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Analytical Hierarchy Process and Power Method for Flood Evacuation Route Selection

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Abstract

Floods are recurrently appearing in the headings of local, national and international mass media. Flood as a geo-hazard challenge in many populated territory on the planet. People are trying to mitigate and find ways to minimize damages. Among the initiatives are flood mitigation plans. These tactics can be classify into two categorihich is (a) structural flood mitigation is where physical structures are constructed or modified to reduce the impact of flooding on individual properties or whole catchments, and (b) non-structural flood mitigation can be considered as a lot of moderation as well as adjustment estimates that don't utilize customary basic flood safeguard measures. The tricky situation in handling flood challenges is the multi-layered information that need to be deciphered by the hydrologists in the decision making. To deal with the flood occasions requires to a noteworthy degree a decent plan and development of a flood control system, and taking appropriate measures for flood relief including non-basic measures, flood determining, cautioning and moderation plans. This paper looks at the evacuation route selection through multi-criteria decision-making. The Analytical Hierarchy Process (AHP) technique is utilized to choose the best evacuation route over variance weighting of different criteria and sub-criteria. A learning-driven expert-based GIS model for Kelantan river basin was developed with three design parameters, i.e. accessibility, technical and safety. The model successfully predicted the best route for evacuation centres in Kelantan. In common, the developed model were reasonably accurate. The resultant maps would be useful for regional flood mitigation planning.

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Keywords: Analytic hierarchy process (AHP), route selection, multi-criteria decision-making, geographical information system (GIS), Power method

1 Introduction

Flood is one of the most common natural disaster happening globally. Throughout history floods have been affecting lives and livelihood and have raised environmental and socio-economical concerns over the years. Flood is also a common natural disaster in Malaysia which occur almost every year during the monsoon season. The 2014/15 Malaysia floods influenced Malaysia from 15 December 2014 – 3 January 2015. More than 200,000 individuals were affected while 21 were killed [1] during this time. This flood has been named as the most deplorable flood that has ever occurred in Malaysia in decades [2].

Flooding happens most frequently from heavy rainfall whereby as soon as natural streams do not have the volume to transfer excess water the water will overflow. Moreover, given Malaysia's topographical position, most floods that happen are a characteristic result of the recurrent rainstorm that is portrayed by overwhelming and normal precipitation from generally October to March [3]. An efficient evacuation route selection is key for a better flood mitigation plan. (Reference). Flood is a run-off of water that stifles land, and may make harm farming terrains, urban zones, and may even bring about loss of lives. [4]

Lacking seepage in the majority of the urban regions additionally improve the impacts of substantial downpour, however endeavours are in progress to determine this. Evacuation centres are identified by the local authorities to help affected lives in the flood affected areas. This work looks at how flood-affected constituents and authorities can identify the best route to an evacuation centre. The principle goal of this study is to identify a technique for flood evacuation route selection in Kelantan river basin, Malaysia. An analytic hierarchy process (AHP) model [5] is developed for flood evacuation route selection in this work.

2 Material And Method

2.1 Study Area

The study area is Kelantan river basin. It is based on the Kelantan big flood of 2014 [6] with data obtained from Department of Irrigation and Drainage (DID) which comprise of (a) discharge river course, (b) rainfall and (c) water level surface.

2.2 Study Approach

The study aims to find a way to generate the best evacuation route during flood occurrence(s). The study began by sourcing both spatial and non-spatial data from difference sources. Upon acquisition of the data, they were pre-processed, standardised and prioritised in order that they become consistence in terms of extent. The Framework for the evacuation route selection as shown in Fig. 1. Simulation for the December 2014 flood event was done at Kelantan River basin using Rainfall-Runoff-Inundation (RRI) Model.

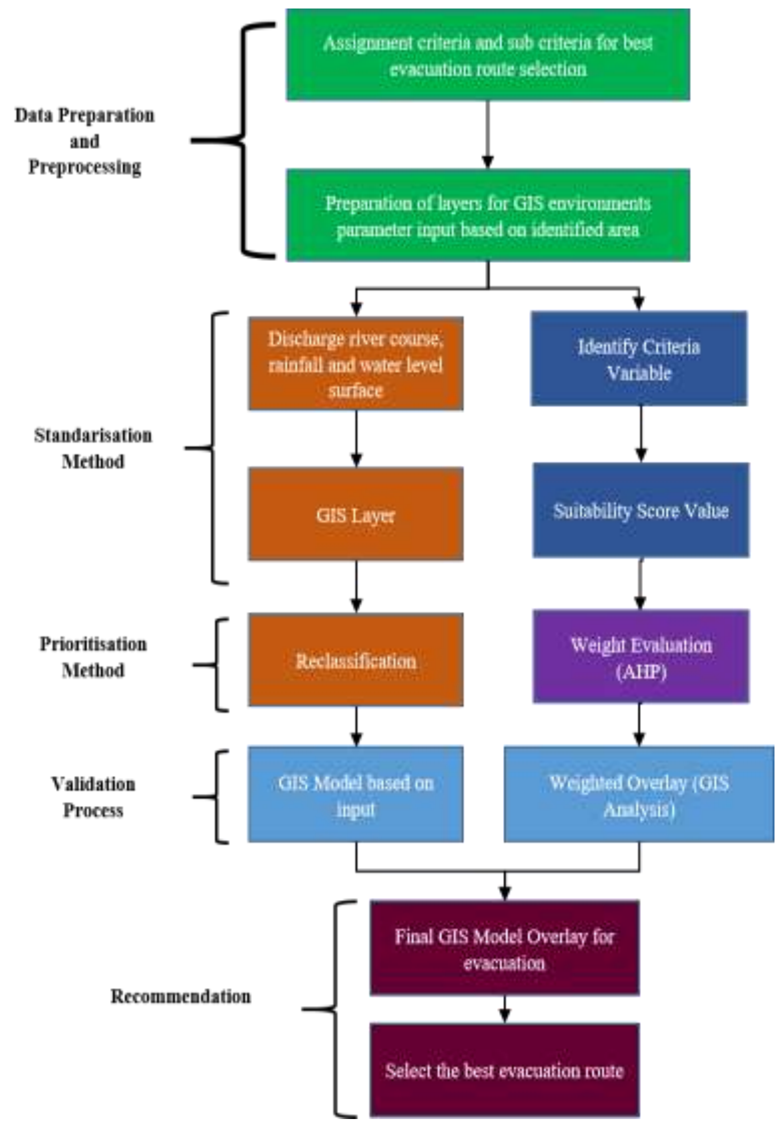


Figure 1 Framework For The Best Evacuation Route Selection

RRI model is a two dimensional rainfall-runoff model which is adept in stimulating rainfall-runoff and flood inundation concurrently.

In in Malaysia, flood monitoring is under the management of Department of Irrigation and Drainage (DID), Ministry of Water, Land and Natural Resources. Fundamentally, the DID holds a web portal that is well-known as "Infobanjir" Portal [7].

This web portal captured and displays day-to-day reading at all flood stations which installed at specific location. The online keep informed to be available for 24-hours and had an interval of 4 hours before it is confirmed to be scattered on its portal.

Subsequently 24-hours display, the statistics will be hold back in the DID records and can only be retrieved by official application to their officers.

Fig. 2 shows the process data of discharge river course, rainfall and water level surface in a viewable format (GIS platform); and simulation for flood event December 2014.

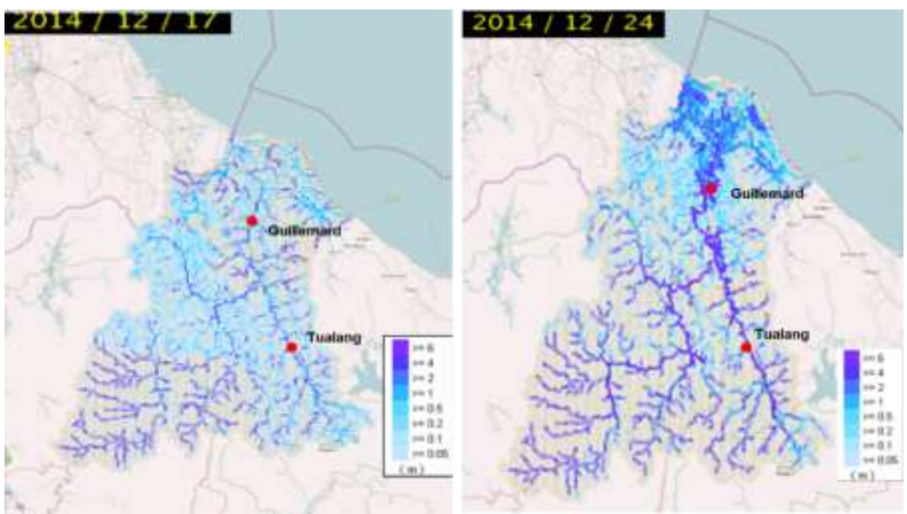


Figure 2 Simulation For Flood Event December 2014 Using RRI Model At Kelantan River Basin

2.3 MCDM and Analytic Hierarchy Process (AHP)

Multi-Criteria Decision Making (MCDM) consist of one or more objectives where characterized as the state of the framework to be chosen, over a characterized set of possible results. AHP strategy is created by Thomas Saaty to help complex choices associating an immense number of decision-makers and criteria [8-9][10][13][14][15][16]. It is extraordinary compared to other portrayed and approves the technique for MCMD. As demonstrated by Saaty, settling on the choice about needs means disintegrating the choice procedure into the accompanying advances:

- By defining the problem and define the kind of knowledge required
- Choice progression is organised start to finish as pursues: the objective of the choice, trailed by the targets from wide-extending

The overall significance of criteria just as sub-criteria as for the goal of study, criteria are positioned utilizing a Saaty scale [7], which structures five fundamental positions of intensity (1 – equivalent significance, 3 – moderate significance, 5 – solid significance, 7 – exceptionally solid or exhibited significance, 9 – extraordinary significance). The best choice is separated subject to the well-portrayed all-out weight need vector via merging entirely weight vectors, this one is depicted through the expression as below:

$$W_i = \sum_{j=1}^{n} c_j w_{ij,} \ \forall i = 1, \dots, m, \quad (1)$$

where: Wi – weight, need of elective I; cj - weight of creation j; m – number of substitutes; n – number of criteria. Saaty watched that for the strong integral system, the greatest eigenvalue is proportional to the quantity of assessments, or on the other hand λ max = n. [9]. He additionally characterized a proportion of consistency, which otherwise called the Consistency Index (CI), which demonstrates the deviance or consistency degree by methods for the going with formulation:

$$CI = \frac{\lambda_{\max -} n}{n-1} \quad (2)$$

Saaty recommended CI must be contrasted and the comparing arbitrary CI (RI). Added by Saaty haphazardly created corresponding networks utilising scale and decided the RI to choose in the event that it was around 10% or less. The CR contrasts the CI and RI:

$$CR = \frac{CI}{RI} \quad (3)$$

On the off chance that CR is littler or equivalent to 10%, the irregularity is adequate. In the event that CR is more than 10%, the inclination should re-examine.

2.4 Route Selection Analysis Hierarchy for Flood Evacuation

Numerous parameters must be mulled over when performing route selection. The determination of best route for evacuation depends on the comprehensive and correct understanding of factors and how to select them. In this study, the particular factors are based on several research studies and expert opinions. The criteria related to this study as shown in Fig. 3 which are Accessibility, Safety and Risk Assessment together with their sub criteria. The subset for the accessibility factor are distance from the rivers (m), distance from the evacuation centre (m), length of route selection (m), and drivability.

The distance from the river is one of the primary sub-factor as the nearer the road towards river it has high tendency to be inundated. Distance from the evacuation centre is also another sub-factor that is considered to be a critical option. The selection of the evacuation centre need to be out of any flood prone area. In addition, length of the route selection and the drivability are another factors that equally important when the route selection process is done.

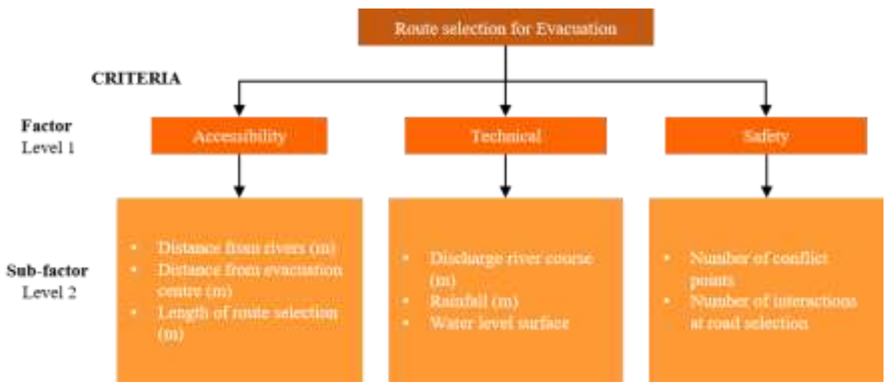


Figure 3 Route Selection Analysis Hierarchy For Evacuation

On the other hand, the technical factor is one of three sub-factors, i.e. discharge river course, rainfall (m), water level surfaced (m). These factors are obtained from the historical data of previous flood occurrences in Kelantan.

The safety factor has two sub-factors criteria which are number of conflict points and number of intersection at route selection. The route selected shall not have large number of conflict points and intersections that meet the river.

3 Results and Discussion

All the technical factors were processed, classified and plotted using GIS platform into viewable format. The discharge river course, rainfall and water level surfaced data are processed, classified and plotted using GIS platform into a viewable format as shown in Fig. 4, 5 and 6 respectively. Fig. 4 shows the plotted discharge river course which is the volume of water flowing through Kelantan river basin. Data Collected rainfall data for Kelantan from DID were converted into GIS as shown in Fig. 5. shows the The data are from the historical flood events at Kelantan. These data are used in studying the relationship on how to select the best evacuation route. Fig. 7 shows the formation of relative importance of one criterion over another and is expressed using the pairwise comparison matrix. A flood inundation map is developed using ArcGIS online with the collected spatial historical data., The evacuation centre which obtained from Malaysia Civil Defence Force and Kelantan road were also developed using the GIS as shown in Fig. 8.

Ranking of priorities from a Pairwise matrix is identified using eigenvector. The ranking is obtained by squaring the matrix of pairwise and the sums are calculated and normalised using AHPcalc developed by Klaus D. Goepel [11,12]. Algorithm of power method is used to solve eigenvalue which resulting in much higher accuracy. Fig. 9 shows the matrix calculation which developed from the pairwise comparison matrix. The normalized principal Eigenvector known as the vector of priority. Since it is standardized, the aggregate all things considered in the priority vector is 1 as shown in the Fig. 10, the overall summary of AHP.

In short, the analytic hierarchy process offers a logical framework to conclude the benefits of each factor as below (a) Technical – 55.84%; (b) Safety – 31.96% and (c) Accessibility – 12.20%. Based on the logical framework the technical factor is ranked highest ranked for the route selection possibility.

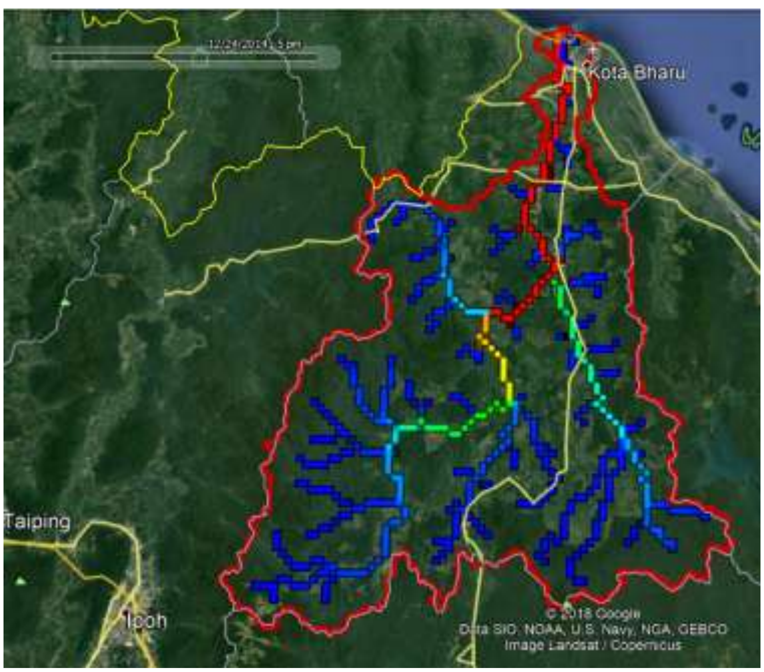


Figure 4 Discharge River Course

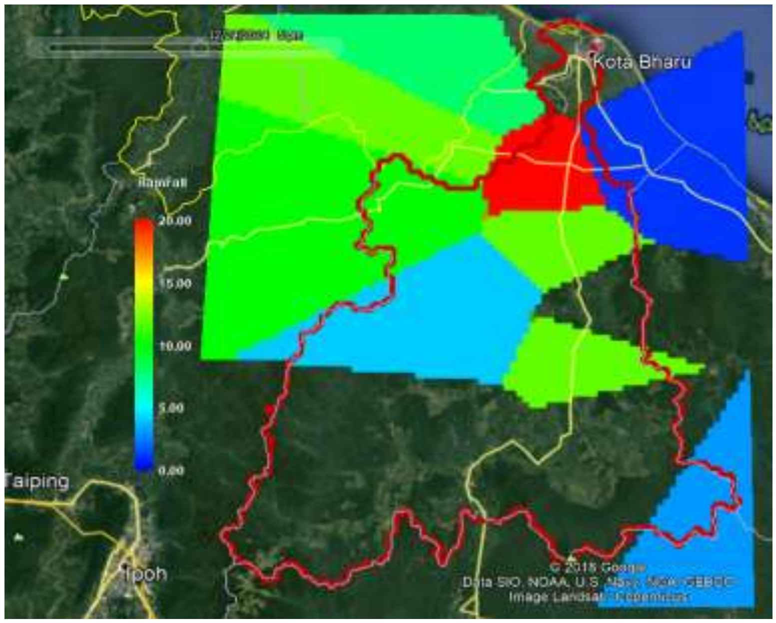


Figure 5 Rainfall Data

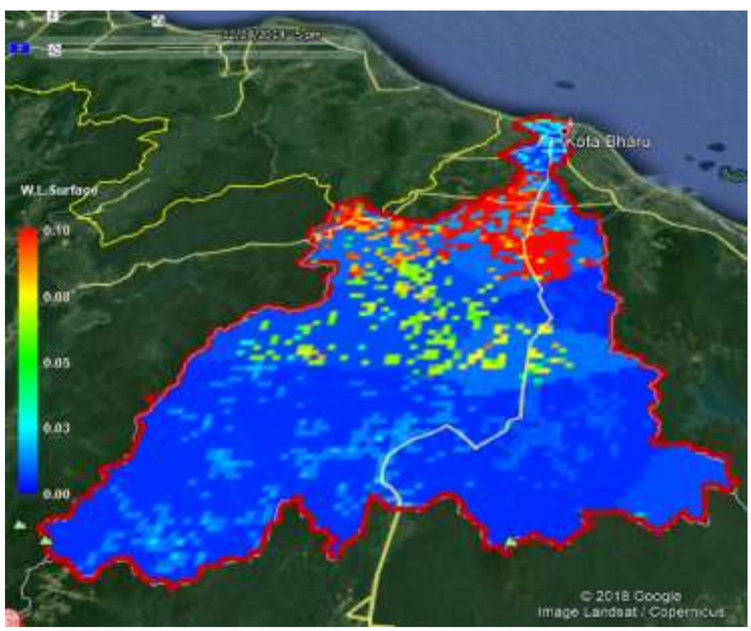


Figure 6 Water Level Surface

	Accessibility	Technical	Safety
Accessibility	1/1	1/4	1/3
Technical	4/1	1/1	2/1
Safety	3/1	1/2	1/1

Figure 7 Pairwise Comparison Matrix

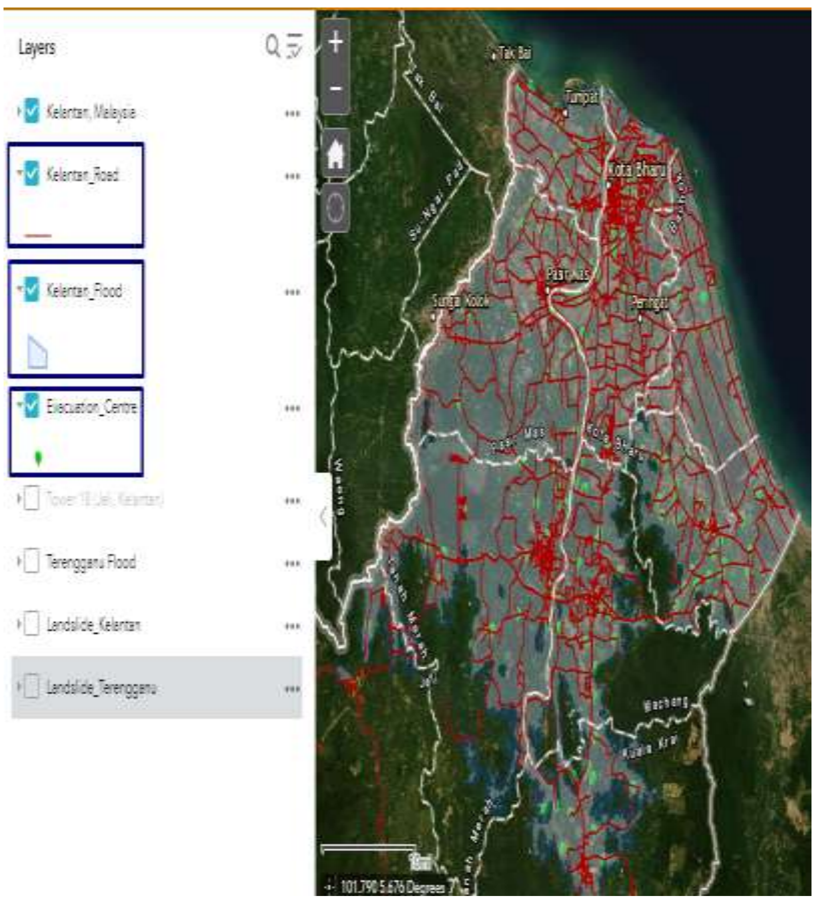
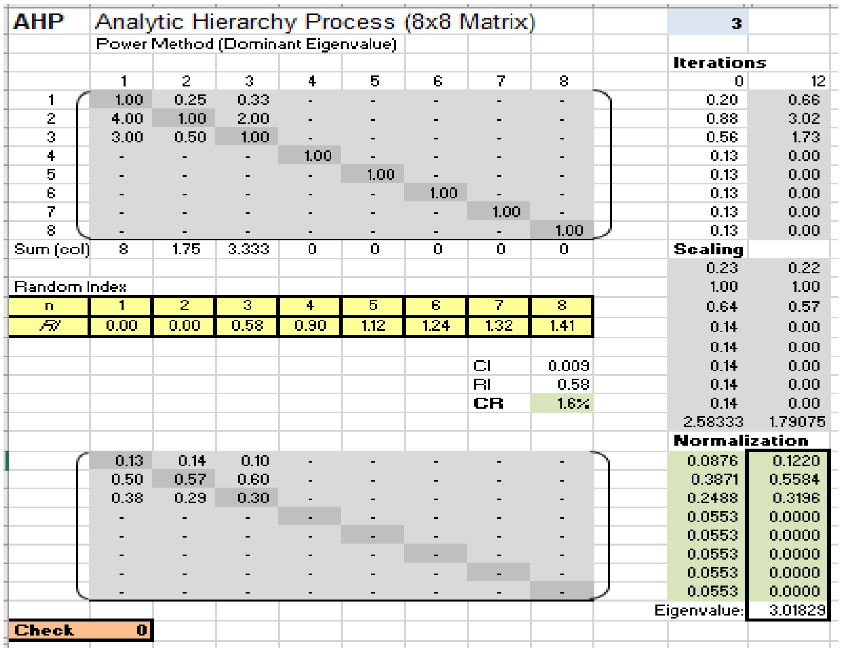


Figure 8 Overlaying Of Inundation Map, Evacuation Centre & Kelantan Road



AHP Analytic Hierarchy Process (8x8 Matrix) — 3

Power Method (Dominant Eigenvalue)

	1	2	3	4	5	6	7	8
1	1.00	0.25	0.33	-	-	-	-	-
2	4.00	1.00	2.00	-	-	-	-	-
3	3.00	0.50	1.00	-	-	-	-	-
4	-	-	-	1.00	-	-	-	-
5	-	-	-	-	1.00	-	-	-
6	-	-	-	-	-	1.00	-	-
7	-	-	-	-	-	-	1.00	-
8	-	-	-	-	-	-	-	1.00
Sum (col)	8	1.75	3.333	0	0	0	0	0

Random Index

n	1	2	3	4	5	6	7	8
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41

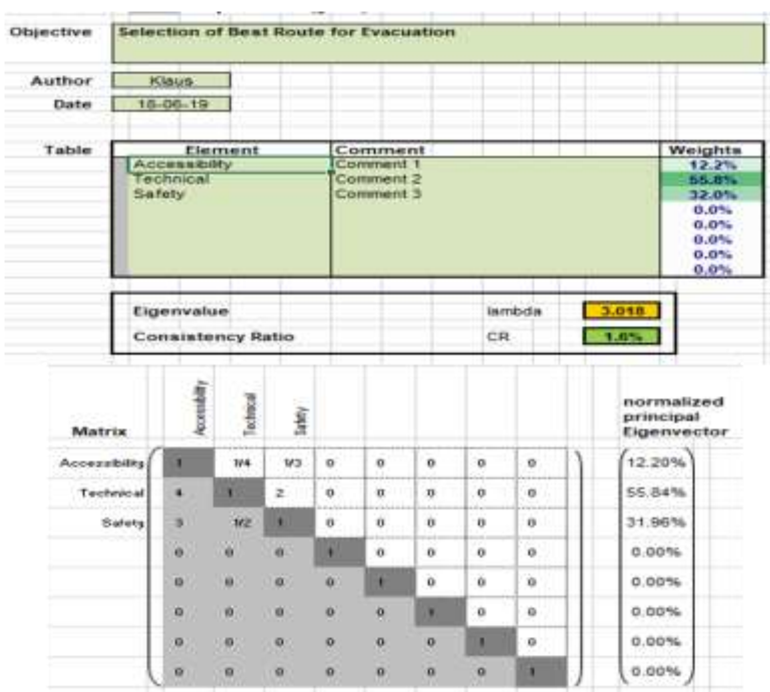
CI	0.009
RI	0.58
CR	1.6%

0.13	0.14	0.10	-	-	-	-	-
0.50	0.57	0.60	-	-	-	-	-
0.38	0.29	0.30	-	-	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-

Check 0

Iterations	
0	12
0.20	0.66
0.88	3.02
0.56	1.73
0.13	0.00
0.13	0.00
0.13	0.00
0.13	0.00
0.13	0.00
Scaling	
0.23	0.22
1.00	1.00
0.64	0.57
0.14	0.00
0.14	0.00
0.14	0.00
0.14	0.00
0.14	0.00
2.58333	1.79075
Normalization	
0.0876	0.1220
0.3871	0.5584
0.2488	0.3196
0.0553	0.0000
0.0553	0.0000
0.0553	0.0000
0.0553	0.0000
0.0553	0.0000
Eigenvalue:	3.01829

Figure 9 8×8 Matrix Calculation



Objective Selection of Best Route for Evacuation

Author Klaus

Date 16-06-19

Table

Element	Comment	Weights
Accessibility	Comment 1	12.2%
Technical	Comment 2	55.8%
Safety	Comment 3	32.0%
		0.0%
		0.0%
		0.0%
		0.0%
		0.0%

Eigenvalue	lambda	3.018
Consistency Ratio	CR	1.6%

Matrix	Accessibility	Technical	Safety						normalized principal Eigenvector
Accessibility	1	1/4	1/3	0	0	0	0	0	12.20%
Technical	4	1	2	0	0	0	0	0	55.84%
Safety	3	1/2	1	0	0	0	0	0	31.96%
	0	0	0	1	0	0	0	0	0.00%
	0	0	0	0	1	0	0	0	0.00%
	0	0	0	0	0	1	0	0	0.00%
	0	0	0	0	0	0	1	0	0.00%
	0	0	0	0	0	0	0	1	0.00%

Figure 10 Overall Summary of APH

4 Conclusion

In this study, the best evacuation route was chosen by means of a learning-driven expert-based GIS model for Kelantan river basin. Three parameters, which are accessibility, technical and safety were introduced to the specialists to matched examination and distributing weight as the fundamental criteria/factors for best route determination in the system of GIS. The flood inundation map of Kelantan was overlaid and compared with the discharge river course, water level surface and rainfall. In the event that it tends to be expected that the inundation map is reliable, the outcome of this study to select the best evacuation route to get to the evacuation centre is then reliable. Henceforth, the AHP and GIS procedure is equipped for making a moderately solid expectation and can be recommended for route determination.

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