Planning Support System interface: the study of an effective plan-making tool

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City is a complex entity. Trying to understand and anticipate change for the development of a city, experts around the world are in the process of developing mathematical models that take advantages of widely available city statistic, geographic information, and rapid development of computational technology. However, the real benefit of these models to the development of a city is still in question. Those data, modelling knowledge, and analytical tools are needed to be made understandable and thus usable by citizen as well as planning experts and policy makers. The model's visualization interface that is easy to use could help citizen tap into the experts thought and at the same time could help the experts access input from the citizen. The author study has focused on how to make this visualization interface effective. Using LEAM as a base model, the study attempts to derive principles from studying the incremental evolution of its interface design. The interface evolved through various prototypical versions in response to changes in information to be visualized, as well as in response to changing ideas of how the interface is to be used, and to informal assessments from different users in the US and later in Thailand. Descriptions of the different versions recount the evolution of interface in response to various concerns, and the extent to which changes were successful or not. From these data, I extract some general principles about what makes visualization interfaces effective.

Introduction

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A Planning Support System (PSS) is designed to provide urban planners, policy makers, and citizens with the data, knowledge, and tools for analysis needed for effective planning. Klosterman (2001) defines PSS as an 'information infrastructure' for planning that facilitates interaction among planners, and between planners and other actors. This infrastructure is comprised of three primary components: a database, a model base, and a user interface. Together, these components integrate and process relevant data from a wide variety of sources, and what emerges is communicated to users in an easily understandable form (Klosterman, 2001).

Brail and Klosterman, in their book *Planning Support Systems* (2001), point out that “while it is unclear whether PSS measurably supports planning in the political arena in definable ways, it is certainly true that the visualization components of PSS aid in communicating broadly.” This statement stresses the importance of effective visualization of PSS interfaces in communicating a plan or design to its stakeholders or participants. Despite its realized importance, there has been very little discussion of issues involved in putting together effective visualization interfaces.

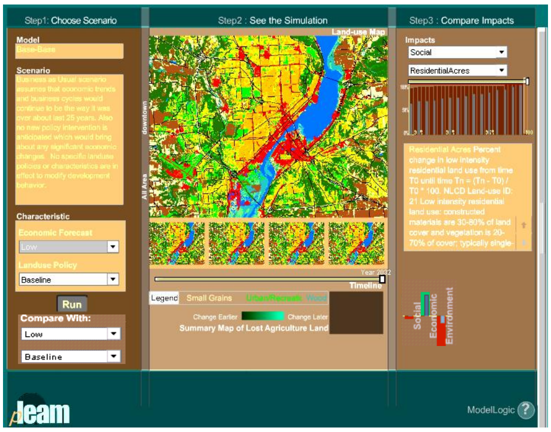

Fig. 1 - LEAM prototype.

Visualization in urban design and planning

Visualization components are being used in planning and design professions. Map drawing, chart, plan, elevation, section, and perspective are all common components that help linking what we see and what we don't. Urban planners, designers and architects can benefit by visualizing their physical design ideas within a broader context. However, as a result of the rapid evolution of the technologies, visualization potential in urban design and planning has expanded to more than just creating attractive maps, charts and realistic images of what is or what the creators plan or design it to be.

Scientific visualization is an example use of visualization components to help user "seeing the unseen" (Langendorf, 2001). For planners and designers the resource includes mathematical modeling and simulation, computer aided design (CAD), mapping and geographic information systems (GIS) which link plan or design with external data and information abundantly available from our fast-growing information-generating industry (e.g. satellite images, and Census data). This provides a vast, largely untapped, resource for planners and designers to enrich the understanding of the place and the processes of change, and to offer images of alternative futures that can capture the imagination, alter taste, shape public opinion, and mobilize support. Exploratory data analysis-the use of graphic images that could provide rapid statistical insight into the data are usually included in this kind of visualization.

Effective visualization of PSS interfaces, borrow from scientific visualization idea in helping user understand information and thus make better decision, is the focus of the study and development in this paper as an example of a more effective use of visualization in urban planning and design.

Visualization in Planning Support Systems

In reviewing existing literature concerning visualization in Planning Support Systems (PSS) and computer interface development, the author starts with current knowledge about the cognitive quality of graphic components and their potential usefulness in helping viewers evaluate data efficiently. The Internet and other electronic media have made vast amounts of data readily available to the community. These data can be useful for making better planning decisions and engaging the public in the planning process. However, sorting and sifting through these enormous data sets is difficult. Several authors in different fields of expertise have studied the suitability of visualization components for different tasks. A few authors also examine the spatial relationships among visualization components and principles governing their integration for the purpose of enhancing the understanding of information. Studies of interaction between viewers and the graphical interface that contribute to the effectiveness of visualizing information are also reviewed (Budthimedhee, 2003).

Graphical efficacy is a function of interactions between subject and visual display. The author's literature reviewed has found elements of visual tools and techniques which, if applied in a PSS interface, are deemed to help users make sense of vast amounts of information available to planning participants. A significant addition to the literature would be the identification of what it takes to successfully put together individual visualization components, software tools and technologies, as well as difficulties encountered in doing so.

To date no published studies have focused exclusively on the topic of effective PSS interface development. An effective interface can promote better communication among professional planners and other participants in the planning process. It can help to shape the attention of participants so that the critical policies, impacts or alternatives, and their interconnection are more readily understood. An effective visualization interface will address the limitations of human working memory and help planning participants focus on the task of making decisions about complex problems that normally exceed human cognitive capacity (Hopkins, 2001).

The Study

In consideration of the preceding observations, therefore, the objective of this work is to identify and present principles for the design of effective visualization interfaces. Based on study of the literature and existing interfaces, the key topics relevant to building a PSS interface are (1) effective layout and graphic representations for displaying complex information, (2) selection and implementation of the technology, and (3) the practical usability of the interface. The examples and guidelines created in this study should be applicable to a wide variety of PSS visualization interfaces.

Underlying this research is the proposition that principles of effective visualization interfaces can be derived in the process of developing a PSS visualization interface. This goal has been accomplished through the progressive development of nine LEAM (Land-use Evolution and impact Assessment Model) interface prototypes, developed at the University of Illinois Urbana-Champaign campus (documented in Budthimedhee, 2003). The interface evolved through various prototypical versions in response to changes in information to be visualized, as well as in response to changing ideas of how the interface is to be used, and to informal assessments from different users. From these prototypes development data, I extract some general principles about what makes visualization interfaces effective. This study provides a useful design and development procedure for building an interface for a small- to medium-scale (township to county) scenario-based dynamic model environment.

Key Principles

Inferences drawn from studying the evolution of the LEAM visualization interface are organized for this paper under two main common topics of interest in building a PSS interface. The first concerns the selection of graphical components; the second concerns unifying the components in an effective layout. Guidelines and examples are presented relating to these topics, which can be applied to a wide variety of PSS interface developments.

Graphical Components

Most applications of graphics in representing planning information involve spatial comparisons across multiple attributes or multiple time steps. For example, to present why a new highway location was chosen, a map of each alternative location and its effect on traffic flow and/or other impacts in the region could be displayed. This display involves spatial comparison among alternative locations of the new highway and the spatial comparison among their impacts on the neighborhood or the region. In some cases, the presentation may include an estimation of the city investment and profit returned to the community over a period of time. This display involves a multiple-time-step representation of the city resources needed to build the highway and the profit or loss projected after the highway has been built (which can fluctuate over time). Spatial or multiple-time-step displays similar to these examples are likely to be included in any planning document.

A goal for graphic representations in the planning context is to enhance the likelihood that a decision-maker will see not only featured information, but also the relationships among features. The first can be termed *univariate* information, the latter can be termed *multivariate* comparison. Using an example of the new highway plan above, univariate information includes location of a proposed new highway, impacts associated with building the highway in that location, or monetary profit or loss in building the highway. Multivariate information, however, involves a bigger picture — relationships or comparisons among local information, such as the display and comparison of several alternative highway locations and their various impacts.

Considering these two modes of planning representation, the criteria for graphical representation of planning information I found to be effective are presented and discussed below.

To identify specific graphic representations that can be used effectively for PSS, two main factors must be considered: information types (spatial versus non-spatial and temporal versus non-temporal) and communication goals (convey univariate versus multivariate information). The following table illustrates examples of these categories as applied in the LEAM PSS.

Tab. 1- Examples of information to be displayed in each matrix.

Information Types		*Communication Goals*	
		Univariate (One variable, Exact information)	*Multivariate (Different variables, Relationship comparison) within scenario, between scenarios*
Non-spatial	*Static (One time)*	Gauging (measuring) an environmental impact of a scenario	Gauging (measuring) an environmental impact of several scenarios
	Dynamic (Different time)	An impact (such as electrical usage) results from a policy scenario from year 2000 to 2020	An impact results from several different scenarios from year 2000 to 2020
Spatial	*Static (W/o time)*	A spatial display of policy boundary, such as Agricultural preservation land	An existing land-use map where the user needs to see proportion of each land-use within the map
	Dynamic (W/ time)	Land-use changes resulting from a policy scenario from year 2000 to 2020	Land-use changes resulting from two different policy scenarios from year 2000 to 2020

Table 2 presents these principles in the form of a matrix that shows the preferred graphic representations for planning information depending on whether the information is spatial/non-spatial, static/dynamic, and local/global, including all permutations of these three parameters.

Tab. 2- Summary of the criteria in tabular format.

Graphic representation	*Univariate (One variable, Exact information)*	*Multivariate (Different variables, Relationship comparison) within scenario, between scenarios*

Non-spatial	*Static (One time)*	-Separated bar or icon [or Table chart] -1attribute used: shape or color	-Description (summarizing data)	-Grouped bar or icons/pies -2attributes: shape and texture/color (Add dimension = see more relationship)	-Comparison -Alternatives -Options -Relations (Comparing Points and Patterns) (summarizing data)
	Dynamic (Different time)	-Line or Bars -2attributes: shape and spatial pattern/location	-Trends (showing trends over time)	-Grouped bars -3attributes: shape, texture/color, and spatial pattern	-Comparison -Alternatives -Options -Relations (Comparing Points and Patterns) (showing trends over time)
Spatial	*Static (W/o time)*	-One-variable map or One object image -2attributes: shape and location	-Description (summarizing data)	-Map using different texture or color for different variables -3attributes: shape, texture/color, and location	-Comparison -Alternatives -Options -Relations (Comparing Points and Patterns) (summarizing data)
	Dynamic (W/ time)	-Summary map, animated map or multiple maps -3attributes: shape, location, and color/pattern	-Aggregation (summarizing data) (showing trends over time)	-Multiple maps or Summary maps -3attributes: shape, color/pattern and location	-Comparison -Alternatives -Options -Relations (Comparing Points and Patterns) (showing trends over time)

This analysis confirms that different graphical representations facilitate different kinds of inferences from the data represented, with a few general assumptions emerging. In general, bar-type graphs are preferred for locating specific information and making simple static comparisons. In contrast, line-type graphs tended to yield better results when used for more dynamic comparisons and with temporal information. PSS efficiency appears to depend on consistency in graphics and symbol used. By using the least graphical variety necessary to provide accurate representations, the efficiency of using the interface appeared to improve. If interface efficiency is one of the objectives, then the overall best non-spatial graphic representation is the modified grouped bar chart.

Effective Layout

PSS may be an alternative to paper documents, which have a limited capacity to promote a user's understanding of city growth. In fact, current planning documents (in both paper and electronic form) may obscure rather than illuminate the connections between factors affecting city growth. Connective elements essential for understanding the nature of planning are forfeited due to limitations of the medium used to document the data and conventional approaches to organizing the summary documents.

Based on the experience of developing LEAM prototypes, two main factors appear to affect PSS interface integration effectiveness. Therefore, these factors can serve as guidelines for better design, as discussed below. The factors are:

1. Taking advantage of non-linear media
2. Applying a layout structure that enhances:
    a. linkage between plan(action) and its consequences
    b. comparison among alternativesLeave two blank lines before the title of a section and one blank line after it. This is a standard paragraph.

Taking advantage of non-linear media

Using non-linear media makes it possible to effectively display interconnection elements between a plan and its consequences. A paper document tends to be organized in a way that separates planning issues. For example, the Peoria-Pekin Future Landscape Project (2002) consists of six chapters: Economy, Population, Housing, Education, Transportation, Natural resources. Because it is in the paper format, this kind of document is linear in structure, and consequently interrelationships and connections are difficult to construct.

Various electronic media are non-linear and, as such, have great potential, but so far these have had only limited application in planning processes. The Internet and other communications technologies offer many opportunities for wider access to electronic information, and they facilitate the use of computer-generated output for documenting and distributing planning projects. Computer-generated systems capable of dynamic display of information can be an important tool for public participation, both as a source of crucial information and for communication among interest groups. As an example of such a system, a PSS is a highly promising way to present the dynamics of planning information. In contrast to the textual structure of a paper document, a typical PSS separates the information by type of graphic representation (i.e., map, graph, and text). Even though the structure is non-linear in nature, the interrelationships and connections essential to understanding the planning issues are not explicitly displayed.

Applying a layout structure that enhances linkage between plan and its consequences and comparison among alternatives

When non-linear media are used in planning, the layout structure must explicitly display the interconnections between the drivers and the impacts of the plan. As the LEAM Interface evolved, the connections between drivers of city growth and its impacts were increasingly made more explicit using spatial relationship principles for information graphics (Wickens, 1992-95; Tufte, 1989-97; Cleveland, 1984-88) to promote user understanding of planning documents.

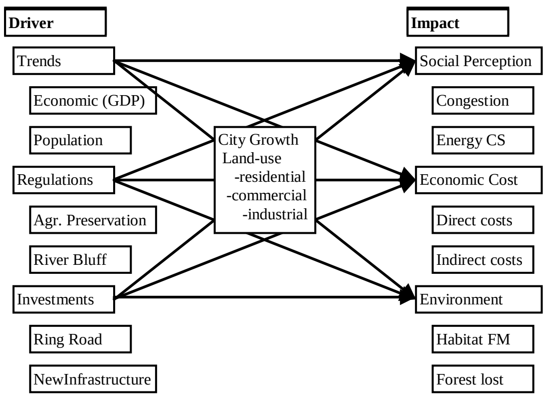

Fig. 2- Non-linear structure of LEAM PSS interface.

This particular PSS structure was well received in LEAM. Difficulty is encountered, though, in medium- to large-scale PSS that often have too many drivers and/or impacts to display all at once. The challenge is to present a complete relationship structure without overwhelming the user. In the most recent LEAM interface, users choose the specific impact they want to see. If users groups can be defined based on similar preferences, an alternative design would be to set display defaults so the impacts each group is likely to be interested in are displayed first. Both of these approaches have proven effective depending on the information available and the user's needs.

a. Displaying interrelationships between plan and its consequences

A PSS is more effective at communicating a plan and its consequences when its layout is non-linear and the interrelationship between various drivers of a plan and its consequences are explicitly displayed. To understand a plan and its impacts, the driver-to-impact logic discussed above has proved useful and consistent with Wickens' Proximity Principle and Tufte's data density of information concept. The driver (policy causes) and impact (effects) information are most effective when displayed together. This approach made interconnections easy to construct. In addition to this driver-impact context proximity in LEAM interface development, users report better understanding of issues and prefer information displayed in both non-spatial and spatial form. For example, displaying a map of the area to which a policy applies along with a description of that policy is more effective than displaying either the map or the description by itself. Integration of these two practical information sources within the LEAM interface supports Tufte's principle of using a high density of data within a single display. Figure 3 is an example layout from one prototype; the bracket shows where the structure (plan-land use change-and its impacts) applied.

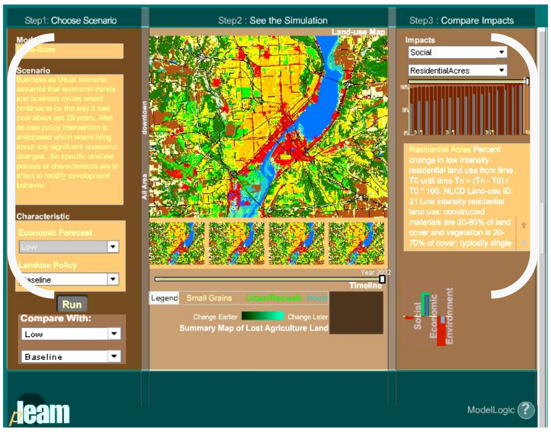

Fig. 3- Proximity of Drivers and Impacts.

b. Displaying comparison among alternatives

A PSS layout will be more effective in helping users to compare alternatives if the two alternatives are displayed close to each other in an aligned scale, as opposed to displaying them separately. For effective scenario comparison in a PSS, graphical representations must help the eye to compare visual information. To compare impacts from different scenarios, the *proximity principle* (Wickens, 1992) as well as *elementary perceptual task and align scale* (Cleveland, 1988) were found to be practical in LEAM development. Spatial arrangement according to these principles encourages the viewer to compare different pieces of data (see Figure 4). With the alternatives displayed next to each other, the PSS encouraged more discussion about the alternatives in colleague meetings than when they were displayed separately or when only the alternative impacts were displayed together. This result suggests that a PSS layout can encourage users to compare alternatives.

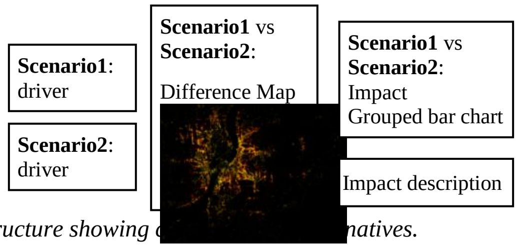

Fig. 4- Layout structure showing [illegible]natives.

Conclusion

A number of lessons drawn from the leam experience in scenario-based interfaces described here are applicable even if scenarios are not involved — in particular the development and use of visualization components. Applying principles relating to spatial relationships among components in a pss interface will help direct interest, promote better information transfer about planning and issues, and engage participants in the planning and design process. If the use of such interfaces is to be encouraged, the tradeoffs related to ease of use, functionality, and sustaining user interest must be carefully considered.

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