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To cite this article: Mohammadreza Jelokhani-Niaraki (2019): Exploring the effect of group decision on information search behaviour in web-based collaborative GIS-MCDA, Journal of Decision Systems, DOI: 10.1080/12460125.2019.1698898

To link to this article: https://doi.org/10.1080/12460125.2019.1698898

Published online: 03 Dec 2019.
Exploring the effect of group decision on information search behaviour in web-based collaborative GIS-MCDA

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ABSTRACT

The combination of Web GIS (Geographic Information System) and Multicriteria Decision Analysis (MCDA) techniques offers an effective tool for collaborative spatial decision making. This study examines the relationship between the group recommendations on alternatives and the information search behaviour of decision makers in a web-based GIS-MCDA for parking site selection in Tehran, Iran. Decision participants used a GIS-MCDA framework without and with an access to group decision/recommendations. Findings show that the access to group decision leads to a decrease in the proportion of information search, the average time spent acquiring each piece of information, and variability of information search per attribute in a parking site selection context.

1. Introduction

GIS-based MCDA systems have been used for tackling spatial decision problems in which the decision alternatives have a geographic connotation such as location, distance, or connectivity (Malczewski & Rinner, 2015). For instance, a spatial decision problem may involve determining optimal locations for new parking sites. Urban planners and decision makers must make quick but effective decisions about where to locate parking sites. With GIS-based MCDA techniques, it is much easier and faster to combine the relevant spatial data (criteria values) and decision maker’s preferences to evaluate candidate parking sites, and select the best ones. These techniques seek to find the best (optimal) solution to well-defined spatial decision problems. Their strength is to contribute to the spatial decision making and planning processes by selecting the best alternative from the number of feasible alternatives according to multiple criteria. The methods have been used for solving a variety of spatial decision problems (e.g., Chen, Blong, & Jacobson, 2001; Chen, Jiang, & Li, 2007; Cheng, 2001; Gorsevski et al., 2013; Jankowski, Nyerges, Smith, Moore, & Horvath, 1997; Jankowski & Richard, 1994; Jelokhani-Niaraki & Malczewski, 2012a, 2015c; Jelokhani-Niaraki, Sadeghi-Niaraki, & Choi, 2018; Kiavarz & Jelokhani-Niaraki, 2017; Mahmoody Vanolya & Jelokhani-Niaraki, 2019; Malczewski & Jelokhani-Niaraki, 2012; Malczewski & Runer, 2005; Omidipoor, Jelokhani-Niaraki, & Samany, 2019b; Raubal & Rinner, 2004; Shorabeh, Firozjaei, Nematollahi, Firozjaei, & Jelokhani-Niaraki, 2019; Simão, Densham, & Haklay, 2009).
The use of GIS-MCDA techniques in the web environment provides appropriate decision support tools and platforms for collaborative/group spatial planning processes (Boroushaki & Malczewski, 2010b; Eldrandal, 2013; Jelokhani-Niaraki, 2018; Jelokhani-Niaraki, Hajiloo, & Samany, 2019; Jelokhani-Niaraki & Malczewski, 2012b, 2012a; Mahmooedy Vanolya, Jelokhani-Niaraki, & Toomanian, 2019; Mekonnen & Gorsevski, 2015; Omidipoor, Jelokhani-Niaraki, Moeinmehr, Sadeghi-Niaraki, & Choi, 2019a). The location-time distributed nature of the web offers not only freedom of using GIS-MCDA in different location and time for the comfort of users, but also gives an equal access to geographical information and tools. The members of an organisation or a particular group of decision makers can examine the spatial characteristics (locations) of alternatives, visualise them, and evaluate them according to their preferences (Voss et al., 2004). The collaboration of community members representing different fields of expertise, political agendas, priorities and opposing goals, situations and public interests offers a synergistic approach during a spatial decision making or land use assessment process. In other words, through a web-based collaborative GIS-MCDA, the decision making is shared by numerous different individuals. Specifically, the GIS-MCDA tools enable individuals to generate their own alternatives, define or select their own criteria, determine the criteria values and weights, and evaluate the alternatives in collaborative land use management applications. For example, in the context of locating new parking facilities, GIS-MCDA provides the spatial data handling and multicriteria spatial analysis functionality, allowing spatially explicit representation and generation of land alternatives (i.e., candidate parking sites), computing the criteria values for the alternatives (e.g., distance between candidate parking sites and transportation stations), weighting the criteria, integrating the criteria values and weights for evaluation of alternatives, and representing alternative evaluation results (e.g., rankings/ratings of alternative parking sites) on the map. Sikder and Gangopadhyay (2002) highlight the organisational and managerial implications of web-based collaborative GIS-MCDA approaches. They argue that the added value of the group/individual interaction in a collaborative GIS-MCDA is similar to the ‘distributed cognition’ which suggests, ‘organisational cognition is a distributed cognition’ (Boland, Tenkasi, & Te’eni, 1994).

The examination and exploration of decision information is essential to web-based collaborative GIS-MCDA (Jelokhani-Niaraki, 2013; Jelokhani-Niaraki & Malczewski, 2015b; Malczewski & Rinner, 2015). Any high-quality GIS-MCDA process begins with searching and acquiring the decision information. In the setting of GIS-MCDA, information acquisition is concerned with the examination of decision information including the spatial alternatives, attributes/criteria, and attribute values associated with the alternatives using the information aids. Jelokhani-Niaraki and Malczewski (2015b) argue that there is relationship between decision strategies used by decision-makers and their information acquisition behaviour. They suggest that given the importance of understanding decision makers’ information acquisition behaviour, it is equally important to understand this behaviour across different types of decision situations. Research on human-computer interaction in the context of GIS-MCDA suggests that decision situations such as information load (task complexity), the use of different types of geographic information aids, and the accessibility to group decision (recommendation) affect decision makers’ information acquisition behaviour (Crossland, Wynne, & Perkins, 1995; Jankowski & Nyerges, 2001; Jelokhani-Niaraki & Malczewski, 2015b; Meng & Malczewski, 2010; Mennecke, Crossland, & Killingsworth, 2000; Speier, 2006). There
is a body of literature on the influence of task complexity and information aids on information acquisition strategies. For example, Jelokhani-Niaraki and Malczewski (2015b) reported the results of an experimental study that investigated the effect of task complexity (information load) on information acquisition strategies in the use of a GIS-MCDA. However, our understandings of how group decision (group choice recommendations) affects decision makers’ information acquisition behaviour are currently limited.

During decision making process, decision makers may employ different information acquisition strategies in the decision modes where they are provided with group advice/recommendations (the group recommendations on the alternative choices) and where they are not (Boroushaki & Malczewski, 2010a; Jelokhani-Niaraki & Malczewski, 2015b; Schrah, Dalal, & Sniezek, 2006). It is suggested that the availability of recommendations regarding which alternative to choose is a situation that influences the way that decision makers acquire and integrate information when making their individual decisions (Redd, 2002; Schrah et al., 2006). A decision maker who receives an advice in favour of one or more alternatives and follows the advice is more likely to focus his/her information search only on those alternatives and ignore the information relevant to the other ones. Accordingly, it is reasonable to expect that the pre-advice information search behaviour of a decision maker differs from his/her post-advice behaviour.

This study aims to investigate the effect of group decision as a kind of recommendation on the alternatives on information acquisition behaviour in the context of a web-based collaborative GIS-MCDA for parking site selection. The key issue of interest is to examine how information acquisition tasks change as a function of viewing group solution/recommendation. The group decision used in this study includes two types of recommendations: (i) the group or consensus ranking of parking alternatives, which are obtained based on the aggregation of individual preferences and (2) the geo-referenced comments, suggestions, and recommendations about parking alternative sites. Decision makers may exhibit different information search behaviours when looking at the group decision. To this end, the study investigates the differences along a set of information acquisition variables between two decision modes: GIS-MCDA individual (without an access to group decision) and GIS-MCDA group (with an access to group decision) mode. Drawing on theories relevant to the study of information acquisition behaviour, we conducted an experiment to examine the impact of group decision on a set of information acquisition variables. The remainder of the paper is organised as follows. Section 2 provides an overview of the research about collaborative GIS-MCDA, metrics used for studying information acquisition behaviour and group decision effects in collaborative decision making processes. Section 3 describes the research hypotheses formulated on the basis of the metrics. In Section 4, we provide a brief description of the research method, including the use of a web-based collaborative GIS-MCDA framework for tackling a parking site selection problem, an outline of the experimental design, and the procedure used in the empirical study. Section 5 presents detailed results of the hypothesis testing. Section 6 presents discussion of the results. Finally, a conclusion is given in Section 7.

2. Literature review

The information needs for spatial planning, decision making and management require appropriate decision analysis procedures. The concept of spatial Multicriteria Decision Analysis (MCDA) or GIS-MCDA has been proposed as an effective tool for spatial decision
making and management processes (Malczewski & Rinner, 2015). These tools extend the GIS techniques to include not only the capabilities of GIS, but also MCDA techniques for decision analysis. The synergetic capabilities of GIS (GIS database and spatial analysis) and MCDA procedures (multicriteria analytical models) can potentially enhance spatial decision making (or land management processes).

Today, many spatial decisions in organisations are made in group settings rather than by individuals acting alone. The GIS-MCDA tools can facilitate spatial group decision making by providing a rich collection of techniques and processes for eliciting the decision makers’ preferences, organising decision problems, as well as designing, assessing, and ordering decision alternatives (Bigdeli, Kamal, & de Cesare, 2013; Lee & Chi-Wai Kwok, 2000; Martin, Miranda Lakshmi, & Prasanna Venkatesan, 2014). Any informed and well-quality decision in a collaborative GIS-MCDA involves the acquisition and integration of information about decision problems (Jelokhani-Niaraki & Malczewski, 2015b). Researchers in collaborative decision making have long recognised the importance of information acquisition as a determinant of decision quality (e.g., Citroen, 2011; Janis, 1989; Meng, 2010; Paul, Saunders, & Haseman, 2005). Janis (1989) suggests that information acquisition by decision makers early in the decision making process likely leads to a high-quality decision since it is assimilated and processed with little bias. Similarly, Saunders and Miranda (1998) argue that relevant information needs to be collected and assimilated in the early stages of the decision making process to form a strong preference for the decision solution.

In the setting of GIS-MCDA, information acquisition is concerned with the examination of decision information including the spatial alternatives, attributes, and attribute values associated with the alternatives using information aids. This includes an examination of information aids (e.g., decision table and map), what pieces of information are acquired, and the pattern in which information is acquired (Jankowski, Andrienko, & Andrienko, 2001; Jelokhani-Niaraki & Malczewski, 2015b; Malczewski, 1999; Smelcer & Carmel, 1997). Typically, the specification of individual preferences (attribute/criteria weights) is the fundamental motive behind examining the available information within the GIS-MCDA context. To determine the attribute weights, one might need to look at information items, such as the preferred range of attribute values (the difference between the maximum and minimum values across the alternatives with respect to a given attribute), least-preferred and most-preferred values for a given attribute, etc. In other words, the weights assigned to attributes should be derived by asking the decision maker to examine information about a change from the least-preferred to the most-preferred values of alternatives on one attribute to a similar change in another attribute (Ligmann-Zielinska & Jankowski, 2012; Malczewski, 2000).

It is suggested that the availability of knowledge or recommendations regarding which alternative to choose is a situation that influences the way that decision makers acquire and integrate information when making their individual decisions (Harvey & Fischer, 1997; Schrah et al., 2006). For example, Schrah et al. (2006) suggest that decision makers employ different information acquisition strategies in the decision modes where they are provided with alternative choice recommendations and where they are not. They argue that a recommendation about an alternative(s) makes that alternative(s) a focus, and consequently, biases information processing by reducing the proportion of overall information processing which could be devoted to the other alternatives. A decision maker who is offered a recommendation in favour of one or more alternatives and follows the recommendation is
more likely to focus his/her information search only on those alternatives. Bonaccio and Dalal (2006) reviewed the relationship between recommendation (advice) taking and decision making. In fact, one of the motivations for their review was to aid in theory generation about recommendation and decision making. They discuss that decision makers may receive advice that recommends a particular alternative and the decision maker ultimately decides to switch to the alternative recommended by the advisor. They concurred with Payne, Bettman, and Johnson (1993) statement that ‘the social context of decisions has been a neglected part of decision research and … is an area worthy of much greater study’ (p.255).

In addition, from the consensus point of view, group members may need to pay more attention to the group advice in an effort to obtain a higher degree of consensus or agreement (Boroushaki & Malczewski, 2010a; Jelokhani-Niaraki & Malczewski, 2015a). Dennis, Hilmer, and Taylor (1997) argue that the way in which individual decisions or choices are made may change depending on whether individuals are aware of others’ preferences or recommendations (see also Lightle, Kagel, & Arkes, 2009). In other words, decision making may be affected by the presence of group solution or majority opinion within the group.

It is evident from the short review of the decision literature that there exists a clear link between the group recommendations on the alternative choices and information processing (acquisition) in a group decision making context. In fact, any informed decision requires the others’ recommendations. The established link between information acquisition and the group recommendations on the alternative choices in the literature is a theoretical basis upon which the research hypotheses for this study will be formulated.

Decision behaviour researchers have made remarkable efforts in operationalising information acquisition and integration variables in a decision table (e.g., Payne, 1976; Svenson, 1979). Several such variables have been suggested in the literature. In order to identify the information search variables, Chestnut and Jacoby (1976) carried out a principal components analysis on a sample of 28 information acquisition variables and found three main factors. These include: proportion (depth), content, and sequence (direction) of information search. The proportion of information search refers to the extent to which all or some of the available information is utilised by the decision maker prior to arriving at a decision (see also Ford, Schmitt, Schechtman, Hults, & Doherty, 1989; Katz, Bereby-Meyer, Assor, & Danziger, 2010; Payne, 1976; Queen, Hess, Ennis, Dowd, & Gruhn, 2012; Roe, Busemeyer, & Townsend, 2001; Schram & Sonnemans, 2011). Content of search refers to the specific type of information searched, e.g., which specific attributes are searched for which alternatives. The sequence of a search is concerned with the specific order in which various information values are searched (see also Katz et al., 2010; Payne, 1976; Roe et al., 2001). Typically, the search sequences are alternative-wise (where an alternative is selected and attributes are searched for that alternative) and attribute-wise (in which case an attribute is selected and alternatives are searched for that attribute).

Along with the search proportion and direction, Payne (1976) suggested an examination of the variability of information search per alternative (see also Bröder & Schiffer, 2003; Carrigan, Gardner, Conner, & Maule, 2007; Payne et al., 1993; Schmeer, 2003). Klayman (1985) argued that in addition to variability in search per alternative, the extent of variability in amount of information searched per attribute should also be examined (see also Bröder & Schiffer, 2003; Schmeer, 2003). He suggested that a distinction between the two different forms of variability would enable decision makers to identify the sources
of total variability; e.g., whether the search is attributable to unsearched alternatives or unsearched attributes. According to Payne et al. (1993), the total time spent acquiring information and average time spent per item of information acquired (i.e., information cells) also provide appropriate metrics for information acquisition (see also Dhar, Nowlis, & Sherman, 2000; Ford et al., 1989; Klemz & Gruca, 2001). In addition to proportion (depth), direction, content, variability, and direction of search, decision researchers have also operationalised information acquisition metrics in terms of the search selectivity, latency of search, degree of top-down search, average attributes referenced, number of different attributes considered, and the proportion of acquired items devoted to the alternative chosen (Archer, Head, & Yuan, 1996; Ford et al., 1989).

Although there are a number of studies that have focused on studying information acquisition behaviour and group decision effects within the realm of non-spatial decisions, the research efforts in the field of spatial decision making or GIS-based MCDA have been rather limited. For example, there are a number of studies in the spatial decision making and management context that examined information acquisition metrics including decision time (Crossland et al., 1995), the number of table and map moves (Jankowski et al., 2001), and etc. The most relevant study is one by Jelokhani-Niaraki and Malczewski (2015b) who addressed the research question of how does the complexity of a decision task affect information acquisition strategies used by decision makers in a GIS-MCDA? This study reported the results of an experiment that investigated the effect of task complexity (i.e., information load) on information acquisition strategies in the use of a Multicriteria Spatial Decision Support System (MC-SDSS).

However, none of these research efforts has examined the effects of group decision on information search metrics within the web-based collaborative GIS-MCDA context. The GIS-MCDA practitioners’ understandings of how group decision (group choice recommendations) affects decision makers’ information acquisition behaviour are currently limited by the scarce empirical studies on the usage patterns of group decision support tools. This limited knowledge on how people search through and combine information with and without access to group decision leaves the design and development side of group GIS-MCDA tools without sound scientific bases for advancing the collaborative GIS-MCDA information aids and tools. The major reason for the limited empirical knowledge is that GIS-MCDA practitioners have mostly focused on software design and development rather than use. Evidence shows that the effects of advanced information technologies on individuals and groups are less a function of the technologies themselves than how they are used by people (Crossland et al., 1995; DeSanctis & Poole, 1994; Jankowski & Nyerges, 2001; Jelokhani-Niaraki & Malczewski, 2015b). The motivation for research coming out of this conclusion is that studying the patterns of information acquisition with the accessibility to group recommendations is as important as developing the GIS-MCDA software.

3. Methodology
3.1. Information search metrics

Information search metrics are the concepts drawn from theoretical frameworks used for studying the information acquisition behaviour in decision making processes (Bettman, Luce, & Payne, 1998; Chinburapa, 1991; Einhorn & Hogarth, 1981; Jelokhani-Niaraki, 2013;
Jelokhani-Niaraki & Malczewski, 2015b; Katz et al., 2010; Payne, Bettman, & Johnson, 1992; Roe et al., 2001; Schmeer, 2003). Jelokhani-Niaraki and Malczewski (2015b) suggest that the variables to measure information acquisition in the collaborative GIS-MCDA context include: the proportion of information search, the average amount of time spent on each piece of information, total time spent acquiring the information in the decision table, variability in the proportion of information search per attribute and alternative, direction of information search, the time spent acquiring the information on the map, and the number of moves on the map. These metrics act as the appropriate determinants of criteria weighting quality in the decision making process. However, according to Schrah et al. (2006), appropriate metrics for examining group decision effects are the proportions of information search, the average amount of time spent on each piece of information, variability in the proportion of information search per attribute and alternative, and direction of information search. Accordingly, these metrics will be used as building blocks in designing our study to investigate the effect of group recommendations on information acquisition behaviour.

In an empirical study, Schrah et al. (2006) found that the proportion of information search, the variability of information search per attribute and alternative, the direction (sequence) of search, and the average time spent acquiring the information change after advice acquisition (Jelokhani-Niaraki & Malczewski, 2015b). The findings of this study suggest a decreased variability of search, increased time spent on information, decreased proportion (depth) of information search, and a more alternative wise direction of search. Because post-advice (after viewing group decision) search is focused on a few alternatives and ignore others, less overall information is searched, with more time being spent per information acquisition relative to pre-advice search. Moreover, as the focus of information search is on particular alternatives, information search is expected along alternatives instead of attributes and judges are primarily focused on comparing alternatives with respect to preferred attributes. Accordingly, decision makers may use a more alternative-wise than attribute-wise information search directions. In addition, it is expected that access to group recommendations will result in a decreased variability in the information searched.

In this study, information acquisition behaviour has been operationalised using a decision (see Table 1). The metrics reflect the information search characteristics derived from the decision table. The main reason for choosing the metrics is that they implicitly characterise the quality of attribute weights (decision quality) in the GIS-MCDA. They could be used as a means of representing decision making behaviour adopted by decision makers in the context of information acquisition in GIS-MCDA processes.

### 3.1.1. The proportion of information search

One of the key variables for measuring the information acquisition behaviour in the decision table is the proportion of information search (or the amount of information use). The proportion of information search refers to the extent to which all or some of the available information is viewed by the decision maker prior to arriving at a decision (see Jelokhani-Niaraki & Malczewski, 2015b; Payne, 1976). It is indicator of the amount of information searched or the amount of available information actually considered in making a decision. This metric can be measured as the amount of first time acquisitions of information (information number of cells viewed) divided by the amount of available information cells (total count of available cells). For instance, in a decision problem involving 5 attributes and 10 alternatives, there are 50 cells available containing different pieces of information that can be examined. Investigation of
a decision maker’s search can easily reveal whether all or only a portion of these 50 pieces of information were actually searched. This measure varies from 0 to 1, with 1 indicating all of the available information pieces are examined (i.e., all attributes available for every relevant alternative is examined), and 0 indicating none of the information cells are examined.

3.1.2. The time spent acquiring information
In addition to the above metrics, the time spent acquiring information in the decision table is also one variable that is typically used as an information acquisition metric in decision research (Queen et al., 2012; Riedl, Brandstätter, & Roithmayr, 2008). This metric serves as an indirect measure of the amount of effort and deliberation required to make the decision. In this study, the average time spent per item of information acquired is used as one of the metrics (Klemz & Gruca, 2001). The average time is calculated by dividing the total time spent examining all acquired pieces of information by the number of acquisitions.

3.1.3. The sequence of search
The sequence of a search is concerned with the specific order in which various information values are searched (see Jelokhani-Niaraki & Malczewski, 2015b; Payne, 1976; Roe et al., 2001). This measure is typically described as a movement/transition from one piece of information searched to the subsequent piece. Since any information value in the decision table is described as a row-column (alternative-attribute) cell, the transition from any D-th to D-th + 1 search can be categorised as one of the following four types: (i) same alternative – same attribute; (ii) same alternative – different attribute; (iii) different alternative – same attribute; and (iv) different alternative – different attribute (Stokmans, 1992) (see Figure 1). If the D-th + 1 piece of information searched is within the same alternative but involves a different attribute, then the search constitutes an instance of an alternative-wise search pattern. On the other hand, if the D-th + 1 piece of information searched is within the same attribute, but a different alternative, then that search constitutes an instance of an attribute-wise search direction. If the D-th + 1 piece of information searched is neither within the same alternative or the same attribute as the D-th piece of information, then that is considered to be a shift in the direction of search. When the D-th + 1 piece of information acquired is within the same alternative and attribute as the D-th piece of information, then the search is considered a re-acquisition strategy. In this study, only the alternative- and attribute-wise search patterns are examined (Jelokhani-Niaraki & Malczewski, 2015b; Schrah et al., 2006).

One common and standard measure to examine search patterns in the decision making literature is Payne’s search index (Payne, 1976). Payne’s index compares the number of alternative-wise transitions and the number of attribute-wise transitions to measure whether the direction of search is alternative-wise or attribute-wise. Assuming that \( F_{alt} \) denotes the alternative-wise transition frequency and \( F_{att} \) the attribute-wise transition frequency, the index is defined as a ratio:

\[
SI = \frac{F_{alt} - F_{att}}{F_{alt} + F_{att}}
\]

(1)

The value of SI varies from −1 (purely attribute-wise processing) to +1 (purely alternative-wise processing). The search direction is considered as alternative-wise if this index has a positive value and as attribute-wise if it has a negative value. Figure 2 shows examples of the search
directions of alternative-wise or attribute-wise search strategies. A direction consisting of only alternative-wise transitions and shift transitions would have a value of +1.00. A direction consisting of only attribute-wise transitions and shifts would have a value of −1.00. If there is equal number of both transitions, the index equals zero.

3.1.4. The variability of information search
The variability of search indicates whether a decision maker searches a constant or variable amount of information per alternative and/or per attribute. The variability of information search per alternative is defined as the standard deviation of the number of information pieces searched across a set of alternatives based on the first acquisition (Jelokhani-Niaraki &
This metric measures the extent to which the same or unequal amounts of information are searched for each of the available alternatives in a decision. If a decision maker examines the same number of information cells for all alternatives, the variability equals to 0 and processing is termed consistent. If however, the decision maker views an equal amount of cells for each alternative, the variability is greater than 0 and the processing is termed variable. The variability of information search per attribute is measured as the standard deviation of the number of information cells searched per attribute. It indicates the extent to which different attributes receive different amounts of search. It equals 0, if the same number of alternatives is searched for each attribute, and it is greater than 0, if a different number of alternatives are searched for each attribute.

### 3.2. Hypotheses

This study aims at addressing the research question of how information acquisition behaviour in the collaborative GIS-MCDA is affected by viewing the group decision/recommendations. This question is addressed by examining the information acquisition metrics in two decision modes: the individual decision making (the GIS-MCDA individual mode) and the group (collaborative) decision making (the GIS-MCDA group mode). In the individual mode, the system allows the participants to evaluate the alternatives without knowing of the group decision. While in the group mode, individuals are able to review the group solution (i.e., the group ordering of alternatives) and the other participants’ map-based comments, and then conduct the decision making process. Accordingly, the following set of hypotheses will be examined: Hypothesis 1: *There is a significant difference in the proportions of information searched between the two decision modes.* Hypothesis 2: *The two decision modes are significantly different in terms of the average time spent acquiring information in the decision table.* Hypothesis 3: *The two decision modes are significantly different in terms of variability in the proportion of information searched per attribute.* Hypothesis 4: *The two decision modes are significantly different in terms of the variability in the proportion of information searched per alternative.* Hypothesis 5: *There is a significant difference in the direction of information searched between the two decision modes.*

### 3.3. Experimental issues

#### 3.3.1. Participants

The experimental study involved the use of a web-based collaborative GIS-MCDA framework for a parking site selection decision task in Tehran, Iran to examine the information acquisition differences between the two GIS-MCDA modes. Students in the urban planning departments at Shahid Beheshti University and the University of Tehran were invited to participate in the collaborative parking site selection process. A total of 55 volunteers participated throughout the parking site selection process. Volunteers had studied the basic and advanced concepts, theories, practices, and techniques associated with GIS and urban planning in different courses.

#### 3.3.2. Participant registration

User registration is the first stage of the collaborative decision making procedure. Each individual participating in the parking site selection process must complete and submit the registration form individually. The anonymous information that individuals provide in
this page includes: age, education, gender, experience with the Internet, and experience with GIS. A drop-down list of predefined entries for each of the user characteristics is provided. For example, two characteristics, ‘experience with internet’ and ‘experience with GIS’, include three entries ('low', 'medium', and 'high') from which users choose the appropriate one. By completing the registration, users are then redirected to the ‘instruction’ page. Returning users can log into the system using the ‘log in’ Web page.

3.3.3. Instruction
A special emphasis was placed on the importance of reading instructions on the tutorial (instruction) page in the system. The instruction page provided the participants with a step-by-step walkthrough on how to use the Website for selecting the preferred location, and how to complete the experimental tasks. This page informed the users that they would be participating in a study aimed at identifying the most suitable alternatives for locating the parking sites. Specifically, the participants were instructed that they: (i) would be performing two decision tasks (individual and group mode tasks) across four decision situations (complexity levels); (ii) would go through both tasks at the four decision conditions; (iii) would be presented with a number of alternatives, attributes, and a certain amount of information about each alternative during each of the decision situations; (iv) would specify their criteria preferences on the basis of the information provided, and eventually the system would compute the individual solution for them according to their preferences; (vi) would be free to look at as much available information as they wanted to or felt was necessary to make a decision; and (vii) could spend as much time on the decision as they desired.

3.3.4. Information acquisition and decision analysis
In this study, we used a repeated-measure experimental design to examine the potential impact of the group decision on the information acquisition metrics (see Jelokhani-Niaraki & Malczewski, 2015b). The experimental tasks involved the use of the GIS-MCDA framework for parking site selection in the two different GIS-MCDA modes: individual and group decision making. In the individual mode, decision participants evaluated the alternatives without knowing about the group decision, while in the group mode, they reviewed the group solution (i.e., group ordering of alternatives) and other participants’ map-based comments, and then reconducted the decision making process. By completing the decision making process in the individual mode, participants were then redirected to the group mode.

In order to examine the information acquisition differences in different decision situations, the participants carried out the decision making process (both the individual and group modes) at four information load levels (for more detail see Jelokhani-Niaraki & Malczewski, 2015b). The information load was manipulated in terms of the number of alternatives and attributes as follows: (i) five alternatives and two attributes; (ii) ten alternatives and four attributes; (iii) fifteen alternatives and six attributes; and (iv) twenty alternatives and eight attributes. The participants were exposed to each of the decision situation, and in turn, the measurement of the dependent variables (i.e., information acquisition variables) was repeated.

The available information relevant to the site selection was represented to participants through common map and decision table information aids. The system employed the
free-of-charge geospatial data and functionalities provided by Google Maps, a web mapping service application and technology provided by Google, to represent the decision information (Boroushaki & Malczewski, 2010b). The ease of use of Google Maps plays a key role in the success of a collaborative decision making process. Thanks to Google Maps, non-GIS scientists are now able to ‘read, write, alter, store, test, represent information in ways that they desire and in formats and environments they understand’ (Miller, 2006, p.188). Specifically, Google Maps was utilised in the collaborative GIS-MCDA to empower decision participants with a visual framework that represents alternative locations (geographic decision space), individual and group orderings of alternatives, and to support geographically referenced argumentations/recommendations in the parking site selection domain.

3.3.4.1. The GIS-MCDA individual mode. In the individual mode, the GIS-MCDA tool provided the relevant information and decision support tools to assist an individual in the evaluation of decision alternatives (Jelokhani-Niaraki & Malczewski, 2015b). The GIS component of this tool provides decision map as well as spatial analysis and database capabilities to generate a set of feasible spatial management alternatives (i.e., parking candidate sites), determine the spatial criteria values and compute the final scores (rankings/ratings) of alternatives. The GIS map and data provide a key role in spatial decision making processes (Hasani, Sadeghi-Niaraki, & Jelokhani-Niaraki, 2015). Participants could use the map to explore the alternatives, and also the spatial distribution of the geographic entities on the base of which criteria are defined. The MCDA tool allows decision makers to examine the decision table, input their judgements with respect to evaluation criteria, and generate a variety of planning and management scenarios that satisfy their decision criteria. This tool offered an OWA (ordered weighted averaging)-based MCDA for generating the individual solution maps (i.e., individual ordering of alternatives) based on the individual preferences (Malczewski, 2006). It enables the participants to input their criteria judgements (the attribute ranks) during or after examining the decision table or map. Decision makers need to seek the information in the decision table as a basis for assigning criteria preferences/weights. During specification of the criteria preferences, one may take into account the preferred range of attributes values (a particular range), the least-preferred and the most-preferred value for a given attribute, compare a change from the least-preferred to the most-preferred value for an attribute to a similar change in another attribute, and so on. Therefore, the process of information search and acquisition is critical to criterion weighting in collaborative GIS-MCDA. After information acquisition, the participants assign a higher rank to the selected criterion by moving it up or assign a lower rank by moving it down.

The system allowed switching between different map views, turning the map layers on and off on the Google Maps, and using the Zoom slider on the Google Maps to zoom in to certain alternatives, features, and places on the map. In decision situation 1 (five alternatives and two attributes), there was only one layer of alternatives on the map, as the criteria in this experiment involve only the alternatives. In the more complex decision situations (2, 3 and 4), the set of criteria involved some other geographic entities in addition to the alternatives, such as main roads, recreational centres, administrative centres, etc. The participants were able to explore the spatial distribution of these entities by turning the map layers on and off on the top the map.
The information cells in the decision table contained the measured values of attributes associated with alternatives. Initially, the values of the information cells were hidden. In order to open and examine the information in a particular cell, the participant had to move the cursor into the cell and click on it. When a cell was opened, its value was immediately revealed and remains visible until the cursor is moved out of the cell. When the participant clicks on another cell, the information in the previous cell disappears and the new cell’s value comes into view. Hence, in this system, information was available in only one cell at a time. This feature allowed us to keep track of the order in which cells are opened, the amount of time and frequency that each cell is opened. Acquiring the decision information in the decision table allows decision makers to take into account their preferred range of attribute values (a particular range), least-preferred and most-preferred value for a given attribute, etc. during the specification of criteria preferences. Once the individual preferences were specified, the system computes and represents the alternative orderings (individual solution) on Google Maps.

3.3.4.2. The GIS-MCDA group mode. By completing the individual decision making process, the participants were then redirected to the group GIS-MCDA decision mode. In addition to the decision table and map, the group mode provided the participants with two types of group decision aids: (i) the group decision aid for representing the group decision (group ordering of alternatives) on the map and (ii) the argumentation mapping aid for representing geo-referenced comments and discussions (Jelokhani-Niaraki & Malczewski, 2015b). The group decision aid employed the Borda voting method for aggregating the individual solutions to a group decision (i.e., group ordering of alternatives). This tool showed the score and ordering of each alternative location based on the preferences of all the participants who had finished the site selection procedure. The argumentation mapping aid was used as a map-centred communication tool to support geographically referenced recommendations, advice, discussions and deliberations (Rinner, 2001). By clicking on the map, individuals could reference their contributions about different dimensions of the decision problem to geographic alternatives or other locations. The participants were able to review the others’ comments, recommendations and suggestions regarding the inclusion of one or more locations as a new feasible alternative or exclusion of alternative(s) from the set of options on the group decision map. Consequently, participants’ information acquisition behaviour may have varied from what it was in the individual decision making mode.

3.4. Data and analysis

The information acquisition behaviour data in both of the decision modes were collected using a logging method. The main incentives for using the logs in the data collection process were low implementation cost, higher speed, and higher accuracy. In addition, the logging method provides a non-intrusive approach for collecting data from the participants and does not require the use of personally administered questionnaires or interviews. Each time a user performed an interaction with the system, the system continuously wrote records to the log database describing the nature of the action.

There are a number of log storage techniques/formats, such as text-based log files, flat text files, and databases (see Chuvakin, Schmidt, & Phillips, 2012). In this study,
a database logging approach was employed to record the log information. Each time a user performed an interaction with the system, the system continuously wrote records to the log database describing the nature of the action. The main advantage of using the database logging approach is that it allows for structuring the log information in a format that can be quickly read, searched, reviewed, analysed, and queried. In contrast to the file-based approaches that take a lot of time and effort to read, filter, summarise, and analyse the log data, the database approaches allow for using standard SQL queries to combine all sorts of information from different entries and easily analyse the log records.

The log data for information acquisition behaviour include the information the subject seeks (information cells) in the decision table, how much information is examined, how long the information is examined for, as well as the sequence in which they are looked at in the decision table. In addition to recording the data on the use of the decision table, the system records decision makers’ activities during the use of the decision map. The database allowed for structuring the log information in a format that can be quickly read, searched, reviewed, analysed, and queried. By querying the log data stored in the database, one can derive data for computing the information acquisition metrics defined in the study.

The research hypotheses developed for this study call for an examination of the differences in the information acquisition metrics when the decision mode changes (individual vs. group). The hypotheses were tested by conducting Linear Mixed Model (LMM) analysis test using the Statistical Package for the Social Sciences (SPSS) software. The LMM test allows for integrating and analysing the correlated repeated measurements by explicitly modelling a variety of correlation patterns (or random effects). Another advantage of this test is that all available data could be included in the analysis, even if some data are missing in the experimental measurements (unequal number of repetitions). Moreover, the correlation between the information acquisition metrics were examined using Pearson correlation tests.

4. Results

**Hypothesis 1**: The null hypothesis is that the group decision has no influence on the proportion of information search. The hypothesis was tested by comparing the mean proportion of information searched in the two decision modes. It is evident that this variable in the group mode is lower than that in the individual mode in each of the complexity levels (see Figure 3). For the effect of the decision mode, the LMM test results give a $p$-value of 0.010 ($p < 0.05$), thereby rejecting the null hypothesis and suggesting there is a statistically significant difference in the proportion of information searched between the two decision modes (see Table 2). In other words, there is sufficient evidence from the data to conclude that decision makers search a significantly different proportion of the available information in the GIS-MCDA individual mode as compared to the group mode.

**Hypothesis 2**: The null hypothesis is that the amount of average time spent on each piece of information is not affected by the group decision. By comparing the average decision
time between the two decision modes in the four experimental conditions (see Figure 3), one can indicate that the average amount of time spent acquiring the information pieces in the individual mode is more than that in the group mode. Under the null hypothesis that there is no difference in the average decision time between the two decision modes, the LMM test gives a $p$-value of 0.033 ($p < 0.05$) (see Table 2). This suggests that there is a significant difference in the average decision time between the two decision modes.

Figure 3. A comparison between the information acquisition metrics in the two decision modes.
Hypothesis 3: The null hypothesis states that the group decision does not affect the variability of information searched per attribute. Comparing the mean variability values of the information searched between the two modes indicates that the variability is higher in the individual mode as compared to the group mode (see Figure 3). The results indicate that there is a statistically significant difference in the variability of information searched between the two modes of GIS-MCDA. For the decision mode effect, the LMM test gives a $p$-value of 0.047 ($p < 0.05$), thereby suggesting that we reject the null hypothesis, or alternatively that the decision mode has a significant impact on the variability of information searched per attribute (see Table 2). Consequently, the group recommendations regarding the rankings of decision alternatives significantly affect the variability of information search per attribute.

Hypothesis 4: The null hypothesis is that the group decision has no influence on the variability of information search per alternative. Figure 3 shows a comparison of information searched per alternative between the two decision modes in each of the four decision situations. A comparison of the mean variability values in the two decision modes indicates that the variability is pretty much the same in the two decision modes. This is confirmed by the LMM results, indicating that the observed difference in the variability is not statistically significant ($p > 0.05$) (see Table 2). Contrary to the variability of information search per attribute, the effect of group decision on the variability of information search per alternative is not supported by the evidence.

Hypothesis 5: The null hypothesis states that group decision has no impact on the directions of information search. Participants were expected to adopt different information search directions when the decision mode was changed. Comparing the SI mean values in the two modes suggests that the participants used different search patterns in the two decision modes (see Figure 3). The LMM results for differences in the direction of information searched between the two decision modes gives a $p$-value of 0.570 ($p > 0.05$) for SI (see Table 2). This implies that the null hypothesis of no difference cannot be rejected (or the decision mode has an insignificant impact on the directions of

Table 1. The decision table: matrix of alternatives and the associated attribute values.

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Attribute 1</th>
<th>Attribute 2</th>
<th>Attribute 3</th>
<th>...</th>
<th>Attribute n</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$s_{11}$</td>
<td>$s_{12}$</td>
<td>$s_{13}$</td>
<td>...</td>
<td>$s_{1n}$</td>
</tr>
<tr>
<td>2</td>
<td>$s_{21}$</td>
<td>$s_{22}$</td>
<td>$s_{23}$</td>
<td>...</td>
<td>$s_{2n}$</td>
</tr>
<tr>
<td>3</td>
<td>$s_{31}$</td>
<td>$s_{32}$</td>
<td>$s_{33}$</td>
<td>...</td>
<td>$s_{3n}$</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>m</td>
<td>$s_{m1}$</td>
<td>$s_{m2}$</td>
<td>$s_{m3}$</td>
<td>...</td>
<td>$s_{mn}$</td>
</tr>
</tbody>
</table>

Note: $s_{ij}$ is the raw value of $i$-th alternative with respect to $j$-th attribute ($i = 1,2, \ldots, m; j = 1,2, \ldots, n$).

Table 2. The effect of group decision on the information acquisition metrics.

<table>
<thead>
<tr>
<th>Information search metric</th>
<th>The effect of group decision</th>
</tr>
</thead>
<tbody>
<tr>
<td>The proportion of information search</td>
<td>$F = 7.24, p = 0.010 &lt; 0.05$</td>
</tr>
<tr>
<td>The average amount of time spent acquiring per item of information (Sec)</td>
<td>$F = 5.04, p = 0.033 &lt; 0.05$</td>
</tr>
<tr>
<td>The variability of information search per attribute</td>
<td>$F = 4.63, p = 0.047 &lt; 0.05$</td>
</tr>
<tr>
<td>The variability of information search per alternative</td>
<td>$F = 1.47, p = 0.233 &gt; 0.05$</td>
</tr>
<tr>
<td>The direction of search (SI)</td>
<td>$F = 0.32, p = 0.570 &gt; 0.05$</td>
</tr>
</tbody>
</table>
information search). It provides evidence that the direction of information search in the individual decision mode is insignificantly different from that in the group decision mode.

**Table 3.** The Pearson correlation coefficients among the information search metrics in the decision table.

<table>
<thead>
<tr>
<th>Decision situation</th>
<th>GIS-MCDA individual mode</th>
<th>GIS-MCDA group mode</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>( P ) and ( SI )</td>
<td>(-0.464^{**})</td>
<td>(-0.339^{*})</td>
</tr>
<tr>
<td>( P ) and ( AT )</td>
<td>(-0.077)</td>
<td>(-0.189)</td>
</tr>
<tr>
<td>( P ) and ( VAL )</td>
<td>(-0.535^{**})</td>
<td>(-0.044)</td>
</tr>
<tr>
<td>( P ) and ( VAT )</td>
<td>(-0.064)</td>
<td>(0.505^{**})</td>
</tr>
<tr>
<td>( AT ) and ( SI )</td>
<td>(0.126)</td>
<td>(0.204)</td>
</tr>
<tr>
<td>( AT ) and ( VAL )</td>
<td>(0.105)</td>
<td>(-0.139)</td>
</tr>
<tr>
<td>( AT ) and ( VAT )</td>
<td>(0.020)</td>
<td>(-0.181)</td>
</tr>
<tr>
<td>( VAT ) and ( SI )</td>
<td>(-0.463^{**})</td>
<td>(-0.492^{**})</td>
</tr>
<tr>
<td>( VAL ) and ( SI )</td>
<td>(0.623^{**})</td>
<td>(0.219)</td>
</tr>
<tr>
<td>( VAL ) and ( VAT )</td>
<td>(-0.297)</td>
<td>(-0.123)</td>
</tr>
</tbody>
</table>

Note: ** significant at \( p < 0.01 \), * significant at \( p < 0.05 \), \( P \) = the proportion of information search, \( AT \) = the average decision time, \( VAT \) = the variability of information search per attribute, \( VAL \) = the variability of information search per alternative, \( SI \) = the search index.

5. Discussion

The findings of this study show that proportion of information search, variability of information search per attribute, and the average time spent per item of information acquired decrease after viewing the group decision. This is consistent with the findings reported by Schrah et al. (2006) who found that recommendations concerning the choice of one or more specific alternatives result in a decrease in the proportion of information search and variability of search per attribute (see also Bonaccio & Dalal, 2006). These findings imply that decision makers examine a smaller proportion of information after having an access to the group decision or choice recommendations. This is because the focus of information search is on few particular alternatives, i.e., those recommended by group, and therefore information search is expected along those alternatives instead of a complete examination of the available alternatives. In other words, a decision maker who receives a recommendation regarding one or more alternatives and follows the recommendation is more likely to focus his/her information search only on those alternatives and disregard the information relevant to the other ones. The reason why the
variability of search per attribute decreases may be because decision makers move their search just along those alternatives recommended by group across the attributes, and dose not switch between alternatives. Therefore, they search a more constant and equal number of information cells across the attributes. Consequently, it is realistic to expect that the information search behaviour of a decision maker in the individual mode differs from his/her behaviour in the group mode. However, the results regarding the average time spent, variability of information search per alternative and the direction of search (SI) are inconsistent with the findings by Schrah et al. (2006). The possible reasons for the discrepancy between the findings of this study and Schrah et al. (2006) findings may be explained by the differences in the type of decision (spatial vs. non-spatial), decision making platforms (moderated decision making vs. web-based non-moderated decision making), and methods (MCDA vs. simple multicriteria choice). The multicriteria method used in the Schrah et al. (2006) study involves the ability of decision makers to simply rank non-spatial alternatives based on multiple criteria, whereas the present study employed a MCDA technique (OWA-based approach) for the evaluation of geographic alternatives based on the individual preferences. In other words, the inconsistency between the findings may be due to the different methods used for the multicriteria evaluations (this applies to all of the hypotheses in the study). Explicitly, with the lack of previous findings consistent with the one reported in this study, one has to be cautious while generalising the findings to other cases. Further research should be undertaken to replicate the present study with a different site selection problem, spatial decision support tool, multicriteria evaluation approach, level of decision importance and consequences associated with it, region and community, and decision makers.

One of the theoretical contribution of this study concerns its overall research framework and output. It makes contribution to the information acquisition in land use planning and management problems by providing a research framework and carrying out an experimental study for studying the effect of group recommendations/decision on information acquisition behaviour. The study provides a formal approach for examining information search behaviours in land use planning and management problems, based on concepts drawn from theoretical frameworks used for studying the information acquisition behaviour in decision making processes. It extends information acquisition behaviour paradigm as one of the theoretical frameworks in the decision literature to the group spatial decision context. Our empirical results demonstrate how information search variables change as a result of accessibility to group decision/recommendations in collaborative GIS-MCDA applications for land use management.

Another theoretical contribution we have made is that, we extend Malczewski and Rinner (2015) research call that ‘the research interests of the two traditions, management sciences and GIS-MCDA, meet at the application of their approaches to the land use planning and management’ (pp.55). The study broadens information-driven management/decision literature to the field of geographically referenced information and GIS-MCDA-based land use management (see also Kemppinen, 2014). It provides an illustrative implementation of a web-based collaborative GIS-MCDA, which supports land use management practices. Results of this study have also practical implications for designers of collaborative GIS-MCDA applications for land use management. The decrease in the proportion of information search and average time implies that the efforts and time spent to search decision information decreases, which eases and improves spatial decision making processes for those interested in group
recommendations. Such findings suggest that managers could improve land use management processes in a collaborative setting by providing proper group information aids that represent group decision (recommendation). The GIS-MCDA developments should represent the consensus rankings of alternatives as well as the consensus degree on the alternatives, etc. as the recommendation in favour of or against a particular alternative(s) on the map. Moreover, the findings stress a need to use more advanced online argumentation mapping tools (map-centred communication tools) or collaborative maps, and facilitate person-to-person interactions/collaborations on the map, where decision makers can easily exchange geo-referenced advices/recommendations. Finally, GIS-MCDA designers may include the capability to allow the participants the option to narrow down their information search by making choices among the alternatives recommended by the group, and then perform the decision making process (information acquisition) using the selected alternatives. Finally, as the accessibility to group decision/recommendation affects the information search behaviour, and in turn, the accuracy and quality of decisions, it is necessary to use more accurate and reliable source of recommendation in the collaborative land use management process. Future studies may adopt GIS-MCDA tools that classify decision makers based on their expertise levels and allow novice participants to use recommendations based on expertise levels as a more reliable source of recommendations. It has been suggested that decision makers value the expert recommendation more than an ordinary recommendation. Decision makers would be able to decide from which advisor/expert to seek information.

Nevertheless, accessibility to the group decision may distract decision makers’ attention from examining the information relevant to alternatives other than those suggested by group, which may affect decision quality. In this context, decision quality may decrease as participants are more likely to reduce their information search instead of a complete cost-benefit analysis of the available alternatives (Vandenberghe, 2011). The findings provide a new viewpoint that group GIS-MCDA tools should be developed in such a way that not to distract decision makers’ attention from searching the whole information, which may affect the decision quality.

The study acknowledges a few limitations that should be taken into account. One of the main limitations of this study is the choice of a Mouselab process-tracing approach (web-based logging technique) to record the human-computer interaction data representing information search activities during the collaborative decision making process (Jelokhani-Niaraki & Malczewski, 2015b). Recording decision makers’ information search activities in the decision table using this approach requires that the attribute values be hidden behind the cells so as to find out which specific attribute values are examined for which alternatives. Due to the recent advances in computer technology and computer vision techniques, eye tracking has gained much attention as an alternative way of keeping track of the decision process (Pfeiffer, 2012). Eye tracking refers to the process of measuring eye movements with eye tracker devices, such as head-mounted, stationary eye trackers, etc. With eye trackers it is unnecessary to hide information since the eye tracker system is able to precisely record fixations on information items (Reisen, Hoffrage, & Mast, 2008).

Another limitation is to make sure that GIS-MCDA techniques are used in such a way that their fundamental assumptions are met. Jelokhani-Niaraki and Malczewski (2015b) argue that decision makers might ignore a complete examination of information during the specification of criteria weights, and inaccurately assign the criteria weights mainly based on the subjective evaluations of importance of criteria. Meng (2010) suggested that
information searching in a web-based cooperative GIS-MCDA framework may vary among community stakeholders as a result of their differences in age, employment, sex and experiences of web surfing and GIS use. According to Sieber (2006), a participatory GIS project is not conducted in a vacuum, but is influenced by the rules, tradition, politics, and history of the population, area, state, or country in which it is applied. Yazdanpanah Dero (2018) argues that community members are harmonised according to background, culture, tradition, structures of social systems, organisations, ideology, territory, and particularly, religion. Consequently, this affects the way members of community use participatory GIS or collaborative GIS-MCDA systems. Although a collaborative GIS-MCDA system can be widely accepted by all parties of one community, the same system in another community may be completely unacceptable. This also relates to our analysis and affects how we generalise the results beyond the research environment. Clearly, this implies that, further research is required to generalise the results to other cases.

Although participants were asked to carefully and precisely perform decision tasks in both of the decision modes, the results may still be subject to uncertainties which arise from the repetition and carryover effects. To reduce carryover or order effects as the main drawback of the repeated-measure experiments (that is, a participant may get better at the task over time because of practice or the participant will become worse at the task over time because of fatigue) the order of presentation of the decision situations (individual and group decision modes) should be counterbalanced across the participants. In other words, decision situations should be presented to each participant in a different order in such a way that each situation is given in each sequential position an equal number of times. While the present study used a within-subjects design for the experimental sessions, future research might consider employing a between-subjects design, where separate groups of individuals are involved at each level of decision situations. Using a between-subjects design allows us to overcome the potential drawback of a within-subjects design (e.g., carryover effects). A combination of the results obtained from the two experimental designs provides the robust and precise insights into the interpretations of decision making behaviour.

Another limitation is that the present study only examined the external information search behaviour during the use of the information aids (the map and table) in the collaborative GIS-MCDA (Jelokhani-Niaraki, 2013). However, it is suggested that, in addition to the external search, researchers should also study decision maker’s internal search behaviours (search in mind) during the decision making process. An internal search is concerned with recalling relevant information from individuals’ long term memories. It involves no sources other than the decision maker’s own memory, prior knowledge, and experience (Lindquist & Sirgy, 2003). For example, a decision maker might deeply analyse particular places and spatial relations or specific attribute values in his/her mind while looking at the map and decision table, respectively. It is suggested that individuals with higher levels of knowledge would replace an external search with an internal one and conduct information searches more efficiently than the less knowledgeable individuals (Brucks, 1985).

6. Conclusion

This study contributes to the research about spatial decision making by studying the information search processes in the use of web-based collaborative GIS-MCDA, based on concepts drawn from information search theoretical frameworks. It addressed the research question of
whether information acquisition and integration behaviour used by decision makers significantly change upon viewing the group solution (e.g., group recommendations on the alternative choices). This question was addressed by a set of hypotheses. The hypotheses stated that there is a significant difference in the information acquisition metrics between GIS-MCDA individual mode (without an access to group decision) and GIS-MCDA group (with an access to group decision). It was found that the two decision modes are significantly different in terms of the following metrics: (1) the proportion of information search, (2) the variability of information search per attribute, and (3) the average time spent acquiring the information in the decision table. However, no support has been found for the effects of group decision on the variability of search per alternative and direction of search. Although, not all of the metrics were found to be significantly different between the two decision modes, the findings overall show that the information acquisition and integration behaviours of decision participants in the GIS-MCDA group mode may differ from those in the GIS-MCDA individual mode. Further research should be undertaken to repeat the test of hypotheses using a different group of individuals, site selection problem, spatial decision support tool, multicriteria evaluation approach, and decision makers. Examining whether the results of the hypothesis tests observed in this analysis apply to other spatial decision making situations would be beneficial. Ultimately, although the current study used a fairly comprehensive list of measures to analyse information search behaviour related to the group decision effect, it can be suggested that there are other important measures to test decision making behaviour. Additional measures of information search should be used in future research to analyse the dynamics of information acquisition in the collaborative GIS-MCDA.

**Disclosure statement**

No potential conflict of interest was reported by the author.

**References**


