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

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ABSTRACT: *City is a complex entity. It is believed to compose of physical systems and social processes that are both common in all the world cities and specific in each city. 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. The model is expected to simulate most of the physical system of the city; the components that are common in all big cities around the world. As these sophisticated models development gather momentum, however, the real benefit of it to the development of a local city is still in question. Dealing with the social processes; the components that are specific in each city studied, those data, modeling knowledge, and analytical tools are needed to be made understandable and thus usable by local 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 the local input from the citizen. The author study has focused on how to make this visualization interface effective.*

KEY WORDS: *Planning Support System Interface, Visualization components, Participatory Planning and Design.*

1. Introduction

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.

2. 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.

3. 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.

Studies of these processes and responses will provide new continuity to the literature on PSS interface implementation and will contribute to a better balance among the three main areas of PSS development (i.e., data, model, and interface).

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).

Effective communication promotes the development of a better, more satisfying plan because it helps participants make decisions that will lead to future developments that are desirable to the participants who share a common future. An important task of planning research is to support communication that can help all stakeholders to reach agreement on their high-priority interests and effectively examine policy alternatives that can serve those interests. Several scholars (e.g., Forester, 1994; Innes, 1999) have explored face-to-face communication processes and how planners can help all parties accomplish successful planning. Ellis (1998), Shiffer (1992), and Klosterman (2001) have explored the similar topics, but with add-in technology or "face-to-machine" communication. This type of communication has the important benefit of reducing the barriers posed by distance and time limitations for public participation. It can facilitate both the real-time face-to-face discussions at public meetings as well as long-distance or 'asynchronous' meetings.

One of the important questions in planning communication is how to present information that is unfamiliar to most interested parties in a familiar and easily understood form so all participants are able to identify their common interests and work toward the most desirable policy alternative. Because people tend to focus on a representation of an issue rather than the issue itself (Kahneman, Slovic, and Tversky, 1982), a good representation can help to establish focus and thus improve communication. If complex planning information can be made available to the public in forms that are more readily understood, planners would be in a better communicative situation (Habermas, 1979), which is desirable for helping citizens reach agreement on a common public interest. Availability and transparency of information can conserve public resources and make the decision-making process easier and more satisfying for the community.

Effective use of information graphics and layout will ultimately enhance PSS development and promote public interaction by enabling interest groups to experiment with different variables and planning policies that affect the growth of their community. Through an intuitive interface, individuals can employ a combination of environmental, economic, and social controls to develop a more democratic and well informed plan for their community than may otherwise be feasible. The process of using such a system could help various interest groups develop a shared understanding about change and steps that may be taken to achieve goals that are satisfactory to all constituencies.

4. 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. 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. 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.

5. Key Principles

Inferences drawn from studying the evolution of the LEAM visualization interface are organized under three 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; the third concerns general design practice related to directing and engaging user attention. Guidelines and examples are presented relating to these topics, which can be applied to a wide variety of PSS interface developments. Discussion is also provided regarding how the prototype experiences support or refute the various information visualization literature (see detail in Budthimedhee, 2003).

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.

Table 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.

Table 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:

    2.1 linkage between plan(action) and its consequences
    2.2 comparison among alternatives

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 (see chart 1). Because it is in the paper format, this kind of document is linear in structure, and consequently interrelationships and connections are difficult to construct.

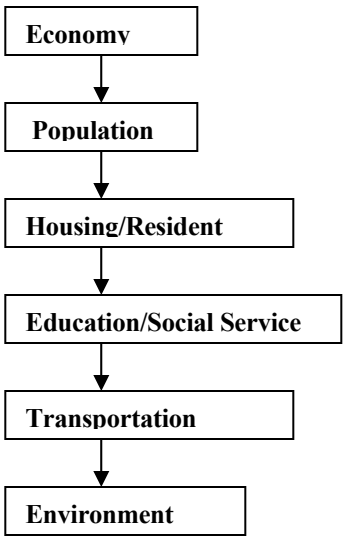

Chart 1*: Linear structure of paper document.*

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). Chart 2 illustrates context organization as found in a typical PSS such as What If and Envision/Quest. Even though the structure is non-linear in nature, the interrelationships and connections essential to understanding the planning issues are not explicitly displayed.

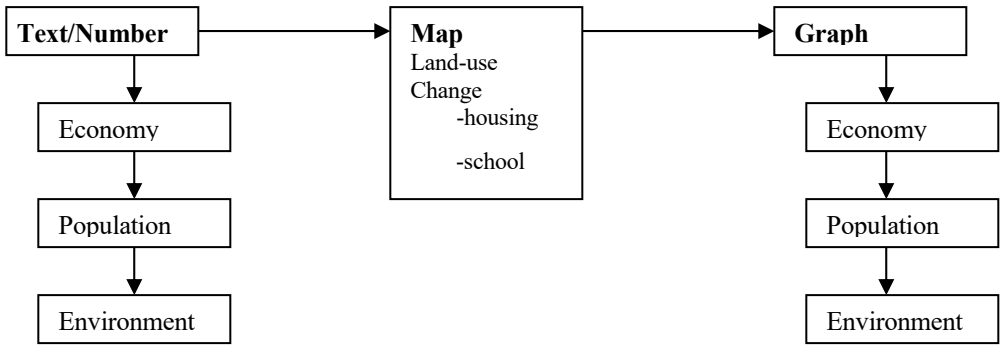

Chart 2*: Non-linear structure of commonly seen electronic document or PSS.*

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.

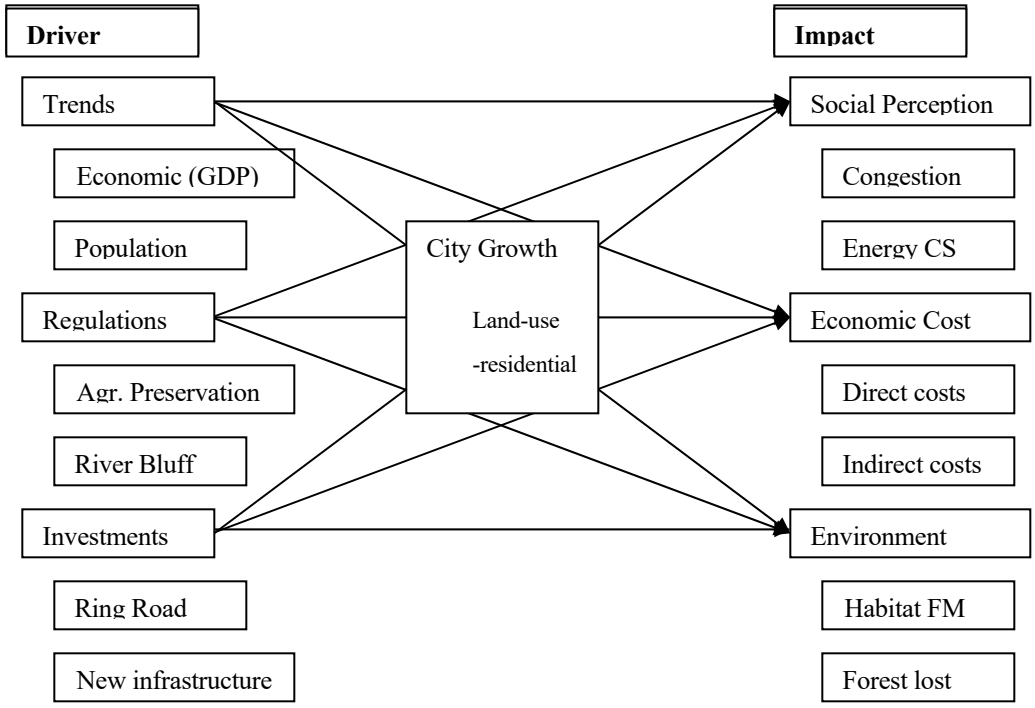

Chart 3*: Non-linear structure of LEAM PSS interface.*

This particular PSS structure was well received in LEAM prototypes 4 and beyond, as compared with the more linear structure in prototypes 2 and 3. 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.

More specifically, as a scenario-based and policy-oriented PSS interface, LEAM inputs different scenarios corresponding to shocks in supply and demand subject to policy constraints. Users can explore alternative policies and visualize how the changes might

affect their environment. A good interface must effectively inform the audience about plans and their impacts. The interface must also help the user to assess alternative plans or policies by comparing impacts resulting from each policy.

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. More favorable user comments were received for prototype 4, in which Macromedia Flash software technology has been used to build a non-linear layout, than for prototypes 1, 2, and 3, in which a linear structure was used due to the limited capability of HTML techniques available at the time. 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 1 is an example layout from prototype 9; the bracket shows where the structure (plan-land use change-and its impacts) applied.

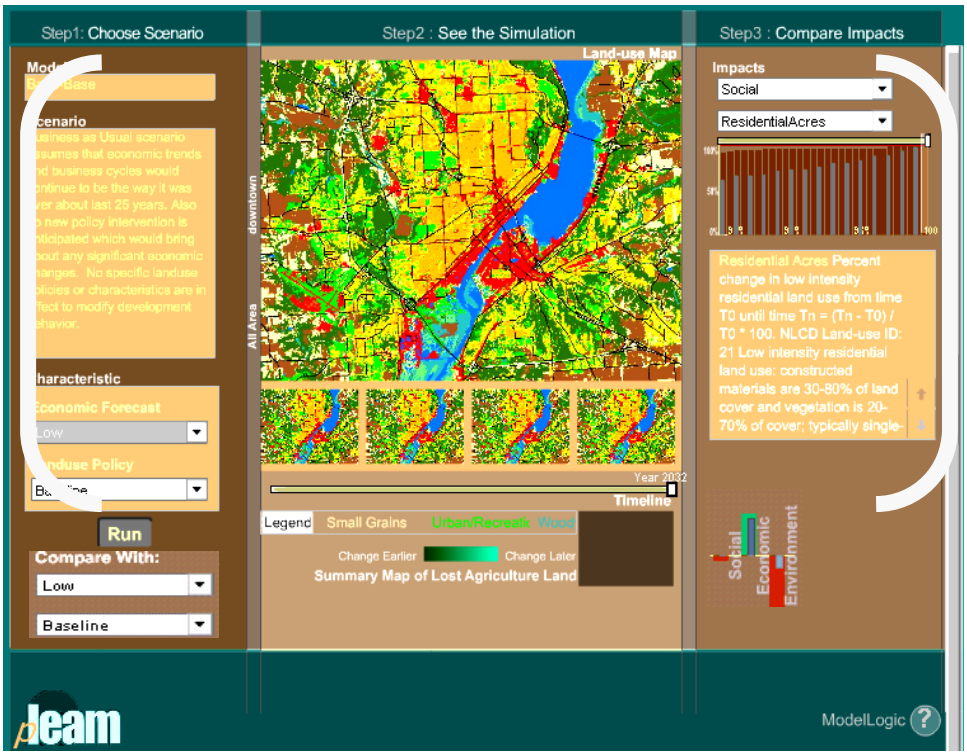

Figure 1*: Proximity of Drivers and Impacts.*

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 chart 4). With the alternatives displayed next to each other (prototype 9, see Figure 2-3), 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 (prototypes 6, 7 and 8). This result suggests that a PSS layout can encourage users to compare alternatives.

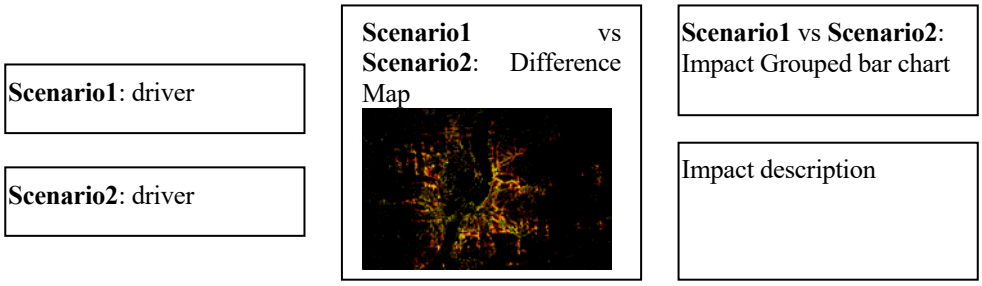

Chart 4*: Layout structure showing comparison of alternatives.*

Figure 1*: Proximity of policies comparison, brackets showing where information to be compared was displayed in proximity of each other.*

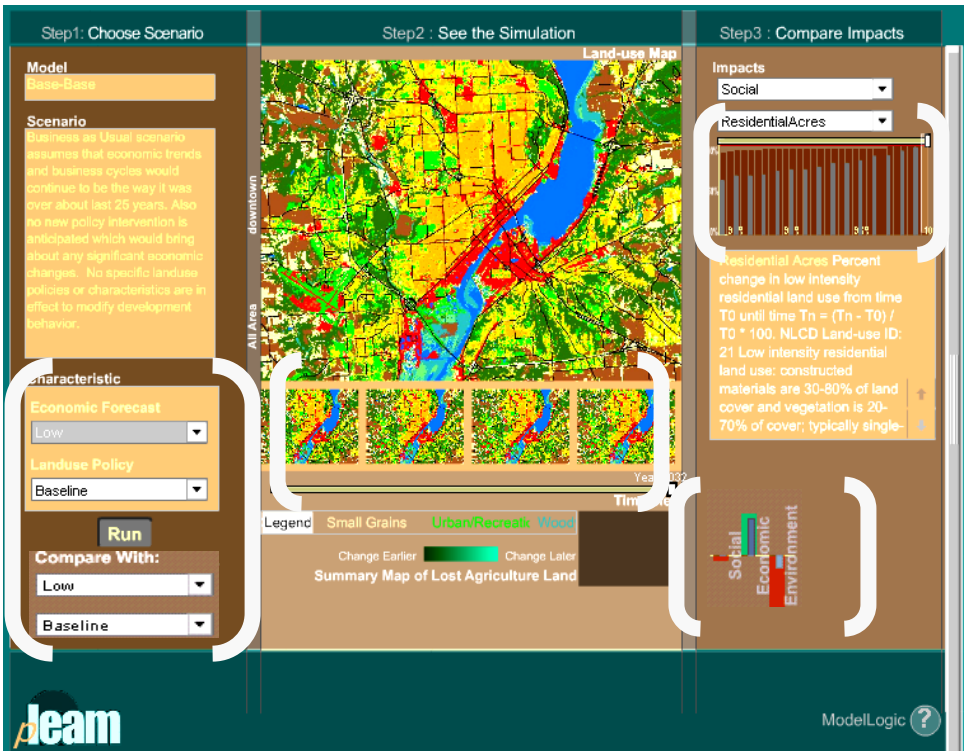

Figure 2*: Aligned scale comparison, brackets showing where the information to be compared was aligned and displayed in the same scale.*

General Design Practice

As with most of the system interfaces targeting large and varied user groups, there are trade-offs to consider when building an effective PSS interface. For novice users, the trade-offs often involve issues of motivation and sustained engagement versus issues of functional flexibility, the latter of which are important to experienced users. Five specific characteristics were found to be important to maintain user interest and to facilitate interaction among the users.

1. Personal Experience and Familiarity

LEAM users showed the need to have elements that resonate with their own experience and familiarity. These elements include conventional interface tools and graphics (e.g.,

labeled buttons instead of complex syntax), non-technical language use and familiar scale or context (e.g., local-level information was considered more interesting than regional or global-scale data). Examples can be seen from prototypes 1 and 2, in which users had to type in a range of factors in order to run the model. While this method was easy to use for the expert users such as planners, it was confusing for novice users. From prototype 3 on, the same function was designed to use more familiar interface features such as buttons and scrollbars. This change was noted as an improvement by all user groups. Another example of this can be seen in prototype 7, in which the interface displayed only the entire model coverage (three counties); the user was overwhelmed and distracted from important changes. With prototype 8, in which the user can refine the interface to display information at the township level, users expressed more satisfaction and interest. Conventional interface tools and graphics help to satisfy the user's need for convenient channels of communication so that they can concentrate on the information content. The findings about the importance of local information needs were consistent with the results of Guimares-Pereira's study of information and communication technology (Guimares-Pereira et al., 1999). In that study, the author suggests that if familiar elements are properly incorporated into a system, they will "help (the users) to get closer to the problematic (issue and) that users can transpose (the issue concerned) to their own, implying a necessary personal and regional geographical dimension" (Guimares-Pereira et al., 1999).

2. Innovative Surprise

In contrast to the emphasis on user familiarity, it was also established that an element of surprise and novelty maintains interest. Examples where users reported surprise and satisfaction include prototype 7, in which a noise map was introduced; and prototype 9, in which the regional map responds to mouse rollovers by showing a clickable path to the detailed maps. Such interactive exchange between the user and the interface has a playful aspect that users reported to be an incentive for further exploration of the system.

3. Interface Complexity

The average user prefers the interface to be flexible and capable of visualizing all aspects of planning information. First-time users often display hesitation when they see a complex interface, but expert or repeat users appreciate more sophisticated functions and detailed information. To encourage widest use of the system, then, the interface needs to be set up so it appears simple to the novice while being powerful enough for experts to benefit from. The interface developer must balance the need to keep users adequately informed against the disadvantages of overwhelming them. It is certainly possible to

decide which information or choices show by default to different types of users based on the nature of the activity, the user's level of interest, and his or her role in the process. This may reduce the confusion that some users experience when using the system, but it also introduces for system developers the complex task of categorizing users into types.

4. Clarity and Transparency

LEAM interface testers often displayed the need to be in control when interacting with the PSS. Knowing how many steps are in the process they will be undertaking and where they are in the process lends users a sense of control and clarity. This type of feedback to users can be achieved by providing indications such as color-coded icons, process symbols, or a list of steps in a given PSS process. Another user concern is the mechanism behind the interface — how the model works and what the system does with user input such as registration information, notes, records, etc. The developer should provide an explanatory document that is easily accessible at the interface. A clickable Help button or pop-up 'tool tips' can be used for this purpose.

5. Easy-to-Follow Path (during and after the interaction)

It is important to provide means for continued exploration of the planning activity or issue of concern. The path should be clearly marked and recorded during the use of the system. The interface must make visible the object of interest and its impact. Showing a path — the choices that lead to associated results — helps users to easily follow up on an activity or change. Recording the exploration path for future reference will also help to remind users of their concerns and decisions that have been made or considered.

Based on the findings of this study, each of these five factors must be taken into consideration when attempting to build a user-friendly interface. In the practical matter of building an effective PSS, some of these factors may demand more priority than others. The chief consideration, however, must be to make a continuous effort to facilitate system use for novice users while maintaining its power and flexibility to attract advanced users.

6. Future research and education plan

The findings reported in this work has not only addressed a gap in the literature related to the qualities of effective PSS visualization interfaces, but also informed urban planning and design education to realize that there is potential knowledge building in the field which requires a different approach and broader set of skills than is traditional in planning and design document production. There are several ways in which to build on the research reported here and that urban educators as well as professions must be encouraged to do so

to advance the use of visualization in planning and design. As more planning and design become more participatory and the quantity and accessibility of information rapidly increases, the role of planners and designers may shift toward their becoming creators of information environment that empower themselves and other participants. To prepare for that role, one possibility is knowledge building in and is to use the principles developed here as points of departure for developing visualization interfaces for other types of PSS models, data, and application contexts, and to thereby further test and refine these principles. At the same time, as also discussed earlier, there are a number of ideas and interface components that were implemented and tested in the evolution of the LEAM interfaces but dropped out of consideration not because they were ineffective, but because they did not fit the current state of the LEAM model, data, and the interface technology used. This set of ideas and interface components represents fertile ground for further research; as they become relevant to a particular PSS they can be integrated into its visualization interface and refined. One example, recording and analyzing public reactions (see Budthimedhee, 2003) but there are several others.

From building and evaluating prototype interfaces, I have become more confident that digital media facilitates documentation and distribution of planning and design information for use by the general public more effectively than paper documents. The dynamic nature of digital media provides novel and highly effective ways to organize and explore complex information. 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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