Unit 127 - Spatial Decision Support Systems

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Advanced Organizer

Topics covered in this unit

- This unit focuses on the concept of Spatial Decision Support Systems (SDSS); it covers:
  - the major characteristics of spatial decision problems
  - the decision-making process
  - SDSS definition
  - principles of SDSS
  - the DDM (dialog, data, model) paradigm
  - technologies for developing SDSS.

Learning Outcomes

- After learning the material covered in this unit, students should be able to:
  - define basic terms underlying the concept of SDSS
  - identify the major components of SDSS
  - differentiate between GISystems and SDSS
  - identify the technologies for developing SDSS
  - know where to look for more information on SDSS.

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Metadata and Revision History

Unit 127 - Spatial Decision Support Systems

1. Historical background

- the concept of Decision Support System (DSS) is based on the seminal work by Simon and associates in 1950s and 1960s (Simon 1960);
- DSS evolved as a field of research, development, and practice during the 1970s and 80s (Sprague and Watson 1996);
- the SDSS concept has evolved in parallel with DSS (Densham and Goodchild 1989);
- IBM's Geodata Analysis and Display System (GADS) - developed in the 1970s - was one of the earliest large DSS (Sprague and Watson 1996);
- the development of SDSS has been associated with the need to expand the GISystem capabilities for tackling complex, ill-defined, spatial decision problems (Densham and Goodchild 1989);
- there has been considerable growth in research, devlopment, and applications of SDSS in the last 10 years or so (NCGIA 1990; 1996);
- the field has now grown to the point that it is made up of many threads with different, but related names, such as collaborative SDSS, group SDSS, environmental DSS, spatial knowledge based and expert systems (see other units of the GISciCC 2.14 section).

2. Spatial decision-making and GISystems

2.1 Spatial decision problems

- The main characteristics of spatial decision problems include:
  - a large number of decision alternatives,
  - the outcomes or consequences of the decision alternatives are spatially variable,
  - each alternative is evaluated on the basis of multiple criteria,
  - some of the criteria may be qualitative while others may be quantitative,
  - there are typically more then one decision maker (or interest group) involved in the decision-making process,
  - the decision makers have different preferences with respect to the relative importance of evaluation criteria and decision consequences,
  - the decisions are often surrounded by uncertainty.

2.2 Decision-making process

- Simon (1960) suggests that any decision-making process can be structured into three major phases:
  - Figure 1 Phases of decision-making
  - ***intelligence*** - is there a problem or an opportunity for change?
  - ***design*** - what are the decision alternatives?
  - ***choice*** - which alternative is best?

2.3 Decision support

- How and to what extend can GISystems provide support required in each of the three phases of decision-making?
- **Intelligence**
  - the intelligence phase involves searching or scanning the environment for conditions calling for decisions;
  - this phase requires an exploratory analysis of the decision situation;
  - GIS can play a vital role at the initial stage of spatial decision-making;
  - the system can help in coordinating decision situation analysis through its ability to integrate and explore data and information from a wide range of sources;
  - GIS can effectively present information in a comprehensive form to the decision makers.
- **Design**
  - the design phase involves inventing, developing, and analyzing a set of possible decision alternatives for the problem identified in the intelligence phase;
  - a formal model is typically used to support a decision maker in generating the set of alternatives;
  - while an increasing number of GISystems are described as systems for supporting the process of designing and evaluating spatial decision alternatives, most commercially available GIS lack the kinds of spatial analysis and modeling required by decision makers;
  - the capabilities of GIS for generating a set of alternative decisions are mainly based on the spatial relationship principles of connectivity, contiguity, proximity and the overlay methods;
  - in current GIS environments, models for generating decision alternatives operate in the background, detached from users insights and qualifications.
- **Choice**
  - the choice phase involves selecting a particular decision alternative from those available;
  - each alternative is evaluated and analyzed in relation to others in terms of a prespecified decision rule;
  - the decision rules are used to rank the alternatives under consideration;
  - the ranking depends upon the decision maker's preferences with respect to the importance of the evaluation criteria;
  - critical for use of GIS in the choice phase is the capability of incorporating the decision maker's preferences into the decision-making process;
  - in general, GISystems do not provide a mechanism for flexible incorporation of the decision maker's preferences into the decision-making process.
- **Conclusions:**
  - GISystems have limited capabilities of supporting the design and choice phases of the decision-making process;
  - the systems provide a very static modeling environment and thus reduce their scope as decision support tools - especially in the context of problems involving collaborative decision-making.

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3. SDSS definition

- SDSS is an interactive, computer-based system designed to ***support*** a user or group of users in achieving a higher ***effectiveness*** of decision making while solving a ***semi-structured spatial decision problem***;
- the three terms (semi-structure spatial problems, effectiveness, and decision support) capture the essence of the SDSS concept:
    - **semi-structured decision problems**
        - Figure 2 Degree of decision problem structure.
        - any decision problem falls on a continuum that ranges from completely *structured* to *unstructured* decisions (Simon 1960);
        - the structured decisions occur when the decision-making problem can be structured either by the decision maker or on the basis of relevant theory;
        - the structured decisions are programmable and can be solved by computers;
        - the unstructured decisions occur when the decision maker is unable to structure the problem and the problem cannot be structured on the basis of a relevant theory;
        - these decisions are nonprogrammable and must be solved by the decision maker without any assistance from a computer;
        - most real-world spatial decision problems, if not all, can be found somewhere between these two extreme cases of completely structured and unstructured decisions; these decisions are called *semi-structured* ones;
        - this is the area where the SDSS concept has major application;
        - the structured (programmed) part of the problem may be amenable to automated solution by the use of a computer, while the unstructured (nonprogrammed) aspects are tackled by decision makers.
    - **effectiveness of decision making**
        - the aim of the system is to improve the effectiveness, rather than efficiency of the decision-making process;
        - the higher effectivness is achieved by incorporating the decision maker judgments and computer-based programs into the decision-making process;
        - to be effective the system must be easy to use.
    - **decision support**
        - the system helps the users to explore the decision problem in an interactive and recursive fashion in all phases of the decision-making process.

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4. Principles of SDSS

4.1. The DDM paradigm

- the technology for a DSS must consist of three sets of capabilities in the areas of ***dialog***, ***data***, and ***modeling*** (the DDM paradigm) (Sprague and Watson, 1996);
- a well-design SDSS should have balance among the three capabilities.

4.2. The components of SDSS

- Figure 3 The components of SDSS

Table 1 The functions of SDSS

- the ***Data Base Management System*** (DBMS) contains the functions to manage the ***geographic data base***;
- the ***Model Base Management System*** (MBMS) contains the functions to manage the ***model base***;
- the ***Dialog Generation and Management System*** (DGMS) manages the interface between the user and the rest of the system.

4.3. Technologies for developing SDSS

- Figure 4 Three levels of DSS technology (Source: Sprague and Watson, 1996)
- ***DSS tools*** facilitate the development of either a DSS generator or a specific DSS; examples include (see Reference Materials - Section 7.2.2):
  - procedural programming languages and code libraries (e.g., Arc Macro Language (AML) scripting tool of ARC/INFO, Avenue - ArcView GIS software's built-in object-oriented scripting language, TransCAD - Caliper Script macro language, MapInfo - MapBasic);
  - visual progamming language (e.g. STELLA II, Cantata and Khoros);
  - inter-application communication software (e.g. dynamic data exchange (DDE), object linking (OLE), open database connectivity (ODBC));
  - simulation languages and software (e.g. SIMULINK, SIMULA);
  - application programming interfaces (API) (e.g. the IBM's geoManager API, Java Advanced Imaging API, TransCAD's API);
  - applets (e.g. GISApplet, Microsoft Visual J++),
  - visual interfaces, graphics and color subroutines (e.g. graphical user interfaces - GUI).
- ***DSS generator*** is a package of related hardware and software which provides a set of capabilities to quickly and easily build a specific SDSS; examples include:
  - GISystems (e.g. ARC/INFO, ArcView, ARCNetwork, Spatial Analyst, MapObjects LT, GRASS, IDRISI, MapInfo, TransCAD);
  - database packages (e.g. dBase, Access, Paradox);
  - decision analysis and optimization software (e.g. LINDO, EXPERT CHOICE, LOGICAL DECISION);
  - statistical and geostatitical software (e.g. S-PLUS, SPSS, SAS);
  - simulation (e.g. Spatial Modelling Environment);
- ***Specific DSS*** are systems devoted to the analysis of a particular set of decision problems; the systems which actually support the decision makers in tackling semi-structured problems; examples include:
  - Active Response Geographic Information System;
  - IDRISI Decision Support;
  - GeoMed;
  - Spatial Group Choice;
  - winR+GIS Spatial Decision Support.

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5. Summary

- This unit has introduced the concept of SDSS.
- SDSS has been defined as an interactive, computer-based system designed to support a user or group of users in achieving a higher effectiveness of decision making while solving a semi-structured spatial decision problem.
- The SDSS concept is based on the DDM (dialog, data, model) paradigm; a well-design SDSS should have balance among the three capabilities.
- There are three sets of technologies for building an SDSS: the DSS development tools, the DSS generators, and specific SDSS
- The DSS tools facilite the development of specific SDSS or they can be configured into a DSS generator which in turn can be used to build a variety of specific SDSS.

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6. Review and Study Questions

6.1. Essay and Short Answer Questions

- What are the major characteristics of spatial decision problems? What is special about spatial decision problems?
- What are the three phases of the decision making process? Discuss how and to what extent GISystems can support the decision makers in each of the three phases.
- Explain the differences between GISystems and SDSS.
- Discuss the three levels of SDSS technology. Give examples of each level.
- Describe the main characteristics and functions of the SDSS components.

6.2. Multiple-choice questions

Choose the best or most appropriate answer(s) to the question.

- What type of decision problems can be tackled using SDSS?
    1. unstructured problems
    2. structured problems
    3. semi-structured problems
    4. programmable problems
    5. unprogrammable problems

- Which of the following can be considered as an SDSS generator?
    1. ArcView
    2. Arc Macro Language (AML)
    3. Graphical User Interface (GUI)
    4. dynamic data exchange (DDE)
    5. none of the above

- Which of the following can be considered as SDSS tools?
    1. Caliper Script macro language
    2. the IBM's geoManager API
    3. open database connectivity (ODBC)

4. Microsoft Visual J++
5. all of the above

- SDSS is an interactive, computer-based system designed to support a user or group of users in achieving a higher effciency of decision making while solving a structured spatial decision problem
  1. true
  2. false

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7. Reference Materials

7.1. Print References

7.1.1. Cited references

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7.1.2. Other relevant publications

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7.2. Web References

7.2.1. Some introductions to SDSS

- Batty M. and P. J. Densham (1996) Decision support, GIS, and urban planning,
- Journal of Geographic Information and Decision Analysis (JGIDA),
- Malczewsk, J. (1997) The internet resources for geoinformation-based decision analysis,
- Larry, D. (1992) SDSS for location planning, or the seat of the pants is out, The Geographer's Craft Project, Department of Geography, University of Texas at Austin
- NCGIA Initiative 6: Spatial decision support systems (SDSS),
- NCGIA Initiative 17: Collaborative spatial decision-Making,
- Power, D.J. (1997) DSS research resources
- Watkins, Jr. D. W. and D. C. McKinney (1996) Recent developments associated with decision support systems in water resources,

7.2.2. Selected technologies for developing SDSS

- **SDSS tools**
  - procedural programming languages
    - Arc Macro Language (AML), http://www.esri.com
    - Avenue scripting language, http://www.esri.com

        - MapBasic
        - Caliper Script macro language
        - C++
        - Visual Basic
    - visual progamming language
        - STELLA II/
        - Cantata and Khoros inter-application
    - communication software
        - dynamic data exchange (DDE),
        - object linking (OLE)
        - open database connectivity (ODBC),
    - simulation languages
        - SIMULINK
        - SIMULA application programming interfaces
    - (API)
        - IBM's geoManager API
        - Java Advanced Imaging API
        - TransCAD's API
    - applets
        - Microsoft Visual J++,

- **SDSS** generator
    - GISystams
        - ARC/INFO
        - ArcView
        - GRASS
        - IDRISI
        - MapInfo, http://www.mapinfo.com
        - TransCAD
    - database packages
        - Access
        - dBase
        - Oracle, http://www.oracle.com/
    - decision analysis and optimization software
        - LINDO
        - CPLEX
        - EXPERT CHOICE
    - simulation software
        - Spatial Modelling Environment
    - statistical and geostatitical software
        - S-PLUS
        - S+SpatialStats
- **specific SDSS**
        - Active Response Geographic Information System (AR/GIS),

- Collaborative Planning Support System for Water Resource Managment
- Collaborative Spatial Decision Making on the Internet,
- Colorado River Decision Support System
- IDRISI Decision Support
- IBM's Collaborative GIS
- GeoMed
- GeoChoice
- WATERSHEDSS
- winR+GIS Spatial Decision Support

Citation

To reference this material use the appropriate variation of the following format:

Malczewski, J. (1997) Spatial Decision Support Systems, *NCGIA Core Curriculum in GIScience*, http://www.ncgia.ucsb.edu/giscc/units/u127/u127.html, posted October 6, 1998.

Created: Novemeber 19, 1997. Last revised: October 6, 1998.

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Metadata and Revision History

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1. About the main contributor

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2. Details about the file

- supporting files (text):
- last revision date: 10 September 1997
- unit title: Spatial Decision Support Systems
- unit key number: Unit 127

3. Key words

- Spatial Decision Support System (SDSS)
- Geographic Information System (GIS)
- Data base managment system (DBMS)
- Model base management system (MBMS)
- Dialog generation and managment system (DGMS)

4. Index words

- spatial decision problems
- decision-making process
- decision support
- the DDM (dialog, data, model) paradigm
- levels of technology
- componenets of SDSS
- coupling strategies

5. Prerequisite units

- 001 - GIS Awareness
- 042 - Fundamentals of computing systems
- 050 - Fundamentals of information science
- 096 - Handling uncertainty
- 110 - Spatial analysis
- 136 - Making it work

6. Subsequent units

- 128 - Exploratory spatial data analysis
- 129 - Collaborative spatial decision making
- 130 - Process modeling and simulation
- 131 - Multimedia and virtual reality
- 132 - Interoperability
- 133 - Knowledge based and expert systems
- 134 - 0bject oriented GIS

7. Revision history

- November 19, 1997 - original draft created
- November 25, 1997 - original draft posted to net
- September 10, 1998 - minor revisions by Malczewski
- October 6, 1998 - minor revisions by Kemp

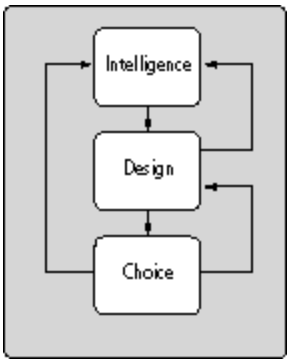

Figure 1. Phases of decision making.

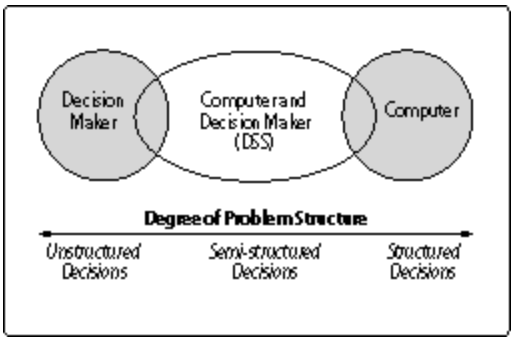

Figure 2. Degree of decision problem structure.

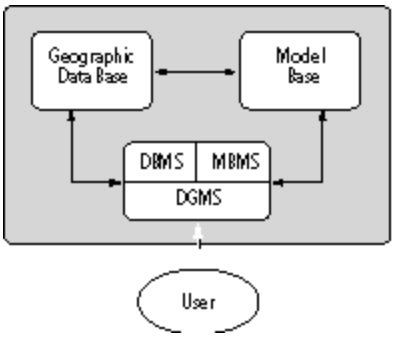

Figure 3. The components of SDSS.

Table 1 The functions of SDSS

Components	Functions

Data Base and Management	• ***Types of data***
	  ◦ locational (e.g. coordinates)
	  ◦ topological (e.g. points, lines, polygons and relationships between them)
	  ◦ attributes (e.g. geology, elevation, transportation network)
	• ***Logical Data Views***
	  ◦ relational DBMS
	  ◦ hierarchical DBMS
	  ◦ network DBMS
	  ◦ object-oriented DBMS
	• ***Management of Internal and External Databases***
	  ◦ acquisition
	  ◦ storage
	  ◦ retrieval
	  ◦ manipulation
	  ◦ directory
	  ◦ queries
	  ◦ integration

Model Base and Management	• ***Analysis***
	  ◦ goal seeking
	  ◦ optimization
	  ◦ simulation
	  ◦ what-if
	• ***Statistics and forecasting***
	  ◦ exploratory spatial data analysis
	  ◦ confirmatory spatial data analysis
	  ◦ time series
	  ◦ geostatistics
	• ***Modeling decision maker's preference***
	  ◦ value structure
	  ◦ hierarchical structure of goals, evaluation criteria, objectives and attributes
	  ◦ pairwise comparison
	  ◦ multiattribute value/utility
	  ◦ consensus modeling
	• ***Modeling uncertainty***
	  ◦ data uncertainty
	  ◦ decision rule uncertainty
	  ◦ sensitivity analysis
	  ◦ error propagation analysis

Dialog	• ***User friendliness***

Management	◦ consistent, natural language comments ◦ help and error messages ◦ novice and expert mode • ***Variety of dialog styles*** ◦ command lines ◦ pull-down menus ◦ dialogue boxes ◦ 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)

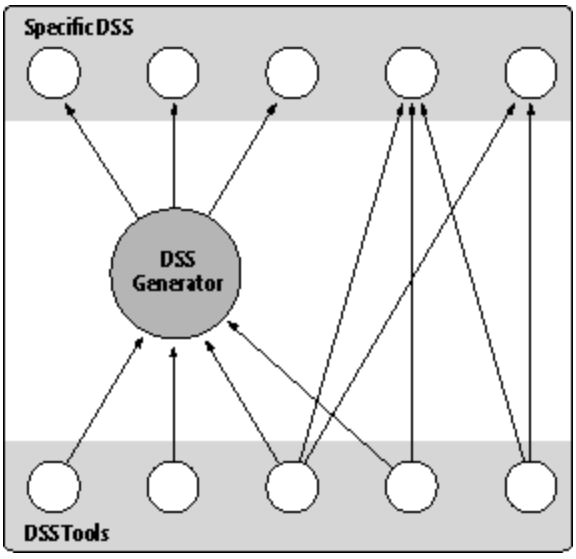

Figure 4. Three levels of DSS technology
(Source: Sprague and Watson, 1996)