ORIGINAL ARTICLE

LEVEL OF INDOOR AIR QUALITY AMONG MALAYSIAN COMMUTER USERS: A CASE STUDY

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ABSTRACT

Research on environmental ergonomics of train/commuter is very limited. Thus, this study was conducted with aims to determine the environmental ergonomic of public transport, whether it is in accordance to indoor air quality standard inside women coach cabin train during operations. Although the number of passengers is increasing, some claimed that the indoor air quality for the Malaysian commuter train is uncertain, especially at peak times. Unsatisfactory feedback from some respondents—especially female passengers—will affect other passengers to remain loyal to use this facility as one of the main transportation to reduce the traffic congestion that will be faced if using private vehicles. The study conducted during peak hours on the weekends and the trip took exactly two hours and covered 18 main stations. The measurement devices placed at the centre of the cabin Komuter using Air Quality Meter (AIRFLOW Instrument Model TA465). The main parameters measured were temperature, humidity, and carbon dioxide (CO_2). This study also counts the number of passengers riding the train. The results showed that the indoor air quality (AIQ) level of the morning hour will affect passengers' health more compared to the evening hour (this is due to the CO_2 level that has exceeded the safety standard). Morning hour gave higher reading of CO_2 (43.8%) and relative humidity (17%) compared to evening hour. Evening hours also showed greater temperature at 3%. The findings can give awareness to the train company to improve the IAQ by installing a suitable ventilation system and can give comfort to the passengers when travelling using Malaysian commuter train.

Keywords: *ergonomic environment, indoor air quality, public transport, KTM Komuter*

INTRODUCTION

In becoming a developed country, public transport is the heart of everyday mobility. Consumers are looking for a comfortable, efficient, and secure public transport service as their travelling mode from one destination to another. Since December 2016, the MRT route at Kuala Lumpur has been operating; marked the rapid development in the public transport sector in the country. The MRT has expanded its existing train travel destinations, namely KTM commuter, Rapid KL, KLIA Express Train, and KLIA Transit Train to address the problems that hit people's well-being due to traffic congestion and mobility of residents either: for work purpose or game entertainment, and sports. This public facility benefits 1.2 million users in the Klang Valley

Table 1 shows that Rapid KL provides four types of routes: Kelana Jaya Line, Ampang Line, Sri Petaling Line, and Monorail Line, where the journey using Kelana Jaya Line (Gombak to Putra Height) takes the longest time of 1 hour 20 minutes. Meanwhile, the KTM Komuter route has provided four types of routes to connect several states within the same railway route based at KL Sentral (KL Sentral – Tanjung Malim, Tampin, Port Klang, and Batu Caves).

Table 1 – Type of train with the time travel

Type of Train	Time Travel
KTM Komuter	
KL Sentral – Tampin	2 hours
KL Sentral – Batu Caves	30 minutes
KL Sentral – Port Klang	1 hours 10 minutes
KL Sentral – Tanjung Malim	1 hours 35 minutes
RAPID KL	
Kelana Jaya Line – Gombak to Putra Height	1 hours 20 minutes
Ampang Lines – Ampang to Sentul Timur	30 minutes
Sri Petaling Lines – Putra Height to Sentul Timur	1 hours 10 minutes
Monorail – Titiwangsa to KL Sentral	25 minutes
KLIA Express Train	
KLIA – KL Sentral	28 minutes
KLIA2 – KL Sentral	31 minutes
KLIA TRANSIT	
KLIA – KL Sentral	35 minutes
KLIA2 – KL Sentral	38 minutes
MRT	
Sungai Buloh - Kajang	45 minutes

The journey from Tampin station to KL Sentral takes the longest two hours. At the same time, KL Sentral also connects the train route to the airport located in KLIA, Sepang. KLIA Express

Train takes about 30-40 minutes train journey from KLS to KLIA/KLIA2. Most recently, the MRT provides the convenience of travelling from Putra Height station to Sungai Buloh within 45 minutes.

The definition of Indoor air quality by ASHRAE Standard 62-2001 "Ventilation for Acceptable Indoor Air Quality" is "Air which there are no known contaminants at harmful concentration as determined by cognizant authorities and with which a substantial majority (80% or more) of the people exposed do not express dissatisfaction"[1]. The investigation on Indoor Air Quality (IAQ) begin on 1970[2] and continues until these days because it has been a strong correlation between air quality and health[3]. Vasile et al.[4] defined IAQ as a condition of air exchange between interior and exterior in addition to organic and inorganic pollutants in particulate matter, which can affect human health. Government, regional and worldwide influential organization has a great concern about this matter because it has impact on human health[5]. Steinemann[6] defined IAQ as a subset of indoor environmental quality (IEQ) that includes factors such as lighting, ergonomics, acoustics, and temperature in addition to pollutants. In summary, IAQ is referring to the air quality within and around a structure that will affect the health and comfort of the people in that environment. Thus, understanding and controlling common indoor air pollutants will immediately help to reduce risk of indoor air quality on health and give long-term comfort to all.

Public transportation is critical as its main function is to ease and aid the movement of residence. The bigger population in a city, the more complex of the road system and infrastructure becomes; thus increase in the usage of public transport. One of the daily challenges faced by public transportation systems is controlling the IAQ level inside the trains and platforms to ensure that it is not over the safety limit because that will create health risk to hundreds or thousands of passengers who use their services every day. Low and high levels of IAQ can give two types of health effects: short and long term effects[7]. There are numerous studies on the health effects when exposed to high or low of IAQ. Table 2 and Table 3 show the results of research on acute health symptoms during exposure to high carbon dioxide concentration and air temperature[8]. For the first 5-10 minutes after been exposed to 380±9 ppm, respondents began to lost focus and cannot think clearly, fatigue, wellbeing and dizzy. Longer exposure to CO_2 concentration (30-70 minutes) cause the heart rate getting lower.

Table 2 - Acute health symptoms and physiological response during exposure to high air temperature and carbon dioxide concentration[8]

CO_2 Concentration (ppm)	Air temperature (°C)	Relative humidity (%)	Time of exposure(minutes)		
			5-10 minutes	20-25 minutes	30-70 minutes
380±9	27.1±0.1	31±3	Cannot concentrate and think clearly, fatigue, wellbeing, dizziness, headache	Dry nose, dry eye, throat, skin, unstable mood	Heart rate getting lower

For this study, the longest train journey time taken into account while conducting a study on the reading of the IAQ value during a train ride from KL Sentral to Tampin using KTM Komuter. More specifically, this study was conducted in women's cabin as the population of women was half as compared to the male population in Malaysia[9]. At the same time, the findings able to create awareness among woman about the importance of indoor air quality knowledge as they ride using train and its health effects if they take an indifferent attitude to the unhealthy IAQ effect.

Train systems are often believed to the cleanest mode of transportation because they are generally operated by electrical, so it can reduce direct emission of air pollutant[10]. Some researchers found that air quality inside train is affected by high levels of particulate matter (PM) for train service in the subway or tunnel, carbon dioxide, temperature, and relative humidity[11,12,13,14]. Indoor carbon dioxide (CO_2) concentration is influence by indoor breathing when passenger exhale CO_2 through respiration. The amount of CO_2 generated on the inside train cabin depends on the number of passengers at one time. Temperature and relative humidity measure must be taken in providing good air quality because it is difficult to satisfy the passengers in a closed place, like the train cabin[15]. CO_2 exceeding a tolerance value can affect passengers' health such as an increase in blood pressure, fatigue level, and stress or feeling of headache[16]. The high CO_2 concentration can also cause sick building syndrome symptoms that have unhealthy impact[17] to the public transport users. Raw[18] summarized sick building syndrome as in Table 3.

Table 3 – Symptoms and effects due to sick building syndrome[18]

No	Organ Involved	Symptoms	Effects
1	Eyes	Irritated, dry/watering	Itching, tiredness, smarting, redness, burning, or has difficulty in wearing contact lenses.
2	Nose	Irritated, runny/blocked	Congestion, nosebleeds, itchy or stuffy nose
3	Throat	Dry or sore	Irritation, or pharyngeal symptoms, upper airway irritation or difficulty swallowing
4	Skin	Dryness, itching or irritation	Rash or specific clinical terms such as erythema, rosacea, urticarial, pruritis, xerodermia
5	Others	Headache, irritability, lethargy, and poor concentration	

The new rail line and extending existing lines results in increasing of passenger ridership, which led to overcrowd. Initiatives under the Tenth Plan enable an increase of 31.7% in the annual ridership of urban rail in Kuala Lumpur and Klang Valley from 171 million in 2010 to 228 million in 2014[19]. However, due to overcrowding, various types of indoor air pollutant such as CO_2, relative humidity and temperature that accumulate in the train environment will directly affect the passengers' health[20]. Therefore, IAQ inside train cabin plays a big role to provide healthy journey to passengers. The objective of this paper is to analyse the IAQ level inside KTM Komuter Berhad in women cabin in order to ascertain that it meets the standards of American Society of Heating, Refrigerating, and Air-Conditioning Engineers and to suggest improvement of IAQ to enhance passengers' experience.

METHODS

KTM Komuter lines currently consists of two cross-city routes, namely as the Port Klang Line (Batu Caves – Tampin) and Seremban Line (Tanjung Malim – Pelabuhan Klang). The combined length of these lines is approximately 175 km and mainly covered for 55 train stations. An Air Quality Meter (AIRFLOW Instrument Model TA465) used to measure the CO_2 concentration, temperature and relative humidity inside women coach travelling for two hours in 18 stations of the KTM Komuter line from Tampin to KL Sentral. KTM Komuter can be described as a popular choice as mode of rail Coach was introduced in 2010[21]. Air Quality Meter were placed roughly 1.0-1.5 meter above the floor of the train cabin according to Cheng et al.[22] and Zheng et al.[10]. The data retrieval done in the middle of the cabin train because this measurement tool requires a direct current power source, which allocated in the middle of the cabin train. The reading of Air Quality Meter and the number of passengers inside the train cabin was monitored after train departure from each station for the whole sampling period following Zheng et al.[10]. When the door closed and the train move to the next station, the count of passengers inside train cabin begun and single direct reading sampling strategy to collect the data of IAQ used.

For one train cabin, only 58 passengers can sit and the rest had to stand up to reach to their destination. The air qualities measured inside train cabin for each station during morning and evening hour periods on weekend. The measurement on the IAQ inside women coach, conducted on 6 May 2017, from 9:00 a.m. until 4:00 p.m. For morning off peak hours, the travel start at 9 a.m. from Tampin and arrive at KL Sentral at 11 a.m. and for evening off peak hour, the travel start at 2:00 p.m. and finish at Tampin at 4:00 p.m.[23]. The data was analysed by using Microsoft Excel. Using descriptive statistics, the results showed by graph to show the relation of air quality and number of passengers. Regression analysis performed to examine the matrix relationships between CO_2 concentrations, relative humidity, and temperature by relating it with number of passengers that were riding the train on morning and evening hours during weekend. This study was conducted on the weekend because the ridership is similar to that in weekdays[24].

RESULTS

Figure 1 shows the graph on number of passengers using the train from Tampin to KL Sentral during morning and evening hours. In morning hours, the graph shows the the passengers are dramatically increased compared to evening hours which steadily increases of users inside women train cabin. For morning

hours, there is a drastic increase starting from Labu Station until it arrives at KL Sentral with 127 passengers. The characteristic that can influence to the number of passengers depends on the population density of the area in which the station is located.

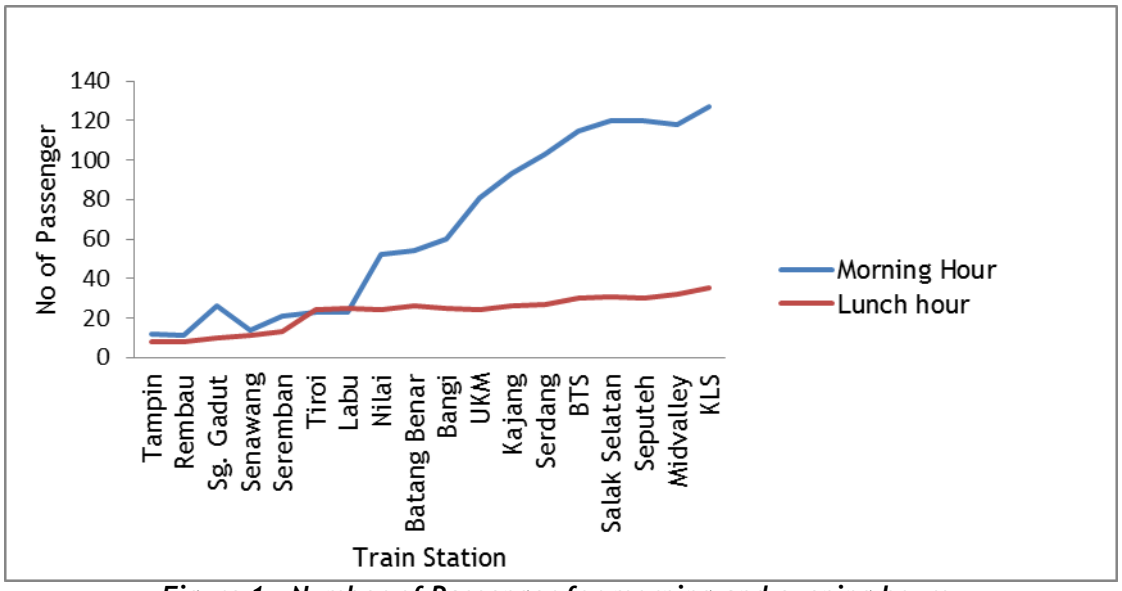

Figure 1 – Number of Passenger for morning and evening hours.

As mention earlier, one cabin on women coach only provided 58 seats for the passengers. In this situation, passengers start has to standing up at Nilai Station until they arrived at their destination. Figure 2, 3, and 4 show the reading of CO_2 concentration, temperature and relative humidity recorded over 18 stations during travelling from Tampin to KL Sentral.

The graph in Figure 2 shows the data value of the recorded CO_2 concentration dramatically increased in parallel with the increasing numbers of passengers travelling using KTM Komuter from Tampin to KL Sentral and from KL Sentral to Tampin. The red line shows the limit from ASHRAE standard 62-2001 (for 1000 ppm). Both journey in morning and evening hours have exceed the safety limit for CO_2 concentration level. From Table 4, in the morning hour, the readings of CO_2 concentration start to exceed the limit from Nilai station (1014.67 ppm) when the value of passenger were 52 people inside the women cabin. The value of CO_2 kept increasing until it reach KL Sentral station which gives the maximum value of CO_2 concentration (2741.00 ppm) with 127 number of passengers. For evening session, the journeys start with 35 women passengers inside the cabin at KL Sentral station with the CO_2 concentration value at 1476.33 ppm. The number of passengers start to decrease until it reach the last destination at Tampin.

Figure 3 and 4 describe about the data in temperature and relative humidity for morning and evening. From Figure 3 and 4, it clearly shows that the data are fluctuated for temperature and relative humidity. Despite the increasing number of passengers, it has no significant impact on the results of the two data. From Table 4, in the morning hours, the average value of temperature is 23.72°C and the average of relative humidity is 68% and goes to 1600 ppm (the maximum value of CO_2 at KL Sentral Station). In this study, data for morning hours also show that the minimum relative humidity value recorded at 58.8 % and the maximum temperature reading is 24.8°C (at MidValley Station).

The measurement on the IAQ inside women coach continued on the same day, with different train number from 2:00 to 4:00 p.m. during travel from KL Sentral to Tampin for evening hours. All users can get a sit because there was only 35 passengers on the way back from KL Sentral to Tampin. There are no issues of crowded people in one cabin during this evening journey. The graph in Figure 2 shows that the level of CO_2 concentration has decreased along with the number of passengers. From Table 4, the average value of temperature recorded at 24.4°C. Meanwhile the average of relative humidity recorded at 56.7% and CO_2 concentration goes to 1467.3 ppm at KL Sentral when having the maximum number of passengers. The minimum relative humidity value recorded at 49.1% and the maximum temperature reading is 26.6°C at KL Sentral Station.

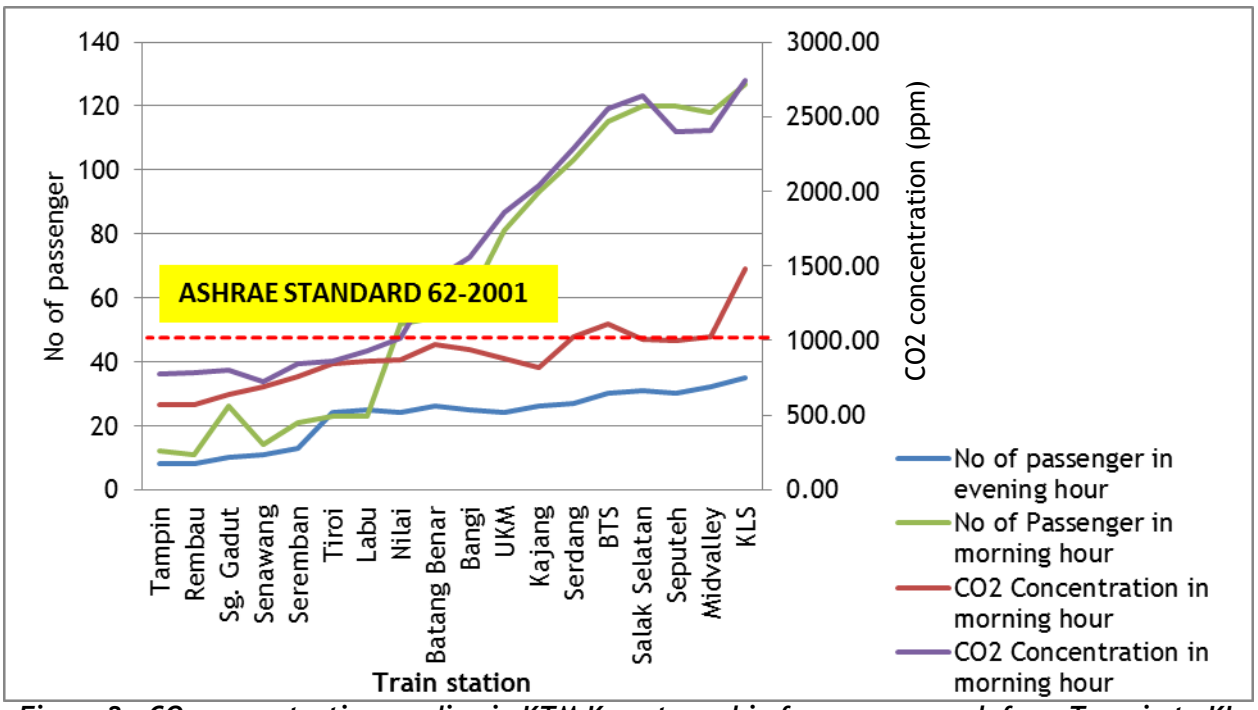

Figure 2 - CO_2 concentration reading in KTM Komuter cabin for women coach from Tampin to KL Sentral for morning and evening hours

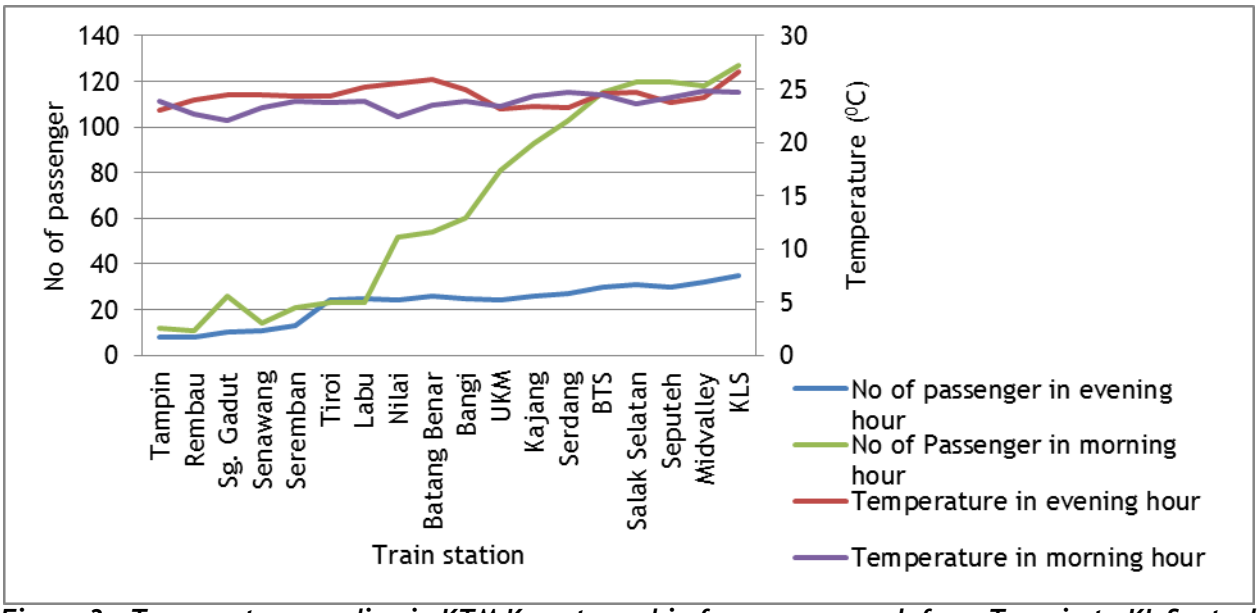

Figure 3 - Temperature reading in KTM Komuter cabin for women coach from Tampin to KL Sentral for morning and evening hour

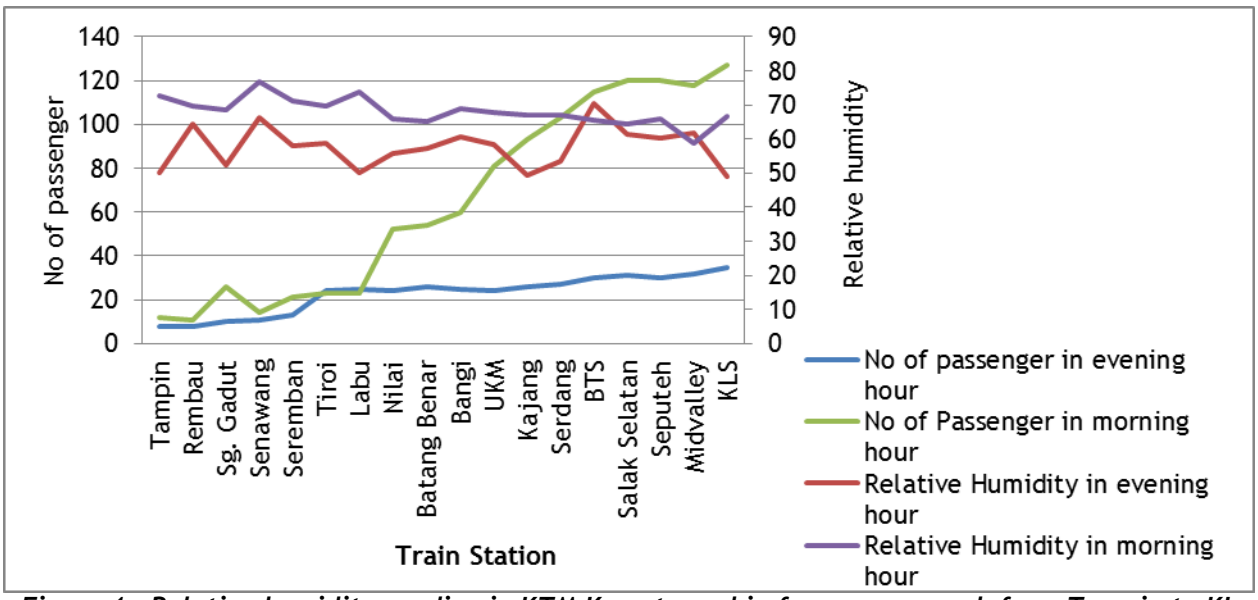

Figure 4 - Relative humidity reading in KTM Komuter cabin for women coach from Tampin to KL Sentral for morning and evening hour

Table 4 - IAQ reading in KTM Komuter cabin for women coach from Tampin to KL Sentral for morning and evening hour

Station	No of passenger		Temperature (^{0}C)		Relative humidity (%)		CO_2 Concentration (ppm)	
	1	2	1	2	1	2	1	2
Tampin	12	8	23.9	23	72.8	50	774.33	571.67
Rembau	11	8	22.6	24	69.5	64.4	784.00	573.00
Sg. Gadut	26	10	22.1	24.5	68.7	52.5	798.00	641.33
Senawang	14	11	23.2	24.5	76.7	66.3	726.00	690.33
Seremban	21	13	23.9	24.3	71.2	58.1	842.67	761.00
Tiroi	23	24	23.7	24.3	69.5	58.8	858.00	848.67
Labu	23	25	23.8	25.2	73.8	50	926.67	864.33
Nilai	52	24	22.4	25.5	66	55.7	1014.67	874.00
Batang Benar	54	26	23.5	25.9	65	57.2	1411.67	975.00
Bangi	60	25	23.8	24.9	69.1	60.6	1557.00	935.67
UKM	81	24	23.4	23.1	67.9	58.5	1858.33	882.33
Kajang	93	26	24.3	23.4	67.1	49.3	2035.00	820.67
Serdang	103	27	24.7	23.2	67.2	53.5	2285.67	1025.00
Bandar Tasik Selatan	115	30	24.4	24.6	65.6	70.6	2554.67	1109.67
Salak Selatan	120	31	23.6	24.7	64.4	61.4	2638.33	1004.00
Seputeh	120	30	24.2	23.7	65.8	60.3	2400.67	999.43
Midvalley	118	32	24.8	24.2	58.8	61.8	2408.33	1027.00
Kl Sentral	127	35	24.7	26.6	66.8	49.1	2741.00	1476.33

Abbreviations and Notes: *1 = morning hour, 2 = evening hour*

DISCUSSION

In order to analyse the changes in air quality according to the number of passengers entering the train, cabin air quality measurement outcome of the morning hours with many passengers and evening hours with far less number of passengers was measured and analysed as shown in Figure 4a, 4b, and 4c. Regression analysis used to predict the number of passengers related with CO_2 concentration, temperature, and relative humidity. When the average of all parameter and R^2 value of each factor of the morning and the evening hours compared, R^2 value and the average result of the parameter of the morning hours was far higher and the evening hours maintained the lowest value of the day.

In the case of the morning hours with a large numbers of passengers riding KTM Komuter, the influence of IAQ result inside the women cabin was significant to the number of passengers, and some of the value have exceeding the indoor environment standard value of ASHRAE standard 62-2001, which is 1000 ppm. There is high value of R^2 in the morning hours (0.977) that make strong relationship between CO_2 concentration and the number of passengers as shown in Table 4 and Figure 4a. This is because the train cabin already congested with passengers inside it. Increased passenger density would increase CO_2

emission per passenger[25]. Congestion in train cabin is due to the increase in number of passengers entering the cabin as in the case study at Guangzhou Subway station, where overcrowding start from 7:45 to 9:30 a.m. This is because people rushing to get to workplace in the morning time[26]. In addition, congestion in the train cabin is also due to the uneven selection from passenger's intrinsic preference for a specific train cabin that give overcrowding in one train cabin[27]. In addition, during the morning hours, despite the circulation of air due to air conditioning inside the cabin, the temperature gradually increased accordingly to the rapidly increasing number of passengers that give R^2 value of 0.40 for temperature in morning hours as shown in Figure 4b. Therefore, there is a need for special interest and effort in air quality maintenance during morning hours with many passengers inside one cabin.

Figure 4c reveal the fluctuation in relative humidity results and are in accordance with recent studies as highlighted by Bong[11] indicating that the results had influenced by various factors and attributed to difficulty in identifying the correlation with the number of passengers.

The results in Table 4 also shown the value of maximum number of passengers for morning and evening hour at KL Sentral station. There are so many reasons of why KL Sentral became the centre of public transport users. Since 2002, KL Sentral and Kuala Lumpur International Airport have provided a non-stop express service for the users that want to travel via flight to arrive for their destination[28]. KL Sentral also serves the interchange station within the same mode; for example, users can transverse from Angkasapuri KTM Komuter (Sentul-Pelabuhan Klang route) to the Mid Valley KTM Komuter (Seremban-Rawang route)[29]. It also have a good of train connectivity between KTM Komuter, LRT (Light Rail Transit) and Monorail[30]. Therefore, KL Sentral is a busy station that is always crowded with users.

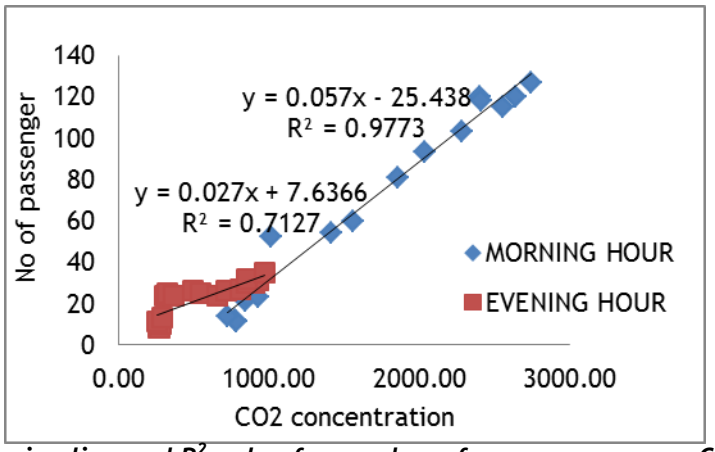

Figure 4a - Regression line and R^2 value for number of passenger versus CO_2 concentration

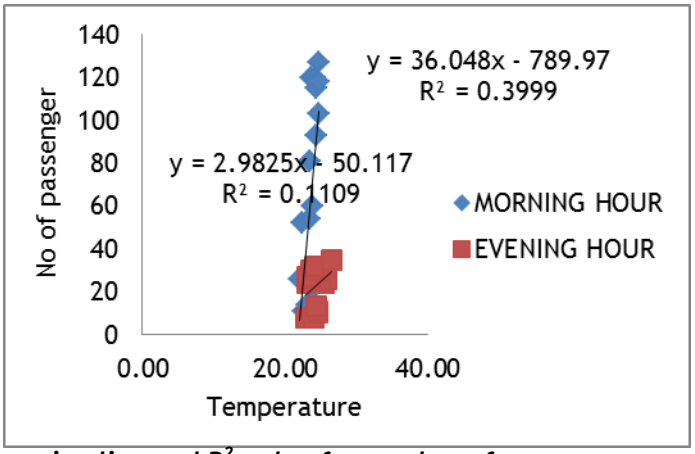

Figure 4b - Regression line and R^2 value for number of passenger versus temperature

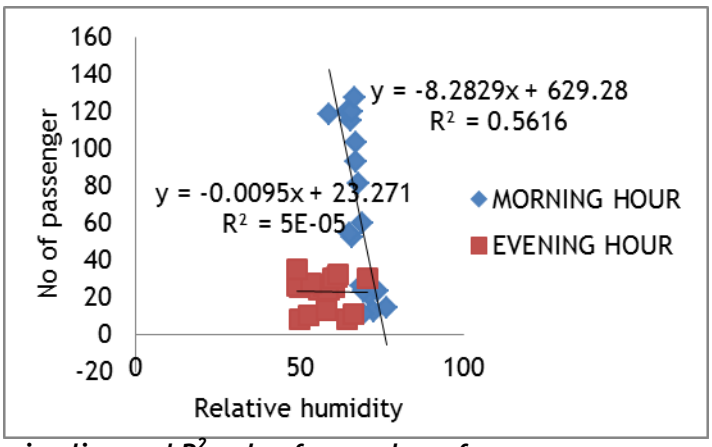

Figure 4c- Regression line and R^2 value for number of passenger versus relative humidity

Table 4 - Comparison of average and regression value of IAQ for morning and evening hour

Parameter	Morning Hours		Evening Hours	
	Average	R^2	Average	R^2
No of passengers	65.17		22.72	
Temperature (^{0}C)	23.72	0.40	24.42	0.111
Relative Humidity (%)	68.11	0.562	57.67	0
CO_2 concentration (ppm)	1589.72	0.977	893.30	0.7127

CONCLUSION

In this study, value of CO_2 concentration, relative humidity, and temperature inside women cabin for KTM Komuter that travel along 18 stations measured for two hours. Value of CO_2 concentration during morning and evening hour does not meet the standards of ASHRAE standard 62-2001 when the train started to crowd with passenger. Therefore, there is a need for special interest and effort in air quality maintenance during peak hours with a lot of population movement to another cabin. A significant positive relationship found between number of passengers and the CO_2 level inside train. The same goes with temperature and relative humidity, which showed an increase in the value in-line with the increasing number of passengers. Based on the findings, the number of passengers has a strong relation with CO_2 concentration value. Others (relative humidity and temperature) have a weak relation.

There are several possible ways the KTM Komuter can ease congestion inside overcrowded train cabin. By developing the model to predict CO_2 concentration change as a function of train cabin volume, vehicle body leakage, and number of passengers inside that coach. This model can be used to design and control air-recirculation mode inside train cabin and can estimate the CO_2 value that can be inside one cabin of train with estimation for number of passenger[31]. Another suggestion that can be made is by using train cabin air purifier which will be activated when the sensor detect overcrowd inside train cabin[32]. By build-up system that can monitor for regulating air quality also can give awareness to the passenger regarding IAQ measurement inside train[33]. This idea can minimize the CO_2 concentration and will give satisfaction and comfort to the passengers during the riding using KTM Komuter. For the next study of this research, mathematical model can predict the number of passengers that can cause harmful value of CO_2 concentration.

ABBREVIATIONS

KL	Kuala Lumpur
RAPID	Rangkaian Pengangkutan Integrasi Deras
KLIA	Kuala Lumpur International Airport
KLIA1	Kuala Lumpur International Airport 1
CO2	Carbon Dioxide
KTM	Keretapi Tanah Melayu
UKM	Universiti Kebangsaan Malaysia
BTS	Bandar Tasik Selatan
KLS	Kuala Lumpur Sentral
NO	Number
ppm	Particulate per meter

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COMPETING INTERESTS

There is no conflict of interest.

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