The Iterative Method in Multi-criteria Decision Analysis: A Case Study of Fuzzy GIS

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1. Introduction and Problem Establishment

Over the last 10 years, multicriteria decision analysis (MCDA) has become an essential subfield of research in GIScience (Malczewski 2006a), and might be considered to improve some domains in real world (e.g. business strategies and national planning). Some theories, such as OWA (Malczewski 2006b), AHP (Saaty 2008) or fuzzy quantifier (Malczewski 2006b), were introduced and applied in order to evolve MCDA in GIScience.

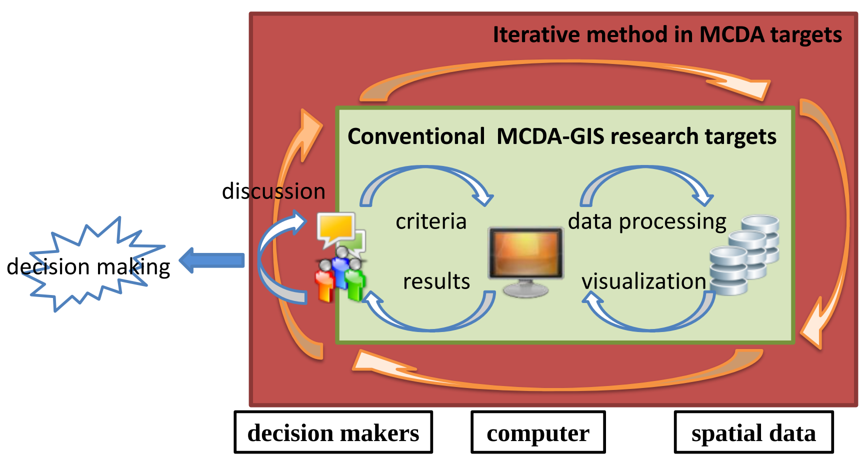

Figure 1. Framework of MCDA processes based on GIS.

Although many techniques have been applied to MCDA, the limitations incorporating with GIS are still existed. The reasons of this limitations are existence of factors which face difficulties digitalisation (qualitative factors), or inexpertness of MCDA implementation in GIS in terms of decision maker's perception and preferences. The targets of conventional MCDA based on GIS research principally involved applications to fields around the *computer* or *spatial data* (AHP, fuzzy quantifier, OWA) (fig.1).

However, the major advantage of incorporating MCDA techniques into GIS-based procedures is that the decision-makers can receive feedback on their implications for policy evaluation (Malczewski 2006a). Therefore, one of the important processes in MCDA based on GIS is the part of *discussion* field (fig.1) that has not been, however, so much considered in the past studies. In this study, the methodologies improving discussion field are proposed.

2. Iterative Method

Generally, the processes of MCDA based on GIS are executing decision making cycle (*criteria – data processing – visualization – results* - *discussion*) at some stages, and then by satisfying a specific condition according to decisions, these processes reach to decision making through the *discussion* field (fig.1). As a matter of course, if a perfect MCDA based on GIS that can incorporate fully the perceptions of decision makers, and also can equip all required data exist, decision making will be realized by only one execution of decision making cycles. However, since any perfect MCDA based on GIS have not appeared, iterative processes through discussion about output of MCDA based on GIS would be more realistic. In this context, iterative processes indicate that a further improvement of MCDA cycle is required with improvement with of criteria. In addition, the feedback of results can be handled by iterative process. In iterative processes, the criteria improvement is important, because MCDA based on GIS cannot express the perception preferences of decision makers completely.

Iterative adjustment method is one of the iterative methods. Because of incomplete interaction between decision makers and MCDA based on GIS, it is possible to consist of the differences between the criteria which decision makers set and the perception preference of decision makers. To improve the criteria by iterative adjustment method the consideration with feedback of results can bridge those differences.

Iterative method might hypothecate a situation that limited to a region to be extracted from study area for specified objectives such as selection of observation point or building candidate site, because such objectives must require the explicit results (site or region) whose number or extent must be along the objectives. In other words, decision makers have the determined extents for suitability regions in result map. Therefore, when decision makers obtained results that are unmatched according to their objectives, decision makers have to conduct the MCDA based on GIS with improvement of their criteria again.

3. Experimental Test

To show the examples of iterative method in MCDA based on GIS, a case study of conventional fuzzy MCDA based on GIS was conducted. DEM data which is 50m mesh were prepared, and slope and aspect maps were created from the DEM data. Criteria in this test were set as “Low elevation”, “Low slope” and “North direction”. Fuzzy membership functions were generated on probation according to the criteria (fig.2). Fuzzy membership function performs mapping of all attribute values ranging from 0 to 1. The closer to 1 the membership values are, the more suitable for the criteria the corresponding attribute values are.

Then, the criteria weights that are relative importance in comparison with each other can be decided. This weight is one of the most important factors in the MCDA, so a number of theories have been applied for determining the criteria weights. In this test, the weights of the attribute maps were standardised using the pairwise comparison method that is basic concept of analytic hierarchy process (AHP) (Saaty 2008, Thapa and Murayama 2008). Using this methodology, the priorities of criteria, that are equal to weights in this method, can be obtained automatically through creating pairwise comparison matrix based on decision maker preferences (Table 1).

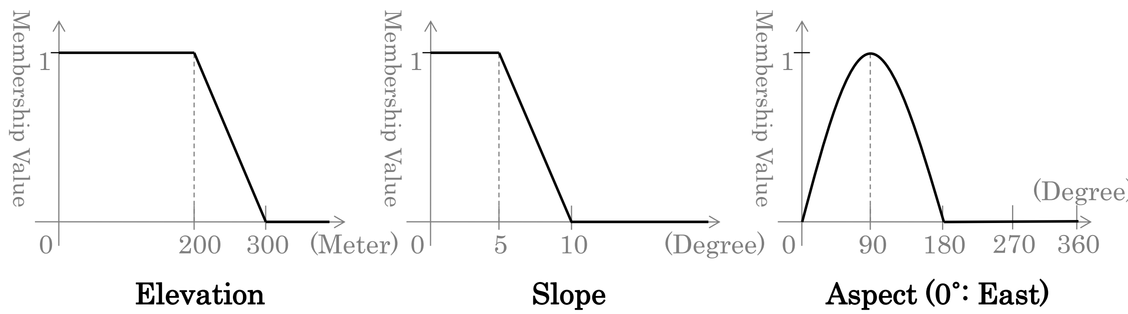

Figure 2. Fuzzy membership functions for decision criteria.

Criteria	Elevation	Slope	Aspect	Priority
Elevation	1	0.200	0.250	0.097
Slope	5	1	3	0.619
Aspect	4	0.333	1	0.284

Consistency Index=0.043

Table 1. Pairwise comparison matrix and the priorities.

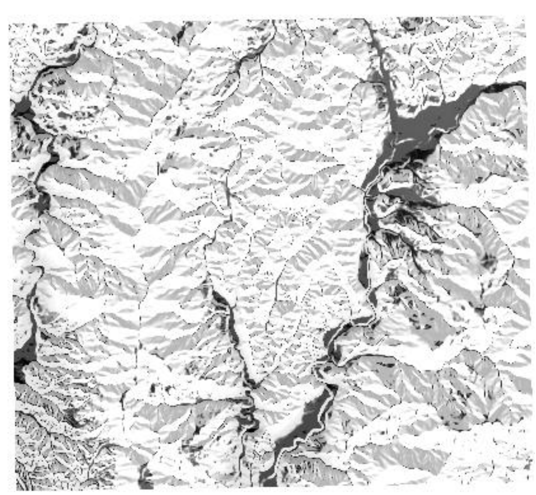

Figure 3. The result map of sum according to Table 1.

According to Table 1, the result map could be obtained (fig.3). Here, two situations can be considered as differences between the perception preferences of decision makers and the criteria they set. The more suitable regions in the result maps (highly grey level) show smaller regions or larger regions than the regions decision makers expected. Therefore, if the result map showing smaller regions were obtained, the criteria should be changed to more lenient.

A representation of shape change method of fuzzy membership functions in conventional fuzzy MCDA based on GIS is in the powered hedge method (fig.4) (Benedikt et al 2002). The powered hedge is one of the transformation methods of fuzzy membership functions. If the powered number is integer, criterion is changed to much stricter. On the other hand, decimal fraction of powered numbers means more lenient criteria.

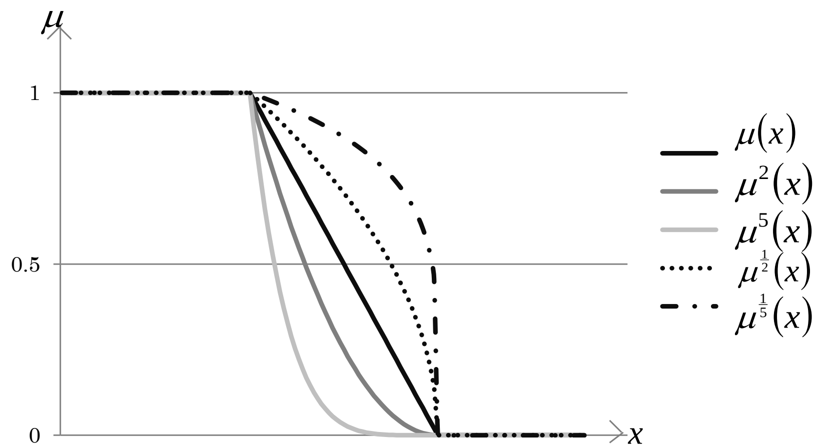

Figure 4. The examples of powered hedge.

Here, the hypothesis is that the fig.3 shows larger suitable regions than the regions decision makers need was employed. According to this hypothesis, powered hedge methods were conducted, and all map were integrated following to the pairwise comparison matrix (fig.5). The figure5 indicates that the larger number of power is the more clear contrast of suitability become. It could be obviously identified that the particular suitability regions were enhanced, and other regions were excluded. Therefore, decision makers ease to select the candidate region in suitable regions according to their objectives.

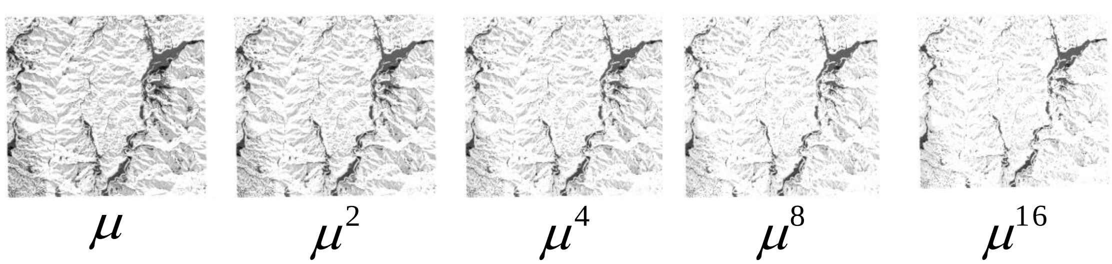

Figure 5. The results of applied powered hedge methods.

4. Conclusion

One of the goals of decisional guidance for MCDA in group decision settings referred by Limayem and DeSanctis (2000) is "to enhance user understanding of the model inputs, processes, and output". The iterative process in this paper can make MCDA more flexible. Since a MCDA based on GIS that can interact with decision makers have not appeared yet, this iterative method is required in order to be close to the complete interaction with perception preferences of decision makers and MCDA interfaces. Therefore iterative method can contribute to this goal, because differences between the perception of decision makers and criteria they set must exist. However, this method has not been considered in depth. Implementation of the iterative method to MCDA based on GIS would contribute to further improvement of MCDA.

5. References

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