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RELATIONSHIP BETWEEN THERMAL COMFORT AND DRIVING PERFORMANCE AMONG MALAYSIAN BUS DRIVER

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ABSTRACT

The purpose for this paper is to investigate the correlation between thermal comfort and Malaysian bus driver's performance and also to determine the response from bus drivers regarding the prevalence discomfort that they experience along their journey. In this study, descriptive or survey study was used. A questionnaire survey was conducted to examine the relationship between thermal comfort and environmental factors that influences the Malaysian bus drivers' performance. In this study, focus are been given to Kuantan bus drivers with sample size approximately 260 drivers. The confidence level is 95% and degree of accuracy of 0.05. From this population, the sample was selected randomly. The descriptive analysis and correlation was used to analysis the raw data that get from feedback of survey. The 'p' value is less than the alpha value, and then there is evidence that the relationship is significant. Therefore, null hypothesis is rejected. Hence, it proved that there is statistically significant positive correlation between thermal comfort and Malaysian bus driver performance. Clearly that all of two parts of thermal comfort and environmental factors have significantly correlated on Malaysian bus driver performance.

Keywords: thermal comfort, relative humidity, air temperature, air velocity.

INTRODUCTION

Malaysia is a tropical country that having hot and humid climate throughout the years. Because of the climate factors, it is important to have comfort anywhere and everywhere in order to have higher productivity in task that we conducted. With population of citizen in Malaysia as many as 29 700 386 in 2013 (Department Of Statistics Malaysia, 2013), this number showed that people need transportation to move from one place to other place. Whether in private or public transport such as taxi, bus, airplane, train and others, these transports help most of the people to move from one place to other place. It is therefore very essential to provide an acceptable thermal environment in vehicles which will not disturb the passengers and give optimal comfort and performance for the driver. In a subjective approach, human response to environment and the comfort level of thermal conditions relied on a set of personal factors and psychological parameters [1]. Thermal comfort can be defined as the condition of mind which expresses satisfaction with the thermal environment [2]. Thermal comfort as that condition of mind which expresses satisfaction with the thermal environment and is assessed by subjective evaluation [3]. In other words, the thermal comfort of people can be determined by surveying a sample of individuals and their responses to their environment. So, thermal comfort is very difficult to objectively quantify because it relies on a wide range of environmental and personal factors that decides on what will make people feel thermally comfortable. The target is to get as few unsatisfied people as possible. According to the ASHRAE thermal sensation scale, which was developed for use in quantifying people's thermal sensation is defined as +3 hot, +2 warm, +1 slightly warm, 0 neutral, –1 slightly cool, –2 cool and -3 cold [3]. Air temperature defined as the temperature of the air surrounding occupant [3]. Besides, air temperature can also be defined as temperature of the air surrounding the occupant that determines the net heat flow between the human body and its environment [4]. Those occupants are preferred to have cooler environment compared to warmer [5]. The warmer environment makes the worker dissatisfied with the environment of working place. The thermal comfort zone temperature was identified to be within the range of 21.6-23.6 °C [6]. The optimum temperature comfortable workplace is between 20-26 °C. In term of vehicular thermal comfort, drivers and conductors are expose to thermal stress, especially during summer when the conditions inside the bus are hot and humid [7]. The rate of air movement at a point without regard to direction is called air velocity [3]. Relative air velocity can be defined as the air movement across skin layer or clothing surface, convicting heat [4]. The air velocity controls the heat convection coefficients which in turn can manipulate the rate of heat transfer without any change in air temperature. Air velocities inside vehicular compartments tend to have small value, ranging from 0.1 to 0.4 m/s [8]. Moving air in warm or humid conditions can increase heat loss through convection without any change in air temperature.

Humidity is defined as the amount of water vapour in a given space; while the humidity ratio or specific humidity is defined as the weight of water vapour

per unit weight of dry air. Relative humidity is the ratio between the actual amount of water vapour in the air and the maximum amount of water vapour that the air can hold at that air temperature [4]. Relative humidity as the ration of the partial pressure (or density) of the water vapour in the air to the saturation pressure (or density) of water vapour at the same temperature and the same total pressure [3]. Although human tolerate to relative humidity variations is much higher than that for temperature variation [8], the relative humidity is still important.

Thermal comfort zone relative humidity was identified to be within the range of 42-54% [6]. The optimum relative humidity for workplace is between 40-60%. Thermal comfort at high relative humidity shows that there are no significant psychological or physiological differences in human response to exposure of between 60% to 90% relative humidity for the temperature range of 20 °C to 26 °C while sedentary [9]. The humidity in vehicles will depend on the outside climate, the air conditioning system and the number of persons in the vehicle. High humidity environments have a lot of vapour in the air, which prevents the evaporation of sweat from the skin. In hot environments, humidity is important because less sweat evaporates when humidity is high (80%+). The evaporation of sweat is the main method of heat loss in humans.

METHODOLOGY

Study Design

In this study, descriptive or survey study was used. A questionnaire survey was conducted to examine the relationship between thermal comfort and environmental factors that influences the Malaysian bus drivers' performance. Survey study involves the studying of large and small populations selecting and studying samples chosen from the populations to discover the relative incidence, distribution and interrelations of sociological and psychological variables. It was a method of getting information about a population from a sample of individuals. Surveys has been used widely because their advantages such as can provide a quick, inexpensive and accurate means of obtaining information from a large group of people. In addition, by having survey study, it can help to get the opinions and perceptions of respondents. Besides, surveys can also be used to explain the relationship and differences between variables.

Sampling/Population

The population of the respondents in this study was among bus drivers in Malaysia. According to *Persatuan Pemandu Bus Semenanjung Malaysia*, the population of Malaysian bus drivers was approximately 800 people. This number includes all the bus drivers of different bus such as express bus driver, tourist bus and others. But, in this study, focus has been given to Kuantan bus drivers only which have sample size approximately 260 drivers. When the population is 800, the sample size should be 260 [10]. There was formula for determining sample size. This is taking the confidence level of 95% and degree of accuracy of 0.05. The sampling size was about 212 (85% from sample population) of bus drivers. From this population, the sample was selected randomly.

$$s = \frac{X^2 NP(1-P)}{d^2(N-1) + X^2 P(1-P)} \quad (1)$$

S Required sample size
X^2 The table value of chi-square for 1 degree of freedom at the desired confidence level (3.841)
N The population size
P The population proportion (assumed to be 0.50 since this would provide the maximum sample size)
d The degree of accuracy expressed as a proportion (0.05)

Research Instruments

Type of survey that used in this study is in questionnaire form. The questionnaire is adapted by from many resources that related for this study and is change for the preference for this study. The questionnaire is adapted from study on thermal comfort at Malaysian Automotive Industry [11], study of thermal comfort in outdoor and semi-outdoor environments in subtropical Sydney Australia [12] and combines comfort model of thermal comfort and air quality on buses in Hong Kong [13]. The questionnaire is divided into nine sections. The first section consists of five items which are age, gender, working experiences as bus drivers, average hour works per day and resting hour along working time. The second section is about the temperature in the bus. Five questions are used to study the temperature in the bus towards bus drivers' performance. The third section is about relative humidity. Five questions are used to study the relative humidity in the bus towards bus drivers' performance. The forth section is about air velocity. Five questions are used to study the air velocity in the bus towards bus drivers' performance. The fifth section is about lighting. Three questions are used to study the lighting in the bus towards bus drivers' performance. The sixth section is about clothing insulation.

Validity and Reliability

To validate the questionnaire, a pilot study has been conducted. 24 bus drivers in Kuantan, Pahang participated in the pilot study. A pilot study was carried out to ensure the clarity and relevance of the questionnaire.

Table-1. Rule of thumb for the cronbach alpha value.

Cronbach alpha, α	Indicator
> 0.9	Excellent
> 0.8	Good
> 0.7	Acceptable
> 0.6	Questionable
> 0.5	Poor
> 0.4	Unacceptable

Then, all the collected data were analysing to find alpha Cronbach's in order to measure its reliability. Reliability is the degree of consistency that the instruments of procedure demonstrate. Reliability and validity are important in determining the effectiveness of any data gathering procedure. Validity is quality data gathering instrument of procedure that enables it to measure what it is supposed to measure [14-15]. Many studies have used the scale in between 0.7-1.0 [16-18]. The Rule of Thumb for the Cronbach alpha value is stated in Table-1. Table-2 shows the result for reliability test. It shows 0.784 which shows positive reliability of alpha Cronbach.

Table-2. Reliability test.

Cronbach's Alpha	No of items
0.784	38

Data Analysis

Data analysis method is a way to analyse and interpret the raw data that have been collected in the survey. In this study, Statistical Packages for the Social Science (SPSS) software version 15.0 was used. The descriptive analysis and correlation was used to analysis the raw data that get from feedback of survey. Correlation is a relationship between two variables [19]. It means that if one variables increases, so does the variable or as the value of one decreases, the other one also decreases. This analysis uses with 5% significant level, unless otherwise stated.

RESULTS AND DISCUSSIONS

Respondents Profile

The respondent for this research are totally 100% male. There are no women respondent recorded. Their average age is 13.2% were in the range 21-30. Another 30.2% are in the range 31-40.

Another 14.6% are in the range 51-60. Only 1.9% is in the range 61-70. Majority respondents' age is in the range 41-50 which recorded 40.1%. While for the question about their average hours working per day, 60.8% said that they are working in between 11-15 hours. 25% choose 6-10 hours of working hour per day. Another 2.4% work in between 0-5 hours. 9.9% worked in between 16-20 hours and 1.9% worked in between 21-25 hours per day.

Table-3. Respondent's profile.

	Frequency	Percentage [%]
Age [years old]		
21-30	28	13.2
31-40	64	30.2
41-50	85	40.1
51-60	31	14.6
61-70	4	1.9
Races		
Malay	195	92
Chinese	7	3.3
Indian	10	4.7
Average hours per day [hours]		
0-5	5	2.4
6-10	53	25
11-15	129	60.8
16-20	21	9.9
21--25	4	1.9

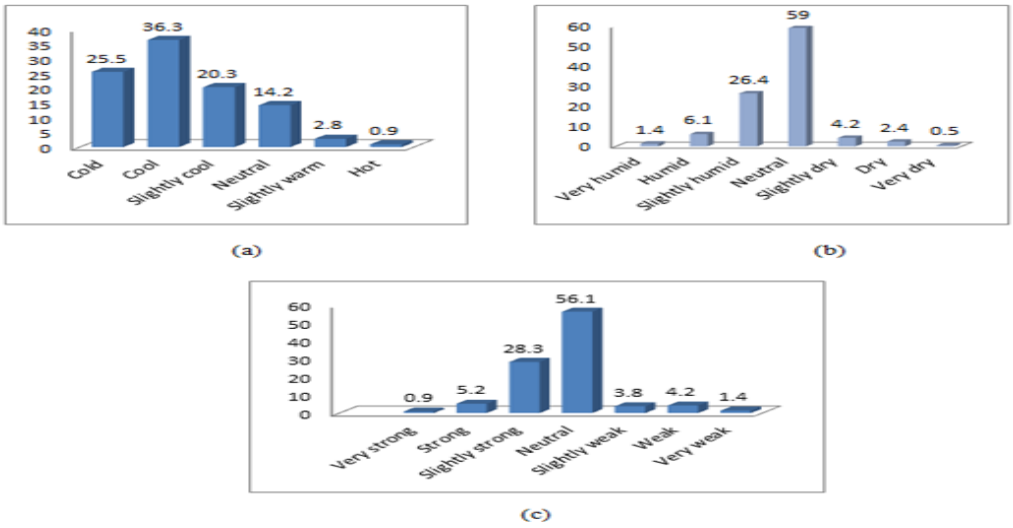

Figure-1. (a) Preference about temperature in bus, (b) Preference about relative humidity in bus and (c) Preference of air velocity in bus.

Descriptive Analysis

Figure-1(a) illustrates the preference of temperature that the bus drivers feel in the bus. They are cold, cool, slightly cool, neutral, slightly warm and hot. 36.3% (77) of the respondents choose cool temperature in their bus which shows the high preference. While, the second highest preference is cold this shows 25.5% (54). Finally, only 0.9% (2) of the respondents feel hot while they driving in the bus. Most of the respondents choose the air temperature in the bus in cool condition is because most of the respondent work in air conditioned bus. In addition, they can adjust the temperature in the bus according their preference and comfort. Three of the respondents choose the temperature in the bus in hot condition because maybe the air conditioning system in the bus is in broke. The effects of cold on human performance are often ignored and can very significant [20]. The effects of cold on manual performance can be attributed to physiological reaction to cold. The main effects from the cold could be slowing speed, due to stiffening of joints and slow muscular reaction, numbness and a loss in strength. These reactions cause deterioration in manual dexterity and hence of performance at many manual tasks.

Figure-1(b) shows the preference of relative humidity that the bus drivers feel in the bus. The choices are very humid, humid, slightly humid, neutral, slightly dry, dry and very dry. 59.0% (125) of the respondents feel to have neutral relative humidity in the bus which shows the highest preference. While, the second highest preference is slightly humid which represent 26.4% (56). Finally, very dry relative humidity contributes the least to the relative humidity in the bus, 0.5% (1). Since the respondents didn't care much about the relative humidity in the bus, half of them choose the relative humidity in the bus is in neutral condition. This condition not only occurs at the bus but also at the building area. Majority of the respondents (49%) choose the relative humidity in the three locations which are in primary and secondary schools, and in public waiting area in health clinic in Johor Bharu in neutral condition [21]. Figure-1(c) demonstrates the preference of air velocity that the bus drivers feel in the bus. Among the choices are very strong, strong, slightly strong, neutral, slightly weak, weak and very weak. 56.1% (119) of the respondents feel to have neutral air velocity in the bus which shows the highest preference. While, the second highest preference is slightly strong which represent 28.3% (60). Finally, very strong air velocity contributes the least to the air velocity in the bus, 0.9% (2). Since the respondent didn't care much about the air velocity in the bus, half of them choose the air velocity in the bus is in neutral condition. This shows that they can accepted the air movement in their location.

Hypothesis Testing

Table-4 shows the value of Spearman correlation coefficient (r) and significant value (p). By referring to the table, all the thermal comfort factor and human performance among Malaysian bus drivers is statistically significant and had moderate relationship.

H_{O1}: There is no significance correlation between thermal comfort and Malaysian bus drivers' performance.

H_{a1}: There is positive correlation between thermal comfort and Malaysian bus drivers' performance.

The 'p' value is less than the alpha value ($p < 0.01$) i.e. $p= 0.000$, then there is evidence that the relationship is significant. Therefore, null hypothesis is rejected. Hence, it proved that there is statistically significant positive correlation between thermal comfort and Malaysian bus driver performance.

Table-4. Nonparametric correlation between thermal comfort factor and bus drivers' performance.

Thermal Comfort	*r	*p
Temperature	0.547	0.000
Relative humidity	0.528	0.000
Air velocity	0.455	0.000

Thermal comfort has a great influence on the productivity and satisfaction of indoor building occupants [23]. It means that the level of productivity and satisfaction of the occupants depends on the thermal comfort. The best way to achieve thermal comfort is to satisfies the majority of people in the workplace, or put more simply, 'reasonable comfort' [20]. Since 1990s, more focus has been increased on the relationship between the work environment and productivity. Many laboratory and field studies showed that the physical and chemical environment could give impact on the health and performance of the occupants consequently on the productivity. Workplace environmental conditions, such as humidity, indoor air quality and acoustics have significant relationships with worker's satisfaction and performance [23-25]. In other words, companies with higher health, facilities and environmental problems could face more performance related problems such as low productivity and high absenteeism. Employees with complaints of discomfort and dissatisfaction at work could have their productivity affected, result of their inability to perform their work properly [26].

CONCLUSIONS

After all the data analysis had been done, it is clearly that all of two parts of thermal comfort and environmental factors have significantly correlated on Malaysian bus driver performance. The bus drivers also give the response rate to the prevalence discomfort that they experienced along their journey. This means that all the objectives for this study were achieved. Safety and health in transportation sector seems like important in nowadays. Many accident involve bus recently occur. So,

other factors need to be give attention to reduce the accident from occur. Maybe this thermal comfort and environmental factor did not give any significant to safety of the bus. But the bus drivers themselves and the nature of their work will give significant relation to their performance.

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