MULTI-CRITERIA ANALYSIS AS A DECISION-MAKING METHOD IN DISASTER MANAGEMENT

A Case Study for Designation of Appropriate Public Facility Buildings as Evacuation Relief Centre in High-Risk Flooded Area, Town of Kota Tinggi, State of Johor, Malaysia

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1. INTRODUCTION

Human will have to face the problem and dilemma in making decision particularly when dealing with a series of options, solutions, problems and criteria. This situation normally, too complex, inter-related and should be organized in systematic way. Therefore, scientific method should be applied to assist and analyze various aspects in the process. In this context, Multi-criteria Analysis (MCA) is one of the most well-known branches of the method and it is referring to making decision in the presence of multiple criteria[1)]. An attempt to apply this method in the context of disaster management could be performed since this field always dealing with complex situations. In other words, involves a lot of criteria, indicators and options or alternatives. In this case, the purpose of the tool is to structure, combine and integrate different assessments that need to be taken into account in planning and decision-making stage. Although MCA is essentially focused on the final result based on the priority, this research extends it to reclassification of solution as well as individual performance oriented.

2. RESEARCH GOAL AND OBJECTIVES

The goal of the research is to propose MCA as a decision-making method in the field of disaster management. This would be achieved through the objectives as follows :-

i. To apply and incorporate analytical method into the process and assessment of its decision problem;

ii. To generate a rational alternative assessment model using integration of several reliable planning Decision Support System (DSS) tools; and

iii. To identify the strength and weaknesses of MCA methodology from the context of disaster management.

3. RESEARCH METHODOLOGY AND CASE STUDY

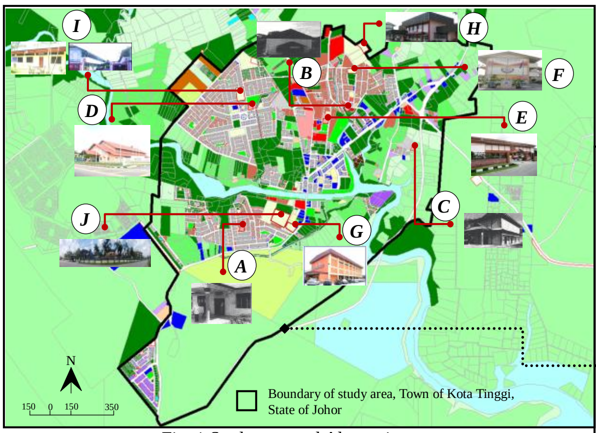
The research is based on both primary and secondary data. Primary data was collected through observations and informal discussions with officers who directly involve in disaster event at local authority, state and federal level. The purpose is to obtain some information and overview regarding current issues and problems faced during disaster particularly floods. Secondary data was collected through studies such as documents and texts, visual images, videos and official reports published by various agencies. MCA method is applied to support decision-making phase in the field of disaster management through a case study. GIS (using MAPINFO and ARCView) and Saaty's Analytical Hierarchy Process (AHP) called 'structured pairwise comparison method' which supported by the Expert Choice® software is used for the preference assessment.

The study area is located in Town of Kota Tinggi, State of Johor, Malaysia which is about 42 kilometers north-east of Johor Bahru capital city[2)] (Fig. 1). The Town has approximately an area of 15 km^2 and it is chosen because of its urban profile and geographical location, which harsh to flood almost every year. The research is focusing on public facility buildings because these assets are directly under the control and administration either by the State or the Federal Government. Besides, they have been used in channeling of aid and financial resources during the previous floods and hence possessing significance to this research. 10 public facility buildings (alternatives), 6 criteria and 15 sub-criteria have been identified for the purpose of research as shown in Fig. 1 & Table 1.

4. MCA AND ITS IMPORTANCE IN DISASTER MANAGEMENT

4.1 What is MCA?

MCA is a decision-making method that dealing with complex decision problems. This involves phase of problem structuring, prioritization, selection, synthesizing and evaluation of the criteria and alternative. It can be used as a tool in many different decision-making processes such as structure the decision problems in hand, improve understanding about the main issues involved, analyze the effects in various forms, identify pros and contras in evaluation, accommodate various types of information (quantitative and qualitative) and analyze



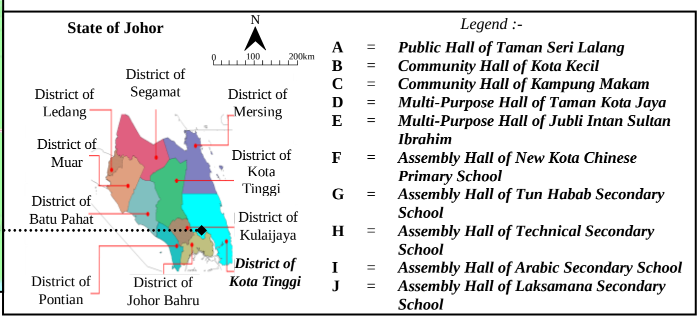


Fig. 1 Study area and Alternatives

Table 1 Evaluation table of case study

Criteria	Sub-criteria	Category (Alternatives)									
		A	***B***	***C***	***D***	***E***	***F***	***G***	***H***	***I***	***J***
Density (DY)	**1**	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	2	Yes	No	No	Yes	No	Yes	Yes	Yes	Yes	Yes
Acreage of the area (AA)	**3**	63m^2	150 m^2	297 m^2	1,540 m^2	1,288 m^2	840 m^2	240 m^2	900 m^2	294 m^2	189 m^2
	4	3,673.28m^2	2,898.63m^2	3,466.75 m^2	4,836.99m^2	6,052.21 m^2	7,667.65 m^2	12,476.50 m^2	17,493.30m^2	22,642.20m^2	43,344.00m^2
	5	80 victims	500 victims	300 victims	800 victims	600 victims	500 victims	400 victims	400 victims	200 victims	250 victims
Security and safety measures for the shelter (SS)	**6**	2,970m	880m	1,900m	1,520m	1,050m	390m	2,600m	400m	1,570m	2,600m
	7	1,750m	660m	1,620m	830m	280m	1,040m	1,360m	1,410m	1,080m	1,360m
	8	1	2	-	1	1	2	1	1	1	2
Basic facilities (BF)	**9**	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	10	1M 1F	2M 3F	2M 2F	5M 5F	1M 1F	2M 2F	3M 3F	3M 3F	3M 3F	4M 4F
	11	No	Yes	No	Yes	Yes	No	No	Yes	No	No
Good accessibility (GA)	**12**	Connected but submerged	Yes	Connected but submerged	Yes	Yes	Yes	Connected but submerged	Yes	Yes	Connected but submerged
	13	Connected but submerged	Yes	No	Yes	Yes	Yes	Connected but submerged	Yes	Yes	Connected but submerged
Away from identified or potential flooded area (AFA)	**14**	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	No
	15	590m	1,170m	650m	1,150m	1,070m	1,700m	460m	2,030m	1,370m	340m

Note:-
M = Male
F = Female

1 = Located within areas of dense population (1,600m)
2 = Located within areas of projected future population (1,600m)
3 = Area of building to cater various types of aids and assistance from disaster relief machinery
4 = Coverage area for future expansion meant for sheltering
5 = Carrying capacity to accommodate victims
6 = Located within walking distance to main police station or community patrol stations (800m)
7 = Located within walking distance to health facility (800m)
8 = Located within walking distance to other evacuation relief centre (at least one evacuation relief centre within 800m)
9 = Electric power supply
10 = Toilet facility
11 = Availability of local food supplier
12 = Connectivity and accessibility to main roads
13 = Connectivity and accessibility to proposed main roads
14 = Located outside identified or potential flooded areas
15 = Far distance from main river that could contribute to flood

the sensitivity of the results.

4.2 The significance of research

Disaster management as a cycle activity, need to be supported by relevant methods and models since it dealing with various factors either structural or non-structural (Fig. 2). In relation to that, the planning process of providing appropriate evacuation relief is one of the fields that need to be considered in the context of Malaysia besides to accommodate victims that are expected to increase in the near future. Therefore, it is essential to understand the significance of these activities and its importance to human and social sustainability within disaster management environment.

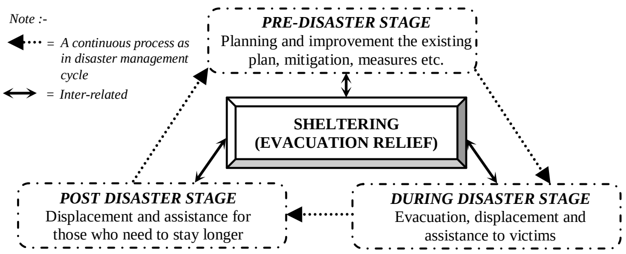


Fig. 2 Sheltering from the context of Disaster Management Cycle

5. STRUCTURE AND METHODLOGY OF MCA

Basically, this method is applied in a sequence of steps that is inter-connected before the final decision is obtained. General structure, elements and basic stages involved in applying MCA and its integration with planning DSS can be described as in Fig. 3. Problem Tree Analysis is applied to assist analyzing the existing situation by identifying the major problems and their main causal relationships. Based on the available primary and secondary data, the Problem Tree Analysis for the case study can be explained as shown in Fig. 4. Hence, core problem can be broken down into manageable and definable aspects. Besides, it could assist the process of analysis, which often helps building a shared sense of understanding besides supporting justifications and lead to the significant of this study to be conducted.

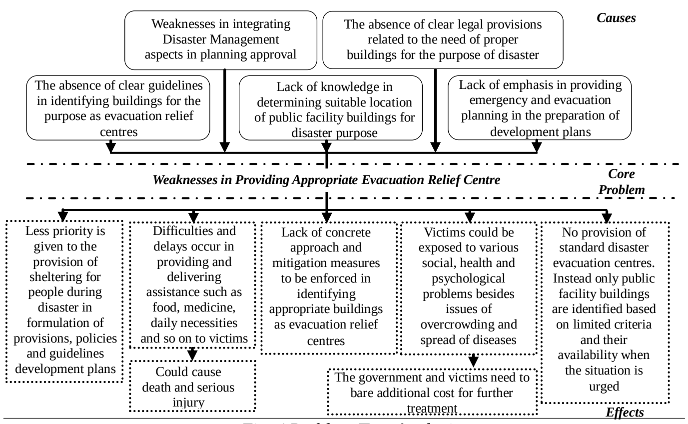


Fig. 4 Problem Tree Analysis

6. MCA AND ITS APPLICATION USING AHP AND EXPERT CHOICE®

The AHP, originally developed by Saaty (1980), is one of the most flexible methods that can be implemented with MCA. To solve a MCA problem by AHP and Expert Choice®, the following steps need to be taken into consideration :-

a. Step 1 : Define the problem and determine its goal. Ten (10) public facility buildings, six (6) criteria and 15 sub-criteria have been identified for the purpose of this research (Fig. 5).

b. Step 2 : Develop hierarchical framework as Model of Analysis (Fig. 5).

c. Step 3 : Construct pairwise comparison matrix (size nxn) for all levels of the hierarchy.

d. Step 4 : Perform judgment of pairwise comparison using Saaty's 1 to 9 scale (Table 2). There are *n x (n-1)* judgments required to develop a set of matrices and hierarchy (Table 3).

Table 2 Fundamental scale of pairwise comparison[3)]

Intensity of importance	Explanation
1	**Equal importance**
3	**Moderate importance one over another**
5	**Essential or strong importance**
7	**Very strong importance**
9	**Extreme importance**
2,4,6,8	**Intermediate values between the two adjacent judgments**

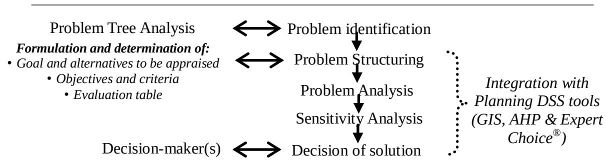


Fig. 3 General structure and elements of MCA

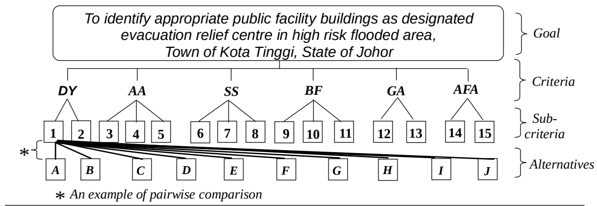


Fig. 5 Model of Analysis

Table 3 Pairwise comparison matrix of criteria

Criteria	DY	AA	SS	BF	GA	AFA	*Total*
DY	1	1	1/2	1/4	1/5	1/8	3.075
AA	1	1	1/2	1/3	1/4	1/7	3.226
SS	2	2	1	1/2	1/3	1/4	6.083
BF	4	3	2	1	1	1/2	11.500
GA	5	4	3	1	1	1/2	14.500
AFA	8	7	4	2	2	1	24.000
Total	21.000	18.000	11.000	5.083	4.783	2.518	62.385

e. *Step 5 : Synthesizing the pairwise comparison to get the priority of the criteria and weights for Eigenvector* (Table 4).

Table 4 Synthesizing pairwise comparison of criteria

Criteria	DY	AA	SS	BF	GA	AFA	*Total*	*Average (Eigenvector)*
DY	0.048	0.056	0.045	0.049	0.042	0.050	0.289	0.048
AA	0.048	0.056	0.045	0.066	0.052	0.057	0.323	0.054
SS	0.095	0.111	0.091	0.098	0.070	0.099	0.565	0.094
BF	0.190	0.167	0.182	0.197	0.209	0.199	1.143	0.191
GA	0.238	0.222	0.273	0.197	0.209	0.199	1.337	0.223
AFA	0.381	0.389	0.364	0.393	0.418	0.397	2.342	0.391
Total	1.000	1.000	1.000	1.000	1.000	1.000	6.000	1.000

f. *Step 6 : Perform the Consistency.* Having made all the pairwise comparisons, the consistency is determined by using Eigenvalue(λ_{max}) to calculate the Consistency Index, CI as follows : CI = (λ_{max}- n)/(n-1); where n is the matrix size (Table 5). Judgment consistency can be checked by taking the Consistency Ratio (CR) of CI with the appropriate value using Random Consistency Index (RCI) in Table 6. The CR is acceptable and consistent, if it does not exceed 0.10.

Table 5 Calculation to get new weights for criteria

0.048	1	+0.054	1	+0.094	1/2	+0.191	1/4	+0.223	1/5	+0.391	1/8	=	0.290	6.044
	1		1		1/2		1/3		1/4		1/7		0.324	6.002
	2		2		1		1/2		1/3		1/4		0.565	6.014
	4		3		2		1		1		1/2		1.151	6.026
	5		4		3		1		1		1/2		1.347	6.040
	8		7		4		2		2		1		2.356	6.041
Total													6.034	36.168
Maximum Eigenvalue (λ_{max})														6.028
CI=(6.028-6)/(6-1) = 0.006														
CR=0.006/1.24 = 0.00														

Table 6 Random Consistency Index (RCI) values[3)]

1	2	3	4	5	6	7	8	9	10
0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

g. *Step 7 : Perform calculation for all levels in the hierarchy model.* The same calculation is applied for all sub-criteria and alternatives according to steps 3-6.

h. *Step 8 : Develop overall priority ranking.* At this stage, the comparison is performed in order to know how important the sub-criterion contributes to each of respective alternative. Table 7 shows the calculation summary for overall priority weights of criteria, sub-criteria and alternatives using Expert Choice®.

i. *Step 9 : Priority of the alternatives.* The overall priority weights can be obtained by multiplying the priority weights for each of the alternatives by the weights of priority of criteria as shown in Table 8. The judgment made can be considered consistent and acceptable since the CR is less than 0.1 or 10%. At this point, decision-maker(s) could get a better understanding of which building should be considered to serve as designated evacuation relief centre. Besides, the priority of criteria and sub-criteria is also able to be indicated accordingly.

Table 8 Overall priority weights

Alternatives / Criteria	DY	AA	SS	BF	GA	AFA	Overall priority	Rank
Priority vectors	0.048	0.054	0.094	0.191	0.223	0.391		
CR	*0.01*							
A	0.118	0.026	0.026	0.049	0.030	0.102	0.065	8
B	0.102	0.035	0.185	0.088	0.147	0.118	0.120	5
C	0.036	0.043	0.031	0.062	0.028	0.104	0.066	7
D	0.114	0.135	0.108	0.221	0.147	0.112	0.142	1
E	0.098	0.110	0.201	0.062	0.147	0.107	0.116	6
F	0.118	0.093	0.170	0.063	0.146	0.136	0.125	3
G	0.118	0.087	0.046	0.098	0.029	0.024	0.049	9
H	0.060	0.146	0.089	0.111	0.147	0.147	0.131	2
I	0.118	0.148	0.071	0.098	0.149	0.126	0.122	4
J	0.118	0.177	0.072	0.147	0.030	0.023	0.066	7

j. *Step 10 : Reclassification of Individual alternative performance.* For the purpose of this study, the reclassification is divided into three categories (Table 9) and the result is shown in Table 10. Further, decision-maker(s) could analyze and review each of alternative's deficiency according to respective sub-criteria. This allows the decision-maker(s) to evaluate individual alternatives based on their individual performance before any decision being made. The reclassification is important and can be used for distribution of allocation, operations, criteria considered and proclamation of proper buildings as evacuation relief centres purpose.

Table 9 Reclassification index

Recommendation	Index
Remain the status quo	>0.6
Recommended to be further improved	0.6-0.3
Need to be improved immediately	<0.30

Table 7 The summary for all priority weights of criteria, sub-criteria and alternatives using Expert Choice®

	Goal (1.00)														
Criteria	DY		AA			SS			BF			GA		AFA	
	0.048		0.054			0.094			0.191			0.223		0.391	
Consistency Ratio	0.02														
Sub-criteria	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	0.833	0.167	0.286	0.571	0.143	0.286	0.571	0.143	0.187	0.715	0.098	0.750	0.250	0.800`	0.200
Consistency Ratio	0.00		0.00			0.00			0.00			0.00		0.00	
Alternatives															
A	0.116	0.129	0.019	0.030	0.023	0.021	0.020	0.055	0.100	0.036	0.045	0.029	0.031	0.119	0.033
B	0.116	0.032	0.025	0.018	0.121	0.150	0.195	0.216	0.100	0.072	0.182	0.147	0.148	0.119	0.113
C	0.036	0.032	0.073	0.023	0.059	0.043	0.028	0.020	0.100	0.055	0.045	0.029	0.022	0.119	0.044
D	0.111	0.129	0.273	0.035	0.261	0.076	0.138	0.055	0.100	0.257	0.182	0.147	0.148	0.119	0.084
E	0.111	0.032	0.189	0.051	0.187	0.104	0.285	0.055	0.100	0.036	0.182	0.147	0.148	0.119	0.059
F	0.116	0.129	0.119	0.074	0.120	0.280	0.104	0.216	0.100	0.056	0.045	0.147	0.146	0.119	0.206
G	0.116	0.129	0.044	0.111	0.078	0.029	0.053	0.055	0.100	0.105	0.045	0.029	0.031	0.024	0.025
H	0.046	0.129	0.166	0.154	0.075	0.207	0.038	0.055	0.100	0.105	0.182	0.147	0.148	0.119	0.259
I	0.116	0.129	0.060	0.220	0.035	0.061	0.080	0.055	0.100	0.105	0.045	0.150	0.148	0.119	0.156
J	0.116	0.129	0.032	0.283	0.042	0.029	0.059	0.216	0.100	0.174	0.045	0.029	0.031	0.024	0.021
Consistency Ratio	0.00	0.00	0.02	0.03	0.02	0.02	0.02	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01

Table 10 Overall priority weights for Reclassification purpose using Expert Choice®

Criteria	*Sub-criteria*	*Category (Alternatives)*									
		A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*
DY	1	1.000*	1.000*	0.314**	0.961*	0.961*	1.000*	1.000*	0.396**	1.000*	1.000*
	2	1.000*	0.250***	0.250***	1.000*	0.250***	1.000*	1.000*	1.000*	1.000*	1.000*
AA	3	0.070***	0.092***	0.266***	1.000*	0.691*	0.435**	0.160***	0.607*	0.220***	0.118***
	4	0.107***	0.064***	0.082***	0.123***	0.178***	0.262***	0.391**	0.544**	0.777*	1.000*
	5	0.088***	0.462**	0.227***	1.000*	0.717*	0.459**	0.299***	0.286***	0.133***	0.162***
SS	6	0.074***	0.536**	0.155***	0.270***	0.373**	1.000*	0.103***	0.739*	0.218***	0.103***
	7	0.072***	0.682*	0.098***	0.482**	1.000*	0.366**	0.186***	0.134***	0.280***	0.205***
	8	0.257***	1.000*	0.094***	0.257***	0.257***	1.000*	0.257***	0.257***	0.257***	1.000*
BF	9	1.000*	1.000*	1.000*	1.000*	1.000*	1.000*	1.000*	1.000*	1.000*	1.000*
	10	0.138***	0.281***	0.212***	1.000*	0.138***	0.217***	0.407**	0.407**	0.407**	0.674*
	11	0.250***	1.000*	0.250***	1.000*	1.000*	0.250***	0.250***	1.000*	0.250***	0.250***
GA	12	0.196***	0.981*	0.196***	0.981*	0.981*	0.981*	0.193***	0.981*	1.000*	0.196***
	13	0.212***	1.000*	0.149***	1.000*	1.000*	0.985*	0.212***	1.000*	1.000*	0.212***
AFA	14	1.000*	1.000*	1.000*	1.000*	1.000*	1.000*	0.200***	1.000*	1.000*	0.200***
	15	0.126***	0.437**	0.172***	0.326**	0.229***	0.797*	0.098***	1.000*	0.603*	0.080***

*	Remain the status quo	**	Recommended to be further improved	***	Need to be improved immediately

7. SENSITIVITY ANALYSIS AND DECISION OF SOLUTIONS

The main purpose of sensitivity analysis is to examine how sensitive the choices are to the changes in criteria weights[4] which performed using Expert Choice®. This is useful in situations such as where uncertainties exist in the definition of the importance of different factors. For instance, based on the actual result, it can be seen that the priority for designation purpose is shown in Table 8. However, as more or less weight is assigned, the priority of alternatives will tend to have a change. The changes in the criteria weights can be attributed to different variations in the result for decision purpose (Fig. 6). In other words, decision-maker(s) have to sacrifice some of the criteria if they want to select or increase the performance criteria of alternative that located at lower ranking. It shows that the sensitivity analysis can help the decision-maker(s) to determine which parameters are the key drivers of a model's results in the process of making decision.

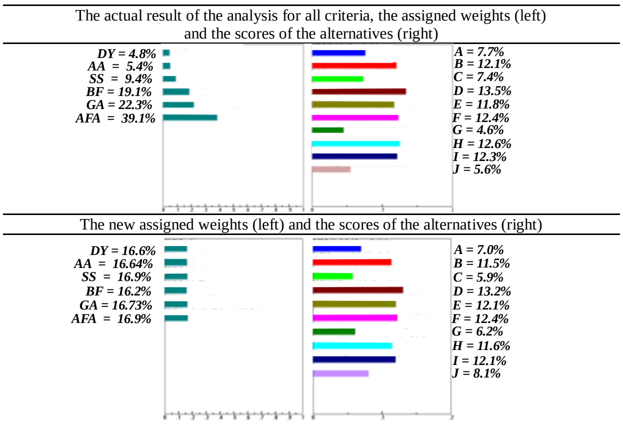


Fig. 6 Sensitivity analysis of the alternatives

8. FINDINGS

An attempt to apply Problem Tree Analysis in the MCA process able to demonstrate 'causes' and 'effects' that are well identified and subsequently addressed. It could provide a foundation in supporting further discussion and exploring the decision problem in hand. It is realized that the MCA assists in filtering the collected information. The actual information could be classified according to its importance and at the same time the decision-maker(s) can obtain a greater insight into the data and decision problem in detail which is important in performing analysis stage.

Reclassification methods is applied in MCA as one of additional steps for further recommendation and diversify the way in finding different solutions according to decision-maker(s) preferences at decision stage.

The evaluation of criteria, sub-criteria and alternatives is based on individual judgment. Hence, in actual, the whole process from determination of decision problems, problem structuring, problem analysis to decision rule particularly in giving weights and judgment should be conducted in groups so that more accurate and satisfying solutions could be produced. In addition, the Sensitivity Analysis shows that changes in weights for all criteria have significant influence to the changes in preference of alternatives priority. It allows decision-maker(s) to decide whether some of the criteria need to be sacrificed if they want to select or increase the performance criteria of alternative that located at lower ranking. This method also provides platform to justify the possibility of such changes before any decision being made.

The analysis results show that there are several criteria need to be addressed and taken into account according to their priority. As a result, these criteria can be used, detailed and adapted in formulating guidelines, laws or strategies besides become value-added to the existing method in making decision from Malaysia context. As GIS is an open source tool, MCA could be integrated to perform spatial analysis (Spatial MCA) and extend it to other fields of disaster management such as monitoring and budgeting purpose. It can be realized that the integration of other applications as planning DSS tools such as GIS, AHP and Expert Choice® could help assisting the MCA process effectively.

Some advantages are discovered through the application of MCA in this case study such as solving decision problem in terms of group consensus, an interactive medium for sharing of ideas and arguments, multi-disciplinary approach, user-friendly and understandable methodology. However, the study has found some weaknesses in application of this method which includes lengthy debates, time factor, availability of the data and technical aspects of the methodology.

9. CONCLUSION

Ideally, it is difficult to achieve perfect solutions from the decision made since there are a lot of factors and parties involved in the process. It can be concluded that MCA is not a tool providing the 'right' solution in decision problem since there is no solution will be judged as 'right' or 'wrong'. Instead, it might be considered 'best' for decision-maker(s) according to their value in the form of weighting or considering factors. However, to ensure it is on the right track, actions should be taken continuously to work towards this ideal way with the aim of making it into acceptable level. For this reason, the methodology applied and integrated in the study area has shown its significance to assist decision-maker(s) in decision-making process in the context of disaster management. Besides, a framework is provided to design effectively and evaluate the criteria and alternative according to goal and set of objectives. It can be said that MCA approach tries to reduce the complexity of the decision problem in aggregating the information besides developing a ranking of the options according to certain preferences.

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