Matlab기반의 다중의사결정 기준 변화에 따른 민감도 분석

Establishment of Matlab-based MCDA Interactive Model for the Sensitivity of the Preferred Alternatives to the Number of Criteria

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Abstract

The impact of adding additional Multi-Criteria Decision Analysis (MCDA) criteria is demonstrated because current research shows MCDA for flood damage has been applied using only a few criteria but for better results the MCDA approach needs to apply more criteria for evaluating the alternatives. By adding additional criteria into MCDA, the capability to make the best alternatives more diverse and show the decision maker more differences in the scores of the alternatives to allow the decision maker to discriminate is significantly improved.

The target region for a demonstration application of the methodology was the Suyoung River Basin in Korea. The 1991 Gladys flood event and five different return periods were used as a case study to demonstrate the proposed methodology of evaluation of various flood damage reduction alternatives.

Key words: MCDA, Matlab, Criteria, Sensitivity, Fuzzy, SFCP.

1. Introduction

Floodplain management involves the use of spatial physical information and information on decision makers' preferences in terms of selecting options. Both of these sources of information can have various degrees of imprecision. This study combines geographic information systems (GIS) with a Fuzzy Multi-Criteria Decision Analysis (MCDA) technique to attempt to consider these sources of imprecision. This combination, Fuzzy MCDA, provides decision makers the ability to have even more definition and discrimination in terms of the alternatives that might be best for particular spatial location. The main question for this research becomes the impact of the number of criteria on the alternatives selected.

2. Methodology

MCDA, sometimes called Multi Criteria Decision Making (MCDM), is a discipline aimed at supporting decision makers who are faced with making numerous and conflicting evaluations.

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MCDA aims at highlighting these conflicts and deriving a way to come to a compromise in a transparent process (Wikepedia).

The purpose of this chapter is to identify, review, and evaluate the performance of a number of various MCDA techniques for integration with GIS. Even though there are a number of techniques which have been applied in many fields, this paper will only consider the techniques that have been applied in floodplain decision-making problems. A Spatial Fuzzy Weighted Average Method (SFWAM) for multi-criteria evaluation was selected to be integrated with GIS. Detailed concepts of SFWAM algorithm are presented in this chapter.

2.1. SFWAM method

Considering the literature available on MCDA techniques, it was realized that there is a need to develop a methodology that combines the three important issues, since time and space play an important role in flood management. Specifically, these are the GIS capabilities for finding more spatially distributed strategies, the MCDA capabilities for considering multiple-criteria in deciding on best alternatives, and the fuzzy capabilities for lessening the effect of the imprecision on the answer (Lim 2008).

The SFWAM was introduced to include these three objectives. Fuzzification has been proposed to account for the vagueness in the entire process of decision-making. Fuzzy distance-based techniques measure the distance from an ideal point, where the ideal alternative would result in a distance metric. Hence, alternatives, which tend to be closest to the ideal solution, will be selected. Fuzzification of the distance metric exponent, *p*, can take many forms but in a practical way, it might be defined by an S-shaped fuzzy set with a mode of 2. The fuzzified distance metric values within the images are calculated by comparing impacts for each location on a cell by cell basis between all alternatives and applying the decision makers' preferences, which are in fuzzy form as well (Nirupama and Simonovic 2002).

$$\tilde{L}_{j,x,y}=\left[\sum_{i=1}^{n}\tilde{w}_i^{\tilde{p}}\left|\frac{\tilde{f}^{*}_{i,x,y}-\tilde{f}_{i,j,x,y}}{\tilde{f}^{*}_{i,x,y}-\tilde{f}^{**}_{i,x,y}}\right|^{\tilde{p}}\right]^{1/\tilde{p}} \quad (1)$$

where $\tilde{L}_{j,x,y}$ is the fuzzy distance metric, $\tilde{w}$ is fuzzified weight of i^{th} criteria, $\tilde{f}_{i,j,x,y}$ is the fuzzy value of the i^{th} criteria for alternative *j*, $\tilde{f}^{*}_{i,x,y}$ is the fuzzy most optimal value of the i^{th} criteria, $\tilde{f}^{**}_{i,x,y}$ is the fuzzy least optimal value of i^{th} criteria, $\tilde{p}$ is a fuzzified power parameter ($1 \le p \le \infty$), $i=1,...,n$ criteria, $j=1,...,m$ alternatives, $x=1,...,a$ rows in the image, $y=1,...,b$ columns in the image, *a* is the number of rows in the image, and *b* is the number of columns in the image.

3. Case Study

3.1. Experimental Design

3.1.1. Suyoung River Basin

The target region for a demonstration application of the methodology was the Suyoung basin in Pusan Province where is located on the southeastern tip of South Korea. The entire study area covers an area of 199.7㎢ and the population of this area is about 4 million people. For the application of the developed methodology for evaluating flood damage reduction alternatives, the 1991 Gladys flood event and five different return periods were selected.

3.1.2. Alternatives, criteria and weights

The key concept of the Suyoung River Basin flood control planning is how to decrease the huge flood inflow from the upstream portions of the Suyoung River Basin during the flood season. As shown below, various alternatives have been derived to find the best way to reduce flood damage.

Table 1. Various alternatives to protect against flooding

Alternatives	Notes
1. Before 1991 Gladys Flood	To leave the floodplain area as it is with no additional action
2. After 1991 Gladys Flood	One of the major communities (Banyeo-Dong) built levees along the east side of the river after 1991 flood
3. Channelization plus levees	Floods in the Suyoung River have demonstrated that levees alone do not provide sufficient protection against flooding on a large river
4. Pumping plus levees	Four pump stations with a capacity of 3,800 ㎥/min are installed along the upstream side of the Suyoung River
5. A combination	Combines Alternative 4 with channelization for more effective flood control

The evaluation candidate alternatives are measured with five criteria for which the data exhibit a spatial variability and need the integration of mathematical procedures in order to make images of criteria maps. The first criterion used in the evaluation of the alternatives is the floodwater depth for the study region. The second criterion is the flood damage under different return periods within the region of interest. The third criterion is the land use disruption of the study area. Land use will be employed as a different criterion from the flood damage. As an example, if the flooded areas contain structures that may have a high population of people like housing, industrial buildings, or hospitals, they will have higher avoidance values than farmland. The fourth criterion is the risk of flooding under different return periods. This criterion varies with different kinds of flood damage reduction alternatives. It is divided into six categories, Zone 1 through Zone 6. Zone 1 represents the area that is likely to flood with a 10-yr design flood. A Zone 2 area will be submerged by a 20-yr design flood but not by a 10-yr flood (Zone 2 area = 20-yr inundation area - 10-yr inundation area). However, there is no flood damage in Zone 6 for any design flood event. The last criterion is the drainage capacity.

The preferences of decision makers are typically expressed in terms of the weights of relative importance assigned to the evaluation criteria under consideration. In this paper the criteria are equally weighted.

3.1.3. Hydraulic and hydrologic data development

In step 1, computed flood frequency estimates are based on more than 25-years of annual peak-flow records, compiled from 1978 through 2005, from the Pusan weather station peak-flow data. After the interval of occurrence data was obtained, it was utilized as input data for the Suyoung River Basin hydrologic model. As a result of step 1, the HEC-HMS hydrologic model was developed. In step 2, the resulting peak flows from hydrographs generated by the hydrologic model were used as input to a HEC-RAS model created for a specific portion of the Suyoung River Basin. The hydraulic model was created in conjunction with the HEC-GeoRAS extension, using 5m resolution DEM. HEC-GeoRAS was used to convert the resulting water surface elevations into specific digital floodplains. In the final step (step 3), these digital floodplains were combined with additional GIS data to evaluate flood damage reduction alternatives (Bedient and Huber 2002)

3.2. Matlab based interface

In order to evaluate the alternatives, an MCDA interactive model containing all of the decision parameters was developed. Matlab software was chosen to implement the MCDA methods. This developed model incorporates user-supplied conditions. The user can select the DEM resolution, resource criteria, alternatives, flood frequencies of interest, relative importance, normalized weights, degree of optimism, best and worst values, results lists, and more. The Matlab coding for SFWAM technique was internally incorporated to calculate every criteria value for an area. The user interface was programmed with Matlab software as well. Using the developed GIS-based MCDA interactive model, one can easily calculate results using SFWAM method for any given data set.

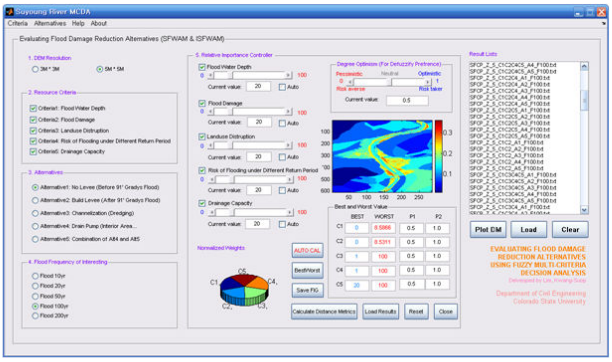

Fig 1. A Matlab-based MCDA model

3.3. The sensitivity of the preferred alternatives to the number of criteria

If there is only one criterion, then the alternative that has the highest rating for that criterion will be ranked the best. This could mask important variations in the answer. If there are multiple criteria, it is not possible to know in advance whether a small number or large number of alternatives will emerge as the best. In other words, the possible impact of inserting additional criteria into the MCDA could cause more or less diversity of preferred options.

Five ranked maps, adding 1 to 5 criteria, are generated by the MCDA model for the area of interest. Figure 2 shows that adding criteria produces more detail on the use of various alternatives in the MCDA results. It is also obvious that the diversity of the answers between using fewer criteria and more criteria is larger in the Suyoung area. The additional criteria clearly make the selection of alternative spatially more diverse. One can infer that by adding criteria it is possible to show greater diversity and greater spatial distribution of the best alternatives.

4. Result

Current research shows MCDA for flood damage has been applied using only a few criteria but for better results the MCDA approach needs to apply more criteria for evaluating the alternatives. The methodology described in this paper was used for the development of a GIS-based MCDA interactive model that:

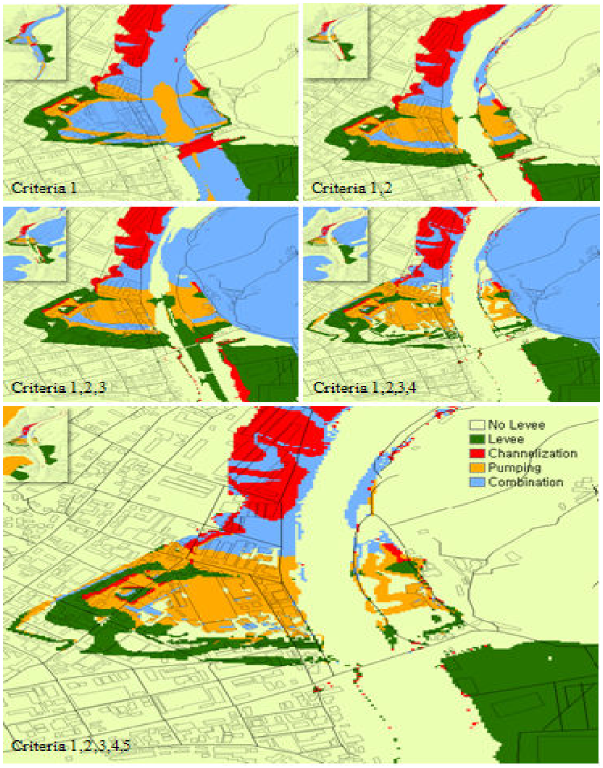

Fig 2. Detailed ranking map

- Provides the means to implement the theoretical advances in MCDA in a user friendly system that enables real-time decision making through interactive and iterative procedures, thereby enhancing the decision maker's perception of the problem and influencing his or her judgment and decision making policy (Gale 2006).
- By adding additional criteria into MCDA, the capability to make the best alternatives more diverse and show the decision maker more differences in the scores of the alternatives to allow the decision maker to discriminate is significantly improved.

참 고 문 헌

1. Bedient, P. B., and Huber, W. C. (2002). Hydrology and floodplain analysis, Prentice Hall, Upper Saddle River, NJ.
2. Gale, T. (2006). "Encylcopedia of Management." S. Neil, ed., International Directory of Business Biographies - F-L.
3. Lim, K.-S. (2008). "Methodology for evaluating flood damage reduction alternatives using a GIS-based MCDA interactive model," Colorado State University, Fort Collins.
4. Nirupama, and Simonovic, S. S. (2002). "A spatial fuzzy compromise approach for flood disaster management." The Institute of Catastrophic Loss Reduction, London, Ontario.
5. http://en.wikipedia.org/wiki/Multi-Criteria_Decision_Analysis