Synthesis of Spatial Results to Recommend a Preferred Alternative

임광섭*, 강신욱**
Kwang-Suop Lim, Shin-Uk Kang

....

요 지

The integration of GIS and fuzzy MCDA(Multi-Criteria Decision Analysis) allows the engineer to determine the preferred alternative for each spatial location in the study area. The next step is to recommend to the final decision makers a single flood management alternative for the entire region. Note that if the study area is large, it might be possible to use the kind of information to recommend different alternatives for different portions of the region. However, for this study it is assumed that only a single alternative will be used.

In this study, a "cost of uniformity" metric is proposed that allows decision makers to compute the impact of selecting a single alternative for the entire floodplain. This metric represents the increase in the average distance metric value as compared to the spatially diverse solution from the MCDA and GIS analysis. The results could be applied to any region of the floodplain as desired. Whether the decision makers decide to apply these calculations to the entire floodplain or to specific important regions within the floodplain, an analysis of the increases in the cost of uniformity provides an integrated way for the decision maker to rank the alternatives. This should provide an improvement in their engineering analysis.

Key words: GIS, MCDA, Cost of uniformity, Decision making, Floodplain

....

1. Introduction

Since one of the important objectives of floodplain management is to reduce the effect of inaccuracies or impression on the answer, the task of improving consideration of imprecision should be extended to the use of the GIS as well as the variety of spatial analysis techniques used within the context of Multi-Criteria Decision Analysis (MCDA).

2. GIS and MCDA

The advantage having spatial data is that it allows the consideration of the unique characteristics at every location. The GIS provides the possibility to develop more spatially distributed information. Ultimately decision makers will typically select a single flood water management alternative (such as levees or a combination of levees and channelization) for the

---
*   정회원 · 한국수자원공사 K-water 연구원 수자원연구실 선임연구원 · E-mail : oklim@kwater.or.kr
**   정회원 · 한국수자원공사 K-water 연구원 수자원연구실 선임연구원 · E-mail : sukang@kwater.or.kr

entire project region. The selected alternative will be more successful in minimizing flood impacts at some spatial locations than others. If the information developed is lumped over the entire floodplain, then the details of the information are lost.

For example, suppose that a floodplain has a large amount of farmland and a smaller urban area. Suppose that in terms of lower flood depths and time of inundation for the urban area, a combination of levees and channelization is the preferred alternative. However, for the farm land, the most preferred alternative is to use only levees. If the decision is made by simply integrating the information over the entire floodplain and the selection is based upon the largest area favoring a specific alternative, then the use of levees will be recommended to the decision maker. However, if the information is provided to the decision maker in a more spatially distributed format, then they can see that the urban area would be better served with the combination of levees and channelization option. This urban area might contain the hospitals and schools that support the entire farming region. This might lead the decision makers to ask for more information such as the increase in costs or increase in impacts for all locations of selecting one flood management alternative over the other. In other words, by providing more spatially diverse information, the decision makers can make a more informed decision. In this study, therefore, more diversity and discrimination is considered to be providing more detailed information and is preferred to less detailed information.

3. Methodology

GIS spatial analysis techniques may introduce problems unique to the technology during the data integration and analysis process. Moreover, floodplain management problems tend to be complex and multi-faceted, requiring an MCDA approach. MCDA allows decision makers to consider multiple-criteria in deciding on the best alternatives. The combinations of spatial and multi-criteria provide the ability to have even more definition and discrimination in terms of the alternatives that might be best for particular spatial locations. Again, more discrimination is taken to mean more information and this is considered highly desirable.

The proposed approach involves integrating a hydraulic model′s terrain data with lower accuracy DEM for flood maps, implementation of deterministic MCDA techniques, and implementing a combination of GIS and fuzzy MCDA into floodplain decision making. 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.

3.1 Study area

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.

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. Various alternatives have been derived to find the best way to reduce flood damage(Fig 1).
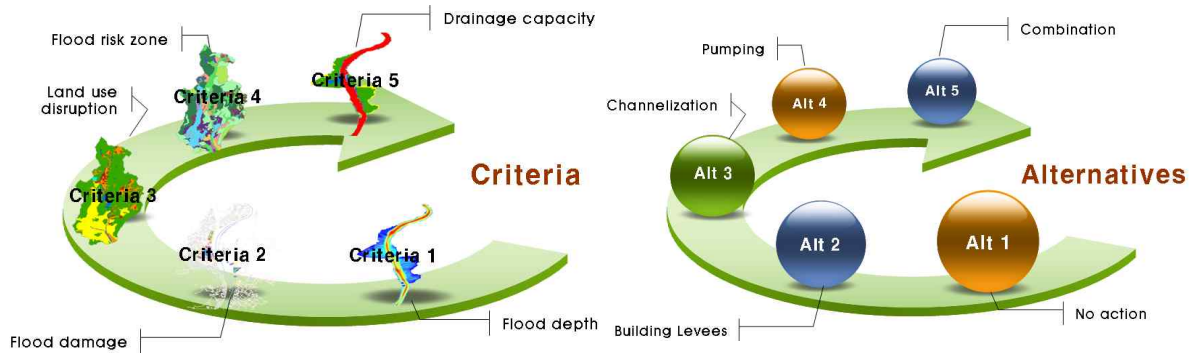

Fig 1. Criteria and Alternatives

3.2 Fuzzy and 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 K-S, 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.

4. Cost of uniformity

As described in the previous section, the integration of GIS and fuzzy MCDA allows

Fig 2. Fuzzy and MCDA method

the engineer to determine the preferred alternative for each spatial location in the study area. The next step is to recommend to the final decision makers a single flood management
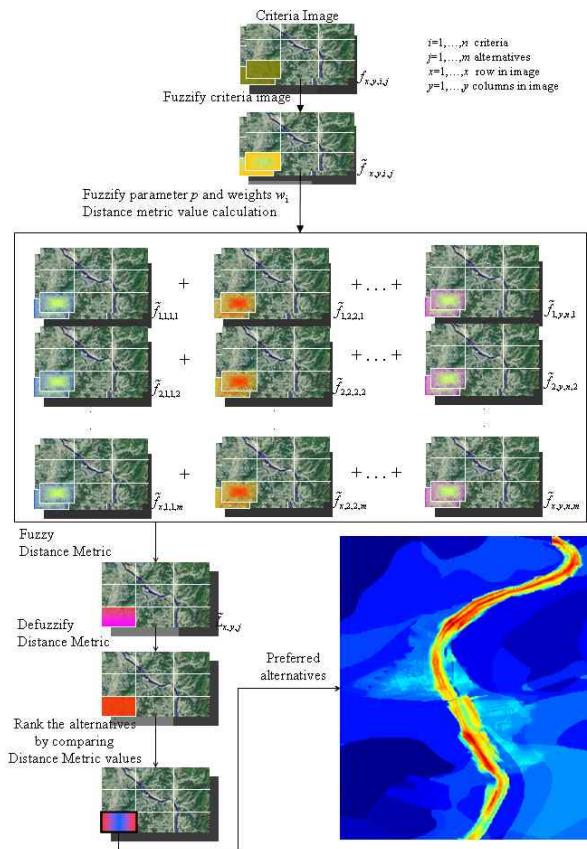
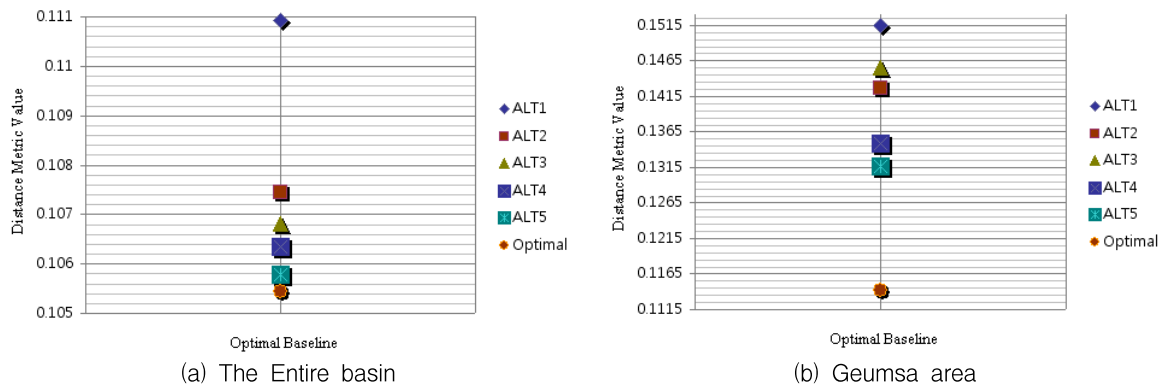alternative for the entire region. For this study it is assumed that only a single alternative will be used.

(a) The Entire basin

(b) Geumsa area

Fig 3. The cost of uniformaty for each of the alternatives for the entire basin and the Geumsa area

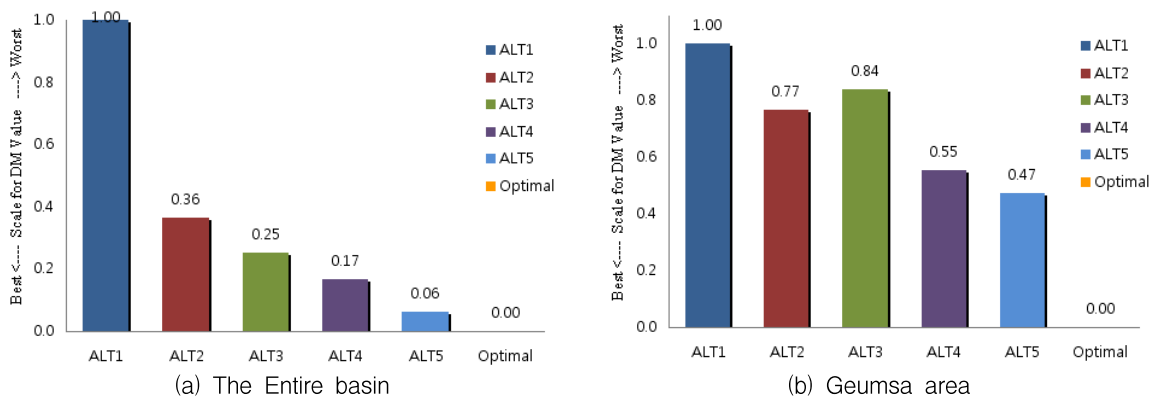(a) The Entire basin

(b) Geumsa area

Fig 4. Scaling the total distance metric for the entire basin and the Geumsa area

The overall sum (or the average) of the distance metrics for all spatial locations represents a lower bound or baseline against which options can be compared. If a single alternative is selected for the entire region, then the average of the distance metrics for all spatial locations will increase. The increase in this average represents a "cost of uniformity" for that alternative. Comparing these "costs of uniformity" for each of the alternatives can give an indication of the relative order of the alternatives in terms of their average scores.

To assist the comparison of the average scores for the alternatives, the increase in average scores was scaled from zero to one, where one corresponds to the largest increase in average score. An example of the calculation of the "cost of uniformity" is shown in Figures 3(a) and 4(a). It is apparent from these figures that selecting Alternative 5 as the entire basin alternative has the smallest increase in the "cost of uniformity." Compared to the baseline condition, selection of Alternative 5 results in an increase of 6% of the average score. If Alternative 4 is applied everywhere, the overall average score increases by 17%. By

comparing these increases to the values for selecting the other alternatives (Alternative 3 = 25%, Alternative 2 = 36% and Alternative 1 = 100%) decision makers can see that alternatives 5 and 4 would clearly be the preferred options.

There might be situations where the selection of the alternative might be influenced most heavily by a particular region in the floodplain. To illustrate this situation the Geumsa area in the upstream portion of the Suyoung River Basin was selected as an important area that might influence the selection of the preferred alternative. The Geumsa area is an urban area with government buildings and hospitals. The "cost of uniformity" calculations were made for the Geumsa area only and the results are shown in Figures 3(b) and 4(b). For this particular region only Alternative 5 still has the smallest increase in the "cost of uniformity" and the second choice is still Alternative 4. However, the relative increase in the "cost of uniformity" was larger (Alternative 5 = 47% and Alternative 4 = 55%). This is an indication of the large amount of diversity of the optimal alternative for individual location in this region.

This kind of analysis could be applied to any region of the floodplain as desired. Whether the decision makers decide to apply these calculations to the entire floodplain or to specific important regions within the floodplain, an analysis of the increases in the cost of uniformity provides an integrated way for the decision maker to rank the alternatives. This should provide an improvement in their engineering analysis.

5. Results

This study shows examples of how the details of the analysis might be synthesized so that the final decision maker can make a more informed decision. Specific key contributions made by this research include the following:

"Proposed the development of a "cost of uniformity" metric that allows decision makers to compute the impact of selecting a single alternative for the entire floodplain. This metric represents the increase in the average distance metric value as compared to the spatially diverse solution from the MCDA and GIS analysis.

참 고 문 헌

1. Kwang-Suop Lim and Dong-Ryul Lee (2009). "The Spatial MCDA Approach for Evaluating Flood Damage Reduction Alternatives" KSCE Journal of Civil Engineering, Vol. 13, Issue 5, pp. 359-369.
2. Kwang-Suop Lim (2008). "Methodology for evaluating flood damage reduction alternatives using a GIS-based MCDA interactive model," Colorado State University, Fort Collins.
3. Tkach, R. J., and Simonovic, S. P. (1997). "A new approach to multi-criteria decision making in water resources." Journal of Geographic Information and Decision Analysis, v. 1(n. 1), pp. 25-44.