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REGRESSION ANALYSIS IN DETERMINING THE INFLUENCE OF RELATIVE HUMIDITY TOWARDS WORKERS' PERFORMANCE

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ABSTRACT

Ergonomics has traditionally been used to improve the workers' performance by discovering the factors that contribute to their performance. Many organizations are forced to consider effects of environmental factors towards their workers' performance in terms of safety and efficiency. The objective of this study is to determine the effects of humidity on the operators' productivity and performance in the Malaysian automotive industry. One automotive components assembly factory was chosen as the sources of subjects of the study. The subjects were the workers in the assembly section of the factory. The examined parameters were the relative humidity (%) of the surrounding workstation area. Two sets of representative data consisting of the relative humidity (%) and production rate were collected during the study. The production rate data were collected through observations and survey questionnaires, while the relative humidity (%) was measured using thermal comfort multi-station (TCM) equipment. Linear regression analysis was performed to obtain the relationship between the effects of relative humidity (%) on worker productivity and performance. The linear regression analysis further revealed a linear model with a positive slope between relative humidity (%) and worker productivity for the assembly section involved. The obtained relationship was $Y = 2.79 X – 46.1$

Keywords: Productivity, Performance, Relative Humidity, Relationship

INTRODUCTION

Ergonomics, the applied science of equipment design intended to reduce operator fatigue or discomfort, has become an indispensable area of knowledge for today's facility managers. As a result of the US Occupational Safety and Health Administration (OSHA) proposed ergonomic compliance program since 1999, facility managers in nearly every industry have to ensured programs were in place in order to prevent complaints by employees (Roper et al., 2007). The utility of ergonomics research is not limited to predicting and eliminating workplace injuries but also can be used to enhance productivity (Resnick and Zanotti, 1997). Since the 1990s, there has been increasing amounts of attention on the work environment and productivity. Laboratory and field studies have shown that the physical and chemical factors in the work environment

could have a notable impact on the health and performance of its occupants and consequently on the productivity. Workplace environmental conditions, such as humidity, indoor air quality, and acoustics, have significant correlation with workers' satisfaction and performance (Tarcan et al. 2004; Marshall et al. 2002; Fisk, 2000). Indoor air quality can have a direct impact on health problems and can lead to uncomfortable workplace environments (Juslen and Tenner, 2005; Fisk and Rosenfeld, 1997; Marshall et al. 2002). In addition, Shikdar and Sawaqed (2003) noted a high correlation between performance indicators and health, facilities, and environmental attributes. In other words, companies with larger health, facilities, and environmental problems could face more performance-related problems such as low productivity and high absenteeism.

'Relative humidity' is a term used to describe the water vapor pressure of the air at a given temperature (Bridger, 1995). If the relative humidity is high, the latent heat dissipation ability of the body is decreased due to the decrease in vapor pressure and the increase of sweat remaining on the body (Atmaca and Yigit, 2006). Previous research by Gavhed and Klasson (2005) showed that a low relative humidity resulted in more discomfort and more frequent symptoms related to facial skin and the mucous membranes such as dryness of the mouth, throat and facial skin, nasal drip, and more frequent symptoms of the eyes and lips. In addition, Wolkoff and Kjaergaard (2007) pointed out that low relative humidity plays a role in increases of reports of eye irritation symptoms and of cases of alteration of the precorneal tear film.

According to the Ishii et al. (1993), Japanese people might be more sensitive to humidity than westerners and so different methods from those used in the western countries should be required for human thermal environmental studies with respect to the hot humid summer in Japan. Tsutsumi et al. (2007) conducted a study to evaluate the effect of humidity on human comfort and productivity after step changes from warm and humid environment. The results of the study revealed that workers' performance was found to be at the same level under all conditions but to more tired at 70% RH after humidity stepchange meanwhile more evaporation of sweat from human body at lower humidity. Atmaca and Yigit (2006) had investigated the relative humidity effects on skin temperature and skin wittedness for different operative temperatures. The results from Atmaca and Yigid study showed that for 30°C operative temperature and above, the relative humidity effect on skin temperature and skin wittedness is more effective than that of the low operative temperatures.

Previous research done by Wim et al. (1997) showed that the level of skin moisture influences the absorption of propoxur via the dermal route, dramatically ranging from, on average, 13, 33–63% of the 'potentially absorbed dose' which is excreted in urine as the primary metabolite 2-isopropoxyphenol (IPP) at relative humidity levels of, on average, 50, 70 and 90%, respectively. This research is done in order to investigate the influence of skin moisture on the dermal uptake of the pesticide propoxur. A study on effect of structures on indoor humidity by Simonson et al. (2002) indicated that the moisture transfer between indoor air and hygroscopic building structures can generally improve indoor humidity conditions. The results show that moisture transfer between indoor air and the hygroscopic structure significantly reduces the peak indoor humidity. A study on the effects of humidity on the operators' productivity in the Malaysian electronic industry by Ismail et al. (2007) indicated a linear relationship between the relative humidity (%) and productivity of the workers. In addition, Dawal and Zaha (2006) pointed out that the environmental condition especially temperature, humidity, noise and lighting, can affect job satisfaction in the

automotive industry. Thus, this study was conducted to determine the effects of humidity on the operators' productivity and performance in the Malaysian automotive industry.

METHODOLOGY

Selection of Location and Subjects

The study is conducted on a selected work station in the automotive industry where it refers mainly towards the assembly section or the manual production line where human energy are involve for in the manufacturing activity. Figure 1 shows the production line layout.

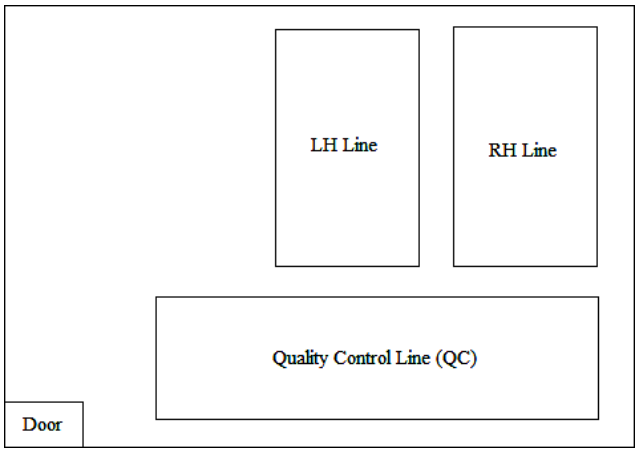

Figure 1: Handle Assembly Door Outside production line

The production is desired to be the repeated production of the same component throughout the entire shift and this is to ensure on the consistency of the data collected towards the data analysis later. Priority of study will be given to the work station where the environmental factors will sponsor the most towards effect of the performance. One automotive vendor has been selected as a place of study. A line producing a product over a period of time and under the effects of certain relative humidity was chosen. Figure 2 shows the flow chart of work sequences on the production line.

This criterion is essential in order to obtain the which factors contribute utmost to the worker performance based on output of assemblies among operators. The production line was consist of 10 woman operators. The task is to assemble an automotive parts which is known as handle assembly door outside. The standard production rate determined by the previous feasibility study to assemble a complete handle assembly door outside was 240 units for every hour of production.

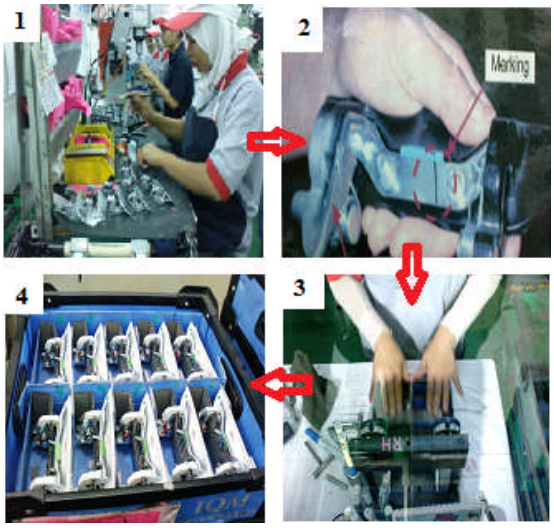

Figure 2: The works sequence to assemble complete Handle Assembly Door Outside

Data Gathering and Analysis

The inferential statistics (i.e., production rate and relative humidity) were computed to generalize the relationships of production rate to relative humidity. Further regression analyses were performed to obtain the relationship and thus test the hypotheses**.** The variables in this study were production rate and relative humidity. A simple regression analysis was conducted to obtain the mathematical equation to present the effects of relative humidity on the production rate at that particular production line. The sample included 10 female operators whose ages were in the range of 20 – 30 years, comprised mostly of local citizens and non-degree holders who had been working with the organizations for less than 5 years. The majority of the respondents reported that they work for more than 49 hours per week. The relative humidity (%) was measured using TCM environmental equipment. The workers' performance level was represented by the production rate. The quantities of assembled products were recorded every 30 minutes, and data was compared to the relative humidity level.

RESULTS AND DISCUSSION

The relative humidity level were taken to identify the effect of relative humidity on the worker performances. Table 1 shows the data of production rate, relative humidity (%) and the time taken for every 30 minutes. A graph was plotted to show the relationship between the production rate and the illuminance level. Figure 3 shows the graph to describe the relationship between production rate versus illuminance level. Based on the graph in Figure 3, we can note that the production rate were increases as we increase the relative humidity. The coefficient of determination, R^2, of 0.708 indicates that 70.8% of the production rate variation was due to relative humidity (%) variation. The results for regression and ANOVA analysis were presented in Table 2. The hypothesis were as follows:

H_o: $\beta = 0$ (The relationship between relative humidity (%) and production rate is not significant).

H_a: $\beta \neq 0$(The relationship between relative humidity (%) and production rate is significant).

Table 1: Relative Humidity, Production Rate and Time Data

Time	Production Target (units)	Production Rate (units)	Relative Humidity (%)
09.05 – 09.35	120	119	60.76
09.35 – 10.05	120	123	59.85
10.05 – 10.35	120	121	59.21
10.35 – 11.05	120	115	59.55
11.05 – 11.35	120	121	59.29
12.05 – 12.35	120	124	59.61
12.35 – 01.05	120	108	55.98
02.10 – 02.40	120	112	55.84
02.40 – 03.10	120	106	55.45

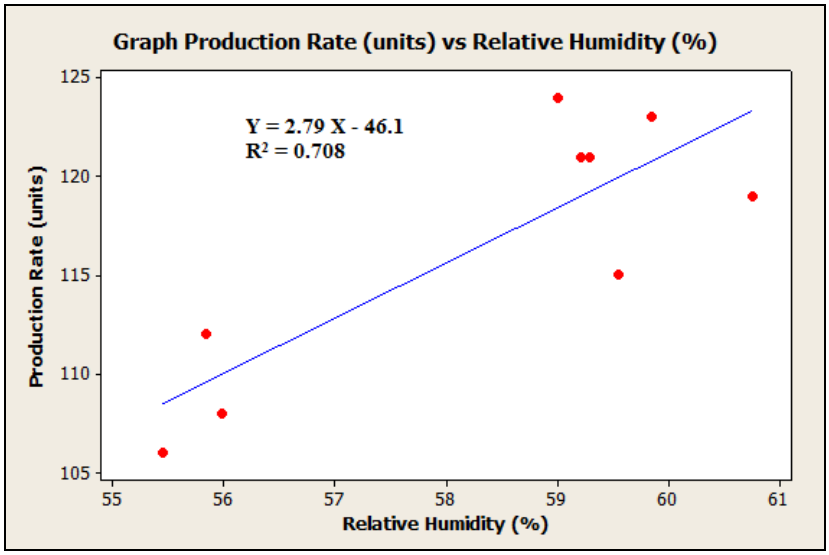

Figure 3: Graph of Production Rate versus Relative Humidity (%)

Table 2 : Regression and ANOVA Analysis

Regression					
Multiple R	0.842				
R Square	0.708				
R Square Adj	0.667				
Standard Error	3.820				
ANOVA					
Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	248.061	1	248.061	16.997	0.004
Residual	102.161	7	14.594		
Total	350.222	8			
Coefficients					

* $p < 0.05$

The F value from the ANOVA is 16.997. The value of the significance level was selected to be 0.05 ($\alpha = 0.05$). Because the P value is 0.004, we can reject H_o: $\beta = 0$ in favor of H_a: $\beta \neq 0$ at the 0.05 significance level. This strongly suggests a significant relationship between the relative humidity and the production rate. Thus, there is a strong evidence that the simple linear model relating production rate and relative humidity (%) is significant. In the literature, there are only a small number of studies that have been conducted in the area to establish a mathematical model relating environmental effects to productivity. The authors believe that the study has achieved the objective of obtaining a mathematical model to quantitatively relate relative humidity (%) to production rate by inferential statistical analysis. The findings on the effect of relative humidity on productivity are in line with the finding by Tsutsumi et al. (2007), who found that the subjective performance was equal under four different levels of relative humidity. However, Tsutsumi et al. (2007) also reported that their subjects were more tired after a step change in relative humidity to 70%. This finding was also was supported by Ismail et al. (2007), who observed that a linear relationship of relative humidity with productivity. Therefore, from this study, the authors expect that in each 30-minutes work cycle, an optimum production rate of 121 units can be achieved. The equation model will be useful for engineers as a guideline during the feasibilities study of production lines to achieve optimum output. The equation model is also useful for engineers in designing proper AHU units or air conditioning systems to minimize the use of power and control while considering the productivity of workers. The obtained mathematical model is only applicable to the current conditions for the selected assembly workstation in the Malaysian automotive industry. From these results, it can be concluded that there is a significant effect of relative humidity (%) on production rate. Further tests proved that the model could be used to strongly predict the production rate based on a certain relative humidity (%) provided by air conditioning or ventilation systems in a particular environment.

CONCLUSION

The linear regression analysis further revealed a linear model with a positive slope between relative humidity (%) and worker productivity for the assembly section involved. The obtained relationship was $Y = 2.79 X – 46.1$**.** The results of the study indicate a significant relationship between humidity and workers' productivity. However, to date, research on the relationship between workplace environmental factors and productivity or performance has been very limited and characterized by a short time perspective or by emphasis on survey methods, statistical analysis, satisfaction preferences measurements. This study was done to empirically confirm the previous perception studies based on the role of environmental factors in productivity. This study is expected to be beneficial to the automotive manufacturing industry in Malaysia. The research findings are restricted to the Malaysian workplace environment, where the awareness of productivity among workers is still low. The results may vary for tests carried out with different sample sizes or in different types of industries and countries. The study could be more extensive if the fraction of defects for the product were included in the analysis. Nevertheless, the authors believed the modeling of production rate as time series data is more than adequate to understand the affect of environmental factors on productivity.

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