The Role Of Geographic Information Systems In Management Information Systems

Devlin S. Fung, (E-mail: dsfung@cc.memphis.edu), University of Memphis
Todd Blankenbeckler, (E-mail: tblnknbc@cc.memphis.edu), University of Memphis

Abstract

In business, industry, and government, information-based systems are increasingly becoming more prevalent. The trend is expected to grow in sophistication in the era of segmented, "niche" marketing in the next century. Different levels of management within an organization require its own unique information system to suit its operational needs. As a functional information system, Geographic Information Systems (GIS) provide the tool to encompass the entire spectrum of management. This article provides an insight into management information systems and the role of GIS in a business environment. The case study presented is intended to demonstrate the implementation of GIS within a management information system, to problem solving and decision making in marketing, resources management, and planning.

Introduction

In the last few decades there has been an explosive growth of information systems and their applications in the business communities. Businesses and commercial organizations have increasingly depended on the use of information systems to achieve a competitive edge in today's dynamic environment. The advent of information systems is tied closely to advances in computer technology, and today, computer systems have become an integral component of information for decision making.

The use of information systems, and

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their applications to management practices in businesses is popularly referred to as management information systems (MIS). In effect, MIS refers to an interdisciplinary field of study, influenced by other disciplines including computer science, political science, psychology, operations research, linguistics, sociology, and organization theory and behavior science. The field of study involves the use and manipulation of information to assist in effective decision-making at various levels of management in an organization (Alavi and Carlson, 1992; McKeown and Leitch, 1993).

Geographic information systems (GIS) represent a class of functional information system designed primarily to manipulate geographic in-

formation organized as map layers. Hence, GIS is highly suited to operating with data that are spatially or geographically oriented. Its role as a functional tool includes its application for organizing and manipulating large information database, and its ability to output information in a variety of format and graphical output (Aronoff, 1989).

Presently, there has been an increasing interest in GIS among businesses and commercial organizations, and it is anticipated that GIS will become an important component in the MIS for business applications. The purpose of this report is to identify the role of GIS as a support tool in MIS for business-oriented applications. This report will provide an overview of the MIS and GIS technologies, demonstrate the use of GIS, and identify its role and function within the framework of the MIS.

Management Information Systems and Managerial Level Organizations

The field of MIS, in a general term, refers to collection of components or organization of procedures designed to facilitate the creation, storage, retrieval, processing, and output of information with the goal of assisting decision-making at different levels of management in an organization. Within the framework, therefore, the MIS includes a variety of information systems, each designed to address a specific level of management within a business organization. Each system may be computerized, and in which case, will include the integration of computers and the users. Basically, the information systems within the MIS include (Cash et al., 1993; Clark, 1995): (a) Transaction Processing System (TPS), (b) Management Information Systems (MIS)¹, (c) Decision Support Systems (DSS), and (d) Executive Information System.

In the efficient management of an organization, various information systems are employed to meet management's information requirements at different levels of management. In effect, an organization's managerial levels can be categorized as: (a) operational management (b)

tactical management, and (c) strategic management. These levels involve different types of management activities, and hence are linked to different types of information systems. The management organization represents a hierarchical (or pyramid) structure with the top managers at the apex, the low-level managers at the base, and the middle managers falling somewhere in between. Each component of the MIS is designed to support any one of the three managerial levels, and the relationship between them is presented in Figure 1 (McKeown and Leitch, 1993).

Management Information Systems

Transaction Processing Systems (TPS)

The TPS is an information system that records an organization's transactions. It supports the day-to-day management of data generated by exchange of goods or services. Transaction processing Systems are employed in our everyday activities, such as when a purchase is made at a retail store, monetary deposition or withdrawal at a bank, or making payment at a utility company, and therefore, represents the main link between an organization and the external entities such as customers, suppliers, distributors, and regulatory agencies. During the transaction, data are processed which involves a) data entry, b) data validation, c) processing and revalidation, d) storage e) output generation, and f) query support.

To illustrate the steps in a transaction process, take for instance when a deposit is made at a bank. Data such as account number, amount deposited, date of deposit, etc. must be entered into the system before it can be processed. Once the data have been entered, they are validated to ensure their accuracy. Next, the data are processed, either on-line or in batch, The output is again validated so that processing errors may be detected. The data are then stored for future use. For the data to be disseminated to decision-makers at the higher management levels, output of the data is generated, usually in the form of documents or reports. In the final processing

Figure 1
Association Between Different Information Systems and Levels of Management

step, the information is queried, for instance, to determine the amount of deposit made in a day.

Management Information Systems (MIS)

The MIS are well-integrated systems, including the users and the computer systems to provide information support to middle management. It is designed to provide reports, scheduled and exception, from information stored in the database by TPS via specific application programs to assist managers in operational and tactical decision making. In marketing, for instance, MIS employed in directing the delivery of products or services to an organization's customers will involve decision-making relating to the amount, characteristics, price, and delivery of the products. These activities will in turn require market research and promotional efforts. As input to assist MIS decision-making, both internal

and external information is required. The former represents information generated by daily activities of the organization with respect to its production of goods or services and interactions with vendors and customers, and the latter represents information obtained from market and economic research. MIS therefore, play an important role in making "market-oriented" decisions which is critical to the success of the organization in the highly competitive and dynamic market environment (Clark, 1995; McKeown and Leitch, 1993).

Decision Support Systems (DSS)

The DSS is typically a set of user-friendly, computer-based tools designed to combine data using a variety of decision models, quantitative or qualitative, to provide solutions to both structured or semi-structured problems.

Structured problems are addressed using routine and repetitive procedures based on pre-defined steps. Conversely, unstructured problems represents unique or unusual situations where decisions are made based on intuition, experience, and judgment of the decision-makers. Semi-structured problems possess characteristics of both structured and unstructured problems, and thus decisions are made using routine and standard problem-solving procedures in combination with intuition and judgment.

The primary roles of DSS are to provide decision support and address ad hoc queries in decision making in resource allocation, demand forecasting, and facilities location. In effect DSS employs such functions as a) Model Building; b) Process "What-if" analysis; c) Goal Identification; d) Risk Evaluation; and e) Graphical Analysis. In model building, internal and external data are integrated into models to produce alternative solutions to a given problem, such as determining annual sales figures of selected products. The alternatives generated can be further analyzed using "what-if" analysis such as "what if the cost of transportation increases by 10%?" Finally, DSS also involves specifying courses of action to meet an organization's goal. If the goal of an organization for instance, is to increase sales of certain goods by 10 %, DSS can help the marketing manager on courses of action such as marketing strategy, advertising, and pricing to accomplish the goal (McKeown and Leitch, 1993; Pinsonneault and Kraemer, 1993).

Executive Information Systems (EIS)

The EIS is designed to assist top-level executives or managers in strategic and unstructured decision-making by providing them the avenue to quickly and efficiently retrieve, analyze, navigate, summarize, and disseminate a large volume of data. In an EIS, both internal and external information is equally important and visualized in a variety of formats. The managers are provided the "drill-down" capability that allows them to access internal information from any desired level. For instance, a manager may be able to obtain information about the total

amount deposited last month at any of the banks owned by the organization.

EIS is designed to enhance decision-making, its design is therefore critical to its successful applications. Because time is a premium to top-level executives, EIS should be user friendly and the sources of information should be readily accessible. The system combines high-speed computing power and high storage capacity with accelerated graphics capability. Through the use of a graphical user interface, the executives should be able to "point and click" to access and display information, determine underlying causes for various results, and presenting results obtained from DSS modeling operations. Outputs are often generated as maps or in combinations of tables and charts. The present day state-of-the-art computing technology is highly suited to provide EIS the computing and graphics capabilities that it demands Cash et al., 1992; Pinsonneault and Kraemer, 1993).

Managerial Level Organizations

Operational Management

The operational management level represents the lowest level of management which involves the daily operational activities of an organization. The operation requires accessibility to very timely, detailed and accurate information generated internally on day-to-day activities. A store manager at this level of management must make decisions based on daily transaction records, job assignments, shipment, and inventory records.

Tactical Management

The mid-level management activities involve effective and efficient use of resources to implement policies and targets set by top management. At this level, operational activities based on tactical decisions. The middle managers require timely summarized information. In addition to internal data, external data are also required to assist the managers in their decision-

making process.

Strategic Management

Strategic management primarily involves the establishment of the long-term vision and goals of the organization, including the strategy to achieve the set goals, and the organizational structures required to implement the strategy. Decisions made at this management level will affect the future direction of the organization. The decision-making process requires top-level managers to rely on various types of information in addition to personal intuition, judgment, and experiences. Generally, strategic managers tend to rely more on external information. Data required at this level should be easily accessible and in a format that can be quickly understood by top management, who in most cases are not very knowledgeable in computer technology.

Managers at each level of management make different kinds of decisions; the information, and hence, the information systems necessary to support these activities vary accordingly. Therefore, three different information systems are designed to meet the individual needs of the managers. The EIS and DSS reside at the very top of the hierarchy, designed exclusively to enhance the quality of decision-making. Both systems are based on MIS, which in turn is based on TPS.

The TPS is oriented towards data recording and conversion into information, with some emphasis on periodic reporting. The MIS involves customizing reports based on historic data and information obtained through the TPS. Therefore, both TPS and MIS produce information about past trends as well as the present trends. The DSS and EIS, on the other hand, are forward looking with an emphasis on the future. They access data and information about what has happened in the past per the TPS and MIS, and then use them in combination with external information to provide solutions that assist decision-making in directing an organization's policies (Cash et al., 1992; Clark, 1995).

Geographic Information Systems – An Overview

Geographic information systems are functional information systems designed for the manipulation of geographic (spatial) information organized as layers of maps (Avery and Berlin, 1992). It originated, in the early 1960s, conceived from the notion of overlaying map layers to one another to identify spatial coincidence among features. Since then, GIS has evolved, in concert with development in computer technology, and today, GIS may be defined as a system of hardware and software designed for data input, data storage and retrieval, data manipulation and analysis, and data output (Figure 2).

The most important component of GIS is the database. The GIS database may be conceptualized as a stack of floating map layers (Figure 3). The maps are registered to one another through a common coordinate system such that features from individual layers will be accurately referenced to one another from a spatial standpoint. Each map layer is linked to a file that contains attribute information of the mapped features. Through a relational database management system, the attribute information can be interactively retrieved or queried by the user as part of the analysis process (Fung, 1995).

The data input component of a GIS involves the conversion of map data into digital format and the incorporation of attributes of the map features. In creating a population map layer for instance, the tasks will include the creation of a map with the population units, usually in the form of census tracts. Once the map layer is created, the population data associated with each tract is input as part of the database. Data have to be checked for accuracy and reliability. The data input component is a very time-consuming operation and is critical to the successful application of the system. Personnel involved in the operation will require specialized training in geographic techniques and must be familiar with the use and manipulation of geographic data. Part of the problem can be eliminated if the data required are available commercially. Even then,

Figure 2
The Components of a GIS Include Data Input, Data Analysis, and Data Output

the responsible personnel should be well acquainted with the setup of the database.

The crux of the functions of a GIS is the spatial analysis component. The analysis involves the retrieval and manipulation of map layers, individually or in combination, to derive solutions to spatial problems that will assist the user in decision-making. Basically, GIS analysis may be categorized as a) map reclassification, b) map overlay, c) neighborhood characterization, and d) network (or connectivity) analysis (Berry, 1987). Most GIS software provides a set of commands and tools to perform these operations, and through the combined use of these functions, various analysis models may be implemented.

In business applications, GIS analysis presents a useful tool for resource inventory surveys, trend analysis, resource routing, and pre-

dictive modeling. A great advantage of GIS analysis is its ability to pose "what if" scenarios, an analysis strategy frequently employed in business applications. As is the case with data input, the analysis component of GIS also requires specialized training and experience in GIS at college or university levels, in addition to the area of applications (e.g. business, marketing, planning, or environmental studies).

Data output represents the design and creation of visual products, including maps, charts, and tabulated reports, representing the results of the analysis component. This requires skills in cartographic design and computer graphics applications. The skill level is different from the data input or analysis components, and many of the skills are intuitive and can be self-taught.

Figure 3
A GIS Database May be Conceptualized as a Stack of Floating Maps
Registered to a Base Map

Role of GIS in the MIS

From the above discussions, it is apparent that GIS represents a functional information system, having components that extend throughout the entire spectrum of a MIS, each associated with a different management level, and incorporated into each of TPS, MIS, DSS, and EIS activities as illustrated in Figure 4. Basically, the data capture component of a GIS is handled primarily by the TPS as well as the MIS activities within the operational management level. Data capture at this level involves the accumulation of both internal and external data, and its conver-

sion into map layers to create the GIS database.

The data retrieval and analysis of the map layers and information from the GIS database are managed within the tactical level of management, linked primarily to the DSS with support from MIS. The GIS analysis will involve modeling, overlay analysis, data query, the identification of goals, and evaluation of risks. Results and solutions obtained will become input in the decision-making process.

The output component of GIS is associated with the DSS and EIS within the strategic

Figure 4
The Comparison of a GIS (Data Input, Data Analysis, and Data Output)
and Their Relationship to TPS, MIS, DSS, and EIS.

level of management. In addition to performing the GIS analysis, DSS also involves the production of output results such as maps, reports, and graphical media in a form that can be easily and quickly retrieved by EIS. The EIS possesses the capability to access and display the information in a variety of formats, and the ability to interactively query the database to obtain instantaneous solutions to "what-if" scenarios.

GIS, MIS, and Decision-Making

In the 1980s, niche marketing made it essential to relate demographic data to consumer information to achieve a competitive edge in business. GIS provided marketers the ideal tool to associate such information within a geographic region. Using GIS, one can easily map a market area, and determine where certain defined demographic characteristics – age, sex, income, and race – overlap. To illustrate the application of GIS within the MIS of a business organization, an entertainment complex, based in St. Louis, Missouri, is presented. The object is to identify potential market areas as part of the input to advertising and marketing strategy. Critical data required for the analysis include both internal and external data.

The internal data relating to addresses and demographic profile -- ages and sex -- of customers are collected in its day to day operations and input into the database through the TPS. Incorporated to the TPS is the data input components of a GIS which is also responsible for the capture and incorporation of the external data such as demographic data as well as the existing infrastructure in the form of transportation network within the region served by the business. The GIS databases development is primarily a TPS operation with inputs from MIS.

A Case Study

The sample project for business application is an entertainment complex that serves an adult population. The complex includes restaurants, bars, and a variety of entertainments

ranging from pool tables to virtual reality computer games, offering a new generation of adults (often referred to as *Generation X*) an atmosphere of fun and games without having to compete with children and teenagers for access to the available resources. The target population is from 25 to 40 years old with a median household income of \$35,000 or greater. The scenario involves an evaluation of the current marketing strategies to see if in fact the target population matches the actual population of customers.

A survey of the customer-base for the establishment was obtained through membership records. The pertinent data required was the customer's zip code. The information was then coded into the database and linked to a map layer containing zip code boundaries for both Missouri and Illinois (Figure 5). Information regarding population age and income was then extracted from the available Census data (1990) by zip code and linked to the relational database for the study area's zip code boundaries. The census data for age was not divided into appropriate ranges for the initial analysis, so a new field of information was calculated by adding the total person for each zip code that fell between 25 and 40 years of age. The result was then divided by the total persons for each zip code to obtain a percentage of the population that was within the target age range.

At this point the project was ready for initial analysis. The customer base was plotted by zip code. In order to verify that the target population was correct, the customer base map layer was displayed by creating ranges for the median household income (0 – 12000, 12001 – 25000, 25001 – 34000, 34001 – 55000, and 55001 and greater). This allowed the database to be queried by these ranges to obtain a total number of customers that fell within the target income level. The results showed that only 46% of the customers were within the initial target population. The zip code database was also queried to determine potential zip codes that were not represented by the customer base that fell within the initial target population requirements. The results showed an additional eighteen zip codes in the surrounding

Figure 5
Customer Base for Entertainment Establishment

area that met the requirements. Based on the results of these queries, it is apparent that the target population criteria is not representative of the actual customer characteristics (Figure 6).

This led to a decision to determine "what if" the target population characteristics were modified? The initial analysis had shown that a sizeable percentage of the customers fell in the median household income range from \$25,001 to \$34,000. Therefore, a decision was made to modify the median household income requirement from \$35,000 to \$25,000. The results showed that a greater portion of the actual customer base (78%) was now being represented by the new target population characteristics. Finally, the zip code database was queried using the new target requirements to create a map showing areas that were not currently represented by customer base. This map identified a total of seventy-eight new zip codes which represent potential market that can be exploited through advertising or marketing strategies (Figure 7).

The above scenario illustrates how incorporating a GIS into an organization's MIS, data acquired through the TPS and maintained by MIS provides the critical information in the database from which the upper-level management can access through the DSS and EIS. In each of these systems elements of a GIS are included to facilitate the mapping and incorporation of the spatial aspect of the market analysis.

Conclusions

Business relies upon the use of Information Systems at different levels of management. The research demonstrates that GIS has an important role to play in business administration and the technology can be incorporated as part of MIS. To fully exploit this technology, personnel at different management levels should acquire expertise in spatial data manipulation and familiarity in GIS operations. Universities that have established curriculum in GIS are valuable sources to provide training and research support. The University of Memphis, for example, is currently developing a curriculum targeted at the

integration of GIS and Business, through a joint effort between the Department of Geography and the Fogelman College of Business and Economics.

Implications For Future Research

The next step in research is the evaluation of an integrated GIS/MIS in order to determine the level of increased productivity at all levels of management that use the MIS. Businesses that are interested in using GIS as part of their decision-making process will need to (1) evaluate investment costs, (2) training issues, and (3) develop an implementation strategy. Consultations with an expert in GIS are highly recommended for any organization seeking to implement this technology.

Endnotes

1. Readers should not confuse the field of MIS with the term 'MIS' indicated in item (b). The latter refers to one of the component information systems within the larger field of MIS.

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Figure 6
Results of Original Scenario

Figure 7
Results of the "What if" Scenario

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