# Using Geographical Information Systems for Decision Making: Extending Cognitive Fit Theory to Map-Based Presentations

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As the use of Geographical Information Systems (GIS) by business becomes more common, we need to better understand when these systems are and are not useful. This research uses a laboratory experiment to extend cognitive fit theory (Vessey 1991) to geographic tasks performed using either map-based presentations or tabular presentations. The experiment found that decision makers using a map-based presentation made faster and more accurate decisions when working on a geographic task in which there were adjacency relationships among the geographic areas. Decision makers using a map-based presentation made faster but less accurate decisions when working on a geographic task in which there were no relationships among the geographic areas.
(*Geographical Information Systems; Cognitive Fit; Maps; Graphics*)

## 1. Introduction

Although Geographic Information Systems (GIS) have been recognized as causing a "paradigm shift in cartography" (Morrison 1994), there is a general lack of understanding of the decision-making implications of their use (Crossland et al. 1995). When Morrison (1994) discussed key challenges in GIS research, decision making effects were not mentioned. Yet, the most common reason for business investment in GIS is the belief that its use improves decision making (Attenucci et al. 1991, Bracken and Webster 1989, Murphy 1995, Robey and Sahay 1996).

Most GIS studies have addressed technical or implementation issues (Mennecke and Crossland 1996). Research assessing decision-making implications has typically been "one-shot" case studies (Crossland et al. 1995). We are aware of only two controlled empirical tests of GIS decision making. Crossland et al. (1995) found that using GIS maps led to faster and more accurate decisions than using paper maps. Smelcer and Carmel (1997) compared GIS maps to tables and found that decision makers using the GIS maps made faster decisions. This paper compares the impact of GIS map-based presentations and tabular presentations on decision processes, decision quality, and decision time for two different types of geographic tasks: those in which there are adjacency relationships among geographic areas, and those in which there are not.

## 2. Cognitive Fit Theory and Prior Research

Cognitive fit theory (CFT) was developed to explain how graphical displays affect the decision processes and outcomes of decision making (Vessey 1991). Although it does not apply directly to the map-based displays in GIS, it can be extended to them (cf. Vessey 1991, 1994). According to CFT, decision makers develop a mental representation of the task and adopt



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decision processes based on the task and the presentation of task information (Vessey 1991, Vessey and Galletta 1991). The outcomes of decision making depend upon the fit between information presentation, task, and decision processes used by the decision maker. See Figure 1.

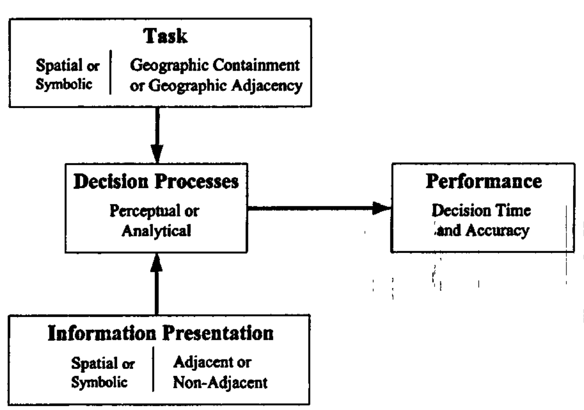
When the information emphasized by the presentation matches the task, decision makers can use the same mental representation and decision processes for both the presentation and the task, resulting in faster and more accurate solutions (Vessey 1991). When a mismatch occurs, one of two processes will occur. First, decision makers may transform the presented data to better match the task, which might increase the time needed and might decrease accuracy because any transformation can introduce errors (Vessey 1991). Alternatively, decision makers may adjust their decision processes to match the presentation (Perrig and Kintsch 1985), decreasing accuracy and increasing time because the information does not match the ultimate needs of the task.

## 2.1. Task Characteristics

**2.1.1. Spatial versus Symbolic Tasks.** CFT has been used primarily to explain behavior on elementary tasks such as simple information acquisition and evaluation (Vessey 1991, Vessey and Galletta 1991). CFT classifies elementary tasks as being spatial or symbolic (Vessey 1991, Vessey and Galletta 1991). Spatial tasks ask decision makers to acquire information or make simple comparisons among alternatives (i.e., a qualitative answer). Symbolic tasks ask decision makers for specific numeric values.

**Figure 1** **Cognitive Fit in Multicriteria Geographic Tasks.**

Adapted from Vessey (1991).




**2.1.2. Multicriteria Tasks.** Multicriteria tasks are more complex than the elementary tasks of CFT (Crossland et al. 1995, Jankowski 1995, Pereira and Duckstein 1993). Multicriteria tasks have a set of alternatives and a set of criteria. The decision maker must perform a series of elementary information acquisition tasks and a series of elementary information evaluation tasks (see Newell and Simon 1972, Vessey 1994). Multicriteria tasks are spatial if they require the reporting of qualitative names (e.g., "which alternative is best?") and symbolic if they require the reporting of numeric values (e.g., "calculate a score for each alternative.").

**2.1.3. Geographic Multicriteria Tasks.** Geographicmulticriteria tasks are a specific type of multicriteria task that are concerned with alternatives and criteria tied to geographic objects. Geographic multicriteria tasks can be either spatial or symbolic. In this study, we focus only on spatial geographic multicriteria tasks (geographic multicriteria tasks requiring the reporting of the name of the best alternative, not the numeric differences among alternatives).

## 2.2. Types of Geographic Tasks

Many different typologies of geographic tasks have been proposed. Space is inherently continuous and seamless (Mark and Freundschuh 1994), but we typically organize it into discrete geographic areas (Fotheringham and Rogerson 1993, Golledge et al. 1995). Many typologies focus on the size of the geographic area (e.g., Mark and Freundschuh 1994), but to understand effects on decision making behavior we need to focus on the relationships among geographic areas as presented to the user (Egenhofer 1991, Smelcer and Carmel 1997).

Building on the work of Egenhofer (1991) and Smelcer and Carmel (1997), we define two distinct types of geographic tasks. The first, *geographic containment tasks*, are those tasks whose data are tied to discrete geographic objects, but the relationships among objects are fully contained within one geographic area. The second type of geographic tasks, *geographic adjacency tasks*, are tasks whose data are tied to discrete geographic objects that are not contained within one geographic area; instead, their relationships extend beyond one area so that decision makers need to consider adjacent geographic areas when making decisions.

For example, consider site selection for a new fast-food restaurant. The first decision is the general area in which to locate the restaurant (e.g., city). The restaurant can be expected to draw customers from within a certain radius, but is unlikely to draw from beyond. This is a geographic task, but there is no concern with the relationships among geographic areas (e.g., in considering Manhattan, we do not consider its relationship with the Bronx). This task uses geographic data, but the relationships are contained within one geographic area—a geographic containment task.

Once the general geographic area has been selected, the next decision is to select the specific piece of land or storefront in which to build. This task requires knowledge of the adjacent geographic areas (e.g., if one is considering building on 42nd Street, the retail stores on 43rd Street could influence the demand). This is a geographic adjacency task.

### 2.3. Information Presentation

Most GIS can present information either as a table of numbers linked by words to their geographic location, or as a map with data displayed by shading different areas on the map in different colors. Map-based presentations differ from tabular presentations in two theoretically important ways (Murphy 1995, Mennecke and Crossland 1996).

First, map-based presentations may provide an information summarizing function. A table presents information as a series of discrete numbers (*symbolic presentation*: Vessey 1991). A map-based presentation summarizes data in the same way as a graphical display (DeSanctis 1984, Jarvenpaa and Dickson 1988) by presenting the information as a series of colors or patterns, each representing different values (*spatial presentation*: Vessey 1991).

The second difference is the way each presents the relationships among the geographic areas. With a map-based presentation, geographically adjacent areas are displayed in a visually *adjacent* presentation (Papadias and Sellis 1992). Relationship information also can be presented in tabular form by listing the names of areas adjacent to other areas in a *nonadjacent* presentation (Papadias and Sellis 1992). The adjacent presentation in the map is a closer to the deep structure of task than is the nonadjacent tabular presentation (Murphy 1995). The adjacent presentation should therefore assist the decision maker by better presenting the complex network of many-to-many adjacency relationships among various geographic areas (Smelcer and Carmel 1997).

**Table 1** **Style of Presentation**

| | Spatial | Symbolic |
|---|---|---|
| Adjacent | Data are displayed on a map by coloring the geographic areas in different colors to indicate their data values. | Data are displayed on a map by displaying numeric values in the different geographic areas. |
| Nonadjacent | Data are displayed in a bar graph or some similar nonnumeric form. The arrangement of the geographic areas in the display does not correspond to the their actual geographic location. Geographic relationships are expressed in a table. | Data are displayed in a table of numbers. The arrangement of the geographic areas in the display does not correspond to the their actual geographic location. Geographic relationships are expressed in a table. |

Each style of presentation, spatial or symbolic and adjacent or nonadjacent, is theoretically distinct. There are four distinct combinations of information presentation, as shown in Table 1. In this study, we focus on spatial, adjacent presentations (which we call map-based presentations) and on symbolic, nonadjacent presentations (which we call tabular presentations).

### 2.4. Decision Processes

CFT classifies decision making processes used for the elementary tasks as being analytical or perceptual (Vessey 1991). *Analytical* processes emphasize precision and the processing of information based on its meaning (e.g., data are interpreted as numbers). *Perceptual* processes are holistic and emphasize visual assessments of relative magnitudes rather than analyses of meanings (e.g., data are interpreted as distances between parts of the display).

There is considerable evidence that information presentation format is the primary factor influencing decision processes (Benbasat et al. 1986, Bettman and Kakkar 1977, Jarvenpaa 1989, Newell and Simon 1972, Vessey 1991, Vessey and Galletta 1991). Decision makers trade off potential accuracy against the time and effort required to use different processes (Beach and Mitchell 1978, Payne 1982, Todd and Benbasat 1991). Choosing decision processes that match the information presentation minimizes effort, because using a different process requires the decision maker to expend more effort to transform the information before using it.

Effort is minimized when analytical processes are used for symbolic information, so decision makers presented with information in symbolic form are more likely to choose analytical processes (Vessey 1991, Vessey and Galletta 1991). Likewise, visual presentation of information is more likely to induce perceptual processes (Vessey 1991, Vessey and Galletta 1991).

Geographic multicriteria tasks are more complex than the elementary tasks of CFT. In extending CFT to geographic multicriteria tasks, the fundamental bias to information presentation rather than task characteristics should remain. To perform multicriteria tasks, the decision maker must perform a series of elementary information acquisition tasks and information evaluation tasks (Newell and Simon 1972, Vessey 1994). Information presentation is likely to strongly influence the elementary process by which the information is acquired, with symbolic displays inducing analytical processing and spatial displays inducing perceptual processing. Once the information has been acquired, it must be evaluated. The format in which the information has been acquired (spatial or symbolic) will likely induce matching decision processes for evaluation. Therefore:

HYPOTHESIS H1. *Map-based based presentations will induce perceptual decision processes, while tabular presentations will induce analytical decision processes.*

### 2.5. Decision Outcomes

**2.5.1. Geographic-Containment Tasks.** For geographic containment tasks, the adjacent presentation of map-based displays is likely to offer few benefits (or disadvantages) from the nonadjacent presentation of tabular displays. The key differences lie in the spatial versus symbolic form of information presentation and the types of decision processes these induce.

Spatial presentation should result in faster performance because it induces perceptual processes which are inherently faster than analytical processes (Vessey 1994). Symbolic presentation will likely induce analytical processes that take longer because decision makers must perform pairwise comparisons of the symbolic data.

CFT makes no predictions for the effects of spatial versus symbolic presentations for decision accuracy in multicriteria geographic tasks. Spatial presentation is likely to induce perceptual processes which are less precise and tend to be less accurate. Symbolic presentation is likely to induce analytical processes which are generally more precise and accurate. Therefore:

HYPOTHESIS H2a. *For geographic containment tasks, decision makers using map-based presentations will require less time than decision makers using tabular presentations.*

HYPOTHESIS H2b. *For geographic containment tasks, decision makers using map-based presentations will make less accurate decisions than decision makers using tabular presentations.*

**2.5.2. Geographic Adjacency Tasks.** Spatial presentation should again induce perceptual processes. This will be strengthened by the adjacent presentation because it is more likely to trigger spatial cognition, a special type of cognition that is often overlooked in the psychological literature (McGee 1979, Taylor 1994). Spatial cognition includes the recognition of spatial patterns almost automatically, without the processing of the underlying individual elements (MacEachern 1992, Taylor 1994). Like perceptual processing, spatial cognition is faster than analytical processes because it is intuitive and holistic. It is also less susceptible to errors because it is closer to the deep structure of the task (Shepherd 1994).

Use of perceptual processes is likely to lead to faster decision making for geographic adjacency tasks for the same reasons it did for geographic containment tasks. But, effects on accuracy are likely to be different for two reasons. First, these tasks require the understanding of relationships among geographic areas. As argued above, spatial cognition is less error prone in understanding these relationships than the detailed pairwise comparisons in analytical processes.

Second, geographic adjacency tasks have high cognitive load because they require the understanding of these relationships. Because human information processing is limited by the amount of information that can be stored and used (Newell and Simon 1972, Simon 1960), processing all the relationships in symbolic form may exceed the decision maker's analytical capabilities. For tasks with a higher cognitive load, perceptual processes supported by spatial presentation may be more accurate (Vessey 1994). Empirical research suggests that as task complexity increases, spatial presentation leads to more accurate decisions, at least to some moderate level of complexity (Hwang and Wu 1990, Wilson and Addo 1994). Therefore:

HYPOTHESIS H3a. *For geographic adjacency tasks, decision makers using map-based presentations will require less time than decision makers using tabular presentations.*

HYPOTHESIS H3b. *For geographic adjacency tasks, decision makers using map-based presentations will make more accurate decisions than decision makers using tabular presentations.*

# 3. Method

### 3.1. Independent Variables

We used a two-by-two factorial design, crossing the type of task (geographic containment or geographic adjacency) with the type of information presentation (map-based or tabular).

**3.1.1. Task Type.** The first independent variable was the type of task. Both tasks asked subjects to select one geographic area in which to locate a fast-food restaurant from a set of 26 areas in San Francisco. Subjects were provided with information on 14 attributes for each of the 26 areas, with each attribute assigned a weighting value reflecting different importance. The data bore no resemblance to the actual values to prevent subjects familiar with the city from having an advantage. Subjects were to determine the area with the greatest "business potential," using the method defined in the task (see the appendix). For the geographic containment task, each area was independent of the other areas. For the geographic adjacency task, the decision maker had to consider the relationships among adjacent geographic areas to identify the best area.

**3.1.2. Information Presentation.** The second independent variable was the information presentation format, either map-based or tabular. The map-based format used a GIS called Atlas-Graphics that displayed data by drawing geographic areas in different colors according to their data values. Following the map construction process suggested by Yamahira et al. (1985), the data were presented using three value categories: blue represented the lowest value, gray the intermediate value, and red the highest value.

Atlas-Graphics can present information in tabular form, but the tabular interface was more cumbersome than the map-based interface. Therefore, we used a simple system called File Reader to implement the tabular information presentation. File Reader provided comparable functions to those of Atlas-Graphics. Users were able to select one set of data from a list of data sets, and to display the values for that attribute for all areas. For the adjacency task, adjacency information was provided in tabular form by listing the names of areas adjacent to each area.

The two presentation formats provided equivalent functions, except in the information presentation format. Both used similar menu-driven user interfaces. Both contained exactly the same information in the database, organized by attribute (because attribute-based processing is typical of GIS and is more often used in tasks with high information load (Payne 1982, Stone and Schkade 1991)). Some GIS provide very sophisticated data analysis models that rely heavily on the use of numbers, not graphics. Therefore, to provide consistency between treatments, only a simple software calculator was provided.

### 3.2. Subjects

Fifty-six graduate business students served as subjects and were randomly assigned to one of four experimental treatments. Fourteen subjects participated in each treatment, except for the containment/tabular, which had 13 subjects, and the containment/map-based, which had 15.

### 3.3. Dependent Measures

**3.3.1. Decision Process.** Subjects were provided with a worksheet to record information as they performed the task. If the information recorded on the worksheet was numeric (e.g., "75," "68,"), the subject was deemed to have used an analytical process. If the information was recorded in relative terms (e.g., "high"), the subject was deemed to have used a perceptual process. No subject used both numbers and relative terms. Three subjects in the containment/map-based treatment did not record any information on the worksheets, so they are excluded from the decision process analysis. We intended to use a second coder to determine the reliability of this coding, but the worksheets were destroyed by a fire at our offices before this could be done.

**3.3.2. Decision Accuracy.** Decision accuracy has often been measured by the distance from the correct solution (Benbasat et al. 1986, Dickson et al. 1986). In this case, decision accuracy was measured by subtracting the "business potential" score for the area selected by the subject from the "business potential" score for the correct area and expressing the result as a percent of the correct solution (i.e., (optimal—subject's choice) / optimal × 100%).

**3.3.3. Decision Time.** Decision time was measured in seconds from the time when the subject began working on the task until he or she recorded his or her decision on a decision form.

### 3.4. Procedures

All experimental sessions were conducted by the same experimenter following a standard script. As previous research has suggested the importance of training and practice prior to the measurement of performance (Jarvenpaa and Dickson 1988), subjects were first trained to use the assigned system (Atlas-Graphics or File Reader) and then worked through five practice tasks requiring them to use various system functions. Three practice tasks were elementary information acquisition tasks, both spatial and symbolic. Two were multicriteria tasks. Subjects were instructed to take as much time as they wanted to practice (typically 10–20 minutes).

After the practice session, subjects were assigned the experimental task. Subjects were not informed of any time expectations for this task, but two still working after 30 minutes (both in the adjacency/tabular treatment) were halted and asked to make a decision.

A performance-based reward structure was used, as research has shown such incentives to affect decision making effort and accuracy (Creyer et al. 1990). Cash prizes were awarded to the subjects making the two most accurate decisions in each treatment. In the event of ties, subjects making the decision in the least amount of time were declared winners.

## 4. Results

Table 1 presents the means and standard deviations. Hartley tests ($\alpha = 0.05$) for inequality of variance found statistically significant differences in variance for both decision accuracy and decision time. A square root transformation was performed on decision time, and a log transformation was performed on decision accuracy (see Neter et al. 1985, p. 615–616). Hartley tests on the transformed variables found no significant differences, indicating that both transformations were successful in reducing the inequality of variance.

### 4.1. Decision Processes

ANOVA analysis on decision processes found significant effects for information presentation ($F(1,49)$ =

**Table 2 Means (and Standard Deviations)**

| | | Geographic Containment Task | | Geographic Adjacency Task | |
|---|---|---|---|---|---|
| Presentation Style | | Map-based | Table-based | Map-based | Table-based |
| Decision Process | Mean | 75.00 | 7.69 | 64.29 | 28.57 |
| (% using perceptual) | Std | 45.23 | 27.74 | 49.72 | 46.88 |
| Decision Accuracy | Mean | 6.93 | 1.49 | 3.29 | 4.56 |
| (% from optimum*) | Std | 10.98 | 2.48 | 3.19 | 5.82 |
| Decision Time | Mean | 579 | 1242 | 1133 | 1449 |
| (seconds) | Std | 174 | 265 | 470 | 239 |

*Lower numbers indicate more accurate decisions.

13.26, $p = 0.001$). There were no effects for task ($F(1,49) = 1.09$, $p = ns$) or the interaction term ($F(1,49) = 0.47$, $p = ns$). Subjects using the map-based presentation were more likely to have used perceptual processes, regardless of task. H1 was supported.

### 4.2. Decision Outcomes

There was a significant correlation between time and decision accuracy ($r(55) = -0.285$, $p = 0.034$), so a MANOVA was used (decision accuracy was measured as the distance from the optimal, so the negative correlation means that as time increased subjects made better decisions). The MANOVA analysis found significant effects for task ($F(2,51) = 24.58$, $p = 0.001$), information presentation ($F(2,51) = 22.78$, $p = 0.001$), and the interaction term ($F(2,51) = 7.07$, $p = 0.002$).

It is common to use univariate F-tests or ANOVAs following a significant MANOVA to identify individual effects (e.g., Vessey and Galletta 1991) but this may inflate the overall alpha level and does not account for the covariation among the dependent measures (Wind and Denny 1974). We followed the approach of Messmer and Homans (1980) by performing an ordered series of ANOVAs (with Bonferroni corrections) starting with the most important dependent variable (decision accuracy) and then using decision accuracy as a covariate in a second ANOVA with decision time as the dependent variable. The conclusions remained the same when we performed the analyses in the opposite order.

ANOVA analysis on decision accuracy found significant effects for task ($F(1,52) = 25.79$, $p = 0.001$) and the interaction term ($F(1,52) = 6.71$, $p = 0.012$). There were no significant effects for information presentation ($F(1,52) = 0.11$, $p = ns$). Subjects using the map-based presentation made less accurate decisions for the geographic containment task and more accurate decisions for the geographic adjacency task. H2b and H3b are supported.

ANOVA on decision time (with decision accuracy as a covariate) found significant effects for task ($F(1,51) = 16.87$, $p = 0.001$), information presentation ($F(1,51) = 44.47$, $p = 0.001$) and the task $x$ presentation interaction ($F(1,51) = 7.20$, $p = 0.010$). Subjects took less time on the containment task (which was less complex). Subjects using the map-based presentation took less time for both tasks, with greater differences for the containment task. H2a and H3a are supported.

## 5. Discussion

This study examined two different ways of presenting information for two types of geographic tasks. Decision makers using the map-based presentation were more likely to use perceptual rather than analytical decision processes. When data were presented in a map-based form and decision makers needed to consider the relationships among the geographic areas, the use of the map-based presentation led to both faster and more accurate decisions. However, when decision makers did not need to consider the relationships among the geographic areas (e.g., a containment task), use of map-based presentation led to faster but less accurate decisions.

One explanation for these results may lie in the decision processes used. Decision processes are affected by the perceived costs and benefits of their use (Beach and Mitchell 1978, Payne 1982). Decision makers choose processes that they believe have the lowest costs and highest benefits, with costs often weighted more heavily than benefits (Russo and Dosher 1983). In this study, subjects using map-based presentations were more likely to use less precise perceptual decision processes. Few took the effort (i.e., cost) to translate the spatial data into the precise underlying numeric data it represented. In contrast, the subjects using the tabular presentation were more likely to use the precise numbers presented in the table.

For the adjacency task, which required an understanding of the relationships among the geographic areas, subjects using map-based presentations made more accurate decisions in less time. The map-based presentation and the perceptual decision processes this presentation induced better enabled the subjects to solve the problem. The map-based presentation better "fit" the task. In contrast for containment tasks, map-based presentation encouraged less accurate but faster decisions. This presentation and the decision processes it induced were less suited to the task.

CFT was originally developed for elementary tasks. This study suggests two extensions to CFT for multicriteria geographic tasks. First, CFT argues that decision makers choose decision processes that match the information presentation format. We found the same effects, and thus conclude that this aspect of CFT can be extended to multicriteria geographic decision making tasks: information presentation format, not task, drives the selection of decision processes.

Second, CFT argues that for elementary tasks, performance (efficiency and accuracy) is improved when presentation matches the task and induces matching decision processes (Vessey 1991). This was not the case for these multicriteria geographic tasks. Matching led to more accurate decisions, but not to faster decisions. Perceptual processes were faster than analytical processes, regardless of whether they matched the task and information presentation or not. Therefore, we conclude that the predicted performance effects of CFT cannot be extended from elementary tasks to multicriteria geographic tasks (see also Vessey 1994).

Our conclusions are that map-based presentations help decision makers in some situations. In cases where it is important to understand the relationships among geographic areas, map-based presentations improve performance. Using map-based presentations on geographic data for which an understanding of relationships is not needed (i.e., a geographic containment task) is more problematic. Subjects traded off accuracy for time, making faster but less accurate decisions. We believe that the higher cost of accurately processing the detailed numeric data induced decision makers to not expend the needed effort. This suggests that if decision accuracy is important, map-based presentation should not be used for geographic containment tasks, even though the data are geographically oriented and map-based presentations **appear** closer to the task's deep structure.

As with any research, there are limitations to this study's conclusions. They apply within this context using these forms of presentation for these types of tasks. We used graduate students as subjects, many of whom had managerial experience, but the issue of external validity must always be raised. Perhaps more importantly, our measure of decision processes was somewhat superficial. We examined only the worksheet information to see if analytical or perceptual processes were used, and were unable to assess reliability due to the worksheets' premature destruction. Future research needs to examine decision processes in more detail to better understand the nature and type of information used. Concurrent verbal process tracing may offer some insights, although it also has significant drawbacks (see Todd and Benbasat 1987).

This study focused only on map-based displays that presented data in spatial formats (i.e., by using colors). It is also possible to use map-based displays in which numeric values are displayed for each area instead of or in addition to using different colors. The use of symbolic map-based formats might induce analytical decision processes and lead to very different results than the spatial (i.e., color-coded) map-based formats studied here.

We investigated the mean effects of presentation formats. One interesting question for future research may be examining the "fit" between an individual's decision-making style and information presentation. In this study, the standard deviations were high compared to the means, suggesting that there were considerable differences in individual performance. It could be that individuals have a preferred decision style or different spatial cognition abilities. Information presentations that better support those styles or abilities may improve performance.

There were significant differences in the variance of decision accuracy among treatments, which has implications for organizational decision making. In many cases, there is equifinality among alternatives. The real goal may be consistency—not to produce the optimal decision, but to routinely produce "reasonable" decisions that avoid "bad" decisions. In this case, the high variance for the adjacency task when using the map-based presentation would pose problems.

Our recommendations to GIS users are to consider the need to understand relationships among geographic areas. Map-based presentations best fit tasks in which relationships among the geographic areas are important (e.g., store location decisions at the tactical level). For tasks where data are geographically contained, map-based presentation may not fit (e.g., store location decisions at the strategic level). A more traditional tabular presentation may be better. Given that the same system may be used for both types of tasks, the best strategy may be to provide users with GIS that provide both map-based and tabular presentations, although this will not ensure that different presentations are used "correctly." Users might not choose the best format for the task.[1]

## Appendix

### Experimental Tasks

You are an analyst in the planning department of a small fast-food restaurant chain that has decided to open its first restaurant in San Francisco. One of the challenges in the fast-food industry is to locate restaurants near other businesses that will generate high sales. Your task is to select the region in which the restaurant will be built.

The city of San Francisco has been divided into 26 regions, based on zip codes. In selecting the region for the restaurant, you will use demographic data to identify the one region that has the greatest potential to generate sales. You will use data in contained in the Decision Support System. [The data have been substantially altered from the actual values to prevent those of you who are familiar with San Francisco from having an advantage.]

Each region has been assigned a value (ranging from 0 to 100) on each of 14 data sets for various types of businesses, as listed below. A value of 100 indicates a very high concentration of businesses of this type, while a value of 0 indicates a very low concentration. The ideal would be to have the highest possible concentration of all types of business in the region.

Market research has shown that the presence of some businesses is more important than others in generating sales. Therefore, in the list below, each category has been assigned a weight—the higher this weight, the more important this category of business is in generating sales. For example, retail sales businesses generate 10 times more sales than real estate businesses, and twice as much as hospitality businesses.

Note: The following paragraph was present in the interdependent task, but not in the independent task. The businesses in each region also generate a small amount of sales (15%) in each adjacent region. No region is independent. For example, if two regions (call them 1 and 2) are adjacent, then to calculate the sales revenue for region 1, you must first calculate the revenue from all the businesses in region 1, and add 15% of the revenue from businesses in region 2.

In summary, you are to select one region that will generate the most sales revenue, based on the 14 data sets and their relative importance. As mentioned earlier, cash prizes will be awarded to the persons identifying the region with the greatest sales revenue. If more than one person identifies the region with the greatest sales revenue, prizes will be awarded based on the time taken to make the decision—the person(s) making the decision first wins.

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| Weight | Name | Categories Included |
|---|---|---|
| 10 | Retail Sales | Index of Retail Sales |
| 10 | Schools | Index of High Schools |
| 10 | Retail Services | Index of Retail Services |
| 5 | Hospital | Index of Hospitality |
| 2 | Man Process | Index of Manufacturing—Process |
| 2 | Man Discrete | Index of Manufacturing—Discrete |
| 2 | Wholesale Dur | Index of Wholesale Trade—Durables |
| 2 | Wholesale Nondurable | Index of Wholesale Trade—NonDurables |
| 1 | Utilities | Index of Trans, Comm, and Other Utilities |
| 1 | Real Estate | Index of Real Estate |
| 1 | Banking | Index of Finance, and Insurance |
| 1 | BUS SIC 70-89 | Index of Business Services |
| 1 | Public | Index of Public Administration |
| 1 | BUS N.E.C. | Index of Businesses Not Elsewhere Classified |

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