Opinion Makers Section

A note on integrating Geographic Information Systems and MCDA

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1. Introduction

A growing number of scientists are merging theories and methodologies from different disciplines to extract new meaning from data and to solve complex problems using new methods. The emerging area of research on integrating Geographic Information Systems (GIS) and MCDA is an example of how linking concepts and methods from ***two distinct*** fields can yield new ways of tackling decision problems. At the fundamental level, GIS-MCDA can be thought of as a collection of methods and tools for transforming and combining geographic data and preferences (value judgments) to obtain information for decision making. Over the last twenty years or so, there has been an exponential growth of theoretical and applied research on GIS-MCDA (Malczewski, 2010). There were only 26 refereed papers about GIS-MCDA published between 1990 and 1995. The volume of papers has increased to more than 350 over the last five years. The field of GIS-MCDA has strongly been adopted within the GIS community. The efforts to integrate MCDA into GIS have also been recognized as a considerable accomplishment in expanding MCDA into new application areas (Wallenius et al., 2008). The hybrid heritage of GIS-MCDA creates new opportunities and challenges for advancing both theoretical and applied research.

2. Opportunities

The opportunities for advancing research on integrating GIS and MCDA come from the synergy between the two distinctive sets of decision support tools. GIS is a system for collecting, storing, manipulating, analysing, and presenting geographic data to obtain information for decision making. The capabilities of handling and processing geographically referenced data distinguished GIS from other information systems. They also make GIS a valuable technology in a wide range of applications, because a wide variety of the public and private sector organizations use geographic data to support their activities. Prominent among the enduring uses of GIS is the task of producing maps. Data outputs in both hard copy and digital map form can be used as a basis for discussing and review of decision problems, which may culminate in the identification of decision alternatives and the choice of a preferred outcome. Here, the map is the basis for both the dialogue and decision outcome, where the discussion and review processes are facilitated not only by analysis of spatial data, but also by review of what the map content reveals to decision participants. GIS can help in coordinating situation analysis through its ability to integrate data from diverse sources. It can enhance the MCDA capabilities for exploring decision situation and supporting the process of learning and discovery. For example, GIS enables geographic data from one sector (such as safe water supply, education, employment) to be combined with data from other sectors (such as health care) to provide a comprehensive picture of the situation in any given community, region or country, and thereby facilitating the setting of priorities for control and surveillance activities, the rationalization of the use of scarce resources, and effective planning.

The capabilities of GIS for generating a set of alternative decisions are mainly based on the spatial relationship principles of connectivity, contiguity, proximity and the overlay methods. For instance, the overlay operations are often used for identifying suitable areas for new development, be it a new industrial facility, waste disposal site, school, hospital, etc. In this context, the functionality of GIS is essentially limited to overlaying deterministic digital map layers to define areas simultaneously satisfying a set of locational criteria. However, when the selection involves conflicting preferences with respect to evaluation criteria, the overlay functions do not provide enough analytical support, because of limited capabilities for incorporating the decision makers' preferences into the GIS-based decision making process. In addition, the complexity of relationships in some spatial decision problems cannot be represented cartographically. Consequently, GIS systems are not flexible enough

to accommodate variations in either the context or the process of spatial decision making.

The limited capabilities of GIS to store and analyze data on the decision maker's preferences can be enhanced by integrating MCDA into GIS. MCDA provides a methodology for guiding the decision maker(s) through the critical process of clarifying evaluation criteria (attributes and/or objectives), and of defining values that are relevant to the decision situation. The major advantage of incorporating MCDA into GIS is that a decision maker can introduce value judgments (i.e., preferences with respect to evaluation criteria and/or decision alternatives) into GIS-based decision making. MCDA can help decision makers to understand the results of GIS-based decision making procedures, including tradeoffs among policy objectives, and then use the results in a systematic and defensible way to develop policy recommendations.

3. Challenges

The hybrid heritage of GIS-MCDA brings about as a series of theoretical, methodological and operational contradictions and inconsistencies. For example, the problem of semantic heterogeneity caused by different meanings of data, terminologies, and models used in GIScience and MCDA has been recognized as one of the major challenges in advancing research on integrating GIS and MCDA. To this end, transparency issues are particularly troublesome to the GIS-based decision making. For instance, decision participants and GIS experts often mix-up fundamental concepts of MCDA such as the notion of value structure, goal, criterion, objective, and attribute without recognizing similarities and differences. It has been only recently that some considerations have been given to how the problem of semantic heterogeneity inherent in GIS-MCDA affects the quality of spatial decision making process. I suggest that an ontology-driven approach (a formal, explicit specification of a shared conceptualization) would reduce the problem of semantic heterogeneity. It could also provide a better organization and understanding of the GIS-MCDA tools through a set of descriptive properties classified by ontology concepts.

Research into GIS-MCDA has so far tended to concentrate on the technical questions of how to integrate GIS and MCDA. Our understanding of the benefits of such integration is limited by the lack of research on conceptual and operational validation of the use of GIS-MCDA in solving real-world spatial problems. More research about human-computer interaction is needed to understand the way users employ GIS-MCDA as a decision support tool. There are also other, more general, concerns surrounding the use of MCDA methods in GIS that require careful consideration. In the MCDA community there has been much discussion on the theoretical foundations and operational validation of the MCDA methods. It is argued that some MCDA methods are lacking a proper scientific foundation and some procedures involve strict assumptions, which are difficult to substantiate in real-world situations. To a large extent, these problems have been ignored by the GIS community. For example, the additive weighting methods are the most often-used GIS-MCDA models. However, the methods are frequently applied without full understanding of the underlying assumptions. In many GIS-based case studies, the models have been applied incorrectly and with dubious results because analysts (decision makers) have ignored or been unaware of the assumptions.

Over the last decade or so, considerable efforts have been made to develop the Web-based GIS to support spatial decision-making. These efforts have been centred on using GIS as a tool for enhancing public participation. However, the GIS technologies have been developed with strong assumptions about the instrumental/functional rationality (rather than the communicative/procedural rationality) as a base for decision-making procedures. Consequently, the GIS-based decision-making methods and practices have often been criticized for the failure to provide suitable tools for an active public participation. The GIS community has addressed this criticism by offering analytical and decision support tools that are accessible to non-experts. This is reflected in the increasing interest in the Web-based methods for public participation GIS (PPGIS). One of the main challenges in developing the Web-based PPGIS is the task of integrating the conventional Web-GIS techniques with the methods facilitating the participants to articulate their preferences, opinions, and values concerning decision-making problems. This challenge can be addressed by integrating the Web-PPGIS and MCDA methods. A related challenge of using GIS-MCDA as a tool for on-line participatory decision-making is to make sure that the GIS-MCDA methods are used properly. To this end, one should emphasize that the main function of MCDA in participatory decision-making is to help the decision participants in developing a constructive and creative approach to the problem at hand, rather than to support them in identifying the "best" solution. The use of argumentation maps (which combine Web-based mapping tools with a structured discussion forum to support geographically referenced discourse) in conjunction with MCDA in the WebGIS environment provides a platform for exchanging facts, knowledge, ideas, preferences, opinions, arguments, propositions, etc. in a dynamic process of human-computer-human interactions. From this perspective decision-making can be considered as a

collective learning process supported by the PPGIS-MCDA on-line system.

4. Concluding remarks

The process of merging traditionally distinct disciplines requires a tight collaboration among researchers and practitioners with different areas of expertise. Regrettably, the collaboration between the two disciplines involved in integrating GIS and MCDA has been rather limited. Most of the contributions to GIS-MCDA research have come from disciplines outside the MCDA community. Specifically, one-direction integration has dominated the approaches for interfacing GIS and MCDA. This approach provides a mechanism for importing/exporting data and information via a single flow that originates either in the GIS or MCDA software. GIS as the principle software has been used in majority of projects on integrating GIS and MCDA. Also, most of the GIS-MCDA applied research has been done without any participation of the MCDA experts and practitioners. The issue of a tighter collaboration between the GIS and MCDA communities is of critical importance for advancing research and practices in the area of GIS-MCDA.

References

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