

A structural regression model for relationship between indoor air quality with dissatisfaction of occupants in education environment

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Abstract. This paper analysis the effects of indoor air elements on the dissatisfaction of occupants in education of environments. Tries to find the equation model for increasing the comprehension about these affects and optimizes satisfaction of occupants about indoor environment. Subsequently, increase performance of students, lecturers and staffs. As the method, a satisfaction questionnaire (SQ) and measuring environment elements (MEE) was conducted, 143 respondents at five classrooms, four staff rooms and five lectures rooms were considered. Temperature, air velocity and humidity (TVH) were used as independent variables and dissatisfaction as dependent variable. The hypothesis was tested for significant relationship between variables, and analysis was applied. Results found that indoor air quality presents direct effects on dissatisfaction of occupants and indirect effects on performance and the highest effects fallowed by temperature. These results may help to optimize the quality of efficiency and effectiveness in education environments.

Keywords: dissatisfaction, indoor air quality, temperature, humidity, air velocity, education environment.

1.Introduction

Long empirical studies have considered the impact of components of indoor environment on residential. But a few of them have investigated the impact of individual indoor air quality on occupants' perception, satisfaction and performance in education environments. Classroom is where students spend a lot of time of day in there with high density of pupils which causes to aggravate poorer indoor air quality. Furthermore, education environment can be a place where are required multiply function or duties. These duties were categorized in two main parts practically and mentally [1]. Analysis of indoor air quality factors, such as temperature, humidity and air velocity in education environment can help to improve learning and teaching [2]. Base on literature review many factors interacted in dissatisfaction of occupants like lighting, acoustics, furnishing, technology, indoor air quality, thermal comfort and so on. But, this paper focuses on temperature, humidity, air velocity. Because many researchers stated (TVH) are more important than other elements [3]. The purpose of this study is designing the equation model with statistically validated that regard the relationship between (TVH) and dissatisfaction. This paper won't explore the effects of other environment elements. It is widely accepted that air conditioning is associated



with absentee rates or academic performance and indoor air quality has significant benefits to health and performance. In addition, the human right emphasis on healthy indoor environment which includes the right to breathe clean air, the right of visual health, comfort and the right of the thermal comfort[4].

2. Literature review

By using keywords, such as temperature, air velocity, humidity, satisfaction of occupants and performance, the literature was reviewed in several databases (Google scholar, Elsevier, Science direct) to explore the presence of the indoor air factors in predicted dissatisfaction of occupants in education environments. From 1960's till now a large quality researches have been done in this field. Maybe, one of the first one was McNall & Nevins in 1967 that by thermal environment control in or near the comfort zone indicated a strong non- statistically significant tendency is between academic performances with the air- conditioned in junior school student in 1959[5]. However, this hypothesis couldn't determine whether these changes exactly related to air- condition or other variables like student motivation, preparation of student, back ground or teachers. Schoer and Shaffran (1973) conducted an experiment in two classrooms which temperature and relative humidity could be controlled but in one air conditioned and just ventilation used. The result of the coursework and tests were identified complex tasks were affected more than simple learning [6]. One of the most important factors in evaluation poor indoor air quality is absenteeism of worker and student. Green (1974) evaluated the absenteeism as function of the humidity. The study has been found that increasing relative humidity causes to reduce illnesses and respectively absenteeism will reduce [7]. McIntyre (1980) has studied about the reaction of people to air velocity and temperature. In this study found that the power of cooling air is more effective than the speed of air and mention to the standards which the German express (air velocity 0.18 m/s with 22⁰c) and (0.30m/s with 27⁰c). And finally, McIntyre refers to the mean of 0.3m/s for air velocity with ± 0.05 that cause maximum of discomfort for highly occupied spaces [8]. Fanger (1988) describes two units in terms of evaluation of air quality which are the Olf and the Decipol [9]. Myhrvold (1996) during three-years in Norwegian school carried out to estimation of the relation between concentrations of carbon dioxide with student performance. The results shown performance were reduced by carbon dioxide levels because of poorer indoor air quality [9]. Clements-Croome & Robert (2008) explained how the air passes via nose to olfactory systems and consequence to the respiratory system where smoke, dust, radon and formaldehyde besides nitrogen and oxygen are transferred through the lung to the blood and hence is circulated around body. In this study has presented a new definition of the word "fresh" that can be associated with cold, cleanliness, new, preserved, salubrious and ventilated. Croome & Robert and Purell & thorne in 1987 in another papers determined how freshness are evaluated by parameters like temperature, air velocity, relative humidity and they built the theory which namely arousal level theory. This theory base on people responded about freshness and founded the significant relationship between temperature fresh air supplies with freshness [10]. Fisk and Rosenfeld (1998) have stated that due to reduction of respiratory infection productivity increase [11]. Seppanen et al (2006) has estimated a quantitative relationship between productivity and performance with ventilation for working in office[12]. Wood and Skaret (1999) has identified to improve indoor air quality because increased productivity that their profit is 10-100 times greater than the cost of maintenance, annualized construction and building energy. In 1990, M. Amerigo and J. Aragonés, presented a conceptual framework for residential satisfaction. This model implies a dynamic interaction between occupants' satisfaction and their environment. In this systematic model are replaced cognitive and behavioral affective as factors which affected direct or indirect on satisfaction of occupants [13]. Humphreys MA (2005) states that human health, productivity, stresses and

wellbeing always influenced by the quality of the indoor environment. This paper is noted to the hypothesis that overall satisfaction of occupants related to way in which they perceived indoor environment. Many researchers are demonstrated that this hypothesis is correct [14]. Frontczak and Wargocki (2011) by analyzing surveys which sent to office building found that the main indoor environment parameters that impact on office occupants are temperature, air quality, light, noise level and sound privacy [15]. In 2009, lai JHK et al. demonstrated that thermal comfort has the highest impact on overall satisfaction in commercial buildings. And, this was followed by noise and air quality [16]. Another investigation in office building showed that ventilation could also have great impact on overall satisfaction of occupants (Steeners K, Manchand S 2010) [17]. The relationship between thermal comfort, air quality, sound quality and overall satisfaction has been widely investigated by A.Zalejska-Jonson, M. Wilhelmsson(2013)[18]. Base on the literature review of this past research, the results obtained to show that indoor air quality has adverse health effects and losing performance. In this field many researches have been done about the impacts of indoor environment quality with productivity and performance in office buildings but less studies considering to indoor air quality in academic environments. However, environments conditions in schools and universities much worse than office buildings. In addition, students have to do mentally and perform work that is not optional and is almost new to them also they cannot change their job to the healthy worker.

3. Methodology

air conditions and windows. The measurements were done by HD32.3- Delta OHM. Each reading data took average within fifteen minutes. This device has three sensors, namely air temperature The methodology applied in this paper comprises the following stapes: 1- objective measurement (temperature, air velocity and humidity) by device. 2- Subjective measurement (Conducting and application of the questionnaire with themes of satisfaction and perceived). 3- Statistical analysis. 4- Estimate the regression equation model and test it. Objective measurements: The indoor thermal investigation consisted of air temperature that included three items 1-Globe thermometer temperature 2- Ambient temperature 3- Radiant medium temperature, relative humidity, air velocity and Predicted Percentage of Dissatisfied. Air conditions were switched on during measurement. Windows were closed throughout the measurement period. In each room or classroom, the measurements had done three times in different places of the room and different distances from, relative humidity and air velocity. Subjective measurements: The subjective measurement was conducted using questionnaire survey. To aid subjects, the questionnaire was prepared with Bahasa Malaysia translation and glossary of sick building syndrome, satisfaction, efficiency. Students, staff, and lecturers were approached. The restriction in the sample collection was due to students that spend a whole day in the class like the students in the studio of design. They were asked for their gender, age, and type of relationship with this faculty. This questionnaire survey conducted in four sections. Section A is about personal. Section B sick building syndrome with Section C, satisfaction and perceived section D efficiency and effectiveness. For all parts used a liker scale of seven answers that were written a pattern of each question as a guide. The sample size is included 143 participations. The sample size was $n > 30$ according to the Central Limit Theorem it has to show the distribution of the people and chosen randomly .Statistical analysis: In this section were used the statistical methods and graphs for comparing the data. The mean, sample standard deviation, the standard error for a sample mean and linear Regression explained the data obtain from device and questionnaire.

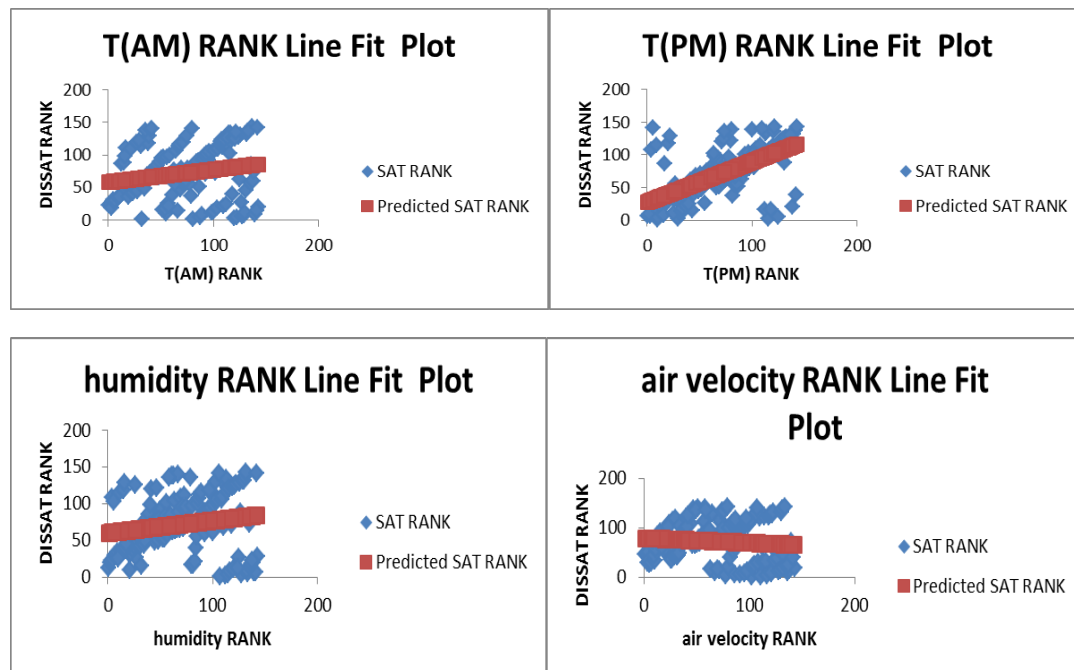
4. Data and analysis

As mention before, we have three main Independents variables which are temperature, related humidity and air velocity and one dependent variable predicted percent dissatisfaction. First of all, correlation will be estimated for each of them with satisfaction. Then, regression equation will be estimated at multivariate. Finally, it will test the significance of a regression equation to determine whether the sample correlation represents areal relationship or is simply the result of sampling error. For the first step Temperature, humidity, air velocity and dissatisfaction have been ranked and then computed the correlation between two variables. The analysis examined the relationships among (TVH) and satisfaction from indoor air quality for n=143 participants. Comparing data showed a consistently one –tail directional relationship but not necessarily a linear relationship. For this reason the (rank-order) spearman correlation used for this experiment and evaluated by hypothesis.

H₀: $\rho=0$ the null hypothesis states that there is “NO” correlation between these variables or the relationship between temperature/ humidity/air velocity and dissatisfaction is equal zero.

H₁: $\rho \neq 0$ the alternative hypothesis states that there is a real relationship between temperature/humidity/air velocity and satisfaction.

data	Sub-objective	correlation	n	α	df	type	table	Sig/non Sig	H ₀ /H ₁	r ²
1-Survey	temperature AM-DISSAT	0.192952001	143	$\rho < 0.05$	141	One-tail	0.164	Significant*	Reject H ₀	0.037230475
2-Survey	Temperature PM-DISSAT	0.620740175	143	$\rho < 0.05$	141	One-tail	0.164	Significant**	Reject H ₀	0.385318365
3-Survey	Humidity-DISSAT	0.167737779	143	$\rho < 0.05$	141	One-tail	0.164	Significant*	Reject H ₀	0.028135962
4-Survey	Air velocity-DISSAT	-0.09524278	143	$\rho > 0.05$	141	Two-tail	± 0.194	Non-significant	fail reject H ₀	0.009071188
5-Device	Temperature-DISSAT	0.810305356	108	$\rho < 0.05$	106	Two-tail	± 0.194	Significant***	Reject H ₀	0.65659477
6-Device	Humidity-DISSAT	0.105247179	108	$\rho > 0.05$	106	Two-tail	± 0.194	Non-significant	Fail reject H ₀	0.011076969
7-Device	Air velocity-DISSAT	0.139518857	108	$\rho > 0.05$	106	Two-tail	± 0.194	Non-significant	Fail reject H ₀	0.019465512
NO	Structural equation model		Y=SAT, X ₁ =T(AM), X ₂ =T(PM), X ₃ =HU, X ₄ =AV							F-ratio
8-	Temperature(AM) dissatisfaction	&	Y= 0.192952001 X ₁ + 58.10745592							5.452495
9-	Temperature(PM) dissatisfaction	&	Y= 0.620740175 X ₂ + 27.30670738							88.38703
10-	Humidity & dissatisfaction		Y= 0.167737779 X ₃ + 59.92287994							4.082022
11	Air velocity & dissatisfaction		Y= -0.095242785 X ₄ + 78.85748055							1.290746
12	T(PM),HU,AV& satisfaction		Y=0.646950317X ₂ -0.045286726X ₃ -0.118574031 X ₄ + 37.21755175							31.57514



NO	Structural equation model	Y=dissatisfaction, $X_1=T$, $X_2=HU$, $X_3=AV$	F-ratio
13	T, HU, AV & dissatisfaction	$Y = 8.874517402 X_1 + 0.009356889 X_2 - 2.018576993 X_3 - 191.6488083$	66.76176716

5. Results

By analyzing surveys and device data found that the main indoor air parameters that impact on dissatisfaction of occupants in education environments is temperature. The vote of participants and device shown that between 38 till 65 percentage of dissatisfaction of occupants predicted by temperature. But, less than 2 percentage of dissatisfaction predicted by humidity and air velocity. In the other words, temperature interference is more than other aspects in dissatisfaction. In number 12 and 13 in table above we have two regression equation models by survey and device, they predicted dissatisfaction of occupants by temperature, humidity and air velocity. The R squared is 0.405285079, 0.658215499. Therefore, dissatisfaction will be predicted between 40 to 65 percentages by these variables or these regression models. The variance predicted by regression equation is significantly greater than would be expected if there is no relationship between variables. In the other words, the null hypothesis will reject and the regression equation predict significant portion of the variance of the dissatisfaction. As mention above, one of the objectives of this paper is increase performance in education environments, so, the model from device is better predictor than model (12) for dissatisfaction. In the other words, the equation model number (13) can predict the level of dissatisfaction of occupants. And, this level has indirectly relationship with performance. It means by increasing dissatisfaction performance of residential in education environment will decrease. Base on the literature review, there is the same relationship between

dissatisfaction and ventilation rate [19]. Consequence, if dissatisfaction is replaced in equation between predict dissatisfaction and ventilation rate; therefore, the ventilation rate that necessary for improve indoor air quality will be estimated. Or the ventilation rate for decreasing dissatisfaction of residential will be estimated. The following formula shows the relationship between dissatisfaction and ventilation rate: $PD = 359 \cdot \exp(-1.83 \cdot q^{0.25})$ or $(3.2149 - \frac{\ln PD}{1.83})^4 = q$ where PD is predicted dissatisfaction and q is ventilation rate.

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