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Enhancement of Application Model for Substation Site Selection

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Abstract: ***The existing ESASIRF program (Transmission Line Route Selection Application Model and Development of Environmental Sensitive Area (ESA) Safe and Intelligent Route Finder (ESASIRF) and integration with PLS-CAD) does not cover substation selection and environmental protection. It focuses only on an assessment of the risk of landslides concerning the proposed route of transmission. This study presents the potential of an integrated system using the Geographical Information System (GIS) and Remote Sensing techniques in substation selection to develop an automatic and intelligence method for substation planning in this specific delicate area of the environment. During the selection of the proposed substation, a social impact assessment was also included in this research by defining requirements, problems as well as suitable mitigation measures. With this research, all spatial data for South Putrajaya is acquired and the previous system can be fully utilized. Spatial data from this research were also used to define soil type and flood-prone areas. Finally, this system will be used to assist TNBs in gazetting by applying sustainable concepts in their Transmission Route and Corridor by following Section 21 and Section 22 ACT 172 1973.***

Keywords: ***Substation, Transmission Line Geographical Information System, Remote Sensing***

I. INTRODUCTION

The substation is a component of the power generation, transmission, and distribution system [1]. It serves as electricity supply sources for the local distribution fields where they are situated. The primary roles of the substation are to receive energy transmitted at high voltage from the generating station and to reduce the voltage to a standard that is suitable for local distribution and to provide switching facilities [2]. At some places, the existing substation facilities are not sufficient to supply energy in a service region due to the rapid economic and population growth. In such cases, new substations must be built or replaced in some critical instances to supply new demand [3]. The decision on the optimum place and the number of new substations to be built is difficult in many cases [4], [5]. Determination of the location of new substations generally depends on several conditions including geographical constraints of the region that horizontal load growth occurs in, possession of the areas (private or public property), and other economic aspects [6].

The Geographical Information System (GIS) has significantly improved the energy industry efficiency [7],[8]. GIS is widely used for fault analysis, optimization of networks, load forecasting, cost estimation and selection of suitable areas, etc [9]. GIS applications serve a significant part in designing, analyzing and controlling contemporary energy systems. It improves the visualization of the energy system by associating spatial data with electrical network transmission and other assets [9].

A. Study Area

South Putrajaya was chosen as the study area in this study. According to the land use agriculture map, Putrajaya South majorly consists of the federal government administration building, village, and orchard. The topography of the area land consists of slightly-to-moderately hilly terrain with elevation varies from 20 meters to 240 meters. Locations of the study area are shown in Fig. 1.

Fig.1Site locations for substation development in SouthPutrajaya

II. METHODOLOGY

The methodology of this study is divided into three (3) main phases as is shown in Fig. 2.

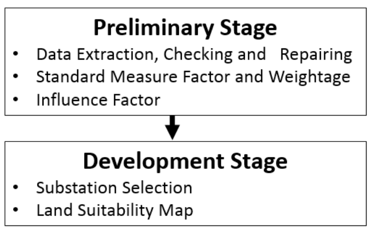

Fig.2 Flow chart for substation finder analysis

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A. Preliminary Stage

I) Data Extraction, Checking and Repairing

In this study, all spatial data involved in soil type's identification, flood-prone area and Digital Elevation Model (DEM) are based on satellite imagery (remote sensing) and GIS. The substation location selection map was generated using several parameters such as transmission line, facilities, growth, geography, geo-hazard, drain zone, ecology, land use, and soil type. These maps were divided into several layers. Each parameter has been categorized into sub-classes with a rating of 0 to 5 based on its significance to land suitability susceptibility. Besides, each factor was considered to have a differential impact on such susceptibility, the weighing process was performed before reclassifying the classes accordingly to the need of the TenagaNasionalBerhad (TNB).

Desktop studies were conducted based on 11 technical criteria (TC) as shown in Table I and 12 social criteria. These two criteria were outlined during the Technical Criteria Workshop on 11 June 2013 and the SIA Criteria Workshop on 25-26 June 2013 respectively.

Table. 1 Description of technical criteria

TC	Technical Criteria	Criteria Description and Weighted
TC 1	Transmission line	• Near to the existing and proposed transmission lines
TC 2	Public Infrastructure	• Near to public infrastructure that has access road. • Near to paved roads, road reserves, unpaved roads. • Access to water, electricity, sewerage, telecommunications systems and drainage systems.
TC 3	Development	• Avoid the development area – cadastral lot, within existing residential areas, contaminated industrial area and water tank. • Reject: rifle range, cemeteries, schools, universities, colleges, polytechnics (education), port (jetty) / sea, railway station, other buildings (places of worship, historical relics), airports.
TC 4	Topographic	• To find suitable area for substation based on topographic criteria. • Reject: Swamp, tin mine, pond, gazette forestry, illegal dumping area/landfills, lakes, valleys.
TC 5	Geo-hazard	• Avoid erosion, steep slopes, soil settlement and landslides areas.
TC 6	Flood Area	• Avoid flood prone area
TC 7	Geology	• Avoid expansive soil, weak rock (limestone area).
TC 8	Agricultural land use	• Identify the types of crops (land use) – paddy, rubber, oil palm, vegetable, 'cash crops', cocoa, annual crops, bananas, bushes, oil, grass areas, open spaces.
TC 9	Soil type	• Identify the types of suitable land (soil type) - bearing capacity between> 60kN/m^2 - continental marine deposits / alluvium, colluvium, residual soil - igneous - Int, B, UB, sedimentary, metamorphic, arenaceous, residual soil (igneous - Felsic).
TC 10	Constraint	• Avoid railway and river.
TC 11	Area size & buffer zone	• The area of substation site should take into account the building line, the distance from the boundary of the lot and the electric power generated. • Avoid development in the centre of cadastral lot.

After data processing, all available data needed by the criteria have been verified and validated. This process is important to minimize any errors affecting 11 technical criteria in the selection of substation sites. Weighting and influence factor was assigned to create a land suitability map for selection of substation sites. These are essential procedures in the selection of substation sites.

II) Standard Measure Factor and Weightage

A suitable weighting system must be designed to weigh each coating to produce a suitability layer. There are 11 technical requirements have been used as weighting levels in this study. This process is essential because it forms the backbone of the methodology. The technique that has been used in this stud is the Analytic Hierarchy Process (AHP). AHP utilizes a Multi-Criteria Decision Making (MCDM) tool to convert person judgments of comparative significance to general results or weights and then transfer them to the GIS system to generate a graph of earthquake sensitivity. Generally, the cost of the project always becomes a major concern and constraint. However, in this project environmental and social aspects are also incorporated in the optimization process during substation site selection. Different weightage ratings are assigned to develop substation site selection in accordance to the TNB technical criteria.

The rating system was assigned accordingly to the needs of TNB. In general, weightage rating 5 was assigned to the least preferred area, and weightage rating 1 was assigned to the most preferred area. The rating acts as a conductor to the substation site selection process, different rating of the data will influence a different result of the substations.

III) Influence Factor

In this project, the influence factor used to generate substation location is based on value as shown in Table II, which is in accordance to the TNB's needs and priorities. This influencing factor is used for a guideline to generate potential substation location. A higher percentage of influence factors indicate the priority of avoiding an area.

In this project-based on influence factor and weightage, land suitability map was generated to locate optimum substation location. Comparative analyses between potential substation locations were made to obtain optimum location which satisfies all criteria.

Table. 2 Summary of influence factor for each criteria

Criteria		Influence Factor (%)
Criteria 1	Near to existing/new transmission line	17
Criteria 2	Infrastructure	8
Criteria 3	Existing development	10
Criteria 4	Topography	10
Criteria 5	Geo-hazard	8
Criteria 6	Flooding area	1
Criteria 7	Geology	8
Criteria 8	Agriculture land use	10
Criteria 9	Type of soil (low cost)	12
Criteria 10	Other Constraint	3
Criteria 11	Site size including buffer zone	13
Total		100

***Remarks:** Influence factor derived during workshop is used as reference and guideline.

B. Development Stage

All the technical requirements involved in the method were analyzed, to determine the optimum site selection. In the early phases, all 11 criteria were processes separately to create a criteria map. The cell size used for this study was fixed at 20 meters x 20 meters. Table III shows the summary of the process involved for every technical criterion. Criteria maps for each technical criteria in the output column in Table II were used in overlaying process using GIS. All technical criteria were processed separately based on the need and type of data. Technical criteria for buffer zone (TC 11) was used to find the best location after land suitability map was generated.

Table. 3 Summary of the process for every technical criteria

Criteria	Data	Process		Output
TC 1	Transmission line	Buffer		Criteria 1 Map
TC 2	Road (bituminous, reserve, none bituminous)	Buffer	Weighted overlay using equal influence factor	Criteria 2 Map
	Main pipe line	Buffer		
	Electrical utility	Buffer		
	Sewerage	Buffer		
	Telecommunication system	Buffer		
	Drainage system	Buffer		
TC 3	Cadastral lot	Reclassify	Weighted overlay using equal influence factor (Rejected area are assigned as NO DATA)	Criteria 3 Map
	Residential	Reclassify		
	Industrial	Reclassify		
	Water tank	Reclassify		
	Rifle range	Reclassify		
	Cemetery	Reclassify		
	Education area	Reclassify		
	Jetty	Reclassify		
	Railway station	Reclassify		
	Other building	Reclassify		
TC 4	Elevation (Contour line)	Create TIN and TIN to raster	Weighted overlay using equal influence factor (Rejected area are assigned as NO DATA)	Criteria 4 Map
	Tidal swamp	Reclassify		
	Tin mine	Reclassify		
	Pond	Reclassify		
	Gazette forest	Reclassify		
	Illegal dumping area	Reclassify		
	Lake	Reclassify		
	Open spaced	Reclassify		
TC 5	Slope	Created from elevation (Raster surface)	Weighted overlay using equal influence factor (Rejected area are assigned as NO DATA)	Criteria 5 Map
	Landslide hazard map	Created from reclassified geology data, elevation data, slope data, Land use data, and aspect data		
	Erosion map	Created from reclassified geology data, elevation data, slope data, Land use data, and soil data		
TC 6	Flood area	reclassify		Criteria 6 Map

Criteria	Data	Process		Output
TC 7	Geology	reclassify		Criteria 7 Map
TC 8	Land use agriculture	reclassify		Criteria 8 Map
TC 9	Soil type	reclassify		Criteria 9 Map
TC 10	River	Buffer	Weighted overlay using equal influence factor	Criteria 10 Map
	Rail	Buffer		

I) Substation Selection

There are two substation kinds to be considered in this study; 275kV substations and 500kV substations that determine the substation area size. The size of the substation 275kV is 260 meters x 250 meters, while the size of the substation 500kV is 640 meters x 640 meters, including the buffer zone. The assessment of the suitability of the substation site was carried out by constructing the land suitability map based on the criteria TNB had listed.

Weightage was assigned to the data and classified in ArcMap software before processing using weighted overlay function. To obtain a cost surface layer, all the layers of criteria involved in this project have been overlaid according to the factors of influence assigned. The land suitability map had been constructed by converting the cost surface layer into the vector file which is shapefile (.shp). By using this land suitability map, the most suitable region was analyzed and chose for substation construction. The comparison is made based on the relevant technical requirements (see Table I).

Maximum and minimum elevations of the location of the substation were recognized using elevation maps generated using contour information. Whereas, a comparative of the landslide hazard map was produced after the Landslide Hazard Map (LHM) was created. Comparisons based on quantitative results have been produced using ArcGIS measurement tools, while location information was acquired using ArcGIS identification instruments. The raster image analysis was performed using a 20 meters x 20 meters cell size and each cell size is equivalent to one pixel used to determine the region of assessment.

III. RESULT AND ANALYSIS

The results of the overlaying processes in the production of the land suitability map were analyzed based on the priority of the influence factor of 11 technical requirements as shown in Table II. The influence factor was used as a guideline for the selection of potential substation locations. Table IV presents a summary of the total lot in the proposed substation area.

Table.4Coordinate of Proposed Locations of Substation for South Putrajaya

Study area	Location name	Coordinate
New Putrajaya South	NPS 1	02°54’19.53” N, 101°43’42.12” E
	NPS 2	02°53’41.02” N, 101°44’18.74” E
	NPS 3	02°54’10.42” N, 101°43’56.71” E

A 275kV transmission line was identified in the study area. Location 1 and 3 are situated near Kampung Sungai Merab, while Location 2 is located within Kampung Bukit Piatu, as shown in Fig. 4.

Fig. 3 Proposed locations of substation at South Putrajaya, Putajaya

The total area of South Putrajaya is approximately 92.5 km2, which is equivalent to 231309 cells. Out of 92.5 km2, only 20.60 % of the area is considered suitable and 61.95 % of the region is classified as less suitable. Although only 1.55km2 is defined as less suitable and 15.77 % or 14059km2 of the study area is rejected due to no information status. Detailed data on the assessment of land suitability can be found in Fig. Table 4 and Table V.

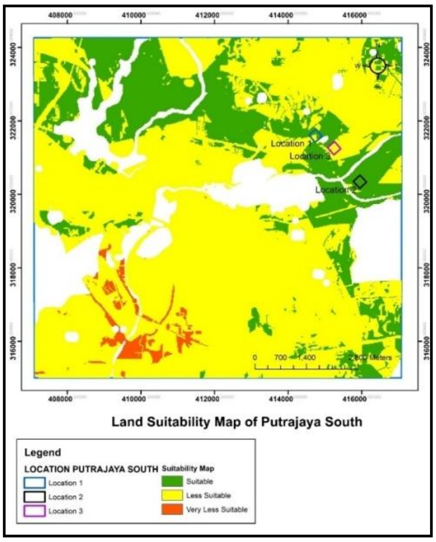

Fig. 4 Land suitability map of South Putrajaya, Putrajaya

Table. 5Analysis result of land suitability map for south putrajaya, putrajaya

Area	Count	Percentage
Suitable (Class 2)	47641	20.60%
Less Suitable (Class 3)	143301	61.95%
Very Less Suitable (Class 4)	3887	1.68%
NO DATA	36480	15.77%

B. Substation Site Selection for South Putrajaya, Putrajaya

A comparative assessment of the results as tabulated in Table VI demonstrates that locations 1 and 2 are the most suitable locations based on the TC1 and TC2 technical requirements.

The total number of cadastral lots associated in all three locations is 8 and below. Analysis indicates that both landslides and floods are classified as non-prone geo-hazards in terms of TC5 and TC6. In terms of the geological function (TC7) (refer Table I), all three places are weighted as Class 2 and all locations are situated within shrubs and palm oil plantations. Based on the map of the soil series, both Location 1 and 3 are classified as Munchong-Seremban soil series in Class 4. While, Location 2 comprises of Telemong-Akob-Local Alluvium, which falls into Class 1 and is preferred among all proposed locations.

Table.6 Comparative analysis of proposed locations in south putrajaya, putrajaya

Technical criteria	Location 1	Location 2	Location 3
TC 1 : Existing transmission line	90 meter	100 meter	230 meter
TC 2 : Infrastructure (Distance from existing road)	60 meter	100 meter	160 meter
TC 3 : Development (Total lot cadastral involved)	3	8	5
TC 4 : Topography (Maximum and minimum elevation)	Max : 40 meter Min : 20 meter	Max : 60 meter Min : 20 meter	~ 20 meter
TC 5 : Geo-hazard (landslide risk map)	Low risk	Low risk	Very low risk
TC 6 : Flood area	No	No	No
TC 7 : Current geology	Devonian	Devonian	Devonian
TC 8 : Current land use agriculture	Rubber plantation, shrubs	Rubber plantation	Rubber plantation, shrubs
TC 9 : Current soil type (soil series)	Munchong-Seremban	Telemong-Akob-Local Alluvium	Munchong-Seremban
TC 10 : Constraint	River : 1.2 kilometer	River : 200 meter	River : 560 meter

IV. CONCLUSION

Potential location for substation development was identified in this study by conducting spatial data analysis using GIS software. This method helps to minimize labor and logistic costs while at the same time providing better database storage compared to conventional methods. Results from spatial data analysis of all three (3) locations of substations incorporating geo-hazards, i.e. landslides and floods, show that floods and landslides have been identified, thus helping TNB to develop appropriate mitigation measures if necessary. This study also allows TNB to fully utilized its database for gazetting purpose with application applying sustainable ideas in its Transmission Route and Corridor BY following Section 21 and Section 22 of ACT 172 1973.

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REFERENCES

1. Moxa Inc. "IEC 61850-3 and IEEE 1588 in Smart Substations" Substation Technical Guide Book. 2011.
2. S. Lohia, "Distribution of Electrical Power Using GIS." International Journal of Advanced Research In Electrical, Electronics And Instrumentation Engineering. Vol.5, Issue 1, January 2016
3. G. Kabir, and R. S.Sumi, "Power substation location selection using fuzzy analytic hierarchyprocess and PROMETHEE: A case study from Bangladesh. Energy 72 (2014) 717 -730.
4. F. M. González, L. Echavarren, T. G. Rouco and J. Cabetas, "Reconfiguration of large-scale distribution networks for planning studies," International Journal of Electrical Power & Energy Systems, vol. 37, no. 1, pp. 86–94, 2012. View at Publisher • View at Google Scholar • View at Scopus
5. S. N. Ravadanegh and R. G. Roshanagh, "On optimal multistage electric power distribution networks expansion planning," International Journal of Electrical Power & Energy Systems, vol. 54, pp. 487–497, 2014. View at Publisher • View at Google Scholar
6. W. Liu, L. Zhang, and J. Zhang, "Intelligent locating and sizing of substation based on GIS and PSO," in Proceedings of the China International Conference on Electricity Distribution (CICED '06), No. CP0341, Beijing, china, September 2006.
7. D. Damilola, "Geospatial ModelingOfElectricit Distribution Network"Geospatial World.2013.
8. N. Rezaee, M Nayeripour, A. Roosta, T. Niknam,"Role of GIS in Distribution Power Systems. World Academy of Science, Engineering and Technology International Journal of Electrical and Computer Engineering Vol:3, No:12, 2009.
9. O. S. Salawudeen, U. Rashidat, Electricity Distribution Engineering and GIS, 2006.