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S. Jarupathirun
University of Wisconsin at Milwaukee

Fatemeh Zahedi
University of Wisconsin at Milwaukee

A THEORETICAL FRAMEWORK FOR GIS-BASED SPATIAL DECISION SUPPORT SYSTEMS: UTILIZATION AND PERFORMANCE EVALUATION

S. Jarupathirun
University of Wisconsin at Milwaukee
jarupat2@uwm.edu

F. M. Zahedi
University of Wisconsin at Milwaukee
zahedi@uwm.edu

Abstract

The spatial analytical capabilities of geographic information systems (GIS) make them good candidates to be used in spatial decision support systems (SDSS). There is little research on utilization and spatial decision performance of GIS-based SDSS. In this paper, we synthesize theories from IS management, organizational behavior, psychology and DSS in developing a conceptual model and subsequent propositions for examining the factors impacting the utilization and spatial-decision performance of GIS-based SDSS.

Introduction

One of the objectives of research on decision support systems (DSS) is to examine how such systems impact users' problem solving, task accomplishment, and decision performance. Researchers have addressed, identified and explained relationships among factors and decision tools that influence users' decision performance. These factors include decision strategies, data quality, cognitive effort, perceived accuracy, and incentive (e.g., Bettman et al. 1990; Todd and Benbasat 1994 and 1999). As new technologies are developed and put into use, lessons from modeling and implementing existing ones should be applicable (Lee 2000). However, novel features and dimensions in new technologies may require modification of existing models for evaluation purposes.

With the rapid increase in computational resources and increased reliance on visualization in decision analysis, DSS systems with spatial capabilities (spatial decision support systems or SDSS) have gained in popularity. The advances in GIS technology make it a natural candidate for creating SDSS. In this context, we call DSS systems using GIS for spatial decisions as GIS-based SDSS. The spatial functionalities in such systems introduce a new dimension to DSS that has rarely been examined before. The evaluation of a GIS-based SDSS requires the modification and augmentation of the existing models of DSS analysis.

The effective use of GIS technology and correct interpretation of spatial patterns require users to have sufficient spatial knowledge (Golledge 1995). Research in non-MIS fields has confirmed spatial ability as an individual-difference variable that significantly predicts the level of performance in spatial tasks (Cooper 1980 and 1988; Thorndyke and Goldin 1981). However, the MIS studies regarding the effect of spatial ability in using GIS have been inconclusive (Smelcer and Carmel 1997; Swink and Speier 1999).

The research question in this study is the examination of factors impacting the utilization and spatial-decision performance of GIS-based SDSS. In answering this question, we synthesize theories developed in IS management (task/technology fit theory), psychology (spatial ability), DSS (cost/benefit theory), and organizational behavior (goal setting theory) in formulating a conceptual model for the evaluation of SDSS under different conditions of task complexities and system functionalities.

Literature Review

The conceptual framework proposed in this study builds on a number of reference disciplines, as discussed below.

Geographical Information Systems (GIS)

Even though there have been a number of attempts to define GIS (Malczewski 1999 p. 15), there is no consensus on a definition, which could be broad or narrow in scope. This is partly due to the variety of GIS implementations and diversity of utilization in different fields (Clarke 1999 p 2; Huxhold 1991 p. 25). Regardless of the definitional scope, GIS have the distinct capability of providing users with functions that facilitate spatial analysis. This capability makes GIS different from other map-drawing systems, even though both share some similar functions, such as displaying spatial maps (Huxhold 1991 p.26). On the other hand, MIS and GIS are similar in their functionality of storing, analyzing, and retrieving attribute data. However, only GIS have the analytical functionalities that use both the spatial and attribute data (Malczewski 1999 p. 16). Hence, GIS could provide distinct tools for making spatial decisions, not found in other support systems.

Fit Theory

The fit theory has been used in a number of fields, particularly in strategic management for strategy/context fit (Venkatraman 1989) as well as in IS for task/technology fit. Goodhue and Thompson (1995) developed the "technology-to-performance chain" model, in which technology performance depends on technology utilization and the fit between the technology and the tasks it supports. Moreover, based on Venkatraman's work, Zigurs and Buckland (1998) proposed the theory of task/technology fit for GDSS effectiveness, in which group performance depends on the fit between task categories and technology dimensions, which they defined as fit profiles.

Based on the task/technology fit theory, we posit that the users' utilization of GIS-based SDSS and the subsequent spatial-decision performance depend on the fit between users' spatial tasks and GIS functionalities.

Another aspect of technology fit is task complexity. Vessey (1991) classifies elementary tasks as spatial and symbolic. Our focus here is on spatial tasks, which require decision-makers to assimilate and analyze spatial and attribute information before making a decision. Spatial tasks can be categorized into two groups, simple and complex. Payne (1976) defines complex tasks as having multiple information attributes and multiple alternatives to be evaluated. Other dimensions of decision task complexity include: the presence of multiple desired outcomes, solution scheme multiplicity, conflicting interdependence path, and uncertainty (Campbell 1988; Zigurs and Buckland 1998). Simple tasks are tasks that do not have any of these characteristics (Campbell 1988).

Spatial Ability

A number of studies in psychology have identified the existence of spatial abilities as a fundamental component of general intelligence (Beaumont 1997). Several spatial ability factors are identified (Fleishman and Dusek 1971), among which two are dominant: spatial orientations and visualization (e.g., Cooper 1980, Golledge and Stimon 1997). *"Spatial orientation is the ability to maintain orientation with respect to objects in space and to remain unconfused by the varying orientations in which a pattern must be perceived"* and *"visualization is the ability to manipulate or transform the image of a two- or three-dimensional spatial pattern"* (Ekstrom, French, and Harman 1976). The question is whether these factors impact the utilization of GIS-based SDSS, and subsequently users' spatial decision performance.

DSS Cost/Benefit Theory and Intrinsic Incentive

DSS research has shown that the utilization of DSS depends on users' incentives (Todd and Benbasat 1999). According to the DSS cost/benefit theory, decision-makers evaluate the trade off between effort and accuracy, and take into account the cost and benefits of required effort in selecting a problem strategy (Todd and Benbasat 1992). In selecting one of two technologies (strategies), a decision maker may utilize the one that requires less effort to solve a problem, but produces the same performance (Todd and Benbasat 1992 and 1993). Similarly, Todd and Benbasat (1993) observe that decision makers are expected to select the technology (strategy) that will produce the highest quality of performance but require the same effort. However, empirical tests show that the incentive of spending less cognitive effort to manipulate and remember information, and the incentive of increasing accuracy by using decision aids may not always result in increased quality of decision performance (Beattie and Loomes 1997).

We define intrinsic incentive as the difference between cost and benefit related to effort expenditure and perceived accuracy of results. Our model builds on and modifies the role of incentive in Todd-Benbasat's model (1999) by introducing users' goal setting and goal commitment. The impact of incentive for utilization and performance is mediated by the level of users' goal commitment.

Goal Setting and Commitment

One of the well-established theories in organizational behavior is the theory of goal setting, described as a positive relationship between goal level and task performance (Locke et al. 1988). A higher level of goal motivates individuals to spend more effort to achieve the desired decision performance. However, goal setting does not work if commitment is not carried over the period of task performance. Goal commitment has found to have a moderating effect on goal level and performance (e.g. Hollenbeck and Klein 1987). Commitment is influenced by external factors (e.g., external reward), interactive factors (e.g., competition), and internal factors (e.g., internal reward). In GIS-based SDSS utilization, we argue that the intrinsic incentives for using the system impact the commitment to system utilization. Furthermore, a higher level of commitment increases the actual utilization of the system.

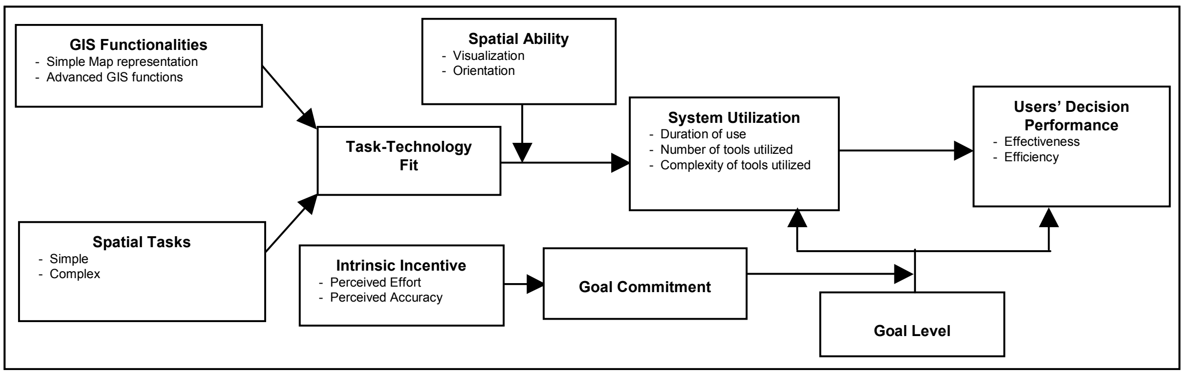

Figure 1. The Conceptual Model for SDSS Utilization and Spatial-Decision Performance

Conceptual Model

We synthesize the above arguments derived from fit theories in IS management, goal setting and commitment in organizational behavior, spatial ability in psychology, and cost/benefit analysis in DSS to derive the conceptual model for the utilization and spatial decision performance of SDSS, as depicted in Figure 1. The model posits four major propositions.

Proposition 1: *A higher level of GIS functionalities is more appropriate for complex spatial tasks.*

To increase the quality of decisions, according to the task/technology fit perspective, the functionalities of the technology should match as much as possible with the task requirements. The effective technology should minimize human cognition required for making a decision. We argue that the advanced GIS tools are not needed for simple spatial tasks, where a static map alone may be sufficient. Complex spatial tasks that require intensive processing of spatial information and knowledge, however, may require more interaction with advanced (i.e. complex and flexible) GIS functions to overcome human cognitive limitations. We posit that as spatial tasks become more complex, a greater utilization of advanced functions is required to reach a desired level of decision performance.

Proposition 2: S*patial ability has a moderating effect in the relationship between task-technology fit and utilization of the system.*

Users' level of spatial ability has an impact on the performance of spatial tasks (e.g., Cooper, 1980, Swink and Speier 1999). Spatial ability becomes increasingly more important as the task complexity increases (Swink and Speier 1999). Goldin and Thorndyke (1981) observed that when the task does not require extensive manipulation of a mental model, the level of spatial ability does not impact the individual's performance. However, performing tasks that require extensive mental manipulation, spatial ability makes a difference in performance. Following these findings, we argue that for complex tasks, decision-makers should use/interact with advanced GIS functions in order to reach a desired level of decision performance.

Proposition 3: There is a positive association between users' goal levels and their utilization and decision performance.

We argue that, based the goal setting theory, a high level of intrinsic incentive does not directly influence greater utilization and higher performance, but it is users' goal level that lead them to use the system and to achieve a higher performance (Hollenbeck and Klein 1987).

> **Proposition 4:** *Intrinsic incentive impacts goal commitment, which in turn acts as a moderator in the relationship of goal setting with utilization and performance.*

The literature on goal setting supports the moderator impact of goal commitment. Furthermore, we argue that intrinsic incentive materializes in the extent of users' goal commitment. This proposition provides an alternative approach to sometimes inconclusive results obtained regarding the effect of incentive on DSS performance.

Discussions

The next stage of this research is the design of instruments and controlled lab experiments for testing the above propositions.

References

References are available upon request from the authors.