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Assessment of the Interpolation Techniques on Traffic Noise Pollution Mapping for the Campus Environment Sustainability

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ABSTRACT

Mapping traffic noise pollution from an increasing number of vehicles facilitate better land use planning in order to measures the environment sustainability performances of institution in higher education. The aim of this research is to analyse the relationship on the increasing number of the motorized vehicles recorded as noise pollution data for further geostatistical analysis. Hence, by using the interpolation techniques, Kriging and IWD, the comparison performed to particularly create the noise pollution map for Universiti Teknologi Malaysia, UTM. With average noise of the collected sample, the performance of two methods; inverse distance weighting, IDW and Kriging evaluated based on the magnitude and distribution of errors where the cross-validation statistics with plots shows IDW better representation of reality for the means of Noise pollution levels measurement. then, other the noise map generated based on the maximum noise level recorded with the indicator Kriging Noise method. Further, these studies can be useful to conduct regular assessments to identify noise pollution level with multiple locations in the study area.

Keywords: campus sustainability, Land use planning, Transportation, Traffic noise, Interpolation

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1. Introduction

As campus sustainability become one of common goal and main agenda of the Universities worldwide, the desire to manages it sustainably faces challenge to measures its performances with its practical applicability. Two unwritten rules, '*Practice What You Preach*' and '*You Can't Manage What You Do Not Measure*' has in every campus sustainability spirit, which stimulate the establishment of data for the assessment. Hence, emphasize on sustainability assessment given measures its performance (Zen, Bandi, Karniah, Bakar, & Zakaria 2018). Assessing carbon from campus operational has been widely adopted as one of the tools linking the University effort in lowering their carbon more on the physical environment of the campus (Yarime & Tanaka 2012).

UTM is one of the universities implemented many rules and actions since 2010 to become sustainable campus which gives a general guideline of campus sustainability by deploy campus as living lab, triangulation of educational, research and campus operation (Zen, 2017), where robust research output apply to achieve campus sustainability status (Omar, Rahman, Din, Taib, Zen & Hanafi, 2018) and with their long-term effect to global warming and climate change (Abdul-Azeez & Ho 2015, Zen, Bandi, Karniah, Bakar, & Zakaria 2018).

The important of spatial analysis to measure the various campus operational activities by using land use data able to estimate greenhouse gas emissions from energy use, water consumption, solid waste, and transportation (Alshuwaikhat, Abubakar, Aina, Adenle, & Umair, 2017). Moreover, noise pollution has been considered in assessing the campus environment sustainability performance in several studies (Saadatian, Salleh, Tahir, & Dola 2009, Khalil, Husin, Wahab, Kamal & Mahat 2011, Torregrosa López, Lo-Iacono-Ferreira, Martí Barranco, & Bellver Navarro 2016), where transportation is also one of the major sources of pollution is emphasized for a compact development of the University (Toor & Havlick 2004). However, limited studies on noise pollution in campus and the relationship with the geo statistical analysis where the practicality of noise map develop helps in strategizing the traffic flow and management in hot spot area.

There are numerous parameters that universities must implement to challenge with their environmental problems, one of the significant and powerful tools to make the sustainable environment for any area particularly for campus area is physical development planning (Abd-Razak, Abdullah, Nor, Usman & Che-AIni, 2011), it's forming and effecting. Campus accessibility and connectivity since users need to have access to the university utilities and amenities, Land use planning and transportation are highly dependent to each other and type of physical development of campus effective parameter to student select they travel transportation (Gim, 2018). Therefore, to achieve sustainable environment for institution and campus physical development design must be considered as the significant element in sustainability but unfortunately in Malaysian university it is not favour coloured to be able for student favourable inquiry (Abd-Razak et. al, 2011). Several studies conducted to measures the various aspect of sustainability transport of UTM physical environment. Study by Zen, Ahamad and Omar (2014) that measures the level of UTM campus conduciveness recognize the index value 0.80 for conducive condition of inter-building connectivity for compacted building design in core zone.

2. Methodology

2.1 Study Area

The study conducted in Universiti Teknologi Malaysia, UTM main campus, Skudai, Johor State, Malaysia. Enclosed by tropical forests and palm oil plantations on a total area of 2,829.90 acres, it has consisted of two-part of development type; compacted and dispersed (Figure 1). The compacted inner circle, hence, the Academic & Administration Zone or Core Zone in sort was named as Knowledge circle. It is shown in blue circle line in land use and conceptual master plan (Figure 1). This area enclosed by seventeen (17) hostels, ten (10) faculties, staff residences, sports and recreational zones (Zen et.al, 2014). According to the planning map created since 1995, UTM campus development was based on the zoning and campus were divided to seven-part, division of land use shown and explained in Table 1. The simple zonation of UTM campus shown in Figure 2 (Lawal, Matori & Balogun, (2011). The core zone area was developed with a radial principle to support pedestrianism with easy accessibility and connectivity of the buildings at the early development stage of the campus. This area of development has high chance of walkability and accessibility by foot and bicycle (Moayedi, Zakaria, Bigah, Muzafar, Puan, Zin & Klufallah, 2013) and enhance the conduciveness level of UTM campus (Zen, Ahamad & Omar, 2014), as shown in Table 1 and Figure 2.

The 'compactness' of the complete campus planning regulate the optimal of students' walkability and connectivity in the building. According to Toor (2004), moral walking distance is about 1 to 2km, while cycling distance is about 1 to 5 km (Kong, Aziz, Rao & Inangda (2009).

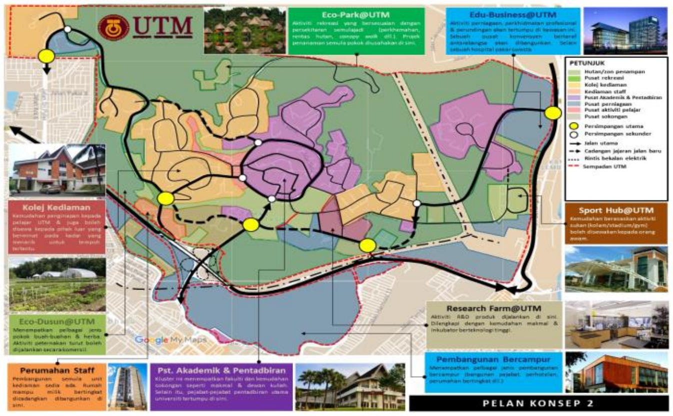


Figure 1 Land Use and Concept Plan for Masterplan UTM (Asset and Development Department UTM, 2017)

Further, the spatial development of UTM namely cluster building project shown in the red circle (Figure 3) spread the first compacted development. Several new buildings also recorded in several area adjacent to Core Zone (Figure 3). However, increase in built up area was recorded since year 2016 where there is expansive development of cluster (Table 2 & Figure 4). The disperse campus development rise vehicular traffic flow resulting an increasing chances of noise pollution for regular transport in campus (Kong et. al, 2009). This supported by recorded number of vehicles registered by the UTM security office shown in Table 3 for year 2011 and Table 4 for year 2017 which has an overall increasing percentage. Number of cars registered recorded in 15,853 (10,686 cars and 5,167 motorcycles) in year 2011, increase to 16,981 (14,287 cars and 2,694 motorcycles) in year 2017. The overall increase about 7.11% are recorded where the percentage for cars increase is 25,2% and the percentage for motorcycle decrease is 47.9%.

Table 1 Component of UTM Land Use UTM, 2011)

Land Use Zone	Area (acre)	Percentage
Academic and Administrative Zone	415.64	14.69
Students Hostel Zone	789.24	27.89
Green Area Zone	1008.40	35.63
Sport, Recreation, and Social Activity Zone	411.16	14.53
Commercial Development Zone	39.00	1.38
Staff Residential Zone	36.46	1.29
Technology Park Zone	130.00	4.59
Total	2,829.90	100.00

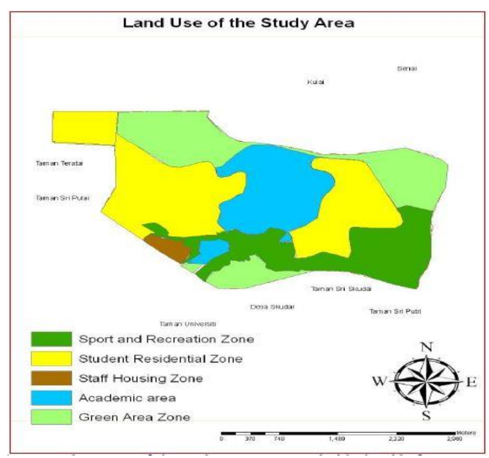


Figure 2 Generated with the Aid of ArcGIS (Lawal et. al, 2011)

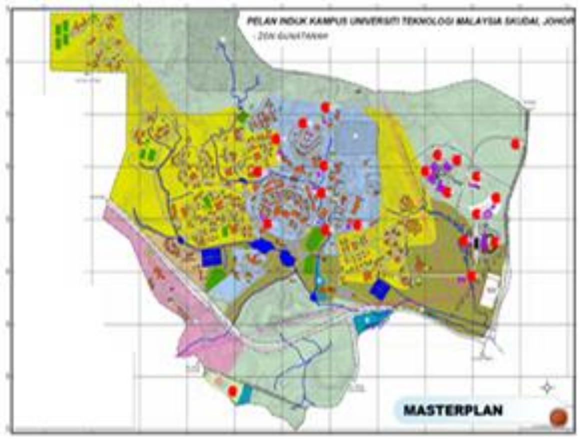


Figure 3 Land Use and Concept Plan for Masterplan UTM (Asset and Development Department UTM, 2017)

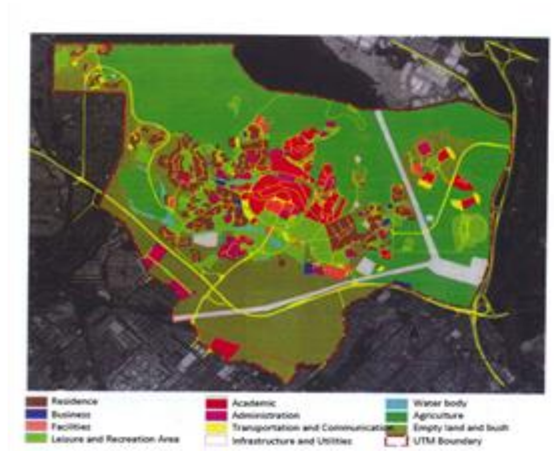


Figure 4 Land Use Map of UTM (Asset and development Department UTM ,2017)

Table 2 Component of UTM Land Use (Asset and Development Department UTM, 2017)

Types of Land Use	**Area (hectare)**	**Percentage (%)**
Build-Up Area		
Residence	80.5	7.0
Business	5.9	0.5
Facilities	12.1	1.1
Leisure and Recreation Area	96.4	8.3
Academic	57.3	5.0
Administration	33.3	2.9
Transportation and Communication	46.5	4.1
Infrastructure and Utilities	54.7	4.8
Sum	385.7	33.7
Non-Build-Up Area		
Agriculture	420.4	36.7
Water body	11.5	1.0
Empty Land and Brush	326.8	28.6
Sum	758.7	66.3
Overall Total	1144.4	100.00

Table 3 UTM Registered Vehicle in Year 2011

Vehicle Ownership		**Qty**	**%**	**Category**
Car	Staff	5,274	50%	10,686 cars
	Student	4,763	45%	
	Public	559	5%	
Motorcycle	Staff	1,166	22%	5,167 motorcycles
	Student	3,932	75%	
	Public	159	3%	
Total		15,853	100%	15,853

Source: UTM Security Office

Table 4 UTM Registered Vehicle in Year 2017

Vehicle Ownership		Qty	%	Category
Car	Staff	5,146	36%	14,287 cars
	Student	9,063	63%	
	Public	79	1%	
Motorcycle	Staff	744	28%	2,694 motorcycles
	Student	1,908	71%	
	Public	42	1%	
Total		16,981	100%	16,981

Source: UTM Security Office

Beside that with Refer to the record of vehicle counting in the 5 station in UTM 5 gates in Nov 2016, number of vehicles mainly private cars and buses are increasing. It is shown in table 5, and the counting conducted by the Office of Asset and Development. The increasing vehicles numbers causes traffic valoume which resulted in increasing noise pollution. The nearest of noise receiver will disturb the most ambient noise level which known as noise pollution or environmental noise. Traffic congestion is the main source of a noise (Kumar, Oberoi & Goenka, (2004). Our study proof that the most high-level noise were recorded in the bus station and in the crowded area with full of the traffics which shown in Table 6.

2.3 Research Design and Method

The source of noise pollution need to be manage properly due to their significant effect on the environment and the health of the people. Various models and tools are already developed by researchers working on this domain (Soulalay 2006). One of potential tool is the Ecomap (Finlay & Massey 2012).

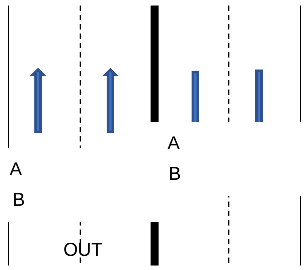
Inverse distance weighting or IDW is the technique use weighting logic to create surface data and weight with distance that are close to one another are more alike than those that are farther apart, means more distance decreasing the value of weight as the function among the points (Lawal et. al, 2011). IDW will use the measured values surrounding the prediction location and interpolation explicitly implements the assumption to predict a value for any unmeasured 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 weights the points closer to the prediction location greater than those farther away, hence the name inverse distance weighted.

Kriging technique is counted based on the significant techniques for the surface calculation to create possibility to surface by combining the statistical assets of the collected data (ESRI 2001). The method divided to two major part liner and non-liner approaches contain Simple (SK), Ordinary (OK) and Universal (UK) Kriging; Non-linear approaches contain Indicator (IK), Probability (PK) and Disjunctive (DK) Kriging (URL-3; ArcGIS. 2008).

To evaluates the accuracy of the results of IDW and Kriging method, the evaluation must be made by "cross-validation" and "validation". Cross validation provides knowledge about how you can model the predicted unknow value by deleting location of the one data or more and doing prediction for their related data by using remain locations. The principle of the cross-validation and validation is based on these way and method. This approach allows comparison between the predicted value to the observed value and obtain useful information about the quality of our models.

Table 5 Vehicle Counting Stations Implemented at All UTM Entrance Gates on 30th Nov 2016

Main Gate (Gate 1)

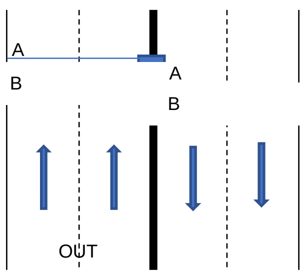


Entrance passage : Gate1/ATC1
Lane : 2 lane
Axle sensor : Paired

Exit passage : Gate1/ATC2
Lane : 2 lane
Axle sensor : Paired

Day	Total In	Peak (AM)	Peak (PM)	Total Out	Peak (AM)	Peak (PM)
Sun	10470	0730	1345	9374	1145	1700
Mon	10444	0730	1345	9291	1145	1700
Tue	10913	0730	1345	9870	1145	1700
Wed	10498	0730	1345	9536	1145	1700
Thu	10882	0730	1345	9933	1145	1530
Fri	6974	0730	1345	6247	1130	1345
Sat	6075	0830	-	5411	1145	-

Senai Gate (Gate 2)

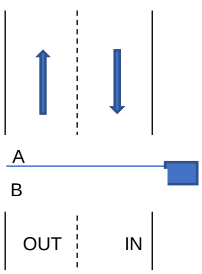


Entrance passage : Gate2/ATC1
Lane : 2 lane
Axle sensor : Paired

Exit passage : Gate2/ATC2
Lane : 2 lane
Axle sensor : Paired

Day	Total In	Peak (AM)	Peak (PM)	Total Out	Peak (AM)	Peak (PM)
Sun	1488	0730	1400	988	1145	1700
Mon	1567	0730	1315	1092	0715	1815
Tue	1576	0730	1330	1188	0730	1800
Wed	1573	0715	1330	1228	0730	1800
Thu	1625	0730	1330	1084	0715	1800
Fri	1238	0745	1330	921	0730	1745
Sat	1152	0845	-	766	1145	-

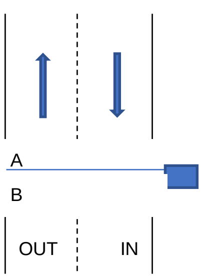
Ladang Gate (Gate 3)



Entrance passage : Gate3/ATC1
Lane : 2 lane
Axle sensor : Paired

Day	Total In	Peak (AM)	Peak (PM)	Total Out	Peak (AM)	Peak (PM)
Sun	4600	0745	1700			
Mon	4277	0730	1700			
Tue	4730	0730	1700			
Wed	4283	0730	1700			
Thu	4862	0730	1530			
Fri	2927	1115	2145			
Sat	2829	1145	-			-

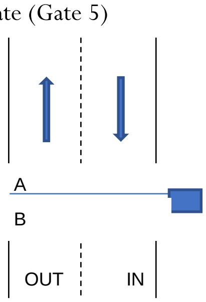
Desa Bakti Gate (Gate 4)



Entrance passage : Gate4/ATC1
Lane : 2 lane
Axle sensor : Paired

Day	Total In	Peak (AM)	Peak (PM)	Total Out	Peak (AM)	Peak (PM)
Sun	1054	0715	1700			
Mon	1224	0715	1700			
Tue	1413	0730	1700			
Wed	1336	0730	1700			
Thu	1245	0715	1530			
Fri	183	1145	1300			
Sat	10	0100	-			-

Sri Pulai Gate (Gate 5)



Entrance passage : Gate5/ATC1
Lane : 2 lane
Axle sensor : Paired

Day	Total In	Peak (AM)	Peak (PM)	Total Out	Peak (AM)	Peak (PM)
Sun	5358	0715	1700			
Mon	5691	0715	1700			
Tue	5993	0730	1700			
Wed	5591	0715	1700			
Thu	5456	0715	1700			
Fri	3595	1145	1300			
Sat	3554	1145	-			-

Source: Asset and Development Department UTM, 2016

Table 6 Highest Noise Recorded Stations UTM Campus (Rozali & Salleh, 2016)

Station	Latitude, N (°)	Longitude, E (°)	L_{MAX}, dB(A)	Location
29	1.56042	103.64156	83.3	P19
17	1.56628	103.62708	75.5	K12 (KDSE) bus station
16	1.56131	103.63231	75.4	K13 (KDSE) bus station
18	1.55872	103.62736	74.4	Near Pusat Kesihatan (PK)
30	1.55672	103.64261	73.0	KTC bus stop near FKE
19	1.56178	103.62817	72.4	Near KTR office
39	1.55256	103.64458	71.1	UTM Gate to Sri Pulai
28	1.56131	103.63231	70.9	Arked Cengal
40	1.55456	103.64103	70.8	Equine Centre (horse)
42	1.55900	103.64928	70.4	K9/K10 Arked bus stop
9	1.57397	103.61906	70.3	Road to D block (near L50)

The calculated statistics serve as diagnostics that indicate whether the model is reasonable for map production (Rozali & Salleh, 2016) for these research IDW and kriging method selected as the interpolation techniques, and comparison shown in Figure 6(a) and Figure 6(b) the procedure of interpolation taken according the process of interpolation (Johnston et al. 2001). Figure 9 and selecting great model for assessment of variable done (Taghizadeh, Zare & Zare, 2013) according to following stages in flowchart Figure 10 then the best method of interpolation was selected using cross-validation.

The judgement and assessment about best model are based on the cross-validation but it is requiring calculating calculation both Mean Error (ME) and Root Mean Square Error (RMSE) therefore for the IDW and Kriging it is calculated by following formulas (Burrough and McDonnell, 1998) what it is applied:

$$ME = \frac{1}{n}\sum_1^n\left[\hat{Z}(s_i) - Z(s_i)\right]$$

$$RMSE = \sqrt{\frac{1}{n}\sum_1^n\left[\hat{Z}(s_i) - Z(s_i)\right]^2}$$

where

$\hat{Z}(s_i)$ = The interpolated (prediction) value
$Z(s_i)$ = The measured actual value
n = The number of validating points

For IDW,

$$ME = \frac{1}{n}\sum_1^n\left[\hat{Z}(s_i) - Z(s_i)\right] = \frac{1}{55}(19.1796) = 0.3487$$

$$RMSE = \sqrt{\frac{1}{n}\sum_1^n\left[\hat{Z}(s_i) - Z(s_i)\right]^2} = \sqrt{\frac{1}{55}(1296.952646)} = 4.8560$$

For Kridging,

$$ME = \frac{1}{n}\sum_1^n\left[\hat{Z}(x_i) - Z(x_i)\right] = \frac{1}{55}(9.3024) = 0.1691$$

$$RMSE = \sqrt{\frac{1}{n}\sum_1^n\left[\hat{Z}(x_i) - Z(x_i)\right]^2} = \sqrt{\frac{1}{55}(1335.214816)} = 4.9271$$

2.4 Sampling and Data Collection

Data sampling for all parameters involved in this study was conducted using the equipment called Sound Level Meter equipment. For each location, reading is taken for duration of 1 hour, at 15- minute interval during day time at outdoor areas on different days. Readings were recorded manually, noise pollution data of 55 selected sites figure 8 in the campus be recorded, Longitude (y-coordinate) and latitude (x-coordinate) of the sampling sites were determined using Garmin Global Positioning System (GPS) device (Tay, 2013). Table 7 shows the noise label ranges used in this study.

Noise pollutant measurements and coordinates of locations were stored in excel format while the shapefile of the present extent of the UTM campus is imported into the GIS environment using ArcGIS 10.3 software. Attribute data were then assigned to spatial objects and the system becomes ready for spatial -temporal analysis and management. ArcGIS Geostatistical Analyst uses to create a statistically valid prediction surface along with prediction uncertainties from a limited number of data points the present study evaluated accuracy of two interpolation methods kriging and IDW (Inverse Distance Weighting) for prediction of noise values in UTM campus Johor Bahru. Each of the interpolation methods create different noise maps based on the mathematics functions used.

3. Result and Discussion

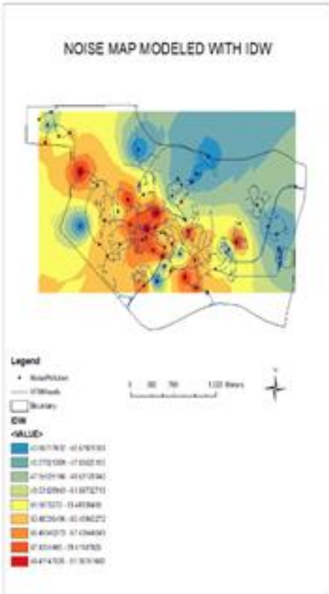
From the average of the noise collected data, the Noise pollution show in Figure 5(a) & 5(b) than the maps compared with the noise level standards defined by the Environmental Protection Agency (EPA) show in Table 6. (Prathumchai & Samarakoon, 2006). For the maximum noise recorded sample by using Kriging method, indicator used than threshold noise level could be chosen based on the standard if the pollution higher threshold number must be 1 otherwise it is 0 Figure 5(c).

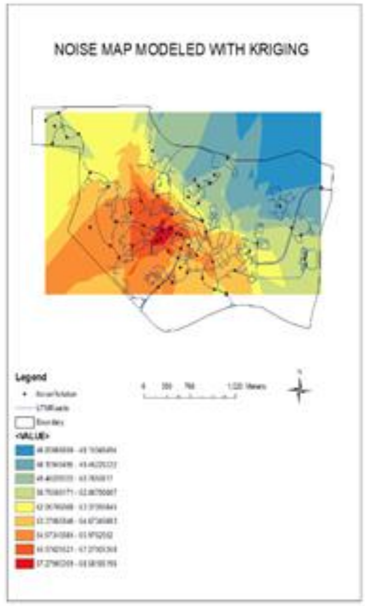
The Countour and 3D surface plots of the Noise pollutant concentration were modelled using Surfer 11 software (Iheanyichukwu, Chizoruo, Chukwuemeka, Ikechukwu & Kenechukwu, 2016) and it is shown in Figure 8.

Table 7 Range of Noise Level based on Subjective Evaluation (Prathumchai & Samarakoon, 2006)

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

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





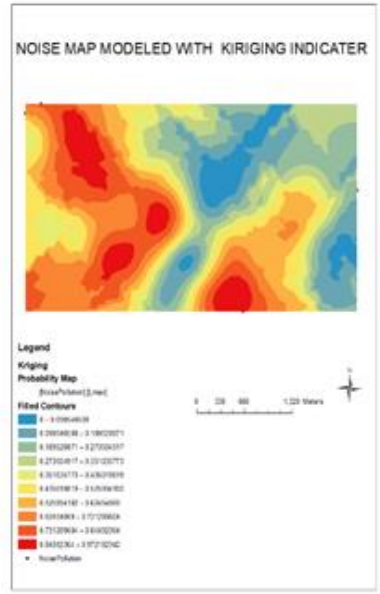
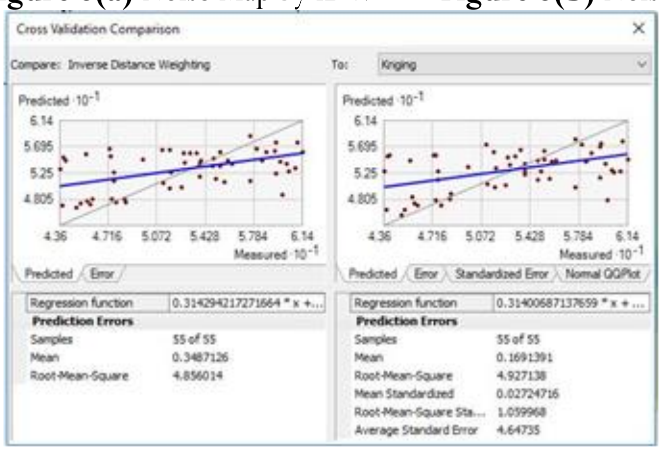


Figure 5(a) Noise Map by IDW **Figure 5(b)** Noise Map by Kriging **Figure 5(c)**Map Kriging Indicator



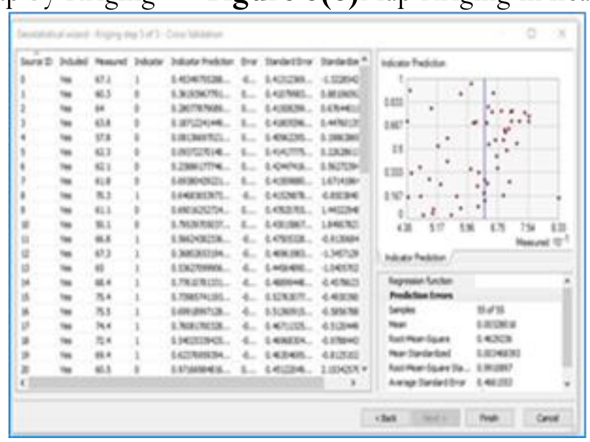


Figure 6(a) Kriging and IDW Comparison **Figure 6(b)** Kriging Indicator

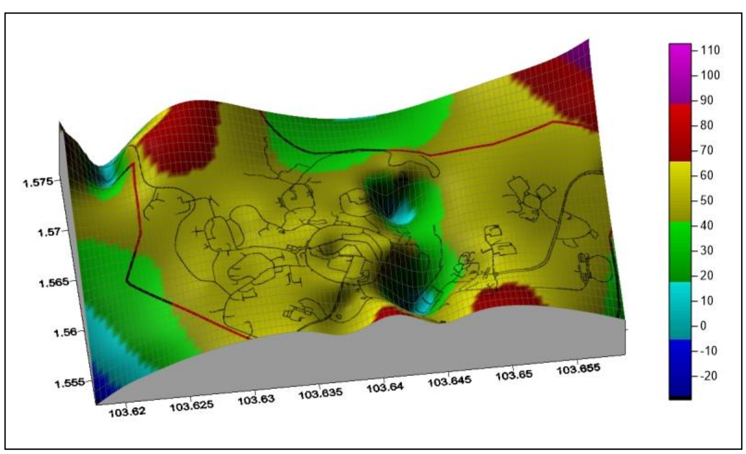


Figure 7 Contour and 3D Surface Plot of Noise for UTM Campus

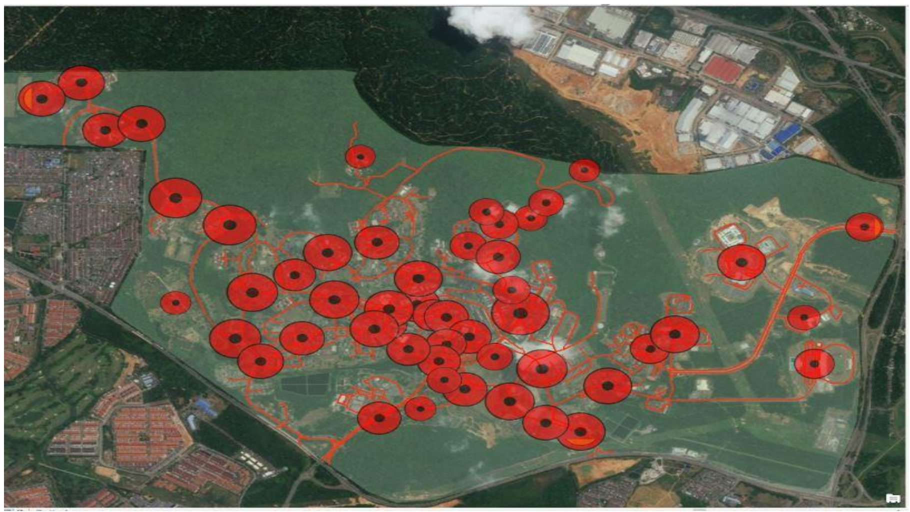


Figure 8 UTM Site Selected Map for Noise Sampling

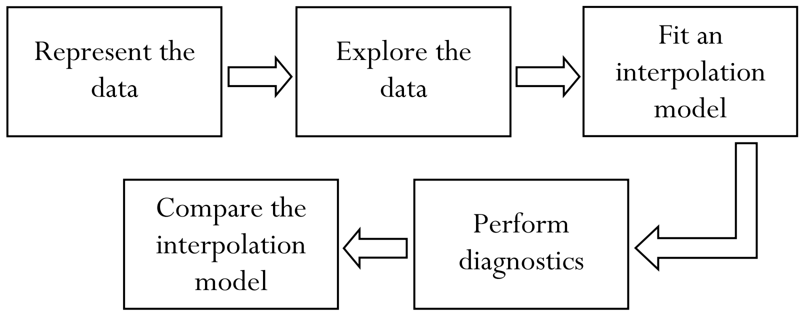


Figure 9 The stages of the interpolation procedure

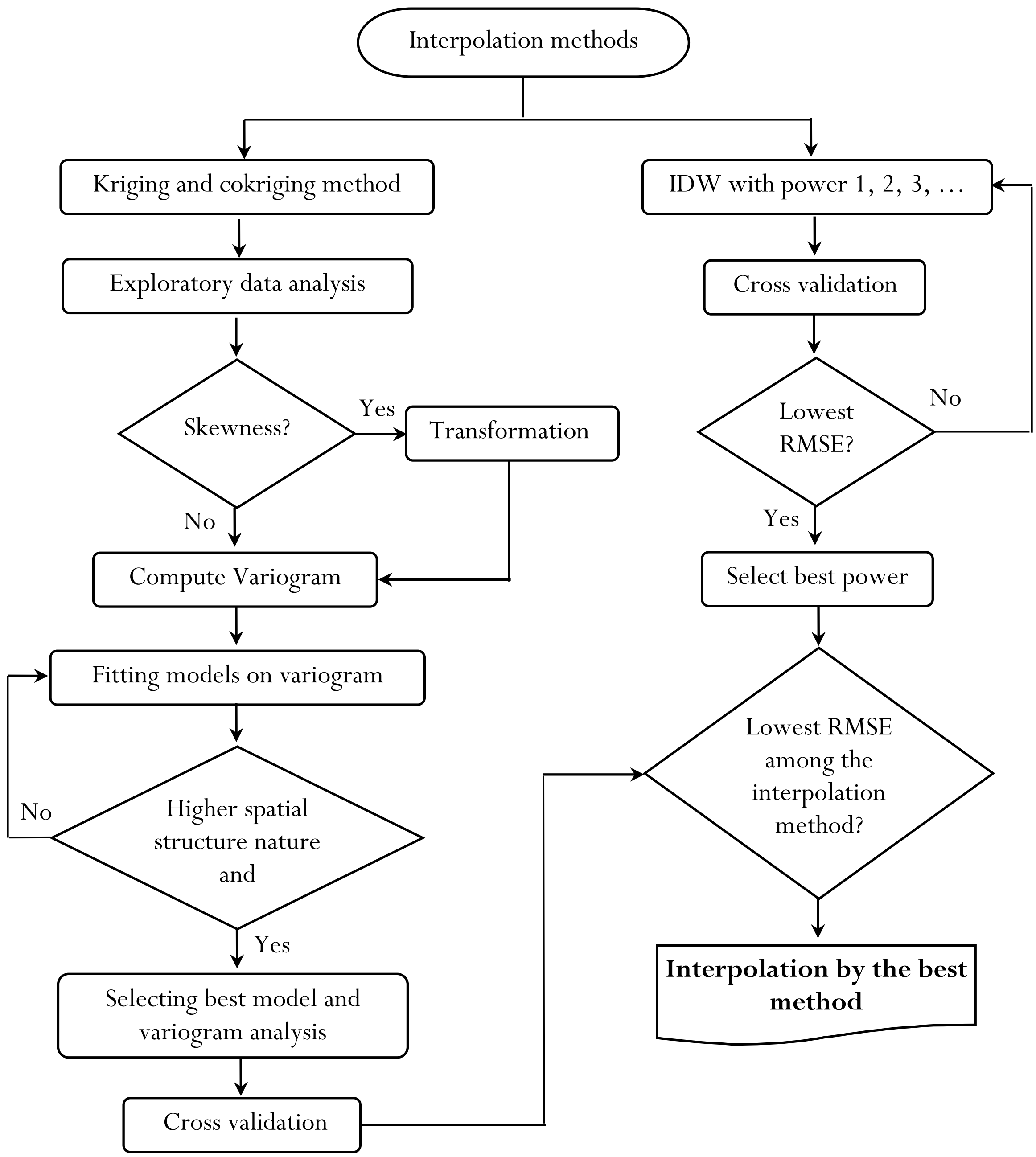


Figure 10 Flow chart of the selecting great model for assessment of variable

4. Conclusion

Results showed that physical development planning in UTM campus is not based on the compact development of building composition has far distance from each other's. Therefore, accessibility and connection between them are very difficult. Supplying facility, amenity to entire area by university has problem and people cannot access to them just by walking and cycling because of the climate condition which mostly raining or hot sun. Also due to security purpose in the evening, people are not interested to walk these distance or cycle to travel as option to zero emission to pollution. So, they mostly use cars and motorbike which resulted in one of the pollutions, that is the noise pollution. Hence, the relation between transportation and physical, land use planning has basis, where distance between facility and travel distance determine people choice of transportation.

The mapping process and interpretation of the data used for these studies shown that mostly high noise pollution was recorded in the transport crowed area and high traffic density. At the same time, the volume of the noise pollution is changing according to their location from another location, according to how close they are to density of traffic. And interpolation techniques for the prediction used were kriging and IDW. Accuracy of the mapping data by these techniques were highly affected by the number of samples, their distance to each other. So, it requires more sample to be taken from study areas specially from traffic and road sides for better accuracy.
The greatest significant part of such Integration is that currently it is probable to measure the value of forecast surface models by computing the statistical error of predicted surfaces. And it can be mentioned that geostatistical analyst is an important package for analysis of spatial changes of a specific parameter on field scale and for evaluating the numerous selections for illustration optimum and unbiased prediction surfaces

In the conclusion it is obviously clear that physical planning and development for the campus have the significant contribution for campus environment sustainability, the perfect sustainable urban shape according to the strategy ideas of sustainable urban method is that which has a high compactness and acceptable range, dense with mixed land uses, and its plan is based on ideal transportation, greening, and passive solar energy and the research can be guides the community of UTM to control measures of sustainable campus and physical planning one of the best way of controlling and as the most effective factors of sustainable campus to enhance UTM community to achieve their goals towards eco campus.

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