A Regression Analysis: Ergonomic Comfort vs. Air Quality, Noise, Lighting and Temperature in the Composite Trimming Process Working Room

A. Shukur, N.I.S Hussein, S.R. Kamat*
Faculty of Manufacturing Engineering,
Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya,
76100 Durian Tunggal, Melaka, Malaysia.
**azurin@mara.gov.my*

D.Yuniawan
Faculty of Technic, University of Merdeka Malang, East Java, Indonesia

ABSTRACT

This study was set to identify how working environment affected workers' comfort and to determine the maximum level of air quality, noise, lighting and temperature allowed for each working environment. Workers seemed uncomfortable with the working environment in the working room. To validate the situation, a survey was conducted in the present study on all workers who were involved in the cutting process to determine their feelings in certain setting environment conditions. Next, the environment values were obtained by using specific and certain measurement tools. All the data taken from these two conditions were analyzed using the Minitab software. The study found that most of the working environment parameters in the trimming room exceeded the maximum allowable level of ISO standards. For air quality an average of 30% RH was obtained, which was below the allowable value of 40 – 60% RH. For noise, the obtained value was about 150 dB, which exceeded the maximum level of 85 dB. For in-room lighting, the obtained value was about 200 lux; far below the ISO standard of 750 lux and finally, for temperature the obtained value was about 31.7^{0}C, which was higher than ISO standard of 26^{0}C. It can be concluded that all the working environments do not contribute to good feeling to the workers while doing their job in that room. This means that measures need to be taken to

ISSN 1823-5514, eISSN2550-164X
Received for review: 2020-08-12
Accepted for publication: 2020-12-10
Published: 2021-01-15

overcome the situation in order to improve the workers' feelings and provide them with comfort while doing their job.

Keywords: *Working Environment; Workers' Comfort*

Introduction

This study was conducted at ABC company at Batu Berendam, Melaka. The company produces ceramic panels for airplanes. This study focuses on the effect of working environment on the workers' comfort. It is generally known that physical working environment at workplace is the top requirement that employers need to provide for the workers for their pleasure, comfort and satisfaction. Workers' performance will be affected by this environment and it has been proven to have a significant impact on job satisfaction. There are several factors that contribute to job satisfaction such as lighting, noise, air quality and working room temperature. In this study, discussing human ergonomic in working environment such as air quality (air ventilation in working room), noise and lighting is inevitable [1].

Today, ergonomic concepts in the working environment of work are increasingly relevant in the field work since development encompasses human life for fun. Several studies conducted by previous researchers have proven to be relevant ergonomic factors in the workplace that influence the level of job satisfaction [1, 2, 3, 4] that carried out their research in circles respondents and the scope of employment. Workers will feel dissatisfied if the light condition is not good [5]. Several environmental factors also contribute to body fatigue and job dissatisfaction with heat and noise at work as the main factor [6].

The main purpose of this paper is to analyze the working environment factors that contribute to the workers' comfort, especially in a manufacturing plant. This is based on previous studies done by Nur Asilah that proved the existence of significant correlation between ergonomic factors and level of job satisfaction among employees due to its existence of sudden take-rest problems caused by fatigue among most local production workers [7]. The study was done by conducting an initial interview with a human resource officer in the study organization, which proved that there was a problem of job dissatisfaction among the workers expenditure in the research organization. This problem contributed to decreased motivation for performing tasks, increasing the rate of termination and consequently decreasing factory productivity [7]. Interviews were also conducted with some workers which found that fatigue and discomfort problems occurred in carrying out the task due to the environmental conditions in their organization [7].

Physical conditions of the workplace in terms of environmental ergonomics, occupational health, and work psychology includes lighting, noise, temperature, relative humidity, and air flow rate [8-10]. Exposure to noise because of work is in connection with negative effects on human health, and its connection with being deaf has been substantiated. In industrial environment, exposure to the noise is in connection with a vast range of physical effects on health. In this regard, we can mention heart disease and absence due to work illness and tiredness [11]. The direct and indirect influences of lighting intensity on human productivity and capacity as another environmental factor have been examined in various studies, such as improvement of lighting condition which will decrease vision disturbance and neck and shoulder pains [12]. Given the above, levels of noise and light by directly and indirectly affecting physical and mental aspects, impact human productivity and performance [15].

The objective of the study is to find out whether the current working environment condition in the working room affect the comfort of workers. This can be achieved through the collection of environmental data and also a survey on workers, which is then analyzed using Minitab software to prove the environmental conditions faced indeed affect the comfort of workers, either in a good way or vice-versa, and to determine the extent to which the reading value of the environment complies with set standards.

Thus, keeping work environment safe and healthy, along with providing human health and comfort, and increasing their productivity and performance will increase an organization's productivity and will also increase quality and quantity of its products and services.

Methodology

The data of all the environment factors were taken at the workplace of the workers to get the real data in a real working room environment during the composite panel cutting process. Firstly, the data for all of these parameters (working environment conditions) were obtained while the workers were doing trimming composite panel in a closed workroom by using specific measurement tools. For air quality and temperature data, a measurement tool called Temperature and Humidity Data Logger was used, a Dosimeter was used for noise data, and a Lux meter for lighting data. All the measurement tools are brought in the cutting room to get the actual value in the room. All the data were taken inside the cutting room in the morning. Using different timings of the day, however, will not affect the data value.

The data were then processed using the Minitab software and at this stage, the system asked for a response value. To get the response value, a survey needed to be done on the 10 workers to get the feedback for every

type of working room environment condition. The survey form employed a scale from 1 to 5 where 1 indicated most uncomfortable, 2 for not comfortable, 3 for less comfortable, 4 for comfortable and 5 for most comfortable. There were 19 sets of working environment conditions that were asked in the survey form. For example, for condition set no. 1, the condition: air quality was 30%RH, working room temperature was 29.8^0C, noise was 120dB and lighting was 150 lux. The workers were required to indicate their own feelings in every condition. Finally, the data were compiled, analyzed descriptively and presented in a graphical form by using Minitab software. The data collected is recorded in the Table 1. Figure 1 shows the flow process of the study. The data in Table 1 were subsequently entered and processed using Minitab application software. Then, the software generated a result in the form of graphs for further analysis to obtain relevant conclusions.

Table 1: The working environment data during the cutting process on 13/3/2017

No	Working Environment	Inside cutting room (min)	Inside cutting room (max)
1	Air Quality	30%RH	58.7%RH
2	Temperature	29.8^0C	31.7^0C
3	Noise	120dB	130dB(3mm), 150dB(5mm)
4	Lighting	150-200 lux	150-200 lux

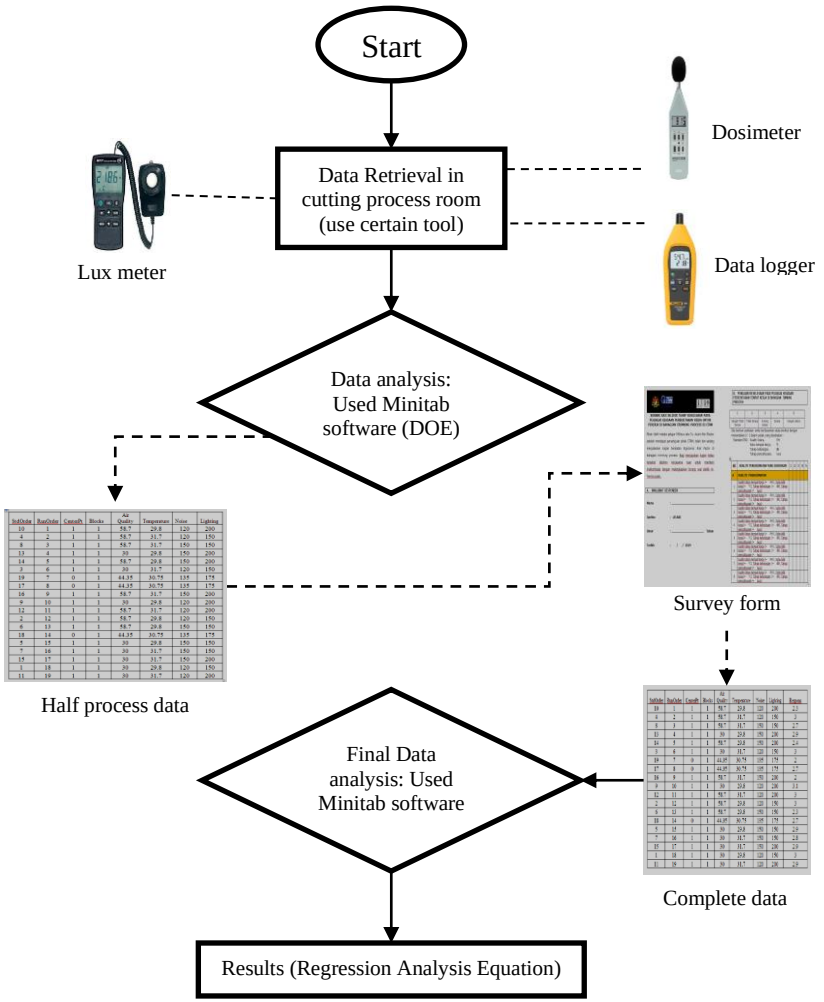

Figure 1: The flow process of study.

Results and Discussion

The present study employed a Regression analysis method because it is a reliable method of identifying which variables have an impact on a topic of interest. The process of performing a regression allows you to confidently determine which factor matters most, which factor can be ignored, and how these factors influence each other. The result below are generated using raw

data from Table 1 and the data from the survey are processed using Minitab software (DOE - Full Factorial design). The result is shown in Table 2.

Table 2: Regression Analysis: Ergonomic Comfort versus Air Quality, Noise, Lighting: Analysis of DOE

	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	4	0.95000	0.23750	2.74	0.071
Air Quality	1	0.49000	0.49000	5.64	0.032
Temperature	1	0.01000	0.01000	0.12	0.739
Noise	1	0.36000	0.36000	4.15	0.061
Lighting	1	0.09000	0.09000	1.04	0.326
Error	14	1.21526	0.08680		
Lack-of-Fit	12	0.88860	0.07405	0.45	0.847
Pure Error	2	0.32667	0.16333		
Total	18	2.16526			

The smaller the P-Value obtained, the greater the impact of the performance properties which total employee comfort. Table 2 shows the results of analysis of DOE. Through this analysis, the factor of air quality is the most impactful factor followed by noise. Thus, this finding has proven that in the actual condition, air quality and noise are very bad to the workers' feelings. The other factors such as lighting and temperature, although give an impact to the worker comfort, are not as bad as air quality and noise. Among air quality, noise, temperature and lighting, there is no correlation between them and they are independent factors. However, the analysis shows that all of them give an impact to the workers' comfort. In this case, it clearly shows that the air quality factor greatly influences the rate of workers' comfort. For controlling dust method, although an effort has been taken by using the dust collector, it still contributes to poor air quality due to poor air ventilation in the working room. The ideal relative humidity is 40% – 60% RH [14].

In this study, the working room is not well-ventilated, causing the working room temperature to be a little bit higher than the normal room temperature. This is followed by the noise produced from the cutting tool while cutting the composite panel which is quite high i.e. exceeding 85 db.

Table 3: Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0.294626	43.87%	27.84%	6.91%

From Table 3, it can be seen that the R-sq (pred) percentage is 6.91% and this value is much smaller and it should be approaching 100%. This means the data obtained for the ergonomic risk response exceeds the max allowable limit. This is because in this study, the feedback provided by the respondents almost entirely mentioned uncomfortable, in which 80% mentioned not satisfied with the set of environment conditions in the survey practices.

Table 4: Coefficients

	Coef	SE Coef	T-Value	P-Value	VIF
Constant	4.32	2.54	1.70	0.111	
Air Quality	0.01220	0.00513	-2.38	0.032	1.00
Temperature	0.0263	0.0775	0.34	0.739	1.00
Noise	0.01000	0.00491	-2.04	0.061	1.00
Lighting	0.00300	0.00295	-1.02	0.326	1.00

From Table 4 that is automatically generated from the analysis, every coefficient value for every single parameter can be extracted from the coefficient column to automatically generate the regression formula or equation for ergonomic comfort as shown below:

Regression Equation (Ergonomic Comfort, EC):

$$EC = 4.32 - 0.01220\ Air\ Quality + 0.0263\ Temperature - 0.01000\ Noise - 0.00300\ Lighting \quad (1)$$

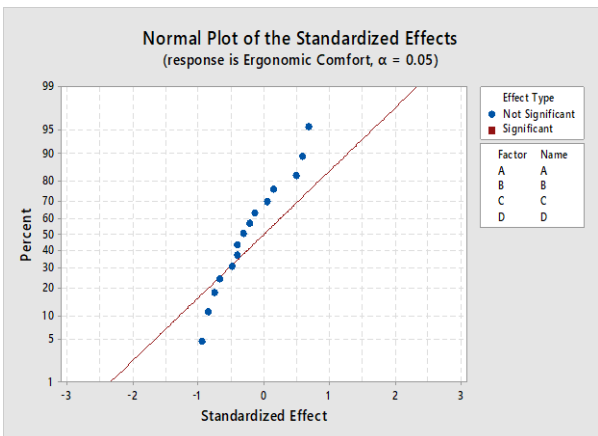

Figure 2: The normal plot of the standardized effects for Ergonomic Comfort.

In Figure 2, Figure 3 and Figure 4, A refer to Air Quality, B refer to Temperature, C refer to Noise and D refer to Lighting. In the Figure 1, there is no significant point indicating all the abnormal factors and in Figure 2, all factors are located far behind the red line 4.303 indicating that all factors are not suitable for the working environment, which is always at an unbalanced level.

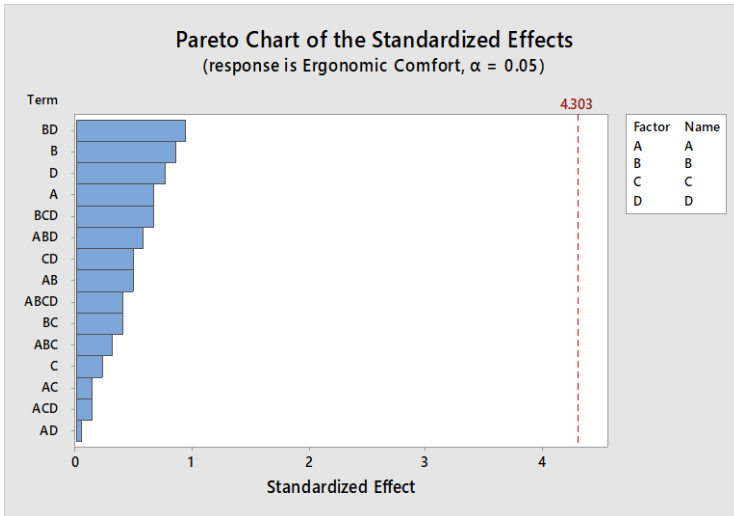

Figure 3: The Pareto chart of the standardized effects.

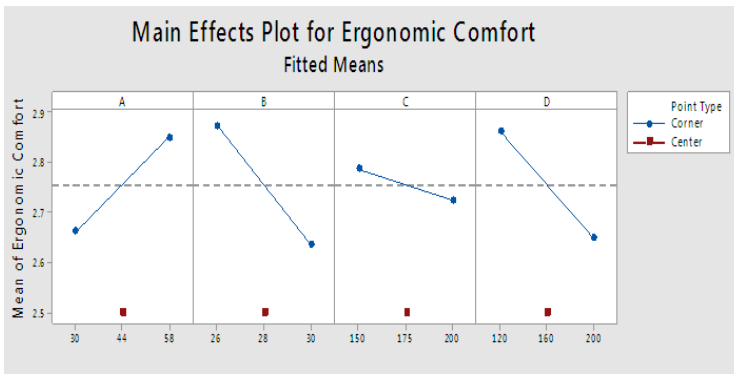

Figure 4: The main effects for Ergonomic Comfort.

In Figure 3, the largest value for each factor is taken (A: Air quality = 58, B: Temperature = 26, C: Noise = 150, D: Lighting = 120) and is included in the generated formula (1) for validation calculation purpose as below.

$$EC = 4.32 - 0.01220\,(58) + 0.0263\,(26) - 0.01000\,(150) - 0.00300\,(120)$$
$$= 4.32 - 0.71 + 0.684 - 1.5 - 0.36$$
$$= 2.434$$

$$\text{Ergonomic Comfort Actual value} = 2.72$$

$$\text{Validation} = (2.434 - 2.72)/(2.434) \; x \; 100\% = \mathbf{11.75}\%$$

Validation for Ergonomic Comfort (EC) was found to be more than 10% as all respondents stated that they were uncomfortable, as a result of the surveys conducted on them for various combinations of factors, namely sound, air quality, lighting and temperature. Workers are uncomfortable in most of the factors associated with composite cutting work, especially sound and lighting factors.

With reference to the ISO 45001:2018, this standard mentioned the importance of identifying the cause of certain problems that can affect the mood or morale of the workers. This study found that discomfort resulting from an unconducive work environment during the cutting process and also the need to do an assessment of this matter as the cause. It is revealed that the management of the company does not take such things seriously to comply with the above-mentioned standard. The results of this study show that the working environment is not very good, and this indicates that the management does not do as recommended in the ISO standard with regard to increasing workers' productivity and morale. Apparently in this study the management needs to improve the working environment.

Several studies done by other researchers were given certain result regarding to the working environment and workers comfort. From Thach [23] study found that noise gave the most effect to the workers stress followed by thermal comfort and air quality and lighting.

This finding is in line with the opinions of Shikdar and Sawaqed [6] who agree that layout factors and comfortable workspace in an organization can maximize productivity, improve performance and job satisfaction. Therefore, it is the employer's responsibility to provide a workplace with good layout and ergonomic features in an organization to ensure the optimum level of comfort among the workers is capable of improving efficiency and job satisfaction.

The findings are consistent with Haiying Wong's who found in his study that 70% of workers had voted comfortable when the temperature was

under 28.9 ^{0}C and most of them were slightly uncomfortable when the temperature increased to 32 ^{0}C and higher [15]. However, workers had low expectation on their working environment and were more easily to be satisfied owing to a limited choice [15].

In a study by Modesta Kameni Nematchoua, a significant effect of the similar indoor environment (air quality, temperature and lighting) on workers performance by using formula that had been generated using INOVA was found [16]. It also found that air temperature has a significant effect in the workers' productivity [16]. Lan et. Al reported that by increasing the indoor temperature to above 28 ^{0}C, the concentration rate of workers reduced by 0.5% [17].

Taffrere said that occupational exposure to heat and noise were found to exceed occupational exposure limits [18]. Any sound environment will be subjected to a substantial number of sound sources that affect ordinary human activities, people's concentration and mood [19]. Most people today spend a great deal of time at work, so it would be desirable that their work environment is acoustically pleasant in order to ensure effective work and satisfaction of the workers. Results from Sun study has illustrate that when exposed to high ILL, U-ILL and CCT environment, participants reported highest satisfaction on productivity and attention, while lowest score on stress, difficulty of conducting work and fatigue [20].

The other result from Sidek shows that the level of satisfaction on the three dimensions of workplace ambient is more than 4.5 out of 7 Likert scale, which implied that the workers are somehow satisfied with their workplace ambient denying the claim of extreme workplace ambient and forced labour practice in the Malaysia Government related palm oil mills [21]. The analysis revealed 6 factors with 18 related elements. From a multi linear regression analysis, we develop a job satisfaction model built on factors of human resource policies, safety, ergonomics, air quality, thermal comfort and disturbing equipment. The results reveal that ergonomics plays the most important role in workers' satisfaction for the respondent Turkish automotive workers [22].

Conclusion

The results of the study revealed that the workers felt that their working environment was stressful. It was also found that the workers had been working under bad working environments with most of the working environment factors exceeding the limit of the ISO standards value. This has contributed to an unbalanced result on regression analysis in Minitab. From the ISO Safety Management System (ISO 45001:2018) [13], the working environment in that working area does not comply with ISO 45001, which

sets the minimum standard of practice to protect workers worldwide such as opportunity to introduce other health, and safety aspects such as worker wellness/wellbeing, and improving worker protection. It is hoped that the results of this study will be used as a guide by other researchers in the future by using the formula generated from this regression analysis and subsequently become a reference or main reason to make improvements to the work process or environment.

Acknowledgments

The author would like to thank the Faculty of Manufacturing Engineering, Universiti Teknikal Malaysia Melaka for the facilities support. The author is also grateful to the Majlis Amanah Rakyat (MARA) and Institut Kemahiran MARA Jasin for their support during the author's postgraduate studies.

References

[1] Zafir Mohamed Makhbul & Fazilah Mohd Hasun. "Ergonomik dan tekanan di Malaysia Implikasi Terhadap Teori, Metodologi dan Pengurusan." *Jurnal Pengurusan*, vol. 26, pp 99-130, 2007.

[2] Siti Zawiah Md Dawal & Zahari Taha, "The effect of job and Environmental factors on job satisfaction in automotive industries", *International Journal of Occupational Safety and Ergonomics*, vol. 12, no.3, pp 267-280, 2006.

[3] Zafir Mohamed Makhbul, Durrishah Idrus & Mat Rebi Abdul Rani. "Ergonomics design on the work stress outcomes." *Jurnal Kemanusiaan*, vol. 9, pp 50-61, 2007.

[4] Zafirah Ab Muin & Maimunah Sapri, "Level of organization on the Importance of ergonomics to health and safety at the workplace." *4th International Conference on Business and Economic Research Proceeding*, Bandung, Indonesia, 2013.

[5] Sarimah Ismail & Faridatul Akmar Talip, "Kepuasan Bekerja Staf Akademik Jabatan Pendidikan Teknikal Dan Kejuruteraan Fakulti Pendidikan, Universiti Teknologi Malaysia, Skudai." *The 2nd International Conference on Business Management 2nd ICBM 2016*. Universiti Teknologi Malaysia, Skudai, Johor, 2010.

[6] Shikdar, A. A. & Sawaqed, N. M. "Worker productivity and occupational Health and safety issues - in selected industries." *Computers and Industrial Engineering*, vol. 45, no.4, pp 563-572, 2003.

[7] Nur Asilah Mohd. Taib, "Kepuasan kerja dalam kalangan operator Pengeluaran", Universiti Utara Malaysia, Sintok, 2015.

[8] K. C. Parsons, "Environmental ergonomics: a review of principles, methods and models." *Applied Ergonomics*, vol. 31, no. 6, pp 581–594, 2000.
[9] Minyoung Kwon, Hilde Remoy, Maartje Van den Bogaard "Influential design factors on occupant saqtisfaction with indoor environment in workplaces." *Building and Environment*, vol. 157, pp 356-365, 2019.
[10] E. Sundstrom and M. G. Sundstrom, "Workplaces: The Psychology of Physical Environment in Offices and Factories." *Cambridge University Press*, United Kingdom, 1986.
[11] P. Leather, D. Beale, and L. Sullivan. "Noise, psychosocial stress and their interaction in the workplace." *Journal of Environmental Psychology*, vol. 23, no. 2, pp 213–222, 2003.
[12] A. Aarås, G. Horgen, H.-H. Bjørset, O. Ro, and H. Walsøe. "Musculoskeletal, Visual and psychosocial stress in VDU operators before and after multidisciplinary ergonomic interventions. A 6 years prospective study —part II." *Applied Ergonomics*, vol. 32, no. 6, pp 559 - 571, 2001.
[13] Brad Kelechava. (2018). The Benefits of ISO 45001. [Online]. Available: https://blog.ansi.org/
[14] Sterling EM et al. (1985). Criteria for human esposure to humidity in occupied building. [Online]. Available: www.codair.com-
[15] Haiying Wong, "Thermal Environment Investigation and Analysis on Thermal Adaptation of Workers in Rubber Factory." *Energy and Building*, vol. 158, pp 1625-1631, 2018.
[16] Modesta Kameni Nematchoua. "Influence of Indoor Environment Quality on The Self Estimated Performance of Office Workers in The Tropical Wet And Hot Climate of Cameroon." *Journal of Building Engineering*, vol. 21, pp 141-148, 2019.
[17] P. Lan, Z Lian, "Use of Neurobehavioral Tests to Evaluate the Effect Indoor Environment Quality on Productivity." *Building Environment*, vol. 44, pp 2208 - 2217, 2009.
[18] Taffere G.R. "Magnitude of occupational exposure to noise, heat and associated factors among sugarcane factory workers in Ethiopia." *Journal of Public Health (Germany)*, vol. 28, issue 5, pp 517-523, 2020.
[19] Suhanek. M, "A case study of different sound environments – a way to a more pleasant and more efficient work." *Sigurnost*, vol. 61, Issue 4, pp 345-356, 2019.
[20] Sun. "Work performance in relation to lighting environment in office buildings." *Indoor and Built Environment*, vol. 28, Issue 8, pp 1064-1082, 2019.
[21] Sidek. "People sustainability in palm oil production: The influence of production technology on workplace ambient." *IEEE Region 10 Humanitarian Technology Conference, R10-HTC 2015-co-located with*

8th International Conference on Humanoid, Nanotecnology, Information Technology, Communication and Control, Environment and Management, HNICEM 201525 January 2016, Articul number 7391849.

[22] Ozturkoglu. "A manufacturing-oriented model for evaluating the satisfaction of workers-Evidence from Turkey." *Industrial Journal of Industrial Ergonomic*, vol. 54, pp 73-82, 2016.

[23] Thach, "Associations of perceived indoor environment of quality with stress in the workplace." *Indoor Air*, vol. 30, pp 1166-1177, 2020.