Beirut Arab University (BAU), Faculty of Architectural Engineering.

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The Use of Geographic Information System (GIS) Based Spatial Decision Support System (SDSS) in Developing the Urban Planning Process

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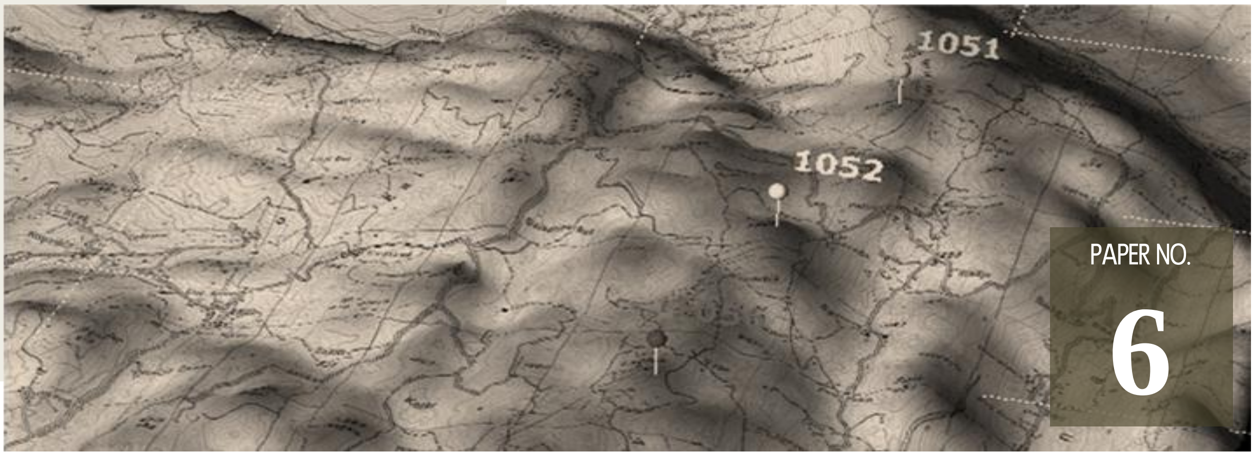

Advanced 3D graphics for Geographic Information System (GIS)
www.sciencegl.com/gis_dem/index.html

ABSTRACTS

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Keywords: Geographic Information System (GIS), Spatial Decision Support System (SDSS), Planning process

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إستخدام نظام دعم إتخاذ القرار الفراغي المبني علي نظم المعلومات الجغرافية في تطوير عمليات التخطيط الحضري

م/ ريما خير سلطاني – أ.د/ أحمد منير سليمان – د/ خالد السيد محمد الحجلة

كلية الهندسة المعمارية – جامعة بيروت العربية – بيروت – لبنان

الملخص

يشهد إستخدام نظم المعلومات المبنية علي برامج الحاسب الآلي تزايداً مضطرداً في مجال التخطيط وذلك بالتزامن مع زيادة تقنيات هذا المجال. وضمن هذه الحقبة من البرامج يحتل برنامج نظم المعلومات الجغرافيه 'Geographic Information System (GIS)' مكاناً متميزاً بإعتباره الأكثر شيوعا ضمن الأدوات التكنولوجية المساعدة المستخدمة من قبل المخططين وصانعي القرار وجميع الجهات المعنية بالتخطيط وذلك لما له من إمكانات تؤهله للعمل كأداةٍ مساعدةٍ لإتخاذ القرارات التخطيطية.

يهدف البحث الي دراسة مدي إمكانية إستخدام نظم المعلومات الجغرافية لتطوير أداء النموذج النمطي لعمليات إتخاذ القرار، وذلك بما يتيح لهذه العمليات أداء أفضل ضمن النطاق الأكبر للمراحل المختلفة لعمليات التخطيط. ومع ما تشهده عمليات التخطيط من تناول مدي واسع من المعارف ومصادر المعلومات فقد تطلب هذا بناء نماذج إفتراضية لمحاكاة كلاً من التفاعلات بين مختلف الأطراف المعنية بالتخطيط من جهة وصناع القرار من جهة أخري وكذلك لرصد التغيرات الحادثة في نقطة محددة من الزمن أو عبر فترات زمنية ممتدة.

يدرس البحث الإحتياج الي منهجية تقنية مناسبة لإستخدامها في مجالي التخطيط الحضري والإقليمي بما يمكّنها من الإستفادة مما تتيحه تكنولوجيا المعلومات من طرق ومفاهيم جديدة للأداء التقني وبما يحسن من مستويات العملية التخطيطية ويسرع بعمليات إتخاذ القرار السليم ضمن مدي واسع من مدخلات

المعلومات. يقوم البحث تحديدا لتحقيق هذا الهدف بدراسة ثلاث مناطق مشتركة بين تكنولوجيا المعلومات وبين التخطيط الحضري: الأولي هي أنظمة الكمبيوتر المستخدمة في التخطيط الحضري، الثانية هي طرق تحويل المعلومات المستخدمة في التخطيط الحضري إلي نماذج معدة مسبقاً بواسطة تقنيات أنظمة المعلومات الجغرافية والثالثة هي النماذج ذاتها علي إعتبارها المكون الأساسي لأنظمة دعم إتخاذ القرار الفراغي. يقوم البحث في جزئه الأخير بإلقاء المزيد من الضوء علي ما اتاحته التقنيات المتقدمة وبخاصة في مجالات نظم المعلومات الجغرافية وبناء نماذج البيانات في تحسين أداء عمليات إتخاذ القرار الفراغي في مجال التخطيط الحضري.

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Abstract

The use of computer-based information systems in the field of planning has been increasingly highlighted with the exploitation of computer technology. Geographic Information Systems (GIS) is the most recognized tool of those Assisting Technological Tolls (ATT), and is well known to the planners, decision makers and other actors of planning episodes as a Decision Support System tool (DSS).

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Keywords: Geographic Information System (GIS), Spatial Decision Support System (SDSS), Planning process

1. Introduction

Decision making is a cognitive process leading to the selection of a course of action among a number of alternatives. Every decision making process produces a final choice. It can be an action or an opinion. It begins when citizens need to do something but they do not know what. Therefore, decision making is a reasoning process which can be rational or irrational, and can be based on explicit or implicit assumptions. Therefore, the decision making process is always associated with every phase of the planning process. However, the process of planning involves many phases and more actors including a process in which activities are defined by conditions in specific areas and by a city's economic development. Decisions made by different actors in different phases all depend on the information available. (Hall, 1996). However, planning, in its broadest sense, is clearly an activity that requires the use of spatial information in undertaking many core planning activities, including land-use plan formulation (Boddy, 1995)

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From other stand point, technology in planning is dictated by what planners do; technology and techniques, models and methods, and computations and controls. GIS allows planners to quickly and efficiently create and test alternative development scenarios and determines their likely impacts on the future environment, i.e., land-use patterns and associated population and employment trends, thus allowing public officials to make informed planning decisions. It uses various techniques for linking policy (aspatial) to plans (spatial) in order to formulate and evaluate spatial planning models. Moreover, a large range of spatial analysis functions – based on the planning data collected and stored within the GIS database- can be performed to create new information layers. These spatial information layers can be presented in the forms of maps (plans), reports, and charts.

2. Computer Systems Used for Urban Planning

The development of a variety of Decision and Planning Support Systems based on computer technology, and the emergence of Geographical Information Systems (GIS) are serving to keep the field actively concerned with the use of information technology. There is very rapid change in that the activity of planning is increasingly pragmatic in its execution (Batty, 1991).The use of GIS as a DSS structure is based on an understanding of both similarities and differences between them. These areas are illustrated in figure 1 as follows:

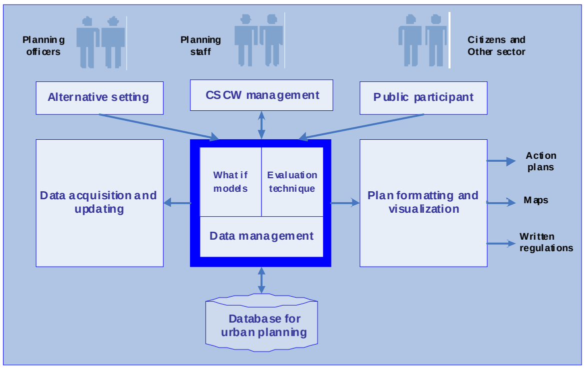

Figure 1: Graph of an architecture of computer system for urban planning (Laurini, 2001: 38).

- The acquisition model is similar to GIS and DSS.
- At output, not only cartographic visualization is present, but also some graphic tools for exhibiting action plans.
- The kernel is similar to that of the DSS, integrating some models to simulate the development of the city together with some evaluation techniques, for instance, to estimate the costs and the efficiencies of some planning alternatives.
- The great difference is the presence of additional modules:

• Alternative setting, which can also be present in a DSS; this module is activated by planning officials.

• Groupware management or more precisely, Computer Supported Co-operating Work (CSCW) in order to organize and schedule the daily work of the planning staff.

• Management of public participation in order to assist citizens in comparing alternatives, giving their opinions, synthesizing them and so on (Laurini, 2001)

Information is the key element in any urban and regional planning process. The data processing systems, i.e., 'Models', offer a vital conceptual framework to understand the role of information systems and offer a developed decision making methodology (Laurini, 2001).

Accordingly, it is important to use different modeling techniques to understand the past or simulate the future; they are especially interested in simulating or forecasting strong trends, and testing assumptions. Different kinds of models could be created (Figure 2):

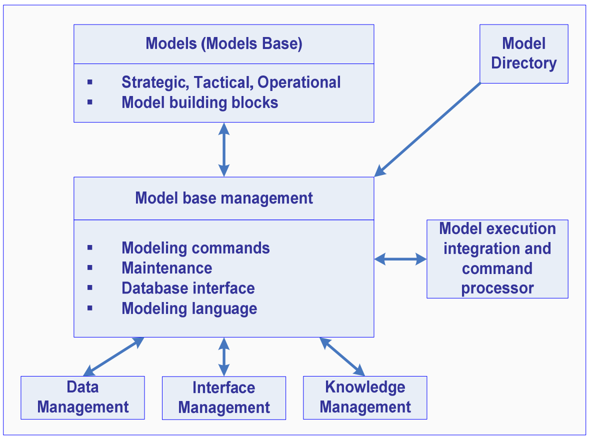

Figure 2: The structure of the model management system (Laurini, 2001:32).

- Strategic models are used to support strategic management planning responsibilities; they should be broad in scope and essentially based on external data.
- Tactical models are used mainly by middle management to assist them in their tasks.
- Operational models for daily management.

Several kinds of connections linking a GIS and an urban modeling package can be envisioned as illustrated in figure 3. Different possibilities can formulate the relationship between the variables; the case is shown in which the GIS is embedded into the urban modeling package or in contrast the modeling package is embedded into the GIS. Another possibility is to have a loose or a tight coupling between the GIS, the modeling package and the statistical package for the technical reason that the preference is for the tight connections (Laurini, 2001).

Based on different types of connections linking GIS and an urban modeling package, a large number of models and modeling techniques have been developed to support decision-makers. Many of these are of interest to potential users of spatial decision support systems. These models are drawn from well-established disciplines such as statistics or management science, and in most cases do not require the use of spatial data. The models in the problem may operate on non-spatial (attribute) data in the SDSS. However the data set to be used for the modeling process may be identified by spatial operations (Keenan, 2004).

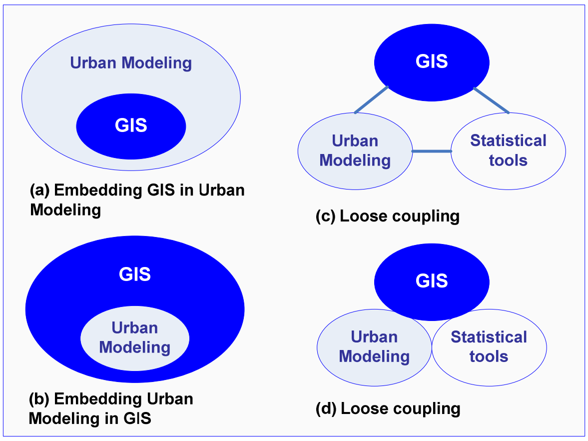

Figure 3: Modeling in GIS (Laurini, 2001. p: 33). This figure illustrates the GIS integration with an urban modeling package, i.e., current practices. (a) Embedding a GIS in the modeling package. (b) The reserve. (c) Loose coupling. (d) Tight coupling (Laurini, 2001).

However; planning support systems include the integration of geographic information with other technologies (e.g. multimedia, models, simulations, and expert systems). Current developments of customized geographic information and other tools only partially respond to analytical, design, administrative, communicative, and the decision-making support needed. The integration of those modules into a functional planning support system and their customization to various planning institutions is yet to be achieved (Nedović-Budić, 2000).

The classic tasks of GIS are the analysis and alphanumeric/graphic presentation of spatial data. However, the functionality of a conventional GIS can be significantly enhanced by the addition of several new data types. Nedović-Budić (2000), classifies three different groups of data based on data source and format:

- Alphanumeric data;
- Vector and raster GIS data; and
- Sound, image and video data.

The more advanced "multimedia GIS" is focused on using vector and raster data. That data core is supplemented by alphanumeric, sound, image and video data. However, three main subsequent stages could be identified; data input, data analysis, and data output and presentation.

■ Data Input

At the beginning of the planning process, the availability of digital data should be determined. Spatial data can be digitized in various ways; Alphanumeric data can be recorded using text processing or database software. Vector and raster GIS data can be digitized from orthophotos, maps or sketches (Figure 4). New methodologies have been created to digitize site data directly in the field using portable pen computers and geo-referenced background information such as digital maps or orthophotos (Figure 5). Sound, photos and videos can be recorded in the field by means of digital or analogue devices such as standard video recorders and 35mm cameras.

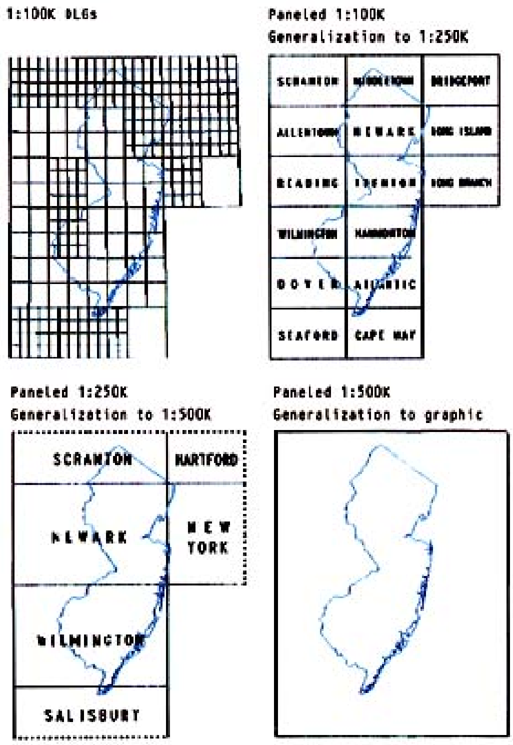

Figure 4: Vector and raster GIS data
(http://erg.usgs.gov/isb/pubs/gis_poster/)

Figure 5: Portable pen computers
(http://erg.usgs.gov/isb/pubs/gis_poster/)

The spatial accuracy of digitized polygons, points and lines is one of the most important issues in GIS. Accuracy depends primarily on the quality of the available, basic information. For instance, in addition to the photogram-metric Land-use interpretation based on orthophotos or aerial stereo photo models, the mapping of landscape features from existing paper maps still remains necessary (Figure 6).

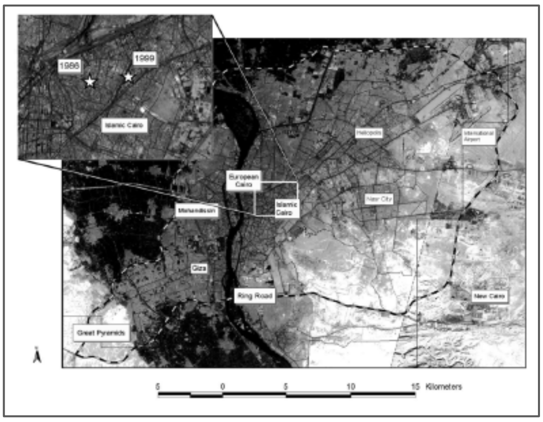

Figure 6: City of Cairo inside the ring road. (Example of the raster image) (Stewart et al., 2003).

■ Interactive Data Analysis on Demand

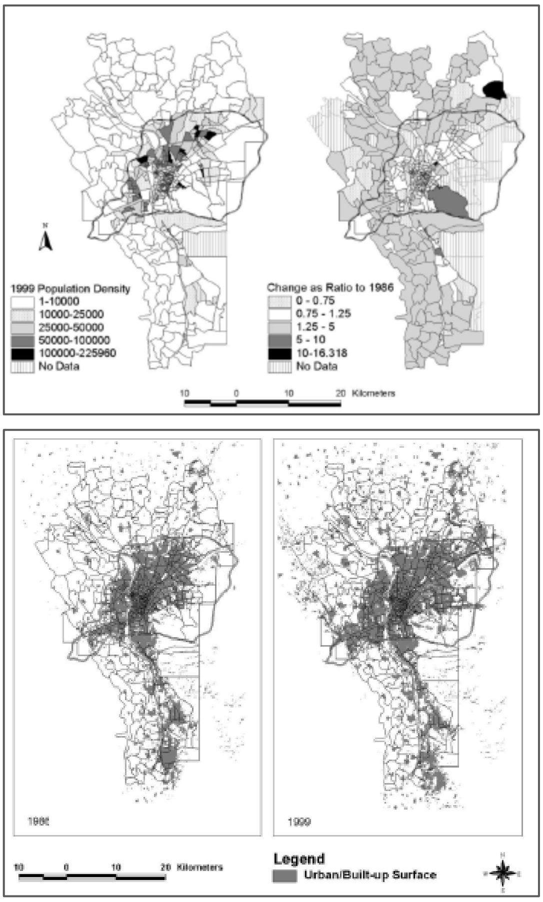

Figure 7: Cairo City (built-up and population /1999) Example of Interactive Data Analysis on Demand (Stewart et al., 2003).

The ability of GIS to analyze ecological and landscape-related spatial data has often been discussed and demonstrated. The primary interest is the ability of GIS to do interactive analysis, analysis on demand. Another advantage of using digital data and GIS is the ability to analyze 3-dimensional landscape models which form the basis for visibility, slope, aspect, line-of-sight or watershed calculations. Queries of this nature can also be handled, providing the necessary base data is available. Multimedia elements can play an important role in visual analysis. One example here is the ability of GIS to overlay selected thematic maps, allowing the viewer to see complex relationships at a glance. Using this technique, land-use conflicts can be quickly identified and displayed with a level of clarity and legibility that cannot be achieved by analogue cartographic illustrations. Additionally, turning different map layers on or off can be useful in illustrating the various steps in the planning process.

■ Visualization and Data Presentation

A Master Plan that is easily understood is essential for the acceptance of design proposals. A client-friendly analysis and presentation of planning results has become an important factor in successful planning. A GIS which is able to simulate geo-referenced landscape stimuli is a suitable tool for creating a general awareness of the relevant planning issues. The various thematic and planning maps are presented as separate "layers" using the ArcGIS software. The vector data-ware ArcInfo coverage's, ArcView shape files and vectors in Drawing Exchange Format (DXF).

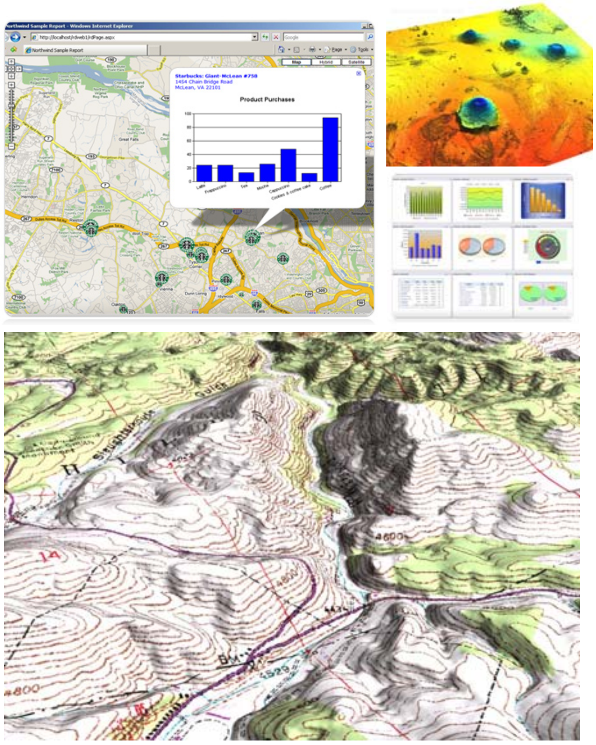

Figure 8: Example Visualization and Data Presentation (http://www.logixml.com)

3. Data Modeling for Urban Planning

The urban planning process is essentially a modeling process, where planners use models to represent the urban reality and the design intervention within. The urban planning process is where evolution of urban models occurs. The mental models are ideas, theories, and regulations which are processed in the planner's mind. The urban planning process may not be systematically linear. The planners often use analogue models, such as hand-drawn sketches, or even build a massive model to express their ideas. The ideas and the ruling knowledge are behind the urban planning process which can be systematically represented in the data model as well as the analysis model and design decision model (Putra & Yang, 2003).

A data model has a role, just as digital and analogue models do, to represent the mental model. Data modeling is the foundation for the digital modeling in the way that the former becomes the dominating system of the latter. Unlike analogue and digital models, data models are able to represent not only geometric and functional ideas, but also regulative knowledge, which may be derived from design guidelines.

For example, by running the data model for the "design" part and for the "regulation" part comparatively and simultaneously, the information system can acknowledge the design "compatibility" with the regulation (Putra & Yang, 2003).

On the other hand, most computerized urban planning activities need a spatial database of some kind, where data are stored in a certain format. Through data modeling, a spatial database should be designed to accommodate urban planning analysis and the design decision-making process. A Planning Support System (PSS) usually contains several levels of predictive urban modeling or simulation, which requires a database modeling as the foundation.

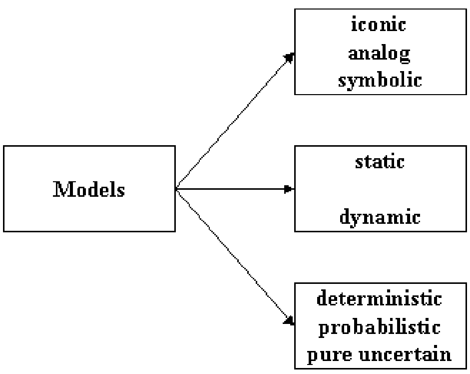

Figure 9: A Classification of Models. (Arsham, 2004).

Spatial database design is very important in the development of planning support systems, since a GIS system should be built on standard components. The components start from a spatial database as the foundation, then comprise editing, analysis, simulation, visualization (Pettit, 2002), and finally, making the proposal for the future.

The combination of data modeling in GIS, Spatial Data Engine (SDE), through XML format as a bi-directional medium, provides the potential for managing virtually unlimited amounts of details representing many aspects of the built environment of the entire city, along with different future or past scenarios.

GIS can be used as an integral component for a decision support system (DSS) for managing forest reserves.

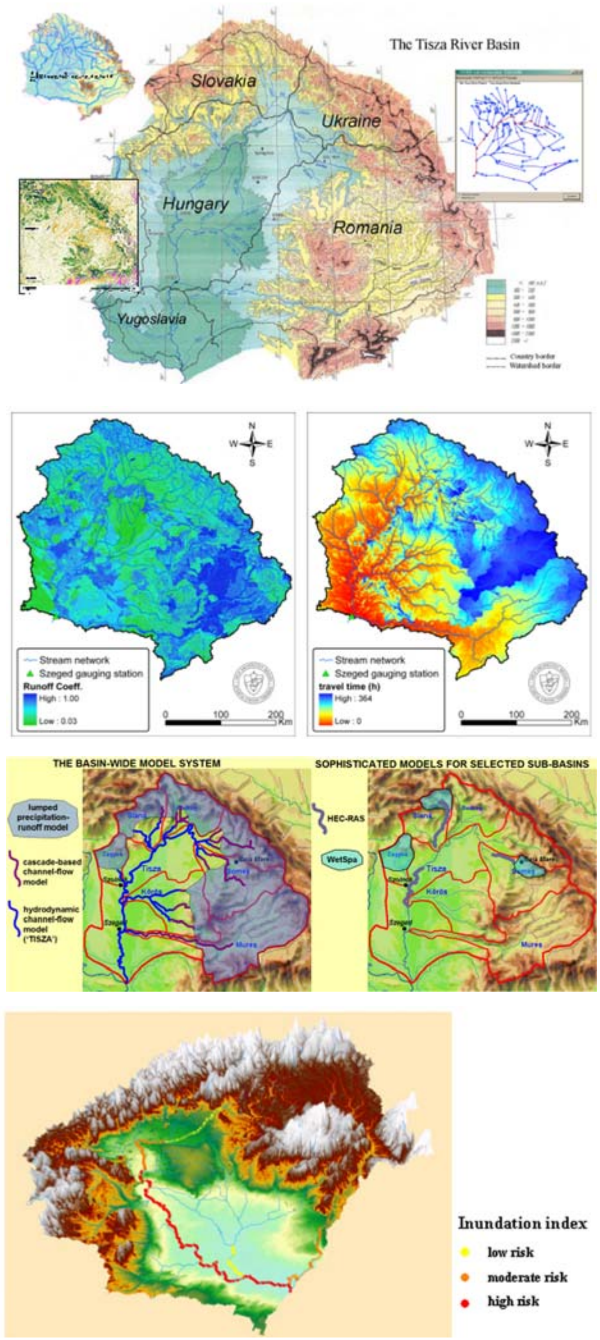

Figure 10: The Tisza River Project. In this example, the GIS is used to model the spatial components of the DSS (http://www.tiszariver.com)

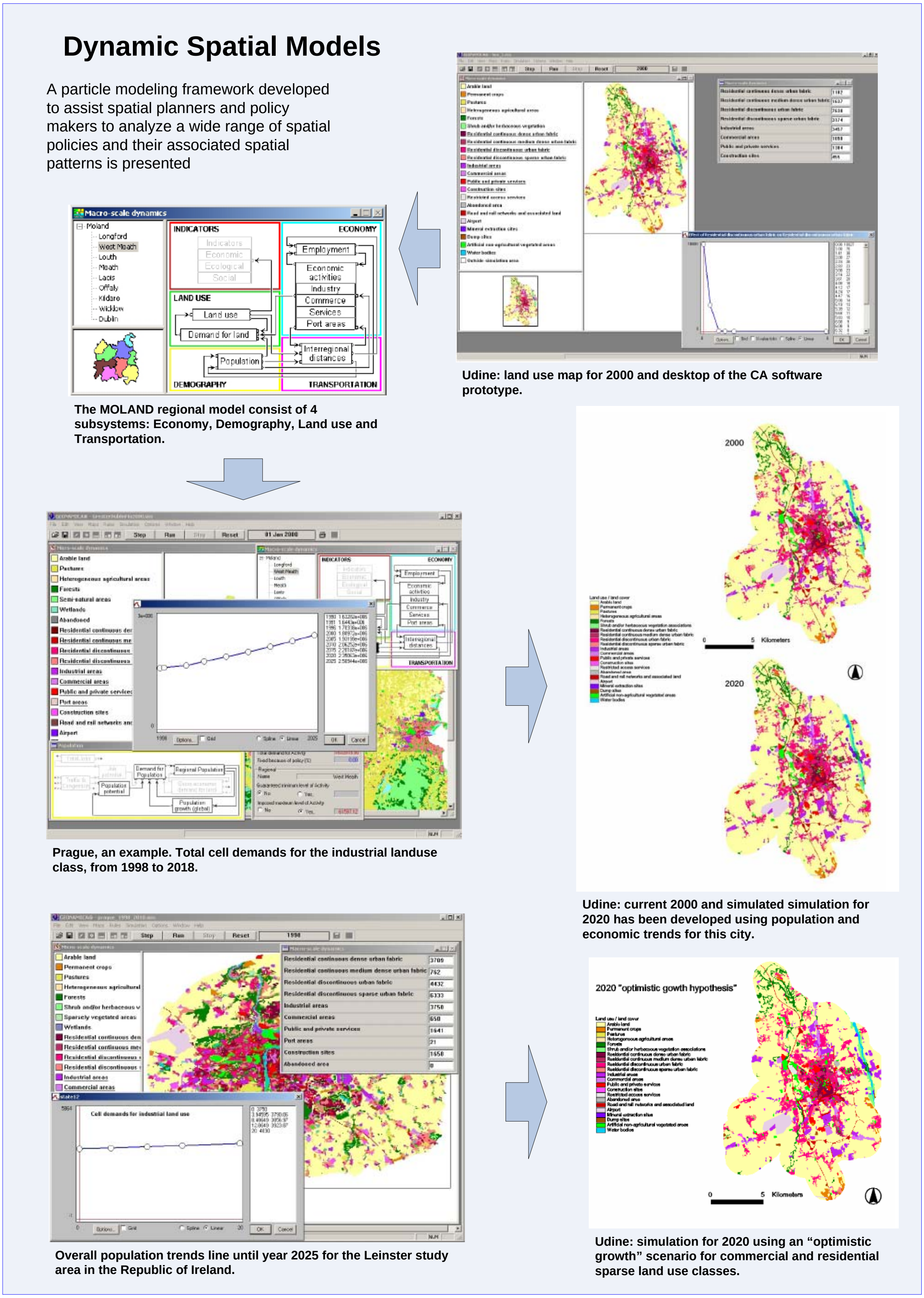

Figure 11: Example of a Dynamic Spatial Model (RJC, 2003)

3. The Components of SDSS

A decision-support system can be defined as a computer system helping one or more actors in their work of making decisions. DSS provides a mean for decision-makers to make decisions on the basis of more complete information and analysis. Among the main advantages of the use of DSS is an increased number of alternatives examined, a better understanding of the business, fast response to unexpected situations, improved communication, cost savings, better decisions, more effective teamwork, time saving, and a better use of data resources.

A particular and important type of DSS is the so-called spatial decision support systems (SDSS). Spatial DSS refers to those decision support systems that combine the use of Geographic Information Systems (GIS) technology with software packages for the selection of alternatives of location for different activities. GIS provides an important source of tools and techniques, which can usefully be incorporated into a DSS system that makes use of geographic or spatial data.

One of the key components is a 'what-if' model used to simulate the future of the city, for example, according to some assumptions. Among those urban models are the following:

- Transportation and traffic models
- Population models
- Service and commercial premises locations
- Energy and water consumption
- Water production, etc.

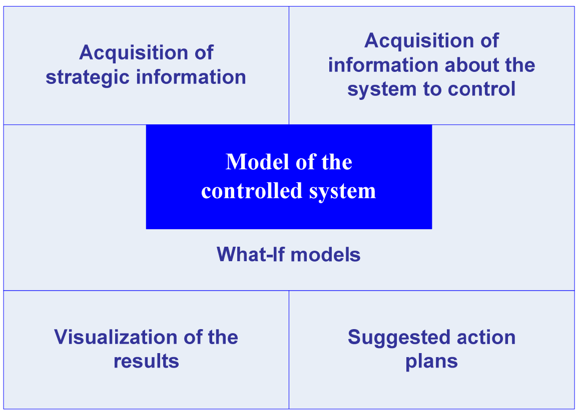

Figure 12: Structure of a spatial decision-support system (Laurini, 2001. p: 11).

Figure 12 illustrates the main components of a spatial decision support system (SDSS) which includes (Laurini, 2001):

- Acquisition of strategic information, that is to say information coming from the steering sub-system, (the role of the steering subsystem is to design and make decisions in order to shape the global system and make it evolve towards the desired directions) together with acquisition of information about the territory under control.
- Acquisition of information about the system to control, that is to say information coming from the controlled system (this sub-system includes all elements for which the decision will be made: it regroups all physical sectors and sociological phenomena which can be influenced by decisions) by means of any kind of acquisition techniques or measuring instruments.
- A model of the controlled system, in order to project or forecast evolution; by projection, it means that it is the continuation of the past, all things being equal. If some parameters or assumptions are changed, one speaks about alternatives and forecasting.
- Modules of what-if models for data and system simulation; the role of this components is to study the data of the past in order to find some regularities for constructing the model. When some performance indices exists, it is possible to evaluate and compare the effects of the simulated alternatives.
- Visualization of the results; for any alternative, the main variables can be displayed in order to compare them visually.
- Action plans; i.e. when an alternative is selected, some action plans should be drawn up and implemented (Laurini, 2001).

4. Spatial Decision Support System Aided Urban Planning

Common to all definitions of DSS is a sense that these systems should support a particular type of decision. This characteristic distinguishes DSS from general purpose management information systems (MIS). While GIS applications may contain the information relevant to a decision, they are usually general purpose systems, not focused on a particular decision. For those types of decision where the standard features of a GIS provide the essential information to the decision maker.

GIS software has proved its ability to provide decision support. Many GIS based systems are described as being DSS on the basis that the GIS assisted in the collection or organization of data used by the decision-maker. For many of the current SDSS applications, the main information requirement of the decision-makers is for relatively structured spatial information. Consequently, the GIS techniques have an important impact on DSS applications (Keenan, 2004).

For the full range of problem areas where GIS techniques can make an important contribution, particular problem related models are needed to fully support decisions. For these areas at least, a standard GIS cannot be said to be a DSS because such a system lacks the support that the use of customized models can provide. For this wide range of second order uses of spatial data, additional processing or integration with non-spatial models is required to fully support the decision maker.

Table 1: The functions of SDSS (Maczewski, 1997)

Components	Functions
Data Base and Management	Types of data. Locational (e.g. coordinates), topological (e.g. points, lines, polygons and relationships between them), and attributes (e.g. geology, elevation, transportation network). Logical Data Views - Relational DBMS, hierarchical DBMS, network DBMS, and object-oriented DBMS. - Management of Internal and External Databases. Acquisition, storage, retrieval, manipulation, directory, queries, and integration.
Model Base and Management	Analysis - Goal seeking, optimization, simulation, and what-if. Statistics and forecasting. Exploratory spatial data analysis, confirmatory spatial data analysis, time series, and geostatistics. - Modeling decision maker's preference. Value structure, hierarchical structure of goals, evaluation criteria, objectives and attributes, pair-wise comparison, multiattribute value/utility, and consensus modeling. Modeling uncertainty - Data uncertainty, decision rule uncertainty, sensitivity analysis, and error propagation analysis.
Dialog Management	User friendliness - Consistent, natural language comments, help and error messages, and novice and expert mode.. Variety of dialog styles. Command lines, pull-down menus, dialogue boxes, and graphical user interfaces. Graphical and tabular display - visualization in the decision space (high-resolution cartographic displays), visualization in the decision outcome space (e.g. two and three-dimensional scatter plots and graphs, tabular rapports).

A number of modules has to be identified to extend the present use of a GIS as a DSS, (Keenan, 2004) as follows:

 Data Entry Module: This module is for entering basic geographic and attributes data. Data control module is also entered using this module.

 Assessment Module: This is used to develop various sub-modules which will be used to support the development module.

 Development Module: This module is used to develop the predictive models for any pollutant at any location.

 Control Module: This module is important for decision-makers and it is used to control the pollution level of criteria pollution. Various regulations and policies are a part of this module.

 User-Interface: Consists of menu-based interface to help various planners and decision-makers in efficient usage of the development DSS.

All the modules should be well linked together within a GIS-based user interface and should provide graphics, dialog boxes, spatial analysis and, other required functions (Agrawal et al., 2003).

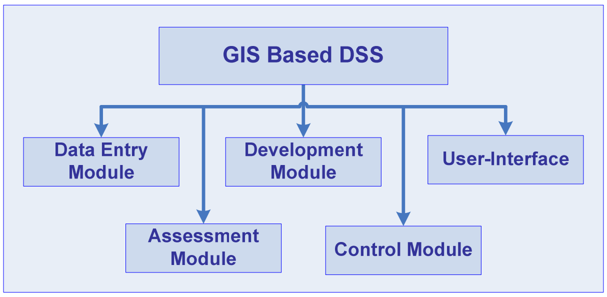

Figure 13: The structure of proposed GIS-Based DSS (Agrawal et al. 2003).

GIS software provides an interface for spatial information and a database support that is designed to allow for the effective storage of spatial data. Furthermore it provides a link between the interface and database to allow the user to easily query spatial data (Keenan, 2004).

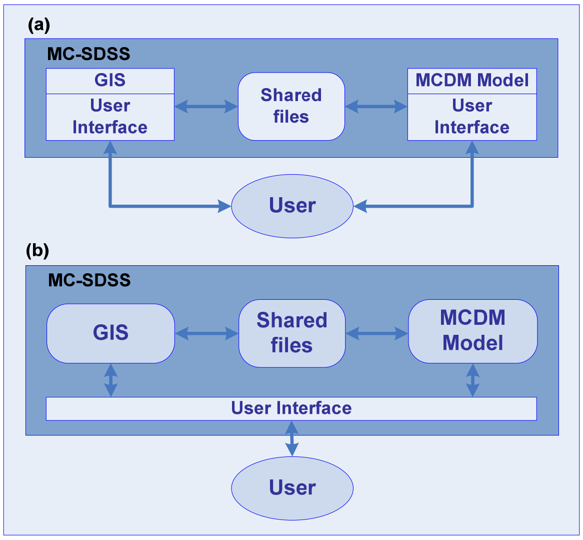

Figure 14: Loose (a) and tight (b) MC-SDSS coupling Strategies (Maczewski, 1999).

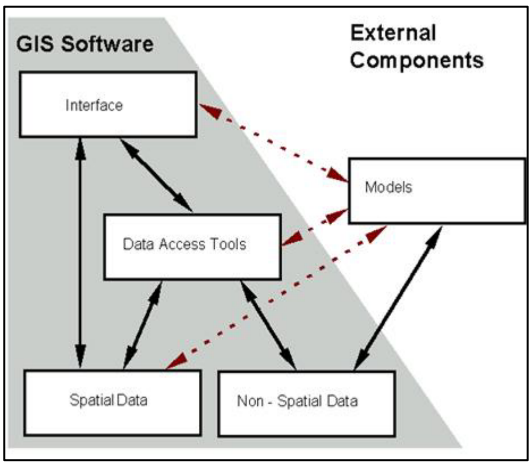

Figure 15: Building a SDSS by integrating models with GIS (Sprague, 1980).

There are four different domains in which SDSS can make a contribution to decision making (Keenan, 2004).

First: in the traditional areas of application of GIS, in disciplines such as geology, forestry, and land planning. In these fields GIS was initially used as a means of speeding up the processing of spatial data, for the completion of activities that contribute directly to productivity. In this context the automated production of maps, in these disciplines, has a role similar to that of data processing in planning.

Second: in fields such as routing or location analysis. The spatial component of such decisions is clear, however, these models are incorporated into GIS based SDSS, providing superior interface and database components to work with the models. This synthesis of management science and GIS techniques provides more effective decision making. Simpler and less effective integration of models only allows the modeling routines access to the non spatial data. Full integration requires that model routines be able to make use of all the features of GIS (Sprague, 1980).

Third: in disciplines such as marketing, where additional possibilities for analysis are provided by the availability of increasing amounts of spatially correlated information, for example demographic data. Furthermore, the geographic convenience of product supply relative to customers' locations is an important tool of market driven competition. The availability of user friendly SDSS to manipulate this type of data leads to additional decision possibilities being examined which are difficult to evaluate without the use of such technology.

Table 2: Computerized Support for Decision Making (Laurini, 2001).

Phase	Description	Traditional Tools	Spatial Tools
Early	Computes, "crunches numbers", summarizes and organizes.	Early computer programs, management science models.	Computerized cartography.
Intermediate	Finds, organizes and displays decision relevant information	Database management systems, MIS.	Workstation GIS.
Current	Performs decision relevant computations on decision relevant information; organizes and displays the results. Query based and user friendly approach. "What If" analysis.	Financial models, spreadsheets, trend exploration, operations research models, decision support systems.	Spatial decision support systems.

Fourth: in decision making for sustainable development, GIS can provide decision-makers with useful information by means of analysis and assessment of spatial database (Figure 6.16). Driving forces include population growth, health and wealth, technology, politics, economics etc., by which human society will set up targets and goals on how to improve the quality of life (www.metu.edu.tr).

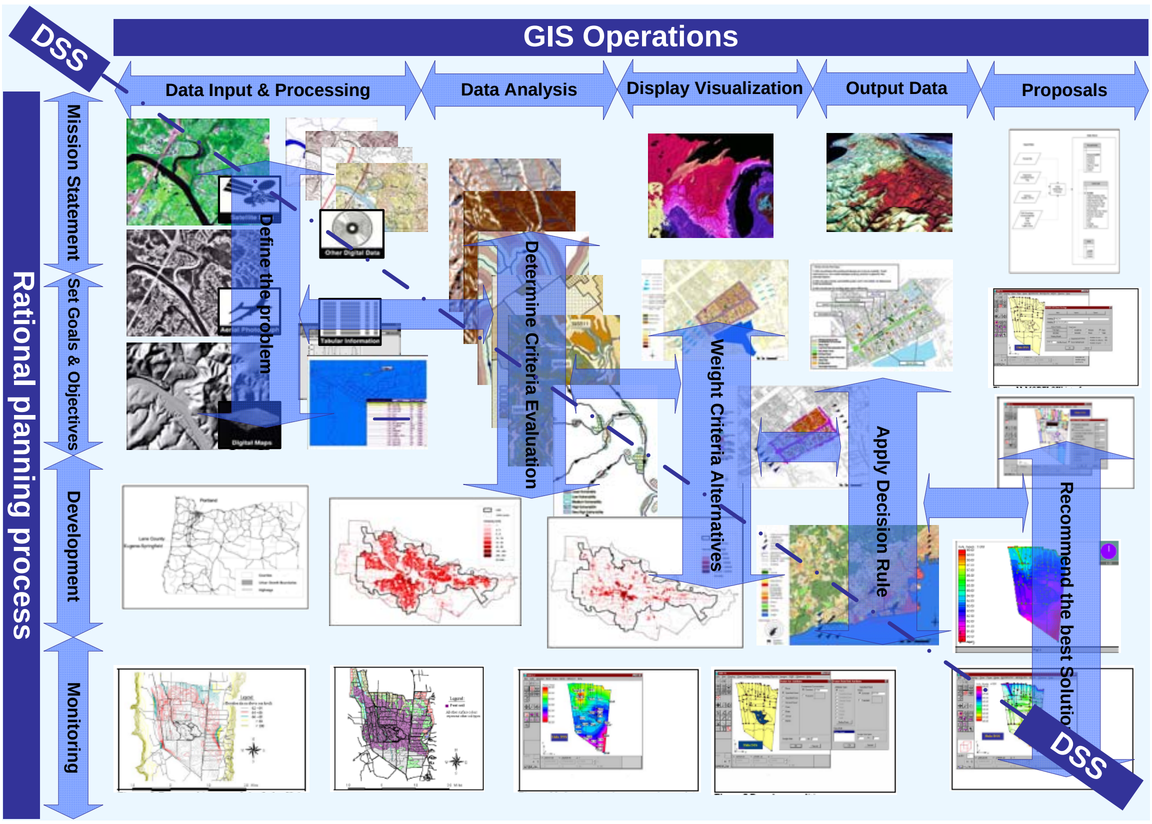

Figure 16: The interaction between the GIS, Planning Process and Decision Support System (the authors)

Thus human driving forces, the key elements of human dimensions, will give impacts on the environment in areas such as development of natural resources, urbanization, industrializations, construction, energy consumption etc. Remote sensing can be very useful for a better understanding of the relationship between human impacts and environmental change as well as for building databases. Physical dimensions monitored by remote sensing can be fed back to human dimensions through analysis and assessment by GIS in order to support better decisions (www.metu.edu.tr).

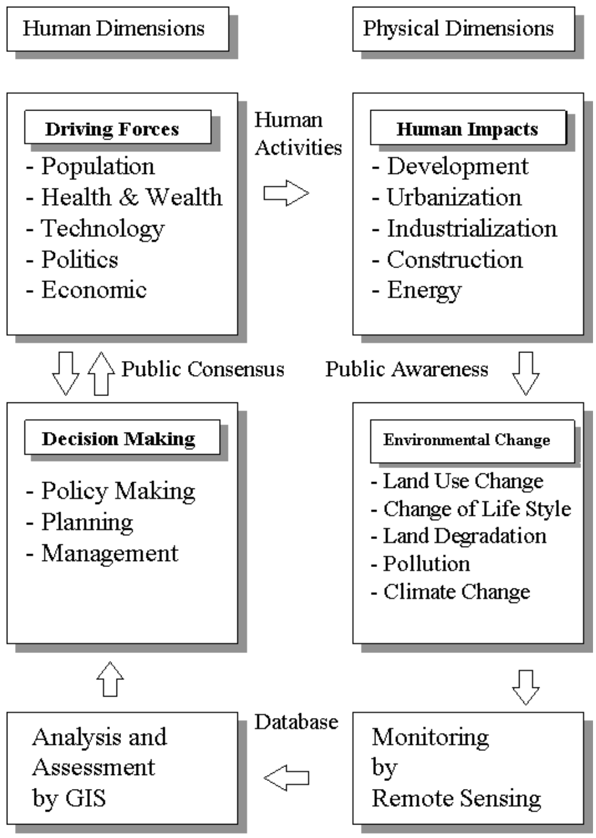

Figure 16: GIS for Decision Support (www.metu.edu.tr).

Conclusion

This paper discusses the role of information technology in developing the computer based systems used for supporting decision making. It reviews – conceptually- different computer system used in urban planning, highlighting the qualities of Geographical Information Systems (GIS) as a DSS structure. Moreover, it reviews the development of Decision and Planning Support System, urban modeling and GIS, and the role of GIS in urban planning.

In addition, the paper emphasizes the role of data as the cornerstone in GIS and planning, and it discusses both the development and the role of data modeling in urban planning. Furthermore, it analysis the potentials of GIS as a concept that has the capacity to integrate information from a variety of sources into a spatial context that is well suited to support decision making procedures. That helps the decision-makers evaluate alternatives, visualize choices and explore certain alternatives.

Given the advances in computer technology in general and GIS techniques in particular, this chapter summarizes that SDSS is an important component of DSS applications. This trend is driven by the relevance of spatial information as a component of the information needed for a wide range of decisions. This class of DSS makes an important contribution because it allows decision makers to incorporate a spatial dimension into their decision making, in addition to its use of the latest technology. This spatial dimension, which is not fully catered for in traditional DSS designs, is an important feature of many areas of DSS application.

On the other hand, comprehensive decision support requires the effective integration of GIS and non GIS techniques. The building of SDSS applications from GIS has been facilitated by recent technical developments, both within GIS software, and generally, in programming tools.

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إفـــــــــــادة

تفيد كلية الهندسة المعمارية بجامعة بيروت العربية بأن البحث المشترك المقدم من:

الدكتور خالد السيد محمد الحجلة
أستاذ مساعد
كلية الهندسة المعمارية
جامعة بيروت العربية

وعنوانــــــــــــه

The Use of Geographic Information System (GIS) Based Spatial Decision Support system (SDSS) in Developing in Urban Planning Process

قد نشر في مجلة العمارة والتخطيط التي تصدر عن كلية الهندسة المعمارية بجامعة بيروت العربية، وذلك ضمن محتويات العدد العشرون – يناير ٢٠٠٩، وهذه إفادة بذلك.

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