



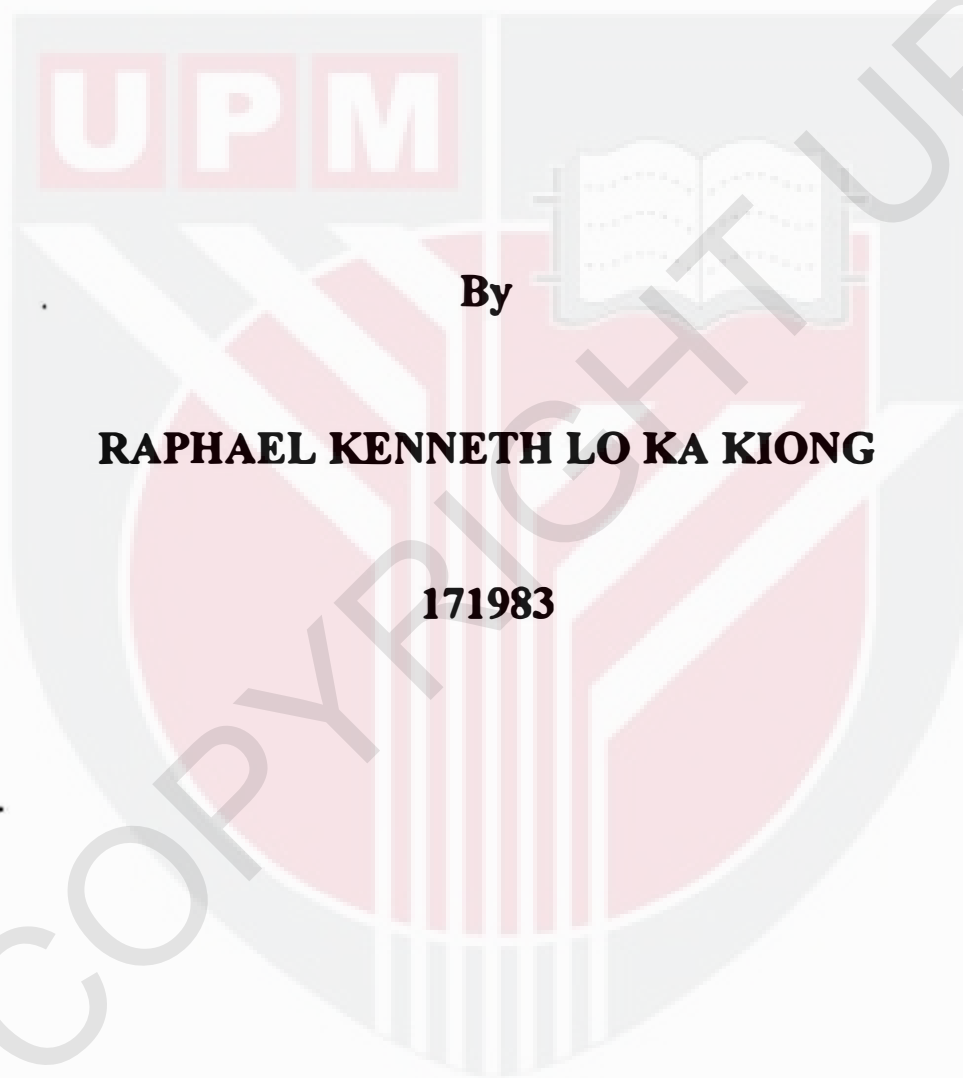
UNIVERSITI PUTRA MALAYSIA

***EVALUATION OF INTERPOLATION TECHNIQUES AND MULTI
CRITERIA DECISION MAKING APPROACHES FOR URBAN NOISE
MAPPING IN GIS***

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MULTICRITERIA DECISION MAKING APPROACHES FOR URBAN
NOISE MAPPING IN GIS**



By

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ABSTRACT

Due to rapid urban development and massive population increase, nowadays many cities are experiencing the problem of noise pollution. This study aims at making use of the spatial technology of GIS in assessment and mapping noise distribution in Sri Serdang, Seri Kembangan area. A total of 15 sampling locations were selected for the collection of noise data classified based on residential, educational and commercial land uses. The Malaysia's Department of Environmental (DOE) standards of permissible noise values were used as limits for the designated land uses. Noise recordings were conducted any one day from weekday and weekend respectively, with three periods of the day – morning, afternoon and night. The lowest daily average of noise ranged between 65 dB (A) and 80 dB (A) across all the land uses. The spatial distributions were then evaluated using several GIS-based spatial interpolation methods. For interpolations of specified parameter, Inverse Distance Weighting (IDW), Kriging and Radial Basis Function (RBF) methods were used. The most optimal model for interpolation was selected by cross validation and error evaluation methods, such Root Mean Square Error (RMSE), Mean Error (ME) and Mean Absolute Error (MAE). The results showed that kriging method with specified spherical semivariogram model is better than other methods for prediction of noise property. It has the lowest RMSE (2.968), MAE (2.405), and ME (0.205) values compared than other interpolation methods. Finally, the noise map was prepared, using the best interpolation method in Geographical Information System environment.

ABSTRAK

Oleh kerana pembangunan bandar yang pesat dan penambahan penduduk secara besar-besaran, pada masa kini banyak bandar-bandar mengalami masalah pencemaran bunyi. Kajian ini bertujuan untuk membuat penggunaan teknologi spatial GIS dalam penilaian dan pemetaan pengedaran bunyi di Sri Serdang, dalam kawasan Seri Kembangan. Sebanyak 15 lokasi persampelan telah dipilih untuk pengumpulan data bunyi dikelaskan berdasarkan kediaman, pendidikan dan komersial kegunaan tanah. Jabatan Malaysia Alam Sekitar (DOE) piawaian nilai bunyi bising yang dibenarkan telah digunakan sebagai had untuk kegunaan tanah yang ditetapkan. Rakaman bunyi telah dijalankan mana-mana satu hari dari hari bekerja dan hujung minggu masing-masing, dengan tiga tempoh hari - pagi, tengah hari dan malam. Purata harian rendah bunyi adalah antara 65 dB (A) dan 80 dB (A) di semua kegunaan tanah. Taburan spatial kemudiannya dinilai dengan menggunakan beberapa kaedah interpolasi spatial berasaskan GIS. Untuk interpolasi parameter ditetapkan, songsang Jarak pemberat (IDW), kaedah 'kriging' dan Radial Asas Fungsi (RBF) telah digunakan. Model paling optimum untuk interpolasi telah dipilih oleh pengesahan silang dan kaedah penilaian ralat, seperti Ralat Root Mean Square (RMSE), Min Ralat (ME) dan Min Ralat mutlak (MAE). Hasil kajian menunjukkan bahawa kaedah 'kriging' dengan model semivariogram sfera tertentu adalah lebih baik daripada kaedah lain untuk ramalan hartanah bunyi. Ia mempunyai RMSE yang paling rendah (2.968), MAE (2.405), dan ME (0.205) berbanding daripada kaedah interpolasi lain. Akhir sekali, Peta bunyi itu disediakan, menggunakan kaedah interpolasi yang terbaik dalam geografi persekitaran Sistem Maklumat.

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TABLE OF CONTENT

ABSTRACT	I
ABSTRAK	II
ACKNOWLEDGMENT	III
APPROVAL SHEET	IV
DECLARATION	V
LIST OF FIGURE	IX
LIST OF TABLES	XII
LIST OF ABBREVIATIONS	XIII
CHAPTER	
1 INTRODUCTION	1
1.1 BACKGROUND OF STUDY	1
1.1.1 Sound and Noise	1
1.1.2 GIS for Noise Mapping	2
1.2 PROBLEM STATEMENT	4
1.3 OBJECTIVES	5
1.4 SCOPE OF WORK	5
1.5 LIMITATION OF THE STUDY	6
1.6 ORGANIZATION OF THE REPORT	7

2 LITERATURE REVIEW	8
2.1 ROAD TRAFFIC NOISE	8
2.1.1 Noise induced by road traffic	8
2.1.2 Effects of road traffic noise	9
2.1.3 Units of Sound	10
2.2 NOISE MAPPING	12
2.3 ROLES OF GIS IN NOISE MAPPING	13
2.4 SPATIAL INTERPOLATION METHODS	14
2.4.1 Deterministic Interpolation Technique	15
2.4.2 Geostatistical Interpolation Method	19
2.5 COMPARATIVE ANALYSIS OF INTERPOLATION METHODS	21
2.6 SUMMARY	25
3 METHODOLOGY	26
3.1 GENERAL	26
3.2 PRELIMINARY STUDY	26
3.3 STUDY AREA AND MATERIAL	28
3.3.1 Sound Level Meters	31
3.3.2 Global Positioning System (GPS)	35
3.4 MEASUREMENT METHODOLOGY	36
3.5 APPLICATION OF INTERPOLATION TECHNIQUES	38
3.5.1 Ordinary Kriging	39
3.5.2 Inverse Distance Weighting	46
3.5.3 Radial Basis Function (RBF)	48
3.6 CROSS VALIDATION	50
3.7 PRODUCTION OF NOISE MAP	51

3.8 SUMMARY	52
4 RESULTS AND DISCUSSION	53
4.1 NOISE LEVEL RESULTS	53
4.2 EXPLOTARY SPATIAL DATA ANALYSIS (ESDA) RESULTS	60
4.2.1 Histogram	60
4.2.2 Semivariogram/Covariance	63
4.2.3 Trend Analysis	65
4.3 INTERPOLATION TECHNIQUES RESULTS	67
4.3.1 Inverse Weighting Distance (IDW) Results	67
4.3.2 Radial Basis Function (RBF) Result	70
4.3.3 Kriging Result	73
4.4 COMPARATIVE ANALYSIS OF INTERPOLATION TECHNIQUES	76
4.5 NOISE MAPPING	79
4.6 RECOMMENDATION AND MITIGATION	88
4.7 SUMMARY	90
5 CONCLUSION AND RECOMMENDATION	91
5.1 CONCLUSION	91
5.2 RECOMMENDATION FOR FUTURE WORK	94
REFERENCES	95
APPENDICES	101

LIST OF FIGURE

FIGURE	PAGE
1: GIS basic structure	3
2: dB(A) scale showing the levels of common sounds	11
3: Radial Basis Function Surface Fitting Through a Series of Elevation Value	16
4: Search Circle	18
5: Characteristics of the Semivariogram	20
6: Relationship between Spline, IDW and Kriging.	21
7: Flowchart for Project Principle	27
8: Study area (outlined with red color)	28
9: Land Use for Residential Area (outlined with an orange color of box)	30
10: Land use for Educational Institution (UPM)	30
11: Land use for combination of Residential and Commercial Activities (outlined with an orange color of box)	31
12: Sound level meters	32
13: Calibrate sound level meterequipment to standard scale of reading.	34
14: Equipment calibrated to standard sound level range (60 – 120dB).	34
15: GPS Equipment	35
16: Base map image that covered samples planning, land cover and road	36
17: Noise survey at residential area	37
18: Noise survey at education institution zone	37

19: Geostatistical Method Selection Dialog Box	39
20: Semivariogram/Covariance Modelling	40
21: Ordinary Kriging Search Neighbourhood Dialog Box	42
22: Ordinary Kriging Predicted Plot (Predicted values Vs Measured Values)	43
23: Ordinary Kriging Error Plot (Errors Vs Measured Values)	43
24: Ordinary Kriging Standardized Error Plot (Standardized Error Vs Measured Values)	44
25: Ordinary Kriging QQ Plot	45
26: IDW Searching Neighbourhood Dialog Box	46
27: IDW Cross Validation Tool (Measured Vs Predicted Values)	47
28: RBF Searching Neighbourhood Dialog Box	48
29: RBF Cross Validation Tool (Measured Vs Predicted Values)	49
30: Maximum Permissible Sound Level by Receiving Land Use for Planning and New Development (Source: The Noise Pollution (Regulation and Control) from Department of Environmental, Malaysia 1974)	54
31: Means Noise Levels in study area	55
32: Means Noise Level in study area	56
33: Maximum noise levels for weekday	57
34: Maximum Noise Levels for Weekend	58
35: Plot showing the frequency distribution of noise data set before log transformation.	62
36: Plot showing the frequency distribution of noise data set after log transformation	62
37: Semivariogram/Covariance Cloud of Noise Measured Dialog Box	64
38: Trend Analysis of Measured Noise Level Dialog box	65

39: IDW with power function of 1 (Measured Vs Predicted Values).	68
40: IDW with power function of 2 (Measured Vs Predicted Values).	68
41: IDW with power function of 3 (Measured Vs Predicted Values).	68
42: RBF completely regularized spline (Measured Vs Predicted Value).	71
43: RBF spline with tension (Measured Vs Predicted Value).	71
44: Cross Validation Exponential Model (Predicted Vs Measured).	74
45: Cross Validation Gaussian Model (Predicted Vs Measured).	74
46: Cross Validation Spherical Model (Predicted Vs Measured).	74
47: Comparison of cross-validation of different interpolation methods between measured and predicted noise level values: (a) Inverse Distance Weighted–IDW; (b) Radial Basis Function–RBF; (c) Ordinary Kriging–OK.	77
48: The map showing noise level in dB, between 8 am to 10 am (morning)	80
49: The map showing noise level in dB, between 12 pm to 2 pm (afternoon)	81
50: The map showing noise level in dB, between 5 pm to 7 pm (night)	82
51: The map showing noise level in dB, between 8 am to 10 am (morning)	84
52: The map showing noise level in dB, between 12 pm to 2 pm (afternoon)	85
53: The map showing noise level in dB, between 5 pm to 7 pm (night)	86
54: Proposed design area of noise barrier fencing (white dashed line)	89

LIST OF TABLES

TABLE	PAGE
1: Measurements of error values used to assess the performance of the spatial interpolation methods (Ahmed and De Marsily, 1987; Burrough and McDonnell, 1998; Hu et al., 2004; Isaaks and Srivastava, 1989; Vicente-Serrano et al., 2003).	23
2: Specification of the Sound Level Meter TES-52A	33
3: Summary statistics of measured noise values data for weekday with different occasions	61
4: Summary statistics of measured noise values data for weekend with different occasions	61
5: MAE, ME, RMSE Values for Inverse Distance Weighting (IDW) with Different Parameters	69
6: MAE, ME and RMSE Values for Different Kernel Function of RBF Interpolation	72
7: MAE, ME and RMSE Values of Different Models of Semivariogram	75
8: Summary of Interpolation Method Analysis.	78

LIST OF ABBREVIATIONS

dB (A)	A-weighted Decibel
dB	Decibel
ESDA	Exploratory Spatial Data Analysis
GIS	Geographic Information System
GPS	Global Positioning System
IDW	Inverse Distance Weighting
MAE	Mean Absolute Error
ME	Mean Error
OK	Ordinary Kriging
RBF	Radial Basis Function
RMSE	Root Mean Square Error
WHO	World Health Organization

CHAPTER 1

INTRODUCTION

This chapter consists of background of study and problem statement of the research project. Then it follows by the aims and objectives of the project and scope of works involved throughout the research project.

1.1 BACKGROUND OF STUDY

1.1.1 Sound and Noise

Typically, sound is a type of energy that caused by the actions which called vibrations. Continuous regular and vibrations produced sound and it can be heard when they enter human's or animal's ear as they travelled through the air or another medium. In some circumstances, sound becomes noise when sound is generated in large amount. Noise can be considered as an unpleasant sound where the cases that the sound is too loud and prolonged exposure to such condition might can be hazardous to a person's

hearing. Typically, noise are generated through many sources such as machinery, motor vehicles, industrial, construction activities, etc.

Due to rapid development of the urbanization, the noise sources that mainly from construction and the road traffic have causes irritation and many of negative effects on the health of human being in the urban areas (Yoshida et al., 1997; Onuu, 2000; Ouis, 2002). Nowadays, noise pollution is considered as the most critical environmental challenges faces in major cities of world. Varlitoprak et al. (1991) defined that noise pollution is an unintentional sound that give rise to negative physiological and psychological effects on the human beings. It is considered an environment pollutant due to the hazard it create to health and the way it affect the people's well-being and quality of life. The increment of noise pollution is unsustainable and in need to be measured and reduced, since it is not only a source of irritation, but also may lead to public health problem. Carter (1996) stated that where the circumstances are likely high exposure to noise may cause many negative impacts such as irritation and annoyance feelings, auditory system destruction, health issues like physiological disorders, disruption of daily routines and activities, hypertension and cardiovascular disease. Therefore, it is crucial to control and manage the noise pollution in particular areas so that the environment surrounding the areas can be protected and improved where the noise level exposure is deemed excessive.

1.1.2 GIS for Noise Mapping

Noise mapping is the most effective way of determining the difference of outdoor noise levels with location (Peters et al, 2011). A noise map is a graphical representation of the foresee condition with regards to noise in a particular area with different colours representing different noise levels (Klaeboe et al., 2006; Guedes et

al., 2011; Vogiatzis, 2011). Noise map act as a tool to control and manage action plans for determining the precautions of reducing the noise. There are number of variables that need to be taken into consideration in the production of noise map, thereby the amount of noise emission at the source can be represented accurately. Noise sources are like noise emission from the traffic flows, construction and industrial activities.

The use of advanced technology in GIS is more feasible in dealing with noise that contains many spatial components. One of the features in GIS application such as advanced interpolation techniques, make it now possible to obtain an accurate picture of the acoustic situation and critical noise zones based on a finite number of noise data measured or recorded using noise equipment. GIS provides the central database management environment and noise data can be inserted into a GIS. In addition, it also provides an effective representation tools of noise data and its propagation surrounding the affected areas.

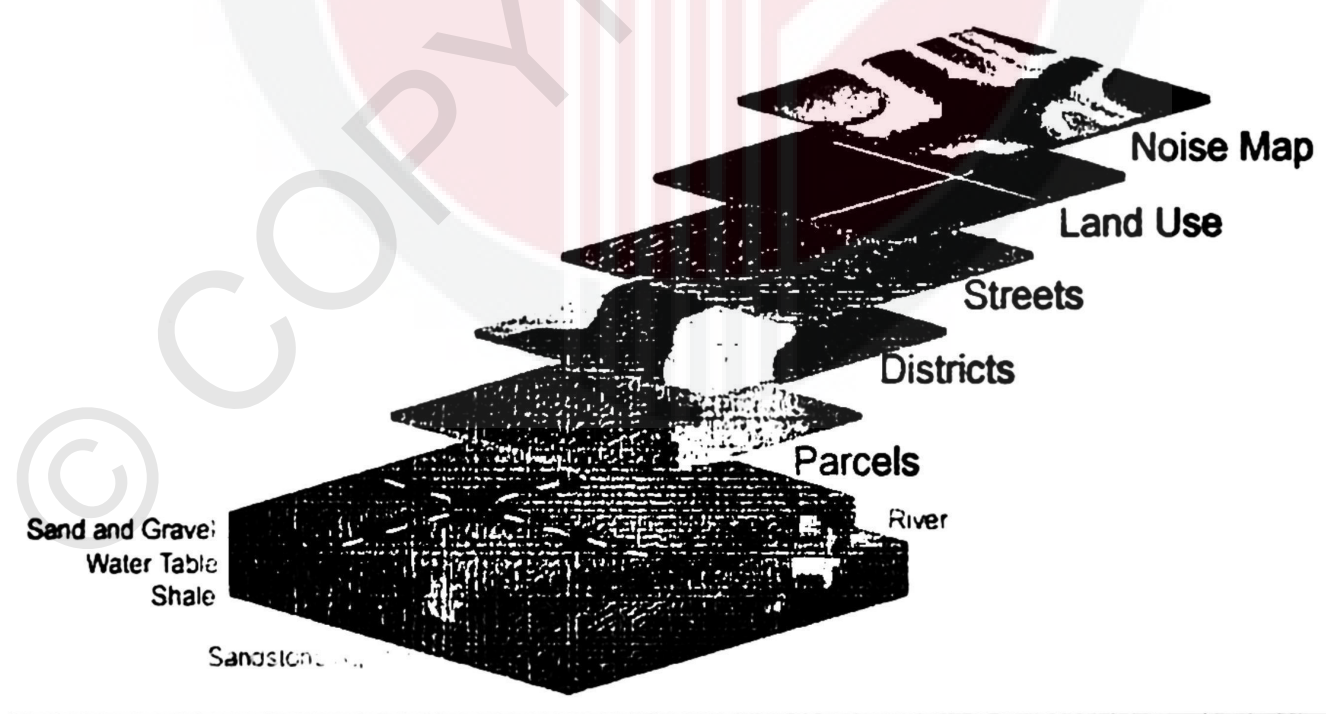


Figure 1: GIS basic structure

1.2 PROBLEM STATEMENT

Zannin et al. (2013) stated that noise mapping is an effective tool for developing vital information regarding environmental impacts and allowing the representation of noise pollution in urban landscapes. In this sense, it is important to produce an accurate and logical noise maps for representing the occurrence of noise pollution in the affected areas. What is the difference between the typical noise mapping and strategic noise mapping? In a simple way, noise mapping is a graphic representation that presents computed and measured noise levels over a geographical area. Nevertheless, 'Strategic Noise Mapping' has different meaning than noise mapping. In contrast, strategic noise mapping is a map designed purposely for the global assessment where it takes into account the noise exposure in a given area caused from multiple sources of noise (European Union, 2002). Therefore, it can be implied that noise mapping is emphasized mostly on the presentation of measured noise data while strategic noise mapping is more prioritize with evaluation of noise exposure under terms of presentation of noise data with taking considerations of noise exposure due different sources in a given area.

Noise mapping can be developed through direct measurement and indirect measurements of equivalent noise pressure levels. Direct measurement is where the noise data are calculated or measured using equipment in a given area. The obtained noise data will then be used in developing noise mapping by using software based on GIS system. Generally, noise mapping in GIS are generated through interpolation techniques of the noise data. From the result, the noise data then calibrated with the noise data obtained from the satellite system. Indirect measurement of noise levels may refers to making decision approaches will be used to refine the noise maps

considering the factors affecting the noise distribution and noise barriers. Which of the two geospatial tools will give a better performance in developing the noise maps? Both geospatial tools of interpolation techniques and multi-criteria decision making approaches will produced different performance under different parameters evaluated for generating the noise maps. The method that gives a better and acceptable result will then use as for final result of noise mapping.

1.3 OBJECTIVES

In order to produce accurate and logical noise maps, there are several objectives that need to be achieved from this project. The objectives are as follow:

- 1) To measure noise levels emission from traffic at any defined period.
- 2) To evaluate interpolation techniques such spline, kriging and inverse distance weighting for noise mapping in GIS.
- 3) To develop noise prediction models based on the traffic noise and decision making approaches for noise maps.

1.4 SCOPE OF WORK

The scope of works for this case study involves the use of software called ArcGIS to develop a noise map. The noise measurement data for vehicles on 'area' would be collected. Then, noise data will be interpolated with the GIS data. This case study will examine several interpolation techniques such spline, kriging and inverse distance weighting. The interpolation will be used to predict the unsampled pixels to produce a noise distribution map for the study area. In addition, decision making the factors affecting the noise distribution and noise barrier.

1.5 LIMITATION OF THE STUDY

The following are the limitation of this project related to the data availability:

- In this project a simple mathematical calculation will be used for noise calculation. Usually, this standard of noise calculation is used for simple situation for preliminary assessment of noise effect studies. The noise calculation will be carried out along with simple input parameters such as traffic type, land use type and observation points. Other parameters such as background noise, reflection, and obstruction of noise and effect of meteorological conditions on noise will be not taken into account for noise calculation.
- In this project accuracy of models in terms of noise information is an issue because this project using different type of spatial interpolation techniques to produce a noise map. Each interpolation technique produces different results for building noise models and therefore evaluation has to be made based on the accuracy and precision of the prediction surface that developed from interpolation process.

1.6 ORGANIZATION OF THE REPORT

This thesis report consist of 5 chapters. For the first chapter, it introduced the sound and noise environment. Then, explanation of the roles of GIS in noise mapping as well as specific problem statement addressed in the study. After the first chapter, it followed by chapter two which presents the literature review for this study research. In chapter 2, relevant subtopics were explained regarding to the research study associated with undertake obstacles in the study as well.

Next, it is chapter 3 which highlighted the methodology and procedures used for this research study that regarding to the data collection and analysis of software. The use of ArcGIS software to do the analysis of data will be described in this chapter. Presentation of the data analysis results will be discussed in the next chapter which is chapter 4. This includes the noise data measurement results, software analysis results as well as development of noise maps. For final chapter, which is chapter 5 that usually gives a conclusion and recommendation of the whole findings for research study.

CHAPTER 2

LITERATURE REVIEW

2.1 ROAD TRAFFIC NOISE

2.1.1 Noise induced by road traffic

In many countries, one of the main source of environmental noise is road traffic and it is significantly contributes more on producing disturbances to the well-being of a person (Bruel & Kjaer, 2002). Based on World Health Organization, WHO (1999), they described that sound engine and the contact area that causes frictional force between the tire of vehicle and the road surface are the main contribution to the traffic noise. The noise produced due to traffic is rely on the volume of traffic, vehicles speed, the amount of heavy vehicle and also the nature of road surface. The accumulation of the noise from an individual vehicle is the one that gives rise to traffic road noise level. The sources from an individual vehicle such as car engine, contact area between the wheel and the road and exhaust system will produce different sound levels and combined to form a basic unit of road traffic noise.

Usually, car engine operates under the combustion of fuel and mechanical works. Seoud (1994) explained that noise produced that range between 68 and 78dB (A) due

to car engine primarily transmitted from the driving shafts, axles of car and gearboxes. The unexpected release of gas and flow into the exhaust system produced the exhaust noise when the exhaust valve is open. As a whole, the most contributes to road traffic noise are the moving vehicles with the wheels rolling on the road surfaces and causes friction action occurred. A car that moves at a high speed of above the 100km/h are likely becomes the most influential to vehicle noise (Harland, 1974). However, the deterioration to the human life quality that caused by noise pollution is still a major concerned issues, even though many initiative actions has been done to mitigate the noise that produced from individual vehicles.

2.1.2 Effects of road traffic noise

Many research studies have been done relative to the negative impacts of the road traffic noise to the human quality life. Based on Environment Protection Authority (EPA), they claimed that 'noise issues are always being overlooked when it comes to environmental pollution'. Noise is not only causes irritation and annoyance but it also form a real and placed the human being health in danger. The harmful effects of noise on public has been classified into two categories which are behavioural and physiological, (Environment Agency, 2002). They stated that irritation and annoyance are the main effects of noise under behaviour category while for under physiological, person may experience of hearing loss and also other potential health effect. Noise effects causes a person's daily activities and performance deteriorates. It will not only affects a person's rest time but also other aspects such as conversation and tasks. Environment Agency (2002) described that noise that give rise to disturbance may lead a person to prevent themselves from undergoing their daily activities such as having conversation, listening to radio or watching a TV and focusing while study.

Urban areas are the place which prone to road traffic noise and due to that quality of residential environment is reducing which results in downsizing of property values. This may lead the society to spend a lot of money of considering implement the sound insulation to the buildings. Other than that, noise pollution may also causes other damages such as loss of productivity, health care cost and also psychological well-being losses. World Health Organization, WHO (1995) explained that the loss of productivity may be due to the affected person that incapable to pay attention and communicate with colleagues during at work, or because of fatigue due to lack of rest and sleep.

2.1.3 Units of Sound

The human ear preferably responds in a logarithmic manner rather than linear manner. Basically, ear responds is based on the intensity of sound pressure. Sound pressure is measured in Micro Pascal (μ Pa). Bruel & Kjaer (2002) defined that sound pressure of 20μ Pa corresponds to the average person's threshold of hearing. It is therefore called threshold of human hearing. A sound pressure of approximately 100Pa is so loud that it cause pain to human ear and it is called threshold of pain. The ratio between these two extremes is more than a million to one (Bruel & Kjaer, 2002). A direct application of linear scales (in Pa) to the measurement of sound pressure leads to larges number. Therefore it is more practical to express the sound levels in logarithmic scale. This logarithmic scale is called decibel or dBA.

Human ear have varying sensitivity to different frequencies, in a sense that it is less sensitive to lower frequencies than to higher frequencies and has a limited range. The sound pressure levels have to be adjusted to give comparatively more weight to the

frequencies which are detected most readily by human ear (Environment Agency, 2002). For these reasons, several different weighting systems have been proposed but the 'A' weighting is now used for all levels of noise. The noise measurement by 'A' weighting scale is denoted as dBA. As per the 'A' weighting scale, doubling of sound frequency is equal to an increase of 10dBA. An indication of some common sound on the dBA is shown in Figure 2. In 'A' weighted scale the linear scale with its large numbers is converted into a manageable scale from 0 dB at the threshold of hearing ($20 \mu\text{ Pa}$) to 130 dB at the threshold of pain ($\sim 100 \text{ Pa}$) (Bruel & Kjaer, 2002).

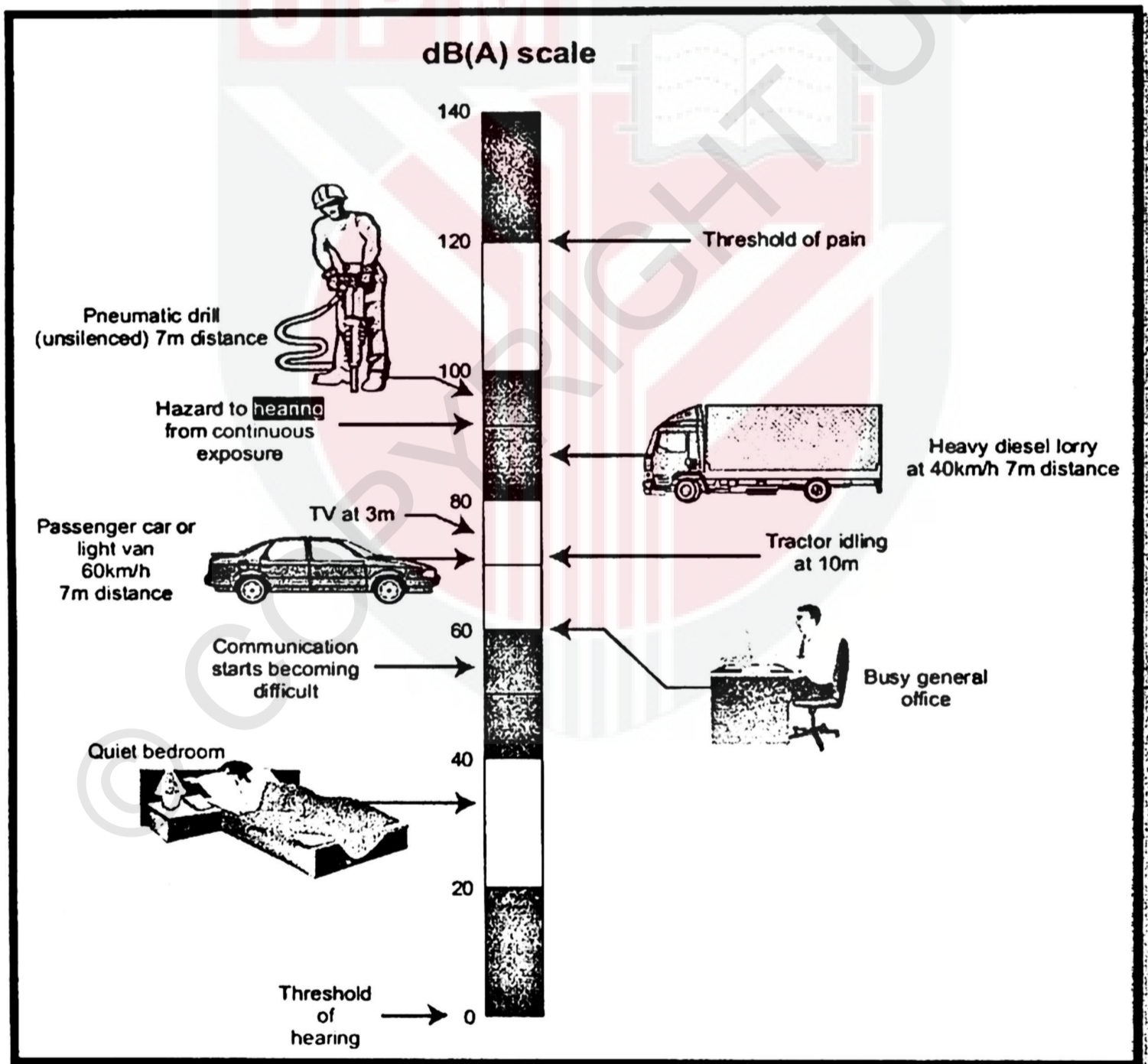


Figure 2: dB(A) scale showing the levels of common sounds

(National Road Authority, 2004)

2.2 NOISE MAPPING

Noise mapping nowadays has been recognized as one of an effective tool for controlling and assess the noise pollution issues. They are not only capable of describing the spatial distributions of noise levels but also can provides an appropriate and efficient visualization of noise propagation in the affected areas. Coelho, J.L.B and Alarcao (2015) defined that noise mapping is an efficient assessment method in urban area. A noise map provides comprehensive look for the difficulty of multiple sources and receivers, and thus can improve urban planning. Santos (2004) explained that the use of noise mapping allows:

1. Measurement or counting or quantification of equivalent noise pressure levels in studied area.
2. Estimation of population exposure.
3. Formation of a database for urban planning with localisation of noise activities and mixed and sensitive zone.
4. Foresee of impact noise of the projected infrastructure and industrial activities.

2.3 ROLES OF GIS IN NOISE MAPPING

Generally, noise maps are developed using Geographic Information System (GIS). It can be effectively used in the gathering, weighting, analysing and presenting spatial and attribute information to facilitate the management of environmental pollutions. It can also be extended to provide an answer to user specific problems through deterministic and statistics models. This is an important consideration in noise mapping research particularly in terms of noise effect studies and in terms of educating public opinion about the impacts of environmental noise. Integrating noise prediction data with a GIS allows for other types of spatial data to be utilised in noise studies. Ultimately, this can provide more accurate noise maps as well as providing more comprehensive data on which to base environmental noise policy decisions. Meskell Craig; Murphy Enda; Rice Henry J (2006) has discussed the exact role of GIS in environmental noise studies in their study work. The exact role that can be played by a GIS in environmental noise studies is now discussed.

According to De Kluijver and Stoter (2003), the appropriate use of GIS in noise mapping makes it feasible to optimize the efficiency and quality of noise studies effects. In dealing with spatial analysis and modelling, GIS has the most efficient way to solve the issues. From previous studies, numerous of researcher have used the integrated GIS traffic noise prediction models to estimate the level of noise in urban areas. For an instance, Sheng and Wa Tang (2011) proposed and applied a GIS-based traffic noise model system to look into the influences of existing urban forms on vehicle transport and pedestrian exposure to traffic noise in the Macao Peninsula. Wazir (2011) prepared a noise mapping using ArcGIS 9.3 software in order to provide better visualisation of noise environment of Guwahati City and its diurnal variations.

Mohammed Taleb Obaidat (2008) has discussed numerous advantages of GIS usage in noise studies like:

1. Enhancing the quality of the study on environmental noise pollution;
2. Providing a monitoring and quantifying noise tool;
3. Establish a link between geographical and geometrical information of the surrounding environment and the noise prediction model;
4. Presenting, storing, managing, manipulating, analysing, and visualizing capabilities of database;
5. Supporting and assisting environment management and also decreasing the cost of noise studies.

2.4 SPATIAL INTERPOLATION METHODS

A number of methods have been developed for spatial interpolation and many terms have been used to distinguish them, including: 'deterministic' and 'stochastic' methods (Myers, 1994), or "interpolating" and "non-interpolating" methods, or "interpolators" and "non-interpolators" (Laslett et al., 1987).

Murphy et al. (2006) have pointed out that different noise maps are produced when different methods of spatial interpolation are used in noise mapping analysis. There are two categories of interpolation techniques: deterministic and geostatistical, (ESRI, 2002). Deterministic interpolation techniques create surfaces based on measured points or mathematical formulas. Methods such as Inverse Distance Weight (IDW) are based on the extent of similarity of cells while methods such as Radial Basis Function (RBF) fit a smooth surface defined by a mathematical function. Geostatistical interpolation

techniques such as Kriging are based on statistics and are used for more advanced prediction surface modelling that also includes some measure of the certainty or accuracy of predictions.

The characteristics of an interpolated surface can be controlled by limiting the input points used in the calculation of output cell values, (ESRI, 2002). This can be done by limiting the number of points sampled or the area from which sampled points are taken. Specifying the maximum number of points to be sampled will return the points closest to the output cell location until the maximum number is reached.

2.4.1 Deterministic Interpolation Technique

Deterministic interpolation techniques create surfaces from measured points, based on either the extent of similarity (IDW) or the degree of smoothing (RBF).

Radial Basis Function (RBF)

Radial Basis Function (RBF) also known as spline interpolation method. Spline estimates values using a mathematical function that minimizes overall surface curvature (ESRI, 2004). This results in a smooth surface that passes exactly through the input points. RBF is conceptually similar to like bending a sheet of rubber so that it passes through the points while minimizing the total curvature of the surface.

There are two variations of spline regularized and tension. A regularized spline incorporates the first derivative (slope), second derivative (rate of change in slope), and third derivative (rate of change in the second derivative) into its minimization calculations. Although a tension spline uses only first and second derivatives, it includes more points in the spline calculations, which usually creates smoother surfaces but increases computation time.

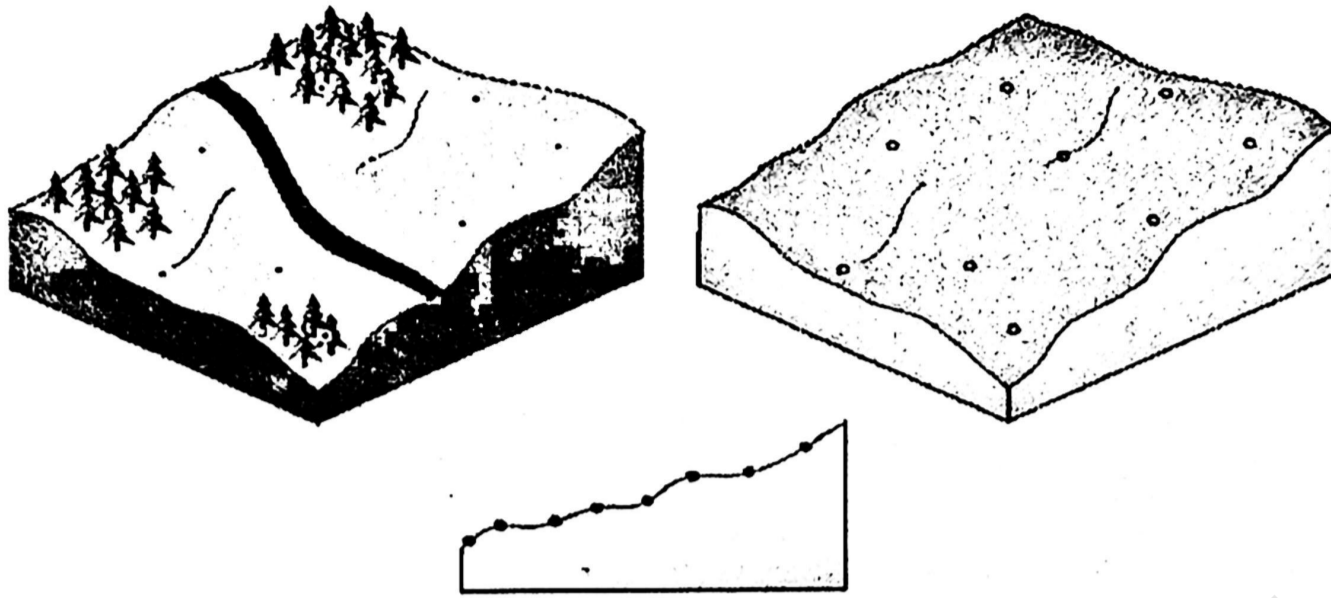


Figure 3: Radial Basis Function Surface Fitting Through a Series of Elevation

Values

Figure above demonstrates conceptually how a RBF surface fits through a series of elevation sample values.

Inverse Distance Weighted (IDW)

Inverse distance weighted (IDW) interpolation method is one of the simplest and most readily available method. IDW interpolation explicitly implements the assumption that things close to one another are more alike than those farther apart. To predict a value for any unmeasured location, IDW will use the measured values surrounding the prediction location. Those measured values closest to the prediction location will have more influence on the predicted value than those farther away. Thus, IDW assumes that each measured point has a local influence that diminishes with distance. It weighs the points closer to the prediction location greater than those farther away, hence the name inverse distance weighted.

Based on computation method, the noise value at point i (N_0) is calculated through the following formula.

$$N_0 = \frac{\sum_{i=1}^n N_i \cdot P_i}{\sum_{i=1}^n P_i} \dots\dots\dots (1)$$

Where,

n = number of measurement points;

N_i = noise value at position i ;

P_i = weight of the noise value at i position

For variable P_i , it can be computed with equation 1 below as a function of the distance between the reference point and the interpolation point from the idea that the effect of the closer points are higher than distant one (Zhan-Ji Y, 2008).

$$P_i = \frac{1}{d_i^k} \dots\dots\dots (2)$$

Where,

$i = 1, 2 \dots n$

d_i = horizontal distance between the interpolation point at (x_0, y_0) and the reference points at (x_i, y_i) and is calculated by the following formula. k is the power of the distance.

$$d_i = \sqrt{(x_i - x_0)^2 + (y_i - y_0)^2} \dots\dots\dots (3)$$

In the IDW method, the reference points around the interpolation point can be used to estimate the noise values, instead of using all of the reference points in the study area. The reference points to be used in the interpolation calculation can be determined by a search circle whose center must be the point which will be interpolated. This gives rise to the problem of determining the dimensions of the search circle. Determining the size of the search circle is directly related with the distribution of reference points in the region as well as the distance between these reference points (Figure 4). In order to accurately calculate the noise values obtained through the interpolation method, at least three points uniformly dispersed around the point must be used. The use of the search circle can significantly affect the performance of the IDW method.

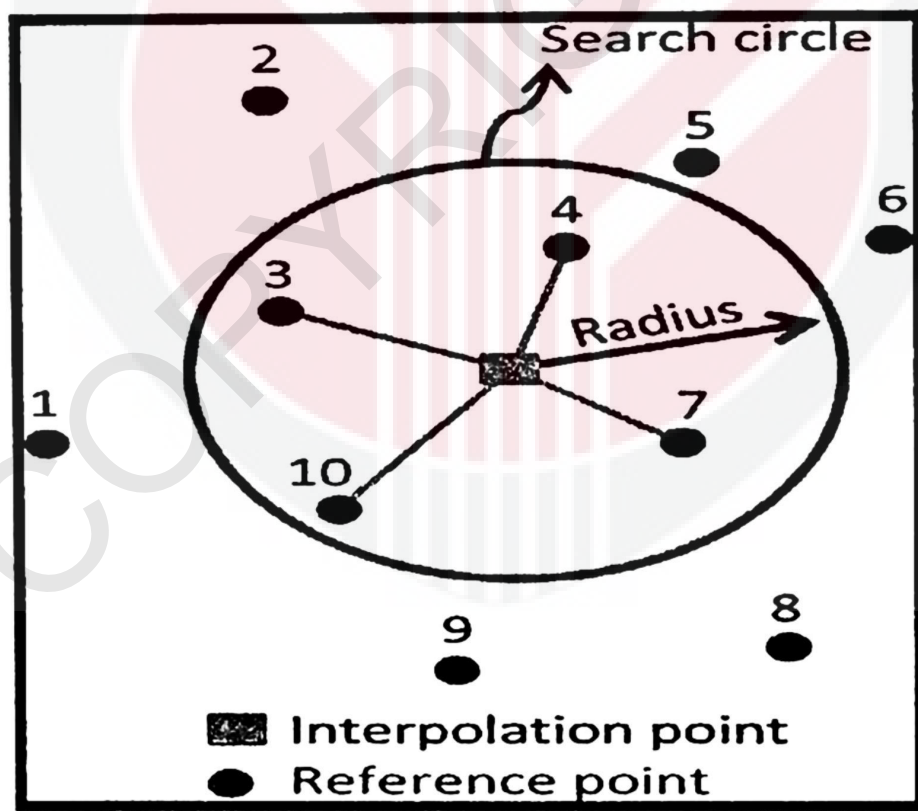


Figure 4: Search Circle

2.4.2 Geostatistical Interpolation Method

The geostatistical interpolation technique is based on statistics and is used for more advanced surface modelling that also includes errors or uncertainty of predictions, (ESRI, 2002). Kriging comes under the geostatistical interpolation technique.

Kriging Method

Geostatistical methods create surfaces incorporating the statistical properties of the measured data. Because geostatistics is based on statistics, these methods produce not only prediction surfaces but also error or uncertainty surfaces, giving the user an indication of how good the predictions are.

Kriging method is a geo-statistical interpolation method which proved its applicability and gained popularity in many areas. The presence of a spatial structure where observations are close to each other are more alike than those that are far apart (spatial autocorrelation) is a prerequisite to the application of geostatistics. The experimental variogram measures the average degree of dissimilarity between un-sampled values and a nearby data value. Thus, can described autocorrelation at various distances. The value of the experimental variogram for a separation distance of h (referred to as the lag) is half the mean squared difference between the value at $z(x_i)$ and the value at $z(x_i+h)$.

$$\gamma(h) = \frac{1}{2nh} \sum_{(i=1)}^{n(h)} [z(x_i) - z(x_i + h)]^2 \quad \dots\dots\dots(4)$$

where $n(h)$ is the number of data pairs within a given class of distance and direction. If the values at $Z(x_i)$ and $Z(x_i + h)$ are auto correlated the result of Eq. (3) will be small, relative to an uncorrelated pair of points.

Kriging uses statistical models that allow a variety of map outputs including predictions, prediction standard error, standard error of indicators, and probability. The flexibility of Kriging can require a lot of decision making. Kriging assumes that the data comes from a stationary stochastic process. A stochastic process is a collection of random variables that are ordered in space and/or time such as elevation measurements. The kriging literature provides a choice of functions which can be used as theoretical semivariograms (spherical, exponential, Gaussian, Bessel etc.: Cressie 1993). The parameters of these functions are then optimised for the best fit of the experimental semivariogram. From analysis of the experimental variogram, a suitable model like spherical, exponential and Gaussian is then fitted, usually by weighted least squares, and the parameters like range, nugget and sill are then used in the kriging procedure. The characteristic of the semivariogram is shown in the Figure 5.

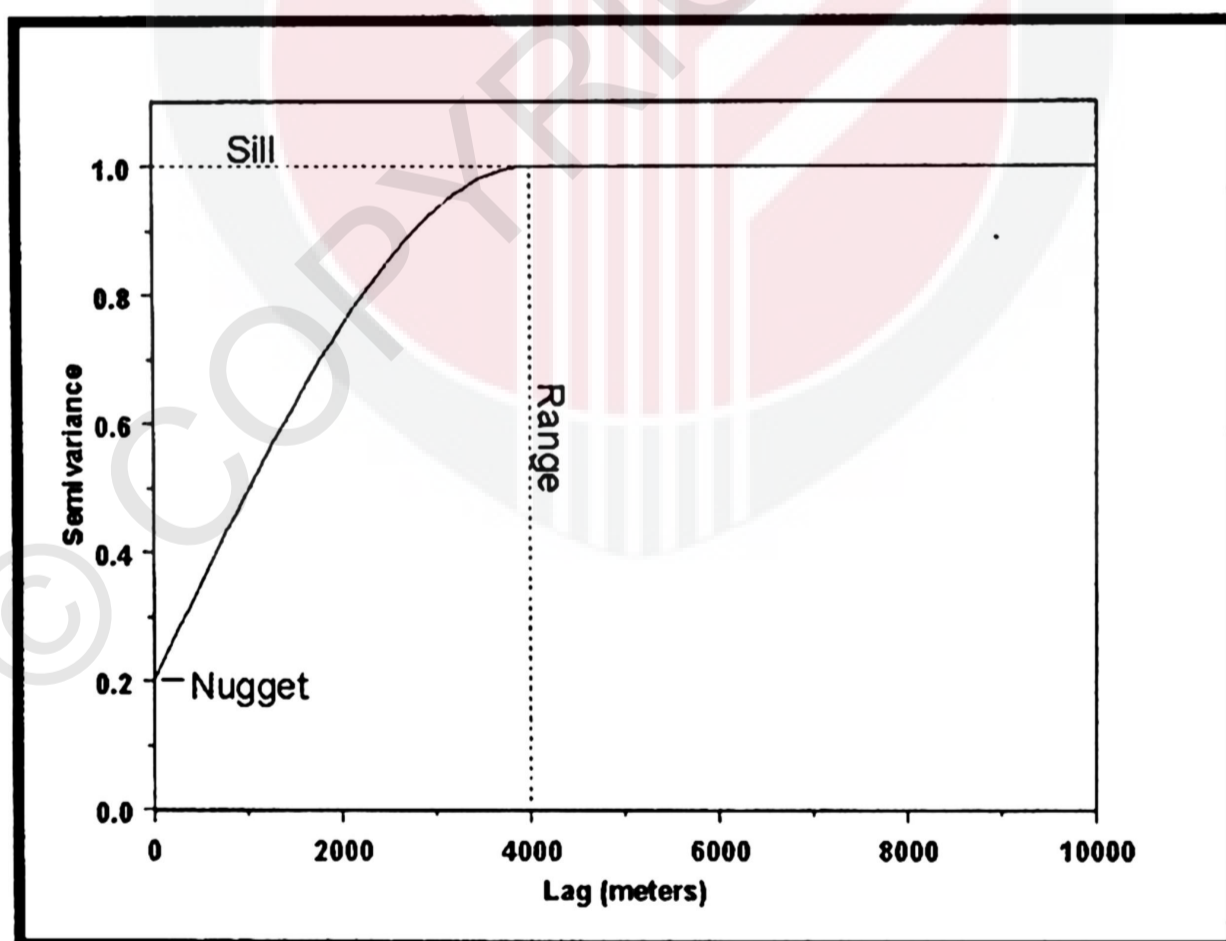


Figure 5: Characteristics of the Semivariogram

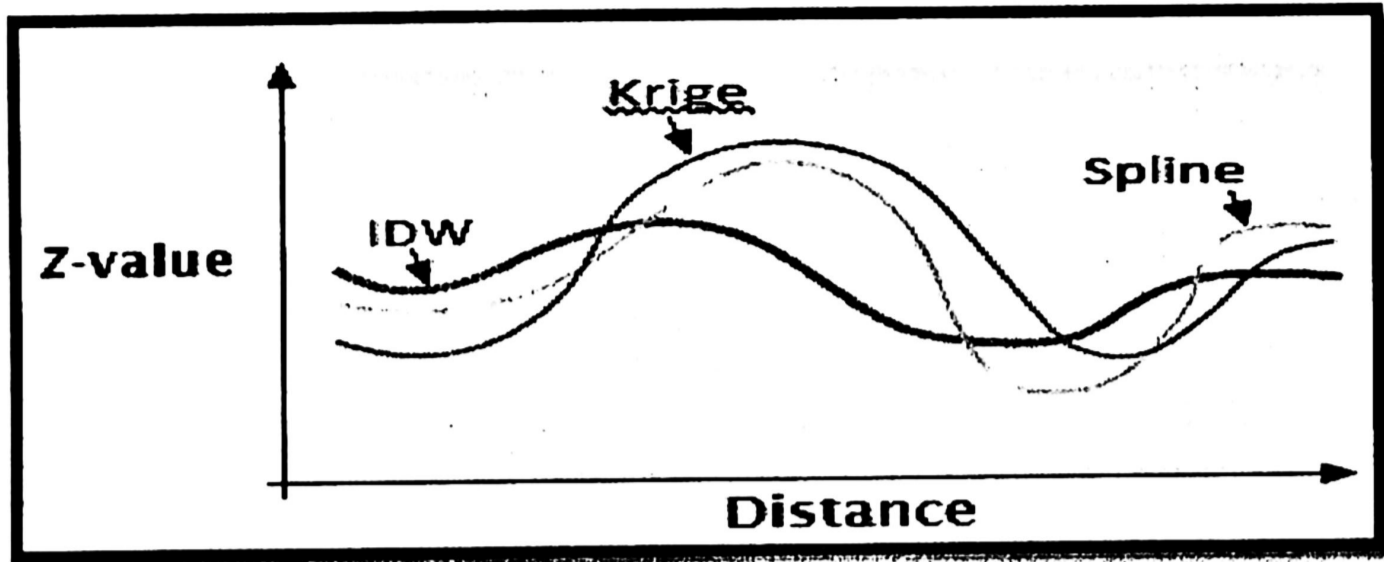


Figure 6: Relationship between Spline, IDW and Kriging.

In summary, IDW and Spline are two deterministic methods that create surfaces from samples based on the extent of similarity or degree of smoothing. However, while a spline surface passes exactly through each sample point, an IDW will pass through none of the points. Kriging is a geostatistical method that uses a powerful statistical technique for predicting values derived from the measure of relationship in samples and employs sophisticated weighted average techniques.

2.5 COMPARATIVE ANALYSIS OF INTERPOLATION METHODS

With the wide and increasing applications of the spatial interpolation methods, there is also a growing concern about their accuracy and precision (Hartkamp et al., 1999). As any other statistical modelling techniques, the spatial interpolation methods also produce a certain degree of errors associated with the estimation.

According to Burrough and McDonnell (1998), the statistics of the differences (absolute and squared) between the measured and predicted values at sampled points are often used as an indicator of the performance of an inexact method. Several error measurements have been proposed (Table 1). Commonly used error measurements include: mean error (ME), mean absolute error (MAE), mean squared error (MSE) and root mean squared error (RMSE). ME is used for determining the degree of bias in the

estimates, often referred to as the bias (Isaaks and Srivastava, 1989) but it should be used cautiously as an indicator of accuracy because negative and positive estimates counteract each other and resultant ME tends to be lower than actual error (Nalder and Wein, 1998). RMSE provides a measure of the error size, but it is sensitive to outliers as it places a lot of weight on large errors (Hernandez-Stefanoni and Ponce-Hernandez, 2006). MSE suffers the same disadvantages as RMSE. Whereas MAE is less sensitive to extreme values (Willmott, 1982; Vicente-Serrano et al., 2003) and indicates the extent to which the estimate can be in error (Nalder and Wein, 1998). MAE and RMSE are argued to be similar measures, and they give estimates of the average error, but they do not provide information about the relative size of the average difference and the nature of differences comprising them (Willmott, 1982). Of course, we can also use cross-validation in together with these measurements to assess the performance of both exact and inexact methods.

Table 1: Measurements of error values used to assess the performance of the spatial interpolation methods (Ahmed and De Marsily, 1987; Burrough and McDonnell, 1998; Hu et al., 2004; Isaaks and Srivastava, 1989; Vicente-Serrano et al., 2003).

Measurement	Definition
Mean error (ME) or mean bias error (MBE)	$ME = \frac{1}{n} \sum_{i=1}^n (p_i - o_i)$
Mean absolute error (MAE)	$MAE = \frac{1}{n} \sum_{i=1}^n p_i - o_i $
Mean square error (MSE)	$MSE = \frac{1}{n} \sum_{i=1}^n (p_i - o_i)^2$
Root mean square error (RMSE)	$RMSE = \left[\frac{1}{n} \sum_{i=1}^n (p_i - o_i)^2 \right]^{1/2}$
Mean squared reduced error (MSRE)	$MSRE = \frac{1}{n} \sum_{i=1}^n (p_i - o_i)^2 / s^2$
Mean standardized error2	$MSE2 = \frac{1}{n} \sum_{i=1}^n (p_{si} - o_{si})$
Root mean square standardized error	$RMSSE = \left[\frac{1}{n} \sum_{i=1}^n (p_{si} - o_{si})^2 \right]^{1/2}$
Averaged standard error (ASE)	$ASE = \left[\frac{1}{n} \sum_{i=1}^n (p_i - (\sum_{i=1}^n p_i)/n)^2 \right]^{1/2}$
Ratio of the variance of estimated values to the variance of the observed values (RVar)	$RVar = \frac{var [p]}{var [o]}$
Model Efficiency (EF)	$EF = 1 - \frac{\sum_{i=1}^n (p_i - o_i)^2}{\sum_{i=1}^n (\bar{o} + o_i)^2}$

*n: number of observations or samples; o: observed value; p: predicted or estimated values; o_s : standardised observed value; p_s : standardised predicted value; s: standard deviation of the estimation error; \bar{o} : mean of observed values

However, the error values measured in this project are only including RMSE, ME and MAE. These values are common error values that many researchers had been studied regarding on evaluation of spatial data interpolation methods. From previous studies, (Chai et al., 2011) had been investigated the relative performance of different interpolation methods in meteorological data of Xinjiang Uygur Autonomous Region. Based on their research, they were using cross-validation method to evaluate the performance of different spatial interpolation methods.

Taghizadeh-Mehrjardi, Zare M, and Zare S were developed a noise map for recovery section of Ghandi Telecommunication Cable Co. with using different spatial interpolation methods to predict the unknown values between the known values of noise level within the study area. In a similar way, the researchers examined the different interpolation method based on the result of cross-validation and error values measurement. For conclusion they discovered that Kriging method showed the best result of RMSE value among other interpolation methods used to produce the noise map.

Marcelo Curtarelli had done assessment on the performance of different interpolation to map the bathymetry of the Tucuruí hydroelectric reservoir, located in the Brazilian Amazon, as an aid to manage and operate Amazonian reservoirs. From their researched, they evaluated three different deterministic (IDW, LPI and RBF) and one geostatistical (OK) interpolation methods. Similarly, the performances from all of the interpolation methods were assessed based on the cross validation results. And the best performance was obtained with the geostatistical method (RMSE = 0.92m).

Through previous studies, it indicated that checking for the accuracy and precision of the performances for different interpolation method is important especially when

dealing with spatial data. An optimal interpolation method must be selected as to create prediction surfaces which acceptable and adequate for foresee situations.

2.6 SUMMARY

In summary, this chapter discussed the review of literatures associated with the address problems that related to this research topic. Firstly, road traffic noise was studied regarding to production of noise caused by road traffic and also its impact as contributor to the noise pollution. This is an important information to this research topic since the noise level data that were collected are mainly from road traffic. Next, production of noise mapping also was briefly discussed correspond to its function as an effective tool to control and manage the noise issues in urban planning areas. Mostly, noise mapping nowadays was made based on the GIS assessment method. The studies regarding to spatial interpolation techniques which one of the features in ArcGIS software were been discussed in this chapter. The spatial interpolation techniques can be classified into two groups which are deterministic and geostatistical interpolation techniques. Each of this technique has their own important parameters for making the noise prediction surface. To check the accuracy and precision of each of the interpolation techniques, cross validation and error measurement methods were studied in order to justify the analysis of result from the software produced. Many studies from the previous years, have used the accuracy methods as to enhance their findings on the quantification of the interpolation techniques to predict the unknown values.

CHAPTER 3

METHODOLOGY

3.1 GENERAL

It is important to extract related information as an input data for the noise mapping. The early stage in the production of a noise map involves the measurement of noise levels at different selected stations. The obtained noise levels data will then be used to generate a noise map using ArcGIS software. The first section in this chapter describes the equipment use to collect the noise levels at each of the station. The second section is about the study area and third section describes the measurement methodology of noise levels within the study area. The last section is about the procedures involved in the production of noise maps.

3.2 PRELIMINARY STUDY

First and foremost, a preliminary study was done on the related issues of noise mapping and spatial interpolation techniques. The related topics were explored and studied through the findings obtained from journals, thesis and project by researchers.

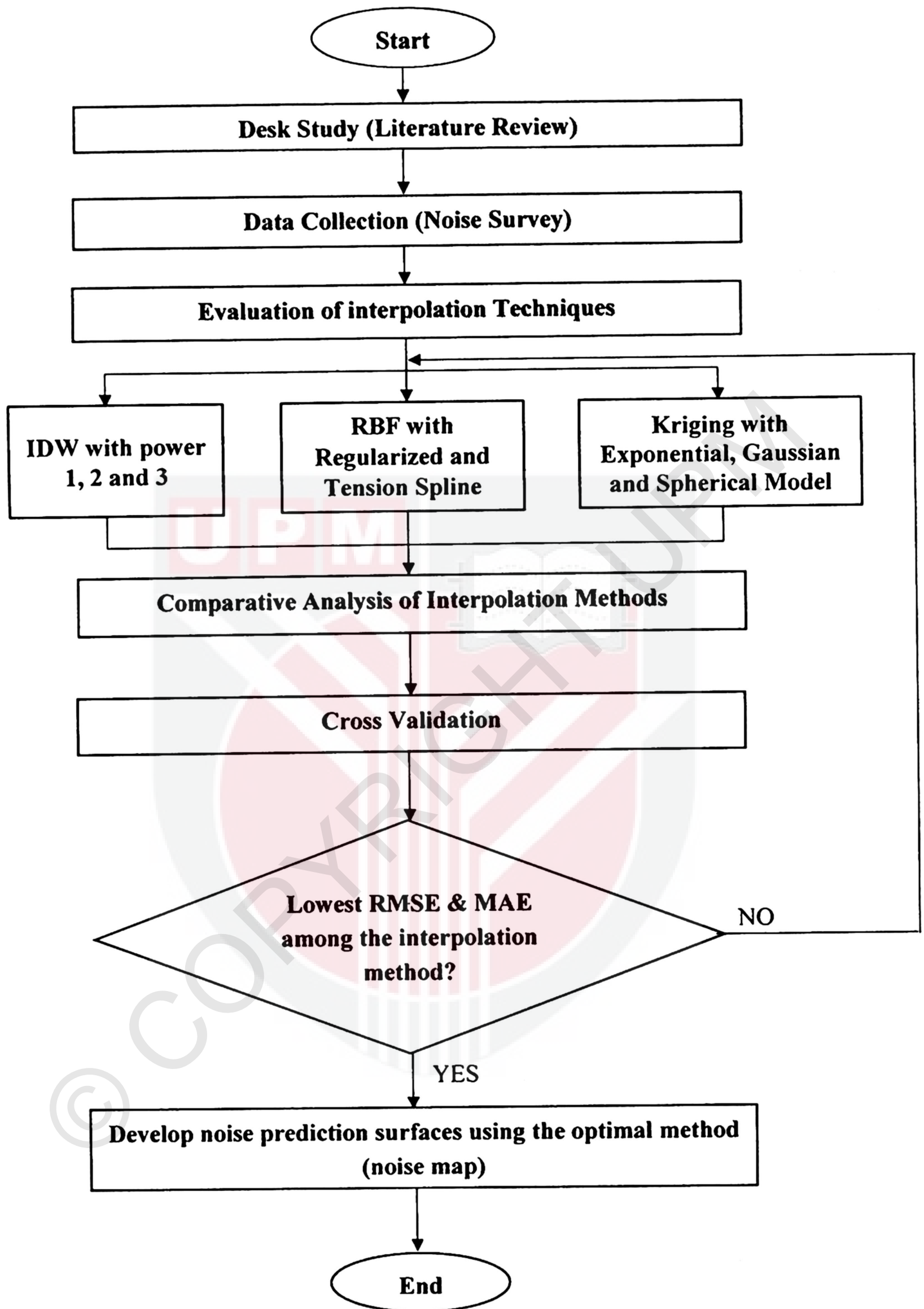


Figure 7: Flowchart for Project Principle

3.3 STUDY AREA AND MATERIAL

The study area for this research is covered within Universiti Putra Malaysia (UPM) region located at Seri Kembangan, as shown in the Figure 8. Seri Kembangan region is a part of district area of Petaling Jaya, Selangor. There are many commercial activities, educational institutions, and residential areas within the study area with approximately 150,000 populations. Geographical location of Seri Kembangan is (3.021998, 101.705541). For the study areas, geographical location of UPM is (3.002190, 101.717005).



Figure 8: Study area (outlined with red color)

(Source: Google Earth Image)

Next, the study area was divided into several zones that based on land use. As shown in Table 2, the study area is divided into three zones, which is residential, the combination of residential with commercial activities and also educational institution. Figure 9 showed the residential area for type of land use. This area covered 1, 2, 3, 4, 5, 6, and 14 locations respectively. In Figure 10, it represent the educational institution (UPM) for type of land use in the study area. This area covered 8, 9, 10, 11, 12, 13 and 15 respectively. For Figure 11, it only showed one location which is location 7 that can be recognized as the combination of residential and commercial activities for type of land use.

Table 2: Selected locations for noise measurement with correspond to type of land use

Location	Type of Land Use
1-6	Residential
7	Residential + Commercial
8 - 15	Education

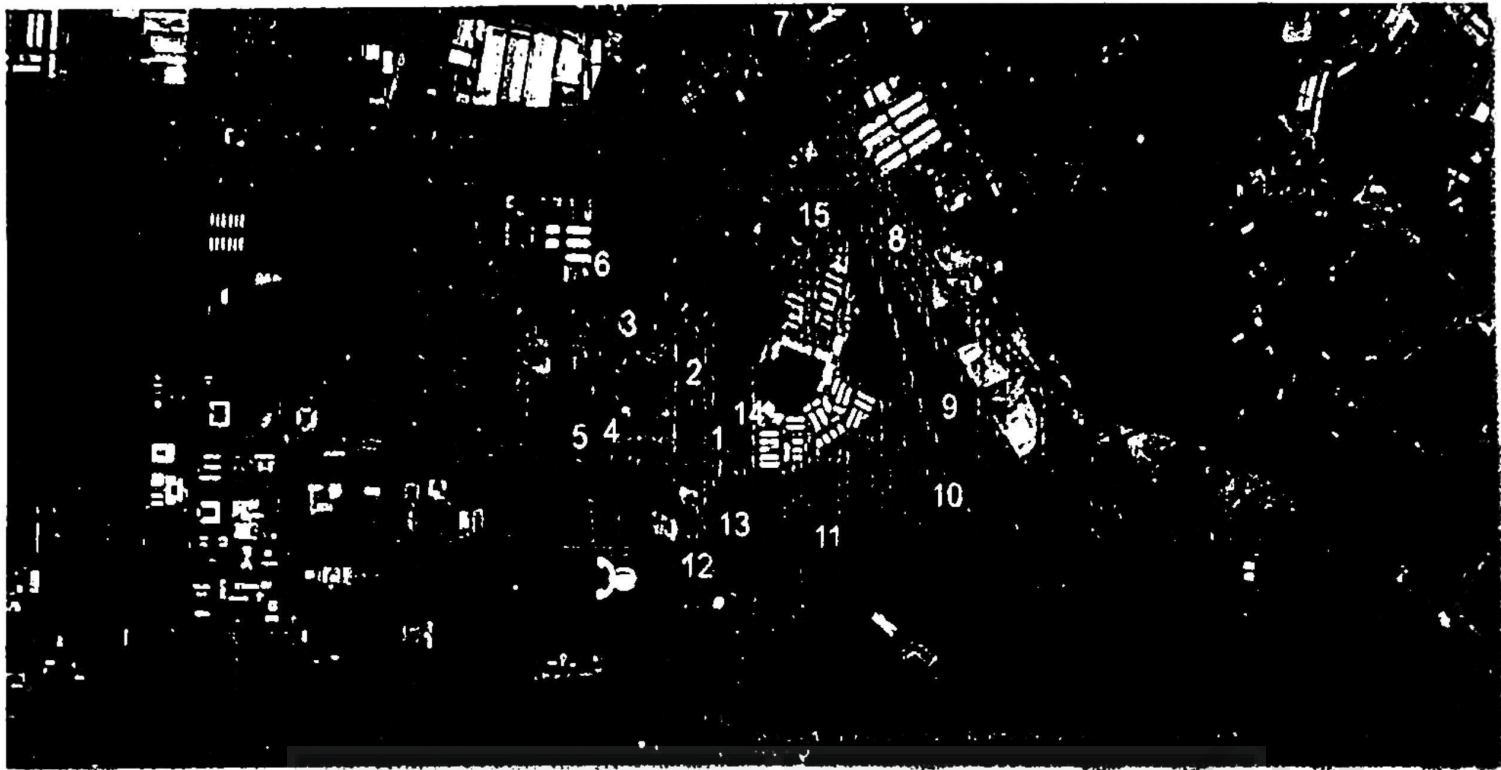


Figure 9: Land Use for Residential Area (outlined with an orange color of box)



Figure 10: Land use for Educational Institution (UPM)

(Outlined with an orange color of box)



**Figure 11: Land use for combination of Residential and Commercial Activities
(outlined with an orange color of box)**

3.3.1 Sound Level Meters

Noise measurements at the field site normally done by using sound level meters equipment. Usually, the decision on which type of instrument should be used is depend on the scope of measurement with which the standards it must comply. The requirements of simple noise surveys on a given area would be covered by a wide variety of sound level meters, where only dB(A) levels need to be measured and to elaborate measurements where Equivalent Continuous Levels ($L_{Aeq,T}$), Sound Exposure Levels (SEL), maximum, minimum, impulse and peak levels are required. Figure 12 below shows the typical sound level meters equipment used to measure noise levels.



Figure 12: Sound level meters

Sound level meter TES-52A produce the feature:-

- 0.1dB resolution.
- 60dB Dynamic range.
- 30 to 130dB Measurement ranges.
- A & C Frequency weighting.
- Fast/Slow Time weighting.
- Max/min/peak Sound level with time.
- Manual data memory and read.

Table 2: Specification of the Sound Level Meter TES-52A

Applicable standards	IEC Pub 60651 Type2 , ANSI S1.4 Type 2.
Digital display	4 digital LCD, 0.1 dB resolution, updated every 0.5s.
Measurement level	30dB to 130dB.
Measurement frequency range	31.5 Hz to 8KHz.
Frequency weighting	A and C.
Time weighting	Fast and Slow.
Accuracy	± 1.0 dB (ref 94dB @1KHz).
Microphone	1/2 inch Electret condenser microphone.
Measurement level range	6 ranges in 10-dB step: 20~80dB, 30~90dB, 40~100dB, 50~110dB, 60~120dB, 70~130dB.
Quasi-analog bar indicator	1-dB steps, 60dB display range, updated every 0.125s.
Display Warning function Over range indicator Under range indicator	Ov Displayed at the upper limit. Un Displayed at the lower limit.
Manual data memory capacity	1-dB steps, 60dB display range, updated every 0.125s.
Analog AC / DC output	1Vrms (at full scale), 10mVDC / db.
Power supply	One 9V battery (006P or IEC6F22).
Battery Life	About 25 hours.
Operating temperature & humidity	-10°C to 50°C (14°F to 122°F) R.H < 90% non-condensing.
Storage temperature & humidity	-10°C to 60°C (14°F to 140°F) R.H < 70% non-condensing.
Dimensions	264 (L) X 68(W) X 27(H)mm.
Weight	Approx. 260g.
Accessories	Battery 9V, Wind Shield, Screwdriver (adjustment), 3.5f plug (3pin AC/DC output), Carrying case, Instruction manual.

Table above shows the specifications of sound level meter TES-52A equipment. Before noise measurement was conducted, the sound level meter must first calibrated with a standard scale of readings. The selected measurement level range of sound level is 60 – 120dB. This indicates that the equipment is only record the sound level within the specified range, below or above the range of the minimum and maximum sound level will not be recorded. Figure 12 and 13 showed some example of calibration process taken on the equipment.



Figure 13: Calibrate sound level meter equipment to standard scale of reading.



Figure 14: Equipment calibrated to standard sound level range (60 – 120dB).

3.3.2 Global Positioning System (GPS)

GPS equipment was used to calculate the point's geographical locations within the study area. It is important to obtain the coordinates of the point as in need to insert the data with known (x,y) coordinates in ArcGIS software for preparing the noise maps.

Figure 15 shows the type of GPS equipment used in this project.



Figure 15: GPS Equipment

3.4 MEASUREMENT METHODOLOGY

Initially, field work of noise measurements was conducted in order to measure and obtain the noise data. A total number of 15 stations were randomly selected in a way to cover the noise that dominantly coming from the traffic. Figure 16 shows the sample points which represent each of the station that measurement of sound pressure level would be taking place. The equipment used is sound level meter to measure the equivalent sound pressure level at all stations. Simultaneously, the geographic coordinate of the measurement points was recorded using GIS.



Figure 16: Base map image that covered samples planning, land cover and road

In order to investigate differences in equivalent sound pressure level on each station, the measurements were done throughout on the weekday (Monday) and weekend (Saturday) at 3 occasions of morning (8:00 am – 10:00 am), noon (12:00 pm – 2:00 pm) and night (5:00 pm – 7:00 pm) to record L_{eq} at the interval of 5 minutes. Within the time interval, 10 values of noise level was recorded in one place. Then the values

were averaged to get the mean noise level in that particular one station. In conjunction to the scenario, the maximum and minimum value for sound levels at all stations were recorded as well.



Figure 17: Noise survey at residential area



Figure 18: Noise survey at education institution zone

3.5 APPLICATION OF INTERPOLATION TECHNIQUES

The different interpolation techniques which are performed for measured noise level in the study area are:

- Ordinary Kriging, OK
- Inverse Distance Weighting, IDW
- Radial Basis Function, RBF

ESRI (2002) explained that the implementation of interpolation method to determine the unknown values is achievable when consider the data obtained from the sources and distances between sources. Generally, interpolation predicts cell values in a raster format using a given limited number of sample. It is a veritable tool for prediction of unknown values for a given geographic point data which in this study is noise (Anile et al. 2003, Pamanikabud 1996, Yilmaz et al. 2005).

3.5.1 Ordinary Kriging

Ordinary Kriging (OK) method incorporates statistical properties of the measured data (spatial autocorrelation). This means OK method rely on both statistical and mathematical methods that can be used to create surfaces. In OK method, it is important for the data to be analysed first by exploratory spatial data analysis (ESDA) tools in order to assess the statistical properties of data. After exploring the data, then one can proceed to next step which create a prediction surface. The result for the ESDA of measured data were discussed in the next chapter.

In geostatistical wizard, the first step in Kriging method is shown in the figure. As the noise measured data in this study area is skewed which is shown in the ESDA tool, the log transformation is applied. For trend removal, no order is applied in this method.

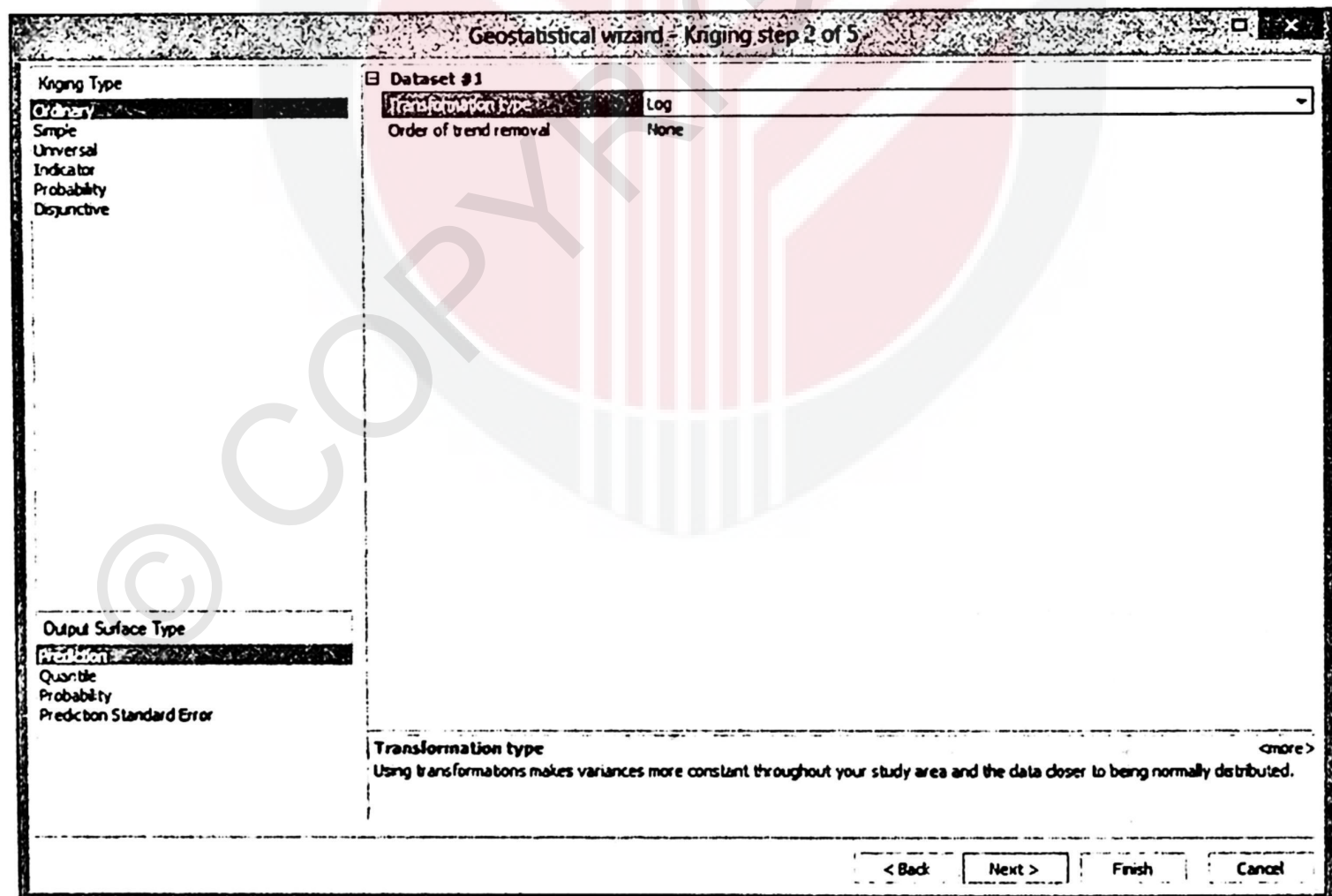


Figure 19: Geostatistical Method Selection Dialog Box

The spatial autocorrelation of the transformed data was then modeled using semivariogram/covariance modeling. The semivariogram displays the statistical correlation of nearby data points. As the distance increases, the likelihood of these data points being related becomes smaller. An empirical variogram is created by calculating the squared difference between all pairs of points and grouping the vectors into similar distance and direction classes (called binning) and then the average of the squared differences for each bin is plotted as the red dot (displayed in Figure 20).

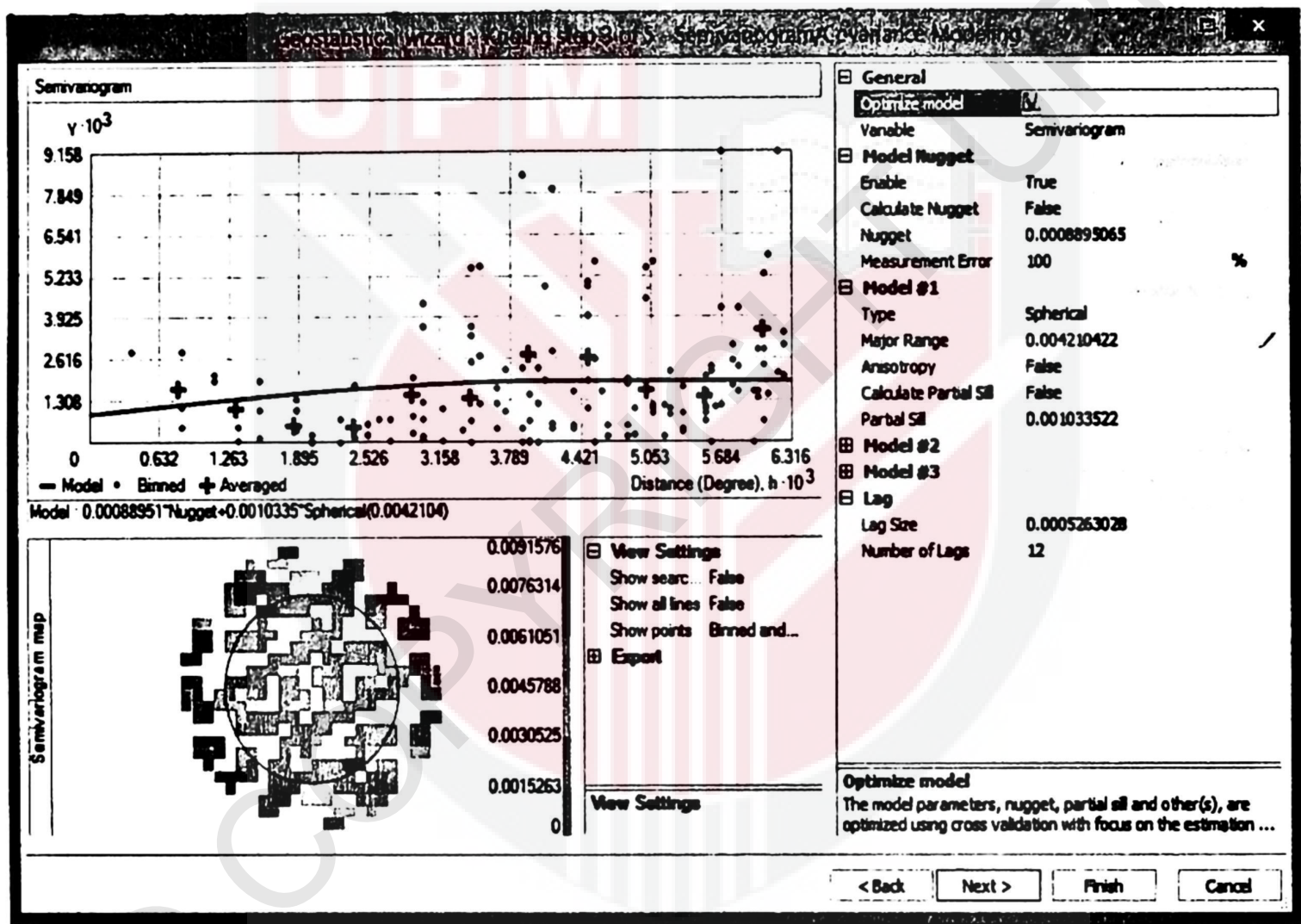


Figure 20: Semivariogram/Covariance Modelling

After calculating the empirical variogram for the measured data points, a model is fitted to fit through the points. For this study, three common models were selected i.e. Exponential, Gaussian and Spherical model to fit through the scattered points. Example of spherical model is fitted (which is the best fit model) and shown by the blue line in Figure 20.

Ideally, the value of the semivariogram should be zero when the separation vector h is zero, (Bohling, 2005). In practice, this is usually not true because of measurement errors. In this case, a so-called 'nugget effect' (nugget variance) exists having a value of 0.00089 as shown in the Figure 20. Cressie (1993) and Chilès and Delfiner (1999) was once stated that the nugget effect is a discontinuity at the origin of the semi-variogram resulting from small scale variability between regionalized variables. As the semivariogram increases, separation distance increases and reaches its maximum at a distance called range parameter which is 0.00421. The maximum semivariogram value is the sill parameter (structured variance) which is 0.00103. The lag size is the size of a distance class into which pairs of locations are grouped. The automated lag size and the number of lags generated are 0.00053 and 12 respectively.

After semivariogram modelling, the next step in kriging is searching neighbourhood, (ESRI, 2002). In some circumstances, where the distance of the data become father away from a location where the value is unknown, they might not be useful when predicting the value at an unmeasured location. At some distance, the points will have no correlation with the prediction location. Therefore, in predicting the noise level of a specific point; the number of adjacent points, the searching radius and the number of sectors of the circle should be specified. As shown in Figure 21, the maximum number of neighbouring points included is 5 and minimum of 2 neighbouring points

are included. A circle with four sectors is considered with the maximum and minimum number of points available for each sector. The points highlighted in the data view give an indicator of the weights associated with each point.

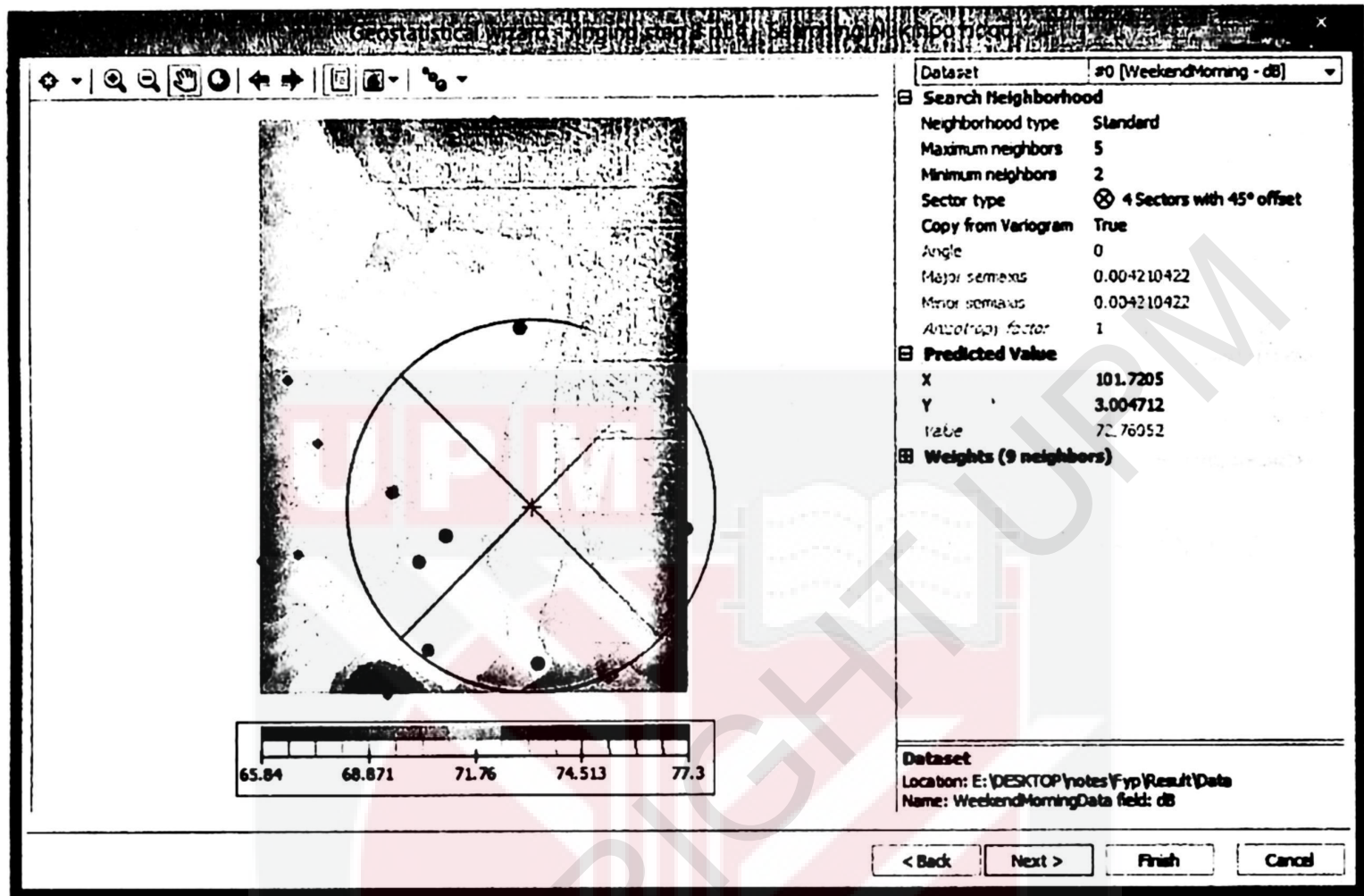


Figure 21: Ordinary Kriging Search Neighbourhood Dialog Box

As for checking the performance of interpolation technique used, cross-validation tool in features of ArcGIS geostatistical analyst compares measured noise levels with predicted ones that derived from the produced surface model, and employ statistical measures to evaluate the performance of surface model. From this, it can be revealed that how effectively the prediction made by surface model to the noise level at a specific location. The statistical measures serve as guidelines for the accuracy of the surface model and its prediction map. Figure 22 provides a graphical comparison between measured and predicted values (predicted plot). The cross validation tool sequentially leave out a point, predicts the associated value using the rest of the noise data, and then compares it with the measured value.

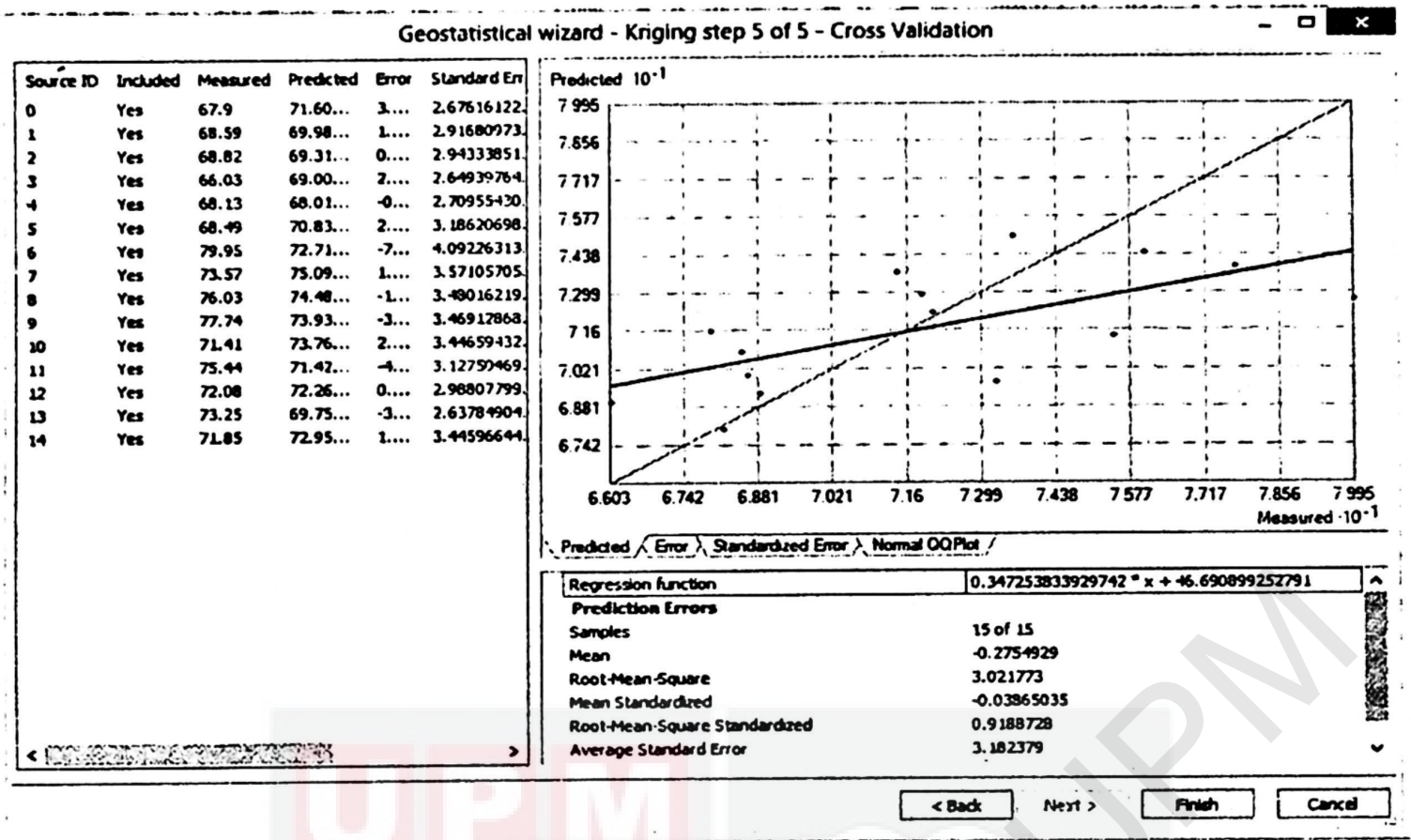


Figure 22: Ordinary Kriging Predicted Plot (Predicted values Vs Measured Values)

Figure 23 shows the graphical comparison between errors and the measured values. In general the error was small enough, since most of the points are almost to zero scale.

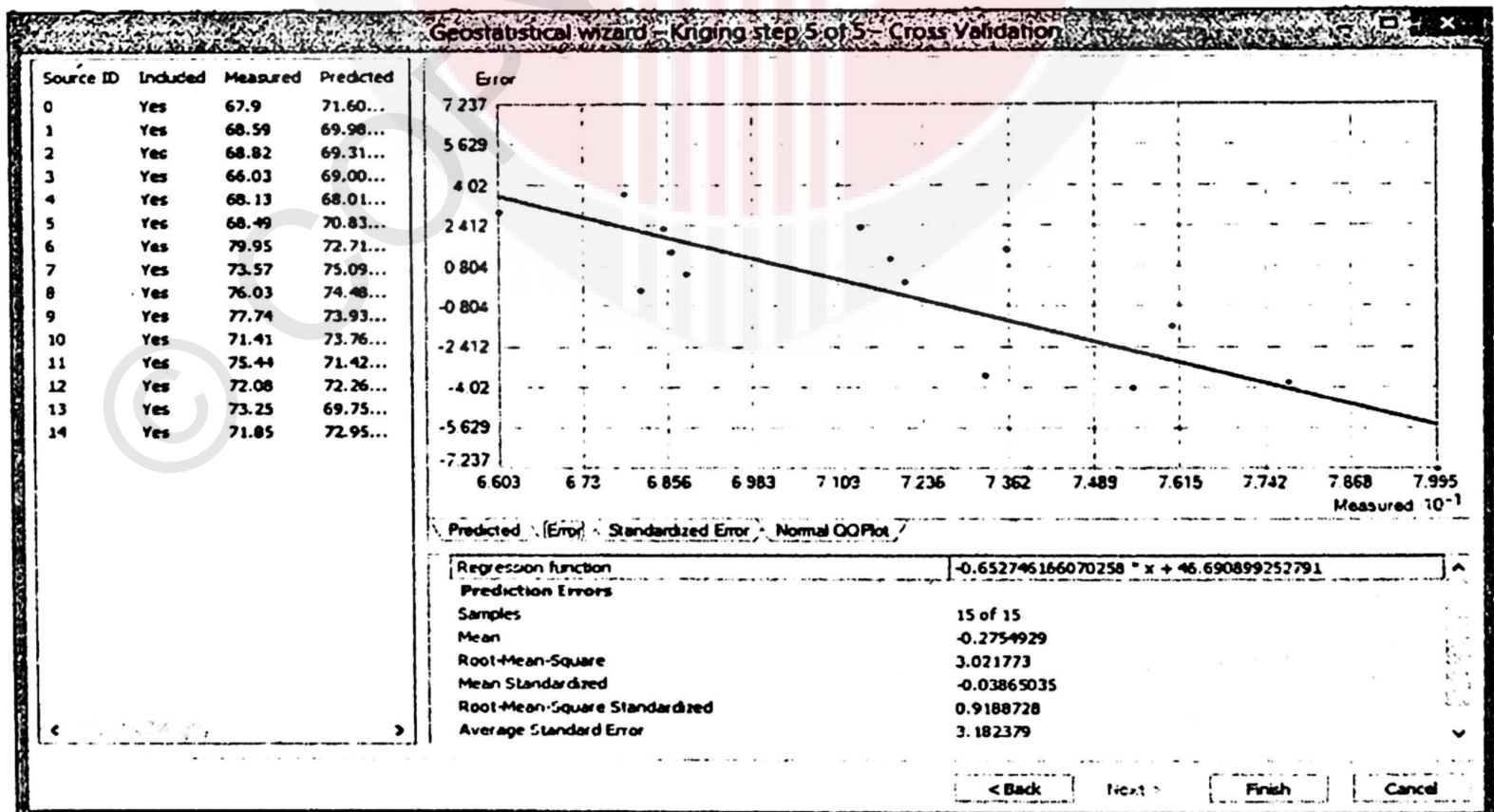


Figure 23: Ordinary Kriging Error Plot (Errors Vs Measured Values)

Figure 24 shows the graphical comparison between standardized error and measured values. The measured value minus the predicted value and then divided by the estimated standard error will give the standardized error value.

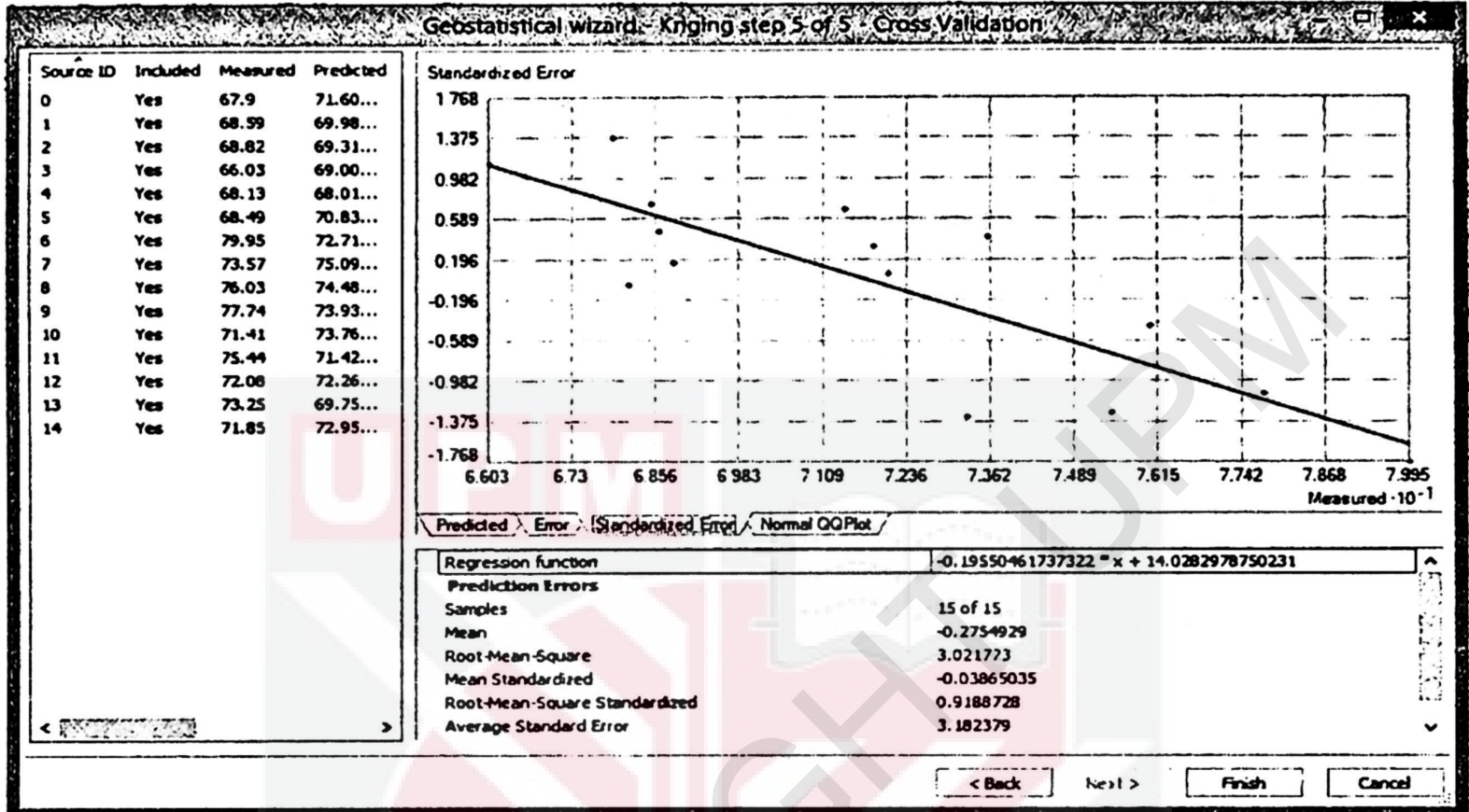


Figure 24: Ordinary Kriging Standardized Error Plot (Standardized Error Vs Measured Values)

The QQ plot shown in Figure 25 illustrates the quantiles of the difference between the standardized errors and the corresponding quantiles from a standard normal distribution. If the prediction errors shows normally distributed behaviour, the points should be roughly lie along the trend line (black line). At figure below, it showed that errors of prediction are nearly normally distributed.

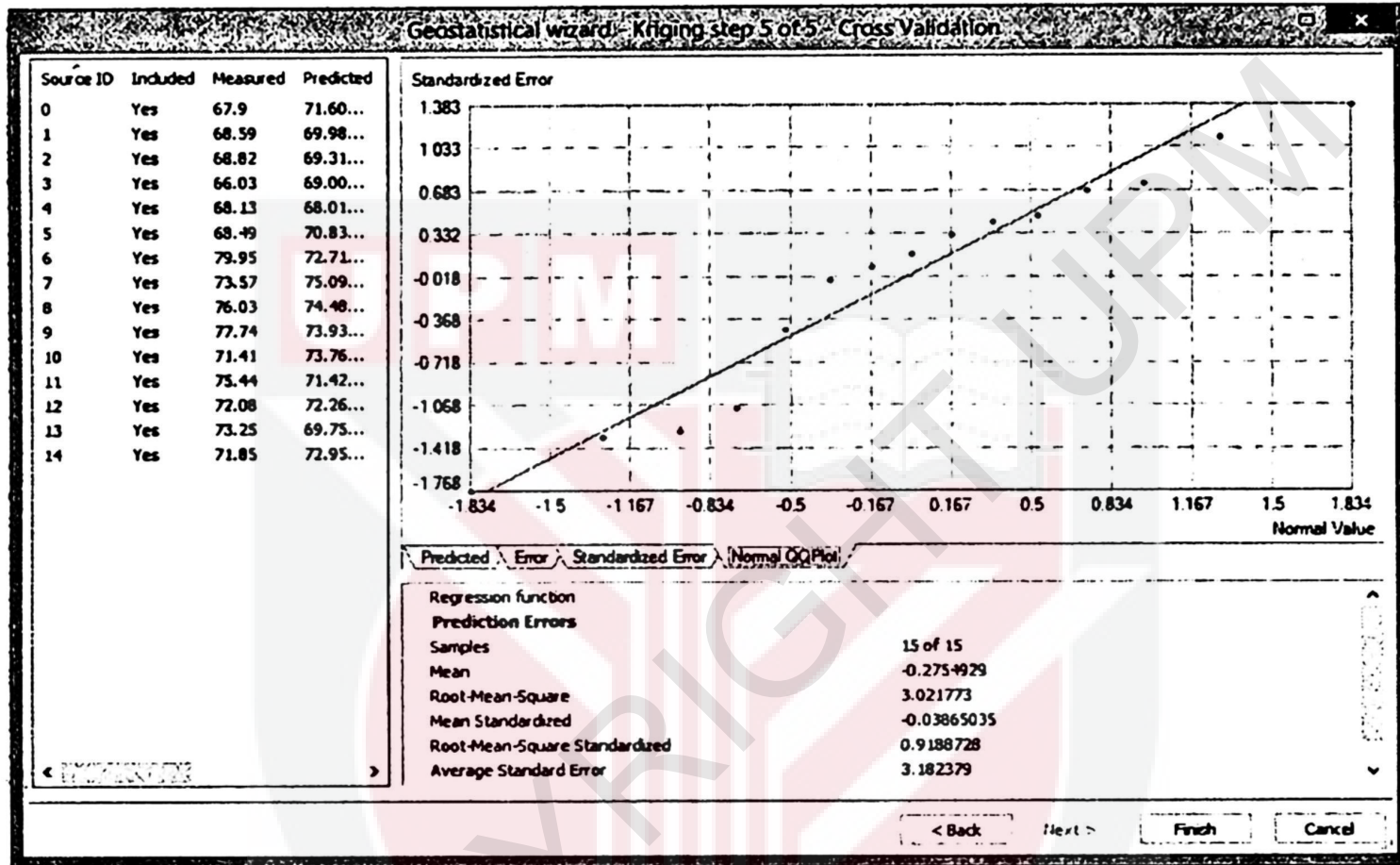


Figure 25: Ordinary Kriging QQ Plot

3.5.2 Inverse Distance Weighting

As mentioned earlier, IDW interpolation follows the assumption that things close to each other are more alike than those things with farther apart. That means the correlation of attributed points are relatively higher when they are located near to one another.

In geostatistical wizard, the first step in IDW is searching neighbourhood which conducted on the interest area with noise level data, as shown in the Figure 26. Some important parameters like power function and neighbourhood type were specified initially before proceed to the next step. For this project, the chosen power functions were 1, 2 and 3 while the neighbourhood type was specified as standard type. The maximum number of neighbouring points included is 15 and minimum of 10 neighbouring points are included. The selected sector type is shown in the figure below with four sectors and the maximum and minimum number of points available for each sector

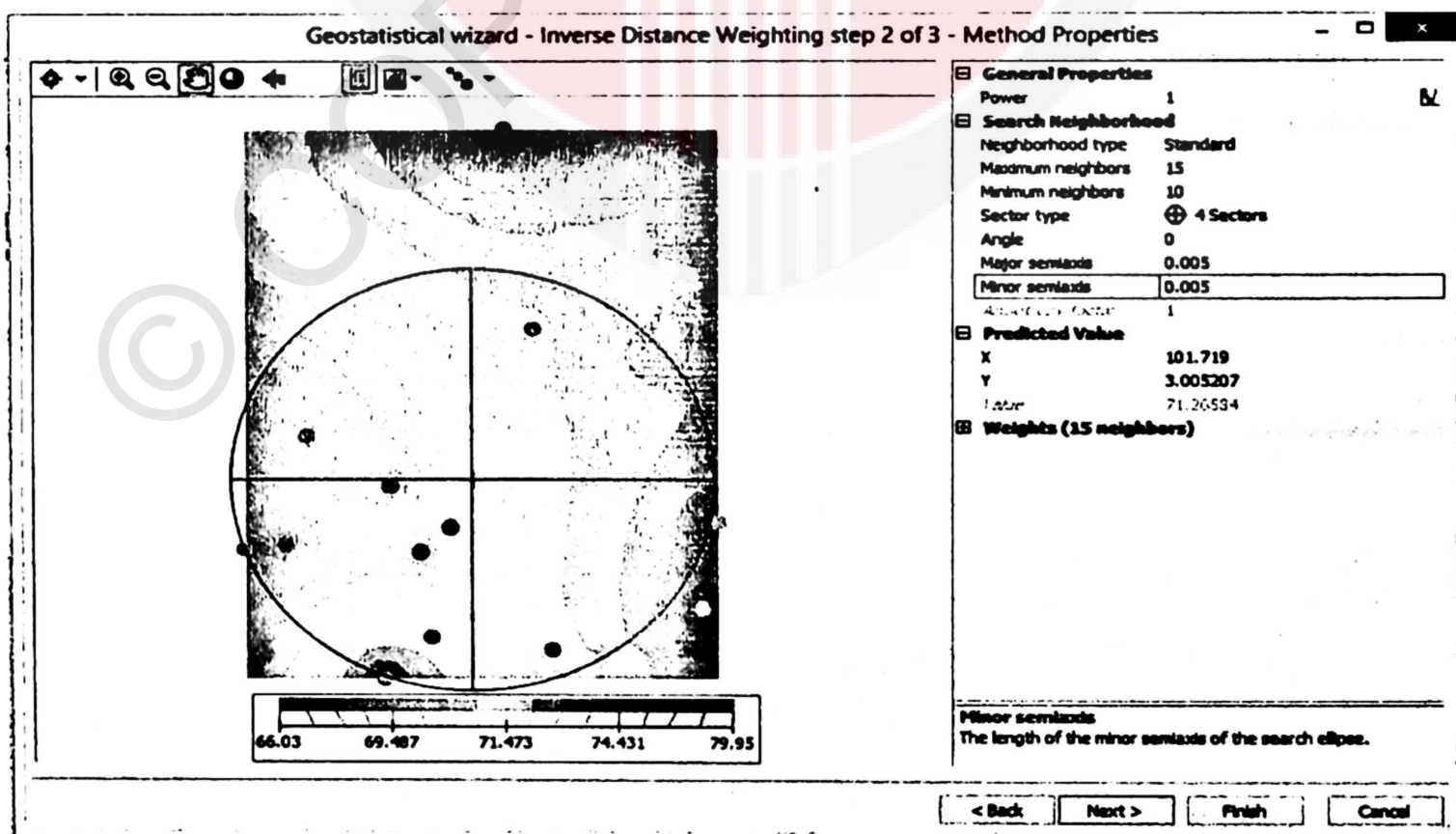


Figure 26: IDW Searching Neighbourhood Dialog Box

After the parameters been specified, the final step is the cross-validation which shows a predicted plot between measured values versus predicted values and an error plot that shows the relationship between error and the measured values. Unlike kriging, in the IDW and radial basis function interpolation techniques, only two plots are generated: predicted plot and error plot. The cross-validation for predicted plot is shown in the figure below.

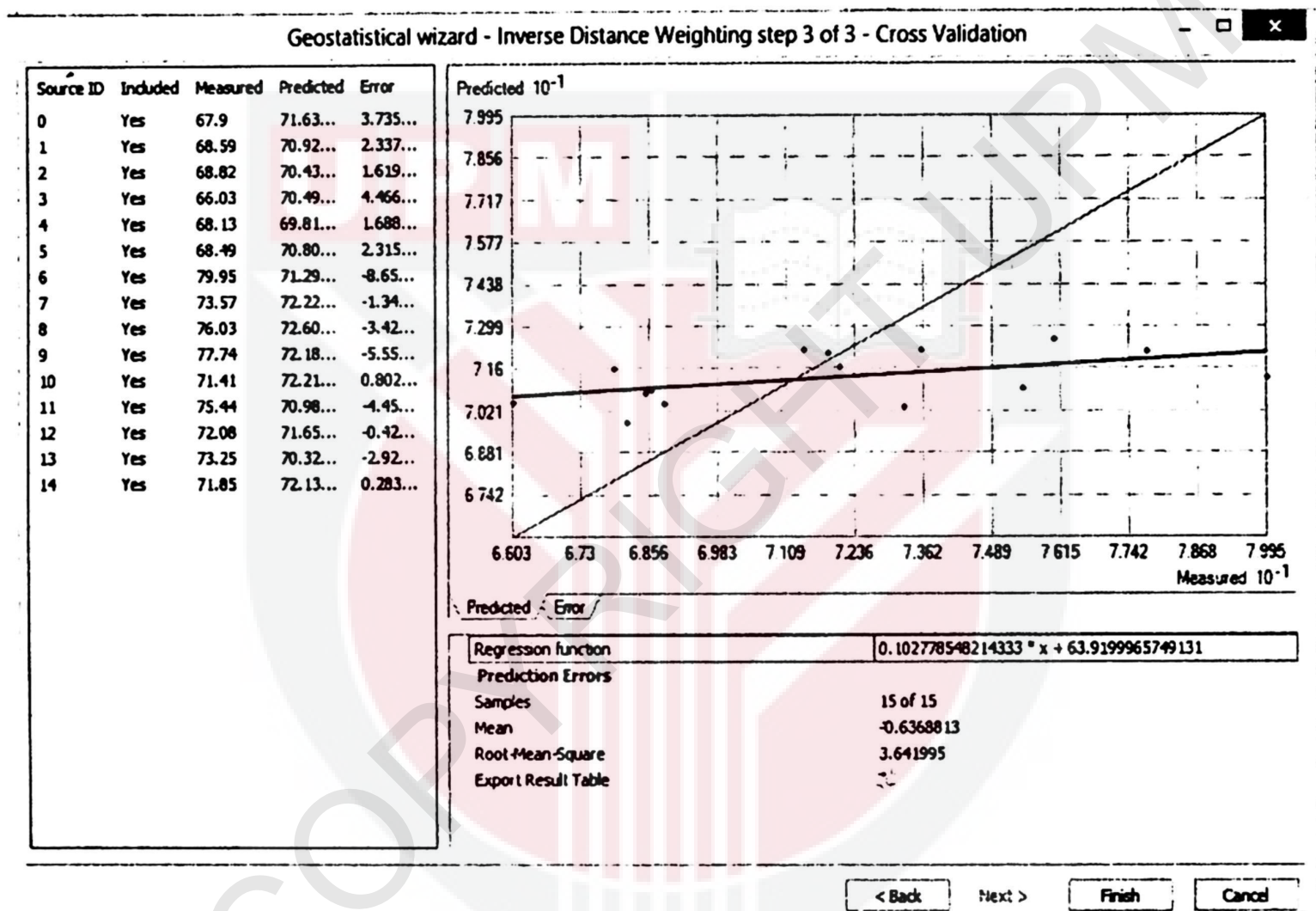


Figure 27: IDW Cross Validation Tool (Measured Vs Predicted Values)

3.5.3 Radial Basis Function (RBF)

Radial Basis Function is similar to IDW which assumes that things closer to one another are more alike than those farther apart except that it predicts values above the maximum and below the minimum measured values.

Similar to IDW, the first step is searching neighbourhood approach which is conducted on noise level data sets using completely regularized spline and spline with tension.

The selected kernel parameter value for the model after it had been optimized is 3779.47. Maximum and minimum number of neighbouring points included is 15 and 10, respectively and the shape type is circle with four sectors shown in Figure 28.

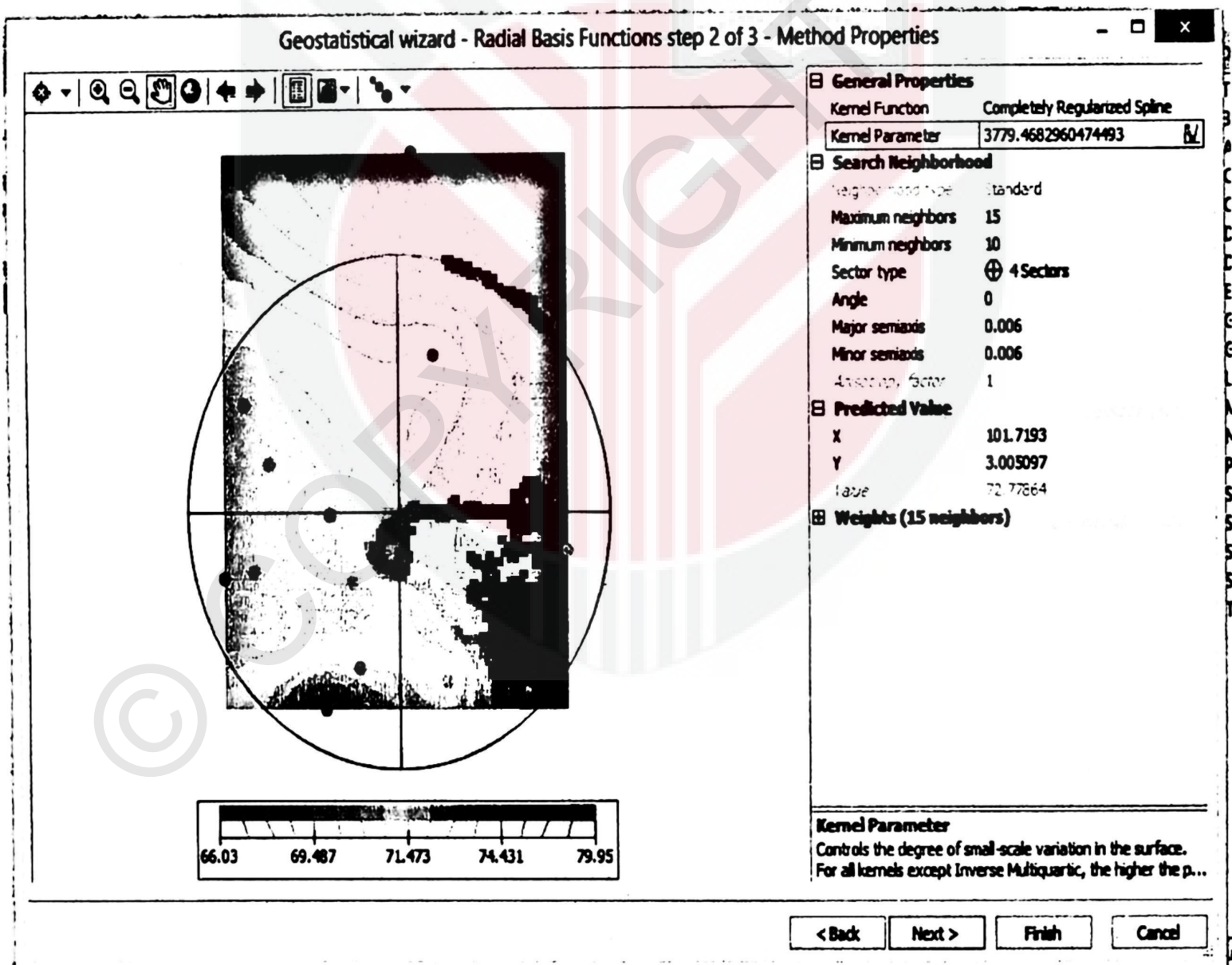


Figure 28: RBF Searching Neighbourhood Dialog Box

The final step is shown in the figure below, the cross validation tool, which illustrates the predicted plot and error plot.

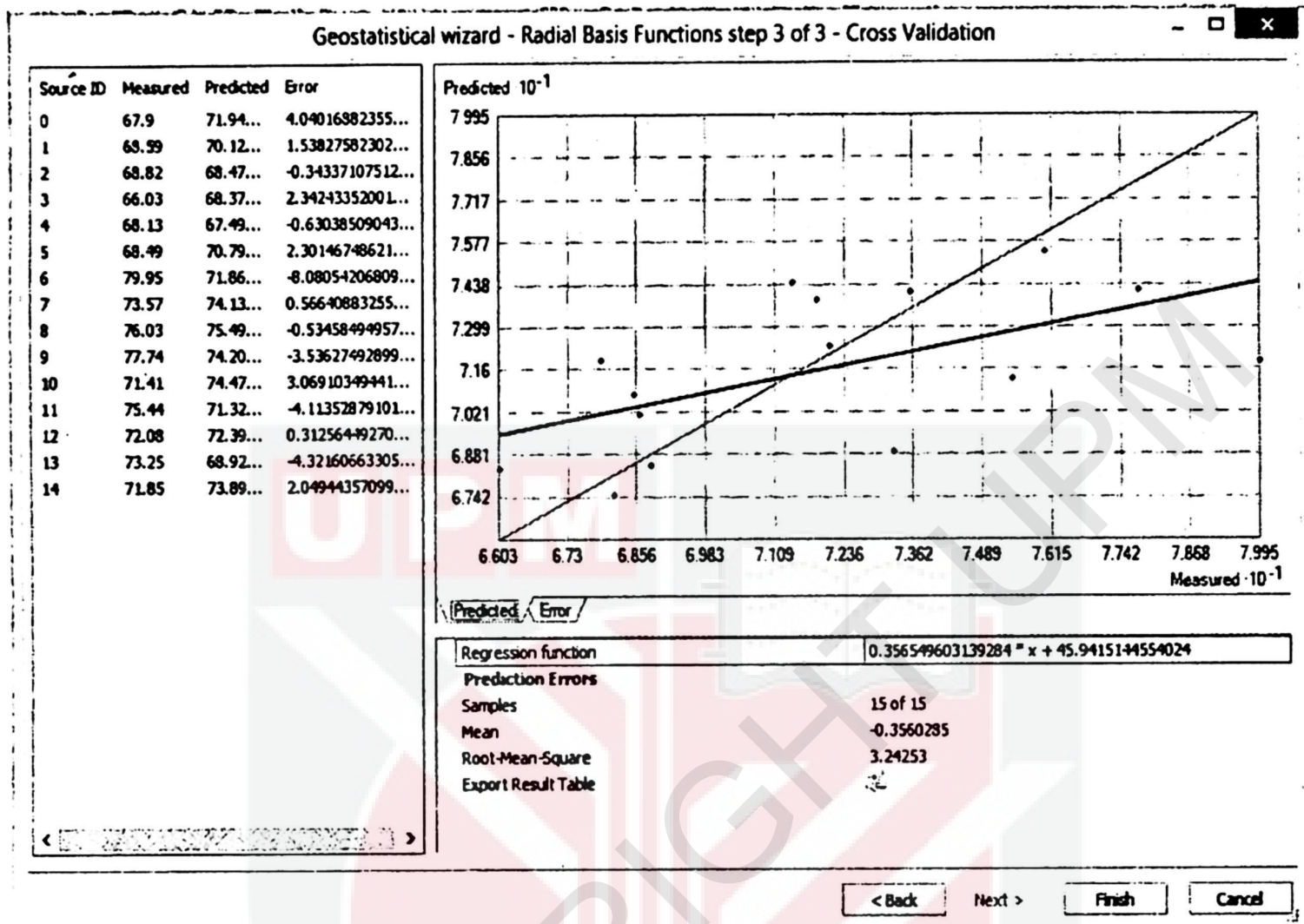


Figure 29: RBF Cross Validation Tool (Measured Vs Predicted Values)

3.6 CROSS VALIDATION

Cross-validation technique was adopted for evaluating and comparing the performance of different interpolation methods. In many years, various researchers have been studied and used statistical methods to make the comparison between interpolation techniques.

According to Chang (2010), a relative repetitive process as following procedures were conducted as to compare among the interpolation methods: (1) isolate a measured point from the data set, (2) Use the remaining points to estimate the value at the point previously removed, and (3) Calculate the prediction error of the estimation by comparing the estimated with the known value. After completing the procedure for each known point, 3 common diagnostic statistics, Root Mean Square Error (RMSE), Mean Error (ME) and the Mean Absolute Error (MAE) are calculated to assess the precision and accuracy of the interpolation method as shown in equation 4, 5 and 6 respectively.

$$\text{RMSE} = \sqrt{\frac{\sum_{i=1}^N (O_i - S_i)^2}{N}} \dots\dots\dots (4)$$

$$\text{ME} = \frac{\sum_{i=1}^N O_i - S_i}{N} \dots\dots\dots (5)$$

$$\text{MAE} = \frac{|\sum_{i=1}^N O_i - S_i|}{N} \dots\dots\dots (6)$$

Where O_i is observed value, S_i is the predicted value, N is the number of samples.

All the error values are available for all exact local methods, the RMSE value derived from geostatistics analyst tool, while for the ME and MAE were calculated manually using equation 4, 5 and 6 respectively. The best interpolation technique should gain a smaller value of all three evaluation criteria.

3.7 PRODUCTION OF NOISE MAP

Using ArcGIS software, with the provided feature of Geostatistical Analyst Toolbar will generate the noise maps for the study region of this project. After the comparative analysis of different interpolation techniques were done, the one that yield a better result on interpolation method will be selected as the method in predicting the unknown noise samples in the study area. Many researchers have used interpolation technique as an effective tool for developing and assessment of noise mapping (Anila et al. 2003, Pamanikabud 1996, Yilmaz et al. 2005).

For production of noise map, the acoustic behaviour of noise propagation within the study area will be assessed based on the selected interpolation technique that shows a better result in cross validation and error measurement methods. Using the ArcGIS, noise maps with different occasions of the day were prepared. From the noise maps generated, the diurnal variation of the noise environment can be observed in the city. Moreover, the noise maps produced from ArcGIS also provides better visualization information of the regions that exposed to higher noise levels and traffic volumes and also recognizes the noise risky zones within the study area.

3.8 SUMMARY

In summary, this chapter discussed the methodology and procedures used for data collection and the software of analysing the data. The study area has been specified which located at Sri Serdang near the education institute of UPM. Data collection for the noise level was conducted with total of 15 sampling points were selected to collect the noise data using sound level meter equipment. After the data collection was done, the noise data are then implement into the ArcGIS software for further analysis of the result. The software is used to evaluate the interpolation techniques that to interpolate the noise level within the study area. Several interpolation techniques like IDW, RBF and kriging were selected to interpolate the noise level. The steps of implement these interpolate techniques to the noise level data were described briefly in this chapter as well as the considered important parameters for each of the interpolation technique.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 NOISE LEVEL RESULTS

The primary objective of this project is to evaluate the interpolation techniques used in development of noise mapping for urban areas. Several interpolation techniques like Inverse Distance Weighting (IDW), Radial Basis Function (RBF) and Kriging were studied based on their correlation parameters that influence the final output of a noise map.

Prior to develop a noise map, data collection for noise level at each particular location was conducted in the study area. Sound levels were recorded at 15 locations across the UPM's campus using the sound level meter, for 3 different intervals of the day. This study only covered for 2 days in a week. The first interval is from 8:00 AM to 10:00 AM, the second from 12:00 PM to 2:00 PM, and the third from 5:00PM to 7:00PM.

After the data collection, a mean, maximum and minimum decibel level was recorded for each location. The mean decibel level is the average of all the decibel levels

recorded for the period of time like 5 minutes per location. The maximum decibel level is the one single highest decibel level recorded during that time. Similar to the minimum decibel level is the one single lowest decibel level recorded at one location during that time.

This noise survey reveals that noise environment of the UPM's campus and Sri Serdang is not at satisfactory level as the standards prescribed by Malaysian Recommended Noise Monitoring Guideline, DOE (Figure 30). This could be the result of increased number of population as well as the number of vehicles in the study area.

SCHEDULE 1
MAXIMUM PERMISSIBLE SOUND LEVEL (L_{Aeq}) BY RECEIVING LAND USE FOR PLANNING AND NEW DEVELOPMENT

Receiving Land Use Category	Day Time 7.00 am - 10.00 pm	Night Time 10.00 pm - 7.00 am
Noise Sensitive Areas, Low Density Residential, Institutional (School, Hospital), Worship Areas.	50 dBA	40 dBA
Suburban Residential (Medium Density) Areas, Public Spaces, Parks, Recreational Areas.	55 dBA	45 dBA
Urban Residential (High Density) Areas, Designated Mixed Development Areas (Residential - Commercial).	60 dBA	50 dBA
Commercial Business Zones.	65 dBA	55 dBA
Designated Industrial Zones	70 dBA	60 dBA

Figure 30: Maximum Permissible Sound Level by Receiving Land Use for Planning and New Development (Source: The Noise Pollution (Regulation and Control) from Department of Environmental, Malaysia 1974)

In figure 30, the mean day time is from 7:00 am to 10:00 pm and the night time is from 10:00 pm to 7:00 am. The study area for this project where the noise level measurement was conducted are identified as category of community, institutional and residential area land use. The area comprising of educational institutions, religious

places, courts, clinic, small businesses and residential. For this study purposes, the receiving land use category as referred from the Figure 30 is designated mixed development areas (residential – commercial).

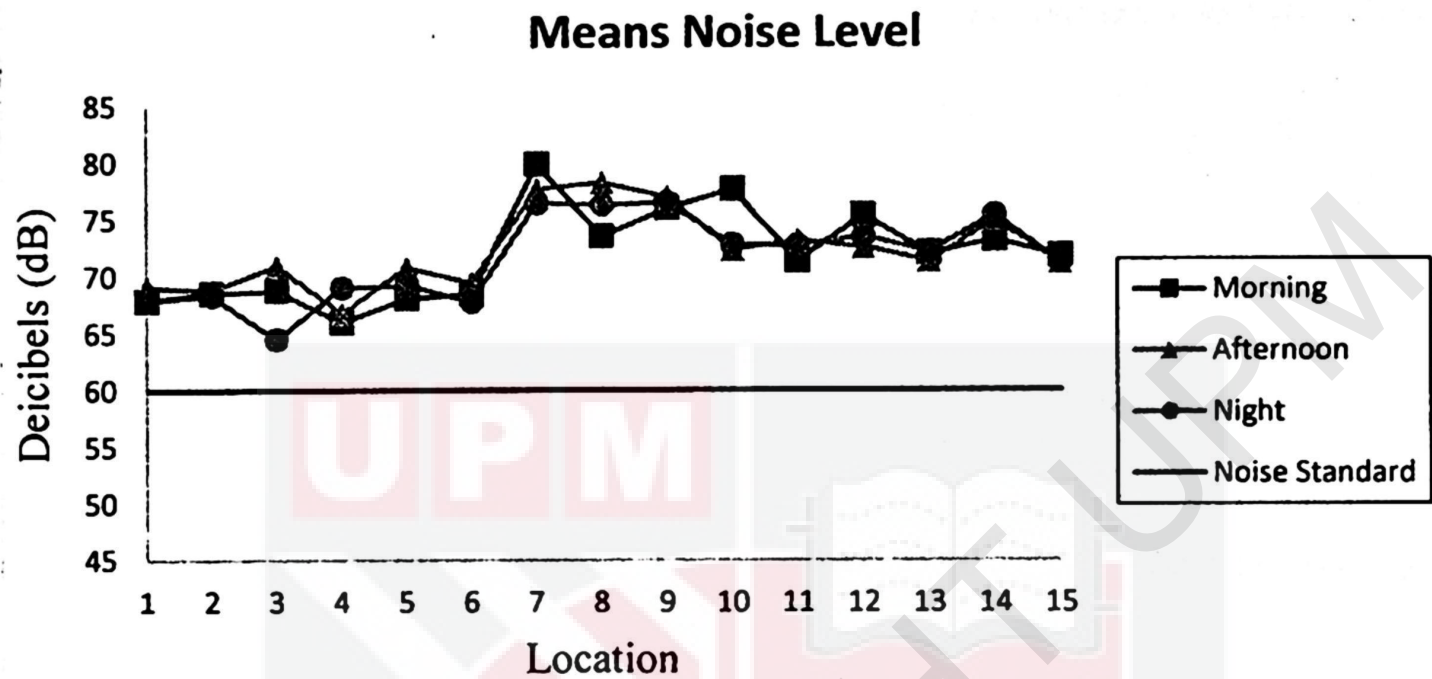


Figure 31: Means Noise Levels in study area

Figure 31 shows the mean noise level that was taken on weekday (Wednesday) at every location with 3 different intervals of time. From the noise survey results, it was observed that the noise level at location 7 during day time at 8:00 am to 10:00 am in the morning is higher due to plying of more vehicles and huge accumulation of traffic of people going to their respective working places than the noise level at other locations. Noise level of 80 dB was recorded on that particular location and showed that it exceeds the noise standard recommended by DOE Malaysia i.e. 60 dB at all sampling time of the day. This study area is having noisier environment in noon time (12:00 pm to 2:00 pm) where most the location (residential and commercial) showed high noise levels than morning (7:00 am to 9:00am) and night (5:00pm to 7:00pm) time of the day.

All other location mainly on commercial location also showed higher noise levels (more than 70dB) than the prescribed noise standard. This can be due to these places are always be a potential place where with all type of vehicles will passed through and caused a huge traffic during the peak hour. Similarly, residential area also showed higher noise levels than the recommended noise standards. In some residential like location 3, 5 and 7 situated nearby roadside showed higher noise levels i.e. more than 70 dB.

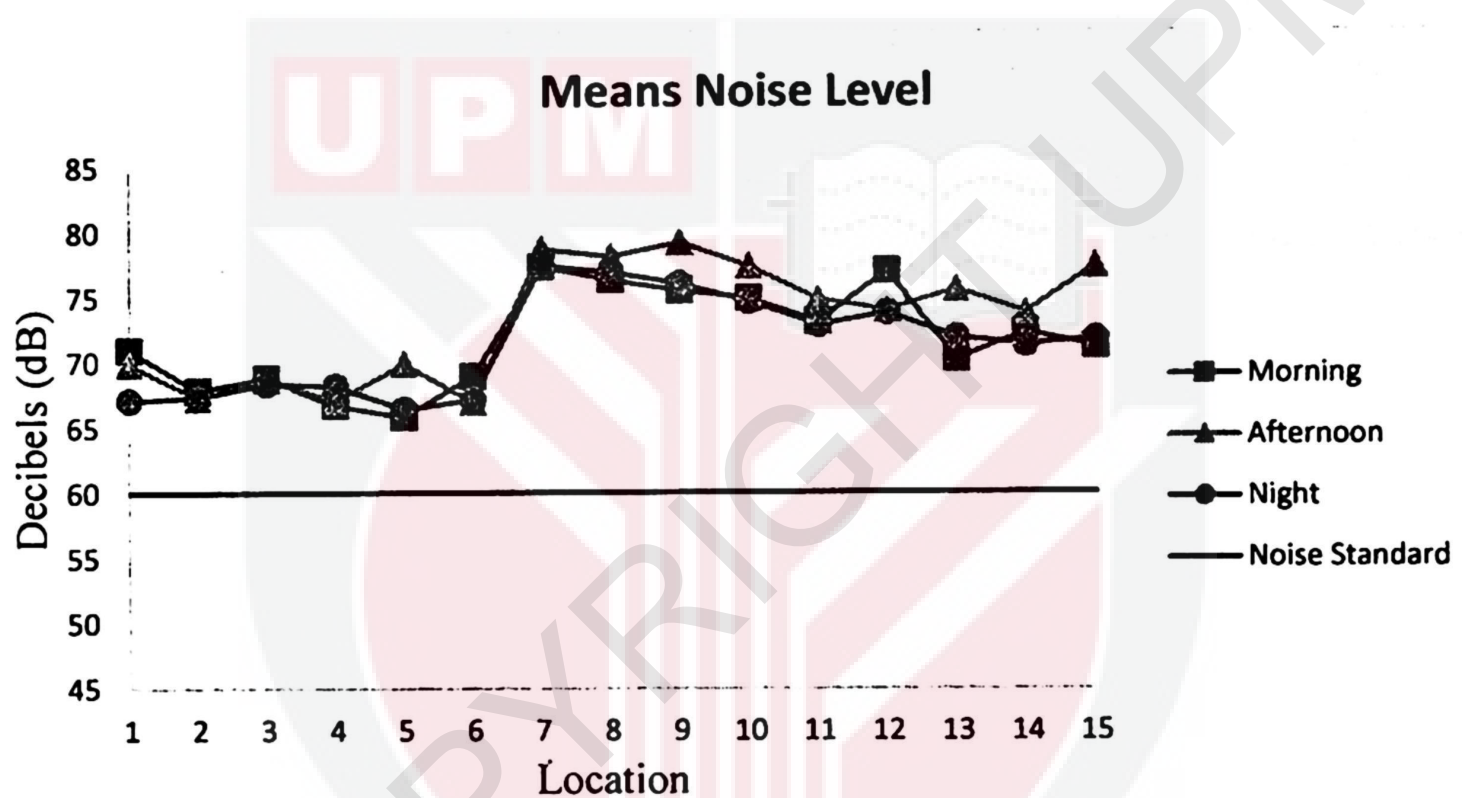


Figure 32: Means Noise Level in study area

As is shown in Figure 32, the highest noise level was recorded on location 9 which recognised as educational institution situated nearby the roadside. The figure above shows the means noise level that was taken on weekend (Sunday) at every location with 3 different intervals of time. As stated earlier, location 9 was observed to have the highest noise level i.e. 79 dB during day time at 10:00 am to 12:00 pm in the noon compared to noise level at other locations. This may due to heavy traffic with present of all type of vehicles that passed through the particular location during the peak hour. Similarly, this study area is also having noisier environment in noon time (12:00pm to

2:00pm) as same as on the weekday where most the location (residential and commercial) showed high noise levels than in morning and night time of the day. Most of the locations were observed to have higher noise level (more than 70 dB) compared to recommended noise standard by DOE Malaysia i.e. 60 dB at all sampling of the day. This can be conclude that most of the locations covered in the study area are in grip of heavy traffic noise and are not safe from noise induced disturbances.

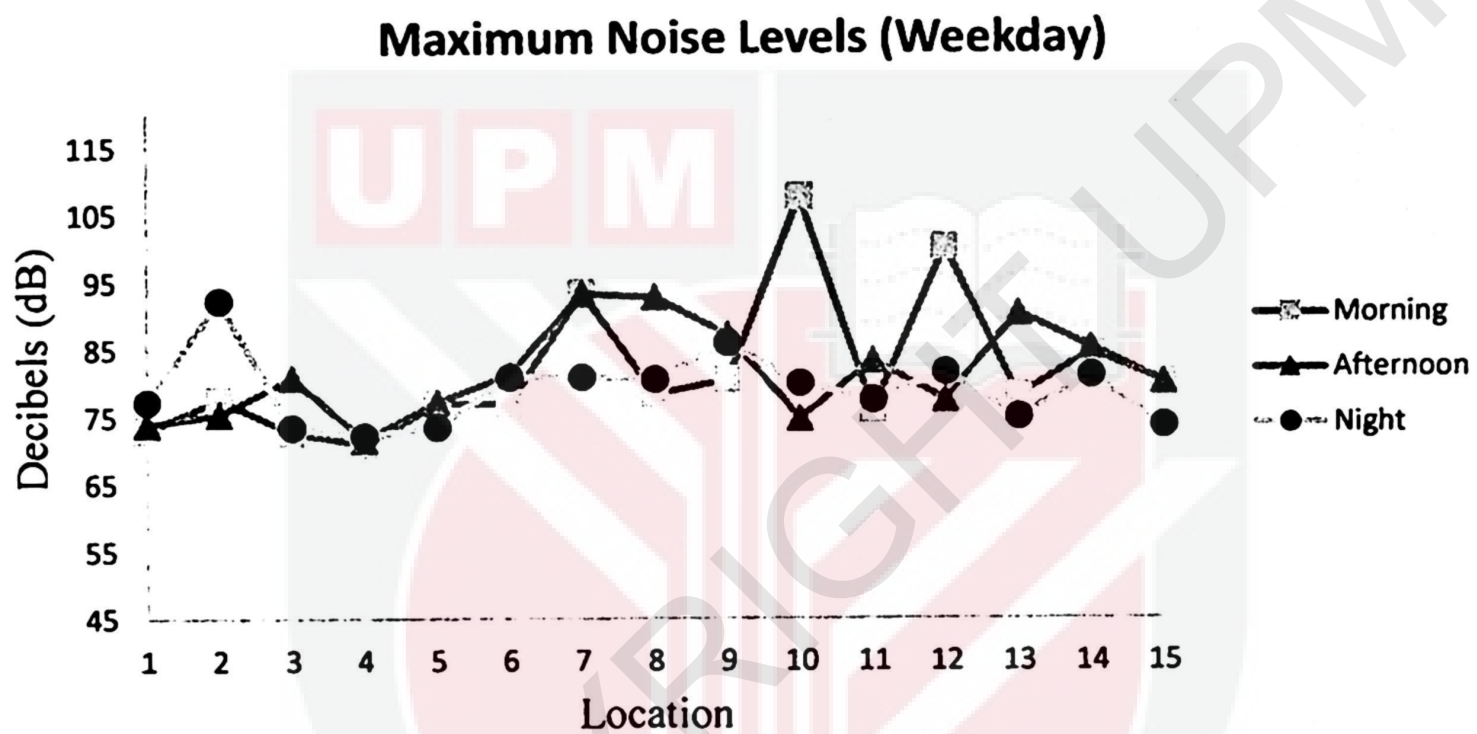


Figure 33: Maximum noise levels for weekday

Figure 33 above shows the maximum observed noise levels on three different occasions that was taken on Wednesday (weekday). The highest maximum noise level recorded was at location 10 with approximately 106 dB of noise value. The location is situated at the entrance of UPM's gate whereby many vehicles passed through the road to enter the university. In fact, the highest maximum noise value was recorded in the day time and hence traffic volume is expected to be high in that particular location. Similarly, the second highest measured noise level was also recorded in the day time that which situated at location 12. The recorded noise level was 96 dB.

On the other hand, it was revealed that on the afternoon time, many locations showed higher maximum noise value compared than other occasion. This can be due many people were going out and travelled from one place to another place with their own vehicles. For residential neighbourhood, the recorded maximum noise levels were in the range of 65 – 80dB approximated value of noise levels. From here, it can be concluded that residential area is not a peaceful area because it still exposed to such high noise levels which somehow exceeded the optimal value of noise level that recommended by DOE of Malaysia.

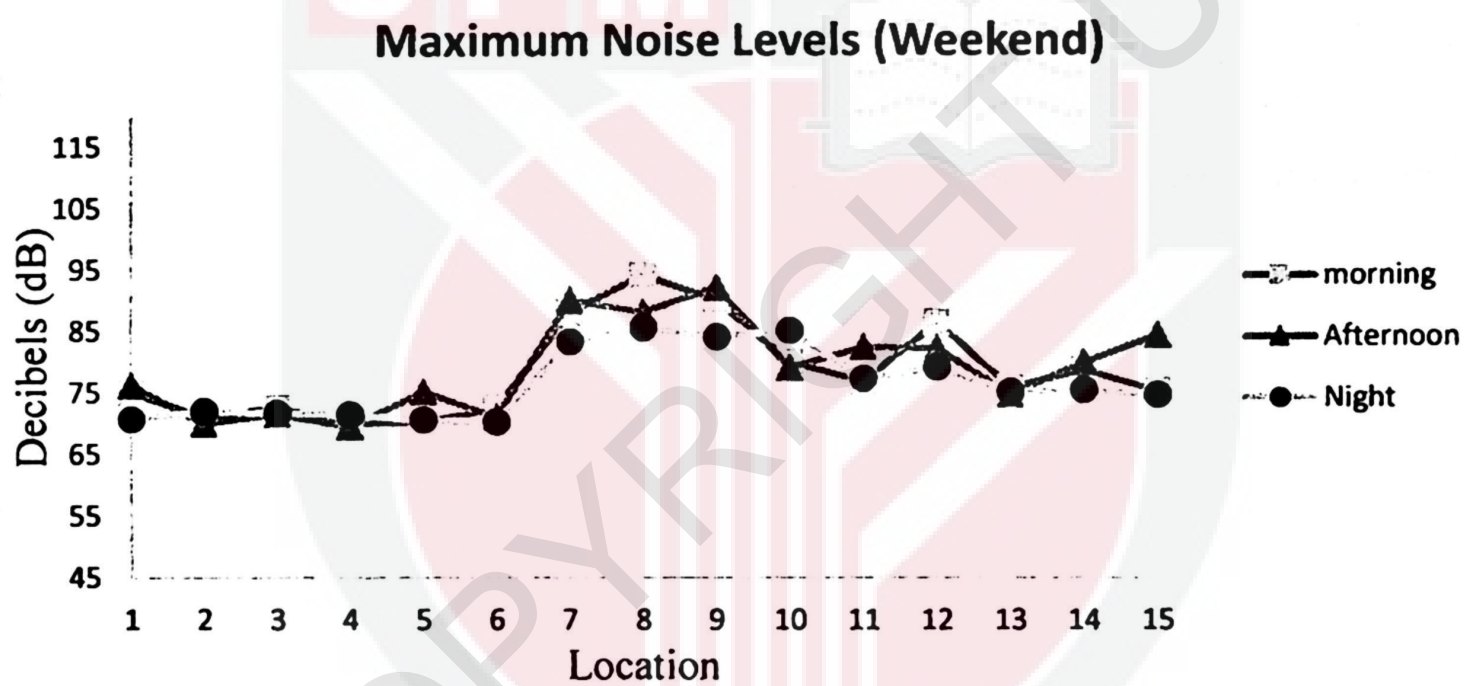


Figure 34: Maximum Noise Levels for Weekend

As shown in the figure above, it is the maximum noise measured levels that were plotted in the same graph in conjunction with three different occasion. In a similar way, the highest noise measured level was recorded during the daytime as same as maximum noise levels that was taken on weekday. The recorded maximum noise value in this particular location (location 8) is approximately 95 dB. This location is actually situated on the main road where the traffic volumes are typically high most of the time as seen in the Figure 34.

Mostly, the maximum noise measured levels for weekend showed no significance difference in three different occasion except on location 7,8 and 9. The maximum noise levels on that specific location were recorded higher during daytime and afternoon compared than night time. The number of vehicles tend to decrease as time goes by at night. In residential neighbourhood, all of the maximum noise levels were almost recorded on the same values. The values are in between 65 – 70dB and it showed that the values are lower than maximum noise level that was recorded during on weekday. The residential area can be considered living more peaceful time during weekend because no more than 75 dB of noise value was recorded within the residential areas.

4.2 EXPLOTARY SPATIAL DATA ANALYSIS (ESDA) RESULTS

The importance of the spatial statistics has been discussed within the background section of this project. Understanding the data's distribution, stationarity trends, and spatial autocorrelation are factors, which influence the decision of choosing an interpolation algorithm. The measured data can be considered as unsatisfied to the basic assumption of normality behaviour of the geostatistics if the variable or data exhibits a non-normal distribution properties. This restriction is eliminated, by applying a data susceptible transform to the sample values that make them more to analysis and estimation. The most useful data transform is the log transform.

4.2.1 Histogram

Histogram tool is one of the feature of ESDA which responsible to check the normality of the data frequency distribution. Summary statistics for 2 days of measured noise level were shown in Table 3 and 4 respectively. Noise level measurement on weekday as shown in the Table 3 was observed that the difference between mean and median were 0.1, 0.96 and -0.59, respectively, for morning, afternoon and night time interval. Similarly, the skewness values of all three interval times were 0.42, 0.42 and 0.6. From the Table 3, the data had high skewness, therefore it was normalized using logarithm method.

Table 3: Summary statistics of measured noise values data for weekday with different occasions

Noise measurement for weekday			
	Morning	Afternoon	Night
Time Interval	8:00 am - 10:00 am	12:00 pm - 2:00 pm	5:00 pm - 7:00 pm
Count	15	15	15
Mean	71.95	72.35	71.64
Min	66.03	66.84	64.55
Max	79.95	78.35	76.56
Median	71.85	71.39	72.23
Standard deviation	4.05	3.41	3.7
Skewness	0.42	0.42	0.6
Kurtosis	2.19	2.24	2.01

Table 4: Summary statistics of measured noise values data for weekend with different occasions

Noise measurement for weekend			
	Morning	Afternoon	Night
Time Interval	8:00 am - 10:00 am	12:00 pm - 2:00 pm	5:00 pm - 7:00 pm
Count	15	15	15
Mean	71.79	72.56	71.64
Min	65.84	66.97	66.41
Max	77.3	77.27	78.15
Median	71.14	73.8	71.73
Standard deviation	3.77	3.86	4.1
Skewness	0.03	-0.28	0.24
Kurtosis	1.75	1.53	1.66

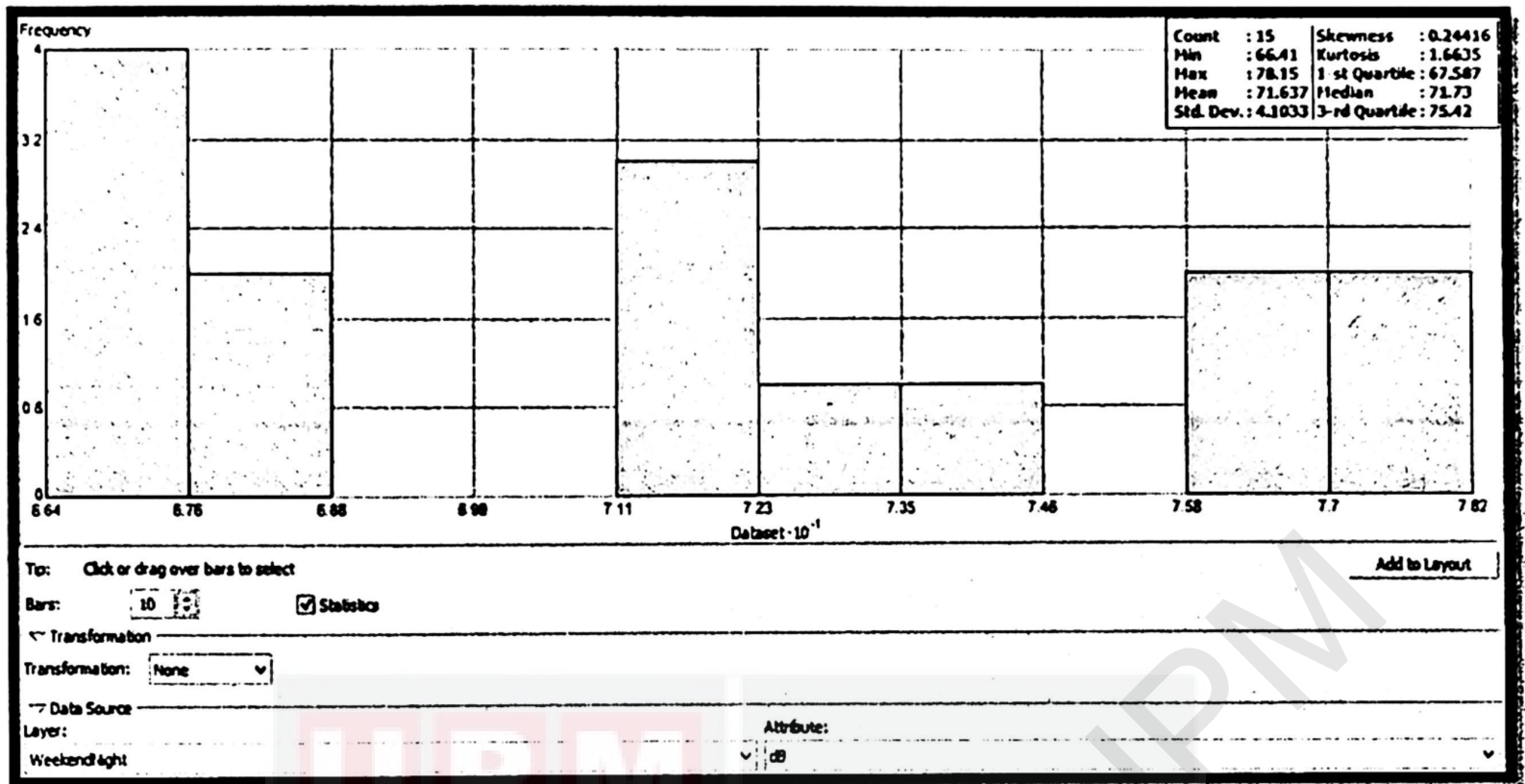


Figure 35: Plot showing the frequency distribution of noise data set before log transformation.

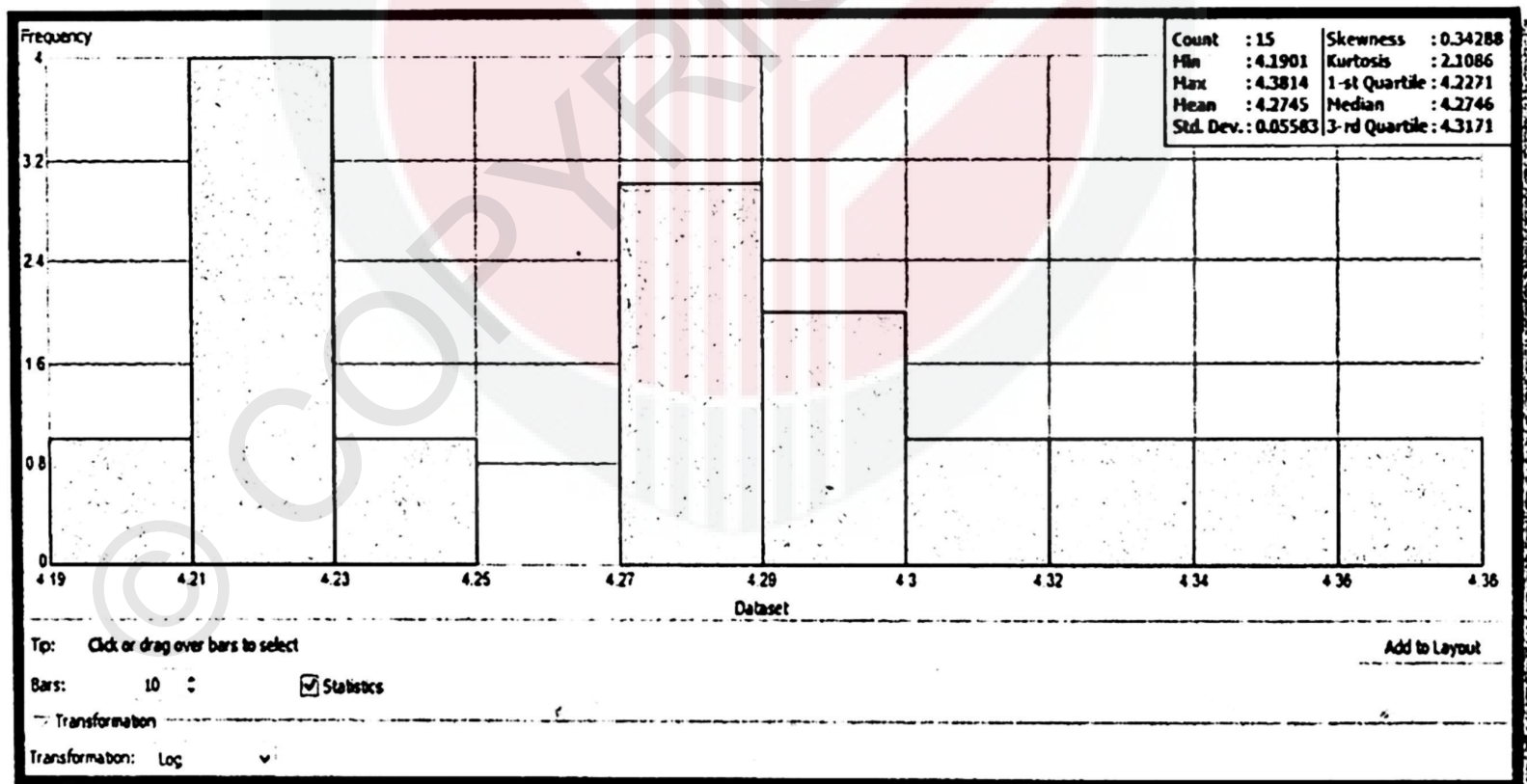


Figure 36: Plot showing the frequency distribution of noise data set after log transformation

As shown in Table 4, the difference between mean and median for noise level survey that was taken on weekend were 0.65, -1.24 and -0.09, respectively, for morning, afternoon and night time interval. From the Table 4, the skewness values for all interval times were 0.03, -0.28 and 0.24. The skewness values for noise level on the weekend were much lower compared than the noise level that was taken during the weekday. Hence, this implies that the measured noise level data is normally distributed. No transformation is required for noise measured level on weekend.

4.2.2 Semivariogram/Covariance

In second step, the semivariogram or covariance cloud allows the spatial autocorrelation to be examined between the measured sample points, i.e. noise sample points. In spatial autocorrelation, it is assumed that things close to one another are more alike. The semivariogram or covariance cloud has the capability of examining this relationship. For doing so, a semivariogram value (the square of the difference between the values of each pair of locations) is plotted on the y-axis relative to the distance separating each pair on the x-axis (Figure 37).

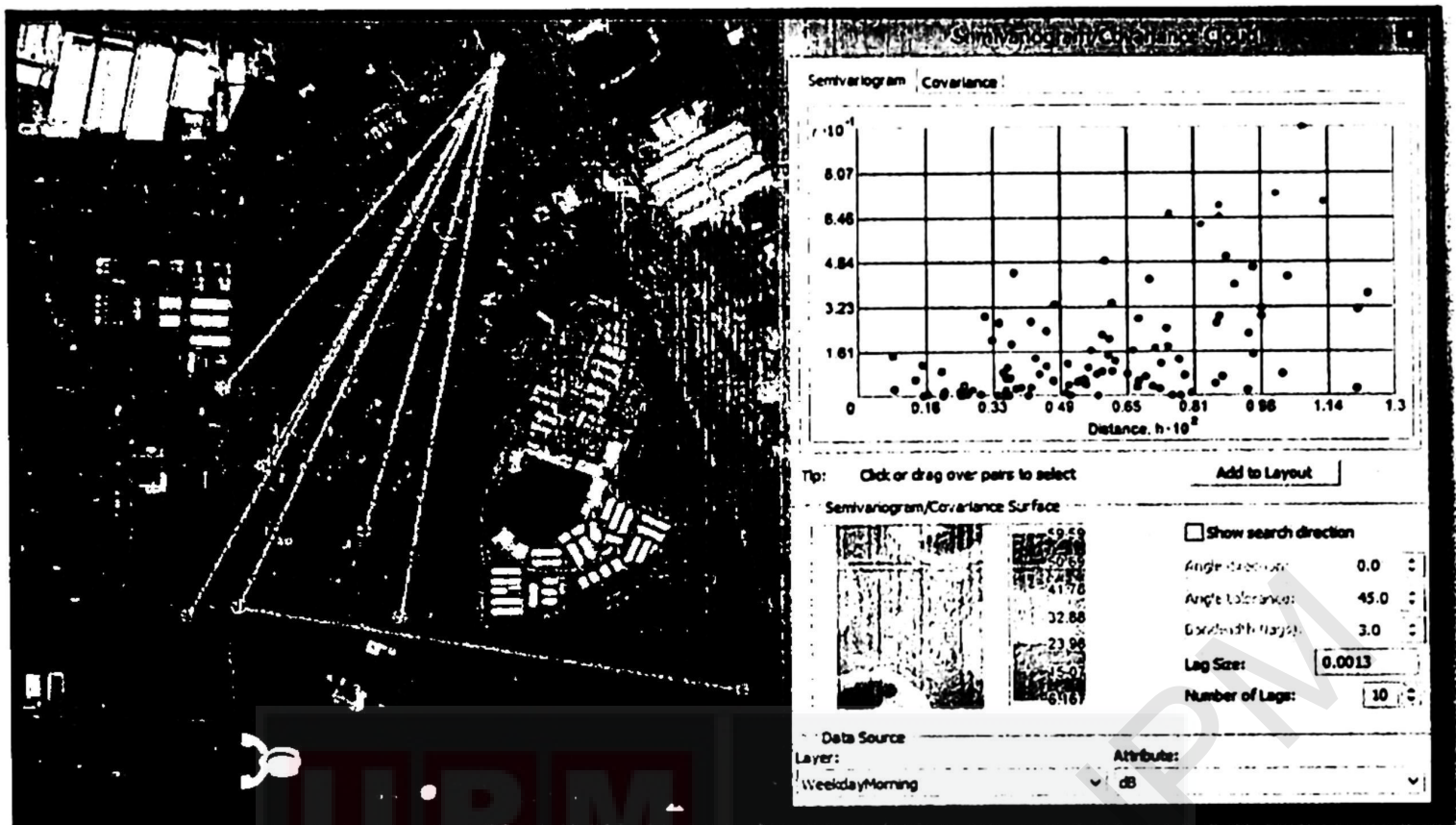


Figure 37: Semivariogram/Covariance Cloud of Noise Measured Dialog Box

As shown in Figure 37, each red dot in the semivariogram cloud represents a pair of locations. Since closer locations should be more alike, the semivariogram will show close location (far left on the x-axis) having small semivariogram values (low on the y-axis). As the distance between the pairs of locations increases (move right on the x-axis), the semivariogram values should also increase (move up on the y-axis). However, a certain distance is reached where the clouds flattens out, specifying that the relationship between the pairs of locations beyond this distance is no longer correlated. Additionally, the values in the semivariogram are put into bins based on the direction and distance between the pairs of location. The semivariogram surface are then produced after those bin values were averaged and smoothed.

4.2.3 Trend Analysis

The Trend Analysis tool helps to identify global trends in the input data set. This tool provides three-dimensional perspective of the data points (Figure 38).

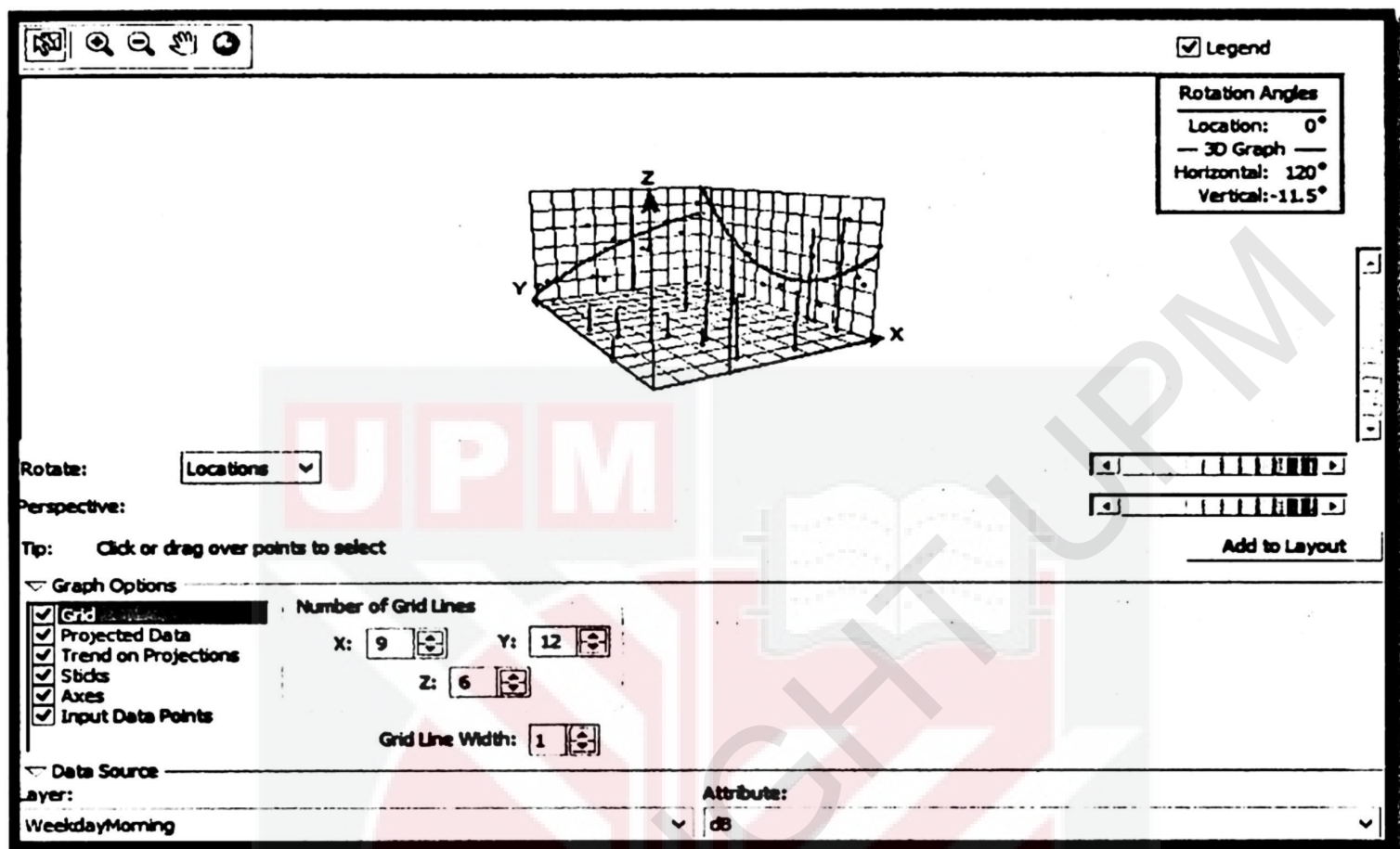


Figure 38: Trend Analysis of Measured Noise Level Dialog box

As shown in Figure 38, the noise measured values are given by the height of each stick in the Z dimension with the input data points on top of the stick. The noise values are projected onto the perpendicular planes, an East-West and a North-South plane. The X axis is specified as the East-West axis and the Y axis is the North-South axis. Then, a best fit line (a polynomial) is drawn through the projected points, which shows model trends in specific direction. The green line indicated as an east-west trend line and the blue line is a north-south trend line.

The data points can be considered showing no trend if it exhibit in flat lines. However, the green line as in the figure above gradually increasing as it moves from east to west direction. On the other hand, the blue line starts out with high values at north direction and decreases as it at centre and then increases once again towards south direction. This indicates that the noise measured value seems to exhibit a strong trend in both north south and east west direction. The trend observed is that the noise measured values increases as it distribute or propagate from east to west direction. Similarly, the noise measured level is increasing as it moves towards south direction. By removing the trend, the semivariogram will model the spatial autocorrelation among data points without having to consider the trend in the data. The trend will automatically be added back to the calculations before the final surface is produced.

4.3 INTERPOLATION TECHNIQUES RESULTS

This section discusses the results of the several interpolation techniques like IDW, RBF and Kriging in producing a noise map for the study area. Different interpolation techniques has their own significant parameters that accounting the accuracy of prediction values to the raster surface of the mapping.

4.3.1 Inverse Weighting Distance (IDW) Results

Inverse Weighting Distance (IDW) explicitly implements the assumption that things that are closer to one another are more alike than those that are farther apart. In IDW interpolation method, the important variable that was mainly focus is the power function. As mentioned earlier, power function weights are proportional to the inverse of the distance (between the data point and the prediction location) raised to the power value p .

In order to measure the qualitative of IDW interpolation method, cross-validation process been carried out to check the precision and accuracy of predicted and measured noise level. The cross-validation analysis between the observed noise level and the noise level predicted by IDW models for different power values are given in Figure 39, 40 and 41 respectively.

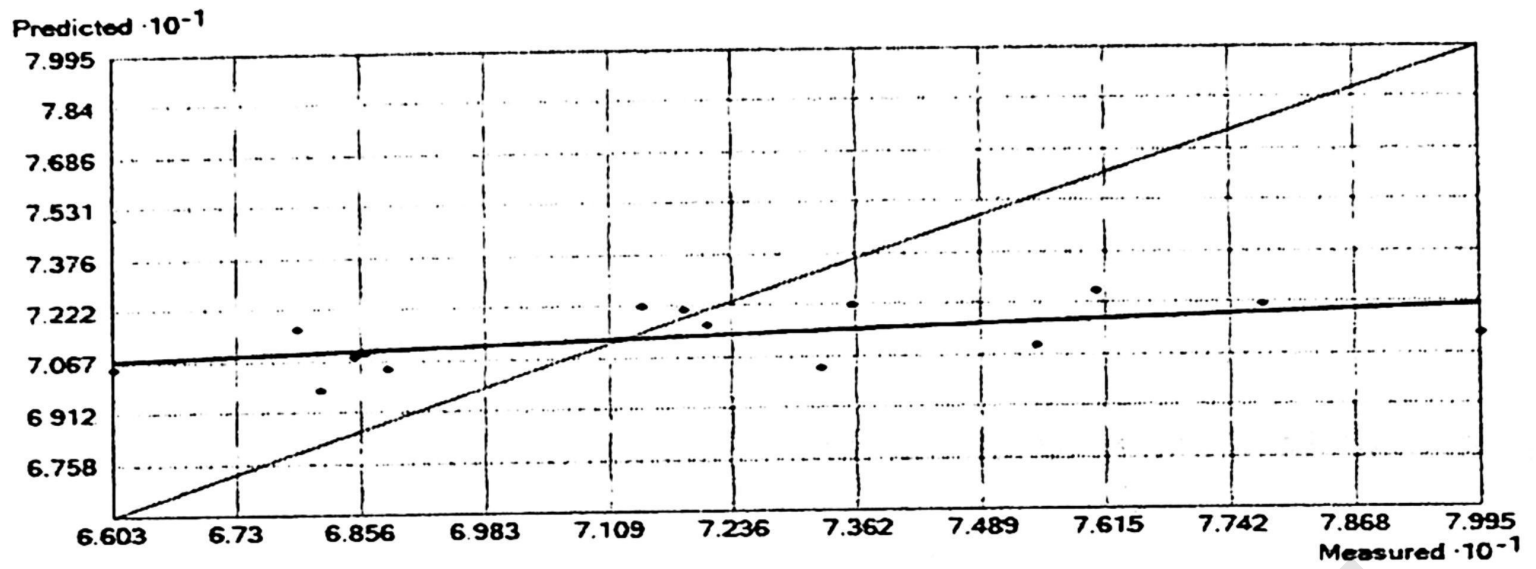


Figure 39: IDW with power function of 1 (Measured Vs Predicted Values).

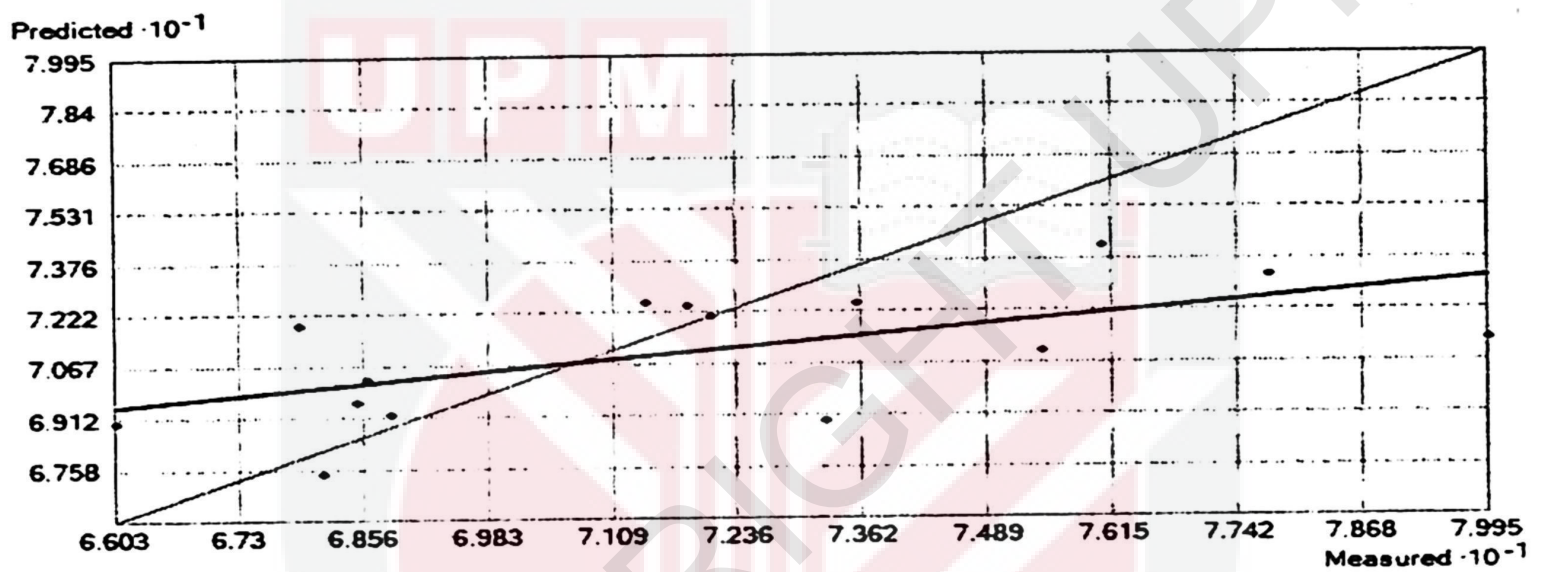


Figure 40: IDW with power function of 2 (Measured Vs Predicted Values).

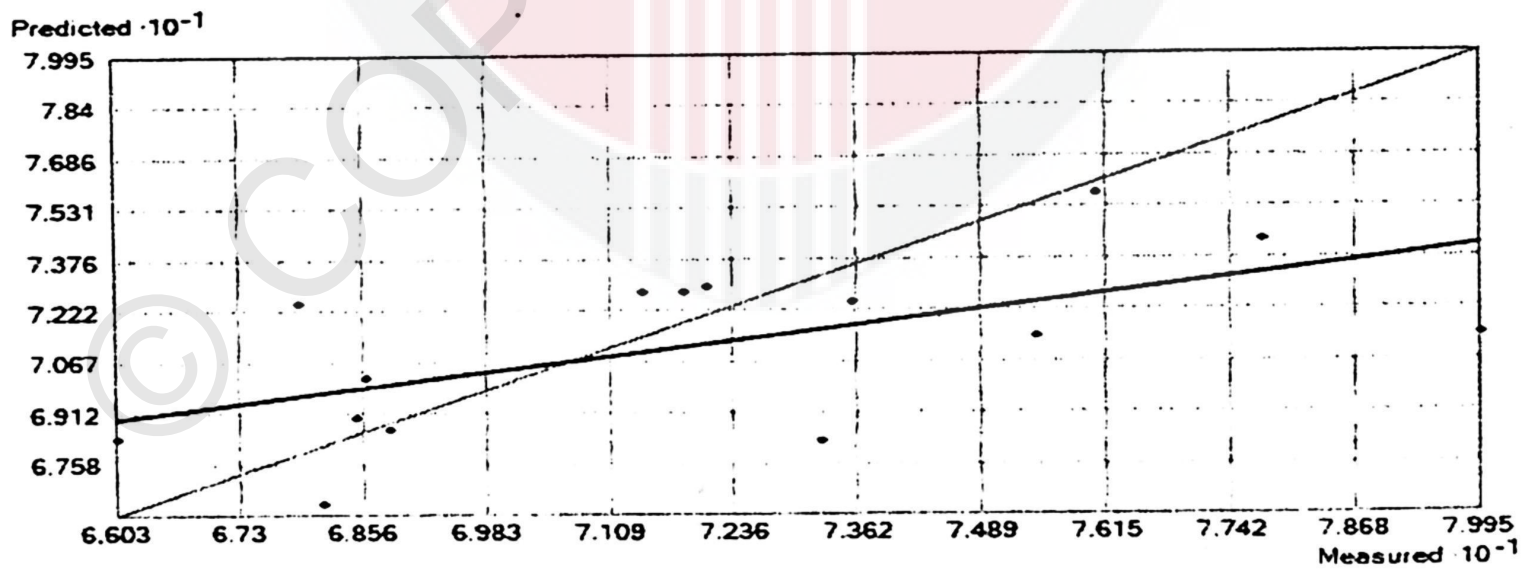


Figure 41: IDW with power function of 3 (Measured Vs Predicted Values).

In the above plots black line is the fitted line drawn through the scattered points, and the grey line is the 1:1 ratio line. Preferably, the predicted values should be the same as the measured ones, and the black line should be close to the 1:1 line. The above plots illustrate that the regression (black) line for the IDW with power function of 3 is close to 1:1 line, when compared to the other power function of IDW interpolation technique.

Table 5: MAE, ME, RMSE Values for Inverse Distance Weighting (IDW) with Different Parameters

Interpolation Method	Neighbourhood Type	Power Function, P	RMSE	ME	MAE
IDW	Standard	1	3.642	0.641	2.935
	Standard	2	3.359	0.899	2.503
	Standard	3	3.294	0.794	2.437

By using IDW method, the accuracy of prediction map for noise distribution in the study area is increasing as further changing the value of power function. As shown in the Table 5, the RMSE values varied from 3.642, 3.359 and 3.294 for 1, 2 and 3 respectively. Among the three validation results, the power function of 3 was the one with the lowest MAE (2.437) and RMSE (3.294) if compared to the other two power function. On the other hand, the power function of 1 was the one with the worst results and hence showed lesser accuracy in the estimation method. It was observed that MAE (2.935) and RMSE (3.642) is higher compared than other value of power function.

4.3.2 Radial Basis Function (RBF) Result

Radial Basis Function (RBF) are a series of exact interpolation technique; that is, the surface must pass through each measured sample value. The difference between IDW and RBF interpolation method is that IDW will never predict values above the maximum measured value or below the minimum measured value but RBFs can predict those value in estimation method.

For this interpolation method, two kernel functions were selected that will be used to create the prediction surface. They are completely regularized spline and spline with tension. Similarly, as in IDW, optimal parameters are determined using cross validation to check for the precision and accuracy of a model produced.

The cross-validation analysis between the observed noise level and the noise level predicted by RBF models are given in Figure 42 and 43.

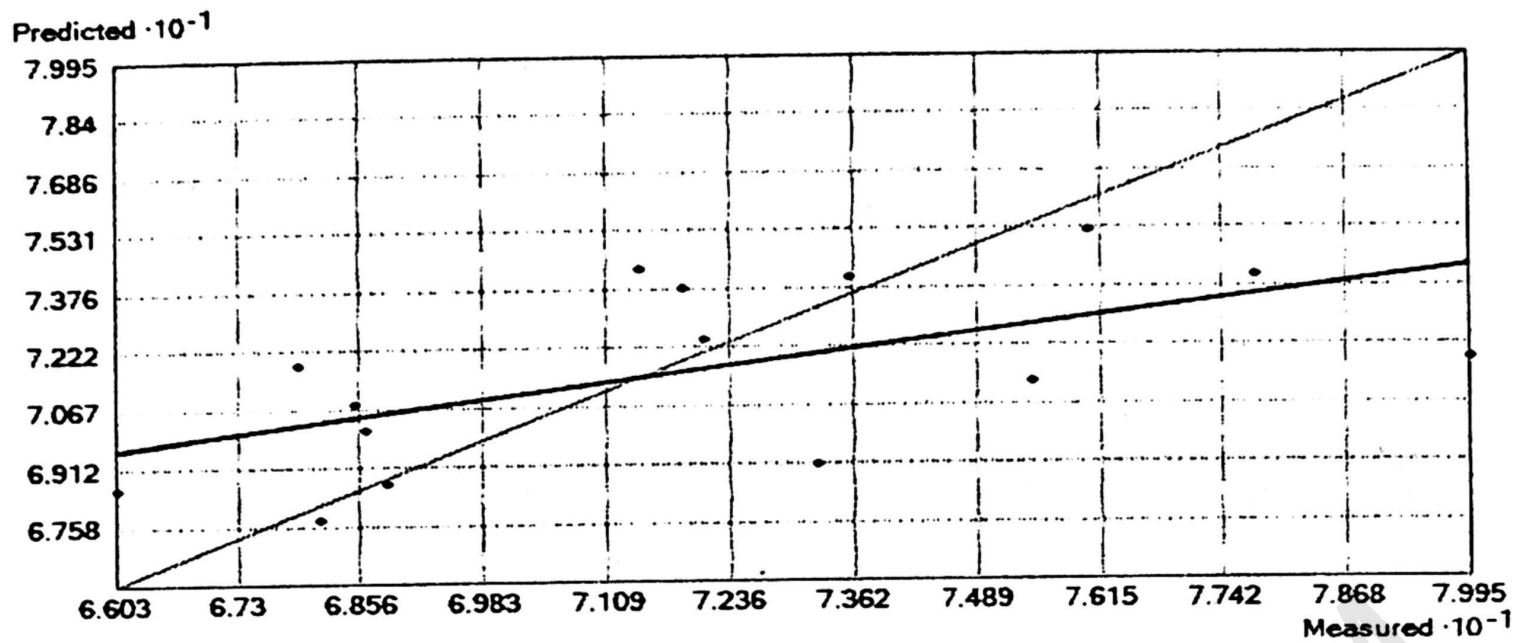


Figure 42: RBF completely regularized spline (Measured Vs Predicted Value).



Figure 43: RBF spline with tension (Measured Vs Predicted Value).

From these two plots, it was observed that RBF model does not showed much difference between the measured noise level and predicted noise level. Both of the black line which is the fitted line are almost close to 1:1 line. Table 6 shows RMSE, ME and MAE values, for test data points for different kernel function that been specified for RBF model.

Table 6: MAE, ME and RMSE Values for Different Kernel Function of RBF**Interpolation**

Interpolation Method	Kernel Function	Kernel Parameter	RMSE	ME	MAE
RBF	Completely Regularized Spline	3779.47	3.240	0.348	2.5
	Spline with Tension	2031.54	3.228	0.354	2.5

From Table 6, it can be inferred that there is no significant difference among the error values for both RBF interpolation methods. The error values were almost similar to each other, for example MAE for both RBF methods are the same which equivalent to 2.5. However, there are slightly different between the RMSE and ME values. For completely regularized spline, the RMSE value obtained is 3.240 while the spline with tension had the RMSE value of 3.228 which slightly lower than previous one RBF interpolation method. The difference between these two RMSE values is only 0.37%. On the other hand, the ME between the measured and predicted noise level by RBF with completely regularized spline and spline with tension were 0.348 and 0.354 respectively.

Since there were no significant differences can be found from the error values of RBF interpolation methods and hence this implies that any of the RBF interpolation methods can be chosen. For further comparative analysis of interpolation methods, RBF method with specified kernel function of spline with tension was selected due to

lower RMSE value than other RBF kernel function in order to compare with other spatial interpolation methods.

4.3.3 Kriging Result

The ordinary kriging, one of the Kriging's method, was adopted in this study for spatial interpolation of noise data to measure noise distributions in the study area. The important factor that need to be consider in kriging method is fitting a model to the empirical semivariogram. In kriging method, it is required to replace the empirical semivariogram with an acceptable semivariogram model. With different selected model for semivariogram will influence the prediction of unknown samples (noise data) in the noise mapping.

The selected model to fit to the semivariogram in kriging method were exponential, Gaussian and spherical. The best model for fitting on experimental variogram was selected based on less RMSE values. Similarly, the measured values of noise data on weekday morning will be evaluated as like in IDW and RBF step.

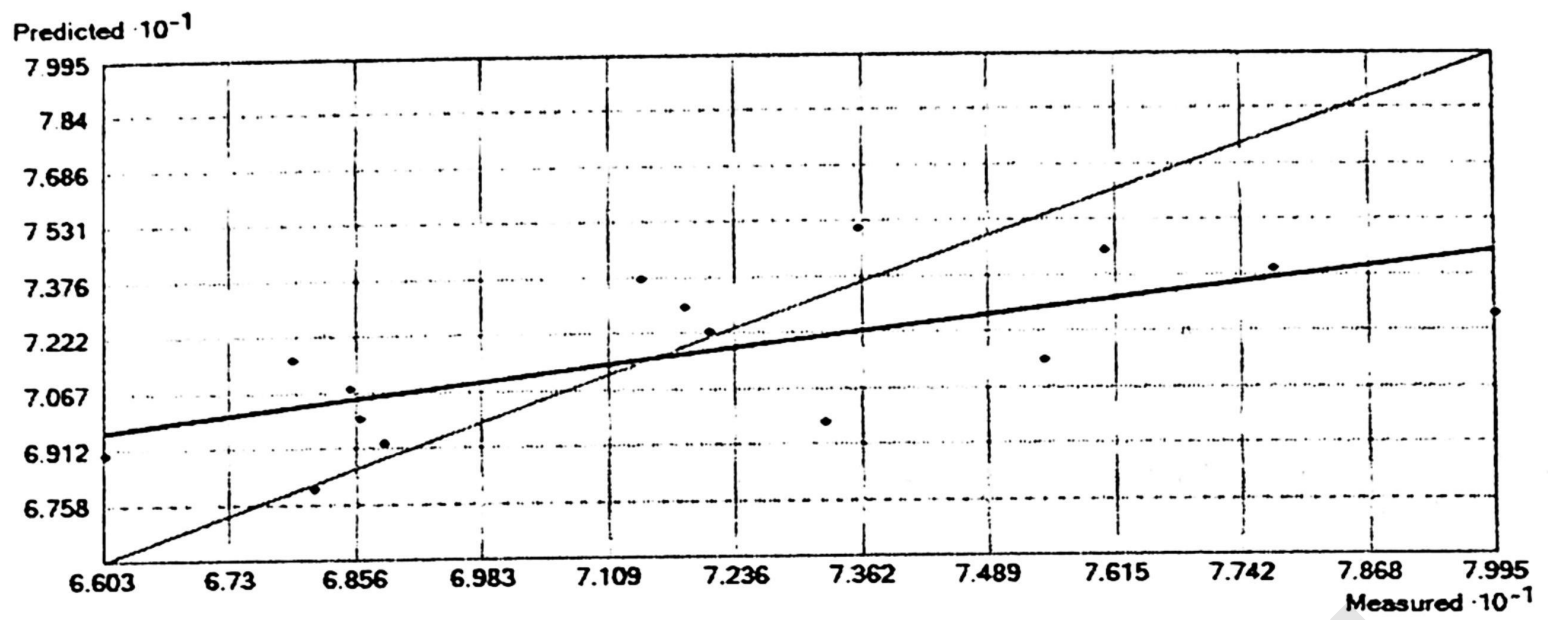


Figure 44: Cross Validation Exponential Model (Predicted Vs Measured).

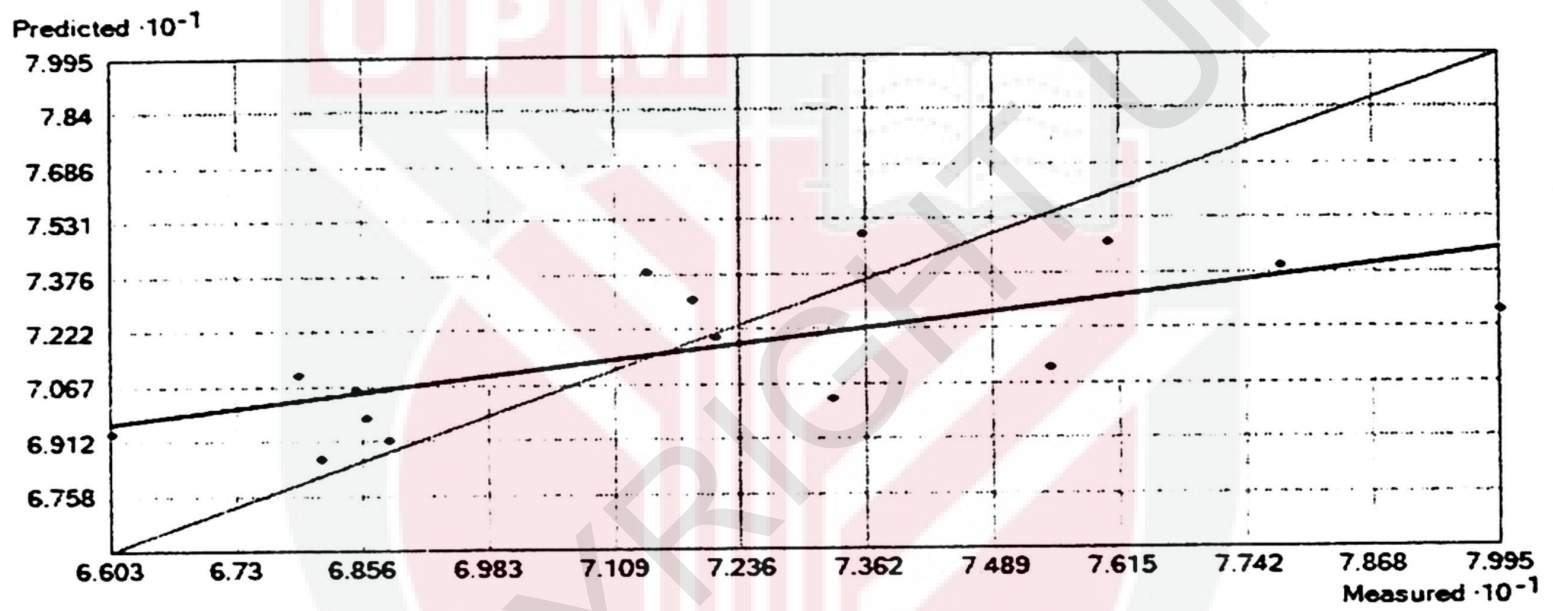


Figure 45: Cross Validation Gaussian Model (Predicted Vs Measured).

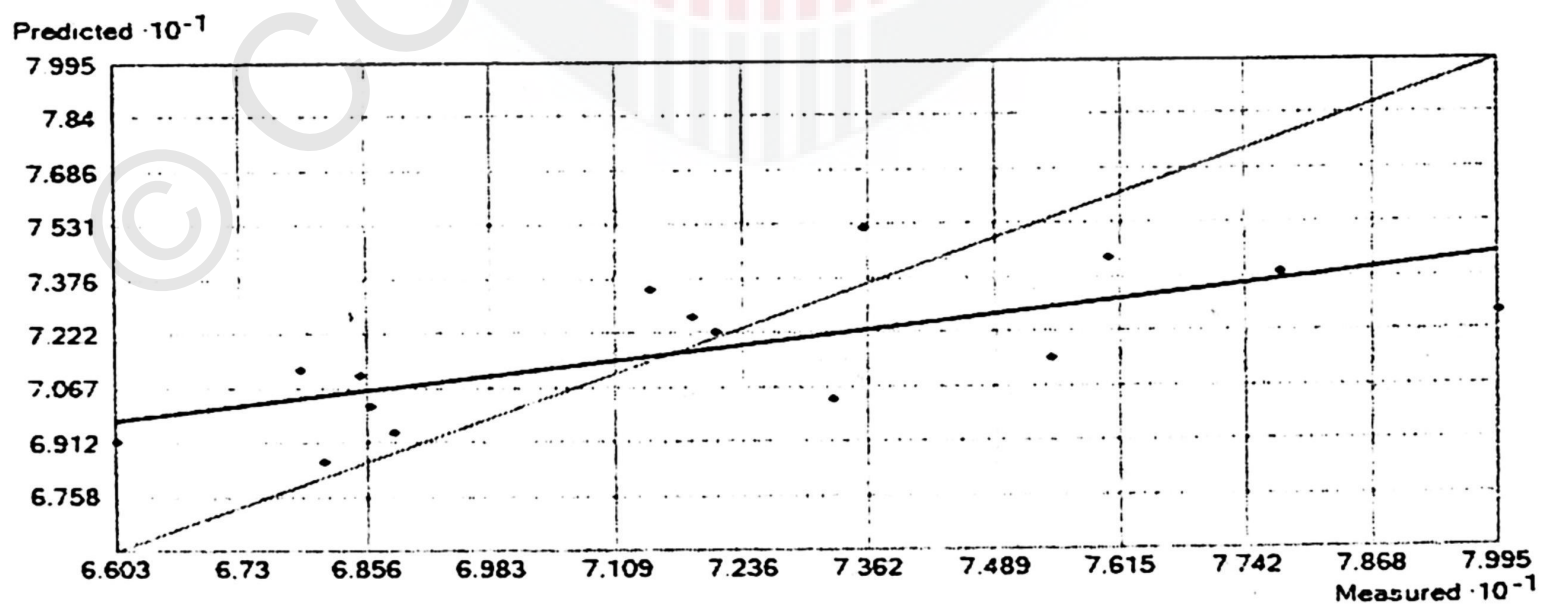


Figure 46: Cross Validation Spherical Model (Predicted Vs Measured).

From the figure 44, 45 and 46 above, those are the cross-validation results from the kriging method with different model types fitted in the semivariogram. From these three plots, it was observed that no significance different between the measured noise level and noise level predicted. Ideally, the predicted values should be the same with measured ones, and the fitted line (black line) should close to the 1:1 line. The above plots illustrate that the black line for the spherical type of model is close to 1:1 line, compared than other model types of kriging method. Table 7 shows MAE, ME and RMSE values, for kriging interpolation method with different types of model selected in semivariogram.

Table 7: MAE, ME and RMSE Values of Different Models of Semivariogram

Interpolation Method	Model	RMSE	ME	MAE
Kriging	Exponential	3.023	0.276	2.421
	Gaussian	2.977	0.271	2.363
	Spherical	2.968	0.205	2.405

After creating a prediction surface from kriging method, it is useful to recognize if the model is optimal to the data set. In order to check the accuracy and precision of models, the error values like RMSE, ME and MAE were calculated as shown in the Table 7. The models then compared with one another and the best results will be selected as for further checking in comparison of other interpolation methods.

As shown in the Table 7, it can be observed that spherical model showed the lowest RMSE value of 2.968. On the other hand, exponential model showed the highest RMSE value of 3.023. The difference of RMSE values between these two models is 1.82%. For MAE values, it can be seen that the values showed no significant

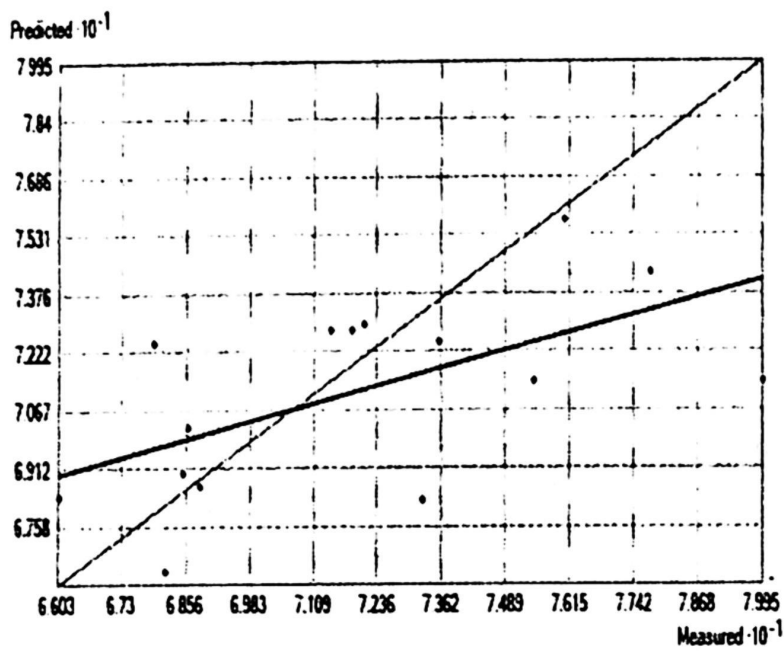
difference. The values obtained were almost the same, where there are no such big difference can be determined. In fact, the error values from the table above, it was observed that the values were almost close to one another. This indicate that any semivariogram model are likely can be choose for kriging interpolation method in determining the predicted noise levels.

For further comparative analysis interpolation method, kriging method with spherical model parameter was selected as to make comparison with other interpolation method, IDW and RBF. This is because it showed the lowest RMSE value compared than other two semivariogram models.

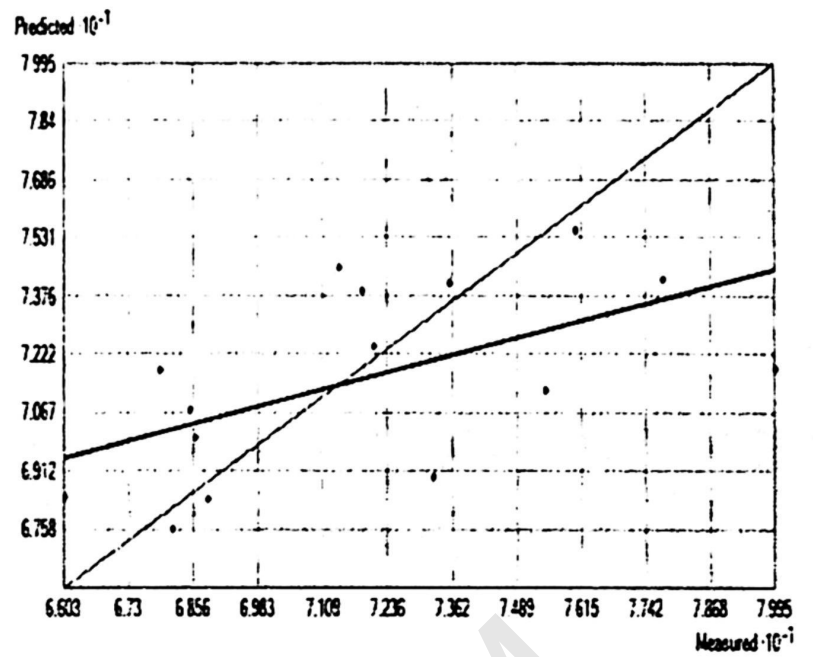
4.4 COMPARATIVE ANALYSIS OF INTERPOLATION TECHNIQUES

In previous section, three spatial interpolation techniques were investigated based on their performance with selected parameter to create a prediction surface. The interpolation methods which showed the best result was selected to make further comparative analysis with other interpolation methods.

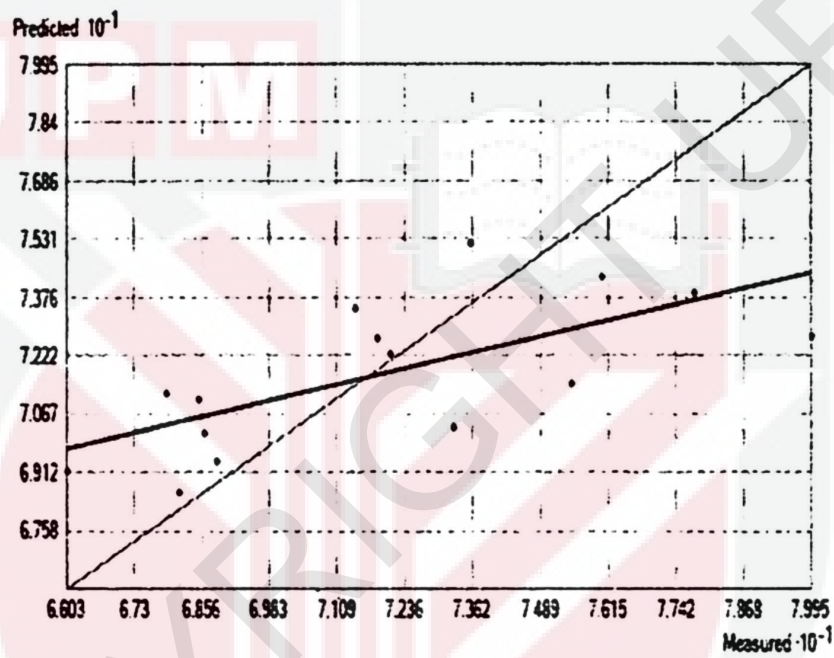
For IDW, a power function of 3 was chosen as the best result compared to other power function. A tension with spline was selected for RBF interpolation technique. In kriging method, the most suitable semivariogram model was a spherical model due to less RMSE value. In this section, the best models from the deterministic and geostatistical methods were compared to find the most suitable spatial interpolation method of noise level in the study area. Assessment measures of model performance are summarized in Table 8. The cross-validation results for IDW, RBF and Kriging are shown in the Figure 47.



(a)



(b)



(c)

Figure 47: Comparison of cross-validation of different interpolation methods between measured and predicted noise level values: (a) Inverse Distance Weighted-IDW; (b) Radial Basis Function-RBF; (c) Ordinary Kriging-OK.

From Table 8, it showed that geostatistical method had more considerable accuracy than the deterministic method. Among the three interpolation methods tested, the OK method which is one of the geostatistical method had the lowest RMSE (2.968), MAE (2.405) and ME (0.205) if compared to the other two methods used. On the other hand,

the IDW method was the one with the worst results, leading to a higher RMSE value than other interpolation methods used.

Table 8: Summary of Interpolation Method Analysis.

Interpolation Method	RMSE	MAE	ME
IDW	3.294	2.437	0.794
RBF	3.228	2.5	0.354
OK	2.968	2.405	0.205

Taking the RMSE value of the OK method as a reference, the IDW and RBF methods showed RMSE values around 9.9% and 8.1% higher, respectively. Low value of RMSE and ME indicated a good match between observed and predicted noise level. The MAE, which provided absolute error of the predicted data in reference to the actual data, was also low for OK compared than the other two interpolation methods. Moreover, results of cross validation illustrated in Figure 47. As mentioned before, ideally, the black lines should be close to the trend line (1:1 line). The above plots illustrate that the black line for all the interpolation methods used are showed almost the same pattern. However, the more efficient result was the Kriging method (c). It was observed that the scattered points were slightly closer to the trend line. This result of the accuracy of prediction method is more reliable in OK method compared than the other two interpolation methods.

To compare with this study, similar results were found by Taghizadeh-Mehrjardi R and Zare when comparing different interpolation methods to generate a noise map. They also reported that geostatic methods had more considerable accuracy than deterministic method, like IDW and RBF methods for preparing maps. Finally, a noise

map of noise value was prepared using Kriging method which was the best method for interpolation in GIS environment.

4.5 NOISE MAPPING

Previously, a comparative analysis were done measured on the interpolation methods, and OK showed the best result because it has the least value of all the error values compared than other interpolation methods. And therefore OK was chosen as the most suitable and efficient model to produce noise maps for this project.

The following figures showed the noise maps for three different occasions on both day. A noise map is an ideal tool for carrying out noise impact assessment in urban areas where it enables one to know areas that are noisy and ones with low noise. From the figures below, it shows the distribution of noise values within the study area. The most affected areas are the educational institution and also some part of residential with commercial activities areas. From the noise maps, the residential areas were observed to be less impacted by the noise distribution. Nevertheless, all of the zones were attained noise value that exceeded the regulatory standards from DOE of Malaysia. Therefore, noise management and action plans need to be conducted in order to mitigate and handle the impacts of noise on people and the environment.

Noise level maps prepared using ArcGIS software are shown in figures below for weekday with three occasions; 8 to 10am, 12 to 2pm and 5 to 7pm respectively. Conversely, another figures below represent the noise level maps for weekend with the same occasions of noise measurements was taken.

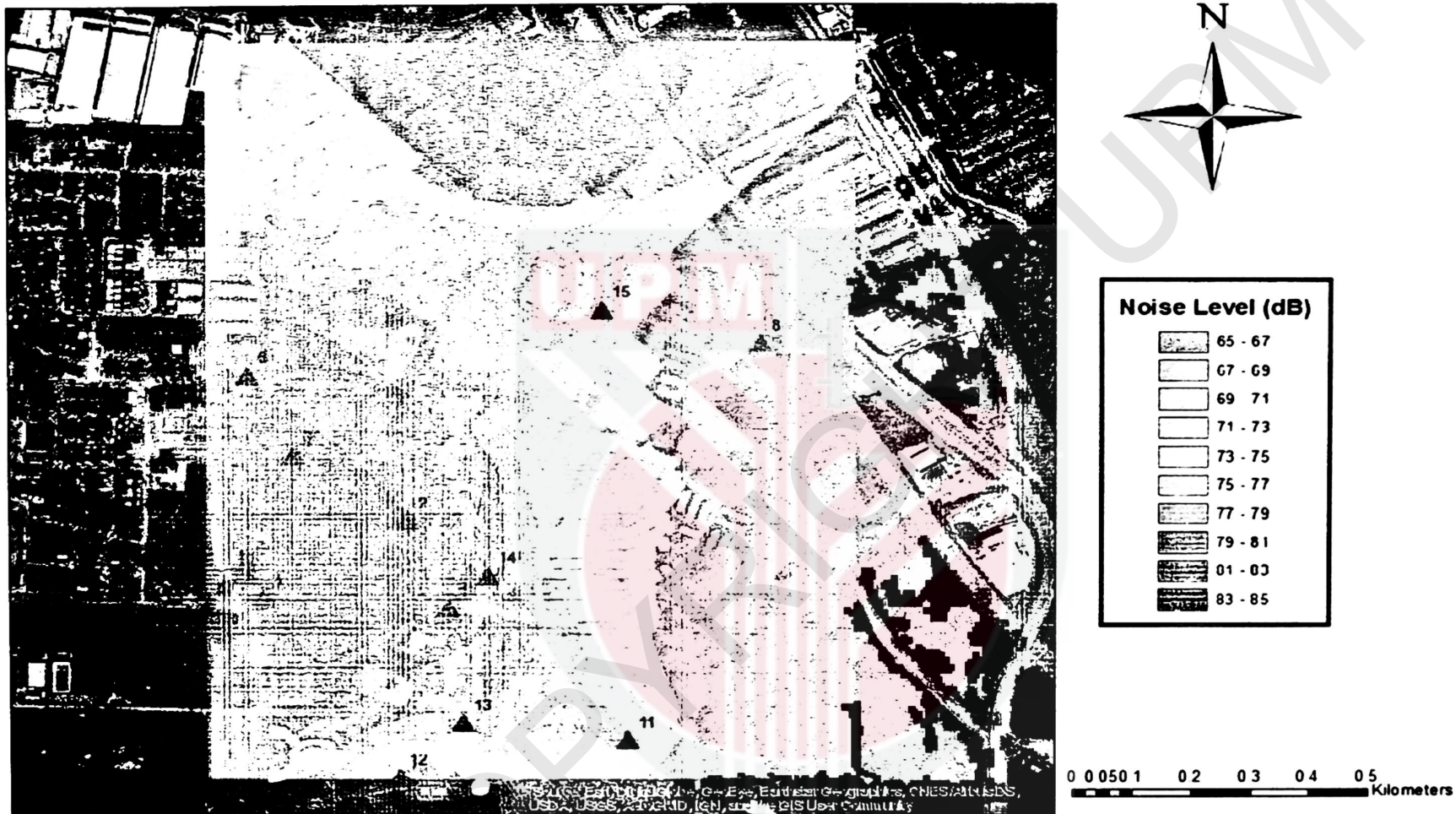


Figure 48: The map showing noise level in dB, between 8 am to 10 am (morning)

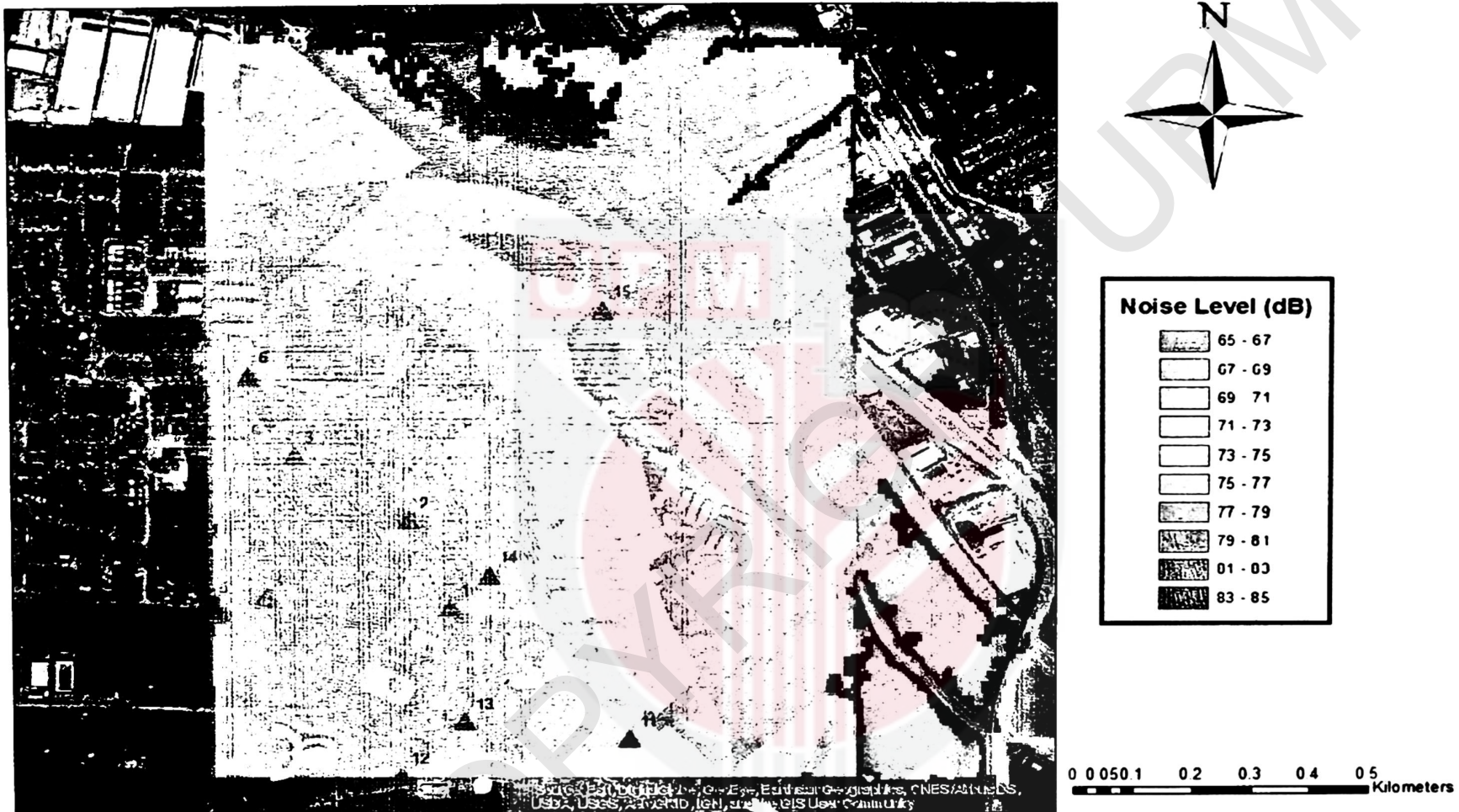


Figure 49: The map showing noise level in dB, between 12 pm to 2 pm (afternoon)

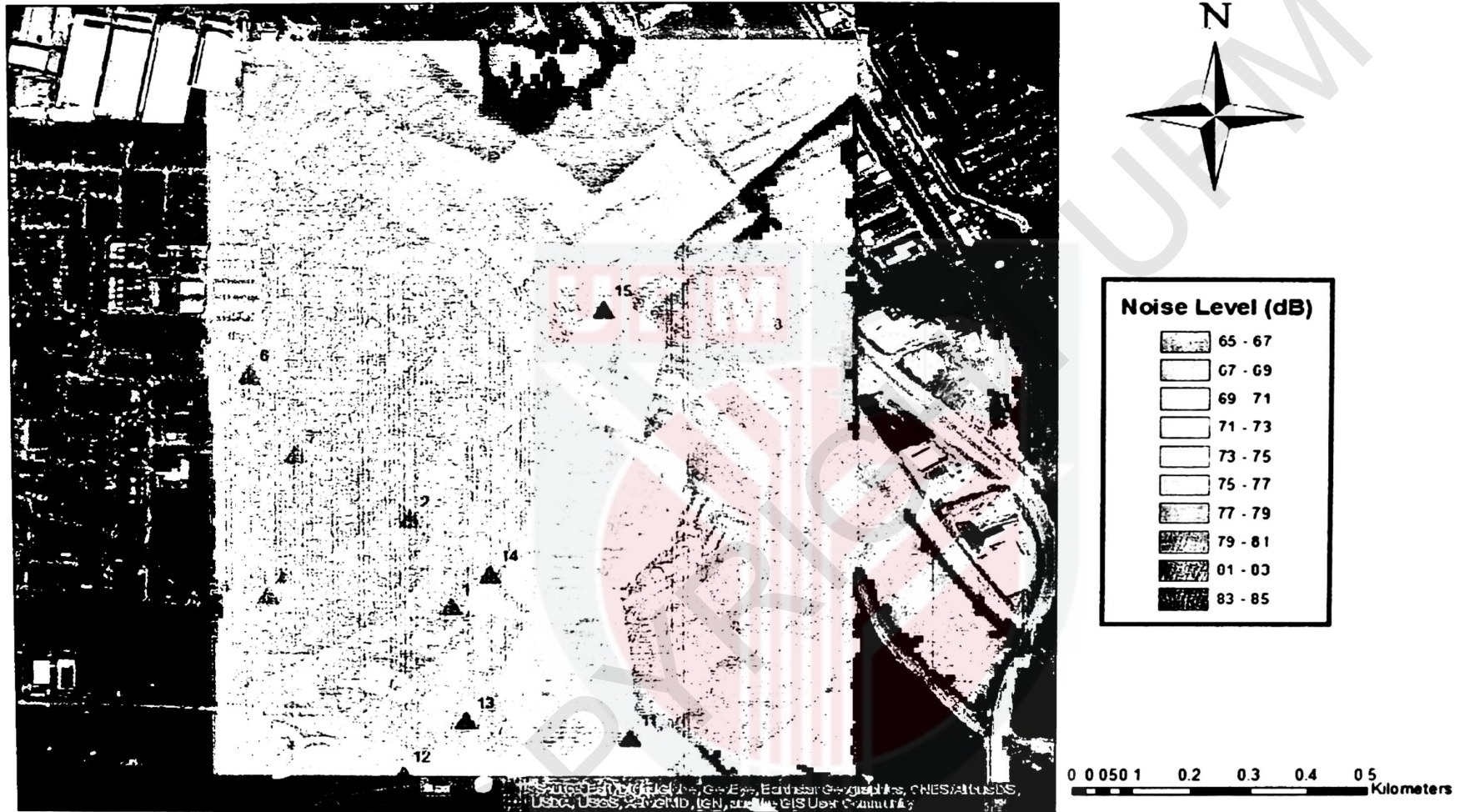


Figure 50: The map showing noise level in dB, between 5 pm to 7 pm (night)

As shown in figure 48, 49 and 50 above, it illustrated that the noise maps for weekday (Wednesday) with three different interval times; morning, noon and night. By visual comparison of the three maps shown in the figures above, we can see that the noise distribution of the three corresponds to the actual situation. Location that denoted 8, 9 and 10 always showed higher values of noise level where the noise level can reached 80dB or above than that. Part of the reason is that the locations are located on the main road where the traffic condition is constantly high with present of every type of vehicles. Noise emission is mainly from the road traffic and is distributed within the surrounding areas as seen in the figures above. The affected areas are mostly community and institutional areas including educational institution (University Putra Malaysia). The most critical time for noise distribution that shown in the map is during afternoon and night time. This can be due to high traffic where there a lot of vehicles on the road travelled from one place to other places. In fact, the noise measurement for this project was taken during the peak hours, and undoubtedly the increment of number vehicles is expected to be happened as time goes by.

Residential neighbourhood which denoted as point 1 to 6 shows that the areas are constantly having moderate noise level. All noise maps from the figures showed similar of noise distribution pattern within the surrounding areas. This implies that the traffic condition in the residential areas is not severe as the location that located near the main road. Location 7 comprised of the combination of residential and community areas. As shown in the figures, it was observed that the particular location was also risky due to high exposure of noise level emitted mainly from road traffic. In addition to that, this area is located near the traffic signals which contributes more on the increment noise values within the area.

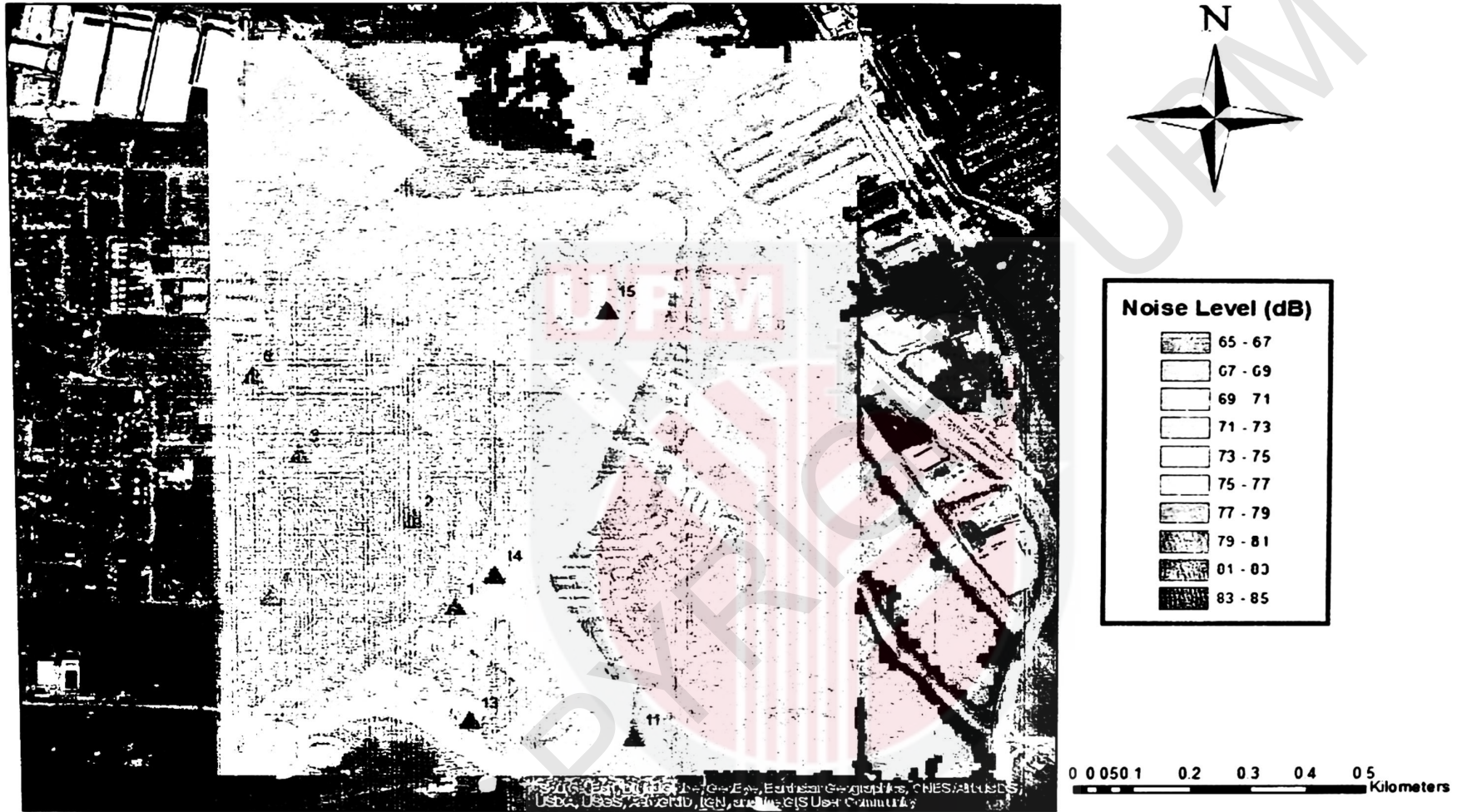


Figure 51: The map showing noise level in dB, between 8 am to 10 am (morning)

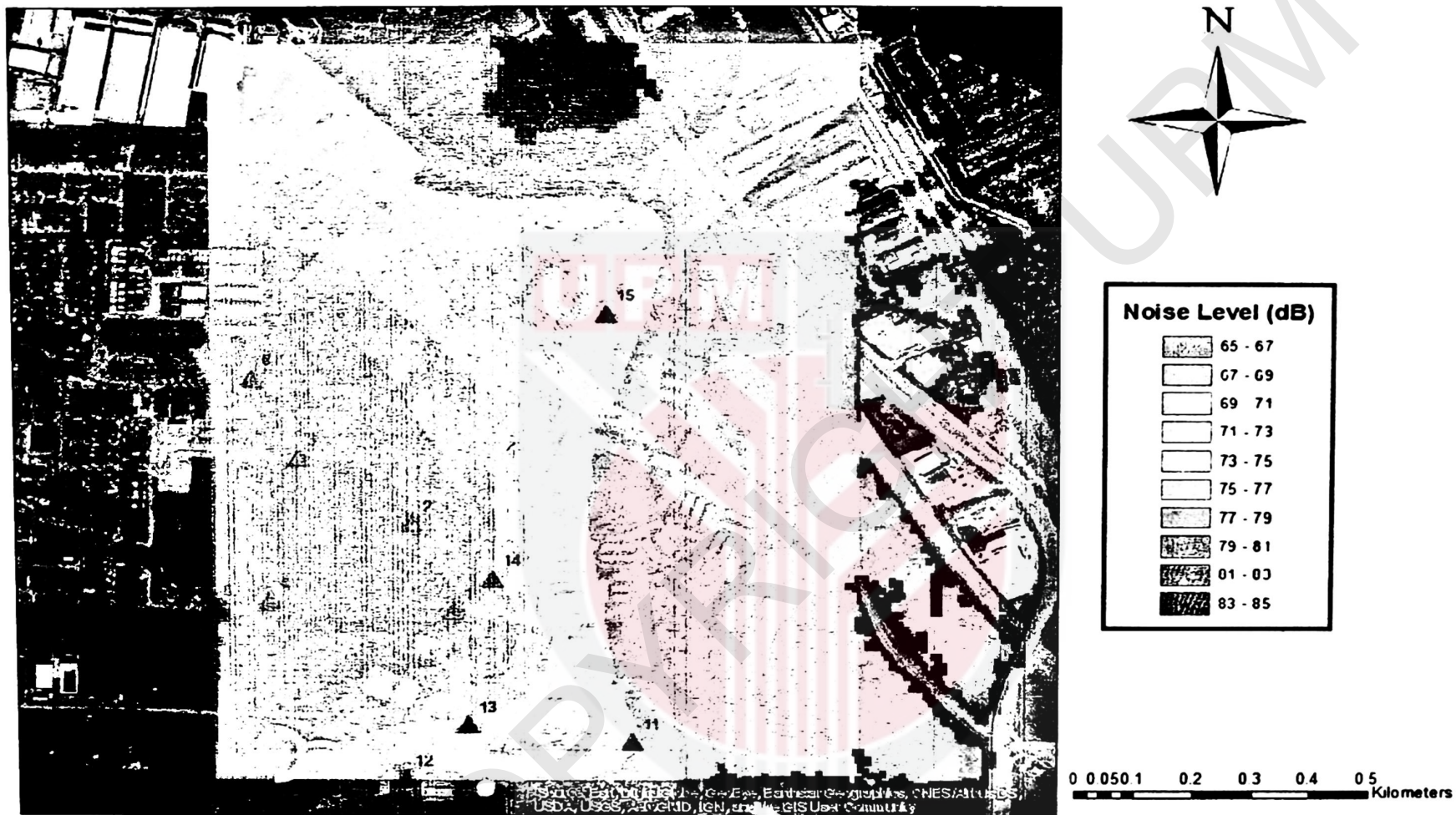


Figure 52: The map showing noise level in dB, between 12 pm to 2 pm (afternoon)

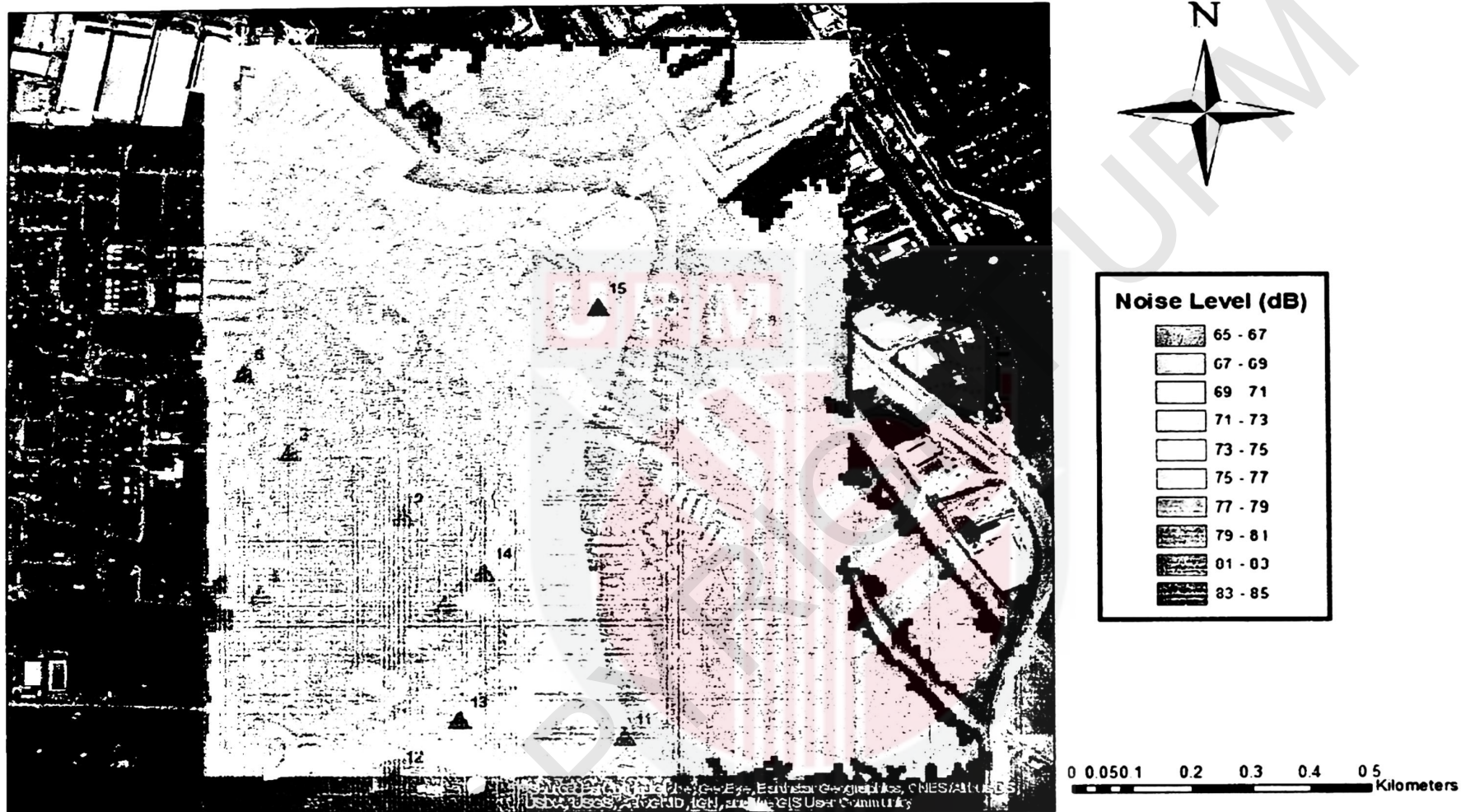


Figure 53: The map showing noise level in dB, between 5 pm to 7 pm (night)

The figure 51, 52 and 53 above showed the noise maps that was taken on Saturday with three different occasions within the day. The noise distribution in the study area is showing no significance difference as compared to noise distribution that were shown on the weekday noise maps. Location 8, 9 and 10 are still showing higher value of noise level due to high accumulation of moving vehicles and pass through these locations. The exposure of noise level to these locations is expected to be high enough (80 – 90dB) which can caused disturbances and annoyance to the community and institutional areas during the weekend. Location 12 somehow exposed to higher noise value in the morning occasion as shown in the figures above. This happened may be due to some of the students are having additional classes or other activities in the campus which lead to the number of vehicles increased in the location.

Furthermore, residential neighbourhood which located at point 1, 2, 3, 4, 5, 6, and 14 was also showed a similar pattern of noise distribution within the areas. The noise exposure levels are in moderate levels as shown in the figures above. This could be result of low traffic volume where there are no many moving vehicles pass through the areas on three different occasion times. In addition, location 7 that comprised of residential areas and shops was also seen exposed to high noise levels. In the location 7, there are concentrations of shops and located near the junction roads with high traffic volume. All these are responsible for high exposure noise levels, therefore, the residents living or trading in this area is exposed to noise levels of 80 – 90dB or more every day. This is very dangerous to health of the people in this area.

This work reveals that a noise map is an ideal tool for carrying out noise impact assessments in urban areas; it enables one to know areas that are noisy and ones with low noise. The study also provides adequate information for technical controls in line with the noise emission standards which should be upheld in Malaysia urban settings. Furthermore, the noise map can make data accessible to the general public in a way that is comprehensible. This could raise people's awareness of noise as a pollutant, and thus help to create conditions necessary for the implementation of a noise-reduction programme.

4.6 RECOMMENDATION AND MITIGATION

Comparison of average noise levels indicates that education and commercial zones are the two noisiest areas of all land use zones followed by community and residential zones. This is due to that the two zones are located near the main road where accumulation of vehicles is surely expected to be high during the peak hours. However, the average noise levels for all of the land use zones were exceeded the regulatory standards, 60 dB (A) recommended from DOE of Malaysia. The highest average noise value was observed to be reached around 80 dB (A) located in education zone. Consequently, it is important to control and mitigate the noise distribution in the study area as to provide a good quality of life and health for the people.

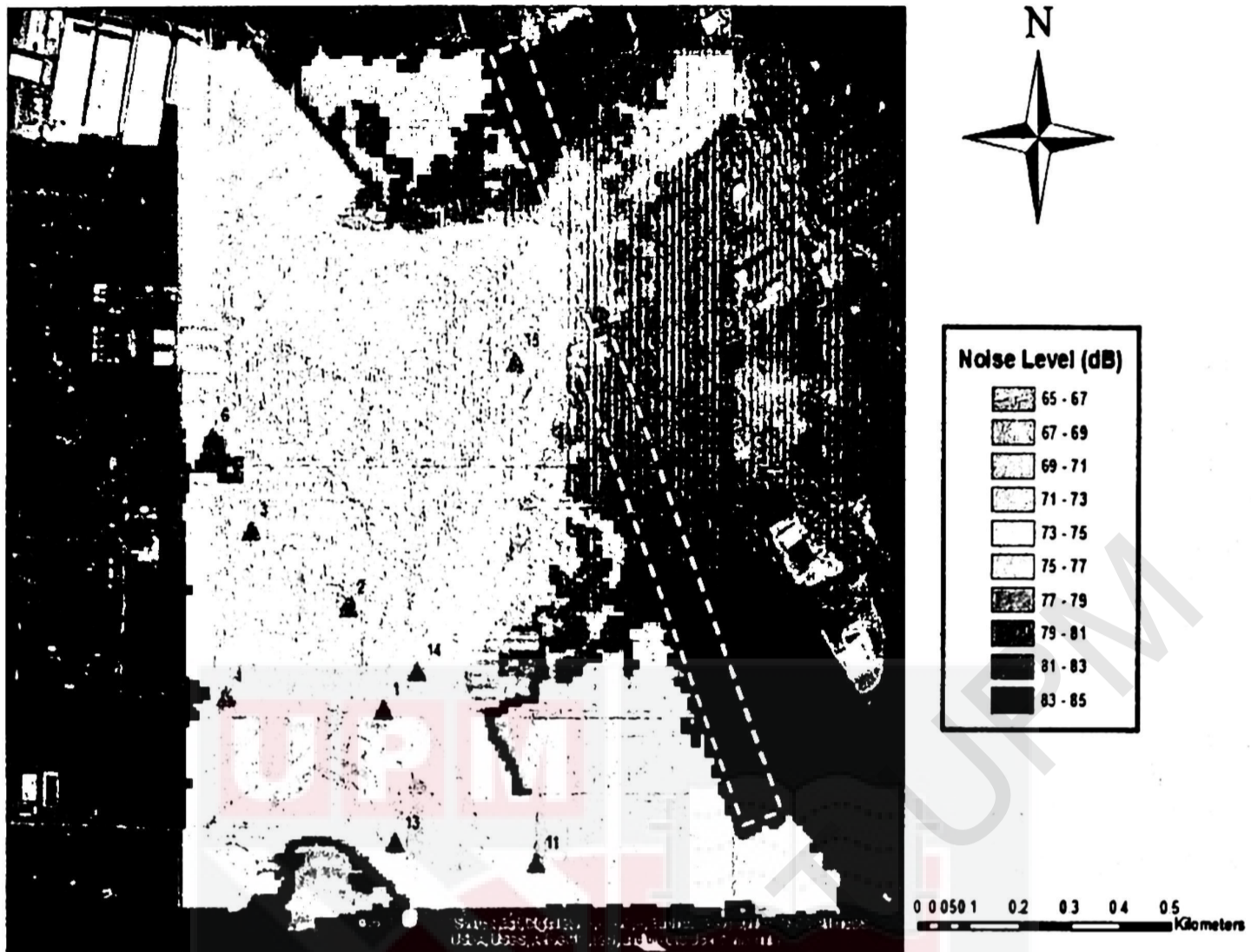


Figure 54: Proposed design area of noise barrier fencing (white dashed line)

From Figure 54, it represent a noise map with proposed areas of implement noise barrier fencing which outlined in white colour dashed line. Noise barrier fencing is designed to surround a property where in this case is an educational institution and commercial zone property and to mitigate the amount of noise that can penetrate into the property. The noise barrier fencing is proposed to be built on the side of combination of the commercial area and small residential area and also faculty of engineering along to the faculty of design and architecture. This proposed area situated near the main roads where the noise distribution is observed to be in critical state. As seen in the figures of noise map, this particular zone always showed high noise values on three different occasions. The noise distribution source is mainly from road traffic thus it is important to control and mitigate the noise levels as to prevent it from causing

disturbances to the residents in the area together with commercial activities and also the students on their studying time.

4.7 SUMMARY

In summary, this chapter presents the analysis of data and presentations of the result. Firstly, the mean noise levels for different occasions of time for each sampling points were calculated. Based on the plotted graph, comparison among these mean noise levels was examined in order to determine which location is most exposed and affected by the noise effect. From the result obtained, it shows residential with commercial activities and educational institutes were among the critical zone that affected by the noise effect. The noise level was recorded approximately around 75 – 80 dB within these affected zones. Each of the interpolation technique was initially evaluated based on their parameters. For example, IDW uses power of function as their parameter to interpolate the unknown values, RBF interpolation technique uses basis functions (completely regularized spline and spline with tension) and kriging method uses variograms and covariance functions concept of fitting a model to the empirical semivariogram to predicts the unknown values. Among these interpolation techniques, that shows adequate and optimal result in cross validation as well as error measurement values, will be selected as the best interpolation methods for noise level data. Then, further comparative analysis was once again conducted between these selected interpolation techniques using the same cross validation and error measurement method. For the final result, it shows kriging method showed the best result in cross validation and obtained lowest RMSE (2.968), ME (0.205) and MAE (2.405) values compared to the other methods. Consequently, prediction noise maps for the study area were developed using the best and optimal interpolation methods.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

Noise pollution of urban areas is one of serious aspects that the local agencies and state authorities have to consider in decision making process. In this study, six noise maps of two different day situations (morning, afternoon & night) were produced for the study area within in the Sri Serdang and UPM's region based on the sound level data collected from the study area. The collection of noise data in this study are mainly from the road traffic noise. From the noise mapping, the distribution of noise levels can be observed and also with the affected zones simultaneously that due to exposure of high noise levels. The noise assessment of the study area indicated that the most affected zones were education and the residential area with commercial activities zones where approximately average noise levels that these two zones received for all occasions were between 80 to 85 dB of noise level. This due to traffic volumes within the affected areas are always high and thus produced a lot of noise to the affected areas. Overall, noise levels obtained at different zones in the study area are found to

be exceeding the noise level or limits prescribed by the DOE of Malaysia, 60 dB of noise level.

The spatial analysis and geostatistical methods of GIS can play an important role to control noise pollution. Several interpolation methods were used for the prediction values that measured between the known values. Due to the relative abundance of methods, many interpolations are presently applied, and investigations continue, aiming at the definition of the “best” method for pollution parameters mapping in noise, air, soil and water. This study had used two deterministic interpolation techniques, IDW and RBF and one geostatistical method, Kriging to interpolate the noise values based on measured noise values to the prediction surface of noise mapping. In order to check the precision and accuracy of the interpolation methods used, the methods are then evaluated using efficiency and error estimates of interpolation techniques. According to the result, the comparison is highlighted that among the interpolation methods, the best performance, in terms of accuracy and precision, was obtained with OK, performing better than the deterministic method IDW and RBF. The performance of the spherical semivariogram model is outstanding with OK interpolation techniques. It yielded quite low RMSE (2.968), MAE (2.405) and ME (0.205). IDW skill has the worst presentations, deriving higher RMSE (3.294) and ME (0.794) than other deterministic and geostatistical methods.

Finally, the results lead to the elaboration of reliable noise maps, which can significantly contribute at decisional level for establishing the adopted solutions of mitigation and control the emission noise levels within the affected zones of study area. In addition, some recommendation of implementing a noise barrier fencing on the side of affected zones was proposed in order to mitigate the noise levels from

penetrate into the study area. It is felt that noise environment of the study area may pose as a great threat to the health of dwellers of the study area in long term. The part of the reason is that high level of noise may not cause serious or immediate effects but if, such noisy environment prevails, and it may impact the population in many ways. Therefore, a strict enforcement of law and regulation should be implement as to consider the related issues of noise pollution.

Results of the study will be helpful to the urban and institutional authorities for developing projects related to preventing and lessening noise.

- In particular, the mapped information could provide important data for studies into noise dose/effect relationships and may also be of considerable help in developing future noise policies, in Malaysia.
- To facilitate a better understanding of the road traffic noise problem, setting objectives and developing plans to address the issue, Geographic Information System (GIS) and large-scale noise modelling technologies can be used to gather and compile the required noise information. And also, identifying and quantifying the scale of noise problems and evaluating the effectiveness of the mitigation measures for road traffic noise.

5.2 RECOMMENDATION FOR FUTURE WORK

The followings are the recommendations of the noise mapping study as for future work.

1. For datasets, increase the number of stations for data collection of noise values in the study area. The increment of noise data, the accuracy and precision of the performance of interpolation methods will be more efficient and accurate.
2. For data availability, other than noise value, factors like height of building, type of building, human population, topographic within the study area and also meteorological data should be consider as well in the process of making of noise map. These factor will give impacts to the noise measurement relative to the noise propagation measures from the noise sources.
3. It is more reliable to measure the noise values in the area where the noise pollution is significantly severe. This allows the public to have better understanding on the distribution of noise in the noise maps and thus established control and management for the noise effect.

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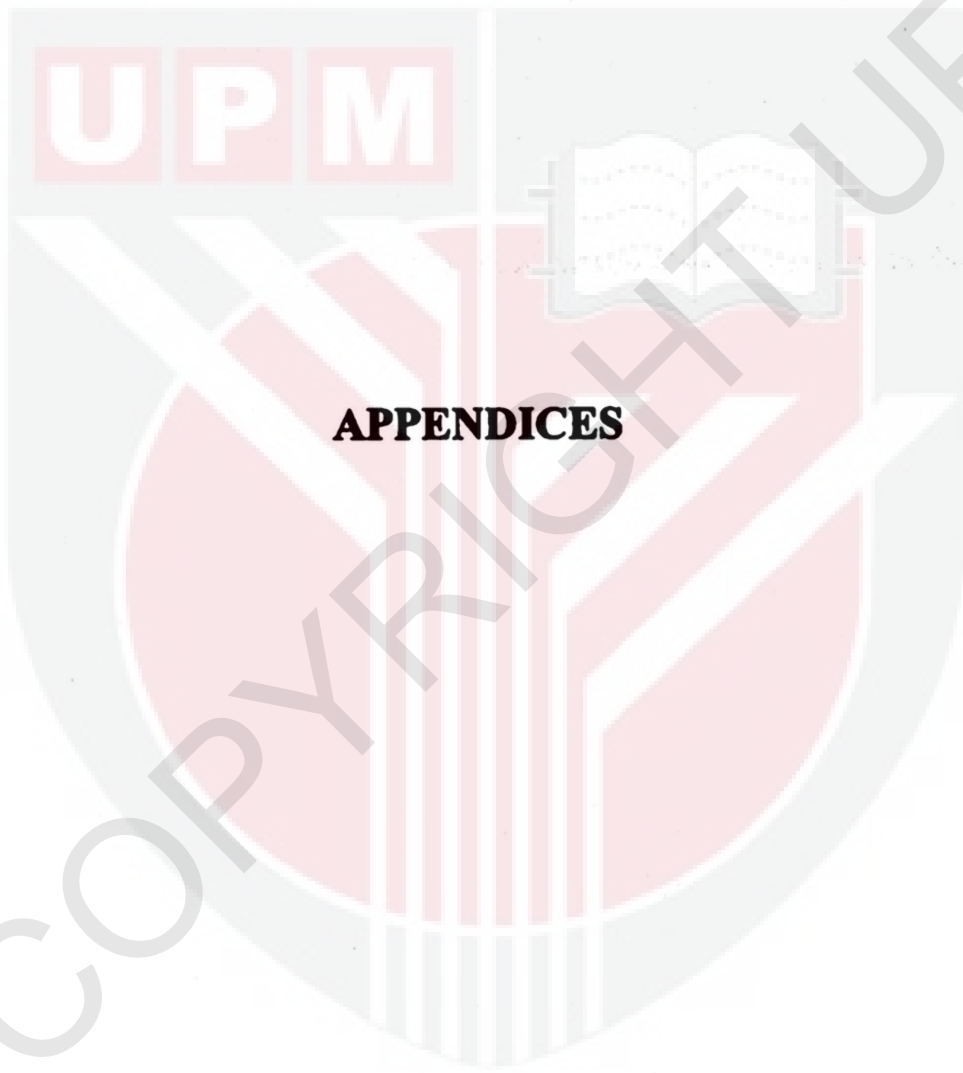
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APPENDICES

Point 1			Point 2			Point 3		
X	Y	dB	X	Y	dB	X	Y	dB
3.00347	101.717978	73.1	3.00503	101.717361	69.8	3.00619	101.715639	67.1
		67			67.4			72.7
		64.3			77.7			67.3
		69.1			66.6			69.3
		68.3			68			66.2
		68.8			65.8			69.7
		70.8			64			68.6
		67.6			70.7			72.7
		66.6			67.5			66.5
		63.4			68.4			68.1
	Avg	67.9		Avg	68.59		Avg	68.82
	Lmax	73.1		Lmax	77.7		Lmax	72.7
	Lmin	63.4		Lmin	64		Lmin	66.2

Figure 1: Total noise measurement level in Location 1, 2 and 3 of morning occasion (weekday)

Point 4			Point 5			Point 6		
X	Y	dB	X	Y	dB	X	Y	dB
3.00367	101.7151940	63.8	3.00353	101.714333	64.2	3.00761	101.715	69.7
		66.8			65.5			67.3
		66.4			67.8			64.9
		68			68.1			66.8
		63.5			66.2			67.9
		62			65.1			77
		66.3			74.6			68.6
		67.2			68.5			69.1
		65.4			76.9			65.3
		70.9			64.4			68.3
	Avg	66.03		Avg	68.13		Avg	68.49
	Lmax	70.9		Lmax	76.9		Lmax	77
	Lmin	62		Lmin	64.2		Lmin	64.9

Figure 2: Total noise measurement level in Location 4, 5 and 6 of morning occasion (weekday)

Point 7			Point 8			Point 9		
X	Y	dB	X	Y	dB	X	Y	dB
3.01347	101.719694	75.6	3.00817	101.722722	69.7	3.00419	101.7241110	72.4
		82.6			68.6			75.1
		73.6			73.6			77.5
		84.4			76.6			77.2
		77.6			78.3			75.7
		83.4			71.8			69.3
		79.2			75.4			80.4
		72.9			71			74.8
		76.8			78.1			79.3
		93.4			72.6			78.6
	Avg	79.95		Avg	73.57		Avg	76.03
	Lmax	93.4		Lmax	78.3		Lmax	80.4
	Lmin	72.9		Lmin	68.6		Lmin	69.3

Figure 3: Total noise measurement level in Location 7, 8 and 9 of morning occasion (weekday)

Point 10			Point 11			Point 12		
X	Y	dB	X	Y	dB	X	Y	dB
3.00211	101.723806	72.7	3.00114	101.721	68	3.00047	101.717	71.7
		93			69.2			72
		68.5			76			74.4
		72.3			73.3			100.1
		71.1			72.9			68.4
		72.2			75			75.3
		69.8			70.9			69.4
		64			66			70.4
		107.5			74.4			71.2
		86.3			68.4			81.5
	Avg	77.74		Avg	71.41		Avg	75.44
	Lmax	107.5		Lmax	76		Lmax	100.1
	Lmin	68.5		Lmin	66		Lmin	68.4

Figure 4: Total noise measurement level in Location 10, 11 and 12 of morning occasion (weekday)

Point 13			Point 14			Point 15		
X	Y	dB	X	Y	dB	X	Y	dB
3.00144	101.718194	68.6	3.00406	101.718583	84.5	3.00875	101.720306	70.6
		69.8			78.4			69.2
		75.4			69.7			71.9
		73.6			73.3			68.6
		72.8			76.4			72.6
		78			71.3			68.8
		69			62.4			76.6
		74.2			68.4			74.5
		73.1			76			80.1
		66.3			72.1			65.6
	Avg	72.08		Avg	73.25		Avg	71.85
	Lmax	78		Lmax	84.5		Lmax	80.1
	Lmin	66.3		Lmin	62.4		Lmin	65.6

Figure 5: Total noise measurement level in Location 13, 14 and 15 of morning occasion (weekday)

Point 1			Point 2			Point 3		
X	Y	dB	X	Y	dB	X	Y	dB
3.00347	101.717978	66	3.00503	101.717361	68.9	3.00619	101.715639	74.5
		72.5			64.8			72.2
		68			71.8			67.4
		74			69.1			68
		64.4			65.5			77
		70.1			74			65.1
		65.9			75.4			80.8
		75			65.8			66.4
		65.6			66.2			68.8
		69.4			67.3			70
	Avg	69.09		Avg	68.88		Avg	71.02
	Lmax	74		Lmax	75.4		Lmax	80.8
	Lmin	64.4		Lmin	64.8		Lmin	65.1

Figure 6: Total noise measurement level in Location 1, 2 and 3 of noon occasion (weekday)

Point 4			Point 5			Point 6		
X	Y	dB	X	Y	dB	X	Y	dB
3.00367	101.71519400	71.1	3.00353	101.714333	70.3	3.00761	101.715	67.2
		69			69.8			72.4
		66.8			67			70.4
		64.5			77.1			68.1
		65.8			75.6			71.7
		67.6			66.9			67.5
		62.1			72.3			63.3
		67.2			70.7			81.3
		71.6			65.6			66.9
		62.7			73.4			66
	Avg	66.84		Avg	70.87		Avg	69.48
	Lmax	71.6		Lmax	77.1		Lmax	81.3
	Lmin	62.1		Lmin	65.6		Lmin	63.3

Figure 7: Total noise measurement level in Location 4, 5 and 6 of noon occasion (weekday)

Point 7			Point 8			Point 9		
X	Y	dB	X	Y	dB	X	Y	dB
3.01347	101.719694	69.2	3.00817	101.722722	80.3	3.00419	101.7241110	87.1
		93.2			85.5			77.8
		78.9			92.6			75.1
		75.9			74.6			73.8
		82.2			84			68.2
		76.7			75.8			86.8
		77.1			73.5			76.7
		72.2			75			73.3
		73.7			73.8			78.2
		78.5			68.4			73.5
	Avg	77.76		Avg	78.35		Avg	77.05
	Lmax	93.2		Lmax	92.6		Lmax	87.1
	Lmin	69.2		Lmin	68.4		Lmin	68.2

Figure 8: Total noise measurement level in Location 7, 8 and 9 of noon occasion (weekday)

Point 10			Point 11			Point 12		
X	Y	dB	X	Y	dB	X	Y	dB
3.00211	101.723806	73.1	3.00114	101.721	71.7	3.00047	101.717	68.4
		73.3			74.9			66.1
		74			71.2			74.4
		68.9			69.4			74
		71.8			76.5			75
		74.7			72.4			68.2
		66.6			68.8			79.6
		73			71.9			70.7
		74			83.2			72.3
		74.7			72.1			77.4
	Avg	72.41		Avg	73.21		Avg	72.61
	Lmax	74.7		Lmax	83.2		Lmax	77.4
	Lmin	66.6		Lmin	68.8		Lmin	66.1

Figure 9: Total noise measurement level in Location 10, 11 and 12 of noon occasion (weekday)

Point 13			Point 14			Point 15		
X	Y	dB	X	Y	dB	X	Y	dB
3.00144	101.718194	73.4	3.00406	101.718583	74.6	3.00875	101.720306	65.7
		67.4			70.5			67.2
		90.2			71			69.9
		71.6			75.2			71.3
		73.2			81			77.4
		62.6			74.1			80
		65.5			85.2			73
		67.2			72.2			66.7
		72			73.3			70.9
		70.8			72.9			70.7
	Avg	71.39		Avg	75		Avg	71.28
	Lmax	90.2		Lmax	85.2		Lmax	80
	Lmin	62.6		Lmin	70.5		Lmin	65.7

Figure 10: Total noise measurement level in Location 13, 14 and 15 of noon occasion (weekday)

Point 1			Point 2			Point 3		
X	Y	dB	X	Y	dB	X	Y	dB
3.00347	101.717978	63.6	3.00503	101.717361	64.8	3.00619	101.715639	65.4
		65.1			67.2			67.2
		68.9			74.9			65.8
		66.3			70.4			68.8
		68.4			66.9			73.5
		77.3			55			66.3
		68			54.5			66.1
		71			71.9			65.9
		67.3			66.3			53.1
		63.3			92.3			53.4
	Avg	67.92		Avg	68.42		Avg	64.55
	Lmax	77.3		Lmax	92.3		Lmax	73.5
	Lmin	63.3		Lmin	54.5		Lmin	53.1

Figure 11: Total noise measurement level in Location 1, 2 and 3 of night occasion (weekday)

Point 4			Point 5			Point 6		
X	Y	dB	X	Y	dB	X	Y	dB
3.00367	101.71519400	66.7	3.00353	101.714333	66.3	3.00761	101.715	67.7
		67.5			68.9			64.1
		69			68.4			68.7
		69.8			65.7			77.7
		72.2			69.1			65.8
		70.1			73.4			66
		69			68.9			70.7
		68.1			72.7			66.8
		70.5			69.3			67.5
		68			70.1			63.2
	Avg	69.09		Avg	69.28		Avg	67.82
	Lmax	72.2		Lmax	73.4		Lmax	80.8
	Lmin	66.7		Lmin	65.7		Lmin	63.2

Figure 12: Total noise measurement level in Location 4, 5 and 6 of night occasion (weekday)

Point 7			Point 8			Point 9		
X	Y	dB	X	Y	dB	X	Y	dB
3.01347	101.719694	80.8	3.00817	101.722722	77.1	3.00419	101.7241110	72.3
		70.7			75.7			70.6
		73.7			77.1			74.5
		78.2			72.5			77.5
		78.6			71.2			75.4
		76			80			78.6
		78.4			75.3			85.9
		74.2			74.3			78
		73.9			79.6			75.7
		80.4			80.5			77.1
	Avg	76.49		Avg	76.33		Avg	76.56
	Lmax	80.8		Lmax	80.5		Lmax	85.9
	Lmin	70.7		Lmin	71.2		Lmin	70.6

Figure 13: Total noise measurement level in Location 7, 8 and 9 of night occasion (weekday)

Point 10			Point 11			Point 12		
X	Y	dB	X	Y	dB	X	Y	dB
3.00211	101.723806	72.2	3.00114	101.721	75.4	3.00047	101.717	76.8
		79.9			77.4			71.7
		70.6			72.5			70.4
		71.9			68.2			68.5
		73.3			73.7			72.1
		69.3			70			74.3
		72.1			73.1			77
		70.4			74.1			73.3
		75			66.9			81.5
		74			76.3			70.3
	Avg	72.87		Avg	72.76		Avg	73.59
	Lmax	79.9		Lmax	77.4		Lmax	81.5
	Lmin	69.3		Lmin	66.9		Lmin	68.5

Figure 14: Total noise measurement level in Location 10, 11 and 12 of night occasion (weekday)

Point 13			Point 14			Point 15		
X	Y	dB	X	Y	dB	X	Y	dB
3.00144	101.718194	70.5	3.00406	101.718583	74.8	3.00875	101.720306	67.1
		72.5			77.7			70.9
		74.7			72.8			73.6
		70.5			74.6			68.1
		69.1			73.4			73.2
		76			76.2			71.9
		69.9			73.2			72.1
		72.6			75.8			71.2
		71.6			81			72.5
		74.9			74.6			72.1
	Avg	72.23		Avg	75.41		Avg	71.27
	Lmax	74.9		Lmax	81		Lmax	73.6
	Lmin	69.1		Lmin	72.8		Lmin	67.1

Figure 15: Total noise measurement level in Location 13, 14 and 15 of night occasion (weekday)

Point 1			Point 2			Point 3		
X	Y	dB	X	Y	dB	X	Y	dB
3.00347	101.717978	67.8	3.00503	101.717361	65.4	3.00619	101.715639	68.2
		65.8			67.2			66.1
		66			65.8			65.1
		75			66.1			69
		74.3			66.9			72
		72.5			71.2			72.6
		69.1			69.6			70.5
		74.6			67.7			70.1
		73.2			70			69
		72			68.8			66
	Avg	71.03		Avg	67.87		Avg	68.86
	Lmax	75		Lmax	71.2		Lmax	72.6
	Lmin	65.8		Lmin	65.4		Lmin	65.1

Figure 16: Total noise measurement level in Location 1, 2 and 3 of morning occasion (weekend)

Point 4			Point 5			Point 6		
X	Y	dB	X	Y	dB	X	Y	dB
3.00367	101.7151940	65.7	3.00353	101.714333	62.1	3.00761	101.715	66.2
		67.2			62.5			69.8
		64.6			64.6			70.1
		62.1			67.8			71.1
		68.2			68.3			69.7
		65.7			69.8			67.5
		66			64.3			65.6
		69.2			65.6			69.1
		70			70.2			67.9
		68.5			63.2			72.4
	Avg	66.72		Avg	65.84		Avg	68.94
	Lmax	70		Lmax	70.2		Lmax	72.4
	Lmin	62.1		Lmin	62.1		Lmin	65.6

Figure 17: Total noise measurement level in Location 4, 5 and 6 of morning occasion (weekend)

Point 7			Point 8			Point 9		
X	Y	dB	X	Y	dB	X	Y	dB
3.01347	101.719694	83	3.00817	101.722722	78.2	3.00419	101.7241110	70.8
		75.2			74.2			81.2
		74.2			75.8			69.5
		79			69.5			69.9
		71.4			79.6			76.8
		78.2			77.3			75.8
		80.1			76.7			79.4
		74.6			68.9			78.2
		79.8			79.9			77.1
		77.5			82.6			76.2
	Avg	77.3		Avg	76.27		Avg	75.49
	Lmax	80.1		Lmax	82.6		Lmax	81.2
	Lmin	70.8		Lmin	69.5		Lmin	69.5

Figure 18: Total noise measurement level in Location 7, 8 and 9 of morning occasion (weekend)

Point 10			Point 11			Point 12		
X	Y	dB	X	Y	dB	X	Y	dB
3.00211	101.723806	68.3	3.00114	101.721	71	3.00047	101.717	79.3
		73.1			69.6			75.7
		75.3			75			74.2
		71.1			72.1			75.2
		72.8			75.3			69.5
		79			76.1			80.4
		80			70			86.3
		76.4			72.9			80.2
		74.2			72.1			75.4
		78.6			76.7			73.2
	Avg	74.88		Avg	73.08		Avg	76.94
	Lmax	80		Lmax	76.7		Lmax	86.3
	Lmin	68.3		Lmin	67.5		Lmin	69.5

Figure 19: Total noise measurement level in Location 10, 11 and 12 of morning occasion (weekend)

Point 13			Point 14			Point 15		
X	Y	dB	X	Y	dB	X	Y	dB
3.00144	101.718194	67.5	3.00406	101.718583	76	3.00875	101.720306	71
		65.3			78.6			73
		68.7			74			71.3
		74.3			71.5			68.9
		75.7			69			67.5
		72.6			72.5			65.4
		71.5			68			69.7
		70.4			71.78			77
		69.2			76.9			72.5
		66.7			70.3			75.1
	Avg	70.19		Avg	72.858		Avg	71.14
	Lmax	75.7		Lmax	78.6		Lmax	75.1
	Lmin	65.3		Lmin	65.6		Lmin	65.4

Figure 20: Total noise measurement level in Location 13, 14 and 15 of morning occasion (weekend)

Point 1			Point 2			Point 3		
X	Y	dB	X	Y	dB	X	Y	dB
3.00347	101.717978	70	3.00503	101.717361	67.6	3.00619	101.715639	68.6
		68.1			64.6			69.4
		72.1			68.9			65.7
		68.8			69.7			70.4
		67.9			66.7			71.6
		68			68.7			67.5
		72			70			66.9
		76.2			68.6			69.8
		66.2			63.2			68.3
		70.1			65.1			69.1
	Avg	69.94		Avg	67.31		Avg	68.73
	Lmax	76.2		Lmax	70		Lmax	71.6
	Lmin	66.2		Lmin	63.2		Lmin	65.7

Figure 21: Total noise measurement level in Location 1, 2 and 3 of noon occasion (weekend)

Point 4			Point 5			Point 6		
X	Y	dB	X	Y	dB	X	Y	dB
3.00367	101.7151940	65.7	3.00353	101.714333	69	3.00761	101.715	64.5
		66.4			67.4			64.8
		63.7			66.7			61.2
		68.7			74			67.4
		65.7			71			70.5
		67.8			68			68.5
		68.3			70			69
		69.5			75.1			65
		69			67.8			67.8
		66.1			69.8			71
	Avg	67.09		Avg	69.88		Avg	66.97
	Lmax	69.5		Lmax	75.1		Lmax	71
	Lmin	63.7		Lmin	66.7		Lmin	61.2

Figure 22: Total noise measurement level in Location 4, 5 and 6 of noon occasion (weekend)

Point 7			Point 8			Point 9		
X	Y	dB	X	Y	dB	X	Y	dB
3.01347	101.719694	79.6	3.00817	101.722722	75.6	3.00419	101.7241110	78.6
		77			73			71.3
		75.3			79			79
		73.1			82.4			90
		78			77			79.2
		84			78.5			82.3
		74.6			78.9			80
		79.1			79.8			73.5
		79.9			78.3			77.9
		86			77.9			79.6
	Avg	78.66		Avg	78.04		Avg	79.14
	Lmax	86		Lmax	82.4		Lmax	90
	Lmin	73.1		Lmin	73		Lmin	71.3

Figure 23: Total noise measurement level in Location 7, 8 and 9 of noon occasion (weekend)

Point 10			Point 11			Point 12		
X	Y	dB	X	Y	dB	X	Y	dB
3.00211	101.723806	79.7	3.00114	101.721	82.3	3.00047	101.717	78
		80.6			76.5			75.3
		76.6			73.1			67
		69			68.8			77.8
		78.9			78.5			82.1
		77			75			69
		78.8			69			78.4
		73.8			77.7			73.2
		79.8			72.1			70.1
		79			74.7			68.5
	Avg	77.32		Avg	74.77		Avg	73.94
	Lmax	80.6		Lmax	82.3		Lmax	82.1
	Lmin	69		Lmin	68.8		Lmin	67

Figure 24: Total noise measurement level in Location 10, 11 and 12 of noon occasion (weekend)

Point 13			Point 14			Point 15		
X	Y	dB	X	Y	dB	X	Y	dB
3.00144	101.718194	83.5	3.00406	101.718583	72.1	3.00875	101.720306	71.9
		72.6			77.5			79.8
		77			73.4			84.3
		77.6			71.1			70.2
		72.6			68.5			76.3
		74.6			73.6			75.5
		71.3			76			78.4
		70			76.6			79.8
		80.4			79.8			78.6
		75.9			69.4			77.9
	Avg	75.55		Avg	73.8		Avg	77.27
	Lmax	74.6		Lmax	79.8		Lmax	84.3
	Lmin	64.2		Lmin	68.5		Lmin	70.2

Figure 25: Total noise measurement level in Location 13, 14 and 15 of noon occasion (weekend)

Point 1			Point 2			Point 3		
X	Y	dB	X	Y	dB	X	Y	dB
3.00347	101.717978	66.6	3.00503	101.717361	65.8	3.00619	101.715639	71.2
		65.6			66.5			70.3
		65			72.1			71.7
		68.6			67.5			68.5
		70.1			63.4			66.3
		67.2			70.5			65
		66			69.8			68.9
		63.1			66.5			67.4
		70.7			63			66.6
		68.5			68.7			68.4
	Avg	67.14		Avg	67.38		Avg	68.43
	Lmax	70.7		Lmax	72.1		Lmax	71.7
	Lmin	63.1		Lmin	63		Lmin	66.3

Figure 26: Total noise measurement level in Location 1, 2 and 3 of night occasion (weekend)

Point 4			Point 5			Point 6		
X	Y	dB	X	Y	dB	X	Y	dB
3.00367	101.7151940	67.5	3.00353	101.714333	66.4	3.00761	101.715	66.1
		65.6			67.8			69.8
		69.9			65.8			70.2
		68.6			66.9			65.3
		67.5			70.6			66
		69.7			65.1			68.3
		71.5			62.3			62.8
		70.7			64.5			69.9
		67.4			65			67.6
		63.7			69.7			65.4
	Avg	68.21		Avg	66.41		Avg	67.14
	Lmax	71.5		Lmax	70.6		Lmax	70.2
	Lmin	63.7		Lmin	62.3		Lmin	62.8

Figure 27: Total noise measurement level in Location 4, 5 and 6 of night occasion (weekend)

Point 7			Point 8			Point 9		
X	Y	dB	X	Y	dB	X	Y	dB
3.01347	101.719694	75	3.00817	101.722722	85.5	3.00419	101.7241110	68.9
		75.3			76.7			74.6
		72.1			75.5			73.2
		88			79			78.7
		78.6			72.1			79.7
		83.2			80.5			75
		79.4			71			76.7
		68.5			76			71
		76.7			82.6			84
		77			70			78
	Avg	77.38		Avg	76.89		Avg	75.98
	Lmax	83.2		Lmax	85.5		Lmax	84
	Lmin	72.1		Lmin	70		Lmin	68.7

Figure 28: Total noise measurement level in Location 7, 8 and 9 of night occasion (weekend)

Point 10			Point 11			Point 12		
X	Y	dB	X	Y	dB	X	Y	dB
3.00211	101.723806	78	3.00114	101.721	77.2	3.00047	101.717	74.5
		77.7			74.5			70.2
		78.5			76.4			73.5
		77			75.9			76.7
		75			67			68.7
		69			66.9			70
		67			72.7			75.5
		75.7			72.1			79
		78.4			71.8			78.4
		70			73.6			70.9
	Avg	74.63		Avg	72.81		Avg	73.74
	Lmax	80.7		Lmax	77.2		Lmax	79
	Lmin	67		Lmin	66.9		Lmin	68.7

Figure 29: Total noise measurement level in Location 10, 11 and 12 of night occasion (weekend)

Point 13			Point 14			Point 15		
X	Y	dB	X	Y	dB	X	Y	dB
3.00144	101.718194	71.6	3.00406	101.718583	71	3.00875	101.720306	71.3
		70.8			73.8			71.6
		71			72.1			74.5
		74.1			70.6			70
		73.7			72.9			72.1
		67.8			67.2			73
		70			66.4			69.8
		69.6			75.3			70.6
		74.8			70.2			72.9
		75			73.8			71.5
	Avg	71.84		Avg	71.33		Avg	71.73
	Lmax	75		Lmax	75.3		Lmax	74.5
	Lmin	68.4		Lmin	67.2		Lmin	69.8

Figure 30: Total noise measurement level in Location 13, 14 and 15 of night occasion (weekend)