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Decision complexity and consensus in Web-based spatial decision making: A case study of site selection problem using GIS and multicriteria analysis

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ABSTRACT

Building consensus over the set of alternative solutions in a spatial decision making process promotes the sustainability, stability and longevity of spatial decisions. Web-based GIS–MCDA (Multicriteria Decision Analysis) facilitates consensus-building in the process of spatial decision making. The level of consensus among decision makers in the Web-based GIS–MCDA can be influenced by various decision situations, including decision complexity. Decision complexity (or information load) is decision situation that may affect individual decisions, and may in turn moderate the level of consensus. This study addresses this potential effect of information load on the consensus level in a collaborative GIS–MCDA context. It examines the changes in the proximity (similarity) of individual decision makers' solutions to a group solution as a function of information load. The effect of information load on the level of consensus is empirically tested using a parking site selection problem in Tehran, Iran in a Web-based GIS–MCDA context. The study finds that an increased information load has a significant effect on the proximity of individual solutions to a group solution, but not essentially lead to a lower level of proximity in all of the levels of information load. This study broadens our understanding of how consensus levels vary depending on information load. For example, the finding that increased information load in a group GIS–MCDA does not necessarily lead to a lower level of proximity indicates that the amount of information available for decision making may not essentially be a critical factor in achieving consensus.

Introduction

Web technologies have opened up new possibilities for the use of GIS-based techniques in a participatory spatial planning or decision making, shifting the paradigm from a closed, place-based (fixed time and location), and synchronous process to an open, distributed, asynchronous and active decision making process (Boroushaki & Malczewski, 2010b; Bugs, Granell, Fonts, Huerta, & Painho, 2010; Jelokhani-Niaraki & Malczewski, 2014b). The concept of Web-based Multicriteria Spatial Decision Support System (MC-SDSS) has been proposed as an effective tool for participatory/collaborative decision making and consensus-building in spatial planning or decision making (e.g., Jankowski, Ligmann-Zielinska, & Swobodzinski, 2008; Karnatak, Saran, Bhatia, & Roy, 2007; Rinner & Jankowski, 2002; Sugumaran, Meyer, & Davis, 2004; Zhu & Dale, 2001). Web-based MC-SDSS extends the Web-based GIS tools to include not only the capabilities of GIS, but also Multicriteria Decision Analysis (MCDA) techniques for collaborative spatial decision making. The synergetic capabilities of GIS (geovisualization and spatial analysis) and MCDA procedures (multicriteria analytical models) can potentially enhance both spatial decision making and consensus reaching processes (AbuSada & Thawaba, 2011; Boroushaki & Malczewski, 2010a; Feick & Hall, 1999; Gorsevski et al., 2013; Jankowski & Nyerges, 2001; Jokar Arsanjani, Helbich, & de Noronha Vaz, 2013; Kyem, 2004; Zhang, Li, & Fung, 2012). GIS maps offer opportunities for consensus-building through a visual language that is easily explained and understood (Haertsch & Smith, 2012). Ozawa (1999) argues that the visual display of data and information can provide an effective tool for helping parties reach consensus in certain types of disputes. GIS consensus and/or argumentation maps can be used to support a group decision making environment, improve public discourse and deliberation about spatial decisions, and resolve conflicts among stakeholders (Jelokhani-Niaraki & Malczewski, 2014b; Rinner, 2006). On the other hand, MCDA procedures have the potential to tackle conflict over the choice of alternative

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solutions by providing mechanisms for revealing decision makers' preferences, identifying various alternatives, determining areas or points of conflict, building a consensus across the decision alternatives, and facilitating a compromise solution acceptable to all decision makers (Achillas, Vlachokostas, Moussiopoulos, & Banias, 2011; Boroushaki & Malczewski, 2010a; Iojă, Niţă, Vânău, Onose, & Gavrilidis, 2014; Zhang et al., 2012).

Web-based GIS–MCDA procedures may facilitate consensus reaching processes by supporting two dimensions of collaborative spatial decision-making/planning: deliberative and analytic (Boroushaki & Malczewski, 2010a; Jelokhani-Niaraki, 2013). The deliberative dimension of spatial planning involves building a consensus among decision makers and interest groups through organizing and facilitating communication, discussion, deliberation, and negotiation. The analytical dimension of spatial decision making focuses on generating the collective/consensus solution that best represents the preferences of all decision makers (Malczewski, 1996). GIS–MCDA can facilitate the analytical dimension by allowing the selection of evaluation criteria (objectives and attributes), criterion weighting, the combination of individual judgments into a single collective preference, and the ordering of alternatives so that a compromise alternative can be identified (see Jankowski & Nyerges, 2001; Malczewski, 2006). This analytical component involves the use of a voting interface for the ranking of spatial alternatives, an analysis of voting results, and the identification of areas of conflict and consensus. Evidence shows that the combination of MCDA for individual decision making with proper voting rules is a valuable tool for group decision making in the GIS environment (Malczewski, 2006). However, consensus may be quite difficult to achieve in practice (Palomares, Rodríguez, & Martínez, 2013). In most spatial decision making situations, full agreement is very difficult to achieve due to the inherited uncertainties associated with spatial factors, and the different priorities of decision makers (see also Feick & Hall, 1999; Massam, 1993).

The degree of consensus is affected by different decision situations. Information load (or decision complexity/problem size) is the decision situation that may moderate the consensus level. In the literature on decision making processes, information overload (the number of alternative locations and criteria) has been considered to be a particular type of task complexity, where an increase in the amount of information available to decision makers is viewed as a complexity factor (Katz, Bereby-Meyer, Assor, & Danziger, 2010; Payne, 1976; Wang & Chu, 2004). It is suggested that the differences or conflicts among decision makers over a set of alternatives and criteria preferences rises in complex situations where the decision problem involves a high number of alternatives/criteria (e.g., Herrera-Viedma, Herrera, & Chiclana, 2002). As the number of alternative locations and criteria increases, it becomes more and more likely that the decision makers' preferences and values will differ from each other and that the similarity of individual solution maps generated by decision makers will decrease. When information load is low, the consensus level required is easier to obtain. Empirical studies in the spatial decision making context have shown that the level of information load also affects the quality of the decisions (e.g., Jankowski & Nyerges, 2001; Jelokhani-Niaraki & Malczewski, 2014a). Decision makers rely on simplifying the decision process as the amount of information available increases, thus potentially leading to low-quality decisions and a high level of distance between the decision makers' solution and the group solution (a low level of consensus). Shih, Wang, and Lee (2004) argue that the level of agreement or consensus among the decision makers in a group decision making process can be related to the decision quality.

A number of studies address the importance of consensus-building methods and the problem of measuring consensus in the context of collaborative GIS–MCDA (e.g., Boroushaki & Malczewski, 2010a; Feick & Hall, 2004; Iojă et al., 2014; Zhang et al., 2012); no attempt to date has been made to examine how decision complexity in a Web-based collaborative GIS–MCDA context affects the level of consensus or the level of proximity of individual decision makers' solutions to group solutions. This study aims at addressing this need by carrying out an experimental research about collaborative decision making in a GIS–MCDA context. To this end, research hypotheses were developed and empirically tested. Urban and regional planning students participated in the experiment by using a Web-based MC-SDSS (GIS–MCDA tool) to address a parking site selection problem (i.e., ranking the parking sites). By using the Web-based MC-SDSS, participants were able to specify their preferences with respect to the decision criteria (criteria priorities). The system then ranked the parking alternative locations according to participants' preferences. The participants used the MC-SDSS at varying levels of decision complexity in two decision making modes: individual and group. In the individual mode, the participants specified their preferences without access to group/majority solution and geo-referenced arguments, while in the group mode, they could use an argumentation mapping tool (i.e., the group ordering of alternatives and other participants' map-based comments), and then re-specified their preferences. Dennis, Hilmer, and Taylor (1997) argue that the way in which individual decisions are made may change depending on whether individuals are aware of others' preferences. In other words, decision making may be affected by the presence of a group or majority solution as represented by argumentation maps.

Decision complexity and consensus measures

Decision complexity

In the decision analysis literature, information load is considered to be a particular type of decision task complexity, in which an increase in the amount of information available to decision makers is viewed as a relevant complexity factor (Payne, 1976; Wang & Chu, 2004). The number of alternative locations and criteria/attributes are typically considered as important information characteristics, potentially influencing decision complexity in a spatial decision making environment (see Jelokhani-Niaraki & Malczewski, 2014a; Payne, 1976). For the purpose of this study, decision complexity or information load is operationalized by the number of alternative locations and criteria that are available for processing by decision makers (see Fig. 1).

It is suggested that conflicts among decision makers over a set of alternatives and criteria preferences tend to rise in complex situations in which the decision problem involves a large number of alternatives/criteria (Herrera-Viedma et al., 2002). As the number of alternative locations and criteria increases, it is more likely that the decision makers' preferences will differ, and that the similarity of individual solutions will decrease. When alternative locations and criteria are added to the decision problem, the diversity of decision information, and in turn the variation in the decision makers' preferences will increase. In this context, the group solution is generated with a lower degree of consensus. In addition, empirical studies in the spatial decision making context have shown that the level of information load affects the quality of decisions (e.g., Jankowski & Nyerges, 2001; Jelokhani-Niaraki & Malczewski, 2014a). As a large number of alternative locations and criteria are available in the decision making process, a higher level of understanding about spatial criteria, locations, and their relations must be considered in the decision making process (see Fig. 1). The relations and dependencies between these information items are sometimes difficult to recognize. In this context, decision makers rely on simplifying decision processes as a kind of cognitive