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GIS-BASED NOISE SPATIAL DISTRIBUTION MAP USING MOBILE APPS

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ABSTRACT

Noisetube apps are used as a platform to collect noise data. However, the data from crowdsourcing are shown as points of locations that is difficult for interpretation. Therefore, to visualize better presentation of noise maps, interpolation method from GIS software tools is used for data processing and analysis. The aim of this study is to prepare noise pollution distribution using mobile apps in UiTM Shah Alam. Based on the aim, the objective is to measure and record sound level data by apps and investigate suitable interpolation methods for creating a continuous surface from discrete points for noise analysis. With the global positioning system (GPS) provided in a smartphone and internet data, NoiseTube apps will run their system for measuring noise data with location. The data will be sent, stored and processed in NoiseTube server so that it can be downloaded and viewed by the user. An accuracy of data is considered by performing calibration process. ArcGIS desktop software is used to perform data processing and analysis by testing difference interpolation method such as Kriging, CoKriging and Inverse Distance Weighting (IDW). Analysis is carried out to identify the crowded place in Education zone. The result shows that ordinary CoKriging is the suitable interpolation method for mapping the noise distribution based on data collected in this study area. The calibration result shows that smartphone is less accurate for noise measuring based on the calibration test result about 7 decibel unit compared to the actual reading from the sound level meter instrument.

***Keywords**: noise, interpolation, kriging, cokriging, inverse distance weighting*

INTRODUCTION

Noise pollution will give significant impact to our environment and disturbing the quality of human life. By scientific definition, noise or sound is a pressure oscillation in the air or water or any medium, which conducts and travels (radiates) away from the source [2]. Noise impacts existed almost from all types of development, such as during a construction and the activities happen after the development. Noise pollution is a problem comes with time due to several factors such as increasing population, industrialization, urbanization and changes in technology.

Technology that is rapidly growth will make easier for data collecting. Apps or application software is developed in replacing the actual instrument but still apply the same function to measure sound. With the global positioning system (GPS) provided in a smartphone and internet data, NoiseTube apps will run their system for measuring noise data together with their location. The data will be sent, stored and processed in NoiseTube server so that it can be downloaded and viewed by the user. Mapping noise

pollution become more interesting with the various method and tools for generalization and analyzing the noise distribution.

Noise can be described as a pollution when its value of sound reaches to danger level and cause to disturb human privacy, physical and psychological health. In order to avoid this disturbance, people should take earlier precaution to decide suitable living environment area. To have an instrument such as a sound level meter (SLM) is not a big problem when the technologies nowadays give some effort to develop apps for mobile device that can give same function as SLM but not as accurately because of different types of microphone detection for each device use. User can use the application to detect the level of sound together with the location by downloading, installing the apps and activate the GPS available on their mobile. The measuring processes require expensive equipment and complex procedures, the publishing is difficult to up-to-date noise pollution information to society. Crowdsourcing for noise pollution can be applied to monitor the noise level by using smartphones with microphone and GPS-enables. In this dissertation, Noisetube apps are used as a platform to collect noise data. However, the data from crowdsourcing are shown as points of locations that is difficult for interpretation. Therefore, in order to visualize better presentation of noise maps, interpolation method from GIS software tools is used for data processing and analysis.

METHODOLOGY

Study Area and Research flow

Site Location: Universiti Teknologi Mara (UiTM) Shah Alam, Selangor Darul Ehsan (Figure 1). This site is located in Section 1. UiTM's main campus started on 14 October 1967 by Tun Abdul Razak and in the mid-70s, the campus was already in full operation. It acts as the main center of development and expansion of a network of other campuses. This campus is very close to Shah Alam city center. Therefore, public facilities and services are within easy reach. An added advantage is the fact that Shah Alam is the hub of information technology and multimedia applications. It is also easily accessible via the major highways that link the city to strategic locations in the country.

Figure 1: The Study Area.

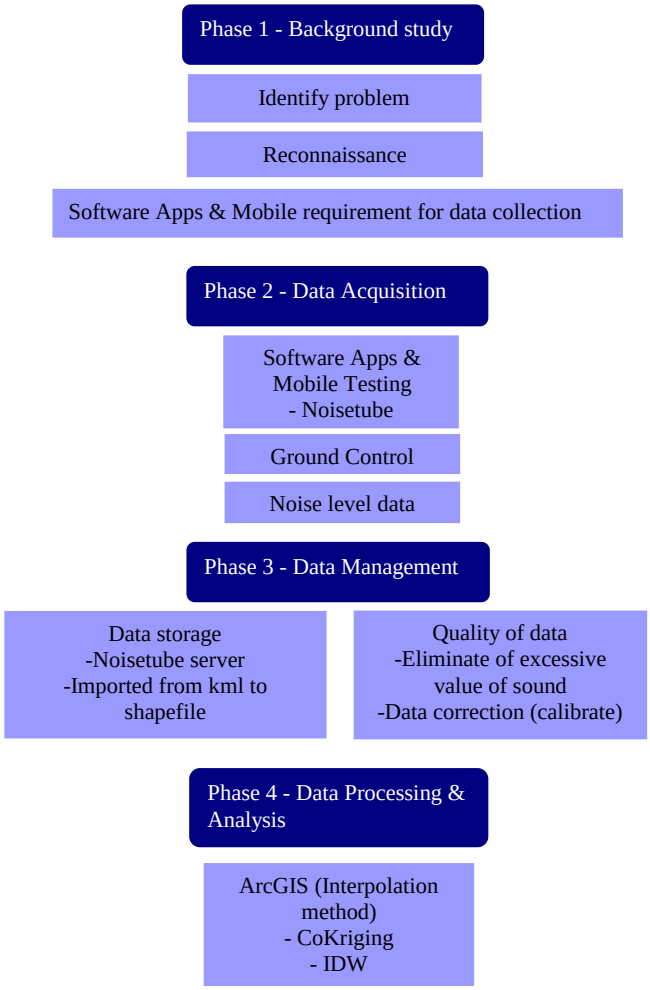

Figure 2: Methodological Flowchart

Software Apps & Mobile requirement for data collection

The software application uses in this study are NoiseTube apps. This apps will be downloaded and installed on a mobile device, HTC Desire 300. It collects information from different sensors (microphone, GPS receiver, user input) which is logged locally and/or sent to NoiseTube community memory server in real-time. There is no specific condition since all smartphones can be used to measure noise level as long as it contains GPS, mobile data (internet connection) and apps.

The requirement for mobile device use:

i. The data plan for Internet access to transmit measurements in real time
ii. A GPS receiver
iii. Platform specifics:
-For Android phones: Android OS version 2.1 or later (minimal API level 7).

Ground Control and Noise Level Data

To establish the ground control or point station, proper planning must be done so that the distribution of noise data can be interpolate very well. The point station is chosen by marking it in the paper obtained from the Google Earth image. Measurement of noise level for each point station has been done in 5 minutes.

Elimination of excessive data is required because it was the process to reduce error by deleting the obtained data that occurred because of sudden phenomenon. It is because the data will generate almost 200 point measurement in 5 minutes. Therefore, the point will be deleted if its value reaches excessive levels more than 120 db (A) or maybe there is a redundant point produced same value.

The data measure by mobile apps is controlled by the real instrument, sound level meter (SLM). The calibration is carried out in a lab where it is free from noise or sound. The instrument involves is calibrator, SLM, HTC Desire 300 with NoiseTube apps and Spectrum Analyzer Pro Lab software.

GIS Techniques for Mapping Noise Distribution

Spatial interpolation is carried out to estimate values at others point by using the known values of the points. The precipitation value at a location can be estimate with no recorded data by using known precipitation value at nearby weather stations. Interpolation is performed in order to create a continuous surface from point data. Interpolation is required when the discrete surface contains different levels of resolution or cell size, a continuous surface is represented by a data model different from required and the data do not cover the domain of interest completely.

There are two methods of interpolation used to test the noise data, kriging and IDW. In the figure 3 shows the workflow of two different interpolation methods. The noise data are explored by semivariogram analysis from kriging/cokriging method in order to obtain the best fitted model for better predictive value. For IDW method, the power value is used to determine the RMS error.

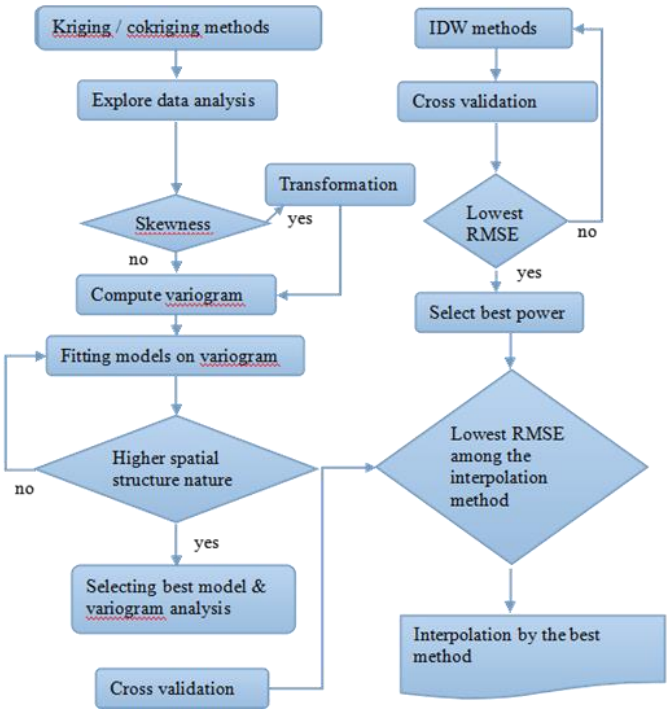

Figure 3: Work flow of two different interpolation methods

RESULTS AND DISCUSSIONS

Calibration

The table 1 shows the result of calibration that is carried out in the lab. The error is calculated and average of the overall error is used for correcting the data in the field measurement. The final error (average) obtained is 7.778.

Table 1: Calibration error result.

No. of measurement (each 5minutes)	Measured db(A)	SLM db(A)	Error	Values after calibrated
1	85.54	94	8.46	93.318
2	86.73	94	7.27	94.508
3	86.43	94	7.57	94.208
4	86.15	94	7.85	93.928
5	86.26	94	7.74	94.038

The graph shows the calibration of noise level apps. The graph indicates comparison between the noise level before and after calibration with the reference calibrated from the sound level meter instrument. There is very big difference of error between the sound level apps and sound level meter.

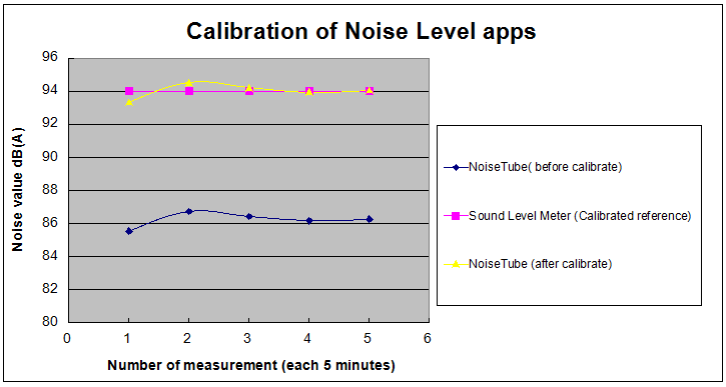

Figure 4*:* NoiseTube level comparison between before and after calibrated.

Cross Validation and Error Evaluation

Kriging method

The result in the table 2 and 3 are obtained using the geostatistical analyst tool by kriging method.

Table 2: Error obtained from different types of model.

Model	Gaussian	Spherical	Exponential
Standardized RMS	0.9062478	0.9063944	0.9019401
RMS	11.33025	11.30711	11.28396

Table 3: Parameter of semivariogram model.

Model	Nugget	Sill	Range	Nugget/sill ratio (%)
Gaussian	105.48892	145.67098	0.002878	72
Spherical	90.34858	144.64533	0.002878	62
Exponential	77.10807	146.9547	0.002878	52

To determine the degree of spatial dependence of the variable by referring to the nugget/sill ratio. Nugget/sill ratio less than 25% have a strong spatial dependence, between 25% and 75% has moderate spatial dependences and ratio above 75% has low spatial dependent variable. The result in table 2 shows that spherical and exponential model has a moderate spatial dependence variable while

Gaussian has a low spatial dependence variable. When referred to the RMS error from table 3, the exponential model gives the less error compared to Gaussian and spherical model. The best model for fitting on variogram is selected based on less RMS error with the closest value to 1 for standardized RMS error.

Inverse Distance Weighted (IDW)

The result shows that less power value gives lowest error. In order to select the best method for interpolation process, RMSE is used to make comparisons.

Table 4: RMSE for different power value.

Power value	RMS
1	11.30435
2	11.44759
3	12.20171

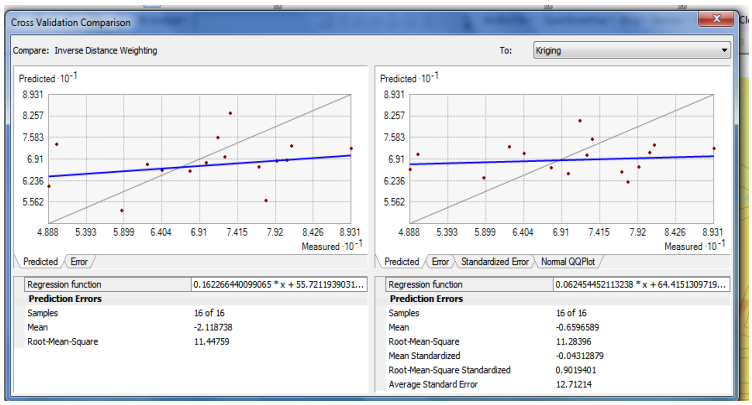

Figure 5: Cross validation comparison between IDW and Kriging method.

Cross Validation Comparison Between Kriging And Cokriging

A better interpolation method should obtain smaller RMS. From the result, CoKriging method gives the lowest RMS error. Figure 6, 7 and 8 shows the comparison of cross validation result between kriging and Cokriging method.

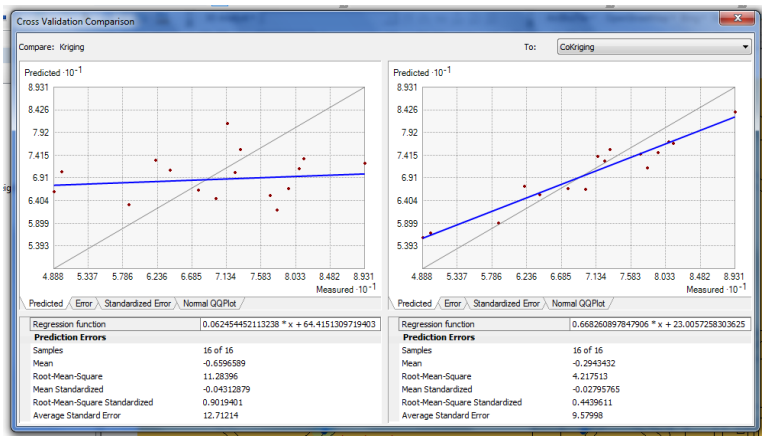

Figure 6: Kriging and CoKriging comparison for morning period.

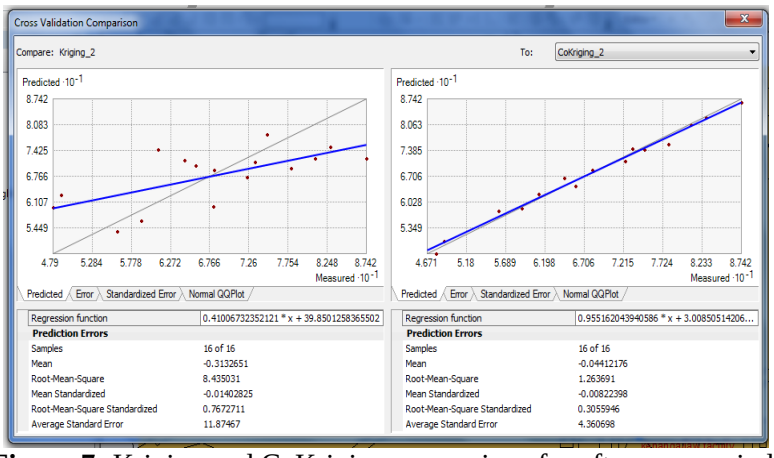

Figure 7: Kriging and CoKriging comparison for afternoon period.

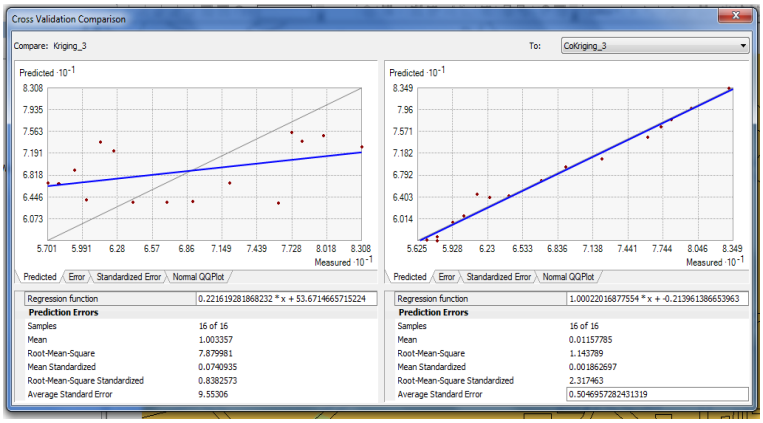

Figure 8: Kriging and CoKriging comparison for evening period.

Table 5: RMS value between difference interpolation method.

Method	RMS		
	Morning	Afternoon	Evening
Kriging	11.284	8.435	7.880
CoKriging	4.218	1.264	1.144
IDW	11.448	8.514	8.141

The predictive value of noise data for cokriging is better than kriging where the point is closed to the model line. The predictions should be unbiased, indicated by a mean prediction error as close to 0 as possible. The standard errors are accurate, indicated by the root-mean-square standardized prediction error close to 1.00. The predictions do not deviate much from the measured values, indicated by root-meansquare error and average standard error that are as small as possible. Overall result shows that ordinary Cokriging method with exponential model type is more accurate than kriging and IDW method for preparing noise maps.

Noise Distribution By Cokriging Method

The following figures shows the result of prediction map from CoKriging interpolation method with the range of predicted values.

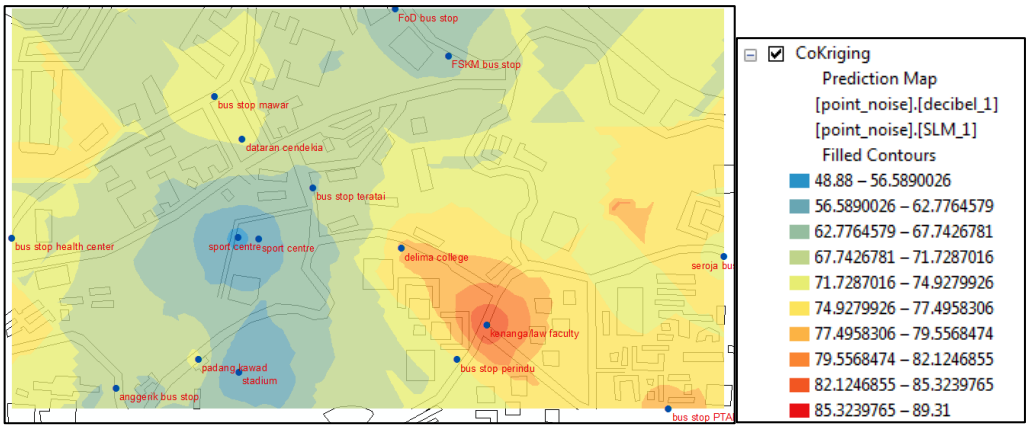

Figure 9 *:* Noise distribution in the morning, 7.45 a.m - 9.00 a.m.

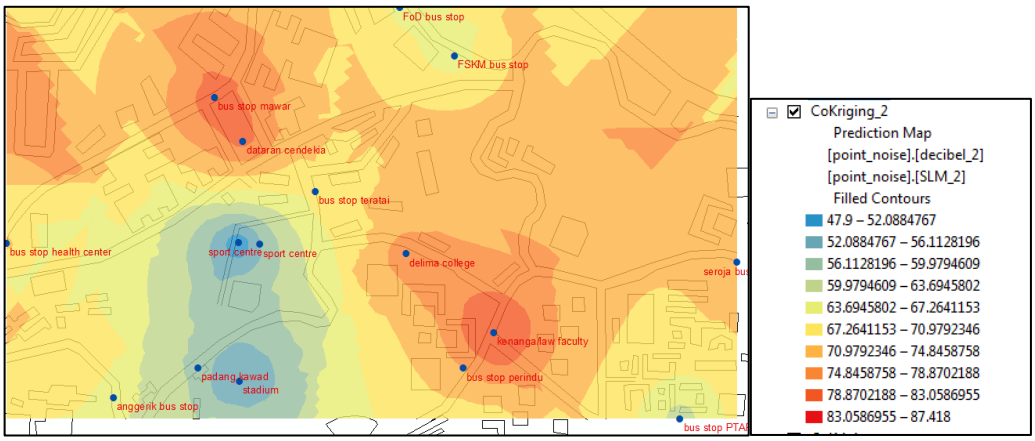

Figure 10*:* Noise distribution in the afternoon, 12.00 p.m - 1.00 p.m.

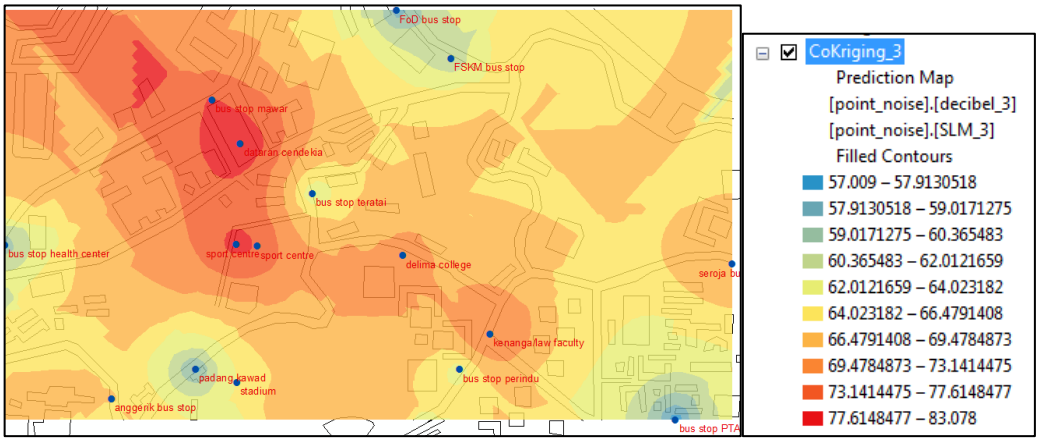

Figure 11: Noise distribution in the morning, 4.30 p.m. - 7.00 p.m.

The interpolation process give a result in the range of the decibel value with 10 classes color coded. In the morning period between 7.45 a.m. till 9.00 a.m., the highest predicted values is 89.31 and the lowest is 48.88. In the afternoon period between 12.00 p.m. till 1.00 p.m., the highest predicted values is 87.418 and the lowest is 47.9. In the morning period between 4.30 p.m. till 7.00 p.m., the highest predicted values are 83.078 and the lowest is 57.009.

The lowest value of noise prediction is detected in the sport center during morning period because student preferred to fill their leisure time at the sport centre during the evening period. In the afternoon period, the place that shows the highest level of noise is at the several bus stop and food court (Dataran Cendekia). Evening period shows the sport center, food court and bus stop near to that place has the maximum level of noise.

Noise Distribution By Reclassify (Cokriging Method)

The following figures show the prediction map after reclassified based on the specific category.

Figure 12*:* Noise prediction map in the morning period.

Figure 13*:* Noise prediction map in the afternoon period.

Figure 14*:* Noise prediction map in the evening period.

The result of prediction map is reclassified into the subjective evaluation. The evaluation is divided into 6 categories which is very faint, faint, moderate, loud, very loud and deafening. The evaluation is categorically as shown in the table below.

Table 6: The range of noise level based on subjective evaluation.

Sound Range, decibel dB(A)	Category	Color coded
0 - 20	Very faint	
20 - 40	Faint	
40 - 60	Moderate	
60 - 80	Loud	
80 - 100	Very loud	
100 - 140	Deafening	

Note: Environmental Impact Assessment Methodologies. (EIA, 2011)

The figure shows the noise prediction map after reclassifying the range of noise level of subjective evaluation. The result indicates that overall period where in the morning, afternoon and evening fall in the range 60 - 80 dB (A) and evaluate as a loud category. The low range is fall in the range 40 - 60 dB(A) and evaluate as a moderate category, while the high range is a fall in the rang 80-100 dB (A) and evaluate as a very loud category.

CONCLUSIONS

There is some recommendation to be suggested for better presentation in this study. It can be the idea to be focused for a new research or make an improvement from the previous project.

i. Add point measurement at the field.

In this study, a total of 16 points is observed. To perform better presentation of interpolation map, the point distribution must be well distributed with an equal distance between each point. Control points to be added should be more than 30 points because it will influence the accuracy of interpolation method. The estimated value can be influenced by nearby points compared to the points that is located far away each other.

ii. Calibration of software apps more detail.

In this study, the calibration is done by determining the error of point measured at the same time is controlled and compared with the calibrated value from actual instrument of noise meters, SLM. The calibration is done only for the value of 94 decibels (dB) because it is only the calibrator available at the traffic lab at the Faculty of Civil Engineering. The calibrator is set to be 94 dB only and cannot be set to various sound levels. To get more accurate for the reading measurement, the sound level must be calibrated by different sound level interval so that it will show the trend of the sound level at each level more detailed.

iii. Add day of measurement

It is necessary to see the pattern of noise level for example, in a month period because to make an analysis require more sample data so that comparison can be made to see the consistency of data measurement.

iv. Use different types of mobile phone

When different types of mobile devices are used to collect data, the user can determine the best smartphone that can detect sound and the close reading with SLM instrument.

An overall analysis shows that the highest predicted sound level in the noise distribution map is influenced by several factor followed by the time period. The factor includes the crowded places surrounded by people and traffic noise. The crowded place occurred because of the public facilities

existing in UiTM Shah Alam such as public transport, sport center, food court and academic zone. The movement of student and staff in the morning period seems to be slow because of different schedule started during Monday. When it comes to the peak time during lunch hour, the population becomes increase and change the pattern of distribution noise into noisier. The evening period becomes more crowded when the movement of people in UiTM is getting active. In the noise distribution map of three periods, overall noise level achieved in the range of moderate category by subjective evaluation classification.

Requirement of apps is identified after an experiment is carried out and the guideline of the apps should be followed so that all data can be collected easily without any obstacle. The main requirement to be focused include the smartphone use and their function. Internet and GPS must be well functioning as well as the sound to be detected by phone. The NoiseTube apps must be installed properly to the personal account created by the user so that data can be stored safely on the web server.

Crowdsourcing can be used to collect data as near real time with location tagging and low-cost instrument. In addition, calibration is required to make the better result because without calibration, the value of noise level of mobile device was different from SLM. To visualize the observation points as the area, interpolation is considered to generate the map. For IDW, Kriging and CoKriging, they are evaluated by considering RMSE. From that result, it shows that cokriging can generate the less error when comparing with IDW and Kriging.

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A FIELD STUDY OF INDOOR AIR QUALITY IN A TROPICAL REFECTORY

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ABSTRACT

A refectory is the building area in educational institutions where meals and beverages are served. Since these areas are often occupied by a large number of students and staff during mealtime, the provision of good indoor air quality (IAQ) is of utmost importance. To supplement the available information about conditions of indoor air in many building areas which have been reported in other studies and to identify the levels of indoor air parameters (IAPs) in a Malaysian refectory, a field study has been carried out in a local university using electronic environmental monitoring sensors and questionnaire survey and the results are reported in this paper. The mean air temperature and concentration level of the carbon dioxide gas were found to be higher than the acceptable ranges stipulated in both DOSH and ASHRAE IAQ standards, while other IAPs were generally within the recommended levels. The split air-conditioning units, albeit installed near the dining zones of the refectory, were found to be inefficient at removing the occupant heat gain during peak hours and provided very limited ventilation effectiveness since there is no fresh air intake for this type of air conditioner. High prevalence of sick building syndrome (SBS) was also found in this building area, possibly due to the high occupancy levels. Increased ventilation with the aid of exhaust fans and retrofitting of the existing air conditioning system to a centralised one were required to lower the CO_2 level as well as removing other airborne contaminants.

Keywords: *Refectory, educational institutions, indoor air quality (IAQ), indoor air parameters (IAPs), field survey, ventilation*

INTRODUCTION

Given the fact that human spend most of their time indoors (Klepeis et al., 2001), a good indoor environment is essential to maintain the comfort, safety and health of building users. Therefore, many experimental studies on indoor air quality (IAQ) and occupant comfort conditions in offices, laboratories, classrooms and other building spaces have been carried out since decades back (Ehsanol et al., 2012; Asadi and Hussein, 2014; Travers and Vogl, 2015; Yousef et al., 2013; Kwong et al., 2014; Rawi et al., 2014). Some of the main parameters that affect indoor air conditions are air temperature, ventilation rate, humidity level and concentration levels of both chemical and biological air pollutants, which would in turn affect human comfort, productivity and learning ability (Kumar and Fisk, 2002; Kosonen and Tan, 2004; Karimipanah et al., 2007; Yu et al., 2009, Frontczak and Wargocki, 2011). As most modern buildings are well insulated and tightly sealed for the protection of occupants, the use of mechanical ventilation equipment to reduce concentration levels of pollutants become inevitable in various places around the world (Lin & Chen, 2014; AIHA, 2015) and the importance of ventilation towards controlling the concentrations and exposures released by indoor sources was also reported (Nazaroff, 2013). However, some previous works had identified the prevalence of sick building syndrome (SBS) in air-conditioned spaces at which some health related issues and dissatisfaction

towards the existing IAQ were reported by the occupants (Mui et al., 2011; McGill et al., 2015). Sekhar and William (2004) specifically noted that air supply volume, location of supply and return air plenums, space design and heat sources had significant impact on IAQ in tropical buildings. Besides, old malfunctioning air conditioning system was found as one of the major reasons for poor IAQ in buildings (Hirshberg, 2011).

A refectory or cafeteria is a dining area located within academic institutes with several unique features compared to other building areas: it is usually designed to accommodate a large number of consumers during peak periods (recess and meal time) of a typical academic session and the occupants are generally exposed to a higher level of air pollutants in this area, as cooking is considered as a major source of producing indoor pollutants in the form of exhaust particles (Sofuoglu et al., 2015). Lee et al. (2001) found that the air contaminant levels were significantly higher at locations where cooking activities were held, and different cooking methods may have different impact on the quality of indoor air. The environmental conditions in the kitchen had been found to be closely related to the respiratory symptoms of the workers (Svendsen et al., 2003). Therefore, setting up partitions to separate the cooking area with other zones has been found to be effective in preventing the spread of the air particles generated by cooking (Zhao et al., 2010). Besides, the effectiveness of the mechanical ventilation systems installed at a food centre in a tropical country was studied and poor thermal environments were identified in several locations (Wong et al., 2006). A more recent study has found that the equipment used in the cafeteria often contributed to the increase of heat gain, which may lead to thermal discomfort among occupants (Zainuddin et al., 2014). Although the abovementioned studies have pointed out the issue related to IAQ in the eateries, the current information on the indoor air conditions in tropical refectories is lacking, which proposed that more work in this field of study is required.

Since indoor contaminants are among the many factors that lead to poor IAQ, experimental studies on IAQ often focus on determining the levels of important indoor air parameters (IAPs) and also the occupants' opinion. This paper examines issues related to indoor air conditions in the main refectory of a local academic institute. The major indoor air parameters (IAPs) were measured in a series of field measurements and occupant perception of their immediate surroundings were also studied. Based on the results obtained from field surveys, recommendations were made for the improvement of indoor air conditions in this building type.

DESCRIPTION OF THE REFECTORY UNDER STUDY

The selected refectory is a part of the administrative building of a local university, which is conveniently sited at the heart of the campus. It provides a diverse catering service to over 200 students and staff at one time. The building layout is a multi-concept plan and is divided into two sections – the air-conditioned indoor area where the kitchen, food serving stations and eating areas were located and the naturally ventilated outdoor space where independent stalls were set up. The main area of the building is concentrated on the right side, which is the indoor section. The dining area consists of both indoor and outdoor areas, circulating the row of food stalls and catering serving counters. Other services like cleaning and kitchen are placed indoors. The semester opening hours of the refectory are from 8.00 am to 5.00 pm and served breakfast, lunch and evening meals. The main entrance is located at the right side of the building. Besides, there are two sub-entrances located between the indoor and outdoor sections of the building, but only one is accessible. Although ceiling mounted air conditioners are available in the refectory, not all units are switched on during the air sampling period. Three windows are located near to the entrance doors and were kept closed throughout the field survey due to the use of air conditioners. The indoor environment of the refectory is shown in Figure 1. Since this academic institution is a public one, smoking within its compound is strictly prohibited.

Figure 1: Indoor environment of the refectory under study

METHODOLOGY

The methodology of this study (as presented in Figure 2) was developed based on the recommendations in IAQ standards and guidelines. In this work, only the IAPs at the interior (air-conditioned) part of the refectory were measured as that was the area where cooking activities were carried out and most of the consumers were seated. A pilot study was first carried out to identify the existing air conditions in the refectory. After that, four measuring points at the dining areas were selected so as to identify the levels of IAPs at different locations, as highlighted in Figure 3. Two of the measuring points (L1 and L4) were nearer to the entrance doors while the remaining points (L2 and L3) were more confined.

Two indoor environmental standards were referred to in this work – ASHRAE Std 62.1 (2016) and DOSH ICOP (2010). ASHRAE Std 62.1 (2016) specifies minimum ventilation rates and other measures intended to create an indoor environment with acceptable IAQ for the occupants and this standard has been widely used by mechanical consulting engineers, building contractors, architects and government agencies worldwide. For instance, this standard specifies that the concentration of interest of the Carbon Monoxide (CO) gas is 9 ppm (8-hour observation period) and Carbon Dioxide (CO2) level in indoor rooms should be controlled below 700 ppm. A sample questionnaire form is attached together with the code so that industrial hygienists/ building engineers can use it freely to assess the quality of air in the interior spaces. On the other hand, DOSH ICOP (2010) is a code of practice introduced by the Department of Occupational Safety and Health, Malaysia to ensure that workers and building occupants are protected from poor IAQ conditions that could adversely affect their comfort, safety and well-being which would in turn lower their productivity. The acceptable ranges of IAPs are listed in this code of practices, as shown in Table 1.

In this work, four IAQ monitoring instruments - Direct Sense-IAQ, VOC meter, HCHO sensor and handheld CO-CO_2 meter were used to measure the IAPs with an 8-hour observation period The instruments were positioned at approximately 1.0 meter above the floor level at the selected measuring points from 9 am to 5 pm daily during the field survey period, following the requirements stated in the standards mentioned above. A questionnaire survey was carried out concurrently to assess the perceptions of consumers towards their immediate surroundings. Consumers were selected randomly in this case study as it was difficult to determine the occupancy duration of each individual, but the majority of the respondents were those who had just finished their meals and those who were standing up waiting to pay for their dishes. Field data were checked and compiled daily for analysis purposes.

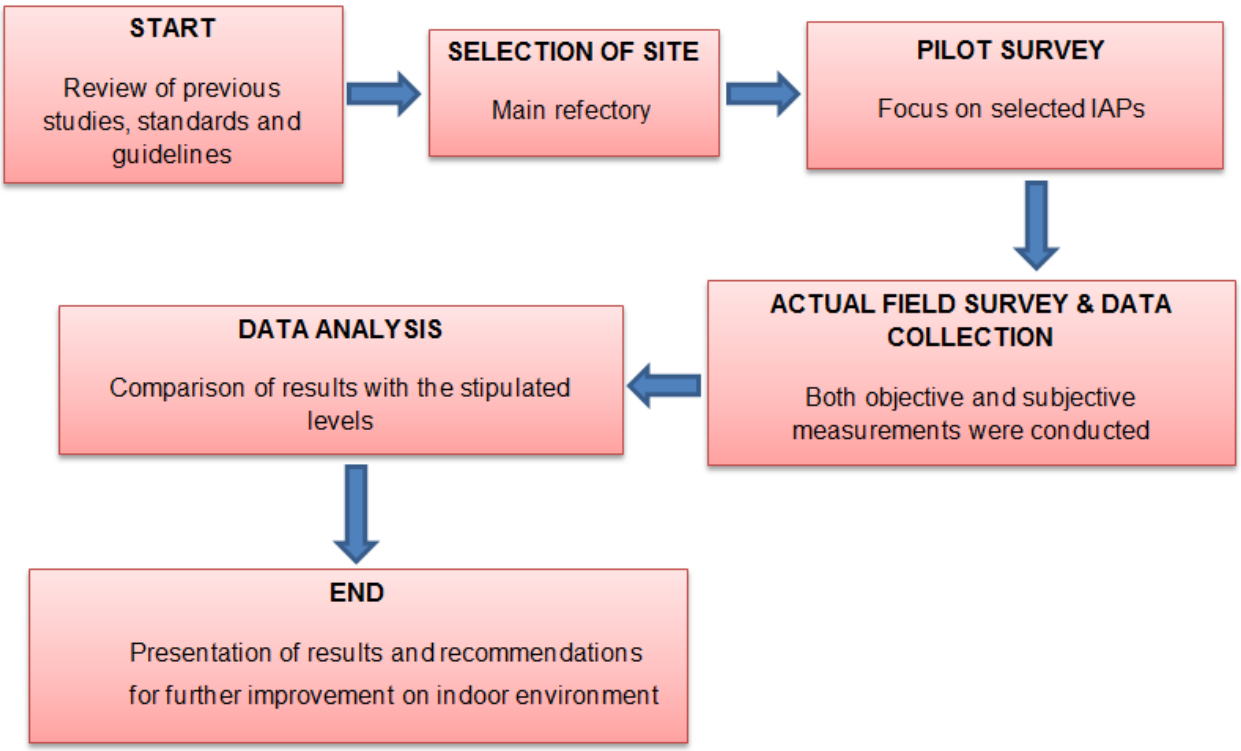

Figure 2: Methodology flow chart

Table 1: Major indoor air contaminants and threshold limit values (DOSH ICOP, 2010)

Indoor Air Contaminants	**Acceptable Limits**	
	ppm[3]	mg/m^3
Chemical Contaminants		
CO	10	-
TVOCs[1]	3	-
HCHO[2]	0.1	-
Particulate Matter (PM)	-	0.15
Ventilation performance indicator		
CO_2	*C1000	

*Ceiling limit that shall not be exceeded at any time
[1]Total Volatile Organic Compounds
[2]Formaldehyde
[3]parts per million

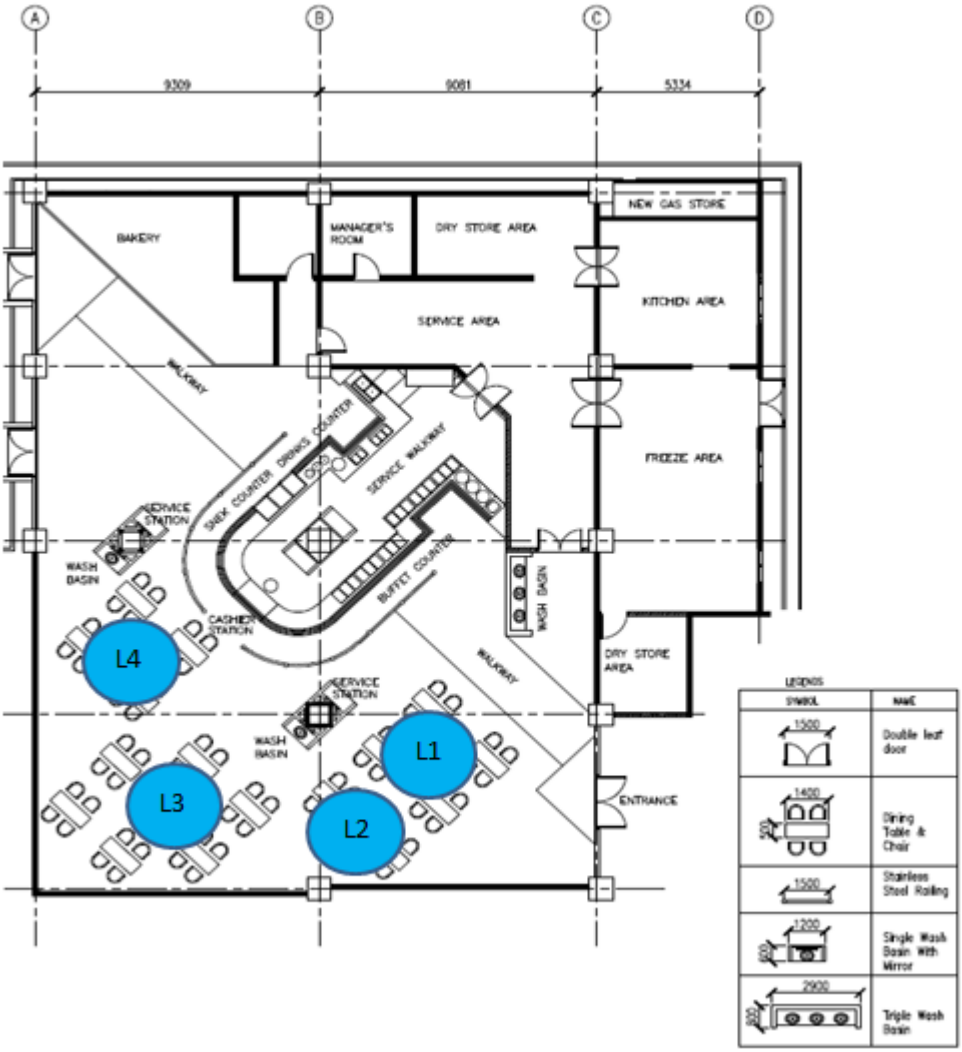

Figure 3: Locations selected for data collection

RESULTS AND DISCUSSION

Physical Measurements

The measurement of IAPs was carried out in September to October 2016 in the main refectory of an educational institution in Malaysia. Each day of the field survey was dedicated to one measuring location (as shown in Figure 3) and no repetition of measuring work at the same location was performed in this work. The measurements targeted CO, CO_2, HCHO, VOCs, air temperature, air velocity and relative humidity levels only.

Carbon Monoxide

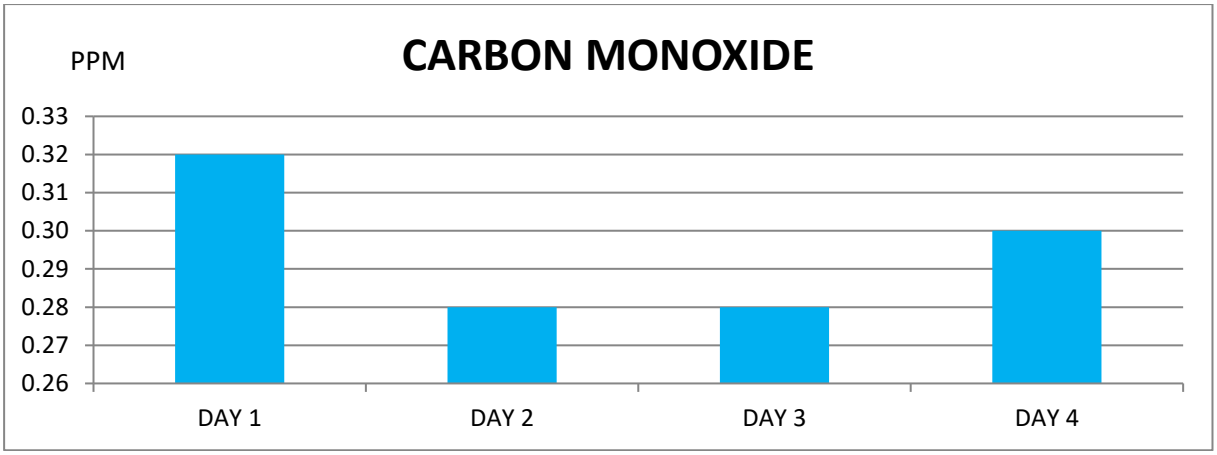

Figure 4: Mean concentration levels of Carbon Monoxide in the refectory

CO is the by-product of incomplete combustion. Figure 4 presents the measured CO concentration levels during the air sampling period. It can be seen that occupants at location 1 of the refectory were exposed to the highest mean CO concentration level of 0.32 ppm, while slightly lower CO levels were recorded at other locations, ranging from 0.28 ppm to 0.30 ppm. This finding shows that the level of CO concentrations in the refectory was within the acceptable range stipulated in both ASHRAE Std 62.1 (2016) and DOSH ICOP (2010) and one of the reasons for this was that there were no barbecue style cooking and food boiling near to the measuring points, as these two cooking methods can generate a substantial amount of this harmful gas (Lee et al., 2001). Besides, the parking area for the university staff was not located nearby and thus the indoor area was not affected by the exhaust gases produced by automobiles. The only food station that sells grilled sizzling food was located at the exterior part of the refectory, which was quite a distance away from the measuring points.

Carbon Dioxide

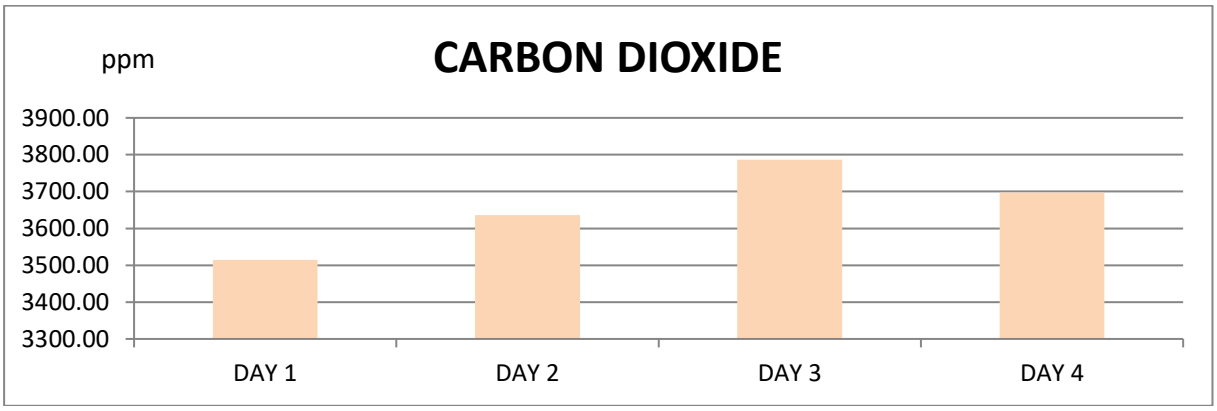

Figure 5: Mean concentration levels of Carbon Dioxide in the refectory

From Figure 5, the highest mean concentration level of CO2 was found at location 3 of the refectory, where a concentration level of 3787 ppm was recorded. The concentration levels of this greenhouse gas at other locations were also high, ranging from 3514 to 3697 ppm. According to ASHRAE Std 62.1 (2016) and DOSH ICOP (2010), the level of carbon dioxide should not exceed 1000 ppm so as to ensure that the majority of people entering a space will be satisfied. This finding reflects the field survey outcome reported by Lee et al. (2001), which also found that the CO2 level of restaurants in Hong Kong exceeded the threshold limit specified in the local IAQ guideline. Among the factors that lead to this elevated CO_2 level were the high occupancy during meal time and insufficient ventilation, since the current air conditioning system only circulated the indoor air without any provision of fresh air. Hence, the proposed mitigation strategies include providing higher ventilation rates by retrofitting the air conditioning system into a centralised one to allow fresh air to be supplied to the inner dining areas

(Location 2 and 3) and allowing more openings to be made in the refectory to enhance natural ventilation especially at location 1. The site observation showed that exhaust fans can be installed in the wall area between location 3 and 4 to enhance the contaminant removal effectiveness. A previous work has also concluded that the loss of occupant productivity in office buildings was often affected by the level of airflow rate (Kosonen and Tan, 2004).

Volatile Organic Compounds (VOCs)

VOCs are chemical contaminants that are emitted by several indoor sources like paints, aerosol sprays, cleansers, air fresheners, sealants, adhesives, partition boards and office equipment. Many sources have reported that VOCs can easily enter the air and cause various SBS, which include headache, shortness of breath, nausea, dry and watery eyes, flu-like symptoms and others. During the field measurement, the readings of the electronic sensor showed no sign of this indoor gas within the refectory. The main reason for this was that this location was unlike office spaces where large numbers of equipment are available. The only possible sources of VOCs were the detergents used for floor and table cleaning, which were only carried out after operating hours and no measurement was held. Moreover, this area has been in use since the past decades and there was no recent renovation or repainting of the interior walls.

Formaldehyde (HCHO)

HCHO is a type of VOC and is widely used in manufacturing domestic products, such as furniture and other household items due to its abundance and low cost (Hirshberg, 2011). New building materials and household equipment often emit HCHO gas at different rates. In this study, a separate handheld electronic sensor was used to measure the HCHO level because of the limitation of the VOC meter, which used a photoionisation detector (PID) that was not able to detect HCHO gas. Similar to the VOC, it was found that the HCHO level was significantly lower than the prescribed value in DOSH ICOP (2010). Most of the time the samples were below the equipment detection limit. The level of HCHO measured in the refectory was within the range of 0 – 0.01 ppm, which is negligible. Therefore, it can be concluded that both VOCs and HCHO levels were generally very low in the refectory and do not pose any major health threat to the occupants.

Air Temperature

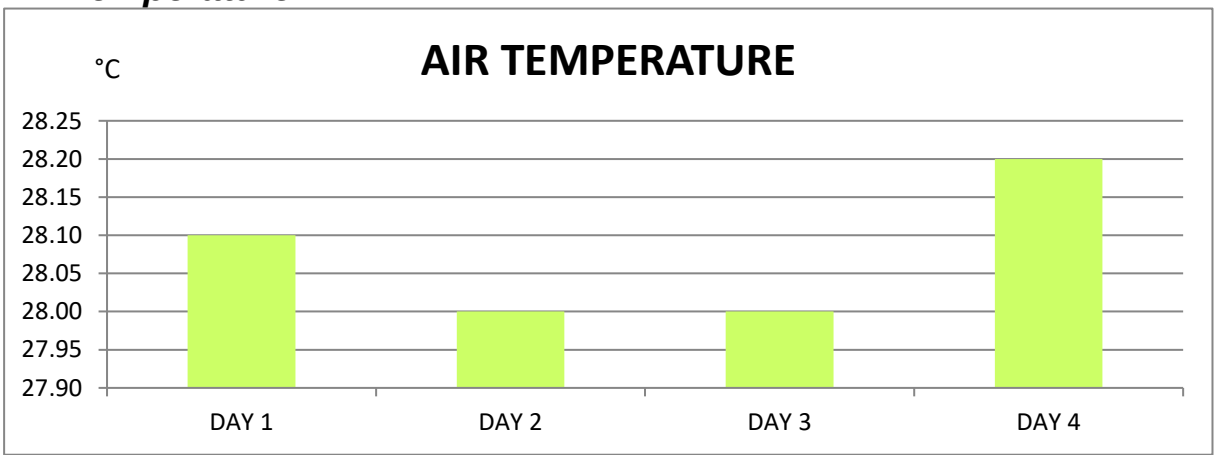

Figure 6: Measured mean air temperature

Good distribution of air flows in buildings is important for overall IAQ improvement (Clements-Croome et al., 2008). The range of air temperature in the refectory is presented in Figure 6. It was identified that the warmest place within the refectory was at location 4, at which an average temperature of 28.2 ^{o}C was measured. On the other hand, location 2 and 3 had the lowest mean temperature where the mean air temperature at both locations was about 28.0 ^{o}C. The results also showed that the air

temperature was higher than the recommended temperature range of 23 – 27°C in DOSH ICOP (2010), which may cause thermal discomfort among occupants. It was found that some of the air conditioning units were not functioning properly during the field survey, where an increase of air temperature was observed during peak hours. Therefore, there was need to retrofit the existing air-conditioning units in the refectory to provide a lower supply air temperature, especially at the dining areas. This suggestion was echoed by the results of a previous study, which proposed the use of additional air-conditioning unit to improve the thermal environment in an air-conditioned cafeteria (Zainuddin et al., 2014).

Relative Humidity

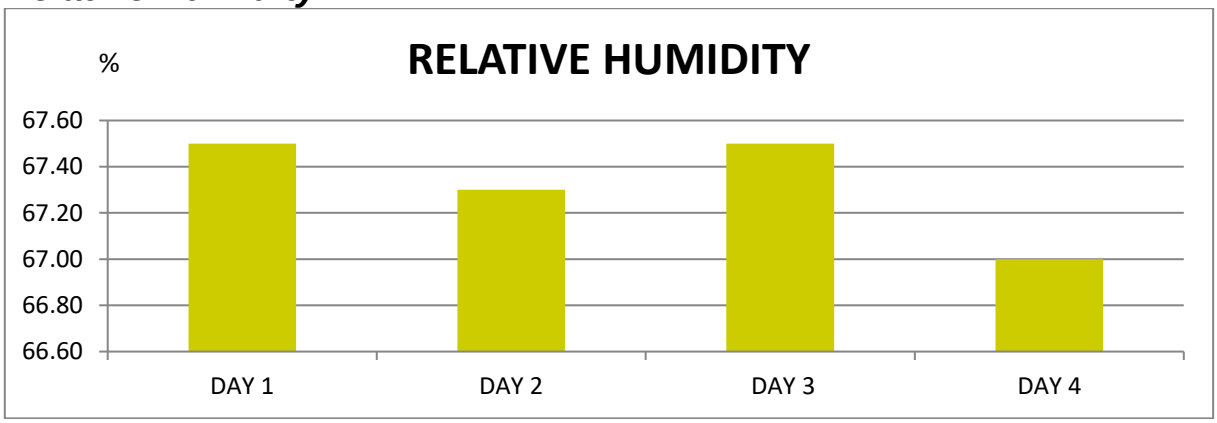

Figure 7: Measured mean relative humidity in the refectory

Occupants are often the main source of the increase of humidity levels in enclosed rooms due to both respiration and perspiration of the human body. Based on the data presented in Figure 7, the mean relative humidity level did not vary much and was within the range of 67.0 to 67.5%. This finding indicates that the relative humidity level in the refectory was within the acceptable range stipulated in DOSH ICOP (2010). Actually, this outcome was rather expected as the occupancy rate during each survey was about the same and during peak hours, almost all seats were taken up by the consumers.

Air Velocity

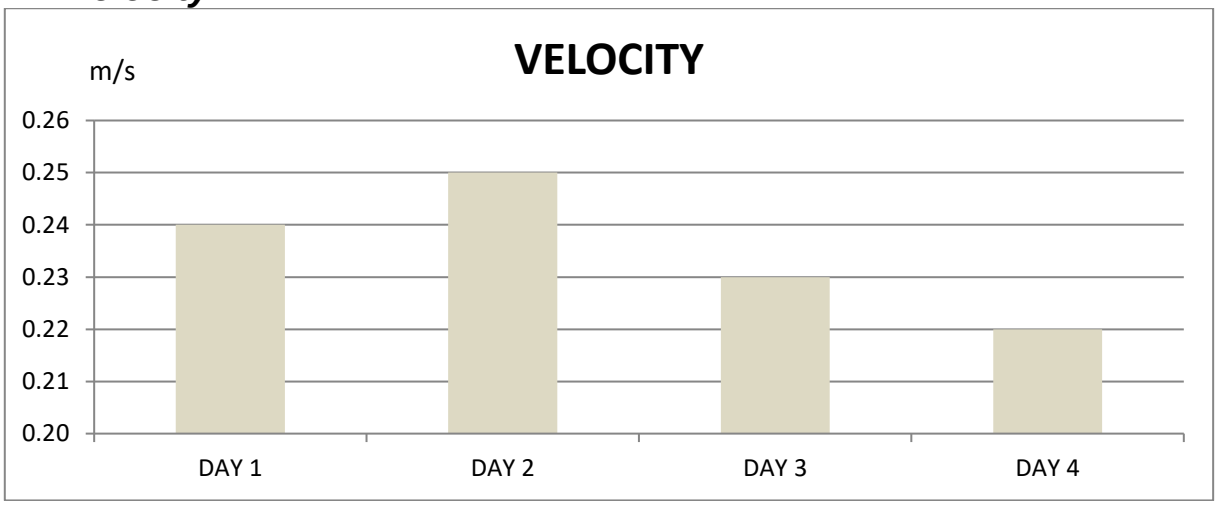

Figure 8: Mean velocity rates in the refectory

The air velocity in the refectory was within the acceptable range of 0.22 to 0.25 m/s, as shown in Figure 8. Referring to the IAQ standards, this range of air velocity was sufficient to provide a comfortable environment for the occupants and may compensate for the high air temperature during peak hours of a day. However, it should be noted that the air velocity near the food serving stations was not recorded in this case study since the placement of measuring equipment may obstruct the consumers'

queue for picking up food and to make payment. The architectural design of the refectory, which had a very narrow queuing path, had also limited the locations available for measurement.

Questionnaire Survey

The occupant perception of the indoor environmental conditions was studied in this work using questionnaire survey. Questionnaires were distributed during the peak hours only where almost all seats in the refectory were occupied. A total of 53 responses was collected throughout the field survey. The outcome of the questionnaire survey is tabulated in Table 2.

Table 2: Subjective response to indoor environment in the refectory

IAPs		**ASHRAE 7-scale Point**							
		-3	**-2**	**-1**	**0**	**1**	**2**	**3**	
Indoor Temperature	Cold	0%	0%	0%	33%	51%	16%	0%	Hot
Relative Humidity	Dry	0%	0%	46%	22%	32%	0%	0%	Wet
Air Movement	Still	0%	28%	43%	29%	0%	0%	0%	Draughty
Air Quality	Smelly	0%	31%	59%	10%	0%	0%	0%	Odourless

As shown in Table 2, most of the respondents found that their immediate surroundings were slightly warm, which concurs with the physical measurement results and therefore the air-conditioning supply air temperature should be lowered. The votes on relative humidity perception focused on the three centre categories of the scale, which was somehow expected because of the small variation of this IAP. As for the air movement, a large number of the respondents, especially those who were seated or standing near to the food serving stations, opined that the air was too still even when the air velocity was generally within the acceptable range stated in the IAQ standards. One of the obvious reasons for this was the crowded environment during peak hours, which directly resulted in restricted air movement. Furthermore, the vendor had to make sure that some of the food to be served while warm due to both hygienic and consumer preference purposes. Therefore, increasing the ventilation rate near the food stations may not be appropriate in this case. Other than that, the general perception of air quality also demonstrated the need for more air movement, since the majority of the votes regardless of the respondents' seating position was placed on the less desirable side of the comfort scale. Many of the respondents were seen either queuing or sitting close to each other because of the limited seats available in the refectory. Based on the findings obtained, the use of commercial electric fan can be considered at locations where low air velocities were measured so as to enhance the cooling effect, especially during lunch break where a sudden increase in occupancy level was observed. Besides, enhanced ventilation can be made through making more openings at the fenestration of the building, which allows more infiltration of outdoor air since people in the tropics were found to be more adapted to the warmer environment if more ventilation is available (Khedari et al., 2006).

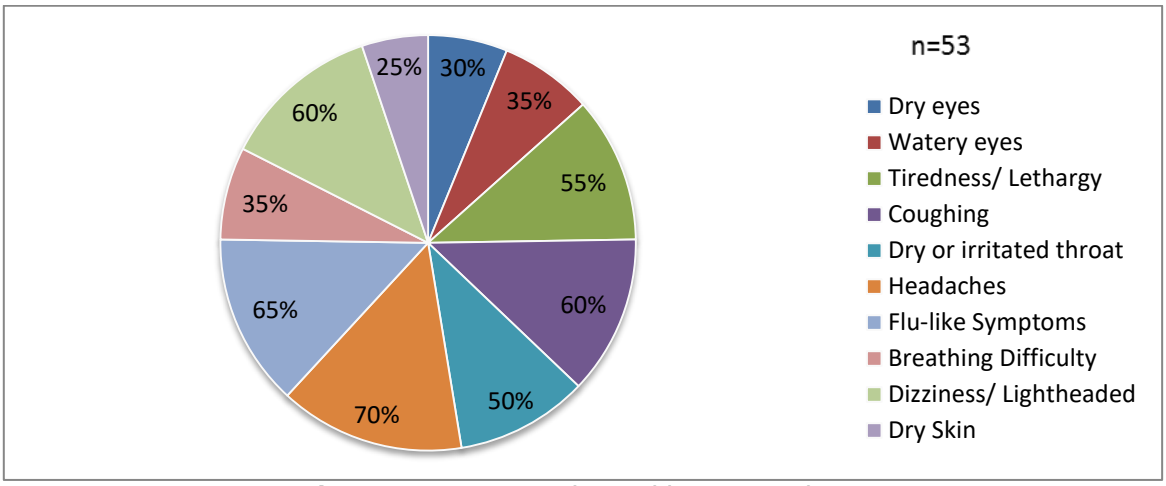

Figure 9: SBS experienced by respondents

The percentage of SBS encountered by the respondents in the refectory is presented in Figure 9. The respondents were allowed to choose more than one SBS that they were experiencing in the questionnaire form. The answers obtained showed that 70% of the respondents had experienced headache symptoms at least once during their visit to the refectory. Besides, 65% of them had also experienced flu-like symptoms, especially those who had chosen to sit at Location 2 and 3. Other symptoms include coughing and dizziness (60%), fatigue (55%), dry or throat irritated (50%), watery eyes and shortness of breath (35%), dry eye (30%) and dry skin (25 %) were also reported by the respondents. Such high percentages of occupant discomfort have demonstrated that the indoor environment was below satisfactory level and thus mitigation plans were required. Similar results were enunciated in other IAQ studies conducted locally, where the IAQ levels of selected office buildings in Malaysia did not meet the occupants' expectations (Kamaruzzaman and Sabrini, 2011) and the importance of using mechanical ventilation systems to improve IAQ was suggested (Sofian and Ismail, 2012). Although dilution of indoor contaminants by increasing the ventilation rate is the most common and practical approach, but this may result in higher operating cost of the buildings and hence further efforts on identifying this cost implication is needed. Since this work only focused on the four major air pollutants stated in DOSH ICOP (2010), more work is required to identify the concentration levels of other harmful gases as well as particulate matters in such food centres in Malaysia which are usually fully enclosed and cooled via mechanical means. There is also a need to conduct more detailed studies on the occupant perception of indoor air conditions, especially in building areas where high occupancy levels are anticipated.

CONCLUSION

Conditions of indoor air conditions play a significant role in governing human comfort, safety and health. The IAQ of a refectory in a local university has been assessed in this work. Measurements of the IAPs were carried out during an academic session in 2016 using IAQ sensors and questionnaire survey. The following conclusions were made based on the analysis of results:

i. The mean CO_2 concentration level was found to be higher than the ceiling limit, while the concentrations of CO were within the acceptable range stipulated in the local IAQ guidelines. This directly suggests the need for providing higher ventilation rates in the refectory under study, especially at the seating areas. A more detailed study targeting the ventilation effectiveness of such space can be considered.
ii. The concentration levels of other harmful air contaminants were found to be lower than the concentration ranges recommended in DOSH ICOP (2010). However, it should be noted that only the HCHO and VOC concentrations were measured. The concentration levels of other harmful gases, which include both biological contaminants and dust particles, were not considered in this work.
iii. The measured air temperature was slightly higher than that of the recommended comfort range. In order to create a more pleasant indoor environment, it was suggested that the supply air temperature can be lowered during peak hours of a day. Besides, although the air velocity was within the acceptable range, an increased ventilation rate could reduce the concentration levels of greenhouse gases in the refectory.
iv. From the subjective questionnaire survey, a significant proportion of the respondents were dissatisfied with the IAP levels and votes were directed towards hot environment, insufficient ventilation and poor air quality. This was possibly due to the crowded environment during peak hours, the need to preserve food temperature and insufficient dining spaces within the refectory.
v. The high prevalence of SBS in this study showed that the indoor air conditions need to be improved by introducing corrective actions such as retrofitting the existing air-conditioning system, allowing more openings to be made, using pedestal and exhaust fans at air stagnant areas and others. More work is needed to identify the presence of other harmful gases in the refectory which may affect the comfort and health of occupants.

ACKNOWLEDGEMENT

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REDEFINING URBAN ASSESSMENT CRITERIA TOWARDS SUFFICIENT FUTURE CITIES

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ABSTRACT

Urbanized areas are typically the most significant sources of environmental degradation, thus, an urban assessment criteria tools aiming at sufficient/self-sustain of the natural environment needs to be firmly embedded in benchmarking planning and design framework. The theoretical model of Sufficient Future Cities (SFC) criteria framework of both qualitative and quantitative evaluation and benchmarking will be develop toward urban sufficient/self-sustain. The SFC sets out a vision for sustainability within the built environment and provides guidance to deliver sustainable townships through six primary dimensions of environmental design and planning. The SFC framework runs on four primary methodology process and sequence in order to optimize urban sufficiency and self-sustaining criteria. Even though the SFC framework is one of the many methods in which to evaluate and benchmark tools to be developed for a comprehensive sustainable township, the principal argument is that comprehensive sufficient/self-sustain is certainly possible if it is properly conceived and implemented through responsible urban design and planning developments.

Keywords: *sufficient, urban assessment criteria, cities.*

INTRODUCTION

The world is experiencing the largest wave of urban growth in history and this process is mainly a domain of developing countries. With approximately 3.4 billion people (in 2009), more than 50 percent of the world population living in cities and both human activities and the use of energy also concentrated in cities, the urban areas have become the root cause of orientating societies toward mass production, mass consumption and mass dumping of waste (Yantovski and Gorski, 2010). The mainstream of sustainable development was progressively developed through the World Conservation Strategy (1980), the Brundtland Report (1987), and the United Nations Conference on Environment and Development in Rio (1992). The aim of the World Conservation Strategy is to help advance the achievement of sustainable development through the conservation of living resources and provide policy guidance on how sustainable development can be carried out (IUCN, 1980) The concept of 'Sustainable Townships' are liveable places that meet the diverse needs of the community, both now and in the future (GBI Malaysia, 2010; McGregor & Roberts, 2010).

The need for integral systematic rating systems is recognized in order to evaluate the performance of Green Township and promote the regenerative development. However, the current available assessment framework is based on low carbon city (LCC) and low carbon society (LCS), the future of green township development should beyond LCC + LCS; and toward zero carbon and regenerative city. The idea of sufficient and sustainable modelled on 'bio-mimicry' regeneration system is way to the future. In recent years there has been a proliferation of urban regeneration initiatives focused on the health and

well-being of urban citizens and the urban fabric – the 'inner-urban environment' (Girardet, 2010). While major sources of environmental degradation, deterioration, and depletion on Earth are irrefutably embedded in urban areas there appears to be an unjustifiable absence of research and development aiming for the comprehensive sufficient / self-sustaining criteria of assessment framework through improved urban planning, management and development.

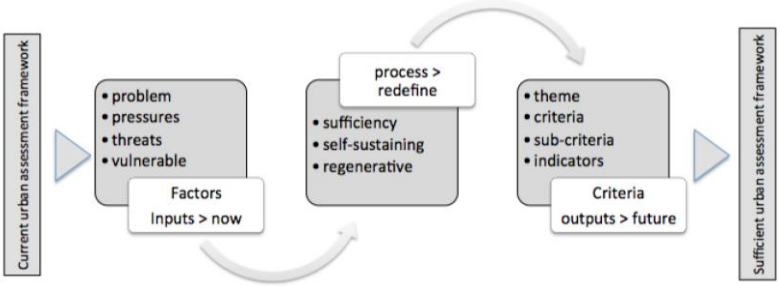

Figure 1: Development Process of Sufficient Future Cities Framework

LITERATURE REVIEW

Sufficient by definition is adequate for the purpose; enough: sufficient proof; sufficient protection. 2. Logic. (of a condition) such that its existence leads to the occurrence of a given event or the existence of a given thing. 3. Archaic. competent. A self-sufficient city is a defined perimeter, inside which lies a population that is self-sufficient: i.e., the economy within the city fully employs the population, and the services and cultural infrastructure within the city are sufficient supply for the population. As definition suggest, sufficient urban development meaning the ability of the cities to self-sustaining. A city which not depend on imported energy and resources from the hinterland. Hence, sufficient is regenerated own resources and beyond sustainable. The relationship of the terms is denoted as in figure 2. Regenerative and degenerative actions subdivided into conceptual diagram below;

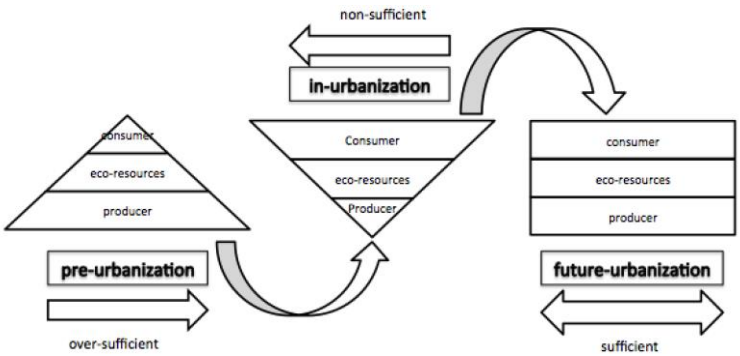

Figure 2: Sufficient concept of urbanization vs ecosystem service

The concept sufficient derived from basic ecosystem services (Figure 3), where the energy from sun is converted by producer (i.e.: plants, algae) into biomass energy or resources, then it was consumed by the consumer, the waste will be decomposed and go into inorganic nutrient pool whereby it was consumed by producer. This process of circular metabolism continues over-sufficiently in pre-urbanization and maintain the ecosystem services pyramid where producer is at the based, eco-resources at the middle and consumer at the tip. Urbanization somehow reversed the pyramid where consumer is bigger than producer, hence, non-sufficient and environment degrade. The future of urbanization suggested to be sufficient; producer, eco-services and consumer should be equal and balance, we cannot go back to the state of over sufficient pre-urbanization but at least we are not urbanized more than we should and need. Thus, urbanization have to be sufficient.

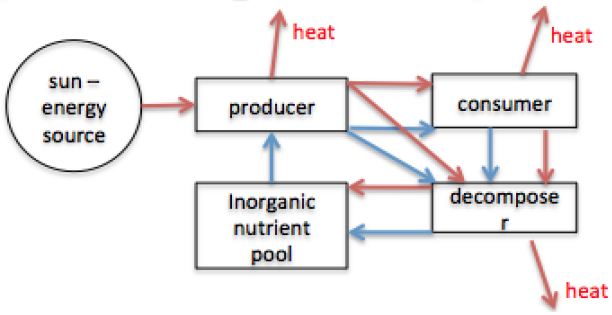

Figure 3: Basic Ecosystem Services

The city development scenarios and challenges today is no longer just to create sustainable cities but truly regenerative cities: to assure that they do not just become resource-efficient and low carbon emitting, but that they positively enhance rather than undermine the ecosystem services they receive from beyond their boundaries. A wide range of technical and management solutions towards this end are already available, but so far implementation has been too slow and too little (Girardet, 2010). The current approach of how city works is very much linear in operation. This linear, open loop approach is entirely unsustainable. In an urbanizing world aiming for long-term viability it cannot continue. The environmental externalities of urban resources use can no longer be ignored. Unless we learn from nature how to create circular systems, an urbanizing world will continue to be an agent of global environmental decline.

Bio mimicry or emulating nature is how to moved forward. Bio mimicry is an approach to innovation that seeks sustainable solutions to human challenges by emulating nature's time-tested patterns and strategies (Benyus, 2002). Similar to nature's organisms, cities as 'eco-technical super-organisms' have a definable metabolism – the trans- formation of resources into vital functions (Girardet, 2008). Nature essentially has a circular zero-waste metabolism: every output by an organism is also an input, which replenishes and sustains the whole living environment. In contrast, the metabolism of many modern cities is essentially linear, with resources flowing through the urban system without much concern about their origin, and about the destination of wastes. Inputs and outputs are considered as largely unrelated.

One of the primary tasks at the start of the 21st century is to try and map out what is necessary to create a sustainable city that emulate nature. The challenge is to find ways of making cities function differently from the way they do today without increasing the costs to financially challenged city administrations. The new task facing of city planners, engineers and managers, in close cooperation with the general public, is to create spatial structures that satisfy the needs of city people whilst also assuring their ecological and economic resilience (Girardet, 2004). Efforts consolidated need to provide secure habitats that allow people to move about in the cities efficiently, and the need to provide pleasant spaces for work, recreation and human interaction. What needed are urban environments that are free from pollution and waste accumulation. But also at the same time need to get to grips with the impacts of cities beyond their boundaries especially the medium that makes cities operable and functions. Cities should be seen as the places where solutions to the world's environmental and climate problems can most easily be implemented because as places where most people live closely together they have the potential to make efficient use of resources. It is also in cities where people interact most strongly and where key decisions, and particularly financial decisions, are being made all the time. This is where the concept of regeneration and urban forestry or an 'Eco-polis'; the ecologically as well as an economically restorative city (Downton, 2009).

The framework in determining the positions of green, sustainability and regenerative related to key terminology of below displayed. It is written in a simplified, clarified and depoliticized manners as three main listed terms;

i. 'degenerative': to decline in value or worth
ii. 'sustainable':3 to maintain; to keep from failing
iii. 'regenerative': to give new life, strength, or vigour

The tier-relationship of the terms is denoted as in figure below (Figure 4). Regenerative and degenerative actions subdivided into twofold spheres of activity on a gradient measure, with the point of neutral set at in between spheres where lies the concept of sustainability. Other used terms that are assigned with clear, simple definitions are: 'living': alive; having animation and vitality; not dead; and 'environments': surroundings or places.

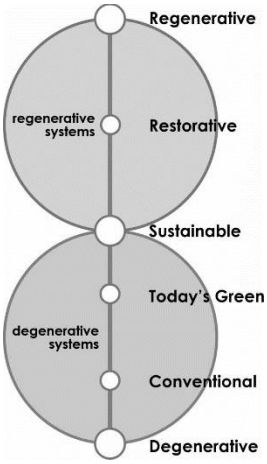

Figure 4: Degenerative and regenerative spheres. Source: Jossette, 2012.

The term living environments was used to avert the distinction concerning human centred, dominated environments and 'nature'. It is likely to be counterproductive to segregate humans and man-made developments isolated from nature. All dwelling environments comprise all or any kind of places. Be it a project of a one particular building, a path system in any national park, a swamplands restoration or a regional urbanization, it would all be life-supporting schemes (Reed, 2007 and Benyus,1997).

The conception of inter-twining sequential between green, sustainable and regenerative methods and viable transition from existing comprehension is the overall ideation of regenerative development. There are varies definitions of the term 'sustainability' used today, but the most conveyed concept is of where humankind is co-exist within the carrying capacity of the planet Earth (Gibberd, 2003). By virtue, therefore, the key notions in sustainability discussion will contain the ever-going relationship of mankind and nature systems. Sustainability by concept underpins; that people are integral parts of ecosystems and that a dynamic interaction exists between them and other parts of ecosystems, with the changing human condition driving, both directly and indirectly, changes in ecosystems and thereby causing changes in human well-being (Millennium Ecosystem Assessment, 2005).

The significance in assuring the condition and integrity of nature eco-systems and the adverse impact cause by human act on it is very vital. The main issues in notioning regenerative framework is as listed below;

> *Within the regenerative literature, 'sustainability' is often presented as an intermediate stage between green and regenerative – a 'neutral' state that, once attained, provides the necessary base condition that permits regenerative capabilities to evolve (McDonough and Braungart, 2002; Pedersen Zari and Jenkin, 2008).*

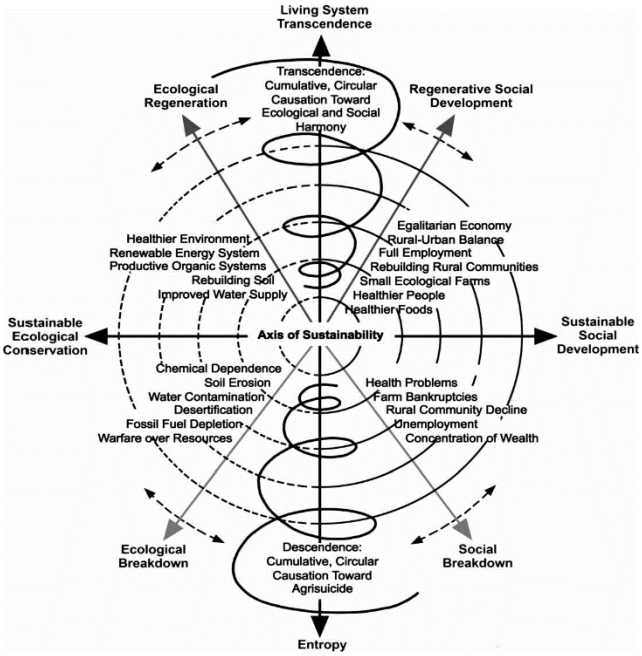

Figure 5: Living systems model of community development. Source: Larrick (1997)

Few frameworks were surfaced in an attempting to grasp the fundamental factors or citeria of regenerative conception. One of the earliest graphic on regenerative conception is by Larrick (1997), it offers a degenerative and regenerative processes and actions and their consequence for human and natural systems (Figure 5). Larrick statuses pre-eminence of ecosphere as the 'basis source of all benefits, thus of entire wealth' conclude that, the superseding goal of an ecological society must be to maintain the critical order of the natural world.

Larrick line-up of key significance criteria of regenerative concept in his model are:

- *The right and left halves of the framework represent the human and ecological domains respectively that must be brought into harmonious coexistence (Larrick, 1997).*
- *The lower and upper halves represent degenerative and regenerative actions and consequences. The degenerative consequences of consuming or polluting at rates greater than productive and assimilative capability speed up entropy. By contrast, the shift that both human and non-human life has made toward more complex and integrated levels of existence is premised on 'using unique regenerative powers to resist entropy' (Larrick, 1997).*

Larrick's model framework also suggests a basis to begin in defining regenerative conception, to clarify and position the green, sustainable and regenerative conceptual approaches (Jossete et al, 2012):

- Regerate - upper half circle of the ecosphere embraces the sustainable state, with an apparent recognition of the roles of ecological and social regeneration as necessary attributes, along with their harmonious co-evolution, required to attain it. Here, continual evolution through regeneration is presented as a primary requirement of sustainability.
- Degenerate - lower half characterizes an unsustainable state, where human activity has initiated degradation of natural systems. Provided Larrick's model conviction regarding the dependence of human 'wealth' on the 'critical order of the natural world,' both increasingly degenerate.

Green township planning and design is a compulsory consideration in reducing this degeneration. As therefore, it's practical to imply that both 'green', as presently delineated, and regenerative planning and development discourses are essentials to support the moulding of future cities concept. The outlining of the discussion of urban design as indivisible from sense of locale: place, conveys the insinuation that it is equally important, proviso not more than, to comprehend how development design, construction and purpose positively impact the social, environment and economic wellbeing of the context setting where it exist within it.

Within that context, this research is motivated by several driving questions:

i. At the largest outset, how can the sufficient future cities assessment framework be successfully developed and incrementally implemented?
ii. If such guiding sufficient framework is not aimed for, is it likely to ever arrive on its own?
iii. What are most significant urban framework assessment criteria on the environment?
iv. How can these criteria be implemented through urban redevelopment?

At this juncture, the necessities of sufficient assessment framework have to be brought to the forefront of contemporary academic as well as professional research and development. Overarching argument of this inquiry is that sufficient framework is not only theoretically possible but also practically feasible if it is responsibly planned and designed for. This research seeks to develop an economically, socially and environmentally balance and responsive approach to Green Township Indexing Criteria, i.e. Sufficient Future Cities (SFC) framework, by which the principles and strategies of assessing and benchmarking are positioned to facilitate sufficiency and self-sustaining criteria through incremental improvements in green urban indexing. The SFC methodology is conceived to address a critical yet currently non-inclusive aspect of Green Township Indexing Criteria, that is, an exclusive focus on the sufficiency and self-sustaining criteria through urban growth and redevelopment. While the SFC framework (Figure 6) is not the only possible venue to implement broad based and widespread sufficient/self-sustain criteria it does form a foundation not only for other urban research and developments to follow but also for countless other regenerative efforts to transform the current urban realities.

This research is to redefined and develop an urban framework based on sufficient/self-sustain criteria, which is intended to stimulate public policy as well as private implementation toward urban regenerative at varying scales of community development and urban redevelopment. The sufficient principles and strategies that shape the Sufficient Assessment Framework hold great potentials to provide feedback in public and private processes of policy- and decision making based on scientific analyses. Perhaps more importantly, these principles and strategies aim to incrementally bring neighbourhoods-scale redevelopments that will culminate in large-scale transformations of urbanized areas. The alternative – lack of regenerative action – is certain to lead to the future consequences of current development patterns, which do not aim at recovery or rehabilitation of natural balances within the living biosphere of the Earth.

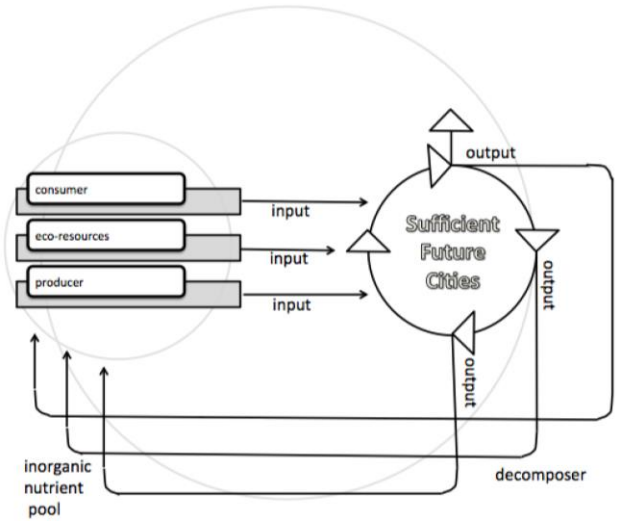

Figure 6: Conceptual Framework of SFC

RESEARCH DESIGN

The SFC Framework is designed to evaluate the key sufficient indexing criteria impacts of urban development by using Climate, Energy and Water (CEE); Ecology & Environment (EEC); Community Planning & Design (CPD); Transportation & Connectivity (TRC); Building & Resources (BDR) and Business & Innovation (BSI), as well as generation and consumption of food, energy, and wastes. Improving on the existing theory, knowledge, and technologies of green township indexing criteria, the sufficient/self-sustain methodology is intended to facilitate transformative contributions toward the comprehensive regenerative urban development through sustainable township indexing scores.

A. Methodology: Mixed Method Scenario Sequencing

The SFC Framework Assessment tools employs a mixed method scenario sequencing methodology that has been inspired by the green township framework and tools development (GBI, 2010) based on comparative analysis, expert focus group discussion, stakeholders survey forecast and pilot project studies. It also using estimated simulations using Building Energy Intensity Tools (BEIT), MS Excel, and Autodesk REVIT. The four mixed method scenarios sequencing of sufficient framework development are (See Figure 7):

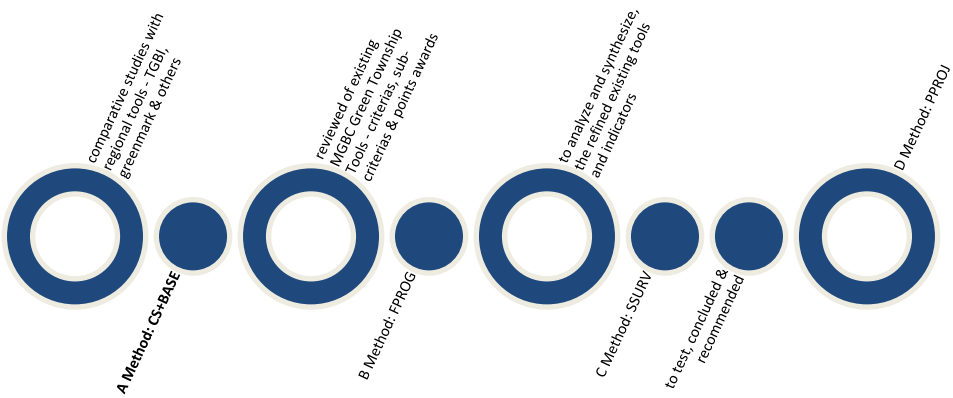

Figure 7: Final deliverables of Mix Method Scenario Sequencing

B. Data Analyses

Consistent through all six dimensions, the analyses start with comparative analyses in determining of criteria for CC+S Baseline (CS+Base) and beyond on all indicators (See Figure 5). This data set represents the baseline criteria, which can be either available criteria researched and compared to exist before or ideal or presumed conditions that are preferable (beyond CC+S or redefined sufficient). The indicators, which are simply not be applicable within a particular study area, may be either left out or assumed to be within normal range for analysis purposes. Second step is the collection of previous and present data representing the green township scoring impacts for the same set of indicators (See Figure 6). For the required and redefined criteria in Expert Focus Group Discussion Progression (FProg) method at least two reference states of criteria are needed, the baseline criteria and the beyond. These reference states are flexible, however, they are expected to represent the refinement and sufficient shift from recent available tools conditions and suggest regenerative principles and values. At this stage the SFC Framework Tools development is preliminary draft.

And, upon, as for the present stage, the preliminary draft will be available for end users and stakeholders perceptional appraisal and comments. Targeted qualified green township industry stakeholders are the policy maker (public authority), building professionals and other similar professionals involved in an urban development projects. When there are gaps in the available data appropriate statistical methods can be applied to interpolate the lacking data. The Stakeholders Survey (SSurv) method is estimated by non-regression analyses based on the data from stakeholder perceptional survey conditions (See Figure 5). The calculated values from these analyses provide a valuable input on applicability and workability of preliminary draft tools that are used for the purposes of evaluating results and optimizing sustainable township indexing scores. The Pilot Project Projection (PProj) method is to appraised the workability, to test and commissioned the redefined Green Township Indexing Criteria based on Sufficient Future Cities Assessment Frameworks. The differences sustainable township indexing scores between the existing tools and newly developed tools are targeted for minimization and offsets. The sufficient criteria conditions are determined by the level of minimization and offsets applied in this step, thus suggest for future recommendation.

C. Data Collection, Interpretation, and Application

This research is conceived to rely almost entirely on secondary data and is not intended to collect or generate new primary data in the form of traditional surveys or questionnaires. Generation of new data is typically limited to data obtained from presumed conditions that are preferable (beyond CC+S or redefined sufficient) of from the BEIT software calculations and reports in the modelling/simulation process. The GBI Indexing data for the indicators analysed in the SFC Framework are typically supplied by freely accessible, non-classified, online public sources. Some of the most popular ones include Ministry of Science, Technology, & Innovation (MOSTI), Ministry of Natural Resources & Environment (NRE), Department of Surveying & Mapping (JUPEM), Malaysian Institute of Planners (MIP), Malaysian Green Building Confederations (MGBC), Singapore BCA Greenmark, Thailand Green Building Institute (TGBI), Geo-Data.gov, data.gov, esri.com, and so forth. Depending on the location of the study area, it is possible to run into breaks and gaps in the coverage of publicly available data, in which case statistical estimations may be utilized.

In addition to the norms and standards reported in the published literature, the SFC Framework development relies on secondary data for most of its data analyses. There is ample amount of public green township indexing data electronically and digitally available to be used for comparative analyses as long as the selected case studies fall within well-developed metropolitan areas. Majority of local jurisdictions i.e. city, county, or regional governments and planning organizations offer the kinds of data that SFC Framework requires. For most of the qualitative analyses in the SFC Framework, the need to collect new data through onsite measurements, focus group discussions, surveys, and/or via questionnaires. Open source secondary data such as online photographs, satellite imagery, and other

geospatial visualization are adequate for most evaluations. Nevertheless, a moderate level of difficulty in collecting, combining, and synthesizing appropriate parcel data for the entire study area is to be anticipated.

D. Application of SFC Assessment Framework: A Pilot Study

The application area of the SFC Assessment Framework can show significant and appraised the workability of the developed tools. From a theoretical urban regenerative perspective, of course, the more advanced assessment criteria the better outcomes will be for future urban development. The breadth and depth of real-world applications are also highly likely to be clouded by various social, cultural, economic, and political circumstances unique to each locality. The population, area, development density or demographic composition of the study area can be anywhere within a wide spectrum. While the actual size and locations of study areas are expected to be different typically there are several research advantages to selecting a large neighbourhood or a small township within a relatively well-developed metropolitan area. Studying these areas not only ensures the availability, reliability, and generalizability of inputs and outputs but also contributes to the spread of knowledge, experience, and expertise for sufficient/self-sustaining principles within urbanized development.

EXPECTED RESULTS AND DISCUSSIONS

The results of this research are expected to inform and improve the current assessment criteria in Green Township Indexing Tools in Malaysia. Following are a few ways that the expected results provide contributions to redefined Green Township Indexing Criteria.

A. Findings Data Analyses

The expected result upon the completion of the research is to identify, compare and understand the conception of sustainable township assessment framework for tropical climate region; to revise and develop sufficient township assessment criterias for tropical climate region and to promote and introduce the redefined (sufficient) Green Township Assessment Tools for future urban development in tropical climate region. In the criteria dimension analyses of the SFC Assessment Framework, the normalized or standardized scoring on each indicator is estimated for each parcel of the study sub-criteria under both CC+S Baseline (LC+Base) and expert focus group discussion progression (FProg) methods combined. During the consensus process, depending on the intensity level of scoring impacts in each sub-criterion, each indicator receives a numerical assessment score ranging from minimum 1.0 to maximum 8.0 where a score of 1.0 represents most basic applicable (closest deviation from baseline) and a score of 8.0 represents most intensive sufficiency (furthest approximation to baseline). The assessment criteria weight is determined by the standard weight factors assigned in the SFC Assessment Framework for each criteria indicator of the sufficiency requirement and refinement. The sub-criteria of assessment criteria and weighting determines the assessment scores for indexing classification.

B. Evaluation of Results

One of the most critical parts of this research is to redefined the criteria and the evaluation of assessment scores for each indicator via the CS+Base and FProg methods. Since the end goal of the SFC Assessment Framework is to produce a single set of green township indexing criteria for future urban development or redevelopments. The mutual consensus from these two methodologies are finalised and critically evaluated in order to determine which aspects of the redefined criteria can be optimized so that expected results from assessment score is optimum alas highly sufficient. All analysis is represented qualitatively in visual representation. The results from all indicator categories are expected to remain within the

sufficiency criteria spectrum, and to require a certain level of refinement in order to achieved high sufficiency scoring impacts. At this juncture, the sufficiency measures – such as increased efficiency in CEW, EEC, CPD, TRC, BRD and BSI – are introduced to mitigate the environmental impacts and improved urban sustainability

C. Optimization of Benchmarking Criteria Assumptions

The next important step in the process the optimization of benchmarking criteria assumptions and appraise workability of the PProj methodology. The initial evaluation results from the previous step are expected to be continually redefined until the most optimum sufficiency concept conditions – furthest to the baseline conditions – are achieved. The strategies to be used in optimization of benchmarking criteria assumptions can be found in a wide range of concepts that are in practice today, which focus on sufficient and self-sustaining of natural ecologies within urban development. Strategies most relevant to restoration can be found in Green Urbanism, Resilient Cities: EcoVillages, Eco-Cities, Living Buildings, Neighbourhoods and Cities, Regenerative Design principles.

The ultimate goal of sufficient and regenerative urban developments may cover beyond efficiency in climate energy and water such as aim for zero net carbon emissions – by maximising passive design principles, minimising the impact of heat island effect, minimising energy consumption, adopting onsite energy generation, utilising renewable energy technologies such as co-generation and micro-generation. It also suggests water neutral – through the reduction of mains water consumption, rainwater harvesting and greywater recycling. Sufficient urban development strives for environment and ecology conservation; the natural cycles and balances within urban ecology would be to integrate number of possible categories of plants and animals, which can naturally coexist within a well-balanced urban community. Cycles of growth from birth to decay in such urban ecology also needs to be carefully considered to approximate the natural cycles and balances as closely as possible. Environment and ecology criteria highlight sensitive to the needs of the local ecology & biodiversity and aims to preserve and enhance the ecological value of the natural environment. It assists in stabilising land – subsidence by reducing the impact of flooding and erosion. Reduction of consumption; Reuse and recycling of local resources; Green Infrastructure; Climatically appropriate passive technologies; Optimization of land uses and redevelopment (interconnectedness and compactness); Protection and rehabilitation of open space, farmland, grassland, and ecosystems; Expanding biodiversity, vegetation cover, wildlife species and habitats; Ecosystem restoration and integration in open lands, grasslands, watersheds, bioswales, wetlands; Minimization of non-renewable consumption; Reliance on local generation of renewable energies; Management of resources and wastes; Diversified modes of transportation (walkability, bicycle, streetcar, bus transit, light-rail, commuter, and heavy rail).

CONCLUSIONS

One of the key conclusions is expected to be the realization that sufficient assessment framework is not only possible but also highly achievable if properly adapted, applied, designed and planned for. This research is designed to heighten the future goals of ecologically responsive and environmentally responsible urban development practices. Another expected outcome is the development of a viable redefined green townships assessment tools for guiding and referencing environmentally sufficient urban agenda. And finally, through pilot project studies the SFC Assessment Framework is tested, commission and recommended for sufficiency significance and effectiveness. The sufficiency considerations include such significant interventions as management of urban growth and expansion, infusion of renewable materials and energy, expansion of open space and resource conservation policies despite formidable limitations and constraints. Improving on the existing theory, knowledge, and technologies of urban design and planning, the sufficient methodology is intended to make transformative contributions toward the comprehensive regenerative urban co-existence with natural environment, which aim to identify significant SFC Framework Criteria of Green Township, redefined scoring impacts & definitions originated in core criteria & sub criteria, form a cluster criteria of ecologically responsive and environmentally responsible urban development sustainable benchmark and

build a green township assessment tools of sufficient redevelopment.

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APPRAISING THE NEED TO STUDY ON THE FORMAT OF BILLS OF QUANTITIES

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ABSTRACT

There are concerns reported on various aspects of Bills of Quantities (BQ). This includes concerns over the BQ format that helps to organise and convey critical information to parties in construction. Although concerns over the BQ format are mentioned in various literature, these however have been highlighted in fragment. Consequently, there is limited opportunity to demonstrate its enormity, in justifying a study to be conducted. Therefore, by reviewing, analysing and synthesising various issues concerning the uses of BQ, this paper seeks to provide theoretical justification on whether a study to re-examine the BQ format is impending. In adopting to the issues-driven-approach, two objectives were outlined: (1) to critically review the literatures to identify the issues on the application of the BQ; and (2) to synthesise the outcome of the review process to identify relevant research focus. The study which had essentially employed an extensive literature review had synthesised three categories of issues related to: (1) information; (2) format; and (3) working methods. It was found that issues concerning BQ information have been mentioned more frequently in the synthesis. Following the approach, it implies that concerns over BQ format is not considered impending. Rather, a study to re-examine BQ information is much needed and may contribute by offering substantial improvement to the uses of BQ.

Keywords*: Bills of Quantities, Construction industry, Format, quantity surveying*

INTRODUCTION

The Bills of Quantities (BQ) itemise information collected from the process of measurement and provides the descriptions, quantities and information of items required in a contract (Kwakye, 1997). The BQ is unique to the Quantity Surveyor and could be used for many purposes. Among its main purpose is to provide the necessary information to the construction participants which according to Hughes (1978), Wilcox and Snape (1980) and Ashworth (2004) imperative to arrive at the following: (1) obtaining competitive tender; (2) serving as a contractual document; (3) uniform basis for tendering; (4) the basis for interim certificates and valuing of variations; (5) assisting the contractor in organizing his works; (6) facilitating financial control by the employer; (7) a basis for feedback of information for the contractor and (8) a data source for the Quantity Surveyor's future estimating. Hence, due to the purposes it serves, the BQ should be regarded as an indispensable tool for the management of a construction project and an important source of information in the process of construction.

In relation to the Malaysian construction industry, the BQ has been recognised as an important component in the overall process of construction. This was largely caused by the extensive domination of the traditional lump sum system of construction procurement

(Khairuddin, 2002, Khairuddin and Samer, 2014) which fundamentally placed the BQ as an integral element in its process (Jaggar et al., 2001, Seeley, 1997). Data from the Construction Industry Development Board (CIDB) shown in Table 1 indicates that the adoption of the traditional lump sum system (TLS) of construction procurement has been consistently strong. Hence, the data reaffirmed the representativeness of the BQ in the Malaysian construction industry.

Table 1: The frequencies on the use of TLS as compared to other types of procurement (2012 – September 2016 - latest)

Procurement types	Year/Percentage									
	2012	%	2013	%	2014	%	2015	%	2016*	%
TLS	7450	*94*	7685	*96*	7692	*96*	7060	*96*	3793	*97*
Others	442	*6*	355	*4*	333	*4*	284	*4*	106	*3*
Total:	7892	*100*	8040	*100*	8025	*100*	7344	*100*	3899	*100*

Source: Adapted from CIDB Quarterly Statistical Bulletin (CIDB, 2014, CIDB, 2015, CIDB, 2016). *Data as at Sept. 2016.

In the context of the Malaysian construction industry, the BQ is generally used for the purpose of tendering and contracting (Rosli et al., 2006, Rosli et al., 2008, Khairuddin et al., 2016). Besides this general use, the BQ could also be used to serve the industry in a variety of other purposes. According to Rosli et al. (2006), the use of the BQ could essentially be viewed from the perspective of the contractors, clients and consultants. To the author, the BQ is used to provide the parties with necessary information that enable them to manage the project effectively and pivotal as the base for making an informed decision. The facts thus situate the BQ as important and indispensable component in the process of construction.

Despite, there have been concerns reported on various aspects of Bills of Quantities (BQ) (Baccarini and Davis, 2002). This includes concerns over the BQ format that helps to organise and convey critical information to parties in construction (Kodikara, 1990, Khairuddin, 2011, Hamimah et al., 2011). Although concerns over the BQ format are mentioned in various literature, these however have been highlighted in fragment. Consequently, there is limited opportunity to demonstrate its enormity, in justifying a study to be conducted. Therefore, by reviewing, analysing and synthesising various issues concerning the uses of BQ, this paper aims to provide theoretical justification on whether a study to re-examine the BQ format is impending. Accordingly, two objectives were outlined: (1) to critically review the literatures to identify the issues on the application of the BQ; and (2) to synthesise the outcome of the review process to identify relevant research focus. The fulfilment of the objectives outlined in this paper has enabled substantial information to be gathered which allowed critical inferences to be made as the basis to support or refute the need to re-examine the BQ format.

Accordingly, this paper is structured to firstly review the development of BQ formats. This is followed by a review of issues that are affecting its uses. The paper ends by discussing important insights gained from the study as well as some recommendations for the stakeholders to consider.

METHODOLOGY

This paper has essentially employed an extensive literature review and applied techniques which are common in content analysis. According to Bowen (2009), the technique involves skimming, reading and interpreting the documents which according to Bryman (2008), necessary in searching-out underlying themes and omission in the materials being analysed. In

this paper, relevant literatures were reviewed to identify the themes in the form of issues before detail categorization is established to represent the aggregated information. The process was considered crucial in identifying the omission or gaps in the existing literature and act as the foundation which links the previous researches which were discrete in nature, into a single interwoven framework for suggesting the research focus aimed in this paper.

DEVELOPMENT OF BQ FORMATS

Prior to 1950s, the common form of BQ produced and used particularly in the UK has been in the form of trade format. As interest in cost planning grew, the Elemental Bill was introduced in which works are measured and organised into its functional elements. This bill however was far from being satisfactory (Seeley and Winfield, 1999). At the time, there were no standard elements to follow and different bodies had used different elements to produce the bill (Kodikara et al., 1993, Rose, 1956, Nott, 1963). In addition, the format which sorted dimensions under elements had resulted repetition of items across the billing elements. This had affected sub-quotation enquiries (Turner, 1983, Kodikara et al., 1993, Lee et al., 2011) and making pricing a time consuming process (Skinner, 1979).

Following the resentment, a Sectionalised Trades Bill was introduced in the 1960s (Nott, 1963). It aims to mediate the arrangement between the popular trade bill and the Elemental Bill. The Sectionalised Trades Bills were basically trade BQ with each trades sectionalised into elements (Kwakye, 1997). It retained its appeal as a trade BQ but at the same time, capable to be re-collated as an Elemental Bill for subsequent use in construction management (Kodikara, 1990, Skinner, 1979, Kwakye, 1997). Although it had removed the objections raised against the Elemental Bill, the industry implementation of this format had been reportedly poor (Kodikara, 1990, Skinner, 1979). It was summed up by the Quantity Surveying Techniques Working Party of the Cost Research Panel that neither bills appear to be amended to relate site costs to bill prices (Kodikara, 1990, RICS, 1962). Hence efforts were stalled without significant improvement to the BQ format.

Further development has coined for a new concept known as the Operational Bill (OB). It moved from the traditional concept of measuring works as it fixed in place to new concept which measured the labour and materials as a separate item in the bill (Skoyles, 1964, Skinner, 1979). In this regard, a scheme was divided in neither trades nor elements but in actual site operations shown with the aid of the precedence diagram (Skinner, 1979, Seeley and Winfield, 1999, Kodikara, 1990, Kwakye, 1997, Skoyles, 1964). In this concept, operation is defined as the amount of work that can be produced by a gang of operatives at some definite stage in the construction process without any interruptions (Skoyles, 1964, Kwakye, 1997, Seeley and Winfield, 1999). These were sequentially arranged and formed the basis of which information was structured in the bill (Skinner, 1979).

One of the major changes brought about by the OB was the separation between labour, materials and factory made components (Skinner, 1979). To illustrate, information on plant required was given together with the labour as a single description without quantities, while materials were given in a unit which corresponded to the contractor's purchasing units (Turner, 1983). These changes involved fundamental divergence from the rules of measurement prescribed in the SMM (Seeley and Winfield, 1999, Turner, 1983). This however was compensated with advantages posed to benefit the contracting organisations. The prime advantage from the OB was its ability to give the contractor's estimator as much information for the purpose of estimating (Skoyles, 1964). This was considered innovative and responded

to the needs of the contracting organisations. It was also lauded to include wider application apart from tendering which has been the BQ's only function.

However, the concept behind OB had received fairly little use (Wood and Kenley, 2004, Seeley and Winfield, 1999, Mohd Hisham and Azman, 2008) due to various issues. It was bulky and costly to produce (Seeley and Winfield, 1999) and the operational arrangement had required similar items to be repeated across the bill (Mohd Hisham and Azman, 2008). This seems to repeat the issue with the Elemental Bill. In addition to this, substantial works was involved in the preparation of drawings. It required conventional drawings to be prepared first before the designer could prepare the operational drawings (Mohd Hisham and Azman, 2008, Kodikara, 1990). This requirement has forced the designers to pre-judge the contractor's method of working which was not in accordance with the actual method (Turner, 1983). This hampered OB's implementation in the industry hence reduced its popularity.

In response to the criticism towards OB, an Activity Bill (AB) was later introduced. AB was an intermediary between OB and later the BQ in operational format (BQOF) (Lear, 1966). In terms of preparation, AB was a mixed between the traditional bill and that of OB (Lear, 1966, Skoyles, 1968b). Gradually, extensive works on AB has enabled BQOF to be introduced (Lear, 1966). In terms of measurement, items in BQOF were measured in accordance with the SMM. Subsequently, these items were billed in sections that were related to the network diagram. Therefore, the approach has retained the features of a traditional bill. This however had removed the separation between labour and materials which was the main feature of OB (Lear, 1966). Despite the changes, uptake was still reportedly poor (Skoyles and Fletcher, 1970). This implies that the industry at the time was not fully prepared to adapt to the changes introduced (Turner, 1983). Hence, this stalled further improvement towards the BQ particularly in aspect related to its format.

The period after BQOF saw efforts to improve the BQ were rather slowing. This was until 1983 when the British Property Federation (BPF) introduces a format called the BPF System (British Property Federation, 1983). In the new format, BQ was replaced by the Schedule of Activities (SOA) (Hodgetts, 1984, Kodikara, 1990, Seeley, 1997, Sierra, 1984). The SOA was prepared by the contractor by specifying and pricing all activities within the total programme (Kodikara, 1990). This was based on the idea that cost model is best represented by the contractor's work programme. It will align the documentation directly to how cost will be incurred on site, thus becoming the basis for planning and control (Hodgetts, 1984, Jaggar et al., 2001). Similar with other formats introduced, the BPF had received very little use (Ramus et al., 2006). This was mainly caused by mind-set issues and some technical problems (Kodikara, 1990). It was also considered too revolutionary to the existing practice in construction (Jaggar et al., 2001).

The effort to develop BQ format later came with the introduction of the Builder's Quantities in 1985 (Kodikara, 1990). This was developed by Pasquire and McCaffer (1985) and aim to suggest alternative to contract where BQ is not supplied as part of the tender document. Together with this, a complete set of measurement guidelines has been prepared to guide on the preparation of quantities. The format was similar to OB but with more advance features of operations, taking-off and buying units (Kodikara, 1990). To justify the operability of this format, field trials were conducted to gauge its performance in live setting. The result indicated that it was well received for contract without BQ and not for contract where BQ is supplied. Further records on this format were sparse, hence placing limit on the elaboration.

Regardless of this scarcity, more generic Builder's Quantities or better known as abridged bill has been mentioned and popular in Australia (Odeyinka et al., 2009, Slattery, 1994, Davis et al., 2009). This followed a drop in principal's sponsored BQ (Davis and Baccarini, 2004, Davis et al., 2009). Although an abridged bill is prepared without following any specific rules (Davis et al., 2009), the inception of BQ in this format indicate a strong desire to simplify the measurement process but at the same time, providing appropriate and sufficient information for tendering purposes (Davis and Baccarini, 2004). In the turn of the 21st century, extensive focus had shifted from proposing further alternative to the BQ to the idea for coordinated project information.

ISSUES CONCERNING THE USES OF BQ IN THE CONSTRUCTION INDUSTRY

Twenty-nine issues impeding the uses of the BQ were identified from various sources of literature as showed in Table 2. To facilitate interpretation, the distinct concepts that underlie the issues were defined, accentuated and reincorporated back in the list of issues identified from various sources of literature (Shamsulhadi and Fadhlin, 2014). In the process, the variables of 'concept identified', 'concern identified' and 'categories of issues' were featured to explicate the identified issues. This process helps in disclosing the gist of the issues and provides a preliminary appreciation on the category of issues embodied in the literature (Bryman, 2008). The process consequently allows the general topography of the issues to be viewed and highlight the pertinent concerns conveyed through the literature.

Following this, a thematic analysis is carried out by enumerating the frequency which certain accentuated concepts have occurred (Bryman, 2008). This is to reveal the predilections that have exaggerated certain number of concepts and disclosing any considerable weightage from the concepts. To assist with the thematic analysis, a word cloud as showed in Figure 1 is used to demonstrate the weight of the identified concepts. Accordingly, it shows that 'information', 'format' and 'methods' are the three most occurring concepts from the issues identified and presumably are the three main concepts by which the issues can be categorised. In relation to weightage, 'information' contain the most number of issues followed by 'format' and 'methods' respectively. The analysis implies that issues concerning 'information' pose a considerable concern with the uses of the BQ, hence suggesting a focus for consideration.

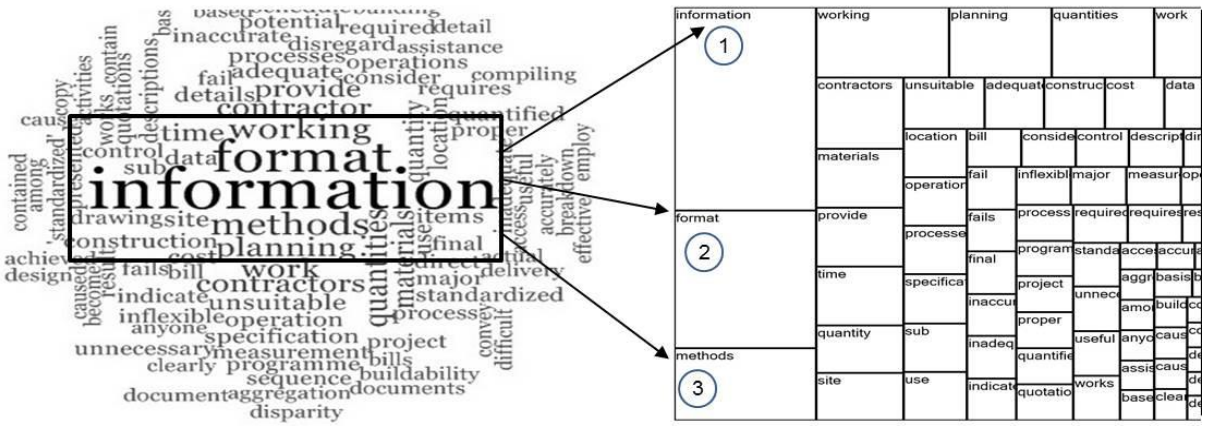

Figure 1: The main concepts underlying the issues identified from the literature

To relate the main concepts identified in Figure 1 with the array of issues concerning the BQ, the issues presented in Table 1 are restated to correspond with 'information', 'format' and

‘methods’. This is conducted within an interpretative context and aim to provide details that can describe the categories developed from the thematic analysis (Hart, 1998, Booth et al., 2012, Shamsulhadi and Fadhlin, 2014). The result from the process is presented in Figure 2. In this respect, pertinent matters related to quantities/quantities location/quantity units, BQ descriptions, material specifications, time, preliminaries and temporary works have described the concern related to ‘information’. The weightage implores that ‘information’ related issues have underlain much concern on the uses of the BQ. This in relation to two other categories prompted from the analysis. The analysis and synthesis carried out provided an insight to understand the issues hence denotes the theoretical framework on the issues impeding the uses of the BQ.

Table 2: The literature review outcome – issues impeding the uses of the BQ

No.	Issues identified from the literature review	Authors	Concept identified	Concern identified	Category of issues
1.	BQ ***does not provide*** **(*information)** on the (**time)** and quantity schedule for the on-site delivery of materials required for the works.	Hamimah et al. (2011), Smith and Hoong (1985)	Time/duration	Insufficient	Issues related to information
2.	BQ **(*information)** provide ***no assistance*** to anyone drawing up a pre tender programme **(*time).**	Contributed (1964)	Time/duration	Insufficient	Issues related to information
3.	BQ **(*information)** only represent cost breakdown structure with ***no link*** to actual project schedule **(*time)**.		Time/duration	Insufficient	Issues related to information
4.	SMM based BQ **(*information)** ***unable to provide*** a useful basis for contractor's work programme **(*time)**.	Jaggar et al. (2001), Smith and Hoong (1985)	Time/duration	Insufficient	Issues related to information
5.	***Preliminaries bill*** and ***specification*** **(*information)** documents ***contain many unnecessary*** **(*insufficient/ inadequate)** items as a result of direct copy and 'standardised' document.	Hamimah et al. (2011)	Preliminaries/ specification	Insufficient/ Inadequate	Issues related to information
6.	BQ ***quantities*** and ***descriptions*** **(*information)** ***do not accurately*** provide information on work sequence and ***contractor's methods*** of operation **(*working methods and planning).**	Hamimah et al. (2011), Leon (1966)	Quantities/descriptions/ working methods	Inaccurate/wrong quantities/Inaccurate description/ Insufficient	Issues related to information/ Issues related to contractor's work planning
7.	The specialist trades contractors consider that the ***tasks of planning*** **(*time)** ***could not be achieved*** by using the bills **(*information)**.	Morledge and Kings (2006)	Time/duration	Insufficient	Issues related to information
8.	BQ **(*information)** is ***unnecessary*** for ***compiling*** **(*format)** sub-contractor's quotations and is ***inadequate*** for reviewing materials quotations from potential supplier as ***quality of materials*** **(*specification)** are ***not clearly stated***.	Hamimah et al. (2011), Kinlay (1984b)	Specification/Unsuitable format	Inadequate/ Unsuitable	Issues related to information/format
9.	**(*Information)** in ***BQ are uncoordinated, aggregation on similar materials*** rather than ***operation*** **(*format and working methods)**.	Kodikara et al. (1993)	Unsuitable format	Unsuitable	Issues related to format
10.	BQ **(*format)** is ***not in final forms*** for direct use by site personnel.	Kodikara and McCaffer (1993), Kodikara et al. (1993)	Unsuitable format	Unsuitable	Issues related to format
11.	BQ **(*information)** ***requires sub-processes*** as the information are ***not presented*** in a standardised **(*format)**.	Cornick and Osbon (1994)	Unsuitable format	Unsuitable	Issues related to format
12.	BQ ***fail to become a mechanism*** to determine ***construction processes*** **(*working methods)**. It does ***not consider input*** **(*information)** to the construction process **(*working methods)** but only identifies the end result or product of construction.	Holes (1990), Jaggar et al. (2001)	Working methods	Insufficient	Issues related to contractor's work planning
13.	BQ ***only present*** (***information)** ***that have been processed*** and ***in final form*** **(*format)**. Detail **(*information)** such as supporting details on ***quantities measured***, ***work location*** and ***types of operations*** **(*working methods)** the contractors have to employ are of use by estimators should access is given.	Hamimah et al. (2011), Turner (1983), Wood and Kenley (2004)	Inflexible format/Quantities location	Inflexible/ Insufficient	Issues related to format
14.	BQ (***information)** had ***inadequacies for utilisation*** by contractors. **(*Quantities)** ***Location of quantified information*** was ***not adequate*** for its purpose.	Baccarini and Davis (2002), Wood and Kenley (2004)	Quantities location	Insufficient	Issues related to information

Note: Bold lettering/*italics* are the accentuated concepts and are reincorporated back in the list of issues.

Table 1: The literature review outcome – issues impeding the uses of the BQ (continued)

No.	Issues identified from the literature review	Authors	Concept identified	Concern identified	Category of issues
15.	BQ do ***not indicate*** **(*information)** as ***where the quantity is located*** **(*location)** and therefore ***difficult to get a feel*** for the projects from the bill.	Slattery (1994)	Quantities location	Insufficient	Issues related to information
16.	BQ ***disregard potential*** further value of reanalysing the **(*information)** into activities, operations or elements **(*format)**.	Kinlay (1984a)	Inflexible format	Inflexible	Issues related to format
17.	BQ **(*format)** is ***not adequate*** as it ***hinder effective use*** of **(*information)** contained.	Rosli et al. (2006), Smith and Hoong (1985)	Unsuitable format	Unsuitable	Issues related to format
18.	BQ ***fails to convey*** details **(*information)** of ***materials*** **(*specification)**, ***plants*** and ***temporary works*** required for ***proper work execution*** **(*working methods and planning)** and to enable those resources to be identified, quantified and valued by contractor's estimator.	Ahenkorah (1993), Hamimah et al. (2011), Holes (1990)	Specification/Working methods/Temporary works	Inadequate/ Insufficient	Issues related to information/ Issues related to contractor's work planning
19.	BQ only useful for tendering and financial control but ***not used extensively*** for ***contractor's site operation*** **(*working methods and planning)**.	Smith and Hoong (1985)	Working methods	Insufficient	Issues related to contractor's work planning
20.	BQ ***do not support*** contractor's management function. BQ **(*information)** ***disregard*** resource requirements and ***only*** measures **(*quantity and units)** ***fixed in place measurement.***	Baccarini and Davis (2002)	Quantities/ Quantity units	Inaccurate/wrong quantities/ Inappropriate	Issues related to information
21.	***Nett quantities*** and ***inaccurate quantities*** **(*information)** are ***major dissatisfaction*** among contractors in the way **(*quantities)** are provided in BQ.	Hamimah et al. (2011)	Quantities	Inaccurate/wrong	Issues related to information
22.	**BQ (*format)** other than trade ***fails to facilitate*** contractor's pricing **(*unsuitable format)**.	The BOQ Working Group (1995)	Unsuitable format	Unsuitable	Issues related to format
23.	**BQ (*format)** ***do not indicate*** project's buildability, work sequence and control of work **(*inflexible format)**.	Skoyles (1968a)	Inflexible format	Inflexible	Issues related to format
24.	**BQ (*format)** ***do not adequately reflect the interaction*** **(*inflexible format)** between the design of a building and the production process **(*working methods and planning)**.	Skoyles (1964)	Inflexible format	Inflexible	Issues related to format
25.	**BQ (*format)** is ***not adequate*** to fulfil its maximum functions **(*unsuitable format)**.	Hughes (1978)	Unsuitable format	Unsuitable	Issues related to format
26.	**BQ (*format)** and ***data presentation*** **(*unsuitable format)** are the ***major cause for inefficient*** flow of estimating data.	Kodikara and McCaffer (1993)	Unsuitable format	Unsuitable	Issues related to format
27.	BQ data **(*information)** ***fail to provide*** contractors with information they need for ***proper planning, organising and managing*** of their work **(*working methods and planning)**.	Contributed (1964), Holes (1990), Leon (1966), Waterworth and Weddle (1978)	Working methods	Insufficient	Issues related to contractor's work planning/ Issues related to information
28.	BQ **(*information)** ***requires sub-processes*** by site QS as the information ***are not presented*** in a standardised format **(*unsuitable format)**.	Cornick and Osbon (1994)	Unsuitable format	Unsuitable	Issues related to format
29.	BQ **(*information)** produced is ***inaccurate*** in terms of its ***quantities*** and ***descriptions***. Inaccuracy is caused from an omission of important cost items, disparity between drawing details and quantity list and over and under measurement of cost items.	Abdul Rashid and Normah (2004), Rosli et al. (2008)	Description/ Quantities	Inaccurate/wrong quantities	Issues related to information

Note: Bold lettering/*italics* are the accentuated concepts and are reincorporated back in the list of issues.

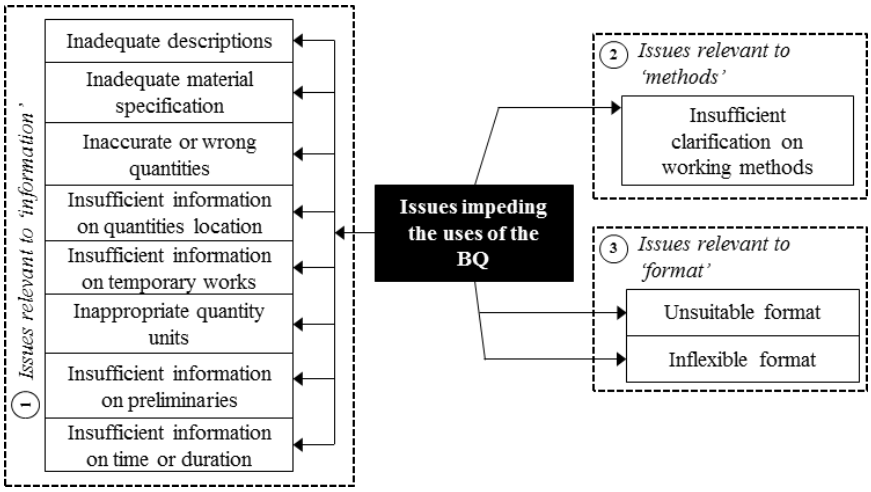

Figure 2: The theoretical framework on the issues impeding the uses of the BQ

IDENTIFYING THE FOCUS FOR A STUDY

The issues identified have prompted several solutions to be proposed to improve the situation. It has centred on suggesting various forms of new BQ format and has concentrated on this aspect to improve its uses to the contracting organisations. Accordingly, the solutions identified and discussed from the review are:

(1) Elemental Bill (Rose, 1956);
(2) Sectionalised Trades Bill (Nott, 1963);
(3) Operational Bill (Forbes and Skoyles, 1963, Skoyles, 1964);
(4) Bills of Quantities (Operational Format) (Skoyles, 1969, Skoyles, 1968a, Skoyles, 1968b);
(5) Activity Bill (Lear, 1966);
(6) BPF System (schedule of activities) (British Property Federation, 1983);
(7) Builder's Quantities (Pasquire and McCaffer, 1985); and
(8) Abridged bill (Davis et al., 2009, Slattery, 1994).

Aspect on format has been the focus of past researches and was proposed to ameliorate concerns over the uses of the BQ (RICS, 1965). It posed to restore confidence over its presence in the construction industry (Mohd Hisham and Azman, 2008).

Apparently, it implies that the solutions had placed much focus in developing new BQ formats. This despite the call made by the Quantity Surveying Techniques Working Party of the Cost Research Panel to focus on improving the usefulness of the BQ data (RICS, 1962). To add, further researches by Skoyles and Fletcher (1970), Turner (1983), Kodikara (1990); Jaggar et al. (2001) and Ramus et al. (2006) have concluded that improving the BQ format seemed not in the best interest of the industry. Within the context of this paper, the solutions proposed show that only issues concerning the BQ format had been considered. This despite issues concerning BQ information was mentioned more frequently in the literature. Besides, as there was too much focus in developing new BQ format, little is known whether the information contain in BQ has truly accorded with the requirements of its main user. For this reason, a study to re-examine BQ information is considered timely. This refute the need to focus a study on BQ formats. Hence, this complies with the evidence synthesised from the literature and stood as the gap for current research concerning the BQ.

Following the gap identified from the past researches, pertinent questions need to be asked which should centre on the contracting organisations which have been identified as the primary user of the BQ. Accordingly, the questions that could be asked concerning the gap are as follow:

i. What are the uses of the BQ to the contracting organisations?
ii. What is the BQ information required by the contracting organisations to achieve the uses of the BQ?
iii. What are the significant issues impeding the uses of the BQ to the contracting organisations?

As the step to answer the questions which will ultimately lead to satisfy the focus, this paper is suggesting the following approach:

i. To determine the uses of the BQ to the contracting organisations;
ii. To determine the important BQ information requirements for achieving the uses of the BQ to the contracting organisations;
iii. To determine the significant issues impeding the uses of the BQ to the contracting organisations.

By following the suggested approach, it is expected that the research could be able to gather evidences which indicates the important BQ information requirements and the significant issues to be considered for improving the uses of the BQ. Hence, the evidences collected could serve as the basis to ameliorate improvements to the uses of the BQ and in line with the gap identified from the synthesis carried out.

DISCUSSION ON THE CONTRIBUTION OF THE PROPOSED STUDY

Narrowing the gap conceptualised in this paper will be of significant value in addressing the current and the future needs of the industry. It will extend the current knowledge on the BQ by placing the actual requirements of the contracting organisations as the focus for improvement which imperative at re-extending the BQ usage to wider groups in a project. This effort is considered timely given the lack of attention currently given to this aspect of research although concerns were reported through the literature. This research is posed to contribute to the contracting organisations in at least one of the following:

i. Determining the uses of the BQ;
ii. Determining the BQ information requirements; and
iii. Determining the impeding issues concerning the uses of the BQ.

Although been focused at the contracting organisations, the outcome of the research is also expected to benefit other parties in a project; hence improving the current construction environment which the industry is currently operates.

Besides focusing the gain to the current needs of the industry, the outcome of the research could also be useful in relation to the development and advancement of the Building Information Modelling or BIM. According to Azhar (2011); Lee et al. (2014), Porwal and Hewage (2013), Succar et al. (2013) and Love et al. (2014), the BIM technology which is still at its formative stage would require much research input before total deployment could be achieved. Following the requirements, several attempts have been identified from the literatures which aim at helping the technology to advance. The work of Taylor and Bailey (2011) for instance, have stressed the need to establish a standard coding structure to streamline construction processes in BIM environment while Jung and Joo (2011) have been acknowledged in developing the BIM practical framework for deployment. Though works

which revolve around the requirements are currently underway, its development is also found to bear some challenges. According to Becerik-Gerber and Kensek (2010); Keat (2012) and Monteiro and Martins (2013), in order to enable the BIM technology to advance, the industry must first address the issues of interoperability and software integration while letting the technology to evolve as it respond to user's specific need. Although the outcome would be far from addressing the major issues related to BIM deployment, yet this research is fundamental and posed to contribute by providing input to the coding structure which was poised as the most important aspect of its development. Accordingly, it is in this regard that the research proposed in this paper would come in to contribute to advance the BIM technology for deployment. This contribution however, is still small in comparison with the actual requirement of the technology. Regardless, it is a fundamental attempt that will situate BQ related research with the need of the BIM and hence, justifying its appropriateness with the current need of the construction environment.

CONCLUSION

The identified research gap has been substantiated with rigorous synthesis of the past researches. This is conducted to propose current research focus in the area concerning the BQ. Following the analysis conducted to the works of past researchers, the incapacity of the BQ to address the information need of its main user has been elevated as the primary concern and is considered as the gap that need to be filled and focused. This is in addition to the identification of issues impeding the uses of the BQ to the contracting organisations. It is proposed that a research concerning the aspects outlined is imperious and currently in need. This is also in line with the categories of issues synthesised from the literature. It is expected that the findings from focusing to the aspect highlighted offers benefit, not only to the immediate need of the construction industry, but also to the emerging concern over the BIM which is envisaged to elevate the quantity surveying profession higher with the need of the current construction environment.

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ASSESSMENT OF SOLID WASTE MANAGEMENT (SWM) PRACTICES IN PANGKOR ISLAND MALAYSIA

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ABSTRACT

This study aimed to characterize recyclable and non-recyclable solid waste generation and identify the impacts of solid waste to the Pangkor island ecology. Methods used in this study were field investigation, opinion survey and domestic waste sampling. The data obtained from field sampling was analyzed by using reliability test (0.753), descriptive test, ANOVA single factor and Pearson Correlation Analysis. Through field investigation and sampling activity, the waste generated in Pangkor Island was found to be 0.34 kg/capita/day which slightly lower than Malaysian average waste generation of 1.3 kg/capita/day. Opinion survey and interview which included 34 items were conducted to local community for understanding; awareness and practice of local communities towards solid waste management (SWM). Result showed that total 34.0 % of respondents chose dumped solid waste into ocean, river or land. Only 43.6 % of respondents practiced recycling and composting in their own house. Result from Pearson Correlation analysis shows that knowledge of local communities towards SWM does not influence their attitude towards recycling (Pr > 0.05). Due to time restraints, language barrier, lack of numerators and expert's opinion, the study did not carry out the field sampling in Malay and Indian communities in Pangkor Island which became major limitation for this study.

Keywords: *Solid waste management (SWM), Municipal waste management (MWM), sustainable development, Pangkor Island*

INTRODUCTION

Increases of population, rapid economy growth and urbanization have posed challenge to sustainable solid waste management. In developing countries, the generation rate of solid waste has increased dramatically (Minghua et al., 2009). Main waste management responsibility is dedicated to local authorities in most developing countries which encounter issues pertaining to human and financial resources constraints as well as identify suitable landfill for disposal (Sujauddin et al., 2008). Apart from waste management, water resources pollution due to illegal solid waste disposal are often reported and become major environmental problem.

There are some issues and challenges in managing waste in places such as islands in Malaysia and Pangkor Island is one of the examples. Firstly, the dumpsites are poorly located on the island, combined with uncontrolled scavenging and lack of rubbish bin in the island, it makes the issue worst. Inefficient

waste collection and transportation are due to inadequate management and maintenance of equipment where there also poses a problem in solid waste management (SWM). Lack of public awareness on solid waste management issues leads to low waste separation and rarely practice of reduce, reuse and recycle (3R) of the waste. Illegal burning and ocean dumping is common in Pangkor Island. Wastes generated in the island are causing environmental pollution, safety hazards and aesthetic problems in the site. The crucial part of the SWM is the high transportation cost and inadequate budget for the waste management (Agamuthu and Nagendran, 2010).

Waste collection in Pangkor Island is contracted out to a private firm yearly. In term of disposal methods, Pangkor Island depends on the location of landfill in the island. Landfill in Pangkor Island is operating as mere open-dumps, which lack proper lining system and leachate treatment. At the open-dumps, there is a layer of natural lining layer, which composed of clay as prevention for leachate leakage to the water table buried beneath the landfill. Currently, no cell system is being practiced at the site and no proper treatment or drainage is allocated for the leachate produced by the waste. Thus, landfill in Pangkor Island has a waste-related aesthetic problem, leachate contamination, and landfill gas or odour problems which are the concurrent problem in Malaysia. Obviously it shows that waste collection in Pangkor Island is an ineffective disposal method. Hence, it gives negative impacts to the environment consequently. Since there is a limitation on landfill disposal site in Pangkor Island, an alternative landfill site is not available. Thus, the incinerator is used as the disposal method for the waste (Agamuthu and Nagendran, 2010).

The municipal solid waste (MSW) is increasing daily and without any preventive action, substantial negative environmental impacts such as air, soil and water pollutions will continue to occur and become the major environmental challenge to Malaysia (Siti and Noraziah, 2014). To further elaborate on its negative pressure to Malaysia, the existing of health and safety problem will skyrocket as the garbage heaps attracted insects and rodents. Besides, the vector diseases associated with different forms of pollution will grow exponentially. Meanwhile, landfill leachate will contaminate the groundwater and adjacent water bodies, whereas the gases of the landfill; greenhouse gases (GHG) are released freely into the atmosphere and contributing to climate change (Zeeda and Jaron, 2013). Thus, the efficiency of the SWM in Pangkor Island becomes a major social and environmental concern (Suna Erses Yay, 2015).

Pangkor Island is located in the state of Perak and under the authority of Manjung Municipal Council (MMC) (MMC, 2010). It is coordinated at 4.2200 ^{o}N, 100.5550 ^{o}E. It is surrounded by Dinding Straits and Malacca Straits. Pangkor Island experiences a tropical climate and temperature ranges from 25 to 35°C. The size of Pangkor Island is 18 km^2 while the population is approximately 20,000 people (MMC, 2010). Fishing, exportation of marine products and tourism are the major industries on the island (Pazim and Rosli, 2011).

Definition of Solid Waste Management (SWM)

A Waste Management Hierarchy (Figure 1) is introduced to minimize the amount of waste entering landfill. In the Waste Management Hierarchy, the top three initiatives are 3R (Reduce, Reuse and Recycle). It is vital to educate the public by organizing awareness program towards implementation of the 3R. By implementing 3R, it can reduce human ecological footprint and improve waste management system. Besides that, it also allows prevention of the loss of resources and reduces environmental impacts from waste disposal; simultaneously lengthen the lifespan of landfills operation. 3R is a successive process in developed countries compare with the developing countries (Jayashree *et al.*, 2012).

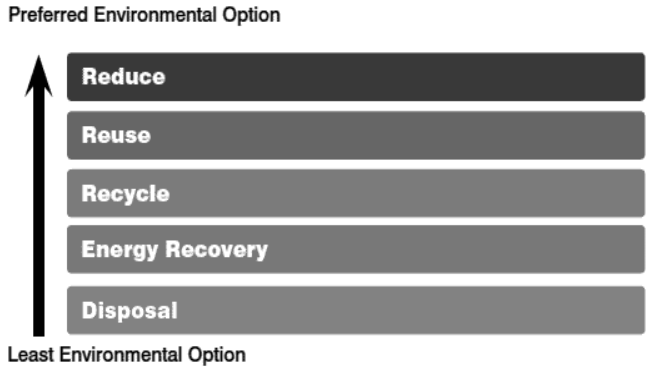

Figure 1: Waste Management Hierarchy (The Scottish Government, 2011)

Solid Waste Issues and Importance

In year 2007, solid wastes generated in Malaysia were enough to fill up 42 buildings that have the same size as the world-renowned Petronas Twin Tower in Kuala Lumpur, which is about 7.34 million tons. Statistics shows solid waste generated is approximately 1 kg/day/capita. On the other hand, due to the factors of urbanizations, changing in living standards and consumption behaviors of the people, the volume of solid waste is boosting at the rate of 1.5 % per year (Idrus *et al.*, 2008).

Malaysia is spending 75% of municipal budget for waste collection (Shamshiry *et al*., 2011). This statistic showed intentionally costly waste management in Malaysia. The waste generation studied in all islands in Malaysia is also increasing yearly. Approximately 400 metric tons/day of solid waste are generated in the islands of Malaysia. The data of population and solid waste generation in Langkawi, Pangkor, Redang and Tioman islands are summarized in Table 1 (Agamuthu and Nagendran, 2010).

Table 1: Population and Waste Generation Rate in the Four Islands

	Langkawi	**Pangkor**	**Redang**	**Tioman**
Size (km^2)	478.5	18	10.87	131
Population	79,000	26,000	1,400	3,400
Waste generated (metric ton/day)	85	13	2.7	6.95
Waste generation rate (kg/capita/day)	1.08	0.48	0.86	0.87

(Source: Agamuthu and Nagendran, 2010)

In Table 2, the comparison of waste composition between islands is summarised. The result shows that approximately 30% of waste is from food waste. Tourism activity at the island has contributed to the increment of recyclables waste disposal. The wastes include Styrofoam food containers, mineral water bottles, magazines, carton boxes and shopping bags. The study illustrates that about 82% of the waste can be diverted from the landfill, if both the compostable and recyclable items (food waste, paper, plastic, yard waste, textile and metal) are successfully separated at source in Pangkor Island.

Table 2: Waste Composition in Malaysian Islands (% by weight)

Component	Redang	Pangkor	Langkawi	Tioman
Food waste	31.0	30.3	36.3	29.8
Paper	24.7	20.7	19.5	18.9
Plastic	13.1	15.1	15.1	13.9
Yard waste	11.8	10.8	8.4	14.1
Diapers	4.7	5.5	4.8	4.8
Glass	5.2	3.4	3.7	5.6
Wood	3.2	5.3	2.9	4.2
Rubber/Leather	2.4	2.8	3.6	3.4
Textile	2.3	2.6	3.2	3.4
Metal	1.0	2.2	1.8	1.0
Hazardous waste	0.1	0.2	0.1	0.2
Others	0.6	0.9	0.7	0.7

(Source: Agamuthu and Nagendran, 2010)

TECHNOLOGIES FOR WASTE DISPOSAL AND MANAGEMENT

Different Types of disposal technologies are applied in Malaysia namely landfill, incineration, composting and recycling.

Incineration

Incineration provides a solution to deal with the problems of solid waste, especially in the country where the land is limited and the rate of SWM is escalating speedily. In fact, incineration is reducing 90% of the wastes volume and only the remaining ash will go to landfill. So, the life span of the landfill will be extended. Besides, incineration could offer energy recovery and the income would offset the high operation cost of incineration if the technology of zero to waste is available (Idrus *et al.*, 2008).

Advantages of incineration are listed in the following, such as less emission during the waste transfer. Meanwhile, decrease in the weight of waste effectively hinder the production of methane after it was disposed to landfill. Since the production of ashes during incineration, majority of the components is an inorganic material which, is in a stable form, where it can be recycled to make profit. Therefore, incineration may be treated as a pre-treatment for landfill. Other than to reduce the waste amount, the main objective of incineration is for the generation of renewable energy. Hence, the function of this waste disposal method will become more attractive. If waste combustion is used sustainably, it is a vital source of energy for energy recovery. Incineration is about introducing another option to burn fossil fuels in an environmental friendly way from the perspective of energy. In a nutshell, incineration is providing a great source of solid waste reduction in terms of volume and weights. It is expensive when waste enters to the landfill, as it requires higher funds for construction of landfill. In addition, there is the need of a principal to monitor and maintain the landfill in long term, once the landfill is established. Next, due to the odour of the landfill, there is reduction of the land value of surrounding areas (Shamshiry *et. al.*, 2014).

However, there are some disadvantages from incineration; such as the incinerated ash contains high level of heavy metals will have higher possibility of leaching rate. In term of energy recovery, not all waste is adequate for incineration. Fuel supplement for combustion might need for waste with low calorific value. With a high moisture and low organic content of combustible materials, waste contributes to a lower calorific value, especially in developing countries. Thus, energy recovery is not economical, since the incineration of wastes with lower calorific values is generally unable to self-sustaining. Furthermore, for the countries which are facing technical constraints in controlling the potential air pollution, the incineration technology is not appropriate to be implemented (Idrus *et al.*, 2008). For instant, the facilities of the “Waste to Energy” in the US had generated 81 mercury tons in

1989. Besides, the emissions of incineration are significant, as it threatens human health, plants and the surrounding environment. The emissions of GHG from incineration are CO_2 and N_2O which are major contributors to climate change (Shamshiry *et. al.*, 2014).

Composting

Wilson (1981) expressed composting process happens when the organic portion of the waste undergoes aerobic degradation and the product of this process can be only used as a soil conditioner. However, Agamuthu (2001) holds the opposite view that compost is important for plant growth and development, and can improve the soil texture as it is a nutrient rich substance. The advantages of using composting as a treatment for solid waste can reduce the volume of solid waste significantly, particularly in those countries where generation of organic waste and yard waste are in high volume. Yet, if high percentages of non-compostable waste such as glass, metals, plastic, and rubber are consisted, separation needs to be done before composting in order to produce an acceptable grade of compost and to avoid contamination of compost with hidden toxic metals. In general, composting is hygienic, environmental friendly and contains substances with only low toxicity. This technology has been available for many years, however, around the world, there are only few composting plants which are successfully economically (Idrus *et al.*, 2008).

Recycling

Recycling is reverting waste materials to productive system in terms of the usage in the manufacturing of goods, through the perception of conservation which viable to scarce and non-renewable resources in order to promote sustainable development as interpreted by Gilpin (2000). Some fundamental issues faced by waste recycling such as recovery of the reusable and recyclable materials through separation of waste materials. Besides, in the market, issues such as specification and identification of the recovered materials are noted free from contamination and homogeneity (Idrus *et al.*, 2008).

There are two principal benefits of recycling. First, the need for waste disposal capacity, emission from landfills and incinerators and litter are cut down by recycling. Next, the energy use and emission from industrial would decrease, simultaneously fewer raw materials are extracted or manufactured, and raw materials are conserved through recycling. Moreover, recycling is providing the lower income group as an additional income source (Nadi *et al.*, 2011).

In recycling field, the type of waste that can be recovered depends on the demand and potential uses of the recovered materials. These only cover materials that only have high commercial value, such as paper and cardboard, plastics, glass, aluminium, ferrous metal, and for which recycling technologies already exist. Facilities are costly to set up and operate for the recyclable materials. Therefore, it may not be practicable to invest in a central material recovery and processing facility, if there are insufficient of recyclable materials generated (Idrus *et al.*, 2008).

METHODOLOGY

This study adopted the case study approach which focuses on sustainable SWM in Pangkor Island. Four methods were chosen for this study specifically domestic waste segregation, field investigation, opinion survey, and statistical data analysis.

Domestic Waste Segregation

In order to characterize solid waste generated in Pangkor Island, 18 households were surveyed from four different villages around the Island. These areas were Sungai Pinang Kechil, Sungai Pinang Besar, Pekan Pangkor, and Taman Desa Pangkor as shown in Figure 2. Each household was requested to collect their daily solid waste and sort into two categories such as recyclable waste and non-recyclable waste,

as shown in Table 3. The samples were collected once a week by determining the weight of the wastes and the number of members in the household. The solid waste segregation was conducted for three months (November 2015 – January 2016).

Table 3: Classification of Recyclable and Non-Recyclable Wastes

Recyclable	Non-recyclable
Paper	
Newspapers	Soiled paper
Office papers	Wax or plastic-coated paper
Phone books	Paper laminated with foil or plastic
Paper grocery bags	Magazines and catalogs
Paper egg cartons	Used paper towels, napkins, tissues and paper plates
Cardboard	
Packing boxes	Waxed cardboard
Cereal boxes (single wall cartons)	Waxed milk cartons
	Soiled pizza or frozen food boxes
Glass	
Jars	Light bulbs
Bottles (clear, green or brown)	Window panes
	Glassware (cups, glasses, plates)
	Mirrors
Metal	
Aluminium cans	Bottle and jar lids with plastic liners
Tin cans	Cans used for chemicals or paints
Scrap metal	Aerosol spray cans
Plastics	
Plastic soda and juice bottles	Grocery and plastic bags
Milk jugs	Styrofoam (cups, plates, packing materials)
Detergent, oil and antifreeze bottles	
Batteries	
Dry cell household batteries	

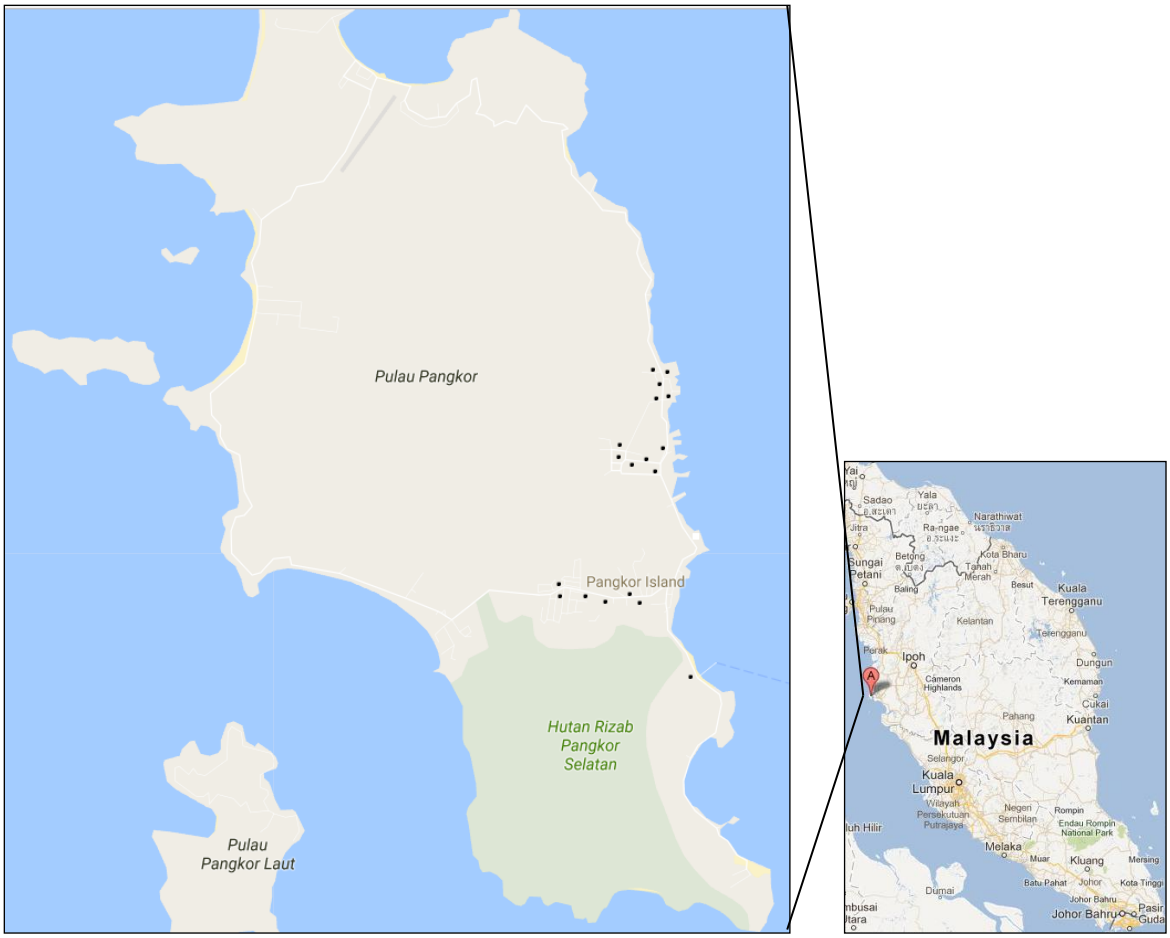

Figure 2: Location 18 Households for domestic waste segregation sampling

Field Investigation

Besides, the environmental impact of the solid waste generated in Pangkor Island was identified in five villages such as Sungai Pinang Kechil, Sungai Pinang Besar, Kampung Teluk Kecil, Kampung Teluk Gedung, and Teluk Dalam, as well as tourist attraction in Teluk Nipah through field investigation.

Opinion Survey

The awareness, understanding and attitude of the communities towards the importance of SWM were identified by using close-ended questionnaire. The questionnaire was designed by using Likert scale. A series of questions with five response alternatives were used in Likert scale: strongly disagree, disagree, neutral, agree and strongly agree (Harry and Deborah, 2012). The pilot survey was conducted in order to determine the reliability of design questionnaire. In total, 94 respondents from seven villages such as Sungai Pinang Kecil, Sungai Pinang Besar, Pekan Pangkor, Kampung Teluk Kecil, Kampung Teluk Gedung, Taman Desa Pangkor, and Teluk Dalam, had been participated in this survey from November 2015 to January 2016.

Reliability analysis was used to measure the 34 variables from 94 respondents towards understanding regarding knowledge towards SWM, understanding and awareness towards SWM, and awareness and attitude towards recycling. The value of Cronbach's Alpha in opinion survey conducted to 94 respondents is 0.753, According to Institute for Digital Research and Education (2015), the Cronbach's Alpha value which is representing of questionnaire should be higher than 0.6, so that the questionnaire is considered reliable. Thus, the opinion survey in this study was reliable and acceptable.

Statistical Data Analysis

The data was analysed by using Statistical Package for the Social Sciences (SPSS Statistics) (IBM Corporation, 2012). Descriptive statistics was used to analyse the descriptive data and inferential statistics such as Pearson Correlation analysis, Analysis of Variance (ANOVA) Single Factor were employed to further explore the differences between the groups of respondents.

RESULTS AND DISCUSSION

Descriptive Analysis

The survey outcome was interpreted with frequency table to describe the data statistically. Thus, all 34 variables were analysed to understand Pangkor's residents' knowledge, behaviour and attitude towards solid waste issue in Pangkor Island as shown in Table 4, 5, 6 and 7.

Table 4: Descriptive analysis for Knowledge of Respondents towards SWM

Symbol	Variables	Value (%)
B1	I understand the Solid Waste Management (SWM) practices	78.7
B2	I aware about Solid Waste Management (SWM) practices	87.2
B3	I attended talks/activities related to Solid Waste Management (SWM)	36.2
B4	I know how much of wastes that my house generated daily.	66.0
B5	I know the function of incinerator	75.5
B6	I recognize the gases generated by the operation of incinerator.	51.1
B7	I know the location of incinerator in Pangkor Island	75.5
B8	I know what illegal landfill is	71.3
B9	I know the location of illegal landfill in my residential area	53.2
B10	I know what are environmental pollutions and its impacts on human health.	94.7
B11	I aware about environmental pollution in my residential area.	63.8
B12	I attended talks/activities related to environmental pollution.	43.6
B13	I know how to conduct recycling practice.	93.6
B14	I have conducted recycling and composting activity in my house.	43.6
B15	I attended talks/activities related to recycling.	52.1

Table 5: Behaviour of Respondents in Household Waste

Symbol	Item	Dump it into sea/river/land (%)	Burn it (%)	Legal solid waste collector (%)
B16	How do you dispose of the household waste?	17.0	17.0	66.0

Table 6: Awareness of Respondents towards SWM

Symbol	Item	Disagree / Strongly Disagree (%)	Neutral (%)	Agree / Strongly Agree (%)
SWM1	SWM is important.	0.0	18.1	81.9
SWM2	MMC is responsible for the waste collection of my house.	13.8	17.0	69.1
SWM3	Privatized company is responsible for the waste collection of my house.	58.5	18.1	23.4
I1	The gases generated by the operation of incinerator are harmful to health.	1.1	45.7	43.2
I2	The incinerator operated in Pangkor Island often breakdown.	11.7	67.0	21.3
IL1	Illegal landfill is carried out during the breakdown of incinerator of Pangkor Island.	24.5	54.2	21.3
IL2	Illegal landfill generates unpleasant smell.	1.1	34.0	64.9
EP1	Environmental pollution is caused by human activities e.g. illegal dumping of solid wastes.	0.0	12.8	87.2
EP2	The aquatic living organisms consume the wastes accidentally.	3.2	18.1	78.7
EP3	Environmental pollution had caused the reduction of marine products.	2.1	29.8	68.1

Table 7: Attitude of Respondents towards Recycling

Symbol	Item	Disagree / Strongly Disagree (%)	Neutral (%)	Agree / Strongly Agree (%)
R1	Recycling is important.	2.1	20.2	77.7
R2	There are someone who influences me to do recycling.	40.4	31.9	27.7
R3	Practicing waste separation is complicated and troublesome.	33.0	29.8	37.2
R4	Practicing recycling used up a lot of time.	38.3	26.6	35.1
R5	Practicing recycling needs a lot of effort.	39.4	24.4	36.2
R6	Practicing recycling needs a lot of space.	34.0	33.0	33.0
R7	Recycling could generate unpleasant smell.	41.5	48.9	9.6
R8	Recycling bins are unsightly.	6.4	24.5	69.2

Total 78.7% of the respondents understand solid waste Management (SWM) best practices, 87.2% and 36.2% of the respondents aware about SWM practices and attended relevant talks or activities, respectively and a total 66.0% of the respondents know how much of wastes their house generated daily (Table 4). Although 75.5% of the respondents know what are incinerator and its function, only 51.1% of the respondents recognize the gases generated by the operation of incinerator. Another 75.5% of the

respondents know the location of incineration in Pangkor Island. While 71.3% of the respondents know what illegal landfill is, more than half of the total respondents which is 53.2% of the respondents know the illegal landfill in their residential area or village. Based on Elizabeth (2006), people used to dispose of their wastes in unpermitted areas to avoid time and effort needed to dispose properly at landfills or recycling centres. Additionally, due to lack of understanding of laws or the inadequacy of existing laws, it leads to the illegal disposal of wastes.

Total 94.7% of the respondents know what environmental pollution is and its impact on human health, whereby only 43.6% of the respondents attended talks or activities related to environmental pollution. Besides, another 63.8% of the respondents understand the environmental pollution occurred in their residential area or village (refer Table 4).

Table 4 shows that 93.6 % of the respondents understand what recycling practice is, but less than half of them practice recycling and composting activities in their own house. Nevertheless, 52.1 % of the respondents attended talk or activities related to recycling. Department of Environment Quality (2015) stated that people who do not conduct recycle practice is due to the reasons such as, time consuming, inconvenient to conduct recycling and also do not know what materials can be recycled. However, from the result, the percentages of respondents who attended to talk or activities which related to SWM practices, environmental pollution, and recycling are different, which are 36.2%, 43.6 %, and 52.1 % respectively.

The understanding, awareness and practice of the local communities towards SWM were also studied through opinion surveyed and interviewed. Based on the result shown in Table 4, 5 and 6, a total 94.7% of respondents knew what environmental pollution is and its impacts to human health while 87.2% of respondents agreed that environmental pollution is caused by human activities such as illegal dumping of solid waste, 81.9% of respondents agreed SWM is important, and only 34.0% of respondents chose their dumping methods to the sea or river or land and even burning it. At the same time, although 93.6% of respondents knew what recycling practice is and 77.7% of respondents agreed that recycling is important, only 43.6% of respondents practiced recycling and composting in their backyard. In layman terms, although local communities aware about SWM, their practice of solid waste disposal is diminutive in order to improve the environment of Pangkor Island. Thus, education of SWM best practices to the local communities is significant for good practice of waste disposal.

Pearson Correlation Analysis

Pearson Correlation Analysis was used to determine the strength of the correlation between the variables of the attitude of respondents towards recycling (Table 7). The correlation was significant at the 0.01 level as shown in Table 8. The strongest linear relationship is between R3 and R4 which is $r = 0.892$, and follow by R4 with R5 which is $r = 0.865$, both are positive very strong correlation. Next, the r value is 0.777 for R3 with R5, it is known as positive strong correlation. Then, the correlation of R5 with R7 is positive strong as $r = 0.681$. For R1 and R2, the r value is 0.634 which is positive strong correlation. In addition, R7 has the same r value with R3 and R4, which is 0.633, a positive strong correlation. As a conclusion, the relationship between R3, R4 and R5 are strong, which means the respondents were strongly agree/ agree that practicing waste separation is complicated and troublesome, a lot of time and effort needed to practice waste separation.

Besides, for the correlation is significant at the 0.05 level, the highest correlation is when $r = 0.232$ for R6 with R7, yet it is known as positive weak correlation. Then, it is followed by R5 with R6 when $r = 0.210$, also known as positive weak correlation. Moreover, r value for R6 with R3 is only 0.191, which is positive very weak correlation. Generally, for the R6 and R7, many of the respondents do not agree with recycling could generate unpleasant smell, but agree with recycling bins are unsightly.

Table 8: Pearson Correlation Analysis

	R1	R2	R3	R4	R5	R6	R7	R8

R1	Pearson Correlation	1	.634**	-.390**	-.477**	-.425**	.012	-.397**	-.220*
R2	Pearson Correlation	.634**	1	-.298**	-.441**	-.465**	-.061	-.319**	-.090
R3	Pearson Correlation	-.390**	-.298**	1	.892**	.777**	.191*	.633**	.040
R4	Pearson Correlation	-.477**	-.441**	.892**	1	.865**	.169	.633**	.051
R5	Pearson Correlation	-.425**	-.465**	.777**	.865**	1	.210*	.681**	-.020
R6	Pearson Correlation	.012	-.061	.191*	.169	.210*	1	.232*	-.300**
R7	Pearson Correlation	-.397**	-.319**	.633**	.633**	.681**	.232*	1	.042
R8	Pearson Correlation	-.220*	-.090	.040	.051	-.020	-.300**	.042	1

**. Correlation is significant at the 0.01 level (1-tailed).
*. Correlation is significant at the 0.05 level (1-tailed).

Domestic Waste Segregation practices in Pangkor Island

A total of 18 households participated in this domestic waste segregation as shown in Table 9. The averages recyclable and non-recyclable from the 18 households per week were 4.45 kg and 6.50 kg. Thus, in average, the total waste from a household with four family members is 10.95 kg in a week and 2.39 kg of waste generated by per capita per week. Hence, generation of waste in Pangkor Island was determined as 0.34 kg/capita/day, which was lower than the finding of Agamuthu (2010), 0.48 kg/capita/day. Besides, the result was also lower than the average Malaysian waste generation, 0.8 kg/capita/day (Zamali et al. 2009). The standard deviation of recyclable waste and non-recyclable waste in a week are 1.46 kg and 3.62 kg respectively, whereas the standard deviation for total waste in a week is 4.18 kg. Then, the standard deviation for waste generation per capita in a week is 0.53 kg.

In order to identify the difference between the variables of recyclable waste (RW) and non-recyclable (NRW) and total waste (TW) and waste generated per capita (PC), analysis of variance (ANOVA) single factor was conducted in this study. Based on the result (Table 10), the F values of RW and PC were 0.123 and 0.175($F<1.000$). The p values as known as sig. of RW and PC were 0.972 and 0.599 ($P>0.05$). Hence, the H_1 was rejected and there was no significant difference between group for recyclable waste and waste generation per capital in Pangkor Island. Besides, the p values for NRW and TW were lower than 0.05, hence, the H_0 was rejected and there was significant difference between group for non-recyclable waste and total waste generation. The result indicated that improving recycling practice in Pangkor Island could help to reduce the total waste generated per capita as the total recyclable waste generated from each household was not significant difference in Pangkor Island.

Table 9: Average for Recyclable and Non-Recyclable Wastes Generation per week of 18 Households

Household	Recyclable waste (kg)	Non-recyclable waste (kg)	Total (kg)	Number of members	Per capita (kg)
1	0.23	1.95	2.18	2	1.09
2	2.35	1.62	3.96	3	1.32
3	1.71	4.83	6.54	3	2.18
4	2.99	3.36	6.35	3	2.12
5	5.66	3.22	8.88	3	2.96
6	2.23	7.35	9.58	4	2.40
7	4.27	5.13	9.39	4	2.35
8	2.00	5.73	7.74	4	1.94
9	1.66	4.01	5.67	4	1.42
10	2.91	5.38	8.28	4	2.07
11	2.33	6.25	8.59	4	2.15
12	1.45	7.56	9.01	5	1.80
13	6.10	5.64	11.74	5	2.35
14	2.77	7.60	10.37	5	2.07
15	4.14	16.03	20.17	6	3.36
16	2.59	9.26	11.85	6	1.98
17	3.77	10.24	14.00	7	2.00
18	2.93	11.82	14.74	7	1.80
Average	4.45	6.50	10.95	4	2.39
Standard Deviation	1.46	3.62	4.18	-	0.53

Table 10: ANOVA of Domestic Waste Segregation

		Sum of Square	**DF**	**Mean Square**	**F Value**	**Sig.**
RW	Between Groups	1.111	4	0.278	0.123	0.972
	Within Groups	29.447	13	2.265		
	Total	30.558	17			
NRW	Between Groups	161.831	4	40.458	13.569	0.000
	Within Groups	38.761	13	2.982		
	Total	200.592	17			
TW	Between Groups	175.214	4	43.803	8.465	0.001
	Within Groups	67.267	13	5.174		
	Total	242.481	17			
PC	Between Groups	.699	4	0.175	0.710	0.599
	Within Groups	3.198	13	0.246		
	Total	3.897	17			

RW = recyclable wastes, NRW = non-recyclable wastes, TW= total wastes, PC = waste generated per capita.

CONCLUSIONS

In order to change the attitudes and willingness of Pangkor Island community towards the current issues on sustainable solid waste management practices, the SWM education is proposed to begin with students as early as primary school age, whereby to instil good practice or behaviour at their tender age. Apart from that, local authority should consult non-governmental organisations (NGOs), such as EcoKnight, Reef Check Malaysia and Environmental Protection Society Malaysia (EPSM), to carry out some environmental campaigns to the local communities of Pangkor Island as well as to the primary and secondary school students in order to educate and inculcate them about the importance of SWM by showing them the severity of the current SWM issues that resulting to human health problem or even to the next generation if the issues persist. Example of themes of the educational campaign can be tips and skills of SWM to Pangkor Island community; thus, they know ways to manage solid waste themselves.

This study was unable to obtain participation of the three major ethnic community's i.e. Malay, Chinese and Indian due to lack of manpower for solid waste segregation and language barrier. Inability to speak fluently in Malay and Tamil languages, hinder the Malay and Indian communities to take part in the solid waste segregation study.

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