GIS-based multicriteria analysis for landslide monitoring base station evaluation using ordered weight averaging

I. S. Mustafa[#1], N. M. Din[#2], R. C. Omar[*]

[#] *Department of Electrical and Electronic Eng,*
**Department of Civil Eng*
College of Engineering,
Univeristi Tenaga Nasional, Jalan Ikram-Uniten, 43000 Kajang, Selangor Malaysia
[#1]*intanshafinaz@uniten.edu.my*
[#2]*norashidah@uniten.edu.my*
**rohayu@uniten.edu.my*

***Abstract*— A slope monitoring system is important for power utilities since its assets, especially transmission lines at high altitude areas, are vulnerable to landslide. One of the best methods for real-time monitoring is by deploying appropriate sensors for slope failure detection. Sensor data are gathered electronically via antenna and sent through communication channels to a centralized location for processing. This telemetry system relies on wide area communication accessible at that location. To improve network performance, the position of every antenna should be strategically planned to ensure data integrity. However, there are numerous factors to be considered in the selection and deployment of communication technologies such as topography, accessibility, power supply availability and others. Therefore, this study proposes a Geographical Information System (GIS)-based system with an emphasis on the multi-criteria decision analysis (MCDA) for preliminary site suitability of antenna placement. The Analytical Hierarchy Process (AHP) is used to generate an alternative decision using a multi-criteria evaluation (MCE) technique, standardized by fuzzy membership functions. The factors are classified into five main criteria which are technical, topography, risk assessment, land cover and accessibility criteria and then the weight is justified by the experts for final weight consensus. The criteria maps were combined and overlaid using weighted linear combination (WLC) techniques and ordered weighted average (OWA). The results yielded that GIS-WLC and OWA model can be integrated into MCDA to select the optimal site of antenna placement.**

***Keywords*— Ordered Weighted Averaging (OWA); AHP; GIS; landslide; network planning.**

I. INTRODUCTION

A large number of transmission towers that networked the electricity distribution throughout the country has been existing for over 40 years. Most of the towers spanned through very remote and difficult topography areas such as mountains, thick forest, lakes and far from the settlement areas which add to the cost and difficulties of maintaining the health and inspection of the transmission towers. Therefore, the landslide hazard risks on these towers are becoming one of a national concern [1].

The early warning system for landslide monitoring concept comprise of consolidating satellite data, real time monitoring through ground sensors, geotechnical data and historical data of the site and coming up with a predictive decision support system for landslide warning. A centralized data acquisition system centre will integrate the data from the various sources and provide risk assessment through a decision support system for the identified landslide prone area site [1]. However, the reliability and the integrity of real time slope monitoring data from the ground sensor to the data acquisition centre is one of the concerns.

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The integration of Geographical Information System (GIS) and Multi Criteria Decision Making (MCDM) can be regarded as a method that transforms and combines geographical data and value judgments or preferences to obtain more facts for decision making [2]. GIS technologies facilitate the decision-making process based on their analytical capabilities with spatial information. Determining the best location from a number of alternative locations is a difficult and complex process. Placement selection is a type of decision-making process that requires criteria to be weighted and alternatives to be evaluated and ranked. The integration of GIS and MCDM is needed to solve the placement problem as GIS is used to handle the spatial aspect of the problem and MCDM is used to calculate weights of the criteria and ranking of alternatives.

The objective of this study is to determine the optimal placement of antenna location in Cameron Highland, Malaysia. To achieve the mention objective, the survey and interview with the expertise is conducted and a selection of criteria are identified. In standardization stage, a suitability score value and fuzzy membership function are used in preparing the criteria map for each parameter in GIS. 13 parameters from 5 category are used in this study as the input data. The five categories are topography (Digital Elevation Map (DEM), aspect and slope), technical (distance from transmission tower, network coverage and solar irradiance), landcover (population and land use), risk assessment (landslide risk and erosion risk) and accessibility (city, road and river network). Analytical Hierarchy Process (AHP) is applied to determine the importance degree or weight of each criteria input data. Ordered weighted averaging (OWA) is applied to aggregate the criteria used in this study.

The remainder of this paper is organized as follows. Section 2 examines the existing research trend regarding the antenna base station suitability placement. Section 3 explore the study area and the methodology applied in the study, while Section 4 discuss the results and Section 5 conclude the studies.

II. Background Studies

Traditionally, the power flow from centralized generation to the transmission and distribution in the load centre with unidirectional way. Due to this, it has disadvantage such as high in transmission and distribution loss, poor quality and reliability supply [3].

Communication has always played a critical role in power utility system and will become even more critical when it comes to implementing an end-to-end and two-way open communication grid infrastructure. Up until today, TNB Malaysia's electrical infrastructure grid has still remained unchanged for more than 50 years with the objective to deliver electricity to the customers. The electricity power infrastructure is extremely exposed to many forms of natural and malignant physical events, which can affect overall performance and grid stability [4]. However, it is impossible or too costly to deploy optical fiber in transmission grid in some location. A wireless solution is thus sought [5]. The concept of using wireless sensors to support substation automation has been proposed in [6]. Nevertheless, they do not study on how to plan the wireless communication technology for substation automation.

Generally, there are two main issues for the antenna placement project in the wireless local area network (WLAN). First is on determining the best placement of the base station (BS) and secondly, the setting of the frequency channel for the station. Correct BS placement can reduce the number of stations needed to cover the area of attendance, furthermore can be minimized the installation costs. The channel assignment determines the frequency band to be utilized by each BS. This can minimizing the interference signal between them and improve the network throughput [7]. The first published paper on optimizing antenna placement was back in 1994 [7]. Since then, there have been a large number of approaches and method of antenna placement problem in the literature. The base station (BS) placement or planning cell problem, involves choosing the position and infrastructure configuration for cellular networks. One of the popular approaches is to use mathematical optimization which known as genetic algorithm (GA) [8][9]. Abdelkhalek et al. [10] present a multi-objective node placement problem that optimizes the antenna location concurrently with our criteria which are communication coverage, structures' costs, total capacity bandwidth and minimizing the noise level in the network. This study concludes that the number of candidate location has a significant effect on the quality of the solution. It increases the quality of communication coverage, nevertheless, it generates a large interference with a high level of noise. A similar approach with the previous study, [9] takes signal coverage, interference and cost as objective functions and handover, traffic demand and overlap as the criteria. Receiving field strength testing services for all items is calculated using simulations and path loss is calculated using the Hatta model. However, this study only considered a flat area to study the performance of their algorithm. Based on the previous study on antenna placement problem (APP), there is little attempt yet to incorporate decision support system (DSS) and geographical information system (GIS). One known attempt was a study from [11], where they proposed a spatial DSS that integrate the multi-objective optimization technique with GIS. Three main criteria for the cell-planning approach are technical, financial and environmental criteria. However, this study did not consider a digital elevation model (DEM) for the conducted area to obtain the height of the building and the building specifications according to the sitting protocol.

There are many MCDA methods such as ELECTRE Method by Bernard Roy [12], TOPSIS [13], PROMETHEE [14] and AHP [15]. Analytic Hierarchy Process (AHP) has been chosen in this study because this method provides a practical way of converting data into decision and produce very useful information for planning purposes. By integrating both AHP and GIS, planners can easily adjust and forecast the parameter or criteria to better understand the problem at hand. The analytic hierarchy process (AHP), introduced by Thomas Saaty in 1980, is a structured technique for organizing and analysing complex decisions making, that help the decision maker to set priorities and make the best decision based on mathematics and psychology. It has been extensively studied and refined since then [16]. By reducing the complicated results to a series of pair-wise comparison, and then synthesizing results, AHP helps to capture both subjective and objective aspects of the results. Furthermore, AHP incorporates useful techniques for checking the consistency of decision-makers' judgments, thereby reducing unfairness in the decision-making process [17].

Beside AHP, Boolean overlay [18][19], fuzzy weight overlay [20][21], weighted linear combination (WLC) [22][23] and ordered weighted averaging (OWA) [24][25] have been widely used in evaluating and analysis on suitability study . In this study, Boolean overlay is used in the restriction model the result is reduced to either TRUE (1) or FALSE (0). It means that in each criterion, the land is classified as either suitable or unsuitable for antenna placement. The combining analysis in fuzzy weight overlay quantifies each location's possibility of belonging to specified sets form various input raster. It reclassifies or transforms the data values to a common scale, but the transformed values represent the probability of belonging to a specified. WLC makes more favourable criteria which have a higher value of weight in the output raster and therefore indicating these locations as being the higher priority. OWA uses two sets of weight. The first set controls the relative contribution of a specific criteria or factors and the other set of weight controls the order of the aggregation of the weight criteria [26][27].

III. Materials and Methods

This section proposed the use of geographic information system (GIS) and multicriteria evaluation (MCE) technique to select a suitable site for landslide monitoring base stations along the transmission tower line in Cameron Highland. First, a brief description of the study is given followed by a detailed description of the steps adopted in the methodology. This includes description and pre-processing of constraint and factor criteria and sub-criteria. Five main criteria have been selected for site suitability analysis of the antenna base station (BS) which are technical, topography, accessibility, risk assessment and landcover. Based on the study and discussion with experts from various field of disciplines, 13 sub-criteria and 4 restricted areas were identified. The generated thematic maps of these criteria were standardized using Fuzzy membership. For weight evaluation, pairwise comparison matrix known as analytical hierarchy process (AHP) is used. A weight for each criterion was generated by comparing them with each other according to their importance. With the help of these weights and criteria, the final site suitability map was modelled using Ordered Weighted Average (OWA).

A. Study Area

The study area was conducted along 275kV TNB Jor-Bintang transmission line in west Cameron Highland, which consist of 44 tower pylons as shown in Fig. 1. The average elevation is 1,180 m above mean sea level. The highest elevation from mean sea level is 1615 meter with hilly is primarily covered by tropical rainforests. The annual rainfall in Cameron Highland is recorded at very high which can be up to 3000 mm yearly and during the monsoon season, with the highest single-day rainfall that was recorded ranged from 87 to 100 mm. As a result, many streams and rivers overflow, and landslides such as debris flow may arise along the river basin [28].

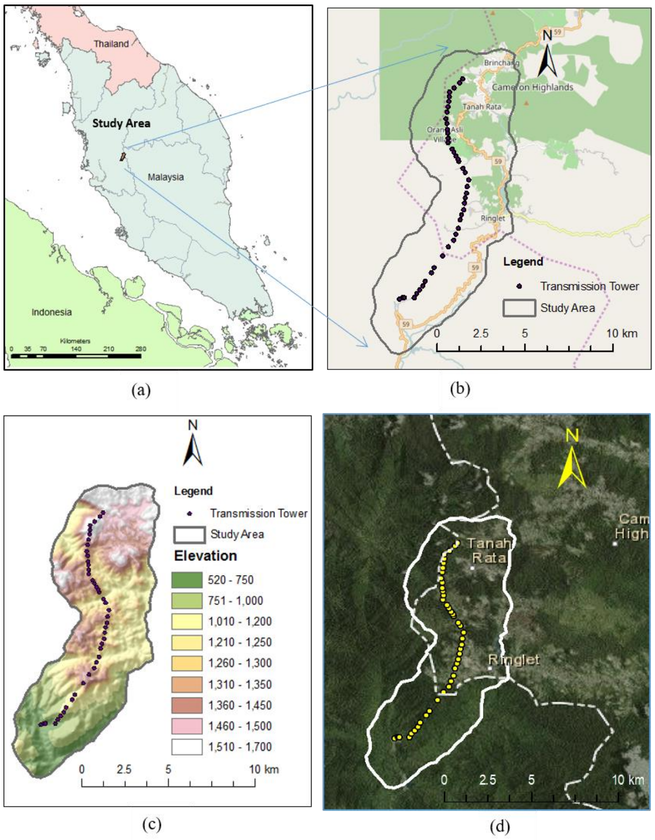

Fig. 1 (a) Study Area; (b) Close-up of the study area together with the transmission tower and the boundary; (c) elevation map of the study area; (d) A study area taken from Google Earth TM.

Generally, Cameron Highland is an environmentally sensitive area where many land development activities such as agriculture, agro-tourism, property development and road-widening projects had been carried out and some are still ongoing to-date [29]. The study conducted by [30], shows that there are 13 identified towers located at high risk landslide area while 22 towers located at high risk erosion area. Furthermore, this area has been selected as a study area as it has the combination of hilly and forest landscape with low population density and small settlements. Hence, this area of interest is deemed as the most suitable pilot area to represent transmission line in Malaysia.

B. Methodology

The integration of Geographical Information System (GIS) and Multicriteria Decision Analysis (MCDA) can be regarded as a method that transforms and combines geographical data and value judgments or preferences to obtain more facts for decision making [31]. In this study, a suitability analysis is used to support decision making in planning to find the optimal location of the antenna tower.

The proposed framework of this study is presented in Fig. 2. In order to identify the suitable antenna placement in Cameron Highland, the integration of multi-criteria decision-making approach and GIS was utilized. In summary, the proposed methodology includes the following stages:

1) Define the problem - To find the optimal location of cellular antenna tower.

2) Determine the criteria (factors and constraints) - The characteristic of the chosen criteria reflected to the desired

location as close as possible. The chosen criteria should be measurable. The main criteria for this study are:

- Technical
- Topography
- Risk assessment
- Accessible to site
- Landuse

4 constraints have been adapted in this study which are clearance buffer distance from every transmission tower, river, reservoir and lake.

3) Standardize the criteria scores - The Fuzzy Membership tool reclassifies or transforms the input data to a 0 to 1 scale based on the possibility of being a member of a specified set. 0 is assigned to those locations that are definitely not a member of the specified set, 1 is assigned to those values that are definitely a member of the specified set, and the entire range of possibilities between 0 and 1 are assigned to some level of possible membership (the larger the number, the greater the possibility).

4) Prioritization method – At this stage, the criteria weighting is produced using Analytical Hierarchy Process (AHP) In this pairwise comparison, AHP method is used to weight the criteria. A matrix is constructed where each criterion is compared to one another, relative to its importance with a scale from 1 to 9.

For the restriction model, where a few restricted areas should be excluded from the model based on legal restriction or due to environmental or infrastructure factors. The constraint criteria data was then converted to a Boolean map by assigning an index value of 1 for suitable antenna placement, while 0 for the least suitable.

5) Aggregate the criteria – Ordered Weighted Average (OWA) methods is adapted in this stage. OWA uses a class of multi-criteria operators and involves two sets of weights that are criterion weights and order weights. A criterion weight is assigned from AHP technique to a given criterion or attribute for all locations in a study area to indicate its relative importance, according to the decision-maker's preferences, in the set of criteria under consideration.

The order weights are associated with the criterion values on a location-by-location basis. They are assigned to a location's attribute values in decreasing order with no consideration of the attribute source of each value. The re-ordering procedure involves associating an order weight with a particular ordered position of the weighted attribute values. The first order weight is assigned to the highest weighted attribute values for each location, the second order weight to the second and so on.

The determination of optimum location of antenna placement for landslide monitoring along transmission line depends on the comprehensive and correct understanding of factors and how to select them. In this study, the selected factors are based on various research studies and expert opinions. The criteria related to this study as shown in Fig. 3 which are Technical, Topography, Accessibility, Risk Assessment and Landcover together with their sub criteria.

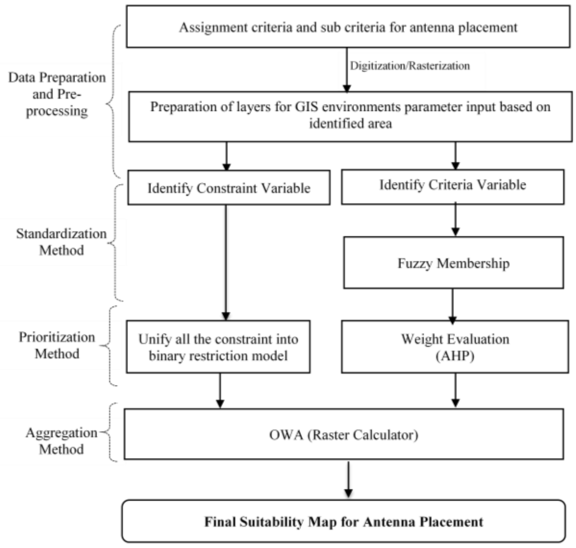

Fig. 2 Framework for antenna placement selection

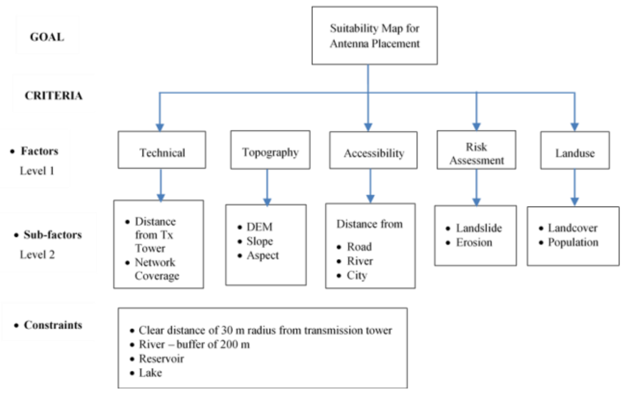

Fig. 3 Suitability analysis hierarchy for antenna placement

In Fuzzy membership assignment, all continuous variable data were directly fuzzified using 2 types of fuzzy classes which are large and linear fuzzy function. For categorical data need to have a pre-processing step. First, using the reclassification method (reclassify tool) in order to attribute numeric values to specific category and to further divide the result by a factor to normalized the output values to be between 0 and 1 (divide tool).

In determining the weight of the criteria, AHP is used to estimate the weight of the criteria, and then these weightings were implemented on their maps' layer within GIS to produce the suitability index map for antenna placement in Cameron Highland. The experts' opinions and literature review were considered in assigning the weight of each criterion as well as the suitability values of each of the sub-criteria. Table 1 represents the criterion weighting defined by the AHP method.

TABLE 1

THE CRITERION WEIGHTING DEFINED FOR THE AHP METHOD

	Criteria	Lev1	Sub-criteria	Lev 2	Normalized weight
1	Technical	44.68	Distance from Tx. Tower	26.54	0.118
2			Network Coverage	67.16	0.300
3			Solar	6.29	0.028
4	Topography	25.69	DEM	75.14	0.193
5			Aspect	7.04	0.018
6			Slope	17.8	0.046
7	Landuse	3.22	Population	35	0.011
8			Landcover	65	0.021
9	Risk	20.89	Landslide	75	0.157
10			Erosion	25	0.052
11	Access	5.51	Road	61.53	0.040
12			River	6.60	0.004
13			City	31.87	0.010

A Ordered Weighted Average (OWA) is used in this study for aggregation stage. This method is a generalization of the Boolean coverage operations and Weight Linear Combination (WLC). The weight averaging technique is a complete spectrum of space strategy decision which in turn conveys the primary gradation dimensions between the involved criteria and risk-taking measure [32].

Fig. 4 demonstrates the Decision Strategy Space where x-axis represents the risk which indicates a maximum caution that is extended from zero risk to the point where the risk factor has been accepted in a complete manner. y-axis represents the trade-off between criteria that extends from no trade-off to the maximum trade-off. The trade-off is defined as a degree that a criterion can compensate on the other criteria. In brief, OWA method can produced a wide range of different and predictive maps by vary its criterion's order weight. As a result, this method allowed the decision makers to gain a wealth of possible solution for different management strategies.

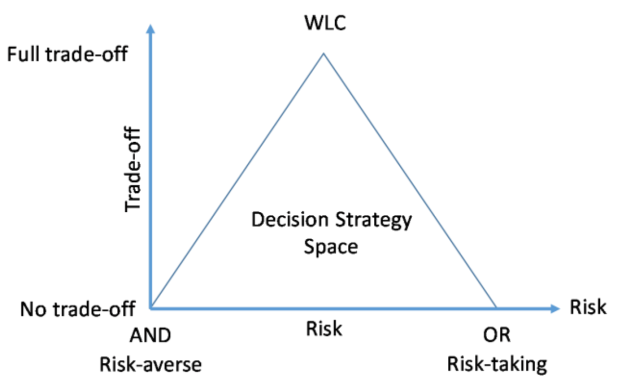

Fig. 4 Decision Strategy Space in Ordered Weight Average (OWA) [33]

OWA involves two vectors of weights, which are criterion importance weights (w_j) and ordered weight (v_j). The importance weight, w_j is assigned to the jth criterion map (attribute) for all locations to indicate the relative importance of the attribute according to the AHP result preferences. The order weight, v_j are associated with the criterion values on a location-by-location basis. Ordered weights assigned to the ith location's attribute value are in decreasing order. Regardless of the location value, the criterion map values can be measured.

For a given set of criterion maps, OWA is defined as a map combination operator that associates with an ith location (raster or point) of order weights such that for j = 1, 2, …, n and , $\sum_{j=1}^{n} v_j = 1$ and is defined as [24]:

$$OWA_i = \sum_{j=1}^{n} \left(\frac{u_j v_j}{\sum_{j=1}^{n} u_j v_j} \right) z_{ij} \qquad (1)$$

Where $z_{i1} \geq z_{i2} \; .... \geq z_{ij}$ is obtained by reordering the criterion values x_{i1} , x_{i2}, …. ,x_{in} and u_j is the reordered jth criterion weight, w_j

The operator OWA consists of two main characters which indicate the behaviour and position of an operator. There are ORness and trade-off relation measure. ORness defines the location of the operator OWA between the relation AND (minimum) and OR (maximum). ORness also act as an indicator of the risk-aversion and risk-taking of a decision-taker [2].

ORness is defined as:

$$ORness = \frac{1}{n-1} \sum_{i=1}^{n} (n-i)\, v_i \qquad (2)$$

ANDness is defined as:

$$ANDness = 1 - ORness \qquad (3)$$

Whereas, trade-off, the second character of operator OWA shows the exchange measure of effectiveness of one index from the other indexes and is defined as:

$$Trade\ off = 1 - \sqrt{\frac{n}{n-1} \sum_{i=1}^{n} \left(v_i - \frac{1}{n} \right)^2} \qquad (4)$$

Trade-off measure specifies the degree of compensation or substitutability between criteria. It indicates the compensation of low values on one criterion by high values on another criterion [2].

In this study, 13 order weights were applied corresponding to the 13 criteria that were rank-ordered for each location. The modified factor weights were calculated and applied for 7 different scenarios:

i. Scenario a – Maximum level or risk and no trade-off. This is the most optimistic scenario where the decision results lead to the maximum risk with the lowest recoverability. The total weight is allocated to the last ordered ranking.
ii. Scenario b – High level of risk and small trade-off.
iii. Scenario c – Relatively high level of risk and some trade-off.
iv. Scenario d – Average level of risk and full trade-off.

v. Scenario e – Relatively low level of risk and some trade-off.
vi. Scenario f – Low level of risk and small trade-off.
vii. Scenario g – Minimum level of risk and no trade-off. This state is very pessimistic condition, where the scenario leads to the worst decision state. In this scenario, the highest values present in each criterion are selected.

Next, the suitability maps for antenna placement was derived using weight overlay method.

IV. Result and Discussions

Ordered Weighted Average (OWA) is used in this study for aggregation stage. As stated in previous section, OWA employs 2 sets of weights. The first set was from AHP where it represents the relative of the factors. This pairwise comparison technique lessens the complexity of the decision problem by evaluating the relative importance of the two criteria at one time to build flexible hierarchies of decision criteria.

The second set is ordered weight where the assignment of weight is according to a pixel basis. This ordered weight will then be applied to the criteria in GIS. By varying the ordered weight, OWA generates an aggregation results where the decision rules or scenario would fall in a triangular decision space between ANDness operator (risk averse) and the ORness operator (risk taking).

In this study, 13 order weights were applied corresponding to the 13 criteria that were rank-ordered for each location. The modified factor weights were calculated and applied as in Table 2 for 7 different scenarios as presented in previous section.

TABLE 2

ORDERED WEIGHT OBTAINED FROM 13 CRITERIA WITH 7 SCENARIOS

v_i	Criteria	Scenario						
		a	b	c	d	e	f	g
1	Network Coverage	0	0.887	0.548	0.077	0.002	0.000	1
2	DEM	0	0.045	0.155	0.077	0.027	0.001	0
3	Landslide	0	0.026	0.104	0.077	0.087	0.013	0
4	Distance from Tx. Tower	0	0.016	0.070	0.077	0.152	0.059	0
5	Erosion	0	0.006	0.029	0.077	0.105	0.067	0
6	Slope	0	0.005	0.025	0.077	0.116	0.100	0
7	Road	0	0.004	0.021	0.077	0.124	0.137	0
8	Solar	0	0.003	0.015	0.077	0.101	0.135	0
9	Landcover	0	0.002	0.011	0.077	0.083	0.126	0
10	Aspect	0	0.002	0.009	0.077	0.078	0.131	0
11	Population	0	0.001	0.006	0.077	0.052	0.093	0
12	City	0	0.001	0.005	0.077	0.050	0.095	0
13	River	1	0.000	0.002	0.077	0.022	0.044	0
	Orness	1	0.974	0.887	0.500	0.484	0.381	0
	ANDness	0	0.026	0.113	0.500	0.516	0.619	1
	Trade-off	0	0.122	0.464	1.000	0.841	0.967	0

The possibility suitability maps derived by OWA method according to 7 different scenarios above presented in Fig. 5. Fig. 5 demonstrates a decision alternative set of continuum produces a risk-taking solution. Fig. 5 (b) and (c) falls between WLC and OR where some trade-off is allowed. The suitability for antenna placement resulted more to the network coverage and line of tower area.

Referring to Table 2, by increasing the value of ORness (from 0.5 to 1), represents an increasing degree of optimism and decreasing level of trade-off among criteria. This implies that bigger probabilities are given to the higher criterion value at a given location at the expense of assigning smaller probabilities to the smaller criterion values at the location.

A comparison of corresponding maps in Fig. 5 (d), (c), (b) and (a), indicates that with the increasing the ORness (optimism), the areas that could be recommended for antenna placement become larger. Fig. 5 (a) is associated with the OR operator and produce a risk-taking solution. The suitable areas for antenna placement have a very large spatial extent and it includes almost all the study area exclude the constraint. This OR solution provide high risk with no trade-off.

The solutions with decision alternative shown in Fig. 5 (d) and (h) are the average and WLC solution respectively. Both fall in the middle of the risk continuum and they are neither risk averse nor risk taking solutions (risk neutral). However, the average solution, Fig. 5 (d) generate slightly different result compared to WLC as in Fig. 5(h). The average solution indicates that antenna placement location is more specific compared to WLC.

Fig. 5 (g) demonstrate a decision alternative associated with AND operator and produce risk-averse solution and referred as pessimistic strategy. In this strategy, a probability of 1 is assigned to the worst-case scenario which implies that no trade-off between evaluation criteria. Increasing the ANDness value corresponds to the increasing the degree of optimism as well as increasing the trade-off value among the criteria.

From the result, the most suitable area for antenna placement are located in the network coverage area only. The legends in map (g) represent a measure of antenna placement suitability where the possibility is observed on a scale range from 0 to 1. As stated in Table 2, the value of 1 for ANDness suggest that the solution coincides with the AND while 0 value for the ORness suggest that the solution is the most distant from OR. This decision produced zero trade-off.

The decision alternative shown in Fig. 5 (e) and (f) is associated in between ANDness and average solution. At this alternative, the risk is increased in the solution and generates an increase area for antenna placement compared to (g). This solution produced a trade-off value of 0.85 and 0.9. Compared to decision in (e) and (f), result in (e) give a very specific compared to (f). However, result in (f) can be used if one decides to build the antenna at those area.

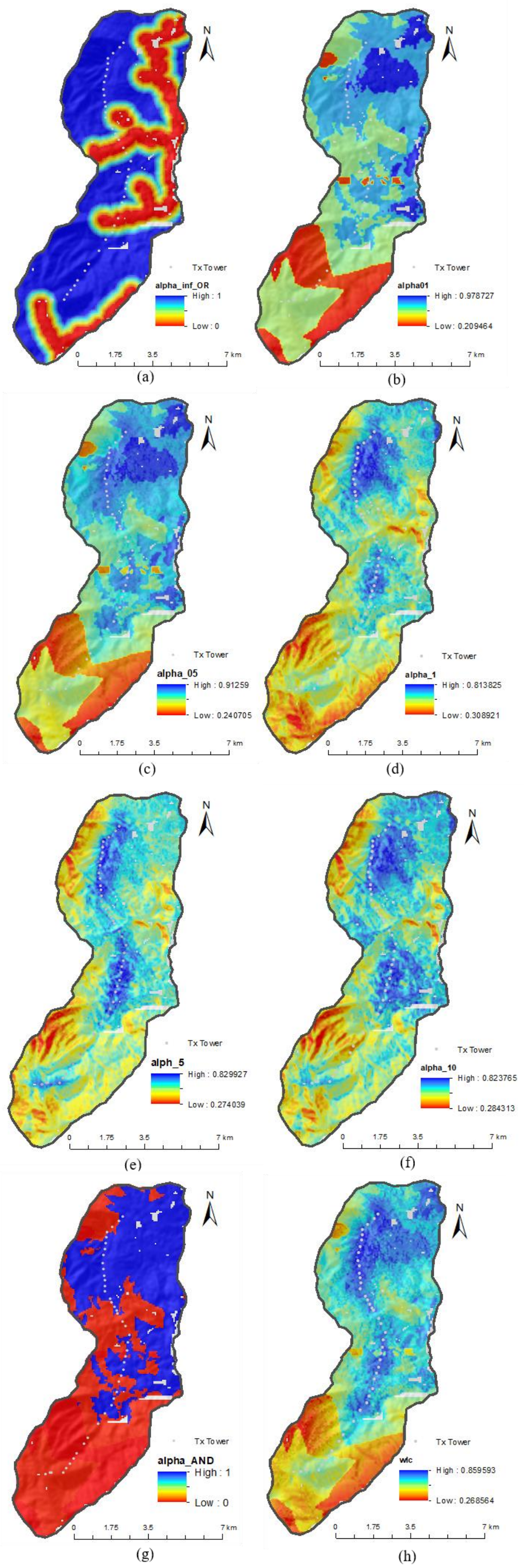

Fig. 5 Suitability Maps for Antenna Placement Derived by OWA Method

By using OWA method, it allowed the decision maker to evaluate several solution and alternatives by considering the risk and trade-off. It also permits the criteria to be differentially weighted and to trade off with each other. In this study, scenario (e) is chosen as the best solution where the value of ORness is 0.4845 and ANDness is 0.5155 with the trade-off equal to 0.8409. This is a moderately optimistic strategy.

The result obtained from the overlay process, were then multiplied with the constraints or restriction map to masked out restricted area. Based on the overlay method obtained, the suitability layer maps were originally categorized using 0 to 9 classes. Area with suitability index from 0 to 5 can be generally considered as not suitable for the antenna placement. Region with grade ranging from 6 to 9 are expected to be the best location for antenna sitting. In this study, the suitability of the four clusters are identified as less suitable, moderately suitable, suitable and suitable. The suitability maps are shown in Fig. 6.

The suitable map layer indicated higher suitable location is in the northern region of the study area and along the transmission line. Northern region has higher elevations with the maximum height 1680 m are usually suitable for antenna placement.

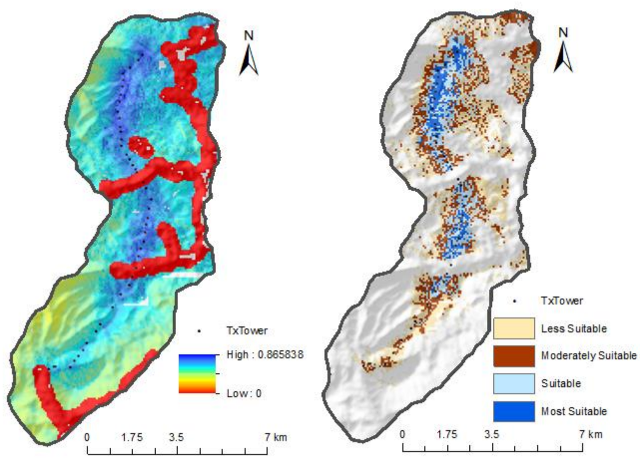

Fig. 6 Suitability Map for Antenna Placement using OWA

The result form OWA method shows that, even though the trade-off is not fully 1, the result demonstrate that the objective is not necessary to find an optimal solution for antenna placement but to explore other strengths associated with the weighting flexibility.

V. CONCLUSIONS

This study presents an application of GIS-based multi-criteria evaluation approach in determining a potential placement for antenna base station location in Cameron Highland, Malaysia. In particular, the case study has presented an application of a combination of AHP and OWA aggregation procedure to generate a wide range of decision alternatives for antenna suitability placement problems. Result based on OWA evaluation studies demonstrate that OWA method allowed the decision maker to control over the risk and trade-off by altering the weight of the criteria.

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REFERENCES

[1] N. M. Din *et al.*, "Early Warning System for Transmission Tower Landslide Hazard Monitoring in Malaysia," *Casp. J. Appl. Sci. Res.*, vol. 2, pp. 119–123, 2013.

[2] J. Malczewski and C. Rinner, *Multicriteria Decision Analysis in Geographic Information Science*. London, Canada: Springer, 2015.

[3] K. Chavan and R. Guhagharkar, "ROLE OF ICT in Power System," in *International Council on Large Electric Systems*, 2013, pp. 2–8.

[4] B. Fateh, M. Govindarasu, and V. Ajjarapu, "Wireless network design for transmission line monitoring in smart grid," *IEEE Trans. Smart Grid*, vol. 4, no. 2, pp. 1076–1086, Jun. 2013.

[5] A. Damiano, G. Gatto, and I. Marongiu, "Decision Support System for biomass energy exploitation in smart grid planning," in *SPEEDAM 2010 - International Symposium on Power Electronics, Electrical Drives, Automation and Motion*, 2010, pp. 1183–1188.

[6] K. S. Hung *et al.*, "On Wireless Sensors Communication for Overhead Transmission Line Monitoring in Power Delivery Systems," pp. 309–314, 2010.

[7] R. C. Rodrigues, G. R. Mateus, and A. A. F. Loureiro, "Optimal base station placement and fixed channel assignment applied to wireless local area network projects," in *IEEE International Conference on Networks. ICON '99 Proceedings (Cat. No.PR00243)*, 1999, pp. 186–192.

[8] Z. A. E. M. Dahi, C. Mezioud, and A. Draa, "A quantum-inspired genetic algorithm for solving the antenna positioning problem," *Swarm Evol. Comput.*, vol. 31, pp. 24–63, Dec. 2016.

[9] A. KHireddine and O. Mohamed Amine, "Base station Placement Optimization Using Genetic Algorithms Approach," *Int. J. Comput. Aided Eng. Technol.*, vol. 12, no. 1, p. 1, 2017.

[10] O. Abdelkhalek, S. Krichen, and A. Guitouni, "A genetic algorithm based decision support system for the multi-objective node placement problem in next wireless generation network," *Appl. Soft Comput.*, vol. 33, pp. 278–291, Aug. 2015.

[11] Y. Yang *et al.*, "Fast Optimal Antenna Placement for Distributed MIMO Radar with Surveillance Performance," *IEEE Signal Process. Lett.*, vol. 22, no. 11, pp. 1955–1959, Nov. 2015.

[12] B. Roy, "The outranking approach and the foundations of electre methods," *Theory Decis.*, vol. 31, no. 1, pp. 49–73, Jul. 1991.

[13] Y. J. Lai, T. Y. Liu, and C. L. Hwang, "TOPSIS for MODM," *Eur. J. Oper. Res.*, vol. 76, no. 3, pp. 486–500, 1994.

[14] M. S. Roodposhti, S. Rahimi, and M. J. Beglou, "PROMETHEE II and fuzzy AHP: an enhanced GIS-based landslide susceptibility mapping," *Nat. Hazards*, vol. 73, no. 1, pp. 77–95, Aug. 2014.

[15] M. Mokarram and M. Najafi-Ghiri, "Combination of Fuzzy Logic and Analytical Hierarchy Process Techniques to Assess Potassium Saturation Percentage of Some Calcareous Soils (Case Study: Fars Province, Southern Iran)," *Agriculture*, vol. 6, no. 4, p. 59, 2016.

[16] T. L. Saaty, "Decision making with the analytic hierarchy process - International Journal of Services Sciences - Volume 1, Number 1/2008 - Inderscience Publishers," *Int. J. of Services Sciences, 2008 Vol.1, No.1*, 2008. [Online]. Available: http://inderscience.metapress.com/content/02t637305v6g65n8/. [Accessed: 16-Oct-2014].

[17] A. Emrouznejad and M. Marra, "The state of the art development of AHP (1979–2017): a literature review with a social network analysis," *Int. J. Prod. Res.*, vol. 55, no. 22, pp. 6653–6675, Nov. 2017.

[18] G. Kwano and M. Nigeria, "Application of GIS Sieve Mapping and Overlay Techniques for Building Site Suitability Analysis in Part of FUT," *www.indjst.org Indian J. Sci. Technol.*, vol. 9, no. 46, 2016.

[19] C. Cheng and R. G. Thompson, "Application of boolean logic and GIS for determining suitable locations for Temporary Disaster Waste Management Sites," *Int. J. Disaster Risk Reduct.*, vol. 20, pp. 78–92, Dec. 2016.

[20] G. S. Arumaikkani, S. Chelliah, and M. Gopalan, "Revelation of Groundwater Possible Region Using Fuzzy Logic Based GIS Modeling," 2017.

[21] A. Amirahmadi, M. Shiran, M. Z. Asadi, and F. Keramati, "Landslide susceptibility zonation using the fuzzy algebraic operators in GIS, Iran," *J. Mater. Environ. Sci*, vol. 8, no. 1, pp. 50–59, 2017.

[22] M. Babalola, Babalola, and M. A., "Application of GIS-Based Multi-Criteria Decision Technique in Exploration of Suitable Site Options for Anaerobic Digestion of Food and Biodegradable Waste in Oita City, Japan," *Environments*, vol. 5, no. 7, p. 77, Jul. 2018.

[23] L. Gigović, S. Drobnjak, and D. Pamučar, "The Application of the Hybrid GIS Spatial Multi-Criteria Decision Analysis Best–Worst Methodology for Landslide Susceptibility Mapping," *ISPRS Int. J. Geo-Information*, vol. 8, no. 2, p. 79, 2019.

[24] H. Zabihi *et al.*, "GIS Multi-Criteria Analysis by Ordered Weighted Averaging (OWA): Toward an Integrated Citrus Management Strategy," *Sustainability*, vol. 11, no. 4, p. 1009, Feb. 2019.

[25] M. Mokarram and A. Mirsoleimani, "Using Fuzzy-AHP and order weight average (OWA) methods for land suitability determination for citrus cultivation in ArcGIS (Case study: Fars province, Iran)," *Phys. A Stat. Mech. its Appl.*, vol. 508, pp. 506–518, Oct. 2018.

[26] X. Liu, "GIS-Based Local Ordered Weighted Averaging : A Case Study in London , Ontario," no. April, 2013.

[27] B. Feizizadeh and T. Blaschke, "GIS-multicriteria decision analysis for landslide susceptibility mapping: Comparing three methods for the Urmia lake basin, Iran," *Nat. Hazards*, vol. 65, no. 3, pp. 2105–2128, 2013.

[28] M. F. Pradhan, Biswajeet; Sezer, E.A; Gokceoglu, C.; Buchroithner, "Landslide Susceptibility Mapping by Neuro-Fuzzy Approach in a Landslide-Prone Area (Cameron Highlands, Malaysia)," *IEEE Trans. Geosci. Remote Sens.*, vol. 48, no. 12, p. 4164,4177, 2010.

[29] T. K. Hui and F. H. Ali, "Development Of EWARNS Forecast And Real-time Early Warning System On Erosion Risks/Hazards," in *Master Builders*, 2nd Quarte., 2005, pp. 30–34.

[30] Nor Hazwani Nor Khalid, "Risk classification for erosion, landslide and slope stability for TNB transmission line," Universiti Tenaga Nasional, Malaysia, 2012.

[31] J. Malczewski, "GIS-based multicriteria decision analysis: A survey of the literature," *Int. J. Geogr. Inf. Sci.*, vol. 20, no. 7, pp. 703–726, Aug. 2006.

[32] S. Drobne and A. Lisec, "Multi-attribute Decision Analysis in GIS : Weighted Linear Combination and Ordered Weighted Averaging," *Informatica*, vol. 33, pp. 459–474, 2009.

[33] R. R. Yager, "On ordered weighted averaging aggregation operators in multicriteria decisionmaking," *IEEE Trans. Syst. Man. Cybern.*, vol. 18, no. 1, pp. 183–190, 1988.