Noise Ratio (SNR)

   The number of output will use Larger the Better (LTB) whereas average of eye blink, number of error, and RPD use Smaller the Better (STB). The equation to calculate SNR is below.

\[
SNR_{LTB} = -\log \left( \frac{1}{n} \sum_{i=1}^{n} \frac{1}{y_{i}} \right)
\]

\[
SNR_{STB} = -10 \log \left( \frac{1}{n} \sum_{i=1}^{n} y_{i}^{2} \right)
\]

where: \( n \) = number of tests in the experiment (trial)

\( y_{i} \) = response value for each replications

2.2.2. Multiple Linear Regression

   The common model is:

\[
y_{i} = b_{0} + b_{1}x_{1i} + b_{2}x_{2i} + ... + b_{n}x_{ni} + e_{i}
\]

2.2.3. VIKOR

   VIKOR requires performance rating of each alternative on each criterion \( A_{i}C_{j} \) wrote normalized calculated by:

\[
r_{i} = \frac{x_{i}}{\sqrt{\sum_{i=1}^{n} x_{i}^{2}}}
\]

where \( i = 1, 2, ..., m \) and \( j = 1, 2, ..., n \)

Positive ideal solution \( A^{+} \) and the negative ideal solution \( A^{-} \) rating can be determined based on normalized weights \( (y_{i}) \) as follows:
\[ y_{ij} = w_{ij} r_{ij} \]  \hspace{1cm} (5)

where: \( i = 1, 2, \ldots, m \) and \( j = 1, 2, \ldots, n \).

\[ A^* = (y_{1}^*, y_{2}^*, \ldots, y_{n}^*) \]

\[ A^+ = (y_{1}, y_{2}, \ldots, y_{n}) \]

where

\[
y_{j}^* = \begin{cases} 
\max_i y_{ij} & \text{if } j \text{ is profit attribute} \\
\min_i y_{ij} & \text{if } j \text{ is cost attribute}
\end{cases}
\hspace{1cm} (6)
\]

\[
y_{j}^- = \begin{cases} 
\min_i y_{ij} & \text{if } j \text{ is profit attribute} \\
\max_i y_{ij} & \text{if } j \text{ is cost attribute}
\end{cases}
\hspace{1cm} (7)
\]

The next step is to determine the utility of measurement (\( S_i \)) and the measurement of regret (\( R_i \)).

\[
s_i = \sum_{j=1}^{n} \left( \frac{y_{ij}^* - y_{ij}}{y_{ij}^* - y_{ij}^-} \right) \hspace{1cm} (8)
\]

\[
r_i = \max \left( \frac{y_{ij} - y_{ij}^-}{y_{ij}^* - y_{ij}^-} \right) \hspace{1cm} (9)
\]

Then calculate the index VIKOR, which is:

\[
Q_i = \left[ \left( \frac{s_i - s_i^-}{s_i^* - s_i^-} \right) + 0 \cdot \left( \frac{r_i - r_i^-}{r_i^* - r_i^-} \right) \right]^{1/\rho} \hspace{1cm} (10)
\]

The smallest the value of \( Q_i \) (VIKOR index) shows that best alternative \( A_i \) then be selected.

2.2.4. Confirmation Experiment

This step aims to validate the conclusion resulted by using Wilcoxon Signed Test. It is used to test the difference of nonparametric repeated measured data. SPSS software is used to do this test.

2.2.5. Analysis of Variance

It is used to identify the contribution of each factor to all responses. The table is as follow:

| Source | \( Sq \) | \( V \) | \( Mq \) | \( F_{\text{ratio}} \) | \( S_{q-} \) | \( \rho\% \) |
|--------|--------|--------|--------|----------------|----------|----------|
| Factor A | \( S_A \) | \( v_A \) | \( M_A = S_A / v_A \) | | \( S_A - v_A \) | \( S_A - 100\% \) |
| Factor n | \( S_n \) | \( v_n \) | \( M_n = S_n / v_n \) | | \( S_n - v_n \) | \( S_n / 100\% \) |
| Error | \( S_e \) | \( v_e \) | \( M_e = S_e / v_e \) | | \( S_e - v_e \) | |
| Total | \( S_T \) | \( N \) | - | | - | - |

3. Results And Discussion

The objective of the experiment is to optimize the environmental parameters (temperature, illumination, beat of instrument, and intensity of music) in order to obtain a better productivity and minimum error and therefore the optimum characteristics should be quantified. The second one is to
know the relationship among four responses and control factors. All the experimental data are already tested their normality and categorized as normal.

4. Effect of Factors to Responses

Table 7 and 8 show the optimal combination for each of responses. \( A_3 \cdot B_2 \cdot C_4 \cdot D_1 \) is the optimal combination for number of output whereas the optimal combination for average of eye blink consists of \( A_3 \cdot B_1 \cdot C_4 \cdot D_2 \). Based on those table, it can be seen that the rank is different each other.

**Table 7. SNR effect to number of output and average of eye blink.**

| Output | Type 1 | Type 2 | Type 3 | Delta | Rank |
|--------|--------|--------|--------|-------|------|
|        | A      | B      | C      | D     |      |
| A      | 87.00  | 82.17  | 88.67  | 87.42 | 5.50 |
| B      | 82.00  | 89.75  | 83.25  | 80.50 | 7.58 |
| C      | 87.50  | 84.58  | 84.58  | 88.58 | 5.42 |
| D      | 87.42  | 80.50  | 83.25  | 87.50 | 8.08 |

| Output | Eye blink | Type 1 | Type 2 | Type 3 | Delta | Rank |
|--------|-----------|--------|--------|--------|-------|------|
|        | A         | B      | C      | D      |       |      |
| A      | 87.00     | 82.17  | 88.67  | 87.42  | 5.50  | 3    |
| B      | 82.00     | 89.75  | 83.25  | 80.50  | 7.58  | 2    |
| C      | 87.50     | 84.58  | 84.58  | 88.58  | 5.42  | 4    |
| D      | 87.42     | 80.50  | 83.25  | 87.50  | 8.08  | 1    |

**Table 8. SNR effect to number of error and RPD**

| Output | Type 1 | Type 2 | Type 3 | Delta | Rank |
|--------|--------|--------|--------|-------|------|
|        | A      | B      | C      | D     |      |
| A      | 8.33   | 8.08   | 6.25   | 9.25  | 2.00 |
| B      | 6.50   | 4.50   | 7.75   | 4.33  | 1.50 |
| C      | 6.33   | 8.58   | 7.17   | 7.58  | 4.92 |
| D      | 2.00   | 4.08   | 1.50   | 4.92  | 4.92 |

| Output | Eye blink | Type 1 | Type 2 | Type 3 | Delta | Rank |
|--------|-----------|--------|--------|--------|-------|------|
|        | A         | B      | C      | D      |       |      |
| A      | 8.33      | 8.08   | 6.25   | 9.25   | 2.00  | 3    |
| B      | 6.50      | 4.50   | 7.75   | 4.33   | 1.50  | 2    |
| C      | 6.33      | 8.58   | 7.17   | 7.58   | 4.92  | 4    |
| D      | 2.00      | 4.08   | 1.50   | 4.92   | 4.92  | 1    |

2.2. Multiple Linear Regression

This step is used to predict the correlation and it follows equation (3). The results are:

\[
Y_{11} = 103.89 - 6.5X_1 + 2.5X_2 - 2.67X_3 - 4.33X_4 \quad (R^2=0.892)
\]
\[
Y_{12} = 68.11 + 2.67X_1 + 5.67X_2 - 3X_3 + 0.67X_4 \quad (R^2=0.895)
\]
\[
Y_{13} = 57.22 - 10.67X_1 + 2.83X_2 - 2.17X_3 + 4.83X_4 \quad (R^2=0.611)
\]
\[
Y_{14} = 112.78 - 5.83X_1 - 6.17X_2 - 0.33X_3 + 2.5X_4 \quad (R^2=0.805)
\]

Meanwhile the multiple linear regression for number of error are:

\[
Y_{31} = 117.78 - 3X_1 - 1.17X_2 - 0.00X_3 + 0.67X_4 \quad (R^2=0.851)
\]
\[
Y_{32} = 13.44 + 0.67X_1 + 0.17X_2 + 0.5X_3 - 4.17X_4 \quad (R^2=0.639)
\]
\[
Y_{33} = 4.22 + 1.33X_1 + 2X_2 + 2.17X_3 - 3.67X_4 \quad (R^2=0.705)
\]
\[
Y_{34} = 7.78 - 3X_1 + 0.00X_2 - 0.83X_3 + 3.83X_4 \quad (R^2=0.805)
\]

By using the same way in SPSS, the multiple linear regression for RPD are:

\[
Y_{41} = 7.67 - 0.17X_1 - 0.83X_2 - 0.5X_3 - 0.67X_4 \quad (R^2=0.810)
\]
\[
Y_{42} = 1.72 + 0.08X_1 + 0.5X_2 - 0.08X_3 + 0.58X_4 \quad (R^2=0.820)
\]
\[ Y_{43} = 2 - 0.5X_1 + 0.67X_2 + 0.17X_3 + 0.67X_4 \quad (R^2=0.837) \]
\[ Y_{44} = 4.28 - 0.67X_1 + 0.33X_2 + 0.08X_3 + 0.33X_4 \quad (R^2=0.840) \]

The \( R^2 \) value of eye blink response is not reach 0.8, so that eye blink response is not used.

2.3. **Analysis of Variance (ANOVA)**

The purpose of ANOVA is to investigate which of the factors significantly affect the workers’ productivity by using F-test, statistically. The larger the value of F, the greater the effect on the performance characteristics. When \( F>4 \), it means that the change of operating factors has a significant effect on the quality characteristics.

**Table 9. Analysis of Variance for Number of Output**

| Factors           | Sq   | V  | Mq  | F    | Sq’  | P (%) |
|-------------------|------|----|-----|------|------|------|
| Illumination      | 10.10| 2  | 5.05| 0.66 | 3.22 | 0.53 |
| Temperature       | 91.27| 2  | 45.64| 6.9  | 84.39| 13.9 |
| Beat of Instrumental | 229.26| 2 | 114.63| 23.65| 222.38| 36.62 |
| Intensity of Music | 28.90| 2  | 14.45| 1.95 | 22.02| 3.63 |
| Error             | 247.78| 72 | 3.44| 1    |      | 45.33 |
| ST                | 607.32| 80 |     |      |      | 100  |

**Table 10. Analysis of Variance for Number of Error**

| Factors           | Sq   | V  | Mq  | F    | Sq’  | P (%) |
|-------------------|------|----|-----|------|------|------|
| Illumination      | 54.26| 2  | 27.13| 17.41| 52.53| 29.88 |
| Temperature       | 6.4  | 2  | 3.2  | 1.47 | 4.67 | 2.66 |
| Beat of Instrumental | 11.88| 2 | 5.94 | 2.83 | 10.15| 5.78 |
| Intensity of Music | 41.04| 2  | 20.52| 11.88| 39.31| 22.36 |
| Error             | 62.23| 72 | 0.86| 1    |      | 39.33 |
| ST                | 175.8| 80 |     |      |      | 100  |

**Table 11. Analysis of Variance for Rating Perceived Discomfort (RPD)**

| Factors           | Sq   | V  | Mq  | F    | Sq’  | P (%) |
|-------------------|------|----|-----|------|------|------|
| Illumination      | 1.29 | 2  | 0.64| 4.63 | 1.21 | 9.99 |
| Temperature       | 1.64 | 2  | 0.82| 6.07 | 1.56 | 12.85 |
| Beat of Instrumental | 3.5  | 2 | 1.75| 15.79| 3.42 | 28.2 |
| Intensity of Music | 3.01 | 2  | 1.51| 12.87| 2.94 | 24.19 |
| Error             | 2.71 | 72 | 0.04| 1    |      | 24.77 |
| ST                | 12.15| 80 |     |      |      | 100  |

It can be seen on Table 9 that only temperature and beat of instrumental music which statistically have significant influence toward number of output (\( F>4 \)). From this result, it is known that there is other factor that also give influence since the error is 45.33%. While illumination and intensity of music being played influence the number of error significantly as shown in Table 10 (p
value is 29.88% and 22.36%). Table 11 presents that all factors have significant effect toward rating perceived discomfort of the subjects. The accumulation of contribution of those four factors reach 75.23%, it can be concluded that those four factors have to be really considered in order to make a good working environment. Eventhough Rating Perceived Discomfort is a subjective measurement, but sometime it can really represent the condition of someone because they felt it by theirself. But of course, the other measurement should also be used to complete in order to get the real effect.

Based on ANOVA test, the effect of total factors which are illumination, temperature, beat of instrument and intensity of music to the number of output, number of error, and RPD are 54.67%, 60.67%, and 75.22%, respectively. It means that those factors are necessary to be considered to find the best working environment setting.

2.4. VIKOR

Table 7 and 8 show the different optimal condition for all responses so that it is necessary to decide the optimal combination experiment by using VIKOR method. To calculate the score of SNR of each response, equation (1) is used to calculate response number of output whereas equation (2) is for response number of error and Rating Perceived Discomfort. The example is shown below.

\[
\begin{align*}
\text{SNR}_1 &= -10 \log \left[ \frac{1}{4 \times 0.0005} \right] = 3.88 \quad \text{(Number of output)} \\
\text{SNR}_2 &= -10 \log \left[ \frac{1}{4 \times 507} \right] = -20.69 \quad \text{(Number of error)} \\
\text{SNR}_3 &= -10 \log \left[ \frac{1}{4 \times 74.25} \right] = -11.99 \quad \text{(RPD)}
\end{align*}
\]

Equation (4) is to determine the normalized decision score.

\[
\begin{align*}
\text{SNR}_1 &= \frac{\text{SNR}_{11}}{|\text{SNR}_{11}|} = 0.115 \quad \text{(Number of output)} \\
\text{SNR}_2 &= \frac{\text{SNR}_{12}}{|\text{SNR}_{12}|} = -0.143 \quad \text{(Number of error)} \\
\text{SNR}_3 &= \frac{\text{SNR}_{13}}{|\text{SNR}_{13}|} = -0.164 \quad \text{(RPD)}
\end{align*}
\]

While equation (5) is to define the positive and negative ideal solution by considering the weight for each response which is equal to 0.33.

\[
\begin{align*}
y_{11} &= 0.115 \times 0.33 = 0.038 \quad \text{(Number of output)} \\
y_{12} &= -0.143 \times 0.33 = -0.048 \quad \text{(Number of error)} \\
y_{13} &= -0.164 \times 0.33 = -0.054 \quad \text{(RPD)}
\end{align*}
\]

Then, the results will be summed at the similar position:

\[
y_{11} = y_{11} \text{(number of output)} + y_{12} \text{(number of error)} + y_{13} \text{(RPD)} = 0.038 + (-0.048) + (-0.054) = -0.064
\]

The positive ideal solution (A\textsuperscript{*}) is calculated based on equation (6) whereas equation (7) is to count the negative ideal solution.

\[
\begin{align*}
y_{11} &= \max (-0.064; -0.044; -0.029; -0.046) = -0.029 \\
y_{1} &= \max (-0.064; -0.044; -0.029; -0.046) = -0.064
\end{align*}
\]

The next step is determining utility measurement (S\textsubscript{1}) by using equation (8) and regret measurement (R\textsubscript{1}) by using equation (9).

\[
S_1 = \frac{(-0.029 - (-0.064)) + \cdots + (-0.029 - (-0.046))}{(-0.029 - (-0.064))}
\]

\[
S_{\text{max}} = 2.941 \quad \text{and} \quad S_{\text{min}} = 1.204
\]

\[
R_1 = \max \left( \frac{(-0.029 - (-0.064)) + \cdots + (-0.029 - (-0.046))}{(-0.029 - (-0.064))} \right) = 1
\]

\[
R_{\text{max}} = 1 \quad \text{and} \quad R_{\text{min}} = -0.031
\]
VIKOR score is the closest value of each responses to the ideal solution and it can be quantified based on equation (10).

$$Q_i = \nu \left[ \frac{S_i - s_i}{S_i^u - S_i^l} \right] + (1- \nu) \left[ \frac{R_i - R_i^u}{R_i^u - R_i^l} \right] = 0.5 \left[ \frac{(1.903 - 1.209)}{(2.941 - 1.204)} + 1.5 \frac{(1-(0.031))}{(1-(-0.031))} \right] = 0.215$$

Based on VIKOR calculation, it can be concluded that the optimal combination is experiment 66 (A3-B2-C1-D3) which is illumination of 325-350 lux, temperature of 24-26°C, fast instrumental music, and 70-80 dB for intensity of the instrumental music being played. This experiment produced the number of output, number of error, and RPD score of 101.75, 3.75, and 3 respectively. Table 12 shows the comparison of the prediction result and confirmation experiment. Wilcoxon test which is used to test the experiment confirmation shown value of 0.321 means that there is no significant difference since it is more than 0.05.

| Prediction | Output | Error | RPD |
|------------|--------|-------|-----|
| Y1 | Y2 | Y3 | Y4 | Y1 | Y2 | Y3 | Y4 |
| 87 | 92 | 119 | 105 | 2 | 0 | 6 | 6 | 2 | 4 | 3 | 4 |

| Confirmation | Output | Error | RPD |
|--------------|--------|-------|-----|
| Y1 | Y2 | Y3 | Y4 | Y1 | Y2 | Y3 | Y4 |
| 90 | 95 | 114 | 108 | 2 | 1 | 7 | 5 | 2 | 3 | 3 | 4 |

For the illumination, it is already relevant since the higher the intensity is better for hand sewing which is need high accuracy. A good illumination will make the worker easily to see the object or the tools used in doing the job and it is in such a way that the visibility of the needlepoints will be optimum [14]. Based on the observation while experiment conducted, the amount of illumination intensity is not appearing glare. For the temperature, it suits with some researches [13][14], in which 24°-26°C is categorized as comfortable working area, but the duration should be considered. If it is for a long duration of work, some negative effect will start to appear such as psychical or physiological problems [14]. The result of this research find that the best is fast beat of instrumental music for sewing activity in which it is not a complex task. If the beat is low, it can make workers to easily get bored or sleepy. However, it was not inline with reference [15] since it said that in the workplace, faster tempos of background music may cause declines in worker output, especially if the employee is engaged in a complex task. Reference [15] also stated that playing background music in the classroom is beneficial and teachers need to be cognizant of the tempo of the background music. For the intensity of instrumental music, that amount is permitted. It is still safe; not becoming a noise factor since the louder the sound, it can disturb the worker. Listening to music can make a positive mood and enhanced perception on design while working [16]. Basically, the influence of music on this performance is difficult to be measured because many factors are involved such as preferences what kind of music they like.

**CONCLUSION**  
This study was done to empirically prove the perception of the effect of work environment factors towards productivity and error. Based on ANOVA test, the effect of total factors which are illumination, temperature, and instrumental music to the number of output, number of error, and RPD is 54.67%, 60.67%, and 75.22%, respectively. From all of processes that have been done in this research, those can be concluded that the optimal combination of working environment setting for sewing activity as one of monotonous work is experiment 66, with the setting condition of A3-B2-C1-D3 or illumination of 325-350 lux, temperature of 24°-26°C, beat of instrumental music is fast, and 70-80 dB for intensity of the instrumental music being played. The findings will also be useful to engineers in the design of working environment system for other monotonous work to improve the comfort of the work station area and control productivity of workers.
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