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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.

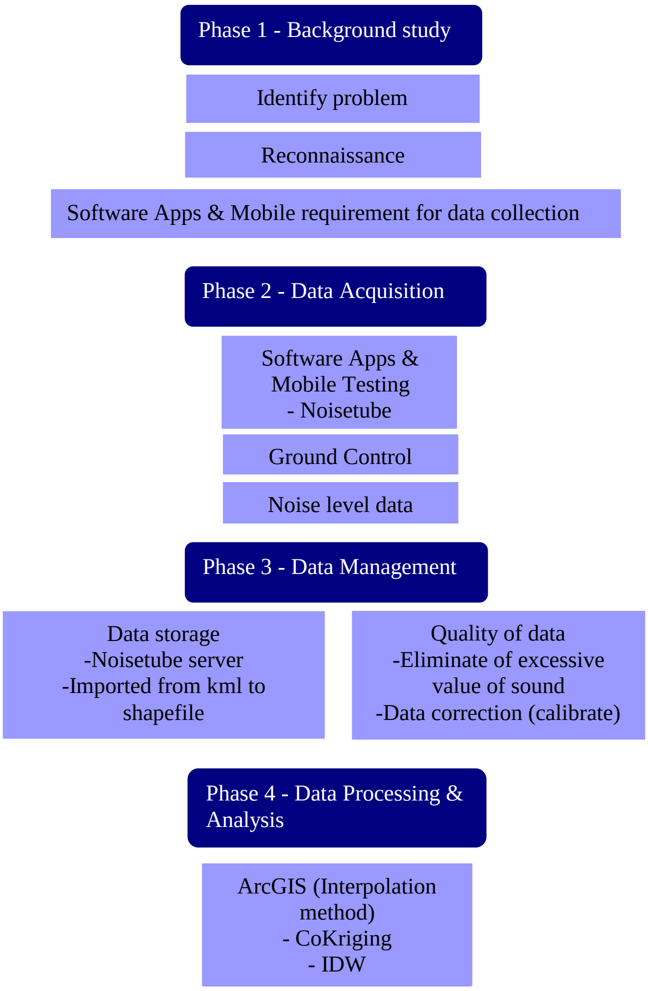

Figure 2: Methodological Flowchart

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.

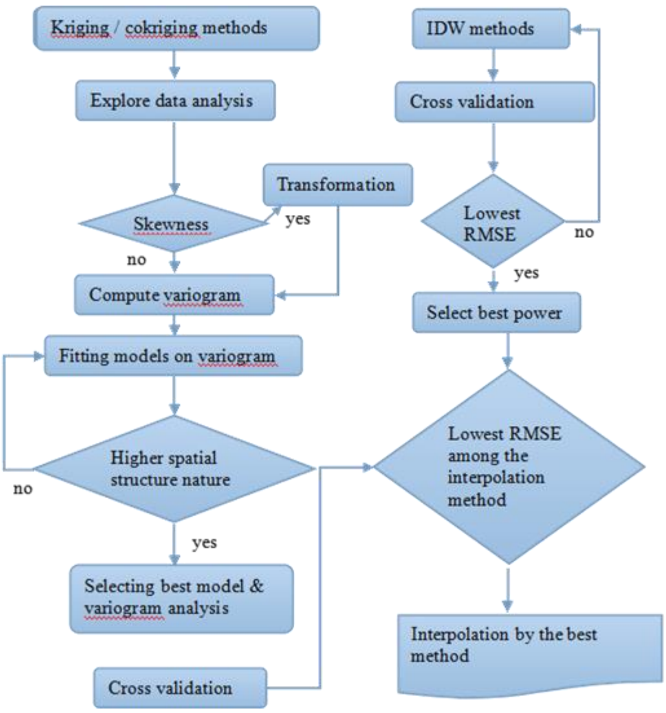

Figure 3: Work flow of two different interpolation methods

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.

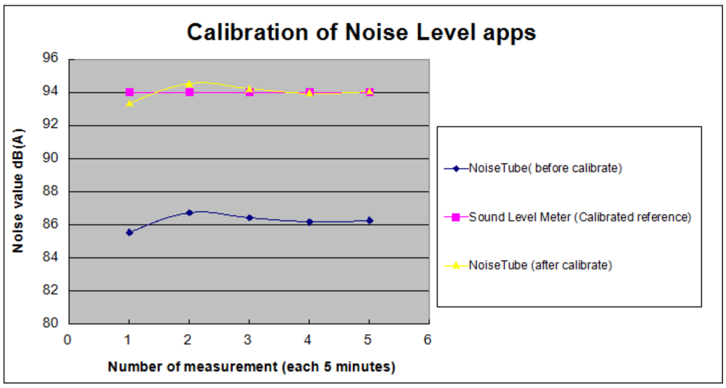

Figure 4: NoiseTube level comparison between before and after calibrated.

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

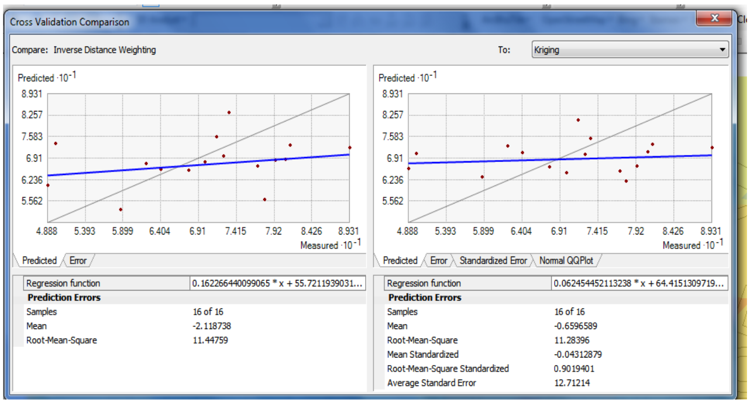

Figure 5: Cross validation comparison between IDW and Kriging method.

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.

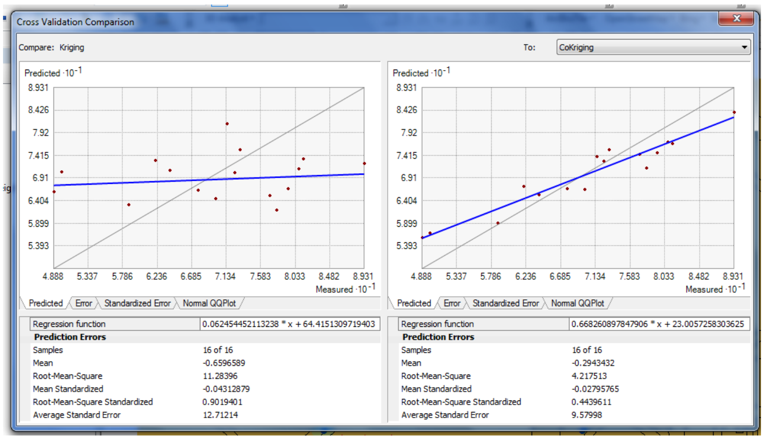

Figure 6: Kriging and CoKriging comparison for morning period.

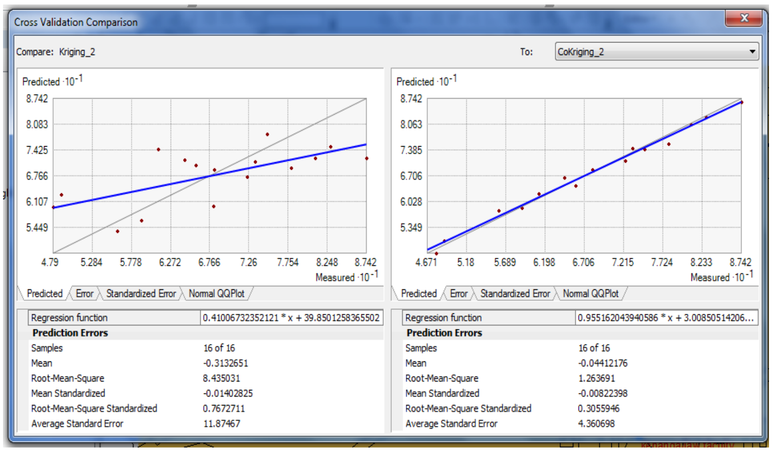

Figure 7: Kriging and CoKriging comparison for afternoon period.

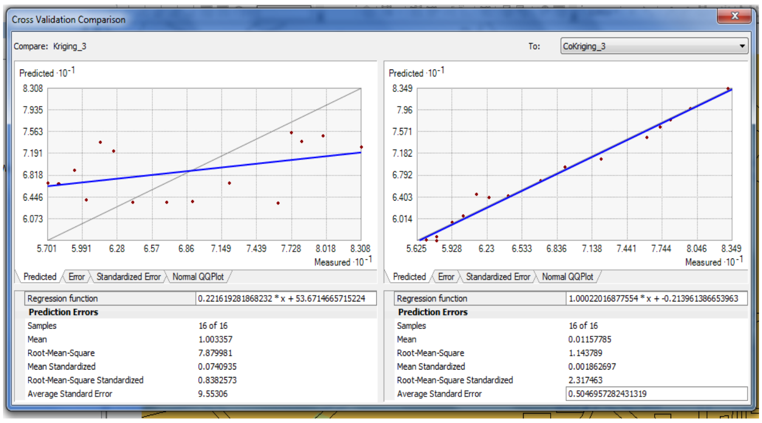

Figure 8: Kriging and CoKriging comparison for evening period.

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.

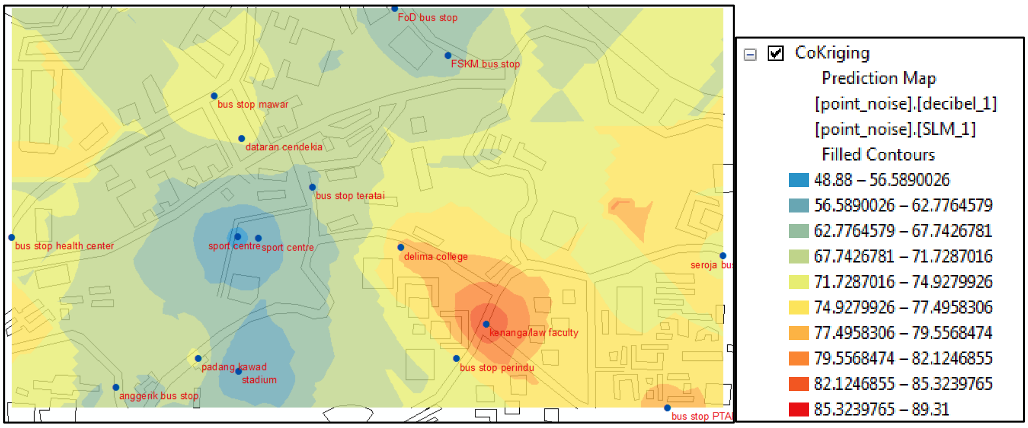

Figure 9 *:* Noise distribution in the morning, 7.45 a.m - 9.00 a.m.

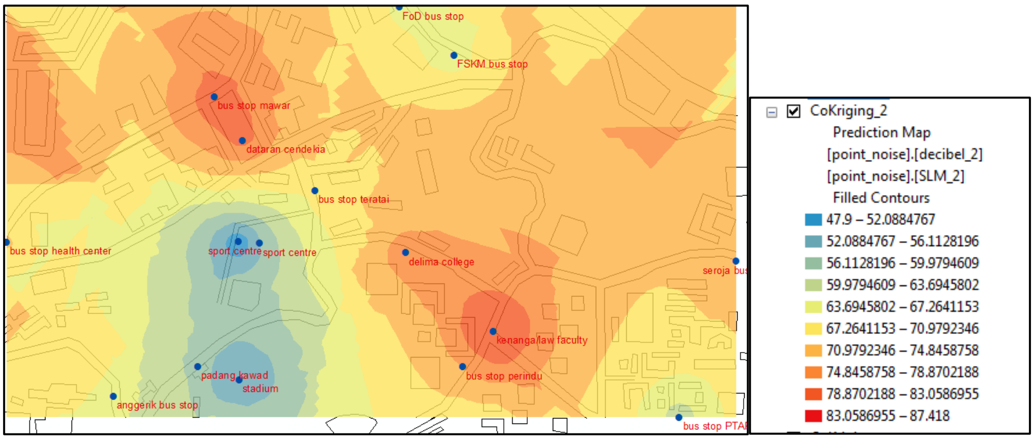

Figure 10*:* Noise distribution in the afternoon, 12.00 p.m - 1.00 p.m.

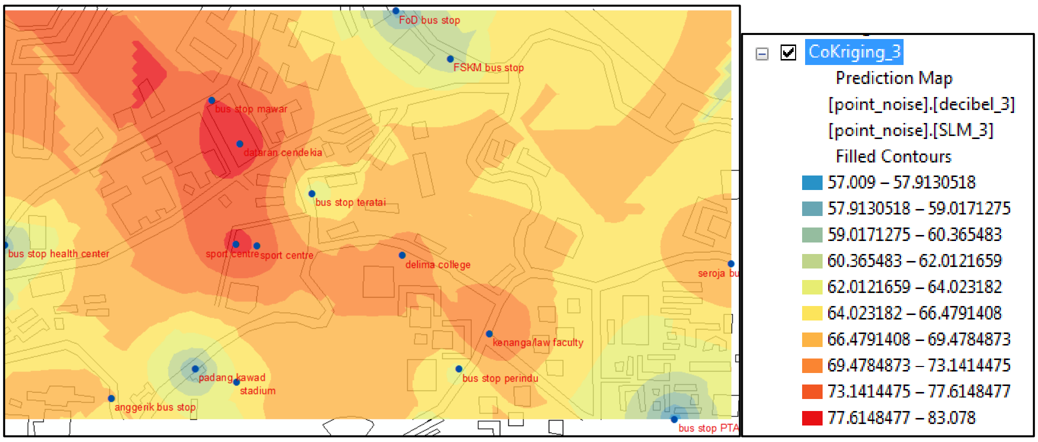

Figure 11: Noise distribution in the morning, 4.30 p.m. - 7.00 p.m.

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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