Tiga Dihaji Dam Access Route Plan Alternative using Geographic Information System (Cost Distance Method)

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Abstract. The Tiga Dihaji dam access route function is destined for heavy equipment during the dam construction period. It is located on Tiga Dihaji sub-district, Ogan Komering Ulu Selatan district, South Sumatera, Indonesia. The Tiga Dihaji access route supervisor stated that the planning justification was done using expert judgement based on contour map and local land cover. This method is considered less measurable. Therefore, the Geographic Information System method is offered in this paper to determine the most suitable Tiga Dihaji dam access route. The parameters considered are landslide vulnerability, land cover and construction factors. These parameters are overlaid based on weights determined by the Public Works Department then validated by expert judgement. The new route is proposed using the cost distance method. Based on the analysis, it can be concluded that the cost distance method is more measurable than the planned method, but this method produces a less suitable route in terms of civil engineering.

1. Introduction
There have been a lot of studies to map the most suitable route plan using Geographic Information System (GIS). The main aim of the earlier study was to present a GIS-based method to determine the optimal layout of the haul route for large earthmoving projects. The methodology used was cost distance measurements to implement a least-cost path analysis to calculate the route with the shortest weighted distance. Various factors, such as truck speed, construction cost, and land use are investigated [4]. However, in this paper, adjustment must be done to the location factors. The route plan must consider the disaster mitigation in case of Ogan Komering Ulu Selatan is categorized as landslide-prone area [10]. The landslide mapping is made based on eight parameters specified by Indonesian Disaster Management Agency namely slope, aspect, slope length, rock type, distance from the fault, soil type, soil depth, and annual rainfall [3].

2. Methodology
2.1 Geographic Information System
GIS is a tool on a computer to capture, store, explore, analyze, and display geographic information. GIS provides spatial solutions in the fields of civil engineering such as transportation, water resources, facility management, urban planning, construction and E-Business. GIS is an effective tool in describing the topography of construction sites. GIS increases the efficiency of construction planning and design by integrating spatial information and attributes in the same scope [1].
2.2 On-Screen Digitation
Remote sensing imagery interpretation can be done in two ways, namely digital and visual/manual interpretation [6]. In the visual/manual interpretation, grouping pixels into a predetermined class is done visually/manualy based on the object interpretation key in the image. This method is a technique for sensing satellite imagery based on the appearance of objects seen on a computer display/on-screen digitation [11]. In this paper, the on-screen digitation is done based on orthorectified SPOT 7 satellite imagery acquired in 2019. The validation is done using the confusion matrix. The ground truth survey is replaced by Google Earth Pro Software (the base map images acquired in 2019 with the resolution of 0.5 m) and RBI map in the scale of 1:50,000 due to COVID-19 pandemic. The minimum kappa value must be more than 0.8 and overall accuracy value of 85% [5].

2.3 Overlay
Overlays are an important part of spatial analysis. Overlays can combine several spatial elements into new spatial elements. In other words, overlays can be defined as spatial operations that combine different geographic layers to get new information [9]. The overlay process is done using ArcGIS 10.3. The weights are determined based on the prior study proposed by Kang & Seo (2013) with the local condition adjustment, Indonesia Disaster Risk Document published by Indonesian Disaster Management Agency (2016) and expert judgement. The weights are as follows:

| No | Parameter               | Sub-Parameter | Sub-Weight | Weight |
|----|-------------------------|---------------|------------|--------|
| 1  | Landslide Vulnerability | Slope         | 0.3        | 0.45   |
|    |                         | Aspect        | 0.05       |        |
|    |                         | Slope length  | 0.05       |        |
|    |                         | Rock type     | 0.2        |        |
|    |                         | Distance from the fault | 0.05 |        |
|    |                         | Soil type     | 0.1        |        |
|    |                         | Soil depth    | 0.05       |        |
|    |                         | Annual rainfall | 0.2 |        |
| 2  | Land cover              |               |            | 0.2    |
| 3  | Construction Factors    | Cut and fill  | 0.3        | 0.35   |
|    |                         | Dump Truck Performance | 0.2 |        |
|    |                         | Safety        | 0.5        |        |

The classifications are also determined based on prior study proposed by Kang & Seo (2013) with the local condition adjustment, Indonesia Disaster Risk Document published by Indonesian Disaster Management Agency (2016) and expert judgement. The classifications are as follows:

| No | Data | Parameter | Pengkelsan | Nilai Kelas | Skor |
|----|------|-----------|------------|-------------|------|
| 1  | DEM  | Slope     | 15 – 30%   | 1           | 0.250|
|    |      |           | 30 – 50%   | 2           | 0.500|
|    |      |           | 50 – 70%   | 3           | 0.750|
|    |      |           | >70%       | 4           | 1.000|
| 2  |      | Aspect    | Flat       | 0           | 0.000|
|    |      |          | South      | 1           | 0.125|
|    |      |          | Northwest  | 2           | 0.250|
|    |      |          | West       | 3           | 0.375|
|    |      |          | Northeast  | 4           | 0.500|
|    |      |          | Southwest  | 5           | 0.625|
| Slope length/shape | Score |
|--------------------|-------|
| <200 m             | 0.250 |
| 200 – 500 m        | 0.500 |
| 500 – 1000 m       | 0.750 |
| >1000 m            | 1.000 |

| Rock type          | Score |
|--------------------|-------|
| Alluvial           | 0.333 |
| Sediment           | 0.667 |
| Vulcanic           | 1.000 |

| Distance from fault | Score |
|---------------------|-------|
| >400 m              | 0.200 |
| 300 – 400 m         | 0.400 |
| 200 – 300 m         | 0.600 |
| 100 – 200 m         | 0.800 |
| 0 – 100 m           | 1.000 |

| Soil type           | Score |
|--------------------|-------|
| Sandy              | 0.333 |
| Clayey-Sandy       | 0.667 |
| Clayey             | 1.000 |

| Soil depth          | Score |
|--------------------|-------|
| <30 cm              | 0.250 |
| 30 – 60 cm          | 0.500 |
| 60 – 90 cm          | 0.750 |
| >90 cm              | 1.000 |

| Annual rainfall     | Score |
|--------------------|-------|
| <2000 mm            | 0.333 |
| 2000 – 3000 mm      | 0.667 |
| >3000 mm            | 1.000 |

Table 3. Land cover classification (Expert Judgement, 2019)

| No | Detail    | Score |
|----|-----------|-------|
| 1  | Open land | 1.0   |
| 2  | Field     | 0.8   |
| 3  | River     | 0.6   |
| 4  | Forest    | 0.4   |
| 5  | Residence | 0.2   |

Table 4. Cut and Fill Classification (Kang & Seo, 2013)

| No | Slope (%) | Detail            | Score |
|----|-----------|-------------------|-------|
| 1  | 0 – 20    | Low cost          | 1.0   |
| 2  | 20 – 50   | Costly enough     | 0.8   |
| 3  | 50 – 100  | High cost         | 0.6   |
| 4  | 100 – 200 | Very high cost    | 0.4   |
| 5  | > 200     | Almost impossible to be filled | 0.2  |

Table 5. Dump Truck Performance Possibility Classification (Kang & Seo, 2013)

| No | Slope (%) | Detail        | Score |
|----|-----------|---------------|-------|
| 1  | 0 – 3     | Normal        | 1     |
| 2  | 3 – 5     | Work hard     | 0.8   |
| 3  | 5 – 10    | Very hard work| 0.6   |
| 4  | 10 – 20   | Too hard work | 0.4   |
| 5  | > 20      | Too much hard work | 0.2  |

Table 6. Safety Classification (Kang & Seo, 2013)

| No | Distance to The Water Body (m) | Detail  | Score |
|----|--------------------------------|---------|-------|
| 1  | 0 – 3                          | Normal  | 1     |
| 2  | 3 – 5                          | Work hard | 0.8   |
| 3  | 5 – 10                         | Very hard work | 0.6   |
| 4  | 10 – 20                        | Too hard work | 0.4   |
| 5  | > 20                           | Too much hard work | 0.2  |
### Cost Distance

The optimal route that connects to the parameters within or outside the route sites can be calculated using cost distance in GIS. Spatial analyst tools [2] provide a method for measuring the cost distance. These tools apply distance in cost units, not geographic units and generate two outputs, namely the least accumulated cost distance raster and the cost back-link direction [4]. This calculation in this paper is done using ArcGIS 10.3.

### Discussion and Result

#### Mapping

The mapping process is done using ArcGIS 10.3 toward the three main parameters, namely landslide vulnerability, land cover and construction factors.

##### Landslide Vulnerability

The landslide vulnerability mapping is based on Table 2 with the result as follows,

|   | Interval | Grade | Cost |
|---|----------|-------|------|
| 1 | 0 – 10   | Bad   | 0.25 |
| 2 | 10 – 20  | Enough| 0.5  |
| 3 | 20 – 30  | Good  | 0.75 |
| 4 | > 30     | Excellent | 1    |

It can be seen that in the southern part of the study area has higher landslide vulnerability compared to the northern regions. This can occur because the topography in the southern region is steeper than the northern region due to the Semangko fault presence. The result above is validated with the landslide vulnerability map published by Indonesia Disaster Management Agency. The total sample points are 30 spread evenly in the study area. The equation and the R² value can be seen through the chart below.
Figure 2. The Correlation of Landslide Vulnerability (Result)

The value of 0.8716 represents very strong correlation [7] between the landslide vulnerability made in this paper and the landslide vulnerability map published by Indonesia Disaster Management Agency. Therefore, the landslide vulnerability map made in this process can be used for further analysis.

3.1.2. Land Cover

The land cover map is obtained through on-screen digitization process based on orthorectified SPOT 7 satellite imagery. The mapping result is as follows,

It can be seen from Figure 3 the land cover of the study area is dominated with field and forest. It happens because this area is still classified as a sparsely populated area. The open land will soon be used by the residents to farm for a profit; therefore, the appearance of open land is far less compared to the field.

The land cover map is validated using confusion matrix. In confusion matrix, the ground truth data is needed. This data should be obtained through field survey. But due to COVID-19 pandemic, this method cannot be implemented. Therefore, to do confusion matrix calculations, land cover maps are matched to the field using the help of Google Earth Pro software (using base map CNES satellite imagery with 0.5-meter resolution) and RBI in the scale of 1:50.000. The confusion matrix are as follows,
Table 7. Ground Truth Calculation Based on Google Earth Pro Software (Result)

| Ground Truth | Open Land | Field | River | Forest | Residence | Sum |
|--------------|-----------|-------|-------|--------|-----------|-----|
| This Paper   |           |       |       |        |           |     |
| Open Land    | 21        | 4     | 1     | 4      | 0         | 30  |
| Field        | 1         | 29    | 0     | 0      | 0         | 30  |
| River        | 0         | 0     | 24    | 6      | 0         | 30  |
| Forest       | 0         | 1     | 0     | 29     | 0         | 30  |
| Residence    | 0         | 0     | 0     | 1      | 29        | 30  |
| Sum          | 22        | 34    | 25    | 40     | 29        | 150 |

Table 8. Ground Truth Calculation Based on RBI Scale of 1:50.000 (Result)

| Ground Truth | Open Land | Field | River | Forest | Residence | Sum |
|--------------|-----------|-------|-------|--------|-----------|-----|
| This Paper   |           |       |       |        |           |     |
| Open Land    | -         | -     | -     | -      | -         | -   |
| Field        | -         | 29    | 0     | 0      | 1         | 30  |
| River        | -         | 0     | 30    | 0      | 0         | 30  |
| Forest       | -         | 1     | 0     | 29     | 0         | 30  |
| Residence    | -         | 1     | 0     | 0      | 29        | 30  |
| Sum          | -         | 31    | 30    | 29     | 30        | 120 |

Based on the confusion matrix above, we can obtain overall accuracy value of 88% for Google Earth Pro and 97.5% for RBI; and a kappa value of 0.85 for Google Earth Pro and 0.96 for RBI. These values present the truth level of classification result, and the results have met the classification accuracy requirements of more than 85% and kappa of more than 0.8 [5]. Therefore, the land cover map can be used for further analysis.

3.1.3. Construction Factors
The construction factors considered are cut and fill needed, dump truck performance possibility and safety. The cut and fill and dump truck performance sub-factors are obtained from Digital Elevation Model (DEM) processing. The safety sub-factor is calculated based on the site distance to the water body. The three sub-factors then overlaid based on Table 1 with the result as follows,
In line with the landslide vulnerability map, this mapping also shows less recommended values in the southern region.

3.1.4. Final Mapping
The final mapping is done based on the final weight in Table 1. The three main parameters are overlaid using Raster Calculator tool in ArcGIS 10.3 with the result as follows.

In line with the previous mapping, this mapping also shows less recommended values in the southern region. This map is further used as a basis for evaluating the route planned.

3.2 Cost Distance Analysis
The cost distance analysis is done using the spatial analyst toolbox in ArcGIS 10.3. The route analysed contains two sections, namely section 1 and section 2. Section 1 connects the nearest village to the dam
site while section 2 connects the section 1 to the public facility. The initial route plan with the base map of final mapping is as follows,

![Figure 6. The Route Location (Result)](image1)

![Figure 7. The Route Layout (Result)](image2)

With each section route are as follows,

![Figure 8. Initial Route Plan Section 1 (Result)](image3)

![Figure 9. Initial Route Plan Section 2 (Result)](image4)

Each point then calculated based on the gradation site as follows,

![Figure 10. Graph of Initial Route Section 1 (Result)](image5)
The cost distance analysis is also done using the final mapping base map. The result of cost distance analysis for each section is as follows,

Each point then calculated based on the gradation site as follows,
planned. The distance determined through the cost distance method is also shorter than the initial plan. But, several problems appear toward the road construction consideration set by the public works department, namely the maximum length, minimum radius, and also the correlation to the unmeasurable components.

It can be seen in Figure 12 compared to Figure 8, that the initial plan needs two bridges while the new plan (obtained by cost distance calculation) only needs one bridge. But, the judgement may not be that simple. The bridges from the initial plan are located in tributaries which have lower flow strength compare the new plan. Furthermore, in the civil engineering field, this case is essential to consider toward the possibility of bridge component scoring, the strength of the structure, the structure length and many more. It is judged that the initial plan has better consideration in this case. The new plan is also not under the regional spatial plan. A part of the initial route intersects with the road plans planned by the government while the new plan does not seem to have the same coordination.

The new route for section 2 is shorter than the initial. It also has a better gradation of recommendation level compared to the initial plan. But, several aspects must be considered beside the length and the gradation. It can be seen from Figure 13 that the route intersects with the part of dam building. Therefore, this plan is not possible to be implemented.

4. Conclusions
Based on the analysis it can be concluded that the cost distance method can determine the shortest and the best gradation for Tiga Dihaji Dam route access. This method is more measurable than the previous method, but this method produces a route that is less suitable in terms of civil engineering. In the future, this method can be used with a qualitative approach and expert judgement to obtain more appropriate measurable route that can be implemented in the field.

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