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ASSESSMENT OF WEIGHTED OVERLAY CONFIGURATION PARAMETERS TOWARDS ROUTE SELECTION IDENTIFICATION

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Abstract:

Finding the route with the lowest cumulative cost is one of the critical task in utilities management especially in power industries. Selection of the right route is a crucial aspect for identifying the most suitable and low cost path from floating solar photovoltaic system (FSPV) to proposed infrastructure facilities (IF) area that is important to reduce the travel time. The selection process involves several environmental parameters and criteria that play essential role for this route selection. Therefore, this study using ArcGIS Spatial Analyst that offer suitable processing tool that able to deals with raster data. In order to get the suitable path, weighted overlay tool being used to generate the cost surface that later used for computing the path distance and cost distance in the route selection processing. As the purpose of this study is to evaluate how the route selected based on different scenarios, different influence factor percentage and evaluation scale were set during weighted overlay processing environment. Land use type, geological type and slope degree are the three main input used to execute weighted overlay process along with the location of the infrastructure facilities and transmission main intake building. A comparative analysis from the results obtained showed that different influence factor percentage resulting to various least costly path line. However, changing the evaluation scale for the land use data giving discourage result as even the restricted value had been assigned to several land use type, the route selection did not avoid the restricted areas. To conclude from all the findings, No Data value should be assigned to the land use type to be excluded in the scale value instead of using restricted value in order to get the best route selected that avoid the restricted areas.

Keywords:

ArcGIS, Cost Path, Path Distance, Route Selection, Weighted Overlay

Introduction

Solar power is becoming more accessible, affordable, environmental friendly and efficient energy source that support sustainability towards power generation. Floating solar play crucial supplementary role as this floating solar photovoltaic (FPV) system able to work about 10% efficiently than land solar power plants as it able to reduce water evaporation with the aid from water that cools the solar panels as well as avoid occupying the land. Infrastructure facility (IF) area is one of the components in floating solar system for floating solar performance monitoring in real time. This IF features with safety equipment and alerts to help tracking any environmental factors that might harm the floating solar system as well as enables swift and timely maintenance and troubleshooting thus making the operation more reliable and robust.

Route selection is an important process to perform in order to choose suitable path that able to reduce the cost for road construction as well as avoiding restricted area to be excluded in the route selection process. Modern technology in mapping enable this route selected based on required parameter thus optimize the path chosen in smart decision making. In this study, proposed route path need to be identified to optimize low cost and travelling time from transmission main intake (PMU) building which is part of floating solar photovoltaic (FPV) system to the infrastructure facilities building.

Spatial Analyst tool in ArcGIS ArcMap is an ideal tool for this route selection process as it is more effective and save time for decision making. Weighted overlay operation in spatial analyst geoprocessing tool is the most used for overlay analysis in order to solve multi criteria problems involving feature selections. Raster data is the main input criteria layers as this tool will assigned value to the cell as the output from the decision making process. Each input raster is weighted based on its importance or influence factor percentage along with the evaluation scales. A few scenarios were prepared with different influence percentage and scale values set in the environment setting. Next, path distance and cost path analysis conducted to determine the minimum cumulative travel cost from FSPV system to IF. As this study generate seven different scenarios with different percentage influence and scale value set up, the path alignment will be observing to determine relevant route to be chosen. This is because, GIS methods proved to be relevant in solving various multi-criteria decision, route planning problems and spatial computation. Notable among them including highway route selection using intelligent optimization method based on extensive weight and TOPSIS (Liu, Wang, & Cao, 2022), least cost path analysis for landscape genetics in order to identify two dispersal routes (Vaissi and Sharifi, 2021), determine an optimum route in order to laying natural gas pipelines (Sawant and Sawant, 2023), using GIS as based for multi-criteria analysis taking consider of environmental, operational, costs and social benefits for bus route prioritizing (Emami et al., 2022) as well as cross country transport route construction which consider the technical characteristics of vehicles using GIS (K Zhigalov et al., 2020)

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Literature Review

Selection Criteria for Route

The optimization for the optimal route location is based on major criteria which includes land use/ land cover, soil classification and land slope. The study had successfully applied and created slope and land use / land cover into the route selection parameter and it is analysed that these two criteria had played major role for the selection. The model able to avoid restricted land use and high slope areas that satisfy the objective of the study (Suleiman, S., Agarwal, V.C., Lal, D., & Sunusi, A, 2015). Selection criteria used as part of multi-modal for route selection system as the selection of suitable section and criteria of the route for transportation is made by comparing multiple alternatives and transportation modes. This criteria system allows unites of various criteria to time and money basis that makes the evaluation process (Bazaras et al., 2013). Study using GIS-based analysis enclosed that multi-criteria recognized proficiently as a tool in order to determine the best route by took into account various consideration that affect decision maker's choice. Plus, this approach also efficiently saves cost, time and most importantly effort (Yasmeen Mohammed Sameer et al., 2021). The results from Least Cost Path (LCP) model by taking consider of environmental and engineering aspects of the road provide good information which can be used by concerned engineers, planners and authorities. Paid attention to the slope that is steep until the very steep, higher order stream, landslides occurrences, variety of land use types, slope aspect and protected areas especially for road development works (Magar, Shrestha, and Kayastha, 2020).

Weighted Overlay Optimization in Route Selection

Weighted overlay method for route selection analysis resulting to estimate least transportation cost from proposed facilities to potential sites based on shortest results output from this process. The least cost distribution had 95% confidence level able to be demonstrated in this study (Nguyen et al., 2022). The least cost path model using weighted overlay tool successfully avoid all the elements to be avoid within the given data and criteria. It is concluding that the shortest path algorithm and environment setting embedded during early planning proved to be time saving, economic and well suited for sustainable route design. The ability of this tool able to provide several alternatives as well avoid many location problems and such alternatives will give benefit to the decision maker (Effat & Hassan, 2013). Data overlay using Weighted Overlay tool is very convenient as it is useful for problem solving that require larger variables set to cover vast area especially for inaccessible area (B. Ashimova et al., 2023). This method also widely used for sampling from routes for commercial vessel in order to capture marine biodiversity distributions efficiently (Boyse et al., 2023), measuring urban bikeability for designing a bike-friendly city (Schmid-Querg et al., 2021) and modelling landscape connectivity for African elephants considering variability across individuals and seasons Osipova et al. (2018).

Study Area and Selection Criteria

Study Area

The study area is located at the southern part of Chenderoh Lake, Perak with elevation of 70m above sea level. It is a natural lake in Kuala Kangsar District that is popular as major and oldest hydroelectric dam in Malaysia situated which is Chenderoh Power Station. The lake was covered mostly by swampy forest that becomes major habitat for flora and fauna. Chenderoh Lake is one of the eco-tourism spot as many activities available such as boat trip, lotus seed

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harvesting and many more. The location of the study area, infrastructure facilities area and FSPV as shown in Figure 1.

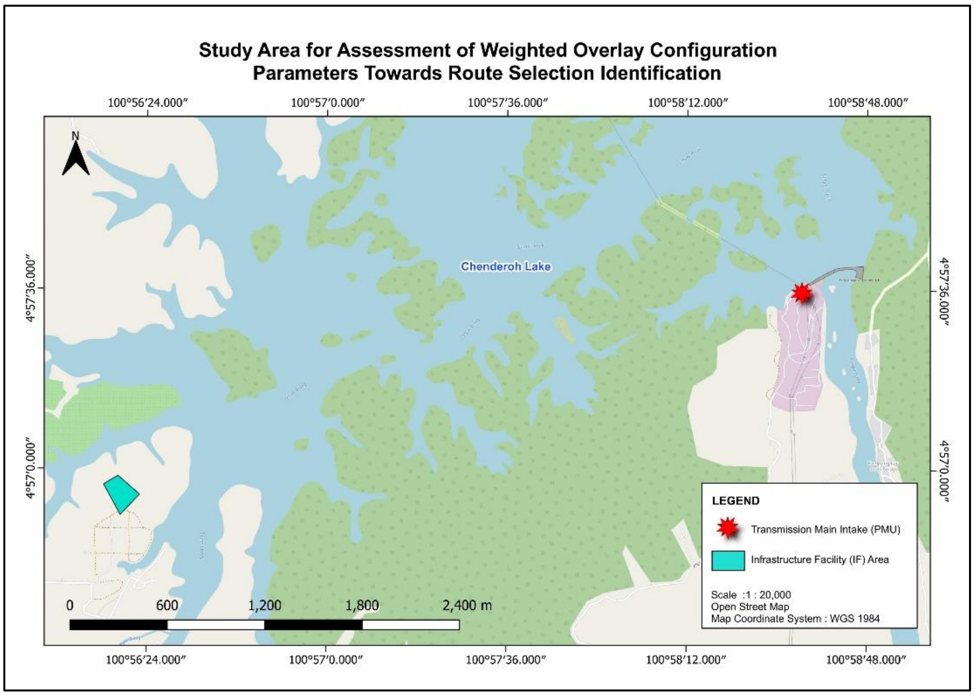

Figure 1: Location of Study Area

Selection Criteria

There were three major criteria considered for route selection process. First, the slope must be gradual as steep slope required earthworks for route construction. Next, the suitability of land use is important as landed and bare area were preferable than water bodies and restricted area as it is costlier to construct route. Last, the geological type must within volcanic rocks lithology as it is more stable for route construction.

Methodology

Data

All the data input for weighted overlay process was in raster data format and had been reclassify into desire ranking.

Slope

Slope data was originally generated from Digital Terrain Model (DEM) with cell size of 30m X 30m obtained downloaded from earth explorer (earthexplorer.usgs.gov). The slope data reclassifies into seven ranks according to the steepness of the terrain. The least steep terrain ranks as top priority and steepest slope ranks with higher value.

Land Use

Land use data is based on existing land use shapefile updated on 2015. This data was converted into raster where the ranking field is the value for the raster data. The ranking of the land use as below depends on the ground condition of the study area. Open area and accessible area were on top ranking while restricted and water bodies area rank higher.

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Geology

Geology data obtained from updated geology map provided by Department of Mineral and Geoscience Malaysia. All the lithology rank into its suitability for route structure and ground stability. Igneous rocks type was at the top ranks while sedimentary rocks ranks the least suitable.

Vector data also used for path distance and cost path process. The data consist of location of transmission main intake (PMU) and infrastructure facility area.

Data Processing

Before starting the processing, it is important to ensure all raster and vector have the same coordinate system. For this study, Kertau RSO Malaya (Meters) has been used as permanent projection. There were three spatial analyst tools that will be used in order to determine the best route selection.

Weighted Overlay

The first step for route selection is to generate cost surface based on the criteria that have been set. The slope, land use and geology data set as the main input for this process. For this study, percentage influence and scale value will be varying as few scenarios will be develop. The seven scenarios were as follows,

- Scenario 1: 50% slope + 35% land use + 15% geology
- Scenario 2: 15% slope + 50% land use + 35% geology
- Scenario 3: 35% slope + 15% land use + 50% geology
- Scenario 4: 33% slope + 34% land use + 33% geology with restricted scale value for water bodies
- Scenario 5: 33% slope + 34% land use + 33% geology with no data scale value for water bodies
- Scenario 6: 33% slope + 34% land use + 33% geology with higher scale value for water bodies
- Scenario 7: 33% slope + 34% land use + 33% geology with higher scale value for restricted area and restricted value for water bodies

In order to minimise the processing time, this study had refer to the model for best highway route selection develop from previous study. Model builder used to weight all the multiple criteria that have been determined during the study as well as ensuring all the criteria had been correctly processed to produce a good weighted overlay result (Yasmeen Mohammed Sameer et al., 2021).

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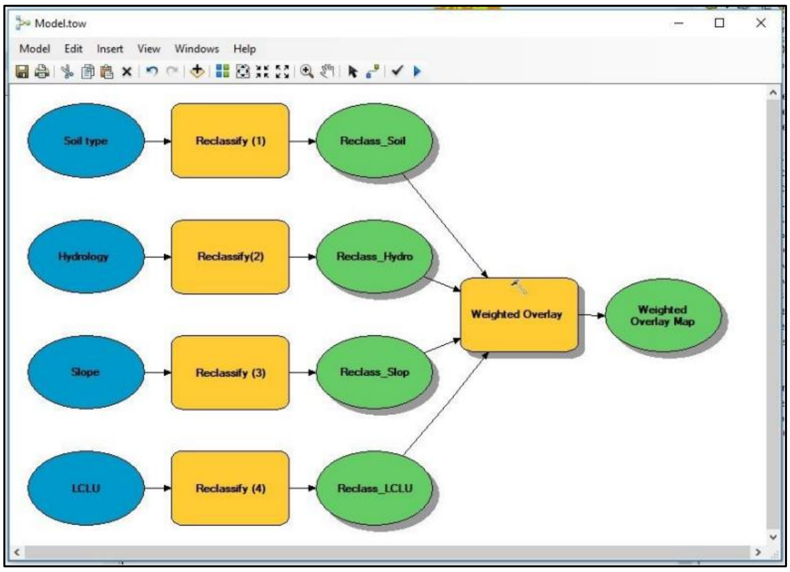

Figure 2: Example of Model for Best Highway Route

Source: (Yasmeen Mohammed Sameer et al., 2021)

Path Distance

After the cost surface had obtained, this process will identify the least accumulative cost distance over the cost surface to the proposed infrastructure facility (IF) area while taking account the surface distance. The result from this process will generate distance and backlink raster to be used for the next step.

Cost Path

This tool will generate recording of the least-cost paths from IF to PMU location within the accumulative cost surface. Backlink raster will be used as input to determine the pattern or alignment of the path according to the least cost distance surface. This raster also determines the direction to travel on the cell with the accumulative cost path returning to the source point.

Selection of Best Route

All the seven results will be compared according to the selection criteria. In order to get a better path alignment visualized, all the results from cost path analysis were converted into polyline. After all, route with less complexity, shortest route and avoiding water bodies will be the top priorities in selecting the best route.

Result and Discussion

Result

Based on the result obtained from the route selection process with different parameters for influence percentage and scale value set during environment setting, there were various route alignment generated by the process. Figure 2 shows the result for all the seven scenarios generated.

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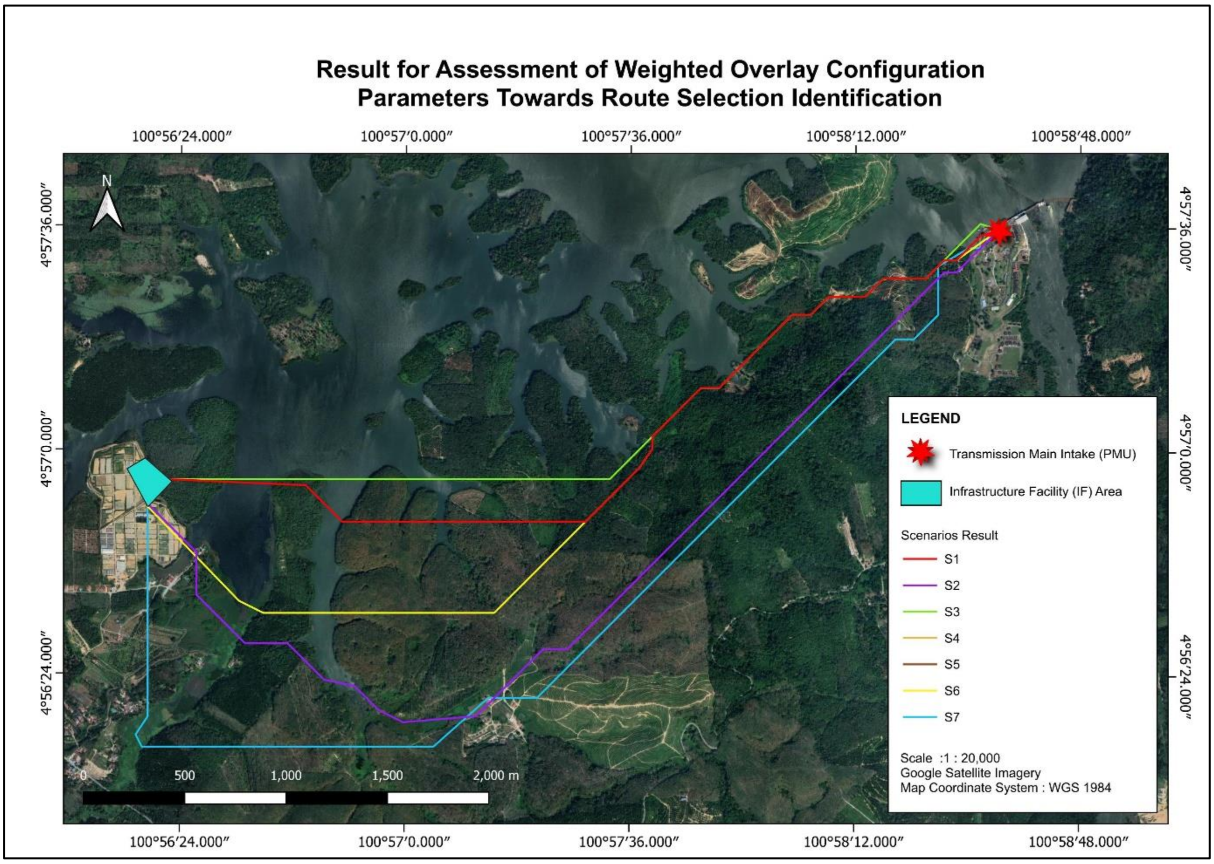

Figure 3: Result of Route Selection Process

Analysis for the result based on the scenarios created is explained as follows:

1. Scenario 1: This scenario indicates higher percentage influence for slope layer. The result shown in red line specify that the route constructed on gradual and low steep slope but crossing the lake area.
2. Scenario 2: This scenario indicates higher percentage influence for land use layer without changing the scale value. The result shown in purple line specify that the route constructed trying to avoid the lake area but still passing through swampy area.
3. Scenario 3: This scenario indicates higher percentage influence for geology layer. The result shown in green line specify that the route constructed on the lowest elevation ground and crossing the lake area.
4. Scenario 4: This scenario indicates same percentage for all layer but using “Restricted” scale value for water bodies and restricted land use. The result obtained unable to create any route path.
5. Scenario 5: This scenario indicates same percentage for all layer but using “No Data” scale value for water bodies and restricted land use. The result obtained unable to create any route path same with Scenario 4.
6. Scenario 6: This scenario indicates same percentage for all layer but using higher scale value for water bodies and restricted land use. The result shown in yellow line specify that the route constructed crossing the lake and swampy area.
7. Scenario 7: This scenario indicates same percentage for all layer but using higher scale value for restricted land use and “Restricted” scale value for water bodies. The result shown in blue line specify that the route constructed did not crossing the lake and swampy area.

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Discussion

The route selected based on different scenarios constructed in various path alignments. It is the best to choose the route that meet the criteria especially for the land use type. This is because the route must be less cost to be construct. If the route crossing any water bodies area, the route is unsafe to be constructed. From all the seven scenarios, five scenarios successfully construct the route even with different alignment. Path from scenarios 7 and 2 is longer than others but these two path successfully meet the criteria for this study. Even shortest route might reduce the time travel, the cost for the route construction may be higher as bridges need to be constructed to cross lake and swampy areas. From scenarios 4, 5, 6 and 7, land use scale value been changed in order to find the route that able to avoid water bodies area. After all, the results from all the scenarios were ranked to select the best route with suitable parameters. Table 1 shows the ranking for the route selection.

Table 1: Route Selection Ranking

Scenario	Water Bodies Avoidance	Ranking
1	No	4
2	Yes	2
3	No	5
4	No	6
5	No	7
6	No	3
7	Yes	1

Conclusion and Recommendations

Conclusion

As the conclusion, this study had successfully carried out assessment based on various scenarios by using different percentage influence and scale value for route selection. From the analysis of result, it is compulsory to avoid any water bodies area in order to reduce the cost for route construction. The longer the route may increase the distance and time travel from the two location but it is the best to avoid this condition. For Chenderoh lake area is famous with its biodiversity and became major habitat for flora and fauna. Environmental need to be conserved even the route need to be constructed at any path alignment. Plus, restricting water bodies in scenario 7 is a good decision as the route alignment had avoided lake and swampy area. The use of "Restricted" and "No Data" scale value need to wisely determine as it will result to unpleasant behaviours towards path generation. "Restricted" scale value assign to the cell is the minimum value of the scale evaluation thus all the area need to be avoided will be chosen as it had assigned with low cost path. Instead, use "No Data" for the avoided area but ensuring there were none no data value in the raster used.

Recommendations

In the future, this study may be extending to different criteria set for the environment setting in weighted overlay process. For example, soil category, Environmental Sensitive Area (ESA), wildlife conservation and water flow element able to play major parts in selecting suitable route. Besides that, evaluation scale may be set differently for each element instead of setting the percentage influence to monitor how the path alignment will be generating from the route selection process. Last, comparison between "Restricted" and "No Data" scale value need to be analysed to identify how this scale type influence the route selection result.

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