European Journal of Scientific Research
ISSN 1450-216X / 1450-202X Vol. 109 No 2 August, 2013, pp.342-349
http://www.europeanjournalofscientificresearch.com

Validation of Multi-Criteria Decision Analysis Model of Land Suitability Analysis for Sustainable Hillside Development

Imtiaz Ahmed Chandio
Department of Civil Engineering, Universiti Teknologi PETRONAS
Seri Iskandar, Perak, Malaysia
E-mail: imtiazutp@gmail.com

Abd Nasir B Matori
Department of Civil Engineering, Universiti Teknologi PETRONAS
Seri Iskandar, Perak, Malaysia
E-mail: nasrat@petronas.com.my

Khamaruzaman B WanYusof
Department of Civil Engineering, Universiti Teknologi PETRONAS
Seri Iskandar, Perak, Malaysia
E-mail: khamaruzaman.yusof@petronas.com.my

Mir Aftab Hussain Talpur
Department of Civil Engineering, Universiti Teknologi PETRONAS
Seri Iskandar, Perak, Malaysia
E-mail: mir_aftab@yahoo.com

Abstract

This paper has described the statistical modeling approach that effectively test the validation of Multi-criteria Decision Analysis (MCDA) models such as Analytic Hierarchy Process (AHP) method for decision-making. A pairwise comparison questionnaire was designed to get experts opinion related with land suitability analysis of hillside development. The collected weights of suitability criteria and sub-criteria using questionnaire were analyzed into an Expert Choice decision support software. To validate MCDA methods, statistical methods were used to enhance reliability of decision-making process. This approach can be guidance to the researchers who are involved in hillside land suitability analysis modelling.

Keywords: Validation, Analytic Hierarchy Process, Pairwise Questionnaire, Decision-making

1. Introduction

Sustainable spatial planning and rational analysis of land needs potential attention for possible alternatives of environment, economic and social development, to choose and get best land-use options for future development (Senes and Toccolini, 1998, Lier, 1998). It can also describe in simple and short way that it consists of various activities e.g. determines future land-uses and improve the land properties and manage sustainable locations (Lier, 1998, Chen et al., 2005, Hurni, 2000).Therefore, it is necessary to adopt rational planning approach to finding sustainable alternatives. This can be achieved by holistic methods, which suggests that sustainable development as a multidimensional concept should be the central goal of good governance and land suitability analysis (Mahmouda and El-Sayedc, 2011, Chen et al., 2005, Doughty and Hammond, 2004) or the better hillside environment and spatial development (Chang et al., 2012). The definition is also given by the World commission on Environment and Development (1987, P.43) that "*sustainable development is one that meets the needs of the present without compromising the ability of future generations to meet their own needs*" published in *Our Common Future* (WCED, 1987). Above definition consensus was unanimously accepted as a universal aim at the UN Conference on Environment and Development (UNCED) in 1992 which was held in Reio de Janeiro, Brazil in "Earth Summit" agenda 21.The sustainable development has become a major puzzled for policy makers and planners in both developed and developing countries. Over the years, the continuing expansion of the extent of sustainable development, planners and policy makers are becoming increasing difficulties to find the right way to plan for sustainable development (Quaddusa and Siddique, 2001).

Sustainable development planning is a very complex task. There is no general consensus of achieving to develop sustainable development plans (Quaddusa and Siddique, 2001). The notion of sustainable development is not without its critics, "what is to be sustained," as the earth, environment or culture (Kates et al., 2005). It is a very much difficult to implement sustainability in developing countries with debt and global inequalities where income distribution is considered a serious impediment to sustainable development (Doughty and Hammond, 2004, Amin, 1997). This discussion highlights the following important aspects of sustainable hillside development planning:

(i) To consider of multiple criteria;
(ii) To obtain weights of criteria from experts' opinion;
(iii) To involve of experts' preferences.

For an analysis of the above models, a multiple criteria evaluation approach is recommended called AHP (Saaty, 1980) for the analysis of hillside development. The decision-making process has attracted, perplexed and challenged for future generations of researchers in a variety of topics such as civil engineering and urban and regional planning. It led to the consideration of scientific aspects of the past, mainly in the planning (Voogd, 1983). In this study, the above mentioned point of view and the fundamentals of the systems analytic approach is adopted. A cursory review of the literature reveals strong evidence to suggest that the planning procedures must have at least three important features:

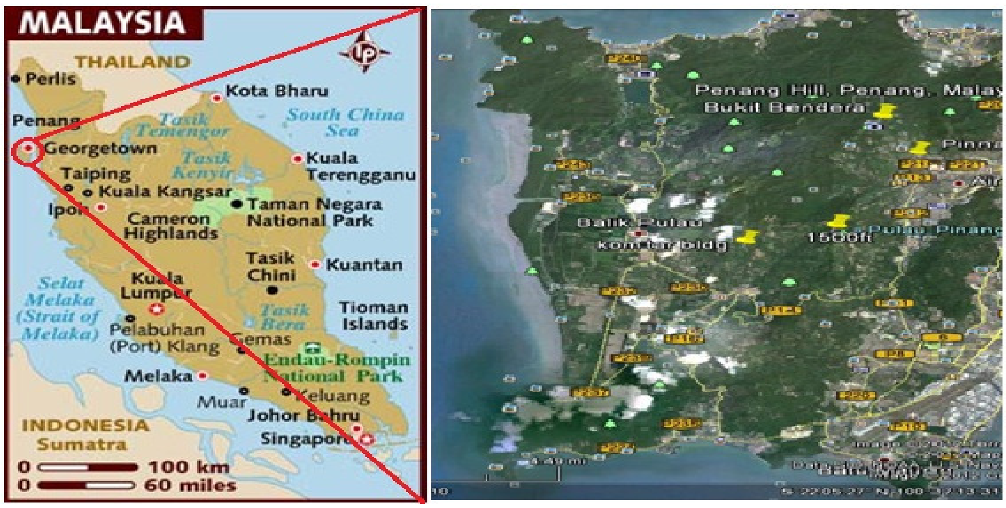
1. They should be flexible;
2. They should match the features;
3. They should be able to integrate systems analytic approach.

Therefore, in this study, an analytic hierarchy modelling approach is a useful method for sustainable planning considering a multi-criteria decision analysis approach for future hillsides development. Validation techniques for AHP method can improve further the confidence in decision making process. In this study, two statistically methods were applied to validate MCDA procedure, named Kolmogorov-Smirnov (K-S) and t-test. The Kolmogorov-Smirnov (K-S) test that is a powerful test for goodness of fit (Justel et al., 1997). It is especially useful for small size of sample that was employed to test the weighting distribution of each criterion in Statistical Package for Social Sciences (SPSS) (Chen and Delaney, 1998). The K-S P-value of the weights of all criterions for hillside suitability was analyzed significance level of 0.05. It is a well-known technique used for normality test (Drezner and Turel, 2011). Subsequently, t-test was also used to observe statistically significance level of criterion (Mirabella, 2006). The outcome of these statistically tests may be positive impact on the MCDA methods results.

2. Material and Methods

The study area is located at Penang city, Malaysia. George Town is the capital of the state of Penang shown in Figure 1. Named after Britain's King George III, George Town is located on the northeast corner of Penang Island. As shown in Figure 1, Latitude and Longitude of the study area are located approximately between upper right (2^{o} 17’ 32.457” E and 5^{o} 23’ 45.426” N) and lower left (2^{o} 11’ 29.151” E and 5^{o} 15’ 45.721” N).

Figure 1: Location of Study Area



3. Criteria Evaluation

The selection of criteria and sub-criteria are an important stage for deciding multi-criteria decision analysis. The criteria and sub-criteria were selected of this study are as follows:

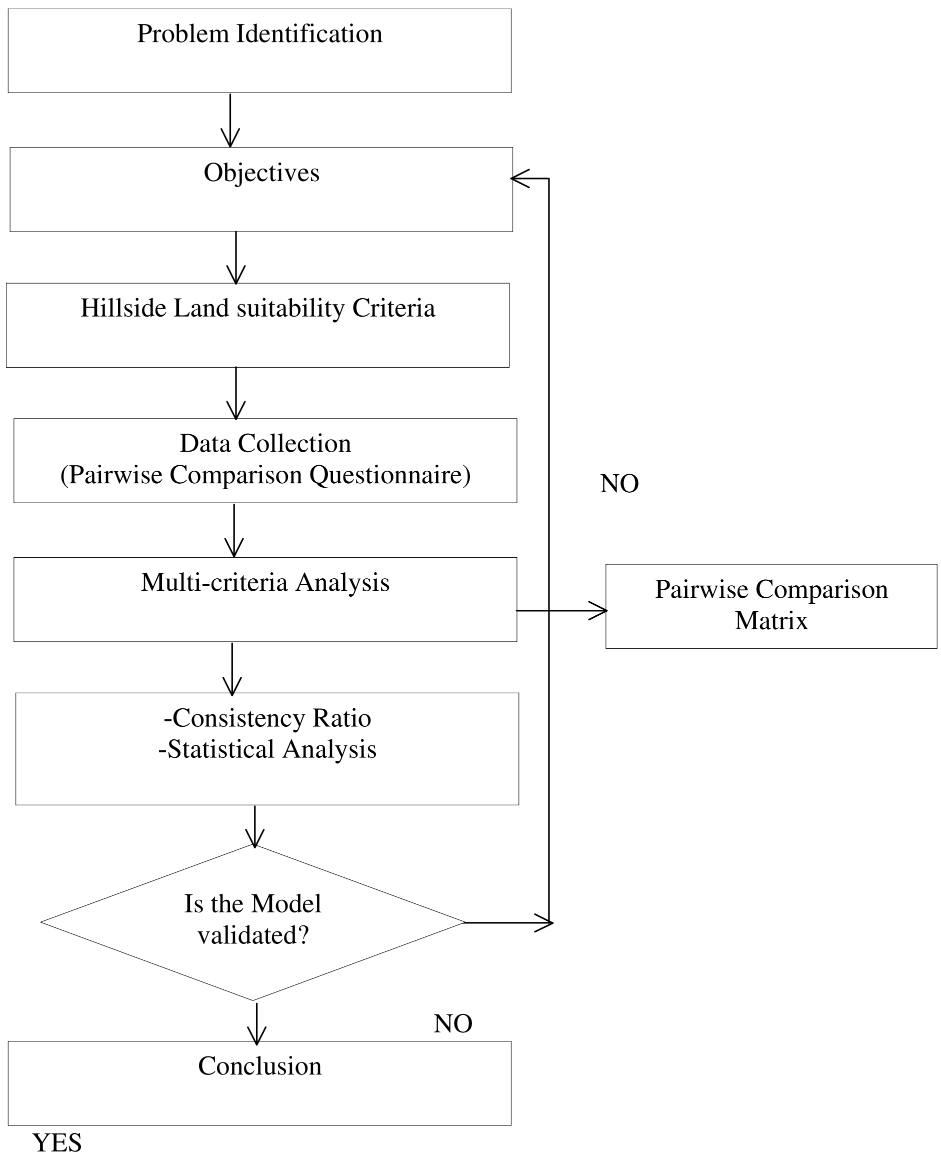
i. Accessibility (Primary road and Secondary road);
ii. Topography (Elevation, Slope and Aspect);
iii. Land Cover (Agriculture land, Forest land, Existing Residential, Wet land and Surface water).

4. Multi-Criteria Analysis

The Analytic Hierarchy Process (AHP) as MCDA method was used to determine hillside development criteria. AHP was developed by the Saaty in 1980 in order to assist in a decision making process. The following Figure 2 shows the overview of methodology of this paper(Malczewski, 2004).

Pairwise comparison matrix questionnaire was sent to the experts obtaining opinion (weights) of the criteria and sub-criteria. Collected weights were used in pairwise comparison method determining the priority vector of each criteria and sub-criteria. There are two decision support softwares available to calculate pairwise comparison matrix such as Expert Choice (EC) and Super Decisions (SD). In this paper, for computation of priority vectors was performed into EC. EC takes a pairwise comparison questionnaire weights as an input and generates the relative weighting of sub-criteria for each land suitability criteria. Actually, AHP is the mathematical approach translating into a priority vector of relative weights for the criteria. Following approaches were focused in this paper for validation MCDA models such as consistency ratio (CR) which is generated by the EC software. Statistical methods were also used for validation of MCDA model for land suitability analysis of sustainable hillside development.

Figure 2: Flow Diagram of Methodology



5. Calculating Consistency Ratio

The acceptable level of consistency ratio (CR) is less than 0.10 then the decision is given by the expert's satisfactory. Table 1 presents the random indices.

CR=CI/RI

Where CI $(\lambda\max - n) / (n - 1)$ =

RI=Random consistency index

N= Number of criteria

λ_{max} is priority vector multiplied by each column total

Table 1: Random Indices for matrices (Malczewski, 1999)

n	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.59

6. Results and Discussion

Pairwise comparison matrix method was used into EC software after collecting weights by the experts (Chandio et al., 2011). Two scenarios were used for evaluation criteria and sub-criteria of sustainable hillside land development economic scenario1 and environmental scenario2. As shown in the following Table 2, the derivation of relative weights of hillside land suitability criteria of economic scenario1. In this table three criteria were selected such as accessibility, topography and land cover. The accessibility criteria obtained the highest priority as compare to other criteria in economic scenario. It means that accessibility is the key element for hillside development. It is true without access hillside land cannot be developed. Each criterion was categorized into sub-criteria. The derivation of relative weights of land suitability sub-criteria of accessibility, topography and land cover criteria in economic scenario1 is shown in the Table 3. In this table, primary road has a high priority in terms of secondary road. Slope has also got high priority. Slope is an important sub-criterion because of hilly topography.

Similarly, same procedure was adopted for environmental scenario's criteria and sub-criteria shown in Table 4 and Table 5. Aggregated CR level of economic scenario is determined (0.05) and environmental scenario 2 is (0.07) which shows acceptable response collected by the experts.

Table 2: Derivation of Relative Weights of land suitability criteria Scenario1

Suitability criteria	Accessibility	Topography	Land Cover	Priority vector
Accessibility	1	2	3	0.55
Topography	1/2	1	1	0.24
Land Cover	1/3	1	1	0.21
∑				1

Table 3: Relative weighting of sub-criteria (S1) for each land suitability criteria

	Criteria	1	2	3	4	5	Priority Vector
	Accessibility						
(1)	Primary road	1					0.667
(2)	Secondary road	½	1				0.333
	Topography						
(1)	Elevation	1					0.105
(2)	Slope	5	1				0.637
(3)	Aspect	3	1/3	1			0.258
	Land cover						
(1)	Agri. Land	1					0.543
(2)	Forest Land	1/7	1				0.20
(3)	Existing Residential	1/3	1/2	1			0.190
(4)	Wetland	1/7	1/7	1/9	1		0.035
(5)	Surface water	1/9	1/7	1/9	1	1	0.031

Table 4: Derivation of Relative Weights of land suitability criteria Scenario2

Suitability criteria	Accessibility	Topography	Land Cover	Priority vector
Accessibility	1	1	1	0.327
Topography	1	1	2	0.413
Land Cover	1	1/2	1	0.26
∑				1

Table 5: Relative weighting of sub-criteria (S2) for each land suitability criteria

	Criteria	1	2	3	4	5	Priority Vector
	Accessibility						
(1)	Primary road	1					0.667
(2)	Secondary road	½	1				0.333
	Topography						
(1)	Elevation	1					0.105
(2)	Slope	5	1				0.637
(3)	Aspect	3	1/3	1			0.258
	Land cover						
(1)	Agri. Land	1					0.573
(2)	Forest Land	1/7	1				0.143
(3)	Existing Residential	1/5	2	1			0.218
(4)	Wetland	1/7	7	1/9	1		0.035
(5)	Surface water	1/9	7	1/9	1	1	0.031

6.1. Validation of MCDA Model

In this study, two statistically methods were applied to validate MCDA model named the Kolmogorov-Smirnov (K-S) and t-test. The Kolmogorov-Smirnov (K-S) test, which is a powerful test for the goodness of fit (Justel et al., 1997). It is especially useful for small size of sample which was employed to test the weighting distribution of each criterion in Statistical Package for Social Sciences (SPSS) (Chen and Delaney, 1998). The K-S P-value of the weights of all criterions for hillside suitability was analyzed significance level of 0.05. It is a well-known technique used for normality test (Drezner and Turel, 2011). In addition, t-test was also used to observe statistically significance level of criterion. These statistical techniques, namely, Kolmogorov-Smirnov (K–S) and t-test statistics which are discussed as follows:

As depicted in Table 6, the bivariate Kolmogorov-Smirnov (K–S) statistic is used for all the 10 sub-criteria variables illustrated in Table 6. In this analysis, we assume 0.05 as the K–S statistic threshold. As a result, the K-S two tailed P of the weights of all the sub-criteria for hillside development observed to be statistically significant in scenario1 with their two-tailed P value higher than 0.05. It means all data are normally distributed; there is no statistically significant difference among experts' opinion (weights). Hence, in scenario2 it is observed that only one sub-criterion (Secondary road) is not statistically significant (Chen and Delaney, 1998, Gong and Huang, 2012). Experts, therefore, shared common opinion on weightings are computed of sub-criteria in scenario 2. There are different views of secondary road sub-criteria.

Table 6: K–S statistics of Sub-criteria S1 and S2 from dataset

Sub-criteria	Description	K-S Statistic (S1)	K-S Statistic (S2)
Sub-C1	Primary road	0.470	0.240
Sub-C2	Secondary road	0.55	0.039
Sub-C3	Elevation	0.284	0.962
Sub-C4	Slope	0.877	0.573
Sub-C5	Aspects	0.728	0.525
Sub-C6	Agriculture land	0.653	0.970
Sub-C7	Residential	0.599	0.810
Sub-C8	Forest land	0.765	0.982
Sub-C9	Wet land	0.178	0.595
Sub-C10	Surface water	0.147	0.636

S1= Scenario1, S2=Scenario2

The one-sample t-test has also been used to see the significance level of all sub-criteria weights for scenario1 and scenario2. In t-test analysis, author assumes 0.05 as the t–test statistic threshold. Therefore, there is no statistically significant change observed among the nine sub-criteria in the scenario1and only one sub-criterion (surface water) is not statistically significant. Similarly, it can be seen in scenario2 that eight sub-criteria are statistically significant and only two sub-criteria are found statistically not significant, i.e. wet land and surface water shown in the following Table 7.Therefore, it is concluded in the result interpretation that there is no major significant change in scenario1 and scenario 2 priority weights.

Table 7: T-test statistics of sub-criteria S1 and S2

Sub-criteria	Description	t-test Statistic (S1)	t-test Statistic (S2)
Sub-C1	Primary road	0.022	0.014
Sub-C2	Secondary road	-0.003	0.048
Sub-C3	Elevation	0.025	0.051
Sub-C4	Slope	0.004	0.013
Sub-C5	Aspects	-0.001	0.013
Sub-C6	Agriculture land	0.034	0.043
Sub-C7	Residential	0.048	0.074
Sub-C8	Forest land	0.054	0.079
Sub-C9	Wet land	0.401	0.457
Sub-C10	Surface water	0.048	0.420

7. Conclusion

Statistically analysis is a helpful technique that improves subjectivity level of AHP as MCDA models in decision-making process. This study evaluated by using Kolmogorov-Smirnov (K–S) and t-test statistic approaches of land suitability sub-criteria weights. It was aimed that computed decision for sub-criteria would be more suitable by the experts of land suitability analysis in decision-making process. This would examine for shorter time giving their suitable opinion of land suitability analysis for hillside development. It was found that statistical validation is a useful method for advance validation of MCDA models as compare with the CR. K-S and t-test offers more validation confidence of AHP as MCDA models.

References

[1] Amin, S. 1997. Economic, political and social distortions in the modern world. In: Smith P, Tenner A, editors. Dimensions of sustainability. Baden-Baden: Nomos Verlagsgesellschaft, p. 19–25

[2] Chandio, I. A., Matori., A.-N., Lawal., D. U. & Sabri., S. 2011. "GIS- based Land Suitability Analysis Using AHP for Public Parks Planning in Larkana City". *Modern Applied Science,* 5**,** 177-189.

[3] Chang, Q., Xue LI, Huang, I. & Wub, J. 2012. "A GIS-based Green Infrastructure Planning for Sustainable Urban Land Use and Spatial Development". *Procedia Environmental Sciences,* 12**,** 491 – 498.

[4] Chen, C.-H., Liu, W.-L., LIAW, S.-L. & Yuc, C.-H. 2005. "Development of a dynamic strategy planning theory and system for sustainable river basin land use management". *Science of the Total Environment,* 346**,** 17– 37.

[5] Chen, F. & Delaney, J. 1998. "Expert knowledge acquistion: A methodlology for GIS assisted industrial land suitability assessment". *Urban Policy and Research,* 16**,** 301-315.

[6] Doughty, M. R. C. & Hammond, G. P. 2004. "Sustainabilityand the built environment at and beyond the city scale". *Building and Environment,* 39**,** 1223 – 1233.

[7] Drezner, Z. & Turel, O. 2011. "Normalizing variables with too-frequent values using a Kolmogorov–Smirnov test: A practical approach". *Computers & Industrial Engineering,* 61**,** 1240-1244.

[8] Gong, R. & Huang, S. H. 2012. "A Kolmogorov–Smirnov statistic based segmentation approach to learning from imbalanced datasets: With application in property refinance prediction". *Expert Systems with Applications,* 39**,** 6192-6200.

[9] Hurni, H. 2000. "Assessing sustainable land management (SLM)". *Agriculture, Ecosystems and Environment 81* 81**,** 83–92.

[10] Justel, A., Peña, D. & Zamar, R. 1997. "A multivariate Kolmogorov-Smirnov test of goodness of fit". *Statistics & Probability Letters,* 35**,** 251-259.

[11] Kates, R. W., Parris, T. M. & Leiserowitz, A. A. 2005. "What is a sustainable Development? Goals, Indicators, Values, and Practice, Science and Policy for Sustainable Development". *Environment: Science and Policy for Sustainable Development,* 47**,** 8–21.

[12] Lier, H. N. V. 1998. "The role of land use planning in sustainable rural systems". *Landscape and Urban Planning,* 41**,** 83–91.

[13] Mahmouda, A. H. A. & EL-sayedc, M. A. 2011. "Development of sustainable urban green areas in Egyptian new cities: The case of El-Sadat City". *Landscape and Urban Planning,* 101**,** 157–170.

[14] Malczewski, J. 1999. "*GIS and Multicriteria Decision Analysis",* Cananda, John Wiley and Sons, Inc.

[15] Malczewski, J. 2004. "GIS-based land-use suitability analysis: a critical overview". *Progress in Planning,* 62**,** 3–65.

[16] Mirabella, J. 2006. "Hypothesis Testing with SPSS" , http://www.drjimmirabella.com/ebook/excerpt%20from%20Hypothesis%20Testing%20with%20SPSS%20ebook%20(Jim%20Mirabella).pdf, Reterived on 03-01-2013.

[17] Quaddusa, M. A. & Siddique, M. A. B. 2001. "Modelling sustainable development planning: A multicriteria decision conferencing approach". *Environment International* 27**,** 89–95.

[18] Saaty, T. L. 1980. "*The Analytic Hierarchy Process",* New York, Mc Graw Hill.

[19] Senes, G. & Toccolini, A. 1998. "Sustainable land use planning in protected rural areas in Italy". *Landscape and Urban Planning,* 41**,** 107–117.

[20] Voogd, H. 1983. "*Multicriteria Evaluation for Urban an Regional Planning".* Proefschriftuitgave:Delfsche Uitgevers Maatschappij-Delft.

[21] Wced 1987. "Our Common Future". *World Commission on Environment and Development,Brundtland Report. Oxford University Press,Oxford.*