Aggregation methods

This document is made of excerpts extracted from:
Malczewski, J. (1999) GIS and multicriteria decision analysis. John Wiley & Sons Inc. New York

These methods are only for attribute aggregation, if necessary, there are more methods for objective aggregation.

1. **Method Summary**

MADM method	Input	Output	Decision types	DM interaction	Assumptions	MCDM software
Scoring	Attribute scores, weights	Ordinal ranking	Individual DM, deterministic	Moderate	Nonrestrictive	Spreadsheets
Multiattribute value	Value functions, weights	Cardinal ranking	Individual and group DMs, deterministic, fuzzy	High	Very restrictive	Logical decisions, MATS, spreadsheets
Multiattribute utility	Utility functions, weights	Cardinal ranking	Individual and group DMs, probabilistic, fuzzy	High	Very restrictive	Logical decisions, HIPRE3+, spreadsheets
Analytic hierarchy process	Attribute scores, pairwise comparisons	Cardinal ranking (ratio scale)	Individual and group DMs, deterministic, probabilistic, fuzzy	High	Moderately restrictive	Expert choice, HIPRE3+, Which&why, spreadsheets
Ideal point	Attribute scores, weights, ideal point	Cardinal ranking	Individual and group DMs, deterministic, probabilistic, fuzzy	Moderate	Nonrestrictive	AIM, spreadsheets
Concordance	Attribute scores, weights	Partial or ordinal ranking	Individual and group DMs, deterministic, probabilistic, fuzzy	Moderate	Nonrestrictive	ELECTRE III and IV, spreadsheets
Ordered weighted averaging	Fuzzy attribute, weights, order weights	Cardinal or ordinal ranking	Individual and group DMs, fuzzy	Moderate	Moderately restrictive	spreadsheets

2. Method references

MADM Method	Citation	Full reference
Scoring	Jankowski and Richard (1994)	Jankowski, P., Richard, L. (1994) Integration of GIS-based suitability analysis and multicriteria evaluation in a spatial decision support system for route selection. Environment and Planning B 21(3): 326-339
Scoring	Heywood et al. (1995)	Heywood, I., Oliver, J., Tomlinson, S. (1995) Building an exploratory multi-criteria modelling environment for spatial decision support. In: P. Fisher (Ed.), Innovations in GIS 2. London: Taylor & Francis, pp. 127-136
Scoring	Lowry et al. (1995)	Lowry, J. H. Jr., Miller, H. J., Hepner, G. F. (1995) A GIS-based sensitivity analysis of community vulnerability to hazardous contaminations on the Mexico/U.S. border. Photogrammetric Engineering and Remote Sensing 53(10): 1417-1421
Multiattribute value	Jankowski and Richard (1994)	Jankowski, P., Richard, L. (1994) Integration of GIS-based suitability analysis and multicriteria evaluation in a spatial decision support system for route selection. Environment and Planning B 21(3): 326-339
Multiattribute utility	Keisler and Sundell (1997)	Keisler, J. M., Sundell, R. C. (1997) Combining multi-attribute utility and geographic information for boundary decisions: an application to park planning. Journal of Geographic Information and Decision Analysis 1(2): 110-123
Multiattribute utility	Janssen and Rietveld (1990)	Janssen, R., Rietveld, P. (1990) Multicriteria analysis and geographical information systems: an application to agricultural land use in the Nethernalds. In: H. J. Scholten, J. C. H. Stillwell (eds.), Geographical information systems for urban and regional planning. Dordrecht, The Netherlands: Kluwer Academic, pp. 129-139
Analytic hierarchy process	Eastman (1993)	Eastman, J. R. (1993) IDRISI: a grid based geographic analysis system, version 4.1. Worcester, MA: Graduate School of Geography, Clark University
Analytic hierarchy process	Siddiqui et al. (1996)	Siddiqui, M. Z., Everett, J. W., Vieux, B. E. (1996) Landfill sitting using geographic information systems: a demonstration. Journal of Environmental Engineering 122(6): 513-523
Analytic hierarchy process	Hickey and Jankowski (1997)	Hickey, R., Jankowski, P. (1997) GIS and environmental decision making to aid smelter reclamation planning. Environment and Planning A 29(1): 5-19

MADM Method	Citation	Full reference
Analytic hierarchy process	Banai (1993)	Banai, R. (1993) Fuzziness in geographic information systems: contributions from the analytic hierarchy process. International Journal of Geographical Information Systems 7(4): 315-329
Ideal Point	Tkach and Simonovic (1997)	Tkach, R. J., Simonovic, S. P. (1997) A new approach to multi-criteria decision making in water resources. Journal of Geographic Information and Decision Analysis 1(1): 25-43 URL: http://publish.uwo.ca/~jmalczew/gida.htm
Ideal Point	Malczewski (1996)	Malczewski, J. (1996) A GIS-based approach to multiple criteria group decision making. International Journal of Geographical Information System 10(8): 955-971
Ideal Point	Pereira and Duckstein (1993)	Pereira, J. M. C., Duckstein, L. (1993) A multiple criteria decision-making approach to GIS-based land suitability evaluation. International Journal of Geographical Information Systems 7(5): 407-424
Ideal Point	Carver (1991)	Carver, S. J. (1991) Integrating multi-criteria evaluation with geographical information systems. International Journal of Geographical Information Systems 5(3): 321-339
Ideal Point	Ewart (1994)	Ewart, G. M. (1994) Integrating geographic information systems and multicriteria decision making to develop a prototype decision support system for health professionals. Unpublished M. S. thesis, University of Idaho, Moscow, ID
Concordance	Martin et al. (in press)	Martin, N. J., Onge, B. St., Waaub, J. P. (in press) An integrated decision aid system for develpment of Saint-Charles river's alluvial plain, Quebec, Canada. International Journal of Environment and Pollution
Concordance	Can (1992)	Can, A. (1992) Residential quality assessment: alternative approaches using GIS. Annals of Regional Science 23(1): 97-110
Concordance	Carver (1991)	Carver, S. J. (1991) Integrating multi-criteria evaluation with geographical information systems. International Journal of Geographical Information Systems 5(3): 321-339
Ordered weighted averaging	Eastman and Jiang (1996)	Eastman, J. R., Jiang, H. (1996)

MADM Method	Citation	Full reference
Ordered weighted averaging	Eastman (1997)	Eastman, J. R. (1997) IDRISI for Windows, version 2.0: tutorial exercises, Worcester, MA: Graduate School of Geography, Clark University

3. Method description

Scoring

They are based on the concept of a weighted average. The decision maker directly assigns weights of "relative importance" to each attribute. A total score is then obtained for each alternative by multiplying the importance weight assigned for each attribute by the scaled value given to the alternative on that attribute, and summing the products over all attributes. When the overall scores are calculated for all the alternatives, the alternative with the highest overall score is chosen. The decision rule evaluates each alternative, A_i, by the following formula:

$$A_i = \sum_j w_j \cdot x_{ij}$$

where x_{ij} is the score of the ith alternative with respect to the jth attribute, and the weight w_j is a normalized weight, so that $\sum w_j = 1$.

Multiattribute value

The value function approach is applicable in the decision situations under certainty (deterministic approach). This approach assumes that the decision maker is relatively "risk neutral" or that the attributes are known with certainty. Formally, the value function model is similar to "scoring method", except that the score x_{ij} is replaced by a value v_{ij} derived from the value function. The value function model can be written:

$$V_i = \sum_j w_j \cdot v_{ij}$$

where V_i is the overall value of the ith alternative, v_{ij} is the value of the ith alternative with respect to the jth attribute measured by means of the value function, and the weight w_j is a normalized weight or scaling constant for attribute j, so that $\sum w_j = 1$.

Multiattribute utility

In the utility function procedure, the decision's maker attitude toward risk is incorporated into assessment of a single-attribute utility function (Keeney, 1980). Thus utility is a convenient method of including uncertainty (risk preference) into decision-making process. The concept of a utility function is inherently probabilistic in nature. Formally, the utility function model is similar to "scoring method", except that the score x_{ij} is replaced by a utility u_{ij} derived from the utility function. The utility function model can be written:

$$U_i = \sum_j w_j \cdot u_{ij}$$

where U_i is the overall value of the ith alternative, u_{ij} is the utility of the ith alternative with respect to the jth attribute measured by means of the utility function, and the weight w_j is a normalized weight or scaling constant for attribute j, so that $\sum w_j = 1$.

Analytic hierarchy process

The analytical hierarchy process (AHP) method, developed by Saaty (1980), is based on tree principles: decomposition, comparative judgment and synthesis of priorities. The *decomposition principle* requires that the decision problem be decomposed into a hierarchy that captures the essential elements of the problem, the principle of *comparative judgment* requires assessment of pairwise comparisons of the elements within a given level of the hierarchical structure, with respect to their parent in the next-higher level, and the *synthesis principle* takes each of the derived ratio-scale local priorities in the various levels of the hierarchy and constructs a composite set of priorities for the elements at the lowest level of the hierarchy. In this final step, the goal is aggregate the relative weights of the levels obtained in the previous step to produce composite weights, this is done by means of a sequence of multiplications of the matrices of relative weights at each level of the hierarchy.

Ideal point methods

Ideal point methods order a set of alternatives on the basis of their separation from the ideal point. This point represents a hypothetical alternative that consists of the most deliverable weighted standardized levels of each criterion across the alternatives under consideration. The alternative that is closed to the ideal point is the best alternative. The separation is measured in terms of a distance metric. The ideal point decision rule is:

$$s_{i+} = \left[\sum_j w_j^p \left(v_{ij} - v_{+j} \right)^p \right]^{1/p}$$

where s_{i+} is the separation of the ith alternative from the ideal point, w_j is a weight assigned to the j criterion, v_{ij} is the standardized criterion value of the ith alternative, v_{+j} is the ideal value for the jth criterion, and p is a power parameter ranging from 1 to ∞.

Concordance methods

Concordance methods are based on a pairwise comparison of alternatives. They provide an ordinal ranking of the alternatives; that is, when two alternatives are compared, these methods can only express that alternative A is preferred to alternative B, but cannot indicate by how much. The most known concordance approach is the ELECTRE method and its modifications.

Ordered weighted averaging

Ordered weighted averaging is an aggregation technique based on the generalization of three basic types of aggregation functions, which are: (1) operators for the intersection of fuzzy set, (2) operators for the union of fuzzy sets, and (3) averaging operators. It provides continuous fuzzy aggregation operations between the fuzzy intersection and union, with a weighted-average combination falling midway in between.

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