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Geographically-referenced information for decision support (GRIDS): A study of spatial decision environments

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The University of Nebraska - Lincoln, 1987

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GEOGRAPHICALLY-REFERENCED INFORMATION FOR DECISION SUPPORT (GRIDS): A STUDY OF SPATIAL DECISION ENVIRONMENTS

by

Merrill E. Warkentin

A DISSERTATION

Presented to the Faculty of
The Graduate College in the University of Nebraska
In Partial Fulfillment of Requirements
For the Degree of Doctor of Philosophy

Major: Interdepartmental Area of Business

Under the Supervision of Professor Kenneth E. Kendall

Lincoln, Nebraska

August, 1986

TITLE

Geographically-Referenced Information for Decision Support (GRIDS) :

A Study of Spatial Decision Environments

BY

Merrill E. Warkentin, PhD

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GEOGRAPHICALLY-REFERENCED INFORMATION FOR DECISION SUPPORT (GRIDS):

A STUDY OF SPATIAL DECISION ENVIRONMENTS

Merrill E. Warkentin, PhD

University of Nebraska, 1986

Advisor: Kenneth E. Kendall

Every decision is performed in a unique decision environment comprised of objective and perceived dimensions. Objective dimensions can be metrically defined. The perceived dimensions of decision environments, including spatiality, are usually poorly-defined and ill-structured.

This exploratory study investigates the spatial decision environment through the design and implementation of two geographically-referenced decision support systems (DSS), which provide geographically-referenced information for decision support (GRIDS) to their users. The spatial decisions and spatial characteristics are fully analyzed. Decision-maker perceptions of the spatial decision environment are emphasized as critical elements of effective system design and implementation strategies.

Four spatial decisions in two organizations are explored in this study. One organization, the Nebraska State Patrol, is a public service agency which must deploy its limited manpower to locations throughout the state to

satisfy the goal of effective statewide traffic law enforcement. Additionaly, the Troopers who actively patrol the state's highways must continually decide where to position themselves in order to quickly respond to service calls and to effectively deter traffic law violations through visible patrol activities. A georeferenced DSS is developed for macrogeographic allocation, and information requirements analysis is performed for the other decisions.

The administrators of the other organization, a financial institution, wish to respond to the newly deregulated banking environment by opening a new branch bank facility this year. A geobased DSS is developed for this branch bank location decision.

The findings show that for decisions perceived to exhibit significant spatiality, unique systems analysis and design approaches are required. Spatial perception analysis is a necessary element of successful decision support system projects. Several decision contingencies exist for which appropriate system design and implementation steps can be defined. These spatial decisions characteristics are presented in a contingency model to be used as a framework of analysis for spatial decision support.

I wish to acknowledge the contributions of the many individuals at the Nebraska State Patrol for their assistance in the Manpower Allocation project. I wish to thank Sgt. Leon Cederlind, who was assigned to the Nebraska State Patrol Career Development Program during the Spring Semester 1986. His patient answers to my many questions helped me understand many aspects of the State Patrol organization and its functions. To Lt. Andrew Lundy and to Sgt. Jerry Petersen I owe a similar debt of gratitude. Their leadership in this project and their efforts to champion the cause of computer support within the Patrol administration deserve congratulations. Most importantly, I wish to thank the Superintendent of the Nebraska State Patrol, Col. Robert Tagg, and Lt. Col. John Buest whose leadership made this entire project possible. The other members of the State Patrol who contributed to the success of this project must also be acknowledged. Fred Oltjen contributed the timely reports from the Incident Reporting System, and other support with the computer needs of this project. John Little gave up his computer many times so that the model could be tested, demonstrated, and used. Jeannine Kohel and others at the Patrol also contributed to see that the model's interface was easy to use.

I owe a great debt of gratitude to the Chair of my Doctoral Supervisory Committee, Professor Kenneth E. Kendall. His encouragement, advice, and support were invaluable in this undertaking. His insight into the information requirements analysis, his critique of user-interaction functions and input/output design, and his direction in the overall systems analysis project were instrumental to the success of the Manpower Allocation Decision Support System for the Uniform Division. Furthermore, his assistance in organizing my dissertation research proved to be very significant. I also wish to express my appreciation for the contributions and support of the other members of my committee, Dr. Lester A. Digman, Dr. Marc J. Schniederjans, and Dr. F. Charles Lamphear of the University of Nebraska-Lincoln.

The staff of the Bureau of Business Research at the University of Nebraska supported the several phases of this research. Most notable is the help of my friend and colleague, Jerry Deichert, for his insight into the branch bank location problem, and of Mary Beth Barr for her expert clerical support.

Finally, there are others to whom I owe a great debt of gratitude. My best friend and wife, Kimberly, gave me constant encouragement and advice on all aspects of the project. She was much more than a proofreader. I would have been unable to complete this dissertation without her total support, understanding, and assistance. My other friends and loved ones also contributed with their patience and support. Most of all, I wish to thank the faith that my parents had in my abilities. Without their support over twenty years of formal education, including two years when my father was my teacher, I would not have succeeded in this, the pinnacle of my education. I want to thank all those who supported me in one way or another.

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Chapter 1

INTRODUCTION

Chapter 1. INTRODUCTION

Many decisions are made in an environment where spatial characteristics significantly affect the decision outcome. A problem arises from the systems analyst's inability to capture unstructured spatial data essential to the development of an effective decision support system. In this dissertation, the relationship between spatial information and the decision-making process is investigated. Several spatially-oriented decisions are explored through in-depth structured and unstructured observation, interviewing, and through the implementation of a geographically-referenced decision support system.

Decision makers in unstructured decision environments utilize different sets of data acquisition and analysis techniques, employ different implicit assumptions about their environments, and apply different heuristics to the same decision. Space and spatiality, as one perceived dimension of the decision maker's environment, is also perceived in different ways by different individuals.

Because of these differences in spatial perceptions and in the decision-making process, the decision outcomes may be inconsistent. One administrator may implement a decision substantially different from that of another administrator in the same situation. This can lead to uncertainty for those who implement these decisions and for those affected by the decision outcome.

Furthermore, because multiple decision outcomes may arise from the same set of variables in an identical decision environment, it follows that some of the decision outcomes may be more efficient, more effective, and/or more appropriate than other possible decision outcomes (even if none is "optimal"). Because of this potential for improved decision outcomes in unstructured spatial decision environments, it is logical to conclude that there exists a need for further investigation into this problem.

The author explores the relationships between the spatial and other decision data, the decision process, and the decision outcome in the contexts of environmental perception and spatiality. Attention is focused on how the decision maker perceives his spatial environment, what data the decision maker collects and considers in the decision-making process, and how they are being collected and used. This study shall also explore the question: Can this **data** be collected, organized and structured, compared and analyzed, and presented to the end users as **information** so that the decision is effectively supported? The systems analyst would seek to develop a technique which can be used to perform these data collection and information management procedures. How will this information be most effectively organized and presented so that it can improve decision making? What is the overall impact of the systems analysis process and its resultant geo-referenced decision support system on the decision, the decision makers, and the organization?

I. The Research Question

This study explores the following questions:

1. How do decision makers perceive their environment and the implicit and explicit decision variables? What are their spatial perceptions of that decision environment?

2. What are the spatial characteristics of decisions and decision variables and what are the relationships between the various components of the decisions?

3. How can the locational and spatial information useful for supporting the spatial decisions be brought together with the decision makers' assumptions and perspectives in an effective framework for decision support?

4. Can a tool be developed to help collect and organize spatial information that would be helpful in designing georeferenced decision support systems?

Several typical spatial decision problems are analyzed, their components are identified and described, a methodology for solving these problems is developed, and problem solutions (two decision support systems) are presented. In addition, a systems analysis and design technique for capturing spatial decision support data is presented in the context of the two cases and recommendations are presented for its adaptation and implementation. Conclusions are drawn and the research implications of the findings are discussed.

The Nebraska State Patrol must make two separate spatially oriented decisions. The administration of the Patrol, which must allocate new manpower geographically in order to provide effective levels of service to the citizens of the state, is one primary group of decision makers under investigation. In addition, the many individual officers of the Uniform Division of the State Patrol, primarily at the ranks of Trooper and Sergeant, constitute another major group of decision makers under investigation. These officers spend much of their work hours making continuous decisions regarding effective positioning in order to enhance the safety of the state's motorists. In addition, they must constantly be available (in good position) to respond to calls for service.

A geographically-referenced decision support system is developed and implemented for the Nebraska State Patrol for use in assisting the administration officials of the Patrol in the task of allocation and reallocation of its Uniform Division highway patrolmen. The entire systems analysis and design process followed for this project is detailed and analyzed. The spatial characteristics of the decision, the spatial thinking of the decision makers, the complete requirements for the decision support system design, and the results of the implementation process are all explored in detail.

A second type of locational decision is introduced for a comparative view of spatial information and spatial decision support systems. A decision support system for branch bank location is presented and analyzed. This interactive geobased DSS assimilates the management perspectives of several decision makers into a consensus weighting of the spatial decision variables to yield clear, useful information in support of this strategic business decision.

II. Dissertation Overview

This dissertation is divided into six chapters. This first chapter is an introduction to and an abstract of the research project. The second chapter constitutes a review of the literature in the four primary contributory areas of theory: Decision Theory, Spatial Theory, Decision Support Theory, and Data Theory. The third chapter details two primary spatial decisions within the Nebraska State Patrol--the manpower allocation decision (at the macro and at the micro scale) and the "Trooper Patrol Positioning Decision" performed by the active Uniform Division officers. This chapter also recounts the experience of designing and implementing a decision support system for aid in the allocation of manpower within the Uniform Division.

The fourth chapter also discusses a spatially-oriented decision, the branch bank location decision, and the factors surrounding the decision environment. The decision to locate a branch bank facility in an outstate site is a strategic one for many of Nebraska's larger banks since the recent deregulation of the financial industry. This chapter discusses that decision and the decision support system designed for support in that decision.

The fifth chapter compares and integrates the three primary decisions, the decision makers, their characteristics, the two decision support systems, the recommendations for the third decision support system, and the need for Geographically-Referenced Information for Decision Support (GRIDS) in a comprehensive discussion of the spatial decision. The sixth and final chapter summarizes the dissertation, presents the conclusions of the study, and outlines the implications for future research.

Chapter 2

LITERATURE REVIEW

Chapter 2. LITERATURE REVIEW

I. Introduction

An eclectic group of established literature offers insight into the investigation of spatially-oriented decision making. Research into this broadly-defined subject benefits from at least four broad categories of theoretical background. Decision Theory and Spatial Theory provide the first two bodies of literature. Decision Theory offers insights into the processes of judgment and choice through models of human information acquisition and information processing. One facet of Spatial Theory fuses concepts from behavioral geography, ecological anthropology, and cognitive (ecological) psychology. A primary focus of this group of researchers is the analysis of human perceptions of space and the environment (cognitive mapping). Industrial location theory offers models of the logic driving the decisions to locate economic activity (especially industrial production) in the economic landscape. The literature on two other specific real-world applications of Spatial

Theory, manpower allocation and branch bank location, are presented.

Decision Support Theory, a relatively new area, grew out of the Decision Sciences, Management Information Systems, Computer Science, and Accounting. It concentrates on the efficient and effective support of decision making through the use of corporate models, simulation, data base management systems (DBMS), artificial intelligence (AI), expert systems, and other conceptual and technological innovations. Finally, the role of data in decision making is explored through a loosely integrated review of data theories and concepts. Data is characterized from a variety of perspectives, spatial data is discussed, and the new field of Geographic Information Systems (GIS) is discussed.

The role of explanation in science has been expressed by Meehan (1968):

> The fundamental cognitive task is to create patterns that can be imposed upon the incoming stream of perceptions in ways that will create understanding of what is being perceived and expectations that will follow -- and that will suggest ways in which man can intervene to alter the course of events for his own ends.

It is interesting to note that this description of scientific explanation is not unlike that of the decision-making task. The creation of "patterns that can be imposed upon the incoming stream of perceptions" is also the major design task of the systems analyst who builds systems to support unstructured decisions.

II. Decision Theory

Decision theory encompasses several bodies of literature which focus on the use and value of information in decision making. Decision theory centers on the action of information acquisition (from the environment), information interpretation (and some interesting biases in this process), and the process of evaluation and choice between alternative decision outcomes.

A. Cognitive Behavioral Psychology

Slovic and Lichenstein (1971) define spatial judgment behavior as behavior which includes evaluation of spatial alternatives, choosing among spatial alternatives, or decision making with respect to spatial alternatives. Behaviors of this type which interest cognitive behavioral geographers are those in which spatiality is a characteristic of considered variables, the response, or of one or more of the consequences of the response.

Robin M. Hogarth, in the comprehensive work, Judgement and Choice: The Psychology of Decision (1980), provides a framework for viewing the decision process. Figure 1 from his book is a diagrammatical presentation of his decision process theory.

Hogarth defines the decision as a process of analysis, judgment, and choice. The decision analysis includes structuring the problem, assessing consequences, assessing uncertainties, evaluating alternatives, performing sensitivity analysis, information gathering, and choice.

Hogarth describes the problem-structuring activity as one which identifies the decision maker(s), the decision alternatives, the dimensions for evaluating the alternatives, the key uncertainties, and the level of detail for the problem. Each subsequent step in the decision analysis process depends on the way in which the problem is originally structured.

Each individual will view the decision in a unique way because of his or her own experiences and subjective "built-in" biases. (Hogarth, 1980) Among the types of biases he describes are the information acquisition bias and the information processing bias. Selective perception is one type of information acquisition bias. (Hogarth,

1980) Descriptions of this bias include the following examples.

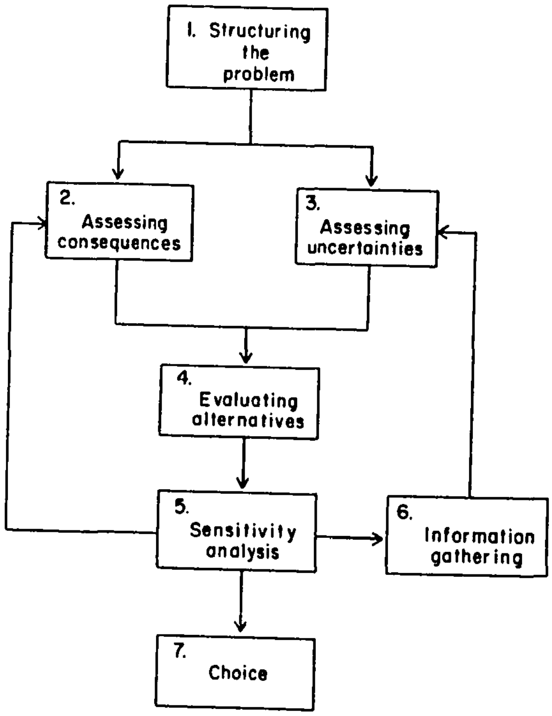
1. People structure problems on the basis of their own experience.
2. Anticipation of what one expects to see biases what one does see.
3. People seek information consistent with their own views and hypotheses.
4. People downplay or disregard conflicting evidence.

The "decision environment bias" is one form of information processing bias. (Hogarth, 1980) Hogarth states that perceptions of decision environment complexity are induced by time pressure, information overload, and distractions. These perceptions of environmental complexity can lead to reduced consistency of judgment. Emotional stress and social pressures can also cause biases through affecting the selection of information and the distortion of judgment. Hogarth (1980) presents many other examples of decision biases which are useful concepts for the systems analyst to consider.

Figure 1

Simplified Flowchart of the decision analysis approach

(Hogarth, 1980, p. 131)



B. Decision Making and Information Theory

Bonczek, Holsapple, and Whinston (1981) acknowledge the role of information in decision making. In the context of decision support systems, which they define as the information-processing system imbedded within a decision-making system, they use the terms "decision making" and "information processing" in similar ways. This imbedded DSS "may be a human information processor, a mechanical information processor, or a human-machine information processing system." (Bonczek, et al, 1981) Managers, as decision makers, are information processors. Decisions are the "finished products" of human-machine information-processing systems. (Bonczek, et al, 1981) Another view of decision making and information concentrates on the differences between programmed and nonprogrammed decision making. (Simon, 1960) Yet other authors have described decision making as a multi-stage process of problem identification, evaluation of decision alternatives, and selection of the best alternative (the decision outcome). Other aspects of decision making and information processing are discussed in the section above, the decision support systems section below, and throughout this work.

Watkins (1982, 1984) has investigated the decision maker's perceptions of information structure. He has shown that decision makers can be identified and classified into groups based on their perceptions of the underlying structure of information. (Watkins, 1982) He also used multi-dimensional scaling (MDS) to generate "preference maps" of the subjects' unique information perceptions. He explored the use of this perceptual knowledge to tailor the decision information to the users of decision support systems.

Research in the field of accounting information systems has also contributed to our understanding of the value of information to decision makers. The economics of information are an important consideration when justifying an information-processing system for decision support.

Simon (1960) has defined cognitive style as "the characteristic, self-consistent mode of functioning which individuals show in their perception and intellectual activities." Some individuals utilize a more analytical decision style, while others employ a less-structured, heuristic decision-making process. The decision maker's cognitive style affects the way that information is perceived. (Blaylock and Rees, 1984) The same environment will be perceived in different ways by different members of the group. (Watkins, 1982) The view of incoming information is affected by the decision maker's information acquisition and information processing biases. (Hogarth, 1980)

Individual decision makers have different information needs. (Watkins, 1982; Blaylock and Rees, 1984) Some persons require a greater volume of information, whereas others will make their decision based on a more limited set of information. "The value of information cannot be effectively evaluated apart from the users of that information. There is no sense providing information to a decision maker whose cognitive make-up is such that he or she will ignore it." (Blaylock and Rees, 1984) The type of information which is required for decision support varies as well. (Wright, 1979) There is some disagreement on whether individual decision makers can identify the type of information that they need. (Blaylock and Rees, 1984) These complex and important relationships must be further taken into consideration in the field of spatial perceptions of decision information.

III. Spatial Theory

Spatial Theories are closely associated with much of the conceptual framework of Decision Theory. The work of many cognitive behavioral psychologists, for example, could be logically placed in either category. In addition to the theoretical support from such groups as behavioral geographers and ecological anthropologists, this section describes the practical-oriented literature in the spatial decision arenas of manpower allocation and branch bank location.

A. Space as a Framework of Thought

Space is an essential framework for the thought process. All modes of thought--scientific, symbolic, metaphysical, and even unstructured modes--utilize spatial and temporal orientation. Space and time simply provide a fundamental ordering system uniting and interconnecting every aspect of human thought. While this description may seem like an obvious statement of fact, it deserves an in-depth analysis in the context of decision making.

Sack (1980) tells us that space cannot be isolated from the events. Space is not only linked to things and events through their location in space, but also serves to provide significant spatial properties of these things or events. Space is a "system which is conceptually, not actually, separable from facts and their relationships." (Sack, 1980) It is the perception of space and spatial relationships which affects the human thought process and decision making. "Human beings employ mental models of the world to organize their spatial behavior." (Burnett, 1976) These mental models, also called "mental maps" (Gould and White, 1974), include spatial characteristics which are unique to each person. "Different conceptions of space arise because this conceptual relation and separation can occur at different levels of abstraction and from different viewpoints and modes of thought." (Sack, 1980) Each individual has a different concept of space, and thus a different spatial framework for knowledge about the world.

B. Spatial Decisions and Their Environments

Many decisions occur in an environment in which spatial characteristics are significant to the decision task or will affect the decision outcome. Such decisions often include those faced by distribution network planners and managers, wholesale and retail warehouse and delivery managers, inventory managers, marketers and advertisers, pipeline operators, traffic administrators, community and regional planners, natural resource managers, soil conservationists, county assessors, zoning law administrators, fire prevention and firefighting professionals, and law enforcement agencies. The objectives vary (profit maximization, cost minimization, effectiveness, maximum delivery of service, visibility, etc.), and the scale of operations vary considerably from urban domains to decision environments with an international scope.

Yet these decisions all share space, location, or geography as a critical decision parameter. Many geographically-oriented decisions are well-structured; the decision variables and their relationships are easily identified, quantified, and built into a decision algorithm, which can often be performed with the support of a computer program. A mathematical model can be employed to perform the requisite computation, and the optimal solution can be used as the decision outcome. An example of this class of spatially-oriented decision is the classical Management Science Transportation Problem.

However, many other decisions must be made under conditions of uncertainty, with poorly-defined spatial characteristics, with imperfect understanding of the interrelationships between decision variables, and with spatial perceptual influences on the decision process. This class of decisions cannot be performed by algorithms; decision makers generally apply heuristics acquired through years of experience at making the decision in its specific environment.

C. Industrial Location Theory

Alfred Weber first explored the location of economic activity in 1909 in his book Uber den Standort der Industrien, translated into English in 1929. He attempted to explain the optimization of industrial location through the use of deductive models, and later through empirical methods. While Weber's contributions to the understanding of spatial decision making are undeniable, his theories were too constrained by limiting assumptions. In addition, his theories focused on static supply-side factors (raw material, capital, and labor locations), ignoring the dynamic nature of economic demand.

Edgar Hoover provided more advanced theories of industrial location by building on the work of Weber and Palander. His 1948 book, The Location of Economic Activity, and his other efforts presented numerous insights into the logic of spatial decision making. One of his critical contributions was the explanation of the role of transfer costs (at a trans-shipment point, such as a port or a grain elevator) in drawing production facilities to markets, to sources of materials, or to junction breakpoints in the transport network.

August Losch (1954), Melvin Greenhut (1956), Walter Isard (1956 and 1960), and others followed by continually adding to the body of knowledge. While these theorists developed useful, elegant models for explaining the decisions to locate various economic activities, and though they eventually applied empirical analyses to the theories to demonstrate their validity, they generally suffered from their underlying assumption of the "rational man." To assume that decision makers are pure optimizers is to totally disregard the complex behavioral and socio-cultural aspects of decision making.

Pred (1967) succinctly stated this position:

> Every locational decision is viewed as occurring under conditions of varying information and ability, ranging at least theoretically, from null to perfect knowledge of all alternatives, and as being governed by the varying abilities (as well as objectives) of the decision maker(s). . . . The apparently chaotic qualities of the spatial distribution of most manufacturing production . . . is ascribable to the fact that the real-world is populated by a broad spectrum of bounded rational, satisficing locational actors and not by undifferentiated profit maximizers.

Massey (1979) also concluded that industrial location theory cannot itself account for spatial behavior. These and other researchers have explained spatial decision making as a perceptual-behavioral phenomenon. Hamilton (1974) points out that locational choice is often a by-product of a particular policy designed to achieve some nonspatial goal.

Of special interest to the MIS researcher is the work of Tornqvist (1970) and of Lloyd and Dicken (1977). These writers stressed the influence of information levels on the location decision. Tornqvist analyzed the placement in relation to communication flows whereby information is disseminated and received. He called these "contact systems." Lloyd and Dicken explored the way in which information flows (from the environment) are filtered by the individual's perceptual process ("coding mechanism") depending on geographic location and other conditions.

The site location problem has also been an important subject among small business managers. The location of a new business, especially in retail trade, is often the primary source of credit or blame for the success of the venture. The LMMD model is one developed for determining an optimal location for a small retail business. (Rudd, Vigen, and Davis, 1983) Many techniques have been employed to analyze site alternatives and to choose an optimal site for economic activity. Goal programming has been successfully applied to the problem of site location for a midwestern trucking firm. (Schniederjans, Kwak, and Helmer, 1982)

Hayes and Wheelwright, in the book Restoring Our Competitive Edge (1984) and in numerous articles (Hayes and Abernathy, 1980; Hayes, 1981; Wheelwright 1984a, 1984b), identify several potential causes of the decline of the U.S. role as the world's industrial leader and focus on what they consider the most probable cause--the lack of understanding that U.S. managers have shown in recent years of the manufacturing component of the organization. Their works focus on the strategic management of the firm's manufacturing component to achieve competitive advantage.

In developing the concept of manufacturing strategy, they discuss how every one of a company's strategic business units must define how it will achieve a competitive advantage in the business in which it has chosen to compete. The authors describe a manufacturing strategy as consisting of a sequence of **decisions** designed to allow the company (or one of its units) to achieve that desired competitive advantage. Furthermore, they say that in order to become a significant competitive weapon, manufacturing strategy must not be developed **in response to** the broader SBU strategy, but that manufacturing must play a key role in the **formulation** of the broader business unit strategies rather than merely in the **implementation** of those strategies. The manufacturing organization must **contribute** to the business strategy.

They present and develop eight manufacturing strategy decision categories in the context of their contribution to the organization's survival. These eight categories are:

1. Long-term capacity (amount, timing, type),
2. Facilities (size, location, specialization),
3. Process technology (equipment, automation, linkages),
4. Vertical Integration and sourcing (direction, extent, balance),
5. Workforce (skill level, wage policies, job security),
6. Quality (defect prevention, monitoring, intervention),
7. Production Planning & Materials Control (sourcing policies, centralization, decision rules), and
8. Organization (structure, control/reward systems, role of staff groups).

These decision categories include spatial decision components, especially for categories #2, #4, and #5. They discuss the role of strategic management in selecting an industrial location. Manufacturing facilities, sourcing and supply questions, centralization versus decentralization issues, and inventory management are some of the other strategic factors which have important locational dimensions.

The use of the manufacturing principles which they advocate will allow the corporation to improve its ability to exploit its competitive advantages. But more importantly, the use of these principles, when combined with a new approach to manufacturing decision making, will give the firm a new strategic weapon. Because some of these decisions are spatially-oriented, spatiality can be a significant component of a firm's strategic management decision environment. Hayes and Wheelwright stress that these spatial decisions must fit the SBU-level strategy; they must support the competitive advantage. The development of geographically-referenced decision support systems to support spatial strategic management positions will help the firm develop a competitive advantage.

D. Manpower Allocation Models

Studies of manpower allocation have been conducted from a variety of academic perspectives. Probably the most common form of manpower planning model is based on management science techniques. In an excellent summary of the state of the art in manpower planning, Edwards (1983) presents the most notable models from the British and

American literature. The works of numerous researchers who have applied management science techniques such as multi-objective goal programming to the problem of efficient allocation of human resources are discussed in his review.

Lee, Franz, and Whynne (1979) used an integer goal programming model for allocating Nebraska State Patrol troopers to road segments within the troop areas. This sophisticated model, an interesting application of management science, is not being used by the Nebraska State Patrol today because of what the authors themselves admit is an inflexible design (Lee, Franz, and Whynne, 1979). The model cannot take into account the unusual overlapping ten-hour shift assignment scheme employed by the Nebraska State Patrol. Furthermore, the model is based on historical data; thus "it must be modified regularly using up-to-date data and revised priority structures in order to assure that the current solution remains valid." (Lee, Franz, and Whynne, 1979) This periodical updating in order to maintain effective decision support is not a feasible task for untrained users of sophisticated management science models.

Goal programming models have been developed for sales effort allocation (Lee and Bird, 1970), for research and development selection and manpower allocation (Taylor, Moore, and Clayton, 1982), and for other manpower-related allocation tasks. Another notable management science model used for manpower allocation was developed by Zanakis and Maret (1981) for use by the Florida Highway Patrol. Other mathematical models for human resource planning are reviewed by Price, Martel, and Lewis (1980). Other manpower planning techniques are based on various simulation languages. The MANPLAN model (Miller and Haire, 1969) and similar models, such as WASP, PROSPECT, and COMSHARE (Price, Martel, and Lewis, 1980), use various simulation techniques for manpower planning.

Many others have applied a variety of methodologies to the problem of manpower allocation. The manpower planning application presented in this project is based on decision support theory. Unlike the algorithmic models discussed above, decision support models do not attempt to provide concrete optimal allocations. Instead they are based on providing useful decision support information or are based on heuristic procedures aimed at producing good results. Maybe the best example of this heuristic-based model is the Minimum Slack Time Heuristic (MINSLK) discussed by Davis and Patterson (1975). Another heuristic tool for constrained allocation is presented by

Wiest (1967). A decision support system for human resource management used for activities in a data processing center is presented by Chan (1984).

Resource allocation in a not-for-profit organization is discussed by Daft (1978). Clearly the absence of the profit incentive confers a different overall framework for manpower planning. That is, while profit maximization is the ultimate objective of every decision for the rational business decision maker, the managers of not-for-profit organizations are ultimately motivated by other objectives. State and local governments, in particular, have special information needs. (Hughes, 1984) These organizations must comply with fiscal mandates and remain financially viable, while trying to manage resources in such a way as to provide the services for which they exist. Decision support systems developed for governmental agencies "can only be responsive if the information need at each level of management is fully recognized." (Hughes, 1984)

For public service agencies, there exist unique decision characteristics that are worth considering when attempting to analyze the manpower allocation decision. (Henderson, 1980) A logical beginning point is the identification of the proper organizational effectiveness measures. (Jobson and Schneck, 1982) The basic problem of public service organizations is not high costs (efficiency), but the lack of effectiveness. (Drucker, 1973) People view many public service agencies as bureaucratic, mismanaged institutions. (Drucker, 1973)

"Designing a solution to a public sector problem is largely an art." (Brill, 1979) The goals, perspectives, and organizational dynamics are often different than those usually encountered in profit-motivated organizations. When designing decision support systems for public sector organizations, the analyst (the artist) must give special attention to how the decision aids support effective learning. (Hammond, 1980) "Without effective learning support dysfunctional consequences are likely to result from policy-making processes." (Henderson and Schilling, 1985)

Eaton, Daskin, Simmons, Bulloch, and Jansma (1985) developed a very cost-effective program for the allocation and deployment of emergency medical services vehicles in the high-growth urban environment of Austin, Texas. The multi-million dollar savings documented by the city were the result of computer modeling of the spatial decision landscape. This technique can also be applied to law enforcement vehicle deployment.

For law enforcement agencies, there are further unique decision characteristics that must be considered when allocating police and patrol officers. Organizational effectiveness measures must first be identified. For law enforcement agencies, many researchers have used internally-generated effectiveness criteria (Goodman and Pennings, 1977a, 1977b; Perrow, 1977; and Scott, 1977) rather than measures which come from the agency's constituents, its clients and the general public. Whether or not organizational effectiveness is a necessary performance criteria of the manpower allocation model, the system developer should give some consideration to the organization's overall success.

Another author has proposed using the police officer's knowledge of his beat as an indicator of both employee and organization performance. (Mastrofski, 1984) This recommendation is based on studies which show that police officers actually do more than **reactively** deal with crime. When an officer knows his beat well (or when a Nebraska State Patrol trooper knows his patrol area well), he can be a more effective **proactive** player in the criminal justice landscape. In other words, one can prevent crimes by knowing where they are likely to occur.

The research in this study clearly shows that Nebraska State Patrol troopers can reduce the incidence of traffic violations by targeting specific road segments known to experience excessive numbers of violations and/or traffic accidents. The Nebraska State Patrol Policing By Objective (PBO) program, in which statistically dangerous areas are targeted for extra patrolling, has proven to be an effective program for traffic violation reduction.

Manpower allocation models and decision support systems developed for law enforcement agencies require special attention to the internal political mechanisms of these organizations. The organizational structure of the Nebraska State Patrol is shown in Appendix A. Because many of these agencies are structured like military organizations, the systems analyst would benefit from using the military institution as a beginning model of the organization. Furthermore, some specific system implementation strategies should be followed for this environment. (Kendall and Warkentin, 1985)

Law enforcement manpower allocation and resource allocation decision support has been developed according to several methodological constructs. Saladin (1982) presents another *goal programming* approach to police patrol allocation. Bres, Burns, Charnes, and Cooper

(1980) use a goal programming model for planning officer accessions. The work of MGT of America (1980), of Zanakis and Maret (1981), and of Zanakis, Gupta, and Kyparisis (1985) for the Florida Highway Patrol was based on operations research and forecasting techniques. Markovian goal programming and algorithms for predicting the location and volume of traffic violations were based on historical traffic citation data. While this system offers useful techniques for patrol manpower allocation, interviews with Florida Highway Patrol members indicate that the system is not currently being used to support the administration's allocation decision.

Heller, Markland, and Brockelmeyer (1971) explored an innovative approach to optimizing patrol beats. They used a political districting algorithm to partition the police districts in St. Louis. Foster and Gorr (1986) look at demographic variables to predict criminal activity distributions. They apply a filtering mechanism to estimate the model parameters for police response times.

The Nebraska State Patrol utilizes a Policing By Objective (PBO) system for targeting specific road segments known to experience high accident rates. Management By Objective (MBO) systems for overall patrol administration, including for manpower allocation, have been described by Shanahan (1975). The Virginia State Patrol has recently completed the first stage of a patrol planning and allocation study to develop an effective allocation tool. (Schuiteman, 1985) The Illinois Department of Law Enforcement has also developed a model for patrol manpower allocation. (Raub, 1984, 1985) This model suffers from several mathematical problems stemming in part from the extremely different spatial landscapes in the state of Illinois. The parameters used to allocate Troopers in rural Illinois cannot be used in and around Cook County (Chicago).

Nebraska has investigated the manpower allocation problem for several years. Ritter (1983), Ueling (1984), and Winkler (1985) laid the foundation for the information requirements, the structure, and the objectives of the geographically-referenced decision support system developed by the author for this project.

E. Branch Bank Location Theory

Recently, states have enacted legislation which makes it possible for banks and savings and loans to open new branch offices in other cities. These events have altered the decision-making environment of financial institutions. Branch bank-enabling legislation has introduced new factors into the marketing and planning departments' scope and has presented a new challenge to the players of the increasingly competitive banking game.

Choosing a location for a branch bank has become a new decision for many financial institutions, one for which they have not gained substantial experience. Because this decision affects the revenues, operating costs, and capital costs of the organization, it usually becomes the responsibility of the top-level management. But because the addition of a new branch is designed to attract new customers and because locational convenience for the customer is considered to be a product offered by the bank, the decision may be regarded as a marketing function, especially when it affects revenues rather than costs (Adam and Ebert, 1978).

In the past decade, however, as states have deregulated the banking industry, banking officers have increasingly utilized quantitative, analytical methods for selecting the sites of branch banks, and researchers have proposed many such methods. Littlefield (1968) describes an estimation technique for future deposits and loans for a proposed bank office which utilizes certain household data and projections for future employment and residential growth. Olsen and Lord (1979) used regression analysis to determine local supply and demand levels in another effort to project deposit levels at potential branch locations. Other researchers (Lundsten, 1978) looked at market shares for banks rather than facility profits.

Davidson (1969) utilized an elegant Management Science model to demonstrate its application to locating branch banks. Sloan (1981) uses a computerized branching model to analyze the decision. Bell and Zabriskie (1978) demonstrated the use of computer mapping to generate a visual representation of locational potentials. Alexanderson (1969) presented a thorough framework for analyzing and applying Census data to the location decision. Bauhoffer (1973) also suggested ways in which Census data could be employed.

Lord and Wright (1981) applied spatial association measures to determine the proximity (and clustering) of potential competitor banks. Finally, Soenen (1974) reviewed the use of gravity models and discussed the relevant quantitative factors of decision making with respect to bank location. For additional discussion of techniques and literature see Love and Deichert (1983).

These models and techniques have made an important contribution to the pursuit of effective branch site decision making. Yet many of these models ignore most non-quantitative aspects of decision making. Though the success of site selection can be improved through the use of quantitative models, potentially injurious mistakes can be made when experiential knowledge, organizational politics, corporate culture, individual perspectives, and other factors are ignored.

IV. Decision Support Theory

The subjects of decision theory and decision support theory cannot be easily divorced, of course. The discussions in the preceding section referred to decision support systems. They are are also further defined in the section on data and information below. Decision support theory is a practical-oriented group of concepts, prescriptions, research conclusions, and techniques for the support of managerial decision making at all levels. The different techniques differ in their focus, their targeted user groups, and their technological characteristics, but the objective of all systems is the effective support of the decision maker.

A. Management Information Systems

Management Information Systems (MIS) were designed to support operational decisions such as those encountered in inventory management, payroll, accounting, order processing, and so on by efficiently providing uniform, timely information to the individuals who use it in their decision-making process. Management information systems present data to the decision maker in a specified structured form as defined by the system developer. The study and development of MIS have benefited from the research and techniques of the decision sciences (Kendall and Kriebel, 1982), of behavioral scientists, and of many other contributors. The field has grown to include the study of decision support systems, strategic information systems, expert systems, and other systems discussed below.

B. Decision Support Systems

Decision support systems (DSS), a term coined by Peter G. Keen and others at M.I.T. in the 1970s, describes information systems designed to facilitate problem solving in unstructured and semistructured decision environments. A decision support system is essentially a way to effectively organize and present information to aid decision making. In addition, DSS are interactive (Little, 1979; Watson and Hill, 1983), combine analytic techniques and decision models with easy access to relevant data through the use of database access and retrieval capabilities (Sprague, 1980; Watson and Hill, 1983), and are designed to be evolutionary (Courbon, et al., 1979), flexible, and adaptable (Keen, 1980; Sprague, 1980). Furthermore, because DSS are designed for unstructured decisions, often in dynamic environments, the users must be more involved in the development process (Mann and Watson, 1984). Decision support systems can automatically perform some functions and can interact with managers to perform other functions (Rockart and Crescenzi, 1984).

While MIS were designed to support operational decisions, DSS were designed to support less-structured, underspecified problems such as market strategies, site selection and analysis, major equipment purchase decisions, divestiture and acquisition strategies, and so on. These decision environments are dynamic, uncertain, qualitatively-defined, and unbounded. Many design prescriptions have been presented in the literature. One of the most notable ones, used in this project, is Alter's taxonomy of decision support systems (1977a, 1977b). This flexible design approach, in which the designer sketches systems of various types to support the decision, enables the system design to benefit from multiple perspectives of system support.

The field of decision support system theory is continually evolving. Valuable current research is being conducted into the benefits of various designs, implementation strategies, factors contributing to system success, and other DSS-related topics. Much of the useful knowledge about DSS comes from the applications which are being generated at an increasing pace each year. The DSS practitioners have added much useful information about the field. Various aspects of decision support systems are discussed throughout this report.

C. Strategic Information Systems

Effective strategic management requires timely, relevant strategic information. (King, 1978; Rhyne, 1984) The traditional Management Information System (MIS), which supports operational decision making, cannot provide the informational support demanded by strategic decision makers. (King, 1978; Beer, 1980; Hirouchi and Kosaka 1984) This information must be collected, managed, and presented by a well-designed Strategic Information System (SIS).

Because the objectives and functions of the SIS are divorced from those of the MIS, it requires unique design, implementation, and administration activities -- independent of the MIS. Design features are contingent on many organizational, personal, and environmental factors. The SIS must be designed and implemented so that the characteristics of the organization and its members are congruent and compatible with the characteristics of the system. The firm's external environment will also determine what form the system's functions and procedures must follow in order to succeed.

The core of the SIS consists of information storage hardware, information management software, retrieval and analysis software, procedures and guidelines, and individuals whose primary responsibility is strategic information administration. Specific tasks include acquiring, processing, evaluation, analysis, compilation, and presentation of the strategic information. This core is bridged to other individuals, systems, and organizational divisions by both formal and informal relationships. The design of the strategic core must facilitate the flow of information into the system through formalized, standardized procedures and processes and through ad hoc measures. Without the insurance of formalization, the danger of strategic information omission increases. The design and implementation of the formalized procedures are the most critical determinants of an SIS's success.

One aspect of the firm's environment, the level and type of environmental uncertainty (see, for example, Thompson, 1967; Duncan, 1973; Jurkovich, 1974; Leblibici and Salancik, 1981), should play a key role in determining the proper design of SIS features. The first SIS design feature which demands considerable attention is the strategic information gathering function. Procedures for the collection of strategic information must guarantee the assimilation of all information concerning states of the environment which have been identified by management as determinants of threats and opportunities. That is, if the ideal conditions for a computational decision strategy are met (Warkentin and Parker, 1985), the SIS must be designed so that the identified sources of environmental information are vigilantly monitored.

But when cause and effect relationships are not estimable and judgmental decision strategies are employed, the monitoring and collection function must be expanded to acquire a greater volume of information (Warkentin and Parker, 1985). This function must be designed in an even broader configuration when diversity increases and bargaining strategies are required. This condition might be typified by a firm which is expanding its geographic market. Lastly, under conditions of extreme diversity and volatility, when inspiration decision strategies must be followed, the environmental sensing function of the SIS cannot be bounded by any limitations (Warkentin and Parker, 1985). Management must be allowed to seek any and all environmental information which is specified; the SIS must be designed to be flexible and responsive. The SIS can still be structured so that the strategic information can be efficiently stored and retrieved, the presentation of the information can still be effectively matched with the characteristics of the system users (friendly interface, etc.), but the source determination and the filtering procedures cannot be designed to follow any prescribed algorithms.

If massive information collection and storage can be performed at low cost, it may be effective for the system to be designed for maximum environmental sensing. Selective retrieval and presentation could then afford the planners a concise view of the environment while allowing for expanded perspectives as requested. However, the costs of information storage, while declining at exponential rates at present, must be economically justified. The costs associated with gathering, storing, and analyzing specific strategic information, which are great considering the diverse nature of the sources, must be compared with the long-run (mostly indirect and intangible) benefits of that information.

At one extreme, the firm could employ limited procedures, expend minimal resources, and collect minimal levels of strategic information, concentrating on information which is perceived to exhibit strong cause-and-effect relationships with organizational success. This strategy might be appropriate where a computational decision strategy is possible. At the other extreme, a firm could engage in extensive problem sensing, issues analysis, and environmental scanning, choosing to assimilate and analyze the greatest amount of external information which might have a (present or future) impact on the firm. Clearly, this strategy would require massive expenditures to support. Most firms choose to employ an intermediate approach; acquiring and analyzing most available critical information, some potentially critical information, and little or no noncritical information. Yet a means for determining these categories of information is needed. A careful analysis of the objectives of, methods for, and costs associated with the SIS information collection and filtering procedures is a critical element of the SIS design and development activity.

Another function of the SIS is the effective analysis and filtering of incoming information so that it can be presented to the planning committee and strategic decision makers. Analysis of the strategic information refers not to the actions of the planning body, but to the automated "processing" of the strategic information by the system. Incoming information must be combined and compared, correlated with other internal and external information, conditionally rejected, and prepared for presentation to the system users. The procedures by which the system analyzes and filters the information must be consistent with the decision style and perspectives of the users of that information. Group and multiple-individual decision environments require unique approaches to filtering system design; a multi-user SIS must utilize a decentralized, multi-criteria information analysis system.

The filtering and analysis function must not only match the perceived cause-and-effect relationships, it must be responsive to user queries. Certain information may be identified as having a critical impact on a firm's strategic position, such as consumer preference surveys or the actions of governmental regulatory agencies and competitors. Yet while the planning committee should be buffered from information overload by the filtering mechanism, they must be allowed to easily acquire other information which they seek to analyze. The advent of the microcomputer-based Decision Support System has facilitated this on-demand, ad hoc environmental analysis objectives (Keen and Morton, 1980).

D. Systems Analysis and Design

Systems Analysis and Systems Design are approaches used by the professional Management Information Systems analyst which include useful tools and techniques for the construction of effective decision support. The systems analysis approach, as opposed to the trial-and-error approach, is a structured process of identifying system influences and constraints, and evaluating these components in terms of their impact on "decision points" in the system (FitzGerald, et al., 1981) "A decision point is that point in a system at which some person or automatic mechanism must react to input data and make a decision." (FitzGerald, et al., 1981) Effective systems analysis and design incorporates a keen understanding of the behavioral, social, technical, and other characteristics of the organizational system. In other words, understanding the people in any social system, such as a human-machine information processing system (a corporation or agency), is critical to successful systems analysis and design.

There are many techniques used by the systems analyst to gain a thorough understanding of these social relationships, the flows of data, the use of information, the decision processes and decision style, the organizational structure, philosophy, objectives, and policies, and the organization's internal and external environments. These include the interview and observation. These two tools can be used in many ways. The advantages and disadvantages of structured interviews and structured observation are discussed elsewhere in this paper, but the systems analyst must use a high degree of care and caution when drawing conclusions about the dynamics of the system when using any systems analysis tool. There are also systems studies, such as "paper work studies," data flow studies, organization contact studies, and so on. Many of these tools can be performed in a combination of structured and unstructured ways.

The systems design process incorporates the knowledge learned from analysis of the business system to develop decision aids in all forms. The aim of any management support tool is to facilitate the coordination of managerial efforts toward the organization's goals and objectives. Effectively designed systems will ultimately support these goals and objectives. To do this, they must provide accurate, timely, and concise information to the right people in the organization. They should also convey clear information about the decision environment by decreasing environmental uncertainty. In addition, they must be able to grow with the organization, adapt to changes within the organization or between the organization and its environment. They should also increase the productivity (efficiency) and effectiveness of the organization's members at all levels.

E. System Implementation

1. Introduction

The management information system implementation process is drawing increased attention recently. While implementation is studied, and while researchers attempt to discover the factors associated with successful MIS implementation, millions of dollars are spent on developing systems which are not put to use or are not used as intended. (Welsch, 1981) While such systems must be considered implementation failures, Welsch's contention (1981) that they might be design and installation successes is disputable. Successful implementation must be considered a criterion for the success of each phase of the MIS life cycle. Indeed, implementation must be viewed holistically; it involves planning, design, and development. It is not simply the introduction of, or conversion to, a new information system.

2. Definitions

Implementation was formerly described as a basic process of organizational deployment. The process was said to involve "inserting the MIS product into the organization so intended benefits are attained." (Zmud, 1983) The conversion step was the only concern. More recently the academic community has begun to view implementation as an overall, continuous process which encompasses formulation, design, development and construction, testing, changing, and postaudit activities. (Roberts, 1977; Lucas, 1981; Lee, 1981; Zmud, 1983) Lucas (1981) states that implementation is "a process which occurs during the entire life cycle of a system." This greater characterization of the implementation process is discussed below in the context of organizational change and the Lewin-Schein model. (Lewin, 1947; Schein, 1961)

Another term which must be understood is "successful MIS implementation." When implementation was narrowly defined in the past, successful implementation would have been assumed once the system was deployed or introduced. The new, broader viewpoint demands that the system is being utilized. (Schultz and Slevin, 1975; Keen and Morton, 1978; Welsch, 1981) Furthermore, some authors choose to restrict the definition of successful implementation to cases which exhibit "improved decision making." (Schultz and Slevin, 1975) And finally, successful implementation of a decision support system

(DSS) has been defined in terms of 1) utilization, 2) "internalization" by decision makers, and 3) institutionalization by the organization including "continuing financial support." (Welsch, 1981)

3. Traditional versus Change Approach

The evolution of MIS implementation definitions accompanies changes in the real-world approach to implementation and in the academic study of the process. The earliest research was the result of the pioneering practitioners who derived several general implementation principles from their experience. (Keen and Morton, 1978) They often prescribed the correct action as being the opposite of the actions employed in failed projects. (Keen and Morton, 1978) Since the earliest implementation approaches followed the technical tradition (which focused on hardware, coding, testing, etc.), the early researchers emphasized gaining greater power to push the change onto the organization, or they advised development of "interpersonal competence" and sensitivity to the reaction of members of the organization. (Keen and Morton, 1978) Yet they ignored the contingency characteristics of MIS implementation; instead they sought general principles applicable to any implementation effort.

Another category of implementation research was the "factor approach," that used statistical methods to "define the general factors that seem to be associated with successful outcomes." (Keen and Morton, 1978) While many studies ascertained factors that enhance the likelihood of successful implementations such as top management support and user involvement, no overall implementation strategy could be deduced because different organizational and decision characteristics demand different approaches.

Practitioners and researchers began to consider the implementation of a management information system in the overall context of social change. There was a greater emphasis on the 'beginning and ending steps'; on initiation, strategic design, conversion, and evaluation. As practitioners focused on the perceptions and reactions of users, sponsors, and designers, theoreticians also concentrated on the **social** factors and interrelations which contributed to successful MIS implementation experiences. The Lewin-Schein paradigm of organizational change (Lewin, 1947; Schein, 1961) provides a useful context to examine these factors.

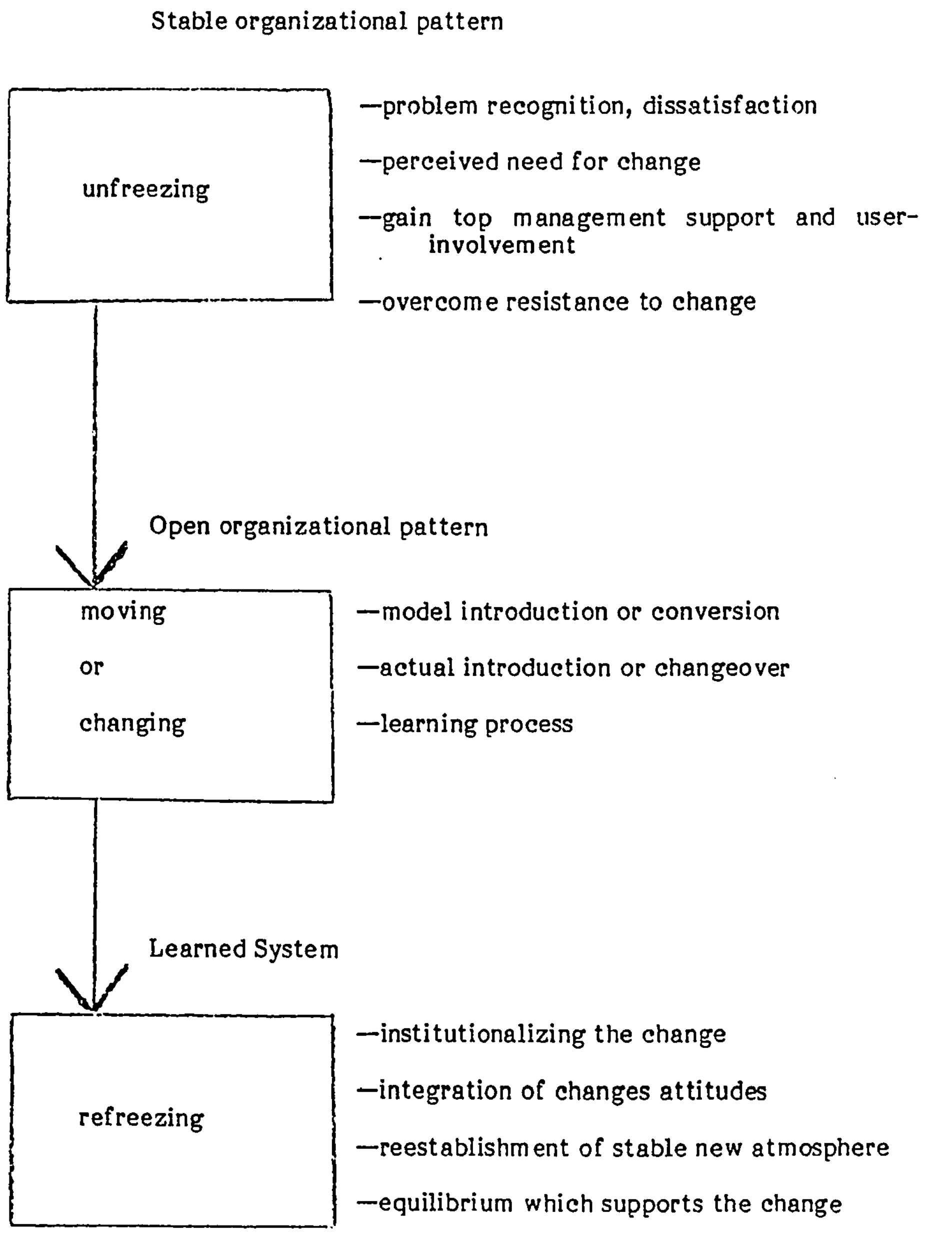
The organizational change process was divided into three steps: unfreezing, moving, and refreezing. Before a stable organization pattern could change (or be changed), they posited it must be "unfrozen" to produce a climate for change. Often this is manifested by managerial dissatisfaction, problem recognition, or a perceived need for change. Once the organizational pattern is open, the actual change, or "moving", can take place. In the context of MIS implementation, this step consists of system conversion or introduction. This step is a learning process; it always involves the learning of new activities, tasks, behaviors, relationships, or objectives. The "learned system" must then be "refrozen" to establish a stable atmosphere supporting the change. The learned attitudes must be institutionalized and a new equilibrium must be built.

For the MIS implementer, this means considering each step of the (implementation) change in order to guarantee success. The "unfreezing" step includes gaining top management support and involving the users in the design specifications and in the project development. To create the climate for change, the implementer may also need to

Figure 2

The Lewin-Schein Paradigm of Organizational Change

(from Lewin, 1947; Schein, 1961; and others)



overcome resistance to change. If the current environment positively recognizes and rewards productivity improvements, the MIS group can educate the new users as to the importance and power they may gain with more timely, accurate information.

The "moving" or changing step is the actual changeover activity. There are three typical situations into which an information system can be introduced; 1) no system is present at all, 2) an existing manual information system exists, or 3) an automated or computerized system is being used. Each of these contingencies merits a slightly different approach. Furthermore, when an existing system is replaced, several conversion strategies can be followed. These are discussed in detail in a later section.

Finally, the "refreezing" step is critical to implementation success; the change must be institutionalized. Tasks and procedures, once learned, must be reinforced and integrated into the organizational pattern. System appraisal, follow-up procedures, and redesign (if necessary) are important elements of ensuring successful implementation. This critical final step has often been ignored by outside consultants who may view installation as the last element of their involvement. (Lee, 1981)

The Lewin-Schein model provides a practical paradigm for analyzing the MIS implementation process. It is important for MIS practitioners and researchers to view MIS implementation from a broad organizational perspective. Success will result from strategies based on careful, holistic analysis of every aspect of the organization, its information needs, the decision, and the personnel.

4. Need for Implementation Strategy

Zmud and Cox (1979) stated that "there is no 'best' way to implement an information system," but they believed that the traditional approach is sufficient when implementing an information system that 1) automates a well-defined procedure, 2) is independent of other organizational systems, and 3) results in little organizational change. On the other hand, they tell us that the change approach is the preferred process when 1) the organizational activity involved is ill-defined, 2) the MIS must interface with other organizational systems, and 3) substantial organizational change is expected. (Zmud and Cox, 1979) This final consideration is especially important for "maturing MIS functions"--

strategic information systems, decision support systems, etc.

Markus (1983) discusses the need for implementation strategies to employ when resistance to MIS implementation has already been encountered. But she also discusses the interaction theory which "leads to a model of organizational analysis and diagnosis that can be used to design systems that do not generate resistance." The interaction theory is one of three theories used to explain why MIS are resisted by the users. The people-determined theory explains resistance as a function of factors internal to the user individuals or group such as personality traits, cognitive style, or resistance to change. The system-determined theory states that resistance is experienced because of factors inherent in the application or system being implemented such as technical deficiencies, lack of ergonomic design, or lack of user friendliness. The first theory would project rejection of all systems in an organizational setting where one system is resisted. The second would imply that a given system will be accepted or resisted in every setting because of its design features.

The interaction theory explains resistance as the result of interaction between people characteristics and system characteristics. For example, systems that centralize control over data might be resisted in organizations with decentralized authority structures; resistance might also arise from the interaction of technical design features of systems with the social context in which systems are used. This third theory indicates that resistance is neither desirable or undesirable. It "is not a problem to be solved so that a system can be installed as intended: it is a useful clue to what went wrong and how the situation can be righted." Markus' interaction theory implies a need for an implementation strategy based on a thorough analysis of the organization's characteristics. If implementation success is considered throughout the life cycle, then early diagnosis of the organization should lead to the design of a system compatible with that organization. This implies a contingency approach to system design and implementation.

Lucas (1978) also states that there is no formula for implementation success but he urges developers to "become more sensitive to the need for specifying what constitutes successful implementation, and the difficulty in doing so." Keen and Morton (1978) clearly state that implementation demands a "flexible, evolutionary strategy" and "enthusiasm and skill in design are not enough." This paper develops a framework of analysis which allows the information analyst/MIS implementer to select the appropriate elements of the implementation strategy.

E. Other Decision Support Techniques

In recent years, there have been several new techniques introduced for the support of management and administrative decision making. The growth of artificial intelligence (AI) has especially been noteworthy. AI encompasses such areas as expert systems, natural language interface, voice recognition technology, optical scanning, 3-D vision and visual pattern recognition, robotics, and expert systems. Natural language interfaces are new man-machine interfaces designed to utilize the "natural" languages (English and so on) that humans speak as the method of communication with (coding, programming, querying, etc.) digital computers. Expert systems are designed to recreate the unstructured decision processes of "experts," individuals with experientially-acquired knowledge about a particular field. (Hayes-Roth, 1983)

They provide a framework for capturing and organizing this knowledge into an expert knowledge data base to be used with a set of decision rules to analyze situations and generate an expert decision. These new decision support techniques, especially expert systems, offer much promise for future management support.

V. Data Theory

A number of theories contribute to the classification and understanding of research and decision data. Data can be classified by their source, their use, their mathematical or nonmathematical properties, and other properties. Verbal data, nominal data, ordinal data, and cardinal data can be gathered and manipulated in different ways. Some data is unsuitable for certain kinds of research. This section will focus on data as it applies to the Systems Analysis and Design process, on spatial data; on techniques for spatial analysis and for geocoding, and on several techniques for data analysis.

Davis (1974) clearly articulates the differences between data and information. Data are potential information. When data are used (processed), they are called information. Information can be conveyed by data; as an abstraction of data, it can be conveyed by a pattern of symbols, such as printed words, for example.

A. Classification of Data

All data represent measurement or description of some thing, event, fact, occurrence, phenomenon, activity, state (level), flow (rate), or position. This measurement or description can be metric (quantitative) or it can be nonmetric (or qualitative). "Nonmetric data are attributes, characteristics, or categorical properties that can be used to identify or describe a subject." (Hair, et al., 1979) Nonmetric data can be verbal, nominal, or ordinal, while metric data is cardinal (measured either on an interval scale or on a ratio scale). Qualitative (metric) data differentiate subjects with respect to amount or degree, and nonmetric data differ in type or kind.

Verbal data may be entirely composed of oral or written accounts, descriptions, portrayals, narratives, depictions, and characterizations. As such, verbal data may be very "rich" (or full of meaning), but may not be analyzed with any statistical techniques. **Nominal data** also do not represent numerical quantification of any phenomenon. As the name suggests, numbers on a nominal scale merely function as names for things. Nominal data is often used for classification purposes. For example, the numbers 0 and 1 often represent "no" and "yes" answers on coding sheet for a questionnaire. **Ordinal data** represent relative measurements of some research variable. That is, numbers on a cardinal scale indicate the relative ranking of various attitudes, priorities, preferences, and so on. A ranking of ten may be higher than a ranking of five (on scale from one to ten with ten being the highest), but it is certainly not intended to represent twice as much as five. Though it is not valid for ordinal data to be manipulated with linear mathematical and algebraic techniques (multiplication, sums, averages, and so on), there is a class of nonparametric statistical techniques developed for analysis of ordinal data. (Siegel, 1956; Senter, 1969)

Cardinal data, however, represent numerical quantification of a research variable or variables. Cardinal data can be based on either interval scales or ratio scales. Interval scales, such as the Fahrenheit temperature scale, are comprised of equidistant numbers. For example, 70 degrees is the same number of measurement units from 60 as it is from 80. Furthermore it is twice as far from 0 degrees as 35 is. But 70 degrees does **not** represent twice as much heat (or twice as much of anything, for that matter) as 35 degrees. The reference point of zero is quite arbitrary and does not represent an absolute quantity of zero. A true ratio scale is essentially an interval scale with an absolute zero point. This type of data allows the greatest flexibility in statistical analysis. Fifty State Patrol officers in one area is always twice as much as twenty-five officers. A ten mile linear distance from a source of a call for service is twice as close as a twenty mile distance (and would take half the time to traverse, assuming equal average response speeds).

B. Spatial Data

In addition to the distinction between verbal, nominal, ordinal, and cardinal data, there is yet another way to classify data. Some data have temporal characteristics; they refer to events (occurrences) in time (e.g., a sales transaction on December 21, 1985). Some data have size characteristics; they refer to the volume or magnitude of some variable, event, object, or force (e.g., the dollar amount of a budget). Some data have spatial characteristics; they refer to the location or position of some event, object, or force (e.g., location of major markets for a product). Other data have other characteristics. Each of these characteristics may be presented in either metric or nonmetric form. A primary emphasis of this project will be the spatial qualities of DSS data and information as they relate to the decision itself.

The literature on geodata treats spatiality as but one attribute of data. Calkins (1984) suggests that spatial data is comprised of image data and attribute data. Image data are "the coded values that describe the location(s) of the event or object," and the attribute data describe other characteristics of the event or object. For physical data storage and retrieval, this construct is sufficient. (See, for example, Lillesand and Kiefer (1979) on methods used by the Earth Resources Observation System (EROS) Data Center at Sioux Falls, South Dakota to store remotely-sensed telemetry such as Landsat satellite image data.) However, when designing a system to support decisions for which spatiality and the users' perceptions of space are critical elements of the global decision environment, an alternate design perspective must be adopted.

The geographic or spatial characteristics of some DSS input data can generate output information which has significant spatial characteristics. Indeed, in certain decision environments, this spatiality can become critical to the outcome of the decision. Without careful referencing of the data's spatial or geographic characteristics, the results of the DSS may be misleading, inaccurate, or useless.

For decision environments with important spatial characteristics, there exists a critical need for geo-referencing and geocoded data. Without the spatial relationships between these DSS variables, the information generated by the DSS may lead to ineffective decision making by the user.

Hayden (1983) presents the theoretical background for developing geobased data systems as tools for evaluating environmental problems. Other authors have discussed the need for geobased decision models. (Hamilton, 1974; Massey, 1979; Kendall, 1980a, 1980b; Hayden, 1984) Techniques for the collection, organization, and analysis of geo-referenced information would contribute greatly to effective decision making and policy formation in many environmental settings in many applications. The development of this useful systems analysis and design tool would clearly represent a major contribution.

C. Geocoding Methodologies

The task of geocoding information has been primarily the work of practitioners. Much of the literature concerning the techniques and issues in geo-referencing of various data types appear in technical reports, U.S. Bureau of the Census sources, and practitioners' journals. The major components of a geographic information system (GIS) are its data input system, a data storage and retrieval subsystem, a data manipulation and analysis subsystem, and a data reporting subsystem. (Marble, et al., 1984) The final component differs the most from MIS counterparts because of its capability of displaying database portions, manipulated data, and spatial model outputs in map form as well as tabular form. That is, a digital computer cartography system is a principle element of a GIS.

Maps are analog information display devices which have been used by man since prehistoric times. Maps display data in a geo-referenced manner; the output variables are presented in a spatial context. Maps allow various degrees of resolution, can convey large amounts of data in an elegant, easy-to-comprehend form (much like good business graphics), and are becoming increasingly easy to generate with the support of new relational, digital cartographic technology.

The drawback of maps is their inability to clearly display more than two or three variables at once and their inability to clearly display the complex relationship(s) between multiple variables. (They become easily cluttered.) Digitally stored spatial information, on the other hand, can include limitless interrelationships between variables. Digital geodata systems can be built to any resolution, can be aggregated and disaggregated easily, can be easily manipulated and expanded, and can be merged with other compatible GIS to perform relational functions. The critical aspect of collecting, storing, and retrieving geodata for a digital GIS is the selection of a geo-referencing technique.

Dangermond (1984) lists the seven basic techniques used for spatial identification of geographic information:

a. Encoding of geographic data to cells;
b. Topological coding of nodes, line segments, and polygons (DIME system);
c. Input of survey data;
d. Manual entry of points, lines, and polygons using manual digitizer;
e. Automatic entry at time of data capture;
f. Automatic line following techniques; and
g. Optical scanning.

The primary geocoding techniques will generally fit into two categories: those which follow grid encoding strategies and those which utilize line segment encoding of geodata (Berry and Tomlin). The latter group of techniques and systems are also known as "polygonal format" data structures. The most widely known example of this group is the GBF/DIME (Dual Independent Map Encoding) file system employed by the Census Bureau. (Bureau of the Census, 1970) This method, combining XY coordinate and topological encoding, involves topologically structuring the graph elements of a map (nodes, line segments, and polygons). However, this system suffers from data integrity problems, manual (human) data entry errors (Marx, 1983), and narrow applicability. The DIME file concept (and polygonal formats in general) do not lend themselves well to the design of DSS. It should be noted that the Census Bureau has discarded this system (at great expense) in favor of the new TIGER system (Topologically Integrated Geographic Encoding and Referencing System), which applies mathematical topology theories to cartographic representation and to geographic relationship, storage, and retrieval.

Purely topological systems (without referencing) define objects relative to each other without the concept of distance. It is possible to build a spatially defined map, for example, without coordinates. This may be a valid abstraction of some human perceptions of space, but certainly does not lend itself to digital manipulation systems.

The grid cell referencing technique, however, is ideally suited to representing point and linear features (presence/absence) and aerial features (dominant type, percent occurrence, centroid of cell, etc.). Grids define a regular, albeit arbitrary, polygon framework for storing spatial data. The grid encoding technique provides an excellent basis for the construction of many geo-referenced decision support systems designed to support multi-objective, multi-variable decisions in a continuous decision landscape plane.

D. Management Science, Metric Analysis, Nonparametric Statistics, and Spatial Quantitative Techniques

The collection of tools termed as management science or operations research is useful for the support of well-structured decisions. When the contributions to a decision outcome are well understood, when the relationships between the decision components are defined and quantified, and when the actual decision outcome is stated in terms of a specific metric (such as "number of tires to manufacture in one day"), then this diverse and flexible set of quantitative techniques is applicable. There are, of course, many other metric tools of data analysis which are available to the researcher. The tools of modern statistics are indispensable to the study of many natural and social phenomena, including decision making, decision support, and management information systems.

Management science techniques have also contributed greatly to the field of Management Information Systems in several important ways. (Kendall and Kriebel, 1982) Among these contributions, the management sciences have provided "tools and techniques to solve managerial and technical problems related to MIS design and development." (Kendall and Kriebel, 1982)

In the field of systems analysis and design, one can collect useful system information in many unstructured ways and with the use of many structured techniques. The structured interview can be employed to elicit specific responses which can be analyzed using the tools of statistics. The carefully-designed questions in this type of interview are usually designed to elicit responses such as "yes," "no," "1," "$2,000," "256K," and so on. Hogarth (1982) presents many insightful examples of how the framing of interview questions and the unique perspectives of the respondents can adversely bias the consistency and usefulness of the responses. He urges the reader to guard against drawing conclusions hastily without proper regard for the way that the questions are interpreted and understood by the various respondent groups. Furthermore, the structured interview is not designed to allow the subject to interject, emphasize, and color the interview data, or to spontaneously redirect the interview itself.

Observation of the business system can also be performed within a systematic and structured framework. (Kendall and Kendall, 1981) The STROBE ("Structured Observation of the Environment") technique has been shown to be a valuable tool for the collection of useful system data. (Kendall and Kendall, 1984a, 1984b) There are many tools of information system analysis which employ statistical methods to count and correlate the flow of data between organizational subunits, the flow of data into and out of the organization, the time spent in various activities associated with decision making, and the characteristics of the decision support data used by the organization's members. (FitzGerald, FitzGerald, and Stallings, 1981; Mittra, 1983)

The use of strictly metric methods of data analysis limits the researcher to the standard parametric tools of variable association of cardinal data. There are, however, many other types of statistical tools useful to the researcher who is analyzing ordinal, nominal, and verbal data. (Siegel, 1956) The nonparametric tools, such as multi-dimensional scaling (MDS) and multiple discriminant analysis are important forms of analysis for the research of behavioral phenomena.

There is another class of techniques useful in the research of spatial phenomena. This class includes a variety of tools known collectively as spatial quantitative techniques or statistical methods in geography. Amadeo and Golledge (1975) present an excellent overview of the theoretical constructs used in spatial research and the basis for scientific reasoning in the field. Some of the specific techniques are targeted at the problems associated with proper measurement of spatial phenomena. Downs (1967) has looked at the approaches to measuring space perceptions. Other techniques are used for spatial data handling. (Dueker, Ericksen, and Noynaert, 1977) Other techniques are designed to facilitate the conceptual and statistical modeling of spatial phenomena. (Minshull, 1975; Silk, 1979) There are many statisticians who have developed a set of techniques uniquely useful for analysis of spatial phenomena. These techniques include areal association (Wrigley, 1979), various measures of central tendency, multi-dimensional analysis of proximity data (Golledge and Rushton, 1976), spatial cluster analysis, point pattern analysis, and factorial ecology. For a complete presentation to the many techniques used in spatial research, see Taylor (1977) or Silk (1977).

VI. Summary

Each of these sources of information contributes in some way to the foundation for the support of spatial decision research. Those who are building decision support systems must become aware of the behavioral issues in spatial thinking. Those who are analyzing decision making must learn about the issues in spatial data collection, encoding, storage, retrieval, and analysis. All facets of the decision sciences can benefit from a greater understanding of the perceptions and thought constructs which can be achieved through continued research into these areas.

Chapter 3

THE NEBRASKA STATE PATROL

Chapter 3. THE NEBRASKA STATE PATROL

I. Introduction - The Organization

The Nebraska State Patrol is the official state-wide law enforcement agency for the state of Nebraska, with responsibilities for traffic enforcement on state highways and interstates, criminal law enforcement and investigation, drug investigations, public safety, and other areas. The Patrol has over 570 employees, 390 of which are sworn law enforcement officers. In addition, the Patrol has a number of significant civilian employees. Sixty-five officers work in carrier enforcement (trucking weigh stations). There are seven liquor control inspectors, and forty-one men and women work as dispatchers around the state. Sixty-eight employees work in a variety of positions including accounting, research, maintenance, laboratory scientists, clerical services, computer support, and personnel management. An organizational chart of the Nebraska State Patrol can be found in Appendix A.

The legislature of the state of Nebraska appropriates a budget for the Nebraska State Patrol annually and determines the Patrol's authorized troop strength. These two factors represent the organization's most significant system constraints. Like many other not-for-profit organizations, the Nebraska State Patrol has begun to adopt the techniques and processes used in the management of business organizations to ensure effective and efficient utilization of its limited resources. The administration of the Nebraska State Patrol requested that the author develop and implement a decision support system designed to facilitate the allocation of available manpower to the various troop areas within the state and ultimately to districts within the troop areas. This model will be used by the Uniform Division, whose primary responsibility is traffic law enforcement on all roads and highways in the state except those within the limits of towns with a population of at least one thousand. Another model has been developed for the Criminal Investigation Division. (Schuldt, 1986)

The decision environment has significant geographic (spatial) characteristics. Traffic, crime, citizen calls for assistance, and so on occur at specific points (or areas) in space, and there are significant spatial relationships between these variables, the decision variables (such as Trooper positions), and many other variables in the decision environment. Some of these locational variables are presently explicitly considered by the administration when they allocate manpower to the various troop areas (and within troop areas). Others are implicit in the decision process.

The problem is easily subdivided into two subsets. One decision type is the allocation of Troopers to the various troop areas. This decision is variously termed the "macro-allocation" decision or the "troop area allocation" problem in this report. The other subset of manpower allocation is the positioning of Troopers and Sergeants **within** the troop areas. This intra-troop area decision is also termed the "micro-allocation" decision. When the author researched this subtroop area allocation problem, he discovered yet another very interesting decision process performed by Nebraska State Patrol personnel. The individual Nebraska State Patrol Troopers and Sergeants in the Uniform Division spend much of each work shift engaged in a continual decision process to determine their position within their area of Patrol. This decision is termed the "Trooper Patrol Positioning

Decision" or the "Patrol Function," and is discussed in greater detail below.

II. The Manpower Allocation Decision

The administration's decision can be disaggregated into two distinct subtasks. The first task, termed the "Macro-allocation" decision or the "troop area allocation" problem, is one of allocating the available manpower to each of the various troop areas within the state. Each of the state's six troop areas represents a spatial allocation area. That is, the individual troop areas are spatially related to one another in several important ways. This allocation decision is performed when a new camp of trainees enters duty into the Patrol and periodically when manpower allocations are assessed (and changed as necessary).

The task in the other distinct subset of the Nebraska State Patrol administration's allocation problem, the "micro-allocation" decision, is to efficiently and effectively position the limited manpower so that the goals of traffic law enforcement, public safety, and general policing and patrolling are achieved to the greatest extent possible, given the system constraints. The specific objective is to position the individual active-duty patrol officers in smaller ("regional") areas, called Sergeant areas, within the troop area so that they can (1) quickly respond to calls for service from citizens and other law enforcement agencies, and (2) conduct routine patrol functions along the state's highways. Within these Sergeant areas, it is each individual Trooper's responsibility to effectively patrol the roads and highways.

A. System Analysis

The author spent over six months determining the Nebraska State Patrol decision makers' information requirements, the system interface needs, the output option needs, and the implementation strategies. This period coincides with the period of implementation. The life cycle approach to analysis, design, and implementation was employed. System implementation was considered from the very beginning. And system design is still being redefined. In other words, it is difficult to divorce the separate phases in the system life cycle when this comprehensive approach is employed. Therefore, elements of system analysis, design, and implementation are discussed throughout this chapter.

Many sessions of structured and unstructured observation provided the majority of the information needed for developing a system design and implementation plan. Some of the information concerned political relationships between various organizational members and factions. Some of the data addressed the formal and informal patterns and flows of data and information within the organization. Much of the observation and interview data added insight into the source of the organization's information. For example, I asked for and received a copy of **every** form currently being used by the Uniform Division of the Nebraska State Patrol. These forms, used internally and for constituent data gathering functions, provided very valuable data for the construction of decision support system.

I spoke with Troopers and Sergeants who patrol the highways of the state. I observed several of these individuals at work as I rode with them on their beats. I spoke with the Patrol's accountant, its Personnel Director, and its Data Processing Coordinator about the manpower allocation problem. I had several high-level meetings with the central administration body of the Patrol, consisting of the Superintendent, the Lt. Colonel, three Majors, and several administrative Captains. I spent many dozens of hours with several key contact persons, discussing the organization, the manpower allocation decision, the computer resources of the Patrol, and many other applicable subjects.

I also gained valuable insight into the manpower allocation decision by meeting with some the dispatchers. In the headquarters troop area, the dispatchers are stationed in the basement of the Department of Roads building, next to the Nebraska State Patrol headquarters building. They were very interested in my project and freely volunteered their insight and anecdotes about the Troopers. It was very evident that there is some dissatisfaction with the current system of Trooper positioning (discussed below). The dispatchers must assign a Trooper or Troopers to a source of a call for service based on their positions relative to the source of the call. However, the dispatchers felt that they were not effective in assigning the nearest Trooper because "the Troopers do not check in" and they did not know where they were at all times. They work in front of a map of their immediate region with variously-colored stickpins representing the active Troopers on duty. Some colors refer to the rank of the Troopers and Sergeants on duty. Purple pins are used to denote the Selective Enforcement Squad members who target specific stretches of road to reduce unusually high accident rates based on the Policing By Objectives (PBO) program. (Purple was said to stand for the "purple people eaters.")

In a subsequent interview with a Sergeant from Grand Island, Nebraska (Troop C), this author asked about the attitudes these dispatchers had toward the Troopers. This officer, who had been stationed in Headquarters Troop previously, related a significant difference between the two troop areas. In Grand Island, the dispatchers are positioned in the same building as the Troopers. They freely interact with the Troopers before, during, and after work hours. He described the relationship as friendly and congenial. The close personal contact lead the two groups to view each other "as people." The complaints expressed by the dispatchers in the Headquarters Troop were not shared by the dispatchers in Grand Island. These groups were able to effectively work together.

The Lincoln-based dispatchers, who are positioned in a separate building, told me that they often did not even know what particular Troopers looked like, even though they spoke over the radio every night. This is an excellent example of how the unstructured interview was a valuable tool of systems analysis. The rich understanding of the physical spatial relationship between two groups of Nebraska State Patrol personnel and its effect on organizational effectiveness would have not have been possible if the systems analysis had only used strictly-worded questionnaires

Lieutenants and Captains are the line managers of the Nebraska State Patrol Uniform Division (at the Troop Area level). Initially it appeared that these individuals engaged in the routine allocation of manpower within their individual troop areas. The author thought they combined the utilization of metric (quantitative) data with the utilization of nonmetric data to perform unstructured decision making in the allocation of law enforcement officers to positions in the traffic landscape. However, the allocation of Troopers at this level was discovered to be essentially static. The assignments often do not change for many years.

Many Troopers are actually assigned to work from a base of a small town (where they usually live). From this clear center of activity, they patrol (and respond to calls for service from within) an area surrounding their town. These assignments may not change for years. Several Troopers have maintained geographic assignments for over ten years. It was learned that often one of these Troopers is the only law enforcement officer for a geographically large area. They may patrol the surrounding county or counties with no contact with other Nebraska State Patrol officers for a week or more (except over the radio). They can become very close with their constituents and very familiar with the territory. They are, in effect, on call 24 hours a day to respond to emergency calls from their district. (One Sergeant was proud of being able to get dressed and be on the road in four minutes! He told of responding to serious highway accidents in the middle of the night when he was the only law enforcement officer available for many miles to respond to the emergency.)

Despite the static nature of many of these assignments, the central administration was very concerned with effective allocation of all Troopers and Sergeants. They are willing to "shake things up" in order to bring about a distribution of Troopers which will serve the public and serve the goals of the Patrol.

Throughout the interviews, it was evident that there were two types of data available to be used in making the manpower allocation decision. Metric or quantitative data include traffic volume data (average daily vehicle miles), incident reporting data (discussed in detail below), current and planned manpower levels, temporal data (shift lengths, holidays, etc.), spatial data (distances, positions, etc.), and other reported data. Nonmetric data include perceived traffic activity levels, perceived spatial patterns of events, experientially-acquired reference data, occurrence of unique events (weather events, parades, athletic events, etc.), and other nonquantified data. Every administration official of the Patrol discussed the decision in terms of both the explicit metric data and the qualitative narratives (nonmetrics). Because their narrative contained both references, direct followup questions were designed for subsequent interviews and discussions to gauge the relative importance placed on the nonmetric component of their decision environment. Consistently, it was shown that these individuals do indeed consider both metric and nonmetric data in their decision process. But more importantly, they use available structured data in an unstructured way (in combination with their perceptions, which they revealed on occasion) to make these decisions.

B. System Design - The Decision Support System

1. Introduction

The decision support system developed and implemented for the administration of the Nebraska State Patrol was designed to support the macro manpower allocation decision discussed above. The DSS compares primarily "hard" input data under user-specified parameter assumptions to generate nearly instant tabular and graphic output for the user. This system (or "model") was developed (and continually modified) by the author over a six to seven month period in which time he continually refined the design by interviewing and observing numerous Nebraska State Patrol officials and Troopers. While the system is now implemented and is being used for current manpower allocation, the tool is viewed as an evolutionary management support tool which will be audited and evaluated for periodic maintenance and modification.

The complete model can be divided into four subsystems with the fifth element being the user interface functions. Finally, the programming code ties each subsystem together and generates the user interface options.

The first subsystem is the data base on which the model is based. The second division is the system for user input of system parameter assumptions and of the decision variables. The third subsystem is the logic of the model. The fourth major component is the DSS output system.

2. The DSS Data Base

The first subsystem is comprised of the "hard" input data on which the model is based. This portion ("VARAREA") of the DSS provides the essential foundation for the generation of usable decision support information. The data in this data base consist of data from the Incident Reporting System, from the Nebraska Department of Roads, from the County Sheriffs of Nebraska, from the United States Commerce Department (Bureau of the Census), and from various other government reporting agencies.

The Incident Reporting System is designed to gather data about the calls for service which come in to the Nebraska State Patrol units around the state. Typically, these calls for service may reach a dispatcher over the phone, and the dispatcher fills out an Incident Report (Nebraska State Patrol form #528, see Figure 5) as he or she assigns an active Trooper to respond to this call. The calls for service can be broken down into several categories ("types of calls"). These are calls to respond to accidents, to criminal complaints, to assist motorists, to traffic violations, to State Patrol relays (of blood, vital organs, evidence, and so on), to REDDI calls (Report Every Drunk Driver Immediately), to other highway emergencies, and to all other requests for service. For each incident, the dispatcher records the source of the call for service, the time the call was received, the time the incident was assigned to an active Trooper, the time when the Trooper arrives at the source of the call for service, the time of disposition, whether or not there was a specified assignment delay, and several other pieces of information about the incident.

The length of time from the assignment time to the arrival time is the response time. A primary operationalization of the Nebraska State Patrol's organizational mission is the reduction of these response times. In order to improve the level of service provided to the citizens of the state of Nebraska, the Patrol wishes to achieve a

Figure 3

Nebraska State Patrol
Manpower Allocation Decision Support System

System Inputs

"Weekly Report"

Badge No. ______________

Name ______________

Soc. Sec. No. ____ – ____ – ____

NEBRASKA STATE PATROL
WEEKLY REPORT

FIRST DAY							SECOND				
DATE			UNIT	ENDING MILEAGE	GAL. OF GAS		DATE			UNIT	
TIME	FACILITY CODE	FUNCTION CODE	TOTAL HOURS	MILES	CONTACTS NC S CC A	CASE NUMBER	TIME	FACILITY CODE	FUNCTION CODE	TOTAL HOURS	MILES
			:							:	
			:							:	
			:							:	
			:							:	
			:							:	
			:							:	
			:							:	
			:							:	
			:							:	
	TOTALS		:					TOTALS		:	

THIRD DAY							FOURTH				
DATE			UNIT	ENDING MILEAGE	GAL. OF GAS		DATE			UNIT	
TIME	FACILITY CODE	FUNCTION CODE	TOTAL HOURS	MILES	CONTACTS NC S CC A	CASE NUMBER	TIME	FACILITY CODE	FUNCTION CODE	TOTAL HOURS	MILES
			:							:	
			:							:	
			:							:	
			:							:	
			:							:	
			:							:	
			:							:	
			:							:	
			:							:	
	TOTALS		:					TOTALS		:	

FIFTH DAY							SIXTH D				
DATE			UNIT	ENDING MILEAGE	GAL. OF GAS		DATE			UNIT	
TIME	FACILITY CODE	FUNCTION CODE	TOTAL HOURS	MILES	CONTACTS NC S CC A	CASE NUMBER	TIME	FACILITY CODE	FUNCTION CODE	TOTAL HOURS	MILES
			:							:	
			:							:	

Figure 4

Nebraska State Patrol
Manpower Allocation Decision Support System

System Inputs

"TMO7 Report"

TM07

NEBRASKA STATE PATROL

FUNCTION REPORT BY EMPLOYEE FOR 06-86

	FUN	HOURS	MILES	UNIT	ACC	SUM	VIO	WRN	PBO
PBO ADMINISTRATION	408	2.5	0	5108	0	0	0	0	
ACCIDENT-INV: ST-HWY	410	6.0	135	5108	2	0	0	1	
NORMAL PATROL: ST-HWY	413	49.0	935	5108	0	0	5	4	
TRAFFIC CONTROL: ST-HWY	415	1.0	10	5108	0	0	0	0	
MOBILE RADAR: ST-HWY	418	.0	0		0	0	0	1	
MOBILE RADAR: ST-HWY	418	.0	0	5108	0	7	0	3	
ACCIDENT-INV: IS-HWY	430	1.0	30	5108	1	0	0	0	
NORMAL PATROL: IS-HWY	433	31.5	545	5108	0	1	7	6	
TRAFFIC CONTROL: IS-HWY	435	8.0	75	5108	0	0	0	0	
MOBILE RADAR: IS-HWY	438	.0	0		0	3	0	0	
MOBILE RADAR: IS-HWY	438	.0	0	5108	0	17	0	6	
AERIAL PATROL-GROUND: IS-STEP	441	2.0	10	5108	0	7	0	0	
ACCIDENT-INV: CO-ROAD	450	1.0	20	5108	1	0	0	0	
AERIAL PATROL-GROUND: CO-ROAD	451	1.0	15	5108	0	1	3	9	
NORMAL PATROL: CO-ROAD	453	34.5	460	5108	0	4	7	7	
TRAFFIC CONTROL: CO-ROAD	455	6.5	75	5108	0	0	0	0	
MOBILE RADAR: CO-ROAD	458	.0	0		0	2	0	0	
MOBILE RADAR: CO-ROAD	458	.0	0	5108	0	0	0	1	
COURT TIME: TRAFFIC	473	10.0	0	5108	0	0	0	0	
CRIMINAL INVESTIGATION	474	2.5	0	5108	0	0	0	0	
RELAYS: EYES	478	.5	0	5108	0	0	0	0	
MISCELLANEOUS	482	11.0	0	5108	0	0	0	0	
IN-SERVICE TRAINING: SPECIAL	486	2.5	0	5108	0	0	0	0	

HOURS	MILES	GALNS	ACC	SUM	VIOL	WARN	AIDS	RMVL	PGMS	ATTND	RENTAL	CLOCK
170.5	2,310	184.5	4	42	22	38	0	0	0	0	.00	.0

PBO FUNCTIONS	.0	0	0	0	0
PBO SELECTIVE	.0	0	0	0	0
PRODUCTIVITY	127.0	2,050	42	22	37

Figure 5

Nebraska State Patrol
Manpower Allocation Decision Support System

System Inputs

Incident Report Form (NSP 528)

NEBRASKA STATE PATROL

INCIDENT REPORT 006272 M

TROOP AREA: STATION: TIME: DATE: RECEIVED BY

1 ☐ ACCIDENT 2 ☐ CRIMINAL COMPLAINT 3 ☐ MOTORIST ASSIST 4 ☐ TRAFFIC VIOLATION 5 ☐ RELAY 6 ☐ OTHER:

OCCURRED WHERE: COUNTY NO.: TIME: DATE:

SUBJECT DESCRIPTION: VEHICLE DESCRIPTION:

REQUESTER 1 ☐ CITIZEN 2 ☐ NSP 3 ☐ SHERIFF 4 ☐ POLICE DEPARTMENT 5 ☐ OTHER

REFERRED TO: TIME ASSIGNED: TIME ARRIVED: TIME COMPLETED: ASSIGNMENT DELAYED ☐

INFORMATION FROM: ADDRESS: PHONE NO.:

REMARKS - DISPOSITION

NSP 528, Revised Sep 84

Figure 6

Nebraska State Patrol
Manpower Allocation Decision Support System

System Inputs

Incident Reporting Summary Data

Dec 85

AVERAGE RESPONSE TIME TO ACCIDENTS

TROOP	CALLS	MINS.	AVE.
A	70	710	10.1
B	98	2,906	29.6
C	69	918	13.3
D	73	1,390	19.0
E	126	5,713	45.3
H	84	1,150	13.6

AVERAGE RESPONSE TIME TO CRIMINAL CMPLNT.

TROOP	CALLS	MINS.	AVE.
A	42	364	8.6
B	29	175	6.0
C	23	177	7.6
D	12	278	23.1
E	7	274	39.1
H	28	1,917	68.4

AVERAGE RESPONSE TIME TO MOTORIST ASSIST

TROOP	CALLS	MINS.	AVE.
A	24	308	12.8
B	18	685	38.0
C	27	254	9.4
D	45	1,088	24.1
E	56	2,036	36.3
H	31	347	11.1

Figure 7

Nebraska State Patrol
Manpower Allocation Decision Support System
System Input Screen
"INCIDAREA"

INCIDAREA - Input Area for numbers from the Incident Reporting System

NUM OF CALLS	HQ Troop	A Troop	B Troop	C Troop	D Troop	E Troop
Accidents	72	57	74	63	69	63
Criminal complaint	47	59	53	37	38	32
Motorist assists	35	23	2	45	43	39
Traffic violations	28	20	6	17	16	16
Relays	18	7	4	11	12	4
REDDI calls	27	20	15	29	39	16
Othr hwy-emergency	16	17	16	30	29	31
Other requests	44	11	25	49	29	15
AVERAGE RESPONSE TIME	(PgDn for forecasts of calls for service)					
Accidents	36.4	13.9	22.0	14.8	22.8	22.4
Criminal complaint	22.1	15.0	12.6	24.4	23.2	37.4
Motorist assists	19.0	17.7	32.0	15.8	24.0	33.5
Traffic violations	22.7	15.0	17.5	39.4	35.7	13.1
Relays	56.8	22.0	36.2	32.6	128.8	29.2
REDDI calls	13.9	21.6	22.8	44.1	30.8	23.5
Othr hwy-emergency	15.1	15.6	21.9	19.3	23.6	32.3
Other requests	32.9	12.2	15.0	25.4	24.4	13.6

VARAREA - Variables for Manpower Allocation Model

Variable	HQ Troop	A Troop	B Troop	C Troop	D Troop	E Troop
Numbr of Troopers	42	24	35	32	28	29
# of prod. hrs/Tpr	23.7	23.3	28.4	27.7	28.1	22.0
Numbr of Sergeants	7	6	7	6	7	5
# of prod. hrs/Sgt	7.8	9.5	10.3	13.4	10.3	6.4

DECISION VARIABLES

MaxDesrResponsTime	20	20	20	20	20	20
Max Response Speed	70	70	70	70	70	70
Fcstd MaxRespSpeed	70	70	70	70	70	70
Number of "Shifts"	=	2				
Number of Troop Areas	=	6				

Figure 8

Nebraska State Patrol
Manpower Allocation Decision Support System
System Input Screen
"VARAREA"

minimum overall response time to calls for service. These response times, disaggregated by type of call and by troop area, also provide a benchmark for comparing the troop areas with respect to the effectiveness of the manpower levels in each troop area.

In addition, data from the Nebraska State Patrol "Weekly Reports" (NSP Form # 726) provide the raw data for calculating a collection of useful information generated as the TM07 Report. The data accounts for each hour of each work week for each Nebraska State Patrol officer. The information in the TM07 report can be manipulated to produce the necessary inputs for the manpower allocation model. The decision support system calculates the average number of productive hours available per week for Troopers and for Sergeants by troop area.

Other data elements include the average daily vehicle miles for the various highways and roads in Nebraska (from the Nebraska Department of Roads), the number of local law enforcement officers in each troop area (from the Nebraska County Sheriffs), the miles of Interstate highway in each troop area, the miles of paved and unpaved non-Interstate highways, the "rural population" (not counting any towns over 1,000 in population), and the geographic area of each troop area in square miles. Some of these data require monthly revisions, others change as seldom as every ten years.

3. The User-Supplied Variables

The second division ("PARMAREA") is the system for user input of system parameter assumptions and of the decision variables. The users may wish to test the results of increasing or decreasing the level of manpower ("troop strength") in one or more troop areas. The decision maker may also wish to change the response speed, the forecasted future number of calls for service, or other assumptions about the decision environment. These variables appear in another color on the computer screen with menus and prompts for their update. The user can return to these screens at any time to change the assumptions, and can then immediately see the results of these changes on other variables in the model.

4. The Logic Portion

The formulae in the third component of the model ("FORMAREA") are tied both to the input data in the system's data base and to the user-supplied inputs. This third subsystem provides the linkage between the raw data

Figure 9

Nebraska State Patrol
Manpower Allocation Decision Support System
System Input Screen
"PARMAREA"

PARMAREA - Factor Input Screen (for Model Parameters)

Parameter	HQ Troop	A Troop	B Troop	C Troop	D Troop	E Troop
Rural Population	190.0	45.6	119.5	88.7	69.7	37.5
# Rur Law Enf Offc	142	187	135	113	125	45
Square Miles	8852	1491	21577	9735	20846	14138
I-80 Miles	59.87	16.21	2.46	109.67	145.49	106.76
I-80 Daily Veh Mls	867.82	282.07	22.97	1108.36	1212.22	409.86
Non-I Miles	1390.11	308.77	1685.64	1129.32	1270.36	849.87
Non-I Dly Veh Mls	2295.74	1261.72	2262.46	1774.49	1394.69	1062.96
Non-I paved miles						
Unpaved miles						
FORECAST PARAMETERS (Use historical figures from above in most cases)						
I-80 Daily Veh Mls	867.82	282.07	22.97	1108.36	1212.22	409.86
Non-I Dly Veh Mls	2295.74	1261.72	2262.46	1774.49	1394.69	1062.96

of the model and the **information** generated as output of the model. The relationships between, for example, the number of Troopers available to respond to calls for service, the average number of "productive hours" per week (available to respond to calls for service), and the number of calls for service (by type of call) are linked through the logic of the decision support system to the output variables (such as the forecasted response times). These formulae have been extensively tested using four separate, consecutive months of data, extreme value sensitivity analysis, and numerous test sessions with trained and untrained users.

5. The Model's Output

The fourth primary portion of the decision support system is made of various output forms and graphs. The decision maker using this model has several output options. The user may want to see a table of critical output variables on the screen. Three screens of compiled summary information and four screens of detailed output data are available. These are titled NSP I, NSP II, and NSP III and are displayed in Figures 10 through 12. The user can also select a view of the incident reporting data output. In addition, there are several output print options which the user may select to instantly obtain a printout of the results of any DSS query.

He or she may also want to view the overall effect of some change in input variables or in model assumptions as a graphical representation. There are currently seven seven separate graphs from which the user may select. Examples of these graphs are shown in Figures 13 through 19. These graphs are designed to show some of the important relationships and output variables that the Nebraska State Patrol central administrators indicated they wanted to see. These include graphs to show response times by troop area and by type of call, forecasted response times by troop area and by type of call, troop strengths, forecasted troop strengths, and ratios of Troopers and Sergeants to administrators. The system has been designed in an evolutionary environment of iterative refinements and model adjustments. One of the Majors has indicated that he wishes to see several other graphical relationships. These views are being added to enhance the overall effectiveness of the decision support.

Figure 10
Nebraska State Patrol
Manpower Allocation Decision Support System
System Tabular Output Screen
"NSP I"

Nebraska State Patrol Uniform Division   Prepared on   14-Aug-86
Manpower Allocation Model Output

NSP - I	==Calls for Service==		======== Response Time ========		
	Number of Calls	Calls to Accidents	Historical Average	Forecasted	Maximum Desired
HQ Troop Area	287	72	28.04	26.83	20
A Troop Area	214	57	15.75	14.14	20
B Troop Area	195	74	18.86	18.86	20
C Troop Area	281	63	23.76	23.76	20
D Troop Area	275	69	29.81	29.81	20
E Troop Area	216	63	26.95	25.29	20
Nebraska Average	1468	398	24.38	23.66	20.00

("PgDn" for more output (NSP - II and NSP - III))
({alt - M} to Retrieve the Main Menu)

Figure 11

Nebraska State Patrol
Manpower Allocation Decision Support System
System Tabular Output Screen

"NSP II"

NSP - II	=====Number of Troopers and Sergeants======				Total Uniform Division Troop Strength
			---Needed for Max--- --Desired Resp Time- -or Policr & Patrol-		
	Historical Time Period	Forecast (Planned)	Histrcl	Forecast	
HQ Troop Area	49	51	69	67	52
A Troop Area	30	33	24	23	33
B Troop Area	42	42	48	48	45
C Troop Area	38	38	46	46	41
D Troop Area	35	35	53	53	38
E Troop Area	34	36	46	44	37
Nebraska Total	228	235	286	281	246

("PgDn" for NSP - III; "PgUp" for NSP - I)
({alt - M} to Retrieve the Main Menu)

Figure 12
Nebraska State Patrol
Manpower Allocation Decision Support System
System Tabular Output Screen
"NSP III"

NSP - III

	--Ratio of Patrols-- --to Administration- Historical	Forecast	Percent of time for Patrolling	-Calls For Service- Historical	Forecast
HQ Troop Area	16.33	17.00	50.42	287	287
A Troop Area	10.00	11.00	48.33	214	214
B Troop Area	14.00	14.00	59.73	195	195
C Troop Area	12.67	12.67	59.86	281	281
D Troop Area	11.67	11.67	57.74	275	275
E Troop Area	11.33	12.00	46.37	216	216
Nebraska Total	12.67	13.06	53.95	1468	1468

("PgUp" for NSP - II and NSP - I)
({alt - M} to Retrieve the Main Menu)

Figure 13

Nebraska State Patrol
Manpower Allocation Decision Support System

System Graphical Output Screen

"BYSTRENGTH"

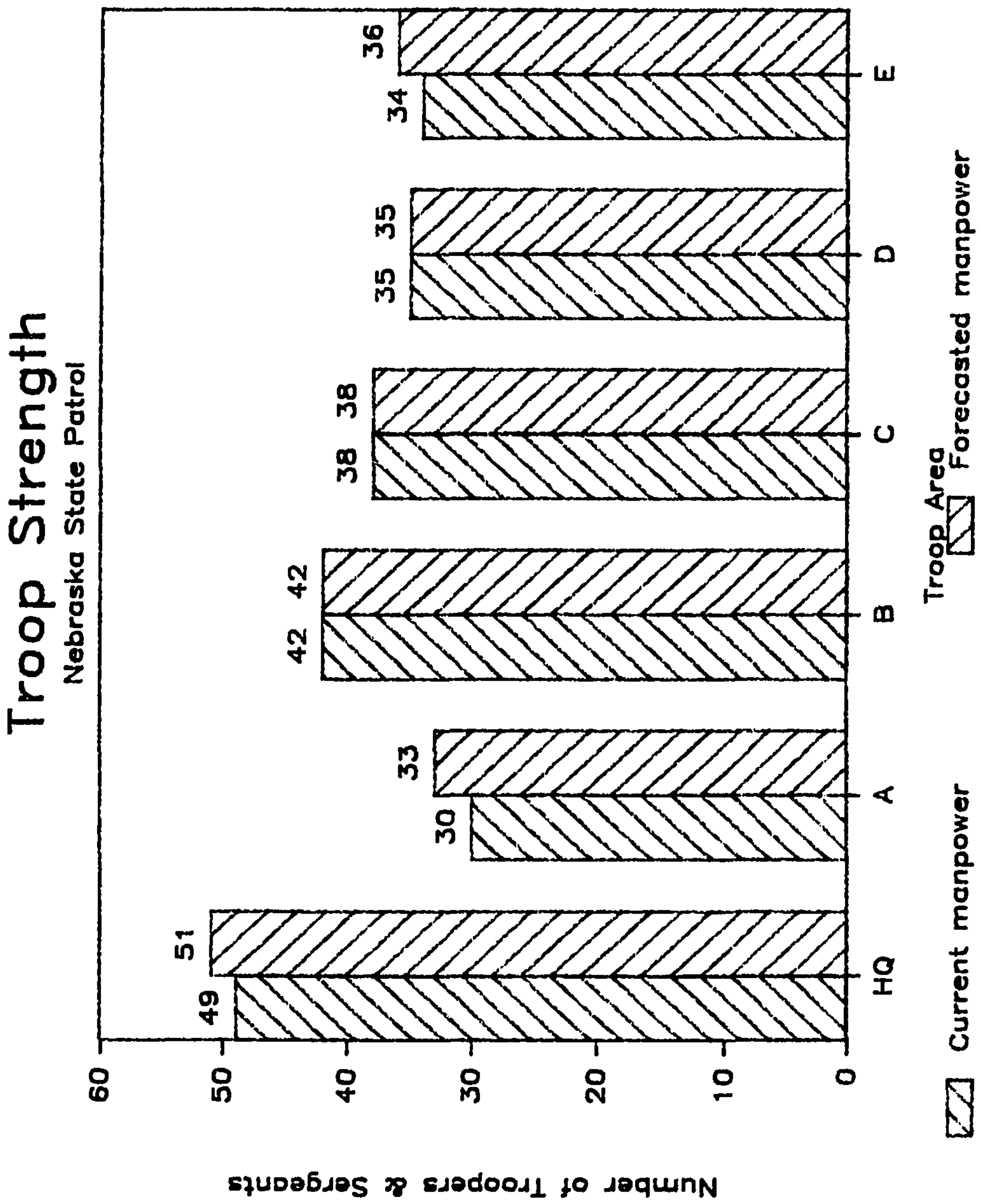


Figure 14

Nebraska State Patrol
Manpower Allocation Decision Support System

System Graphical Output Screen

"BYTROOP"

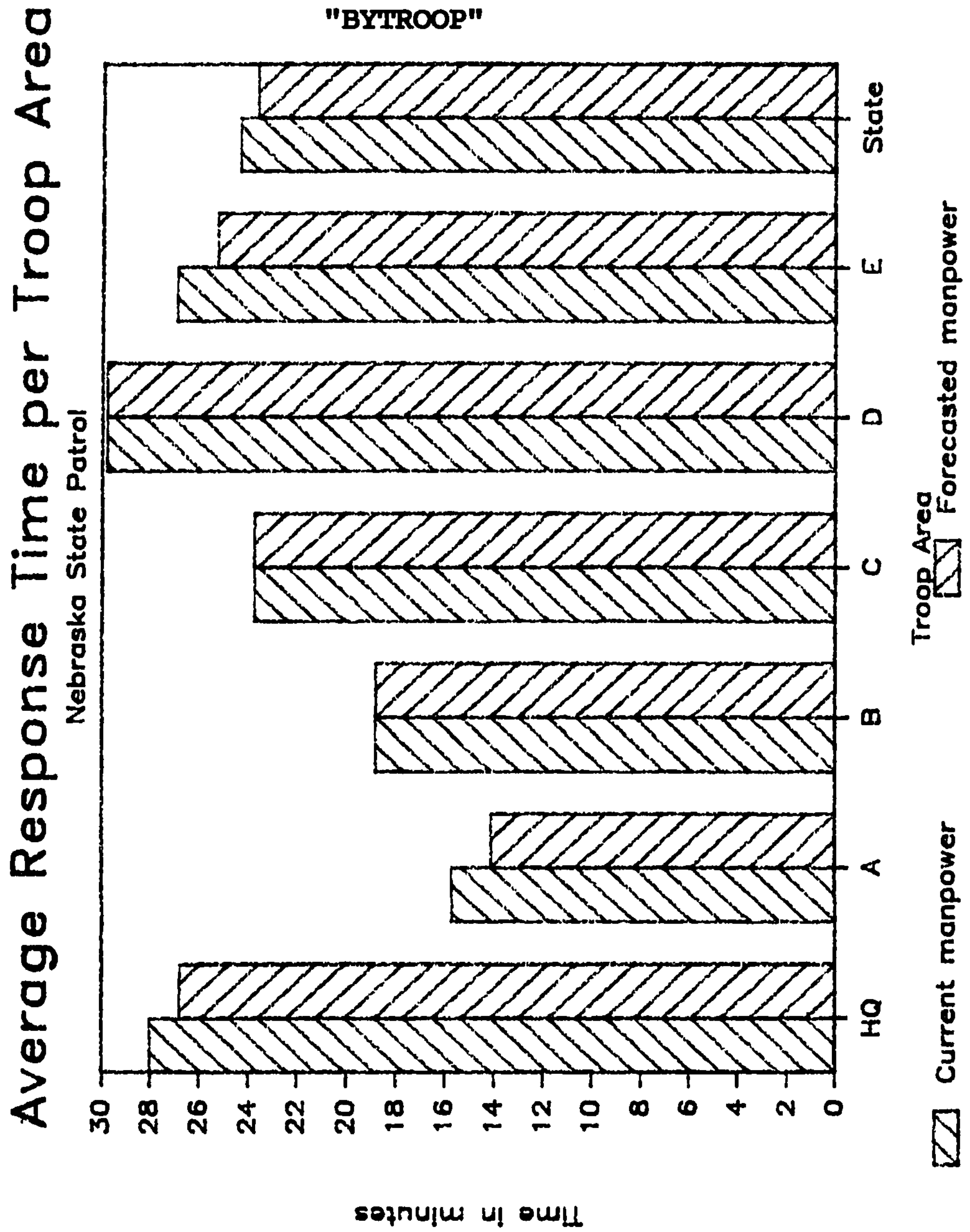


Figure 15

Nebraska State Patrol
Manpower Allocation Decision Support System

System Graphical Output Screen

"BYTROOP3"

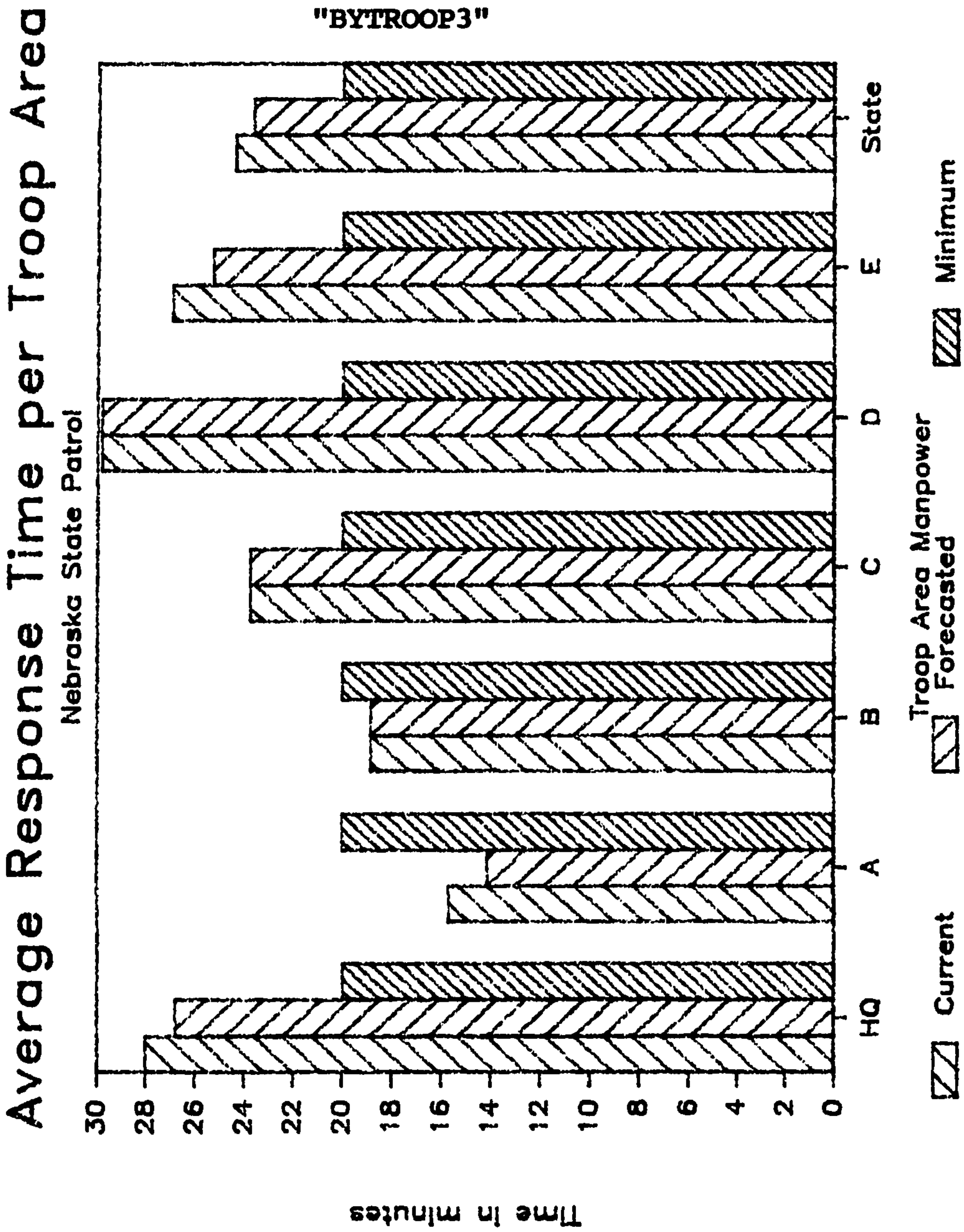


Figure 16

Nebraska State Patrol
Manpower Allocation Decision Support System

System Graphical Output Screen

"BYTYPE"

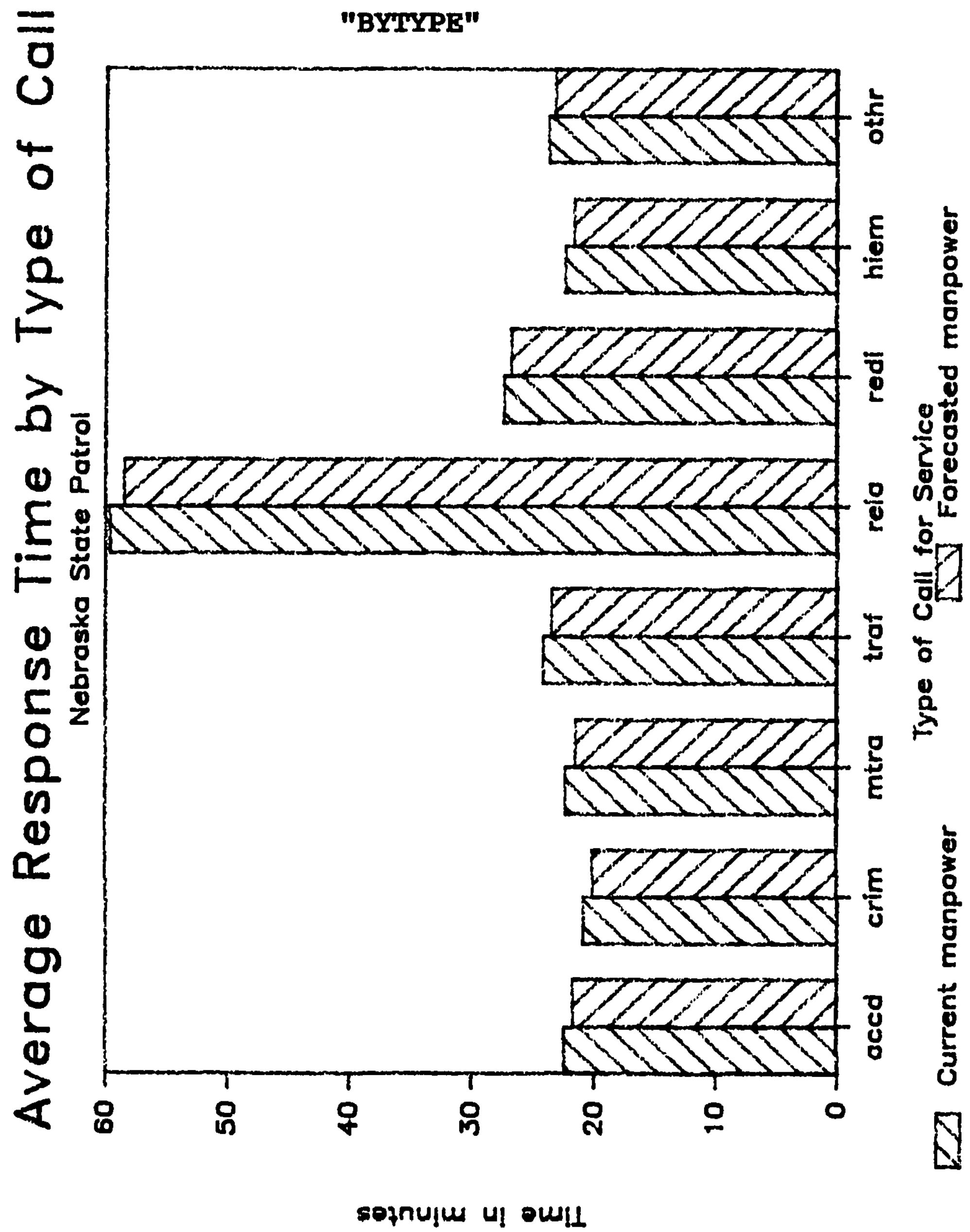


Figure 17

Nebraska State Patrol
Manpower Allocation Decision Support System

System Graphical Output Screen

"RATIO"

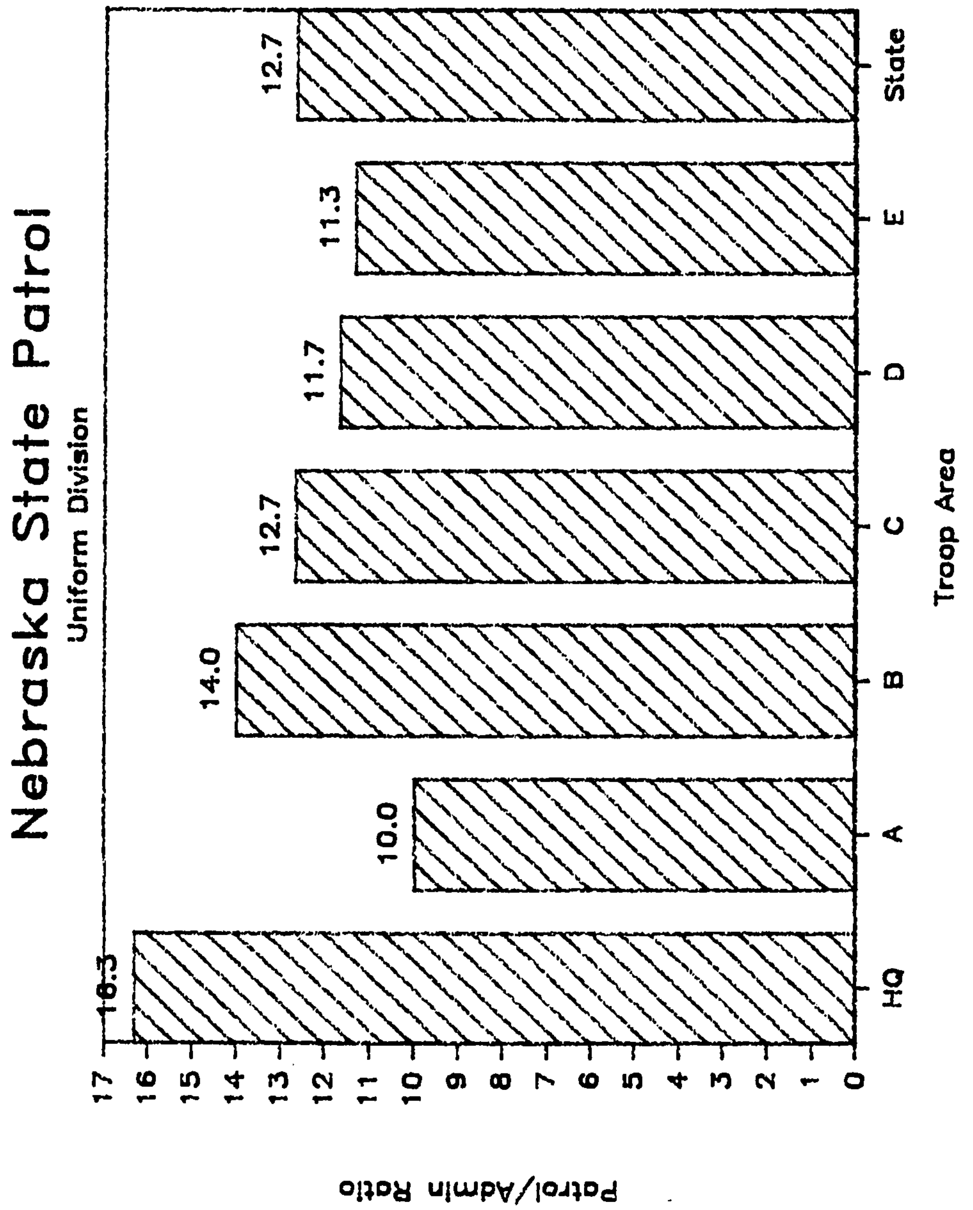


Figure 18

Nebraska State Patrol
Manpower Allocation Decision Support System

System Graphical Output Screen

"STRENGTH"

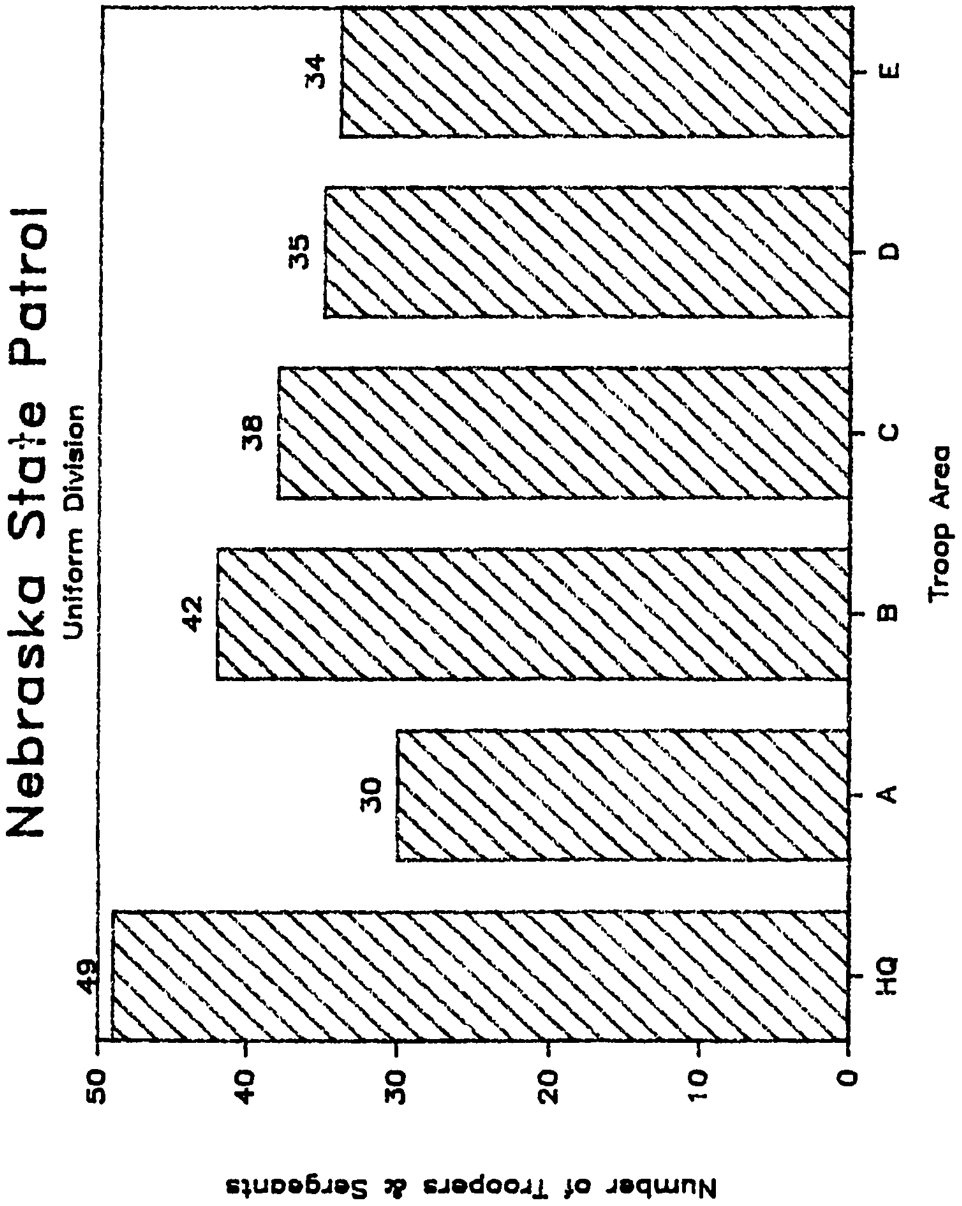
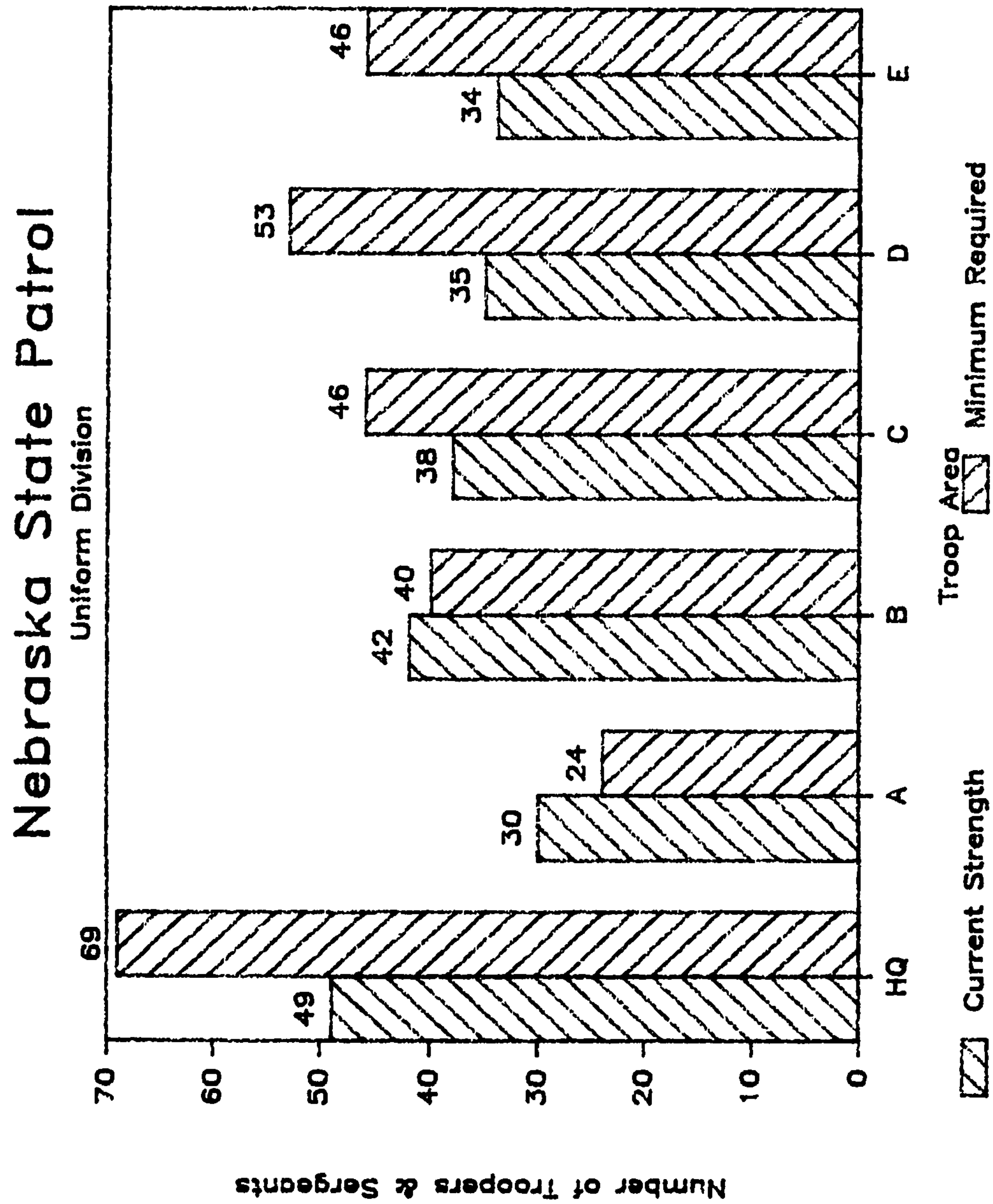


Figure 19

Nebraska State Patrol
Manpower Allocation Decision Support System

System Graphical Output Screen

"STRENGTH2"



More graphs may be added as the use of the system indicates the need for new views and relationships between various model variables and parameters. For example, in one system session, one Major indicated to the author that he would like to see the relationship between quarterly and monthly data. This capability will soon be added to this decision support system.

6. Summary

The decision support system designed and developed during the course of this project incorporates several unique and effective design elements. The user interface was particularly effective. The users indicated that the process of generating desired output was very simple to learn and use. The nearly instant graphical feedback was also particularly effective. The iterative implementation (discussed below) in which multiple users were involved afforded the author the ability to fine-tune the model to fit the users' needs. Ideally, several individuals within the organization will take over the maintenance of the DSS, so that future changes required by organizational or environmental evolution can be implemented.

C. System Implementation and Findings

The majority of the decision makers within the Patrol's central administration group, analogous to the corporate strategic management group, sought the aid of microcomputer decision support systems in the important process of "macro-allocation." With one notable exception, there was a general agreement that the personal computer could provide some support in the task of allocating the new recruits in the 1986 camp. Some persons were interested in the DSS for its inherent value in providing structured quantitative data for decision support. Others had little interest in anything "the computer" could provide. At the Troop Area Captain rank, several individuals primarily wanted numbers to support their positions within the organization. The members of the central group were either supportive and excited about the new management support techniques or were at worst neutral about the new tools sought by the new Administrator. One member of this group, one of the three Majors, had some reservations about the use of computer data to make this decision.

So though the Lieutenants and Captains do not perform the routine allocation, there is a process of periodic macro-allocation which occurs at the central administrative level. One such decision took place in late July and early August 1986 when the DSS was implemented. A new group of trainees (at the rank of Trooper I) was coming out of camp, and each troop area commander sought to have as many of these new recruits assigned to this troop area as he could.

The decision support system implementation process took place over a six month period (the period of the system life cycle thus far). As the author worked with many individuals on this project at every rank within the State Patrol, useful information was acquired to support the design and implementation of the system. Insight was sought and gained into the various perspectives of the administrators, of the "middle managers" (the Lieutenants), the Troopers and Sergeants, and the important civilian employees of the State Patrol. Early user involvement was a critical component of the implementation planning.

To a great extent, the users shaped the direction of the system design. The author conducted sessions with the central administration in the beginning of the project to determine the information requirements for manpower allocation decision support. Further meetings with the primary contact personnel in the Research and Development Division (now called Operational Research) helped to redefine the organizational goals, the "vision" of the model, and the specific system constraints within which the author would have to work. As the model was being developed, the author worked closely with several individuals in the Patrol to determine whether the output of the geographically-referenced decision support system was perceived to be clear and useful for the manpower allocation decision. The system was continually redefined and reshaped to take into account the valuable information gained from these interactive sessions with State Patrol personnel. This iterative development and implementation process contributed to the overall success of the project. The system was shown over and over to several individuals, and there were two high-level meetings with the Colonel, the Lt. Colonel, the three Majors, and several other significant system users. The evolutionary system design process, in which the system interface and system linkages were incrementally reshaped, was a critical element of the overall system project.

The author was concerned with the system interface design. Much time and careful attention was focused on the development of the user interface aspects of this geobased DSS. Without a "friendly" and easy to use system, it might suffer the all-too-common fate of disuse after the system developer's involvement ends. That is, successful implementation requires careful planning throughout the entire life cycle of the project: problem definition, system analysis, information requirements determination, system design and development, conversion activities, postaudit, and system evaluation.

The results of the system implementation indicate that the decision support system has been accepted as a significantly useful tool for decision support. It has been used for several tasks by the central administration to this date, and has also been used interactively for general exploration of the decision variable relationships. It has affected decision making by adding structure to the decision process. The spatial relationships between the various decision alternatives have been thoroughly explored by the members of the central administration group.

Continued system implementation activities will be performed by the author and by the several members of the

Patrol who are assuming the role of system maintenance. It is imperative to the continued success of the project that the system use is monitored, that new data are added to the system, that more individuals are shown the decision support system, and that the system is modified if necessary.

The other side of this trooper allocation decision is the microgeographic manpower allocation problem. In this case, the troopers are assigned to specific areas within the Troop Area. These smaller areas may be Sergeant Areas (usually several counties), they may be counties, or they may be road segments. When the central administration officials allocate individuals to these smaller areas, the goal is also effective traffic patrol and short response times. However, the decision is significantly different than the macro decision in several important ways.

The organizational political elements which play a role in the decision environment for assigning Troopers to the Troop Areas do not contribute to this decision. The contributing variables are different for this decision and the spatial relationships are also different. While the two decisions share many characteristics, they are sufficiently different that this author made an early determination to divorce them for decision support purposes. Originally, the system users defined this problem poorly. However, this was attributable to the lack of structure of the decision. That is, the problem was evaluated from the Patrol's several groups of decision makers, and was determined to be a more poorly-defined and ill-structured problem. The following section describes a closely related State Patrol allocation decision. The microgeographic manpower allocation decision and the Trooper patrol positioning decision share many goals and decision elements.

III. The Trooper Patrol Positioning Decision

While the two allocation subtasks provide a sufficiently rich laboratory for the investigation into spatial decision making, there is yet another decision made by Nebraska State Patrol personnel which is perhaps of even greater value. This is termed the Trooper Patrol Positioning Decision.

A. The Decision

As the author spent many hours riding with several Nebraska State Patrol Troopers and Sergeants in an effort to learn more about the way in which they respond to calls, it was discovered that the really interesting aspect of their job was not the response to calls for service, but rather the continual "policing and patrolling function" which they perform. The other primary decision category under investigation in this case is the spatial decision which is made by the patrolling Troopers. These men make many implicit judgments and decisions each shift. They are not given precise geographic assignments, only general areas of patrol which often cover two or three counties.

For example, around Lincoln there are four quadrants covering approximately a radius of about 20-25 miles in southeastern Nebraska. During any particular shift, several Troopers might be assigned to cover each of these quadrants (depending on the time of day, the day of the week, and special circumstances such as Nebraska Cornhusker home football game traffic). While the

Troopers were observed crossing over the quadrant boundaries "to find a little action to show me," they basically kept within their assigned quadrant while engaged in policing and patrolling. They would, of course, cross over the quadrant boundaries to respond to calls for service if directed to do so by the dispatchers.

This administrative directive (quadrant boundaries) was implemented for several reasons. It provides an obvious deterrence to ineffective patrol clustering during the shift. That is, if there were no guidelines, the troopers could conceivably cluster near the areas which provide the most source of activity (in this case, Interstate 80 east and west of Lincoln and U.S. Highway 77 to the north and south). It was also intended to provide the radio dispatchers with some usable information. The dispatchers, who position variously-colored stickpins on a map to represent the shift's active Troopers, are told to assign, in most circumstances, the Trooper or Troopers believed to be the closest to the source of a call for service. The quadrants were designed, in part, to help the dispatchers quickly decide who to assign to each particular call. Theoretically, the quadrant assignments would mean that Trooper X was somewhere in Quadrant III during a particular shift. However, the dispatchers confided in me that they were frustrated by the troopers' practice of not "checking in" and informing the dispatchers of their position. Because the system of identifying the troopers' locations is ineffective, it is possible that response times are longer than necessary in the circumstances when the dispatchers operate under incomplete information. (The problems of dispatcher-Trooper relationships is discussed in the section titled "System Analysis" in this chapter.)

In small towns throughout the state, there is no need for quadrants because each Trooper will act as the sole state law enforcement officer for a specific area, often two or three counties. In these areas, the dispatcher in the Troop Area headquarters or in another dispatcher office within the Troop Area (see the map in Appendix A) will always know which trooper to assign to a call for service because there will be one and only one on duty in that area at a time.

In each case, however, the Trooper must determine where to place himself within his sphere of Patrol responsibility during the entire shift. In some cases, there will be certain events which tend to attract his attention, such as the traffic leaving a factory at the end of a shift, closing time at a bar, or some other regular traffic event. In other cases, he may have some information that indicates a need for routine patrol. In still other cases, he may have an unspecified belief that there will be cause for concern. Perceptions play an important role in this decision. He perceives the need for patrol based on past experiences, on time of day and day of week, and on weather and road conditions. Understanding these perceptions is critical to understanding the decision process.

In addition to being pulled to various positions within the patrol area for policing and patrolling, he must try to be close to the sources of calls for service. That is, when the dispatcher calls him to instruct him to respond to a call for service (an accident, for example), he should be in a position to respond to that call quickly. Therefore, there is some attention given to being close to places where he thinks calls may come from. (This aspect of this decision is decidedly less important to him. Calls for service occur much less frequently than normal patrol activities, such as issuing traffic citations.)

The research shows that the officers themselves implicitly analyze the available information (metric, nonmetric, and perceived), combine all available data with their extensive experiential knowledge base, and decide which locations to patrol within their assigned areas. This process was identified after many sessions of unstructured interviews and observations in which the researcher learned all about law enforcement from the perspective of the Trooper. Without any prior knowledge of the Trooper's job, without any extensive insight into the Trooper's decision processes, and without any appreciation for the Trooper's decision environment, appropriate research questions would have been impossible to formulate. Therefore, structured interviews would have been nearly useless. Observation sessions proved to be the most valuable tool of information requirements analysis for this system project.

Because the observation periods were necessarily open and unstructured, the researcher gained valuable and rich information about this spatial decision. For example, while riding a shift with a Trooper who works from a base of Lincoln, I observed him deciding to patrol the town of Emerald, Nebraska (approximately 10 miles west of Lincoln). He said he thought there might be some action there. Though his reasons weren't given, it was clear that the time of day and day of week had something to do with his decision. It was about midnight on a Saturday night. Once in Emerald, he identified a potential crime in progress: a car had entered a used car lot behind us. I observed the officer as he pulled into a corner lot across the street and immediately turned off his headlights, showing a keen awareness of his potential role in the suspect's decision landscape.

While we waited, he commented that he had noticed the car in question had out-of-county license plates. His ability to keenly sense his environment was evident, for I had not even noticed the car, let alone its plates. The plates seemed to indicate that the driver or drivers may have a greater chance of being thieves because they were not "native" to that area. After several minutes of undetected observation of the suspects from across the street, he decided they probably were not attempting to steal a car, so we drove across the street to question the men. Though they were legitimately looking at several used cars, the owner of the car had just purchased his car and did not have proper registration for his car, so the officer cited him for this violation.

The ability of this officer to acutely sense his decision environment points out the expert nature of the task. The normal interface between driver and passenger was never present when I rode with Nebraska State Patrol personnel. They always were carefully "scanning" their environment, often commenting on objects and events in their decision space. For example, another time a Sergeant pointed to the fact that the woman passenger in a nearby car was holding her baby in her arms, an illegal and very unsafe act. (Nebraska has child restraint laws.) His ability to recognize such a fact about the interior space of another car also demonstrates the perceptive abilities which the individuals in this position are able to develop.

Extensive structured sampling of Nebraska State Patrol decision makers' spatial perceptions was not possible due to several limiting constraints and to the lack of commitment by the Patrol to that extent. Nevertheless, the author was able to collect a good deal of rich data about the way that these individuals view their decision landscapes. Each officer possesses a unique perception of the volume of traffic in discreet locations in space, of the level of traffic violations in those locations, of the need for traffic enforcement and patrol activities, and of other critical spatial decision variables. Though each decision maker possesses unique decision characteristics, the same questions to different Troopers repeatedly elicited the same answers. These individuals reach similar conclusions through similar decision processes, or their common background and shared experiences are responsible for the similarities.

B. Decision Support Requirements

The research question centers on the spatial decision process and the spatial perceptions of the decision maker. Given this research orientation and given the Troopers' goals of positioning themselves effectively in the Patrol landscape, the requirements for a decision support system development tool are presented and discussed.

The Trooper is depicted as a spatial expert and his spatial perceptions an expert knowledge base. To build a geographically-referenced decision support system for this problem, the systems analyst must be able to acquire the information in the users' knowledge base. He or she must then organize and relate the knowledge data in a spatially-meaningful manner. To do this, the analyst must observe the decision makers "in action" and must seek out the perceived spatial relationships between variables in the decision makers environment. By identifying, collecting, and measuring the spatial decision information, the researcher can investigate the heuristics employed by the decision maker when he continually decides where to position himself within his domain.

A tool for capturing and analyzing this data must be flexible enough to match with each decision maker's heuristic style. If the users' perspectives, especially the spatial perspectives, are not compatible with the decision support system's orientation, the valuable and rich "expert knowledge" cannot be effectively captured for including into the decision support model. However, if the system implementation is performed iteratively in an evolutionary process of design and redesign, the system can be developed as effectively as the macrogeographic manpower allocation model.

Unstructured spatial data is implicitly organized and evaluated by the decision maker in the organizational setting described above. This process is investigated by employing a "spatial questionnaire" to elicit information from the decision makers in the field. These data must be geo-referenced so that they may be organized and compared. An effective geodata collection and analysis tool must be employed to facilitate the construction of a successful geographically-referenced decision support system.

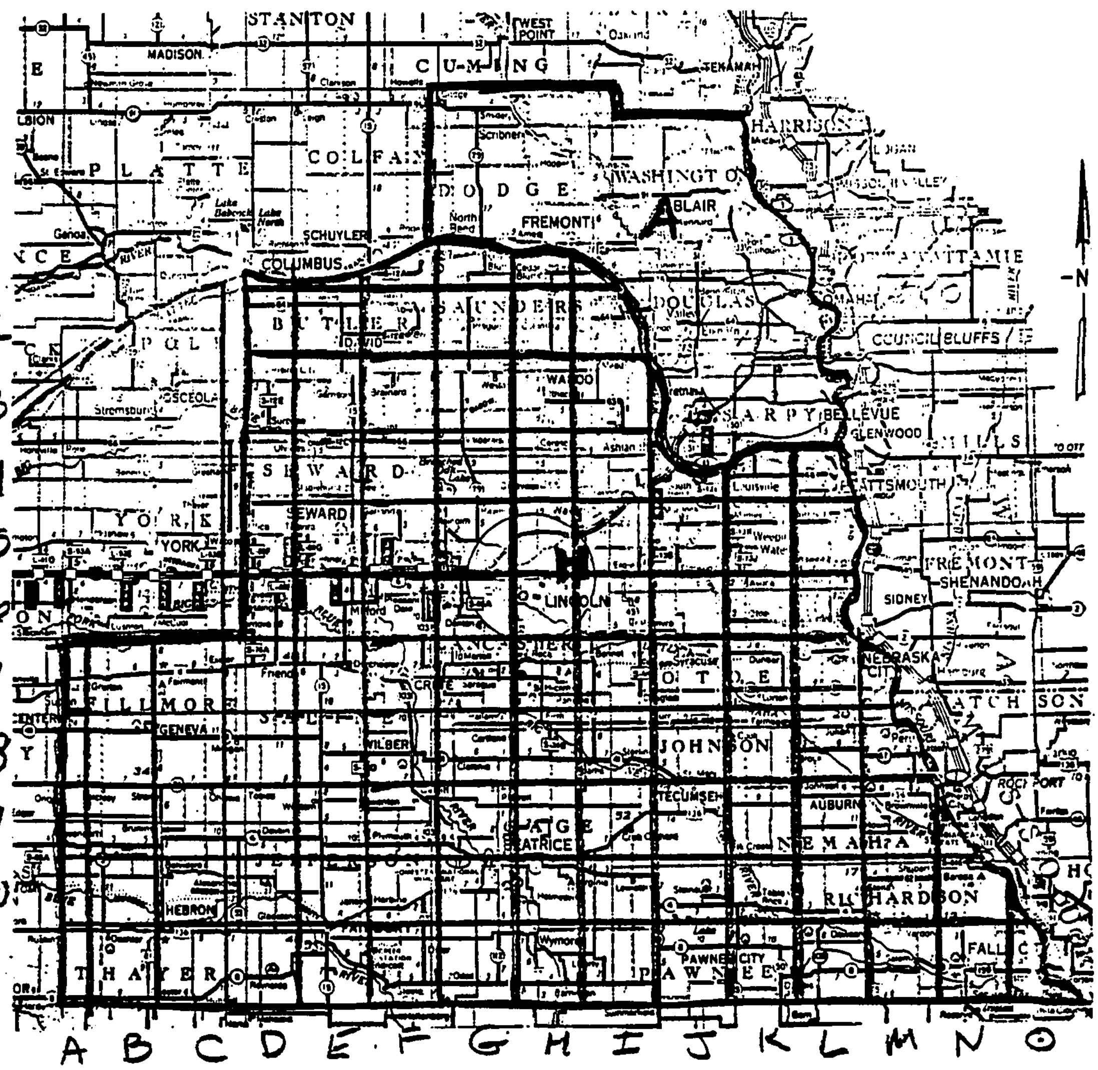
The state of Nebraska is divided into six troop areas ranging in size from the "A Troop," a four-county area centering on the Omaha metropolitan area, to the "B Troop," which covers about one-third of the state. Maps of these troop areas can be subdivided with a geodetic reference system. Within the boundaries of the latitudinal and longitudinal gridlines, higher-resolution grid squares are placed. Because some of the "hard data" is referenced by highway mile markers (such as traffic volume data and traffic citation data), these grid squares must correspond with sections of highway. Thus, the grid-cell referencing process begins not with an arbitrary sampling framework, but with one designed to accommodate the integration of currently available data. Figure 20 demonstrates how such a reference framework divides the headquarters troop area into grid cells.

The number of separate grid squares for each troop is based on factors learned while conducting a pilot study, on the size of the troop area, on the number of roads, and so on. This number will be at least 20 (even for the smallest troop area, A) to provide enough resolution so that each grid cell defines a unique meaningful geographic area (spatial sample). The specific research framework evolves as further research needs and information requirements are discovered.

The Headquarters Troop Area is comprised of the following counties in southeastern Nebraska: Butler, Saunders, Seward, Lancaster, Cass, Otoe, Fillmore, Saline, Thayer, Jefferson, Gage, Johnson, Nemaha, Pawnee, and Richardson. County maps produced by the Nebraska Department of Roads, all generated at the same scale (1/4 inch = 1 mile), can be used to generate reference maps for further definition. The result is a large analog geographic information storage and display system, a map, which displays the locations of towns, roads, lakes and streams, intersections and interchanges, and political boundaries. In addition, several other inconsequential data are displayed. This represents the reference data for further research.

Figure 20

**Georeferencing Framework for Spatial Data
to Support Trooper Positioning Decision
Headquarters Troop Area
Nebraska State Patrol**

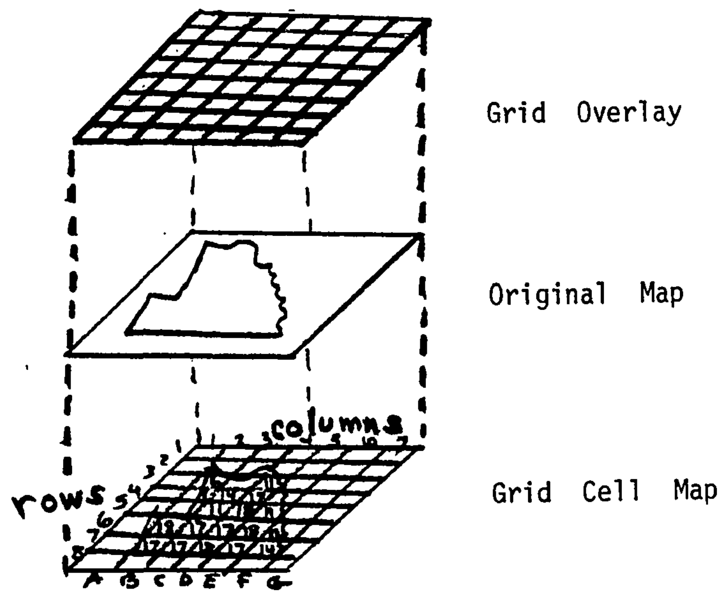


This map can be subdivided into grid squares (or grid cells), which are referenced by a row-by-column technique commonly employed by GIS practitioners to build a grid cell referenced file structure (Berry and Tomlin). Each grid square is identified by a row identifier and a column identifier, so that each can be referred to as G_{ij}, where i = the row number and j = the column number. This system of assigning row and column numbers to each cell in the area is demonstrated in Figure 21 for the headquarters troop area. Furthermore, the structure of the file allows spatial analysis to be performed on any geo-referenced variable(s) placed into the system (e.g., events, activities, distance, direction, dispersion, connectedness, contiguousness, measures of central tendency, etc.). The subjects of the study, however, need know nothing of the grid cell identifiers nor of the geo-referenced decision support system design. They see only the grid squares on various maps.

The subjects in the study are asked to rank each grid cell in their area according to the cells' volume of traffic (at various time reference points), level of criminal activity, perceived need for routine patrol activity, and several other factors. In addition, for several variables, each subject is asked to assign a value to each grid cell (possibly from 0 to 10) to represent that cell's quantity (or activity level) for each variable. These perceived quantities and actual "hard data" currently available at this level of disaggregation are combined in various ways to form spatial cardinal data sets. Many variables are defined by both cardinal data and ordinal (rank) data. For each variable, there are multiple times per cell, multiple cells per subject, and multiple subjects. Or conversely, there are multiple variables, times, and subjects for each cell. In other words, to fully appreciate and utilize all relationships within the data set, the data base management system software selected or designed for this project must have relational capabilities. The cell file must be related to the variable file, and so on. While two or three variables can be displayed at once on a map, a GIS can be designed to be n-dimensional, where n is only limited by the computer software and hardware.

Figure 21

Geocoded data file structure
Headquarters Troop Area
Nebraska State Patrol



Rows	Columns	Value (variable 1)	Value (variable 2)	Value (variable 3)	......
1	1 (A)	6250	18	3	......
2	2 (B)	1851	17	1	......
3	3 (C)	2007	17	7	......
4	4 (D)	6890	18	23	......
5	5 (E)	131	11	14	......
⋮	⋮	⋮	⋮	⋮	⋮

To the geocoded "perception data," the researcher can add another large set of metric data. This set includes average daily traffic (ADT) data, mileage data (country roads, 2-lane, 4-lane, interstate highways), incident reporting data (accidents, citizen calls for assistance, etc.), and other "hard" quantitative data. These data must be assigned at the greatest resolution possible. In some cases, the data are reported at the county level; in other cases, data are disaggregated to the grid cell level. The grids can initially be designed to accommodate the available "hard" spatial data.

The geodata base developed to support the microgeographic manpower allocation decision represents the basis for all further research. In order to develop the georeferenced decision data base necessary for the design of an effective geographically-referenced decision support system, this data must be analyzed, organized, and transformed into usable georeferenced information for decision support. This project is the subject of the next phase of research for the Nebraska State Patrol.

IV. Summary

The Nebraska State Patrol is a public service agency with a primary organizational mission of law enforcement in the state of Nebraska. The Uniform Division was formed to patrol the highways and small towns of Nebraska with the direct purpose of enforcing traffic laws and the indirect goal of enhancing the safety of the state's travelers. To effectively satisfy this goal, the administration of the Patrol must geographically deploy its personnel so that they can respond to calls for service quickly and so that they can maintain a high degree of visibility and road coverage. The manpower allocation decision is, therefore, one which occurs in a spatial decision environment.

The Nebraska State Patrol administrators have asked for a decision support system to assist them in the task of allocating their Troopers throughout the state. This task can be logically disaggregated into two subtasks. The first is termed the macrogeographic manpower allocation decision, in which Troopers are assigned to work within one of the six Troop Areas. A decision support system designed to support this first task has been carefully designed and implemented successfully. The second task, termed the microgeographic manpower allocation decision, has also been analyzed. The decision support requirements analysis (information requirements analysis) has been performed for this decision and the model is being planned.

These decisions, because they have significant spatial characteristics, demand a georeferenced support environment. Therefore, DSS designed for these tasks must be designed to reflect the decision makers' perceptions of the spatial relationships between the components and variables in the decision environment. The geographically-referenced decision support system developed for the Nebraska State Patrol has been successfully implemented. The administrators accept its validity, and with one exception, all actively use the model to assist them in the strategic allocation decisions they make.

Finally, there is yet another decision taking place in the Nebraska State Patrol. The Troopers and Sergeants, who actively patrol the highways of the state, must continually decide on the most effective position to serve the goals of traffic law enforcement and fast response to calls for service. This heuristic decision is one which is based on their experientially-acquired expert knowledge about their decision landscapes. This expert information must be collected and organized into a geographically-referenced decision support system to support future Nebraska State Patrol functions.

Chapter 4

THE BRANCH BANK LOCATION PROBLEM

Chapter 4. THE BRANCH BANK LOCATION PROBLEM

I. Introduction

Site selection for branch banks has historically been conducted by either an intuitive, unstructured method or through the use of quantitative models which may ignore the valuable, experientially-acquired contributions of decision makers. This chapter presents the development of a decision support system (DSS) for branch bank location which utilizes both types of information in a semi-structured format. The DSS allows the decision maker to select the many relative "weighting factors" for each of the criteria considered significant in choosing a location for a financial branch facility. The model focuses on selection of a county for operations, the major decision when considering alternatives in the rural-oriented areas within any state.

II. The Decision

The savings and loan institution, headquartered in Lincoln, Nebraska, will expand its Nebraska network by one new location in 1984. The S & L has determined that it will open this branch in one of the many Nebraska counties dominated by a major community which offers significant profit opportunities. In an effort to preserve the anonymity of this organization, the set of counties for consideration has been changed. The counties used in this study are Platte (Columbus), Dodge (Fremont), Adams (Hastings), Buffalo (Kearney), Madison (Norfolk), and Lincoln County (North Platte). The populations of these counties range from 28,800 to 36,500 and the major towns (listed in parentheses above) are between 17,300 and 24,500 in size. The ratios of official city population to county population fall between 0.60 and 0.75.

A properly constructed decision support system will allow the decision maker to better organize the information; while at the same time, it aids him in evaluating the qualitative aspects of the decision. The decision maker has not developed any structured method of analyzing the data; he admitted to "eyeballing the numbers and looking for patterns." The DSS will allow him to offer a more structured model for the CEO's consideration, and it will include the qualitative, experiential aspects of the decision which his colleagues wish to consider. The DSS must begin with the decision makers' perspectives if it is to have any impact on decision making. To enhance future decision processes, it should help managers adapt and learn. (Keen and Morton, 1978)

One way in which a DSS can increase decision-making effectiveness is through facilitation of interpersonal communication. It can facilitate negotiations through the provision of a common framework of analysis. It can also provide individuals with both proactive ("offensive") and reactive ("defensive") tools of persuasion. (Alter, 1980). These communication-enhancing characteristics may account for "at least as much" of DSSs' benefits as would "any direct impact on the way individuals solve problems." (Alter, 1980)

III. The Decision Support System

The bank seeks primarily to maximize its assets through attracting new savings deposits in one of four counties in Nebraska. In addition, some consideration may be given to the demand for loans in these counties. Some of the decision support variables, found in Tables 1 and 2, were identified by Love and Deichert (1983) as they developed the Site Evaluation and Location System (SELS). The variables are found in (or calculated from) the Census Bureau's Summary Tape Files 1 and 3 (STF1 and STF3) for Nebraska (U.S. Department of Commerce, 1981b) with the exception of the 1990 population projections for Nebraska counties (Deichert, 1982); persons employed, 1982 and percent change, 1976-1982 (Nebraska Department of Labor, 1977 and 1983); retail sales, 1982 and percent change, 1976-1982 (Nebraska Department of Revenue, 1976 and 1982); payroll 1981 (U.S. Department of Commerce, 1981a); and the user-supplied "intuition variables."

TABLE 1

Environmental Variables - Asset Acquisition Potential

1. POPUL 90/80 — Ratio of projected population in 1990 to the population in 1980

   This variable is considered to be some indication of the future overall growth potential of a county.

2. POP 45 TO 65 — Population, aged 45 to 65, 1980

   Members of this age group are the primary savers; they are high income earners in the peak of their careers and they are planning retirement.

3. TOTAR INCOME — Total area income, 1979 ($ millions)

   This is considered a general indicator of overall potential for volume of business.

4. MED F INCOME — Median family income, 1979 ($)

   This is viewed as a measure of relative prosperity.

5. %FAM W 25-50 — Percent of families with incomes between $25,000 and $50,000, 1979

   Though this group does not represent major savings on the individual family level, the aggregate savings potential for this group is substantial.

6. %FAM OVER 50 — Percent of families with incomes over $50,000, 1979

   This group represents the major source of large savings deposits--this is a formidable group.

TABLE 1 (continued)

Environmental Variables - Asset Acquisition Potential

7. INT,DIV,&RNT Income from interest, dividends, and rent ($ millions)

   The recipients of this type of income tend to be a high saving group.

8. PAYROLL 1980 Total wages and salaries, 1981 ($ millions)

   This is sometimes viewed as an indicator of the expectations of total savings from employees.

9. EMPL 82/76 Ratio of persons employed in 1982 to persons employed in 1976

   This can point to recent trends in business opportunities, in savings, deposits, or to overall economic activity.

10. DEPOS / BANK Commercial Bank Demand Deposits per Commercial Bank, 1982 ($ millions)

    This does not include savings and loan institutions. This can indicate the relative competitiveness or the expectations for individual new banks.

TABLE 1 (continued)

Environmental Variables - Asset Acquisition Potential

11. POPUL /FACIL Population per financial institution facility, 1980

    This can suggest the current degree of saturation by existing banks and their facilities (branches).

12. RECEPTIVENES Community receptiveness to business

    This is a factor supplied by the user on a scale of 0 to 100 which measures his or her perceptions of the local atmosphere for business in general.

13. COMPETITION Relative degree of bank competition

    Also furnished by the user--this measures the aggressiveness of existing banks' marketing departments. (High values will generate low "relvars" and low values render high "relvars.")

14. LOYALTY Strength of existing customer / financial institution linkages

    Another user-supplied index which indicates the perceived strength of current loyalties to the existing bank and S & Ls in the area of savings and checking accounts, certificates of deposit, and money market funds. (High values will generate low "relvars" and low values render high "relvars.")

These numerical variables are converted into relational variables ("relvars") in the following manner. The six values for each variable are divided by the smallest value (of the six). In this way, the smallest "relvar" is always 1.00, and the largest "relvar" may be 1.00 to 1.75 for per capita variables or much higher for absolute variables. For example, the counties have the following numbers of people aged 45 to 65: 1) Adams, 5,879; 2) Buffalo, 5,446; 3) Dodge, 7,161; 4) Lincoln, 6,723; 5) Madison, 5,663; and 6) Platte, 5,311. When each value is divided by the minimum value, 5,311, the "relvars" are calculated: 1.11, 1.03, 1.35, 1.27, 1.07, and 1.00, respectively.

Weights are then placed on these relational variables by the decision makers. This is the aspect of the model which incorporates their particular sets of experientially-acquired perspectives and their personal biases. Although a weighting scheme such as one which uses integers from 0 to 10 is suggested, any convention of relativity measurement may be employed. The user need only to move down the column and enter a number for each weight until he or she reaches the bottom. The program will add the weights together and store the sum near the bottom as "TOTAL WEIGHT."

The user must then supply values for three variables at the end of the user-input screen in Figure 23: RECEPTIVENESS, COMPETITION, and LOYALTY. These values are provided in the form of an index from 0 to 100; i.e., if one county's residents exhibit strong linkages to the existing financial institutions, then a value of 95 might be entered for LOYALTY. (The "relvar" will reverse the index range for these final two variables so that low values generate higher potentials than high values.) The criteria are weighted and added together and the total for each county is saved as "TOT CRITERIA."

Finally, the program divides each county's criteria total by its weight total to determine the asset-generating potential of that county relative to the other counties in the model. The decision maker is immediately able to quantitatively compare the counties with respect to the suggested ability of each to attract demand deposits.

The same procedure is employed to enter weights into the second portion which is used to compare the counties with respect to their loan-generating potential for the S & L. Figures 22 and 23 display the asset portion of the model and the potentials which results from a set of weighting factors.

Figure 22

Branch Bank Location Decision Support System

System Input Screen

Asset Acquisition Potential

	ADAMS	BUFLO	DODGE	LINCN	MADSN	PLATT	(min)
Popul in 80	30650	34797	35847	36455	31382	28852	
Pop Proj 90	31188	37483	39606	40476	34412	31959	
POPUL 90/80	1.02	1.08	1.10	1.11	1.10	1.11	1.02
(RELVAR #1)	1.00	1.06	1.09	1.09	1.08	1.09	
WEIGHT #1--	1	1	1	1	1	1	
CRITERION #1	1.00	1.06	1.09	1.09	1.08	1.09	
Pop. over 45	10669	9608	12579	11065	10243	8840	
Pop. over 65	4790	4162	5418	4342	4580	3529	
POP 45 TO 65	5879	5446	7161	6723	5663	5311	5311
(RELVAR #2)	1.11	1.03	1.35	1.27	1.07	1.00	
WEIGHT #2--	3	3	3	3	3	3	
CRITERION #2	3.32	3.08	4.05	3.80	3.20	3.00	
TOTAR INCOME	212	224	254	282	218	196	196
(RELVAR #3)	1.08	1.14	1.30	1.44	1.11	1.00	
WEIGHT #3--	1	1	1	1	1	1	
CRITERION #3	1.08	1.14	1.30	1.44	1.11	1.00	
Families	7974	8542	9771	9921	8153	7584	
Med F Income	18852	18332	19727	20814	19545	20224	
Fam w/25000+	2360	2504	3069	3593	2671	2534	
Fam w/50000+	308	397	408	410	387	303	
MED F INCOME	18852	18332	19727	20814	19545	20224	18332
(RELVAR #4)	1.03	1.00	1.08	1.14	1.07	1.10	
WEIGHT #4--	2	2	2	2	2	2	
CRITERION #4	2.06	2.00	2.15	2.27	2.13	2.21	
%FAM W 25-50	25.73	24.67	27.23	32.08	28.01	29.42	24.67
(RELVAR #5)	1.04	1.00	1.10	1.30	1.14	1.19	
WEIGHT #5--	1	1	1	1	1	1	
CRITERION #5	1.04	1.00	1.10	1.30	1.14	1.19	
%FAM OVER 50	3.86	4.65	4.18	4.13	4.75	4.00	3.86
(RELVAR #6)	1.00	1.20	1.08	1.07	1.23	1.03	
WEIGHT #6--	2	2	2	2	2	2	
CRITERION #6	2.00	2.41	2.16	2.14	2.46	2.07	

The members of the decision-making groups ideally each utilize the DSS on an individual basis. In this way, each time the DSS is used, it reflects the individual's personal perspectives. Unless one county clearly leads the others in every category, the various results generated by the DSS may not be the same. That is, when one member's weights are utilized, the DSS may offer the highest asset potential for one county; yet another county may be suggested when another member uses the system.

Each member of the Marketing Department is exposed to a new structured way in which to view his decision. Every time the decision maker changes any weighting factor, the program will immediately recalculate the individual potentials. Discussion between members may also enhance the meaningfulness of individual weighting choices.

Finally, the group shall come together and make the decision in one of several ways. The group may wish to "average out" the results and adopt a median recommendation. An alternative is for the group to employ the Delphi technique, in which a series of successive parameter-focusing sessions might generate a consensus weighting scheme. (Linstone and Turoff, 1975; Friedman, 1983; Blaylock and Rees, 1984; Preble, 1984) Regardless of which method is used, group dynamics will determine the ultimate recommendation.

Figure 23
Branch Bank Location Decision Support System

System Input Screen with Output Potentials

Asset Acquisition Potential (continued)
User-Determined Variables

RECEPTIVENES	90	83	78	95	90	80	78
(RELVAR 12)	1.15	1.06	1.00	1.22	1.15	1.03	
WEIGHT 12--	1	1	1	1	1	1	
CRITERION 12	1.15	1.06	1.00	1.22	1.15	1.03	
COMPETITION	80	90	86	70	75	86	70
(RELVAR 13)	0.67	0.33	0.47	1.00	0.83	0.47	
WEIGHT 13--	1	1	1	1	1	1	
CRITERION 13	0.67	0.33	0.47	1.00	0.83	0.47	
LOYALTY	65	75	58	50	67	47	47
(RELVAR 14)	1.17	0.83	1.40	1.67	1.10	1.77	
WEIGHT 14--	1	1	1	1	1	1	
CRITERION 14	1.17	0.83	1.40	1.67	1.10	1.77	
------------	-----	-----	-----	-----	-----	-----	
TOTAL WEIGHT	21	21	21	21	21	21	
TOT CRITERIA	26.09	22.89	25.13	25.55	24.73	23.04	
===========	=====	=====	=====	=====	=====	=====	
ASSET POTENTIAL	1.24	1.09	1.20	1.22	1.18	1.10	

TABLE 2

Environmental Variables - Loan Generation Potential

1. %FAM W 25-50 Families with incomes between $25,000 and $50,000, 1979

   This group accounts for the major share of mortgage loan applicants/recipients.

2. %WHO OWNHOME Percent of households not renting, 1980

   Homeowners represent a primary block of borrowers because of the high value of mortgage loans.

3. MED HOUSEVAL Median house value, 1980 ($)

   This will give some indication of the relative size of the average mortgage loan in each county.

4. TOT HOUSEVAL Total area owner housing stock value, 1980 ($ millions)

   This could suggest the overall volume of mortgage loan business in the county.

5. MED OWNCOSTS Median monthly owner costs, 1980 ($)

   This figure includes mortgage payments, fire insurance, property taxes, and certain other fees. Yet it provides an excellent signal of the current median mortgage payments.

6. TOT OWNCOSTS Total area monthly owner costs, 1980 ($ thousands)

   This also includes the additional payments but could be used to calculate the total volume of mortgage business

TABLE 2 (continued)

Environmental Variables - Loan Generation Potential

7. %W 2 EARNERS Percent of families with two income earners, 1980

These families have a greater propensity for mortgage loan applications, for home improvement borrowing, and for consumer loans of all types.

8. SALES 82/76 Ratio of Retail Sales in 1982 to Retail Sales in 1976

This can provide an excellent indication of the growth trends and the future growth potential.

9. LOAN DEMAND Demand for loans, index

This is a user-supplied variable of the perceived future demand for loans. (A scale of 0 to 100 must be used.)

10. COMPETITION Relative degree of bank competition

Also furnished by the user--this measures the aggressiveness of existing banks' marketing departments in offering loans or in lowering interest rates on loans. (High values will generate low "relvars" and low values render high "relvars.")

11. LOYALTY Strength of existing customer / financial institution linkages

Another user-supplied index which indicates the perceived strength of current loyalties to the existing banks and S & Ls in the area of mortgages, other consumer loans, and business loans. (High values will generate low "relvars" and low values render high "relvars.")

The loan demand portion of this DSS is used in the same way as the asset acquisition potential portion. The decision maker or makers attach their own values to the last three variables based on their experience with these counties. Then they attach weights to all the variables in the model. When they generate composite potentials for the target counties, they can compare the results of the loan side of the decision with the asset side. With most weighting schemes and with most similar counties, the county which is identified as the one with the greatest potential for generating assets (deposits) for the bank will not be the same county as the one identified for its superior loan-generating capacity. Because the asset side of the equation is considered to be more significant, the results of using that portion of the model are used more frequently to support the branch location decision. Nevertheless, the analysis of loan-generating potential is valuable information to the decision makers in this case.

Figure 24

Branch Bank Location Decision Support System

System Input Screen

Loan Demand Potential

	ADAMS	BUFLO	DODGE	LINCN	MADSN	PLATT	
%FAM W 25-50	25.73	24.67	27.23	32.08	28.01	29.42	24.67
(RELVAR #1)	1.04	1.00	1.10	1.30	1.14	1.19	
WEIGHT #1--	1	1	1	1	1	1	
CRITERION #1	1.04	1.00	1.10	1.30	1.14	1.19	
%hh renting	34.6	34.3	29.7	29.4	31.3	24.9	
%WHO OWNHOME	65.4	65.7	70.3	70.6	68.7	75.1	65.4
(RELVAR #2)	1.00	1.00	1.07	1.08	1.05	1.15	
WEIGHT #2--	3	3	3	3	3	3	
CRITERION #2	3.00	3.01	3.22	3.24	3.15	3.44	
MED HOUSEVAL	41400	44500	34300	44000	40100	42400	34300
(RELVAR #3)	1.21	1.30	1.00	1.28	1.17	1.24	
WEIGHT #3--	1	1	1	1	1	1	
CRITERION #3	1.21	1.30	1.00	1.28	1.17	1.24	
TOT HOUSEVAL	287	265	283	323	260	257	257
(RELVAR #4)	1.12	1.03	1.10	1.26	1.01	1.00	
WEIGHT #4--	2	2	2	2	2	2	
CRITERION #4	2.23	2.06	2.20	2.51	2.02	2.00	
MED OWNCOSTS	359	369	352	360	360	345	345
(RELVAR #5)	1.04	1.07	1.02	1.04	1.04	1.00	
WEIGHT #5--	2	2	2	2	2	2	
CRITERION #5	2.08	2.14	2.04	2.09	2.09	2.00	
TOT OWNCOSTS	1262	1264	1547	1647	1228	1154	1154
(RELVAR #6)	1.09	1.10	1.34	1.43	1.06	1.00	
WEIGHT #6--	1	1	1	1	1	1	
CRITERION #6	1.09	1.10	1.34	1.43	1.06	1.00	

Figure 25

Branch Bank Location Decision Support System

System Input Screen with Output Potentials

Loan Demand Potential (continued)
User-Determined Variables

LOAN DEMAND	78	80	68	75	70	80	68
(RELVAR #9)	1.15	1.18	1.00	1.10	1.03	1.18	
WEIGHT #9--	2	2	2	2	2	2	
CRITERION #9	2.29	2.35	2.00	2.21	2.06	2.35	
COMPETITION	90	85	85	88	68	80	68
(RELVAR 10)	1.00	1.00	1.00	1.00	1.00	1.00	
WEIGHT 10--	1	1	1	1	1	1	
CRITERION 10	1.00	1.00	1.00	1.00	1.00	1.00	
LOYALTY	65	50	53	60	58	60	50
(RELVAR 11)	1.09	1.56	1.47	1.25	1.31	1.25	
WEIGHT 11--	1	1	1	1	1	1	
CRITERION 11	1.09	1.56	1.47	1.25	1.31	1.25	
------------	-----	-----	-----	-----	-----	-----	
TOTAL WEIGHT	17	17	17	17	17	17	
TOT CRITERIA	18.18	18.60	18.15	19.16	17.94	18.89	
============	=====	=====	=====	=====	=====	=====	
LOAN POTENTIAL	1.07	1.09	1.07	1.13	1.06	1.11	

Figure 26

Branch Bank Location Decision Support System Graphical Output

Asset Acquisition Potential

This is the graph which results from assigning each of the variables an equal weighting.

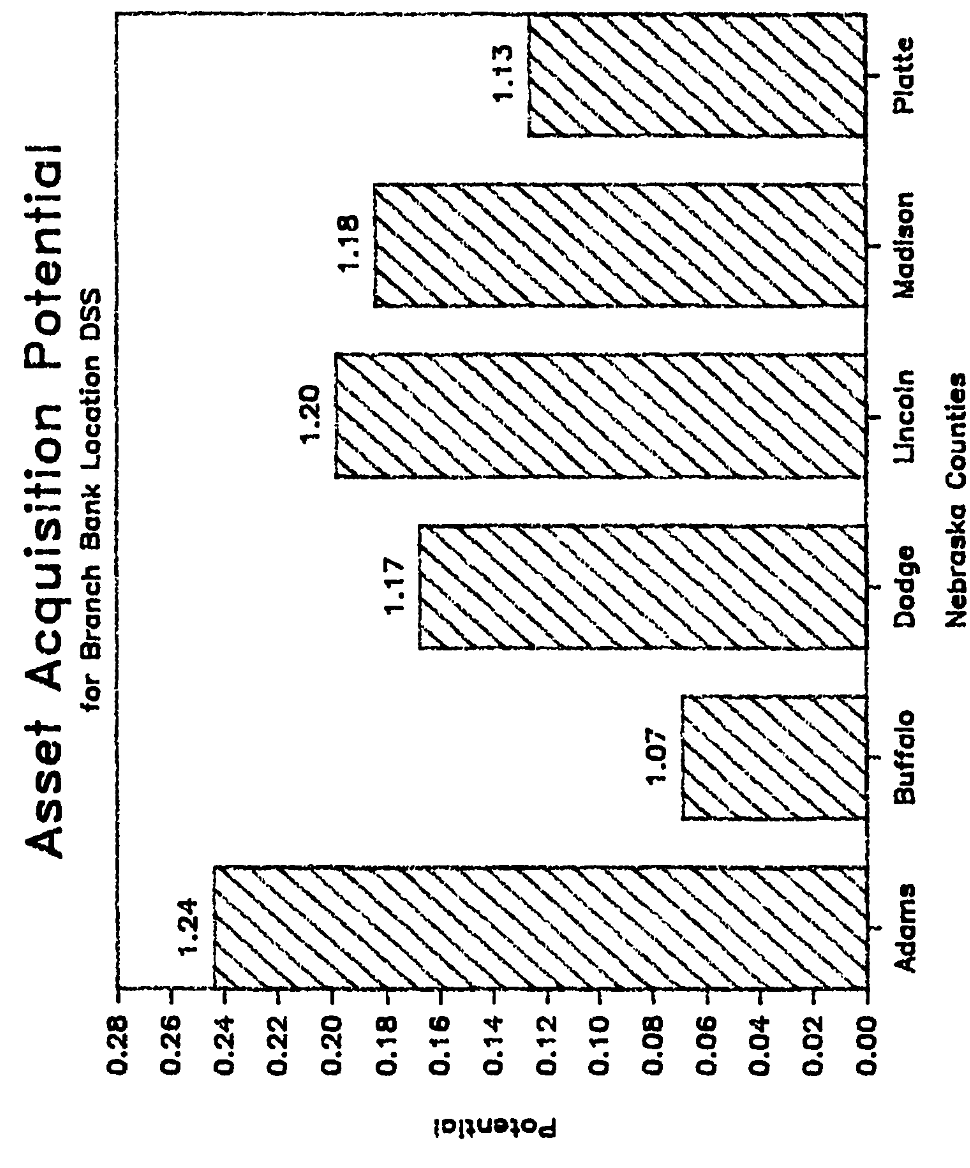


Figure 27

Branch Bank Location Decision Support System Graphical Output

Asset Acquisition Potential

This is the graph which results from the assignment of one particular user's weighting framework.

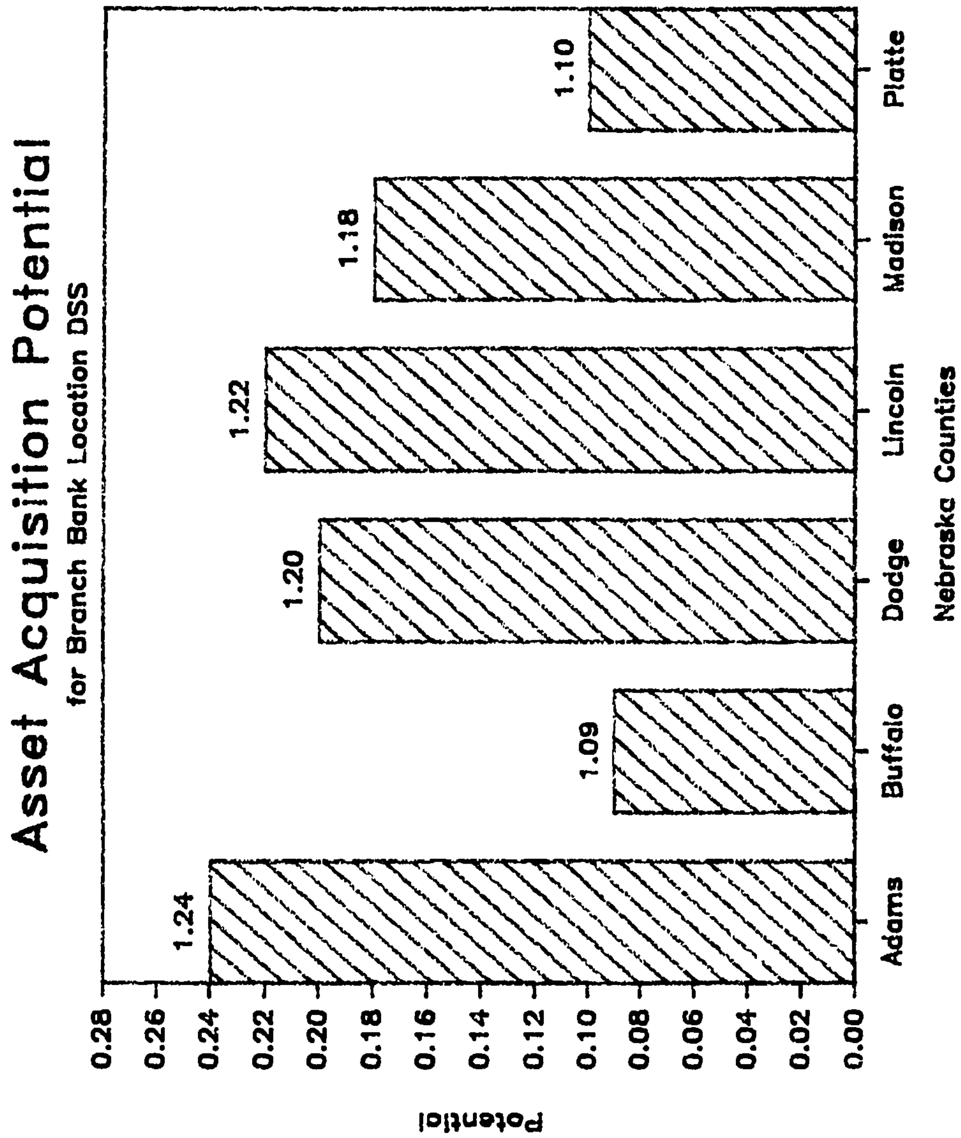


Figure 28

Branch Bank Location Decision Support System
Graphical Output

Loan Demand Potential

This is the graph which results from assigning each of the variables an equal weighting.

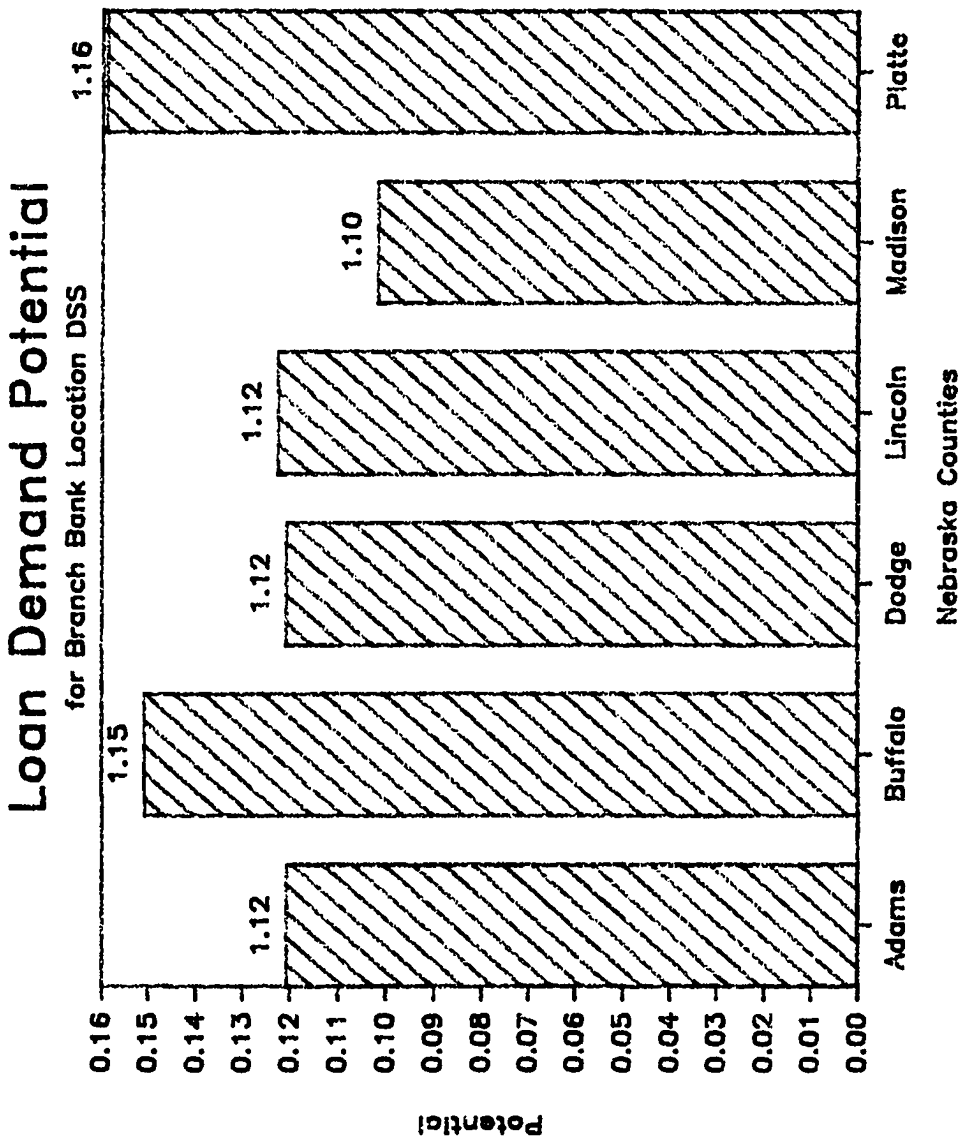
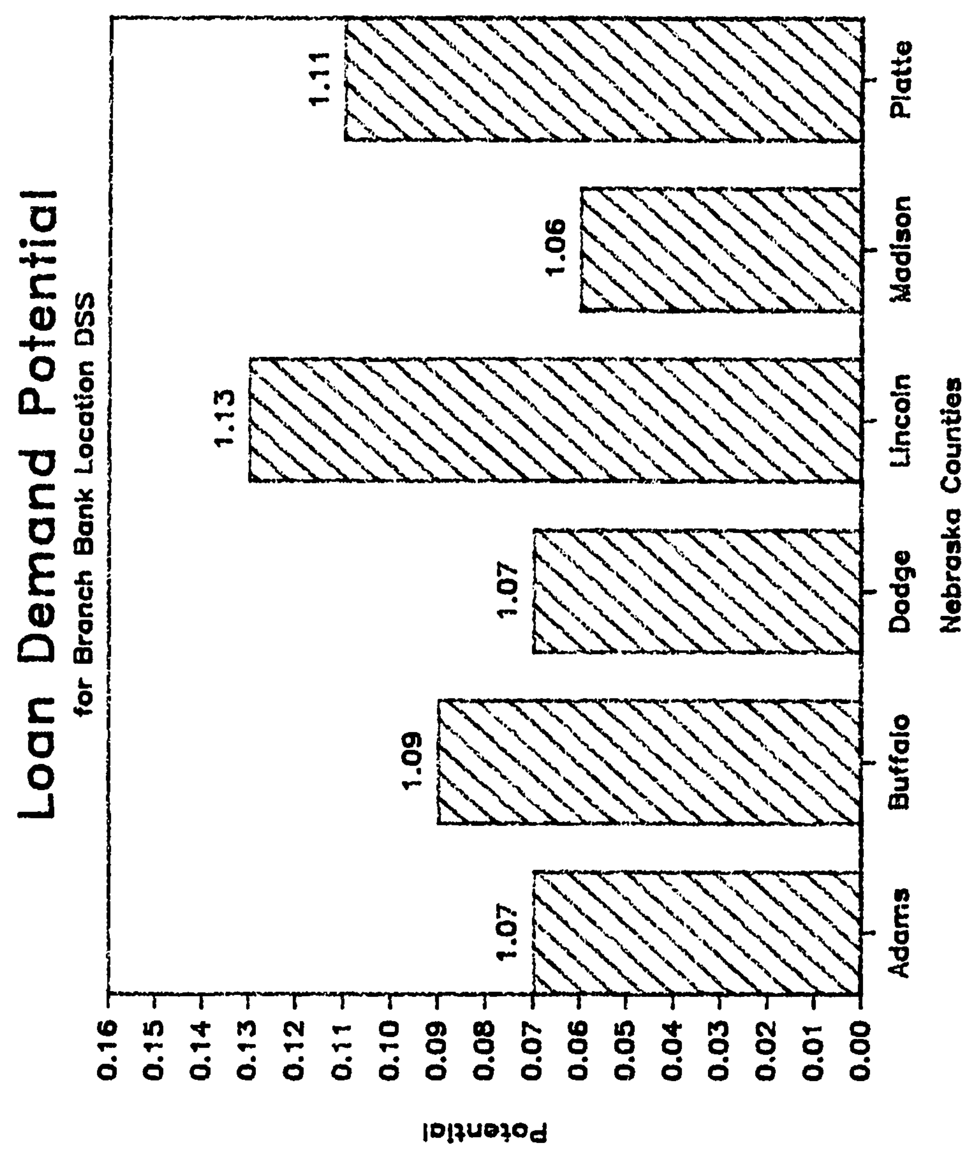


Figure 29

Branch Bank Location Decision Support System Graphical Output

Loan Demand Potential

This is the graph which results from the assignment of one particular user's weighting framework.



IV. Summary

This decision support system is an important and useful tool for the bank officer who wishes to organize and structure data used in branch site location decision making. While providing a framework of analysis, it will also influence the decision maker or the decision-making group to re-evaluate individual perspectives, to attempt to understand the rationale of other individuals' prioritizing systems, and to incorporate additional information into the decision process.

The DSS is not intended to be an algorithm for solving complex problems, nor does it encapsulate all the nonquantifiable variables which must be considered when making this decision. It does, however, seek to assimilate quantitative analysis into the decision process of heuristic-oriented, intuitive, satisficing decision makers. It also serves to incorporate some subjective thinking into the analytic thinking of the subject.

The best results will probably be obtained when the DSS is used by each individual of a group, and when the group follows the DSS exercises with dynamic group decision techniques, such as the Delphi technique. The individuals can explain the rationale behind their weighting system within a common framework rather than engage in unstructured debate.

Chapter 5

GRIDS :

GEOGRAPHICALLY-REFERENCED INFORMATION

FOR DECISION SUPPORT

Chapter 5. GRIDS -- GEOGRAPHICALLY-REFERENCED INFORMATION FOR DECISION SUPPORT

I. Introduction

Just as every decision has its own singular set of components, each spatial decision is also unique. Each one has unique objectives, variables, and environmental factors, and thus requires a separate set of design, development, and implementation approaches. The four separate spatial decisions presented in this study share several factors and yet are unique in many ways. By analyzing these decisions, we can learn about the spatial decision. The complete understanding of every decision and its components and relationships must be the goal of every systems analyst.

In this chapter, the four spatial decisions presented in this study will be compared and contrasted. The comparisons will serve to point out the significant elements of spatial decisions which lead to unique decision support system design and implementation strategies. These elements will be discussed in a common framework for the analysis of spatial decisions and geographically-referenced decision support systems.

II. Comparisons and Contrasts

This study presented and analyzed four separate spatial decisions and their decision makers. These are the macrogeographic manpower allocation problem, the microgeographic allocation problem, the microgeographic Trooper positioning decision, and the branch bank location decision. These four decisions are described in terms of the spatial component of the decisions. They share many characteristics and environmental factors, yet each one is unique in many respects. The four situations provide the researcher with some contrasting views of the spatial decision and of the job of designing decision support systems to aid decision makers in those decisions. This section will draw on some of these decisions' similarities and differences to further analyze the spatial decision. These similarities and differences offer a framework for the analysis of spatial decision making and spatial decision support.

The Nebraska State Patrol macrogeographic manpower allocation decision and the branch bank location decision are based on larger geographic decision areas than the microgeographic allocation decision and the Trooper positioning decision. They treat counties or groups of counties as the decision areas, and no additional disaggregation of the data is sought. These two decisions are also based on a limited number of areas. There are six Nebraska State Patrol Troop Areas, and the branch bank location decision support system was based on six counties, although either DSS could be based on any number of decision areas.

The microgeographic allocation decision is usually also based on only a small number of decision areas within the troop area (usually less than ten sergeant areas). The Trooper positioning decision is based on a **continuous geodecision landscape**, not on a set of discreet decision areas. This has an impact on the perceptual framework of the decision maker. The decision alternatives are less specified and less structured than those of the other two decisions, and are more consistent with heuristic decision processes. Any system built to support this type of decision requires a much more complex and intuitive system design.

Some decisions are based on discreet decision area alternatives, whereas others are based on a continuous decision landscape. When the bank manager must decide between two distinct sites for his new branch, the selection of one precludes the selection of the other. Similarly, when the Colonel of the Nebraska State Patrol assigns a new recruit to Troop Area E, he cannot also assign this individual to another troop area.

However, the working Trooper can make certain compromise decisions when he analyzes his decision landscape. For example, he may perceive two stretches of highway to be particularly dangerous areas for motorists during an ice storm. Rather than positioning himself on one or the other stretch, the Trooper may be able to split his time between them. He may also be able to choose a central location from which he can quickly respond to any accidents occurring along either stretch. By positioning himself in a visible place between the two, he can also deter unsafe driving (traveling in speeds which are not safe for the icy conditions) by individuals traveling toward both stretches of road.

There are countless other examples of how the decision maker in this environment can choose to position himself not in a specific place but in a general area by moving his patrol car along a section of highway. This aspect of his decision forms a fundamental distinction between the decision made by the Trooper and those faced by the central administrators. The continuous decision landscape of the Trooper is analogous to the decision environment of the air traffic controller.

The former type of decision is similar to that faced by advertising executives or marketing managers who are targeting their promotion expense dollars geographically. By spending dollars in the Dallas-Fort Worth market, they may be precluding the expenditure of advertising dollars in the San Francisco-Oakland-San Jose consolidated metropolitan statistical area. Many corporate manpower allocation decisions, such as the insurance company's allocation of its agents, also resemble the discreet market area decision. This type of decision is structured so that the allocation alternatives are distinct choices. These decision processes can better be supported by a decision support system which is analogous to the Nebraska

State Patrol macrogeographic allocation model. This model structures the GRIDS so that the trade-offs are clearly understood by the user. When the Nebraska State Patrol officials used this decision support system, they were able to clearly identify the consequences (direct impacts, opportunity costs, etc.) of selecting one alternative over another.

Furthermore, these decisions are similar in that they are made by individuals who may not necessarily be within the decision space itself. That is, the central administration of the Nebraska State Patrol and the decision-making body at the savings and loan company are based in Lincoln, Nebraska and they are making decisions about the placement of individuals or assets in places throughout the state. They should, but wouldn't necessarily need to, know very much about those areas beyond the published figures which constitute the basic data base for the decision support systems.

Stated another way, the central administration of the Patrol does not need to be as familiar (as the troop area commanders and the Troopers) with the road conditions, the traffic patterns, the weather, the positions of crimes, and the other unique characteristics of the individual troop areas. Their knowledge of these facts, nonetheless, assists them in understanding the assumptions on which the model is based and the results of using the model. In the same way, it is not imperative that the Savings and Loan Chief Executive Officer (CEO) and Marketing Department members fully appreciate and understand the local economic and demographic factors which they are analyzing when they use the branch bank location decision support system. However, the results of using this model are undoubtedly more effective when they are made by an individual who is firmly familiar with the decision areas. Whether or not he or she uses the branch bank location decision support system, better decisions are probable when the decision maker knows the decision environment.

III. Group and Individual Decision Processes

Another significant distinction to be drawn in spatial decision making is, like with every decision, the distinction between group decision processes and individual decision making. When the bank's managers select a site for a new branch and when the Nebraska State Patrol administrators allocate manpower to the troop areas and within the troop areas, the decision will be affected by the interaction between the members of the group. The dynamics of the group in any group decision process will impact the process and the outcome of the decision. There will be conflicts of opinion and perspective. There can be power struggles within the group between individuals with different goals and objectives. Each individual will view the decision in a unique way because of his or her own experiences and subjective "built-in" biases. (Hogarth, 1980)

In addition, the cognitive style each decision maker possesses will affect the way that information is perceived. (Blaylock and Rees, 1984) The same environment will be perceived in different ways by different members of the group. (Watkins, 1982) The way they view the incoming information is affected by their information acquisition and information processing biases. (Hogarth, 1980)

Individual decision makers also have different information needs. (Watkins, 1982; Blaylock and Rees, 1984) Some persons require a greater volume of information, whereas others will make their decision based on a more limited set of information. "The value of information cannot be effectively evaluated apart from the users of that information. There is no sense providing information to a decision maker whose cognitive make-up is such that he or she will ignore it." (Blaylock and Rees, 1984) The type of information which is required for decision support varies as well. (Wright, 1979) There is some disagreement on whether individual decision makers can identify the type of information that they need. (Blaylock and Rees, 1984) These complex and important relationships must be further taken into consideration in the field of spatial perceptions of decision information. Without understanding the way that people perceive their spatial environment (spatial decision data), we cannot effectively develop geographically-referenced decision support systems.

Each individual will also approach the decision itself in a unique way. Simon (1960) has defined cognitive style as "the characteristic, self-consistent mode of functioning which individuals show in their perception and intellectual activities." Some individuals are inclined to utilize a more analytical decision style, while others employ a heuristic decision-making process. Those who use the analytical style can sometimes view with mistrust the opinions and decisions of those who do not. They may not want to base any important decisions on an interpretation which they view as subjective, biased, intuitive, or simply "soft." Someone with an entrepreneurial decision style may impress the analytical decision maker as an individual who "plays hunches." This behavior was observed by the researcher.

While these two groups of decision makers **can** work together effectively in a group decision environment, there is a distinct possibility that discord and conflict will result. Kilmann and Mitroff (1976) have shown that individuals with different cognitive styles prefer different information sources. If the systems analyst designs a system based only on his or her decision style, the system may satisfy only one (or none) of the groups of decision makers. Early user involvement is critical when the system will be used by multiple individuals. If the system is able to satisfy the needs of each type of user (that is, if it supports both types of decision styles), then it will be effective. If not, some members of the group may not accept the validity of the results generated by using the system. In other words, the decision support system must be flexible and adaptive so that it can be used in a variety of ways by the various users.

It is important that the decision support system be designed and implemented for this group decision environment. Early planning for each potential implementation contingency is essential. One approach to facilitating the group decision process is the design of a system so that the users can view ranges of results within which each user's output falls. A predetermined weighting system is another approach to resolving individual differences. This system uses a set of mutually agreeable weights or weights set by the top official for the individual users. This approach was used in the branch bank location DSS. This weighting system can be devised so that the users' assumptions and perspectives contribute equally to the interpretation of the data in the model. The Delphi technique (Linstone and Turoff, 1975; Friedman, 1983; Blaylock and Rees, 1984; Preble, 1984) is yet another valuable technique for resolving the group members' individual differences; system implementation planning ensures that the members of the decision-making group understand the process and its results. The Delphi technique can also be used for generating the summary results of the decision support model.

Another class of methods for resolving the differences between the decision perspectives of the group members is the set of procedures known as multi-dimensional scaling. This family of procedures enables researchers to create "spatial maps" of the respondents' perceptions. (Hair, et al., 1979) Decision makers tend to view the problem along perceived dimensions and along objective dimensions. These spatial maps have been proven to provide insights into people's perceptions. (Hair, et al., 1979) The multi-dimensional scaling (MDS) techniques allow the system developer to capture the users' perceptual images of the spatial decision environment in a common framework for analysis. By having each member compare two variables at a time until each spatial variable has been compared to all others, the system developer prepares a spatial map which shows the perceptual responses along a multi-dimensional map of perceptions. Furthermore, the individual users' perceptions of each decision variable can be compared two at a time until a consensus view of the spatial decision environment is reached.

The significant similarities between these various decisions also provide important insight into the spatial decision-making process. These decisions all are based on both metric (quantitative) and nonmetric perceptual data. Geobased decision models must follow a decision support system design, which support unstructured, underspecified decisions based on ill-defined data. (Keen and Morton, 1978; and others) Space and spatial phenomena have

objective characteristics (such as linear distance, proximity, cluster patterns, aerial distributions, and so on) and **perceptual** (perceived) characteristics. Spatial decisions, because of their strong perceptual characteristics, are by nature the type of decisions which require the DSS approach. However, the decision support systems built for this project had these several unique design characteristics.

One design aspect which these geographically-referenced decision support systems have in common is the mechanism for incorporating decision-maker assumptions and perspectives into the system in a quantifiable form. The bank administrators were asked to provide values for several variables (responsiveness, loyalty, competition, and long-term loan demand) as inputs into the model. They were also asked to attach weights to the decision variables in the model so that the variables can be used in concert to provide an overall asset acquisition potential (and a loan demand potential). The users of the Nebraska State Patrol manpower allocation model were also asked to provide response speeds, forecasted manpower levels, and other variable values to the model. The Trooper positioning support system will also collect and use perception-oriented data about the troopers' patrol landscape. This common design element ensures that the system's logic is based partly on the rich and valuable perceptual knowledge that the users possess. It also adds a layer of user involvement that helps ensure acceptance and effective use of the systems.

IV. System Analysis and Implementation

The two system analysis and implementation projects provided several interesting sources of comparison. While investigating the Nebraska State Patrol, the researcher noticed a strong sense of support for (and interest in) the use of computers and computer-based systems for decision support. As detailed above, except for one notable exception, the top administrators of the Patrol were very involved with the development of the DSS designed for manpower allocation. They were primarily interested in the results of using the model, but several also had a keen interest in the way that the model was constructed and the actual operation of the model. That is, while their main interest was in the output variables, some of them were also interested in the "mechanical" workings of the microcomputer-based decision support tool.

On the other hand, the bank officials which were involved with this project had little interest in the use of microcomputers as a management support tool. They viewed the model as a tool with little potential. Financial institutions have been heavy users of large mainframe computers to perform operational, transaction-oriented management tasks such as check processing, billing, payroll, bookkeeping, and so on. However, many of them are not accustomed to thinking about computers as useful tools for supporting strategic-level management functions (such as branch bank location).

The Nebraska State Patrol administrators had more experience using their computers to generate reports that could be used to support a variety of decision categories. In fact, the ability to incorporate some of these data sets (previously seen only as printouts) into the geographically-referenced decision support system built for this project was very exciting for them. The ability to query the DSS, to insert new decision assumptions, and to see instant tabular or graphical output based on these inputs was said to be very helpful in seeing the impact of various decision alternatives which they were considering.

The implementation success with the Nebraska State Patrol geobased DSS can be attributed in part to the early project involvement by the users of the model. The branch bank location DSS did not have the same degree of early support, and the users had less input into the model's design.

The implementer must take the group dynamics into account when planning the decision support system, whether the Delphi technique is employed or some other method of conflict resolution is used. It is critical that the systems analyst involve many users early to gauge each member's reaction to the operation of the model. This was the approach used when implementing the Nebraska State Patrol macrogeographic manpower allocation DSS. If this is not done, the system may eventually fail due to improper consideration of important information, or simply due to lack of use by the members of the decision-making group.

V. Considering Organizational Objectives

Another difference in the spatial decisions discussed in this project is the difference in organizational goals for the decision support systems. While the bank (S & L) was motivated by the profit-maximizing goal, the Nebraska State Patrol was motivated by both efficiency and effectiveness objectives. The Nebraska State Patrol manpower allocation decisions can be viewed as "service maximization" through "response time minimization" decisions, though the goal of providing sufficient, effective service to the citizens of the state is also present. Of course, these effectiveness objectives are difficult to quantify.

The branch bank location decision can be viewed superficially as a decision for selecting a county which will provide the greatest source of deposits or investment assets (and/or the greatest demand for loans). Of course, this complex decision has more objectives than profit maximization. The bank administrators are interested in locating in a county which will strengthen the bank's asset portfolio, provide visible evidence of the bank's size and strength, increase market share, diversify the investments of the bank, and satisfy (not necessarily maximize) the targets for returns on the bank's investments. In other words, the decision makers at the S & L may wish to "satisfice" all requirements for this branch facility while trying to optimize a few very important ones.

VI. An Integrated Framework

The common decision elements presented in the last section demonstrate the need for a common framework for analyzing spatial decisions. There must be one systems analysis and design tool which can be employed to determine the degree of spatiality in any decision environment, another for assisting the analyst in the task of understanding the spatiality of the decision (or the perceived spatiality), another for acquiring the spatial perceptions to include in a decision support system, and also a tool or technique for organizing the "hard" metric data and the "soft" perceptual data into a structured system to aid decision makers in spatial decision environments. The realization of these diverse and unique objectives leads to a comprehensive framework for the analysis and design of geographically-referenced decision support systems.

Space has been described as a framework of thought. If space is a dominant decision perception dimension, spatial characteristics must be categorized and organized into a framework for systems analysis. This framework takes the form of a **contingency model.** The exploration of this study's research decisions has shown that important distinctions exist. There are many ways to categorize a spatial decision. These categories of decision makers, decision type, cognitive style, decision landscape, degree of spatiality, and so on will determine the approach prescribed for the system design and implementation.

The spatiality can have a large or a small degree of impact on the decision maker. The spatial characteristics, if they affect the decision outcome in a significant way, must become a major feature of the system design. The spatiality was less significant in the macro-geographic decision support system than in others under investigation in this study. The degree to which the decision makers consider their spatial environment must be implicit in the system design.

Whether the decision landscape is comprised of discreet decision areas or is a continuous decision plane will affect the design of the system. When the decision is performed in a poorly-structured continuous landscape, the analyst must be able to define areas which are meaningful to the decision maker(s). "Hard data" availability will dictate the logical starting point for any decision grids used. But it is critical that the collection of spatial perceptions is a process which is consistent with the perspectives of the decision makers.

The distinction between group decision processes and individual processes will also play a key role in determining the appropriate georeferenced DSS design and implementation strategies. The important characteristics of each, which were explored in this study, can generate some potential sources of system failure. The systems analyst must consider the political relationships between decision makers and the differences of perspective. The political conflicts can be solved through the application of techniques such as the Delphi technique and various weighting schemes. The differences of perspective stem partially from the unique ways that individuals perceive their spatial environment. If geographically-referenced decision support systems are to be developed correctly, they must be flexible and adaptable to accomodate multiple users' views of the spatial dimensions. If GRIDS (Geographically Referenced Information for Decision Support) is to be developed, spatial perception analysis must become an integral part of systems analysis and design. As long as systems are designed with no regard to the spatial componenet, they will be ineffective in the spatial decision environment.

These and many other contingencies provide the framework for analyzing spatial decision environments for the purpose of developing GRIDS. Geographically Referenced Information for Decision Support has proven to be an effective tool for supporting spatially-oriented decisions. Tools for the development of future GRIDS must be based on the contingency framework discussed in this section.

VII. Summary

Decisions which are implemented in a spatial decision environment may fail if care is not taken to analyze the role of spatiality in the decision process. It is recognized that determining the spatial perceptions (like all perceptions) of respondents is a difficult task which requires careful attention to the decision-maker narratives of the decision and thoughtful design of questionnaires to elicit the critical spatial components of the decision. The decision support system itself requires an added element of attention to its perceived structure. If the users do not perceive the spatial environment in the same way that the model portrays it, they are unlikely to accept the system and it will never be utilized effectively.

Chapter 6

CONCLUSIONS

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This study has investigated the spatial decision, its environment, and the relationship between the decision maker and the spatial variables. The spatial decision was viewed from the perspectives of State Patrol administrators, Troopers, and bank managers. Several geographically-referenced decision support systems were constructed to demonstrate some of the special design and implementation components that are required for successful decision support.

Information requirements for a GRIDS-based system for the support of Nebraska State Patrol Troopers have been determined. This geographically-referenced decision support system developed from the GRIDS must effectively support the trooper positioning decision of Uniform Division law enforcement officers within the Nebraska State Patrol.

I. Conclusions of this Study

Many decisions are executed in decision environments significantly characterized by spatial variables. There exists a great need for the development of many geographically-referenced decision support systems. In addition, there is a need for a fundamental framework to be used in designing these systems. Future research will determine whether an effective technique for collecting geographic information can be developed for systems analysts and for building decision support systems.

Extensive structured sampling of Nebraska State Patrol decision makers' spatial perceptions was not possible due to several limiting constraints and due to the lack of commitment by the Patrol to the extent required for this part of the project. Nevertheless, the author was able to collect a substantial amount of rich data about the way that these individuals view their decision landscapes. Each officer possesses a unique perception of the volume of traffic in discreet locations in space, of the level of traffic violations in those locations, of the need for traffic enforcement and patrol activities, and of other critical spatial decision variables. Though each decision maker possesses unique decision characteristics, the same questions to different Troopers repeatedly elicited the same answers. These individuals reached similar conclusions through similar decision processes or because their common background and shared experiences contributed to this observation. These decision processes and experiential knowledge bases must be researched and analyzed by every system designer building geographically-referenced decision support systems.

The remarks of several Troopers strongly indicate that the spatial perceptions of these individuals were very similar if they had similar backgrounds and experiences. In other words, the Troopers and Sergeants, who spent most or all of their time on the highways of their troop area, shared a similar perspective that was not evident in the Captains and Majors, who may have lost sight of the nuances of active policing and patrolling activities. Furthermore, officers with rural or small-town backgrounds exhibited similar views of distance and time which were not seen when I observed the work of Troopers headquartered in Lincoln. For example, the Lincoln-trained Troopers sought more action; they were more excited about the activity in their patrol realm. The rural-based Troopers who worked further from Lincoln were clearly willing to patiently cruise longer and wait for the activity. The following observation serves to make this point. One Trooper told me that it was "no trouble" to attain the unofficial goal of one arrest of a drunk driver per month, because he said he did not have to look for them. "They come to you," he said. This attitude exemplifies that of other rural-based Troopers I observed. The individual's background and experiences served to shape his perspective of his spatial decision environment.

The actions of these groups of officers in various circumstances indicated that they may have used similar decision processes to analyze their spatial decision environment. If they employed the same decision process, then it is worth examination. It may not be an 'optimal' decision process, but it is an acceptable (satisficing) one and may be the most effective approach in use. Therefore, any DSS designed to facilitate that decision process through the organization and analysis of pertinent spatial data is an effective aid to Nebraska State Patrol personnel who spatially allocate uniformed manpower if it is designed to reflect those observed perspectives.

Watkins (1982, 1984) investigated the decision maker's perceptions of information structure, using multi-dimensional scaling (MDS) to generate "preference maps" of the subjects' unique information perceptions. He explored the use of this perceptual knowledge to tailor the decision information to the users of decision support systems. If it can be shown that the spatial data are perceived to lack structure, but that separate subjects perceive the data in similar ways, then it can be argued that these subjects will also perceive the data in similar ways if structure is imposed (or is perceived to be imposed) on the data. A project for collecting the spatial information which is pertinent to these decisions must be instigated. The project must include the collection, organization, and analysis of the perception data, the "hard data," and the underlying structure of both types of data. The comprehensive collection of structured metric and nonmetric data must then be used to generate a more extensive set of Geographically-Referenced Information for Decision Support (GRIDS). This information provides the basis of further geographically-referenced decision support systems for use in manpower allocation.

The geo-referenced DSS must be analyzed in its organizational environment. Its degree of acceptance must be examined, its perceived contribution to the decision process must be investigated, and its impact on the organization must be observed and recorded. A life cycle approach to DSS design must be employed to evaluate the system's effectiveness.

The research must, however, also be based on economic justification. It is unclear whether this project can be initiated without some a priori assurance of its effectiveness and validity. The resulting decision support system must be structured in such a way that it captures the decision makers' perceptions of their spatial landscape. A technique which is useful for collecting, analyzing, and presenting this spatial data for the Nebraska State Patrol administrators to aid in their decision-making processes can be generalized for use in a variety of spatial decision environments.

If the DSS can be demonstrated to improve decision making (by contributing to the **perceived structure** of the decision), then its effectiveness can be judged. The tasks of proper testing of the GRIDS and implementation of the resultant geographically-referenced decision support system require the secured approval and a commitment in time and resources of the Nebraska State Patrol administration and from the researcher. The project requires hundreds of hours of valuable time from a large number of decision makers at all ranks.

Another interesting area of potentially valuable research is the investigation of spatially-oriented cognitive processes and their role in judgment and choice. Professor Gardner's theory (1983) of multiple intelligence--linguistic, musical, logical-mathematical, spatial, bodily-kinesthetic, and the personal intelligences--may lead to tests of intelligence type. In other words, despite the well-documented problems with Intelligence Quotient (IQ) scores, there may be merit in determining whether one individual has a greater propensity for perceiving spatial relationships in his environment than other individuals ("spatial IQ"). This information may lead to more effective selection of Nebraska State Patrol troopers, air traffic controllers, football quarterbacks, submarine pilots, and so on. If spatial problem solving can be understood, it may also be possible to teach these skills, enabling the spatial education of troopers and police officers, traffic engineers, military tacticians, chess players, and so on.

Probably the most important aspect of this spatial intelligence research is the resulting data base containing information about the spatial cognitive processes that affect the decision process. If the systems analyst who is constructing management information systems or decision support systems for spatially-oriented decisions can learn about these spatial thought processes, he can design and implement the system in a more acceptable form. Because successful implementation is the primary goal of all DSS development projects, it behooves the analyst in the spatial environment to understand this spatial thought process so that he may gain an empathetic appreciation of the decision-makers' view of the decision environment.

II. Implications for Future Research

Much additional research is required to determine the role of spatiality in decision making. The perceptions of the decision makers must be identified and thoroughly analyzed. Effective ways to collect, organize, store, and retrieve Geographically-Referenced Information for Decision Support in a decision support system environment must be found. It is also critical to ascertain the specific relationships between the spatial decision variables and the decision process and decision outcome.

Traditional decision support systems designed to aid decision making in a variety of unstructured decision environments will continue to increase in importance as tools of modern management. However, there is a need to understand the role of decision-maker perceptions, which should be included as DSS design factors. One area in particular that warrants further investigation is the role of spatiality in the decision environment. Appropriate questions include the following: how can we better understand the spatial perceptions of the managers?, and How do these spatial perceptions affect the decision process?

For the Nebraska State Patrol, specific research needs present themselves. For example, the Trooper needs to know where to patrol under the various contingencies in his decision-making space and time. Future research can perhaps determine whether this is only nebulous, acquired expert knowledge or information which can be used in designing Trooper positioning decision support systems or expert systems. Determining the answer to this question requires a considerable commitment from the Patrol and from all those involved. The knowledge to be gained from answering these basic questions can be used to design many expert systems to support a wide variety of management decisions.

The geodatabase developed to support the microgeographic manpower allocation decision, which was discussed in Chapter 3, represents the basis for all further research. In order to develop the georeferenced decision database necessary for the design of an effective geographically-referenced decision support system, an information analysis procedure must be performed. One tool which can be employed to analyze the data is factor analysis. Factor analysis can be used to establish parsimony in the data. Two or three factors may represent the wealth of information available in this large database as it applies to the problem of spatial manpower allocation.

The next stage of the research must use these factors to build second-stage questionnaires for the subjects. The subjects are asked to further classify each grid cell according to the new factors established by the factor analysis. The resulting set of data is further analyzed. This data can eventually be used for constructing another geographically-referenced decision support system, but it is important that the research be initially directed toward understanding the perceived spatial relationships between the decision variables before a useful DSS can be built.

A database management system must be designed to store and retrieve values associated with each grid cell in an interactive user interface environment that supports the decision process. The system must efficiently manage the DSS which will provide the decision makers with concise, meaningful, georeferenced decision information which they can use in an interactive, flexible manner. This system must emulate the one currently being employed for the macro allocation problem, because its format and user interface have been accepted by the administration and they have indicated that it will be very useful in supporting the decision-making process.

Like the geographically-referenced decision support system now being used by the Nebraska State Patrol, the microgeographic manpower allocation DSS must allow user-defined queries of the system for tabular or visual (graphical) output. It must provide the Nebraska State Patrol administrators with a relevant set of information which can be effectively utilized to support the manpower micro allocation decision. One feature of this system is the sophisticated geographical queries which allows the user to see spatial relationships not currently evident. This comprehensive system of geodata collection, organization, analysis, and display will facilitate improved decision making.

The analysis of the Nebraska State Patrol organization and its components yielded valuable information about the goals, objectives, and information requirements of the organization. The design and implementation of the geographically-referenced decision support system now being used for macrogeographic manpower allocation also proved to be a useful exercise both from the perspective of the system users and for the researcher interested in learning more about spatial decision making. The administrative objective of spatial allocation suggests multiple future research objectives for the systems analyst. The problem requires a coherent method of data collection and analysis.

There exists a great need for both geocoded decision support data and the georeferenced information (GRIDS) derived from that data. In addition, there are many decisions which can be effectively supported by a well-designed geographically-referenced decision support system. There is a great need for research of all types to support the development of this field. The technique can be refined and enhanced through repeated applications and redesign. Systems analysts must conduct case studies of organizations which perform spatial decisions, as a first step to improving our understanding of these activities. Behavioral geographers and cognitive judgment psychologists must contribute further to our understanding of the way in which people perceive their spatial environments, and the way in which they make spatial judgments based on those perceived stimuli.

Researchers with technical skills, such as information analysts, computer scientists, cartographers, and statisticians can advance the capabilities of the physical structures associated with the georeferenced DSS. Increased speed and efficiency of data storage and retrieval is one goal, improved graphical and cartographical output capabilities is another.

III. Summary

This project has used the analysis of several decisions to explore the special problems associated with supporting spatial decisions with geographically-referenced decision support systems. Various factors in the spatial decision environment have been presented as contingencies to be used in determining the proper design and implementation strategies for successful spatial decision support.

This study has added to the research knowledge base concerning decision maker perspectives and their contribution to the design and development of decision support systems. The findings of this research project include the contingency requirements for spatial DSS design and implementation, the specification of spatial information requirements analysis, and the results of the two DSS implementation projects in the study.

In addition, this study has served to lay the foundation for further research into decision makers' spatial perceptions as they relate to geographically-referenced decision support systems. These perceptions must be fully understood by the system designer in order to build a useful and effective DSS. Other research needs are presented; geodata storage and retrieval systems can be improved, spatial data presentation systems can be designed for greater impact, and each system life cycle stage can be tailored to the unique demands of the spatial decision.

REFERENCES

REFERENCES

Adam, E.E., Jr. and R.J. Ebert. Production and operations management: concepts, models, and behavior, Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1978.

Alexanderson, K.W. Bank branch location feasibility analysis, Burroughs Clearing House, February 1969, 54, 26-27.

Alter, S.L. "Why is Man-Computer Interaction Important for Decision Support Systems?" Interfaces, Volume 7, Number 2, February 1977a, pp. 109-115.

Alter, S.L. "A Taxonomy of Decision Support Systems," Sloan Management Review, Volume 19, Number 1, Fall 1977b, pp. 39-56.

Alter, S.L. Decision Support Systems: Current Practice and Continuing Challenges, Reading, Mass.: Addison-Wesley, 1980.

Amadeo, D. and R.G. Golledge. An Introduction to Scientific Reasoning in Geography, New York: John Wiley and Sons, Inc., 1975.

Andrews, Frank M. and Robert C. Messenger. Multivariate Nominal Scale Analysis: A Report on a New Analysis Technique and a Computer Program, Ann Arbor: Institute for Social Research, The University of Michigan, 1973.

Armstrong, R. D. and W. D. Cook. "Goal Programming for Assigning Search and Rescue Aircraft to Bases," Journal of Operational Research Society, Volume 30, Number 6, June 1979, pp. 555-561.

Athappilly, Kuriakose. "Successful decision making starts with DSS evaluation," Data Management, February 1985, pp. 24-28.

Bahl, Harish C. and Raymond G. Hunt. "Decision-Making Theory and DSS Design," Data Base, Volume 15, Number 4, Summer 1984, pp. 10-14.

Barbosa, L. C. and R. G. Hirko. "Integration of Algorithmic Aids into Decision Support Systems," Management Information Systems Quarterly, Volume 4, Number 1, March 1980, pp. 1-12.

Bauhoffer, R. J. "The census data gold, how to mine it for new branches," Savings Bank Journal, Volume 53, February 1973, pp. 68-77.

Bell, R. R. and N. B. Zabriskie. "Assisting marketing decisions by computer mapping: A branch bank application," Journal of Marketing Research, Volume 15, February 1978, pp. 122-128.

Bennett, John L., ed. Building Decision Support Systems. Reading, Mass.: Addison-Wesley, 1983.

Berry, Joseph K. and C. Dana Tomlin. Papers in Spatial Information Systems, unpublished workbook for the Geographic Information Analysis "Mini" Workshop, Yale University.

Boggs, S. L. "Urban Crime Patterns," American Sociological Review, Volume 30, 1965, pp. 899-908.

Bonczek, Robert H., Clyde W. Holsapple, and Andrew B. Whinston. Foundations of Decision Support Systems, New York: Academic Press, 1981.

Bonczek, Robert H., Clyde W. Holsapple, and Andrew B. Whinston. "Future Directions for Developing Decision Support Systems," Decision Sciences, Volume 11, 1980, pp. 616-631.

Bres, E. S., D. Burns, A. Charnes, and W. W. Cooper. "A Goal Programming Model for Planning Officer Accessions," Management Science, Volume 26, Number 6, August 1980, pp. 773-783.

Brill, E.D., Jr. "The Use of Optimization Models in Public Sector Planning," Management Science, Volume 25, Number 5, May 1979, pp. 413-422.

Bryce, Tim. "Information Systems: A Field in Transition," Journal of Systems Management, Volume 34, Number 8, issue # 268, August 1983, pp. 6-13.

Brown, M. A. "Modeling the Spatial Distribution of Suburban Crime," Economic Geography, 1982, pp. 247-261.

Burch, John G., Jr., Felix R. Strater, and Gary Grudnitski, Information Systems: Theory and Practice. New York: John Wiley and Sons, 1983.

Burnett, Pat. "Behavioral Geography and the Philosophy of the Mind," in Golledge, Reginald G. and Gerald Rushton, eds. Spatial Choice and Spatial Behavior: Geographic Essays on the Analysis of Preferences and Perceptions. Columbus: Ohio State University Press, 1976, Ch. 2, pp. 23-48.

Calkins, Hugh W. "Creating Large Digital Files from Mapped Data" in Marble, Duane F., Hugh W. Calkins, and Donna J. Peuquet. Basic Readings in Geographic Information Systems. Williamsville, N.Y.: SPAD Systems, Ltd., 1984.

Carlson, Eric E., et al. "The Design and Evaluation of an Interactive Geo-Data Analysis and Display System," Proceedings of the IFIP Congress 74, Amsterdam: North-Holland Publishing Company, 1974, pp. 1057-1061.

Chan, K. H. "Decision Support System for Human Resource Management," Journal of Systems Management, April 1984, pp. 17-25.

Courbon, J. "Transpency of Data, Information, and Models in Decision Support Systems," Operational Research, 1984, pp. 90-102.

Courbon, J., J. Drageof, and T. Jose. "L'Approache Evolutive," Information El Gestion No. 103. Grenoble, France: Institute d' Administration des Enterprises, January-February 1979, pp. 51-59.

Cox, Nicholas J. and David W. Rhind. Geographical Networks and Automatic Data Processing. Durham: Department of Geography, University of Durham, 1978.

Cumming, Paul D., Kenneth E. Kendall, C. Carl Pegels, and J. P Seagle. "The Impact of an Information System on Regional Blood Service," Information and Management, Volume 3, 1980, pp. 63-72.

Curley, K.F. and L.L. Gremillion. "The Role of the Champion in DSS Implementation," Information and Management, Number 4, August 1983, pp. 203-209.

Daft, Richard L. "System Influence on Organizational Decision Making: The Case of Resource Allocation," Academy of Management Journal, Volume 21, Number 1, PP. 6-22.

Dangermond, Jack. "A Classification of Software Components Commonly Used In Geographic Information Systems" in Peuquet, Donna and John O'Callaghan, eds. Design and Implementation of Computer-Based Geographic Information Systems. Amherst, N.Y.: IGU Commission on Geographical Data Sensing and Processing, 1983.

Davidson, F. "Locating bank branches with management science help," Bankers Magazine, Summer 1969, 84-89.

Davis, E.W. and J. Patterson. "A Comparison of Heuristic and Optimum Solutions in Resource-Constrained Project Scheduling," Management Science, Volume 20, April 1975, pp. 944-955.

Davis, Gordon B. Management Information Systems: Conceptual Foundations, Structure, and Development. New York: McGraw-Hill Book Company, 1974.

Davis, Michael W. "Anatomy of Decision Support," Datamation, Volume 30, Number 9, pp. 201-208.

Deichert, J. Nebraska population projections 1985-2020. Lincoln, NE: Bureau of Business Research, University of Nebraska-Lincoln, November 1982.

Desanctis, Gerardine and J.F. Courtney. "Toward Friendly User Implementation," Communications of the ACM, Volume 26, Number 10, October 1983, pp. 732-738.

Dickie, R. James. "Implementation Demands a Personal Approach," Data Management, February 1984, pp. 28-29.

Dickinson, L. V. and J. W. Hall. Evaluation of Pedestrian Accidents Using Factor Analysis. College Park: Trans-portation Studies Center, University of Maryland, January 1976.

Didner, Robert S. and Keith A. Butler. "Information Requirements for User Decision Support: Designing Systems From Back To Front," Proceedings of the IEEE, 1982, pp. 415-419.

Downs, Roger M. Approaches To, and Problems In, The Measurement of Geographic Space Perception. Seminar Paper Series A: Number 9. Bristol, England: Department of Geography, University of Bristol, 1967.

Drucker, P.F. "Managing the public service institution," The Public Interest, 1973, pp. 33, 43-60.

Dueker, Kenneth J., Robert H. Ericksen, and Evan Noynaert. Geographic Data Handling Issues: An Alternative to Variable Grid Resolution. Iowa City: Institute of Urban and Regional Research, University of Iowa, 1977.

Duncan, R. B. "Multiple Decision-making Structures in Adapting to Environmental Uncertainty: The Impact on Organizational Effectiveness," Human Relations, Volume 26, Number 3, 1973, pp. 283-291.

Eaton, David J., M. S. Daskin, D. Simmons, B. Bulloch, and G. Jansma. "Determining Emergency Medical Service Vehicle Deployment in Austin, Texas," Interfaces, Volume 15, Number 1, January-February 1985, pp. 96-108.

Economides, Spyros and Mark Colen. "Microcomputer-Based Decision Support Systems Aid Managers In Evaluating Alternatives," Industrial Engineering, Volume 17, Number 9, September 1985, pp. 44-51.

Edwards, John S. "A Survey of Manpower Planning Models and Their Application," Journal of the Operational Research Society, Volume 34, Number 11, 1983, pp. 1031-1040.

Eilon, S. "Goals and Constraints in Decision Making," Operations Research Quarterly, Volume 23, Number 1, March 1972, pp. 3-16.

FitzGerald, Jerry, Ardra F. FitzGerald, and Warren D. Stallings, Jr. Fundamentals of Systems Analysis, 2nd edition, New York: John Wiley & Sons, 1981.

Foster, Stuart A. and Wilpen L. Gorr. "An Adaptive Filter for Estimating Spatially-Varying Parameters: Application to Modeling Police Hours Spent in Response to Calls For Service," Management Science, Volume 32, Number 7, July 1986, pp. 878-889.

Frankel, Martin R. Inference From Survey Samples: An Empirical Investigation. Ann Arbor: Institute for Social Research, University of Michigan, 1971.

Friedman, Daniel. "Effective Scoring Rules for Probabilistic Forecasts," Management Science, Volume 29, Number 4, April 1983, pp. 447-454.

Fuerst, William L. and Paul H. Cheney. "Factors Affecting the Perceived Utilization of Computer-Based Decision Support Systems in the Oil Industry," Decision Sciences, Volume 13, Number 4, October 1982, pp. 554-568.

Gardner, Howard. Frames of Mind: The Theory of Multiple Intellegences, New York: Basic Book Publishers, Inc., 1983.

Gingrich, Gerry and Sigfrid D. Soli. "Subjective Evaluation and Allocation of Resources in Routine Decision Making," Organizational Behavior and Human Performance 33:2, April 1984, pp. 187-203.

Golledge, Reginald G. and John N. Rayner, eds. Proximity and Preference: Problems in the Multidimensional Analysis of Large Data Sets. Minneapolis: University of Minesota Press, 1982.

Golledge, Reginald G. and Gerald Rushton, eds. Spatial Choice and Spatial Behavior: Geographic Essays on the Analysis of Preferences and Perceptions. Columbus: Ohio State University Press, 1976.

Goodman, P.S. and J.M. Pennings, eds. New Perspectives on Organizational Effectiveness. San Francisco: Jossey-Bass, 1977a.

Goodman, P.S. and J.M. Pennings. "Perspectives and issues: An Introduction," in Goodman, P.S. and J.M. Pennings, eds., New Perspectives on Organizational Effectiveness. San Francisco: Jossey-Bass, 1977b, pp.1-12.

Gould, Peter and Rodney White. Mental Maps. Middlesex: Penguin Books Ltd., 1974.

Green, Gary I. and Robert T. Keim. "After Implementation What's Next? Evaluation," Journal of Systems Management, Volume 34, Number 9, issue #269, September 1983, pp. 10-15.

Greenhut, Melvin L. Plant Location in Theory and in Practice. Chapel Hill: University of North Carolina Press, 1956.

Gremillion, Lee L. "Managing the Implementation of Standardized Computer Based Systems," Management Information Systems Quarterly, December 1980, Volume 4, Number 4, pp. 51-59.

Gregory, S. Statistical Methods and the Geographer, 2nd ed. London: Longman Group Limited, 1963.

Hackathorn, Richard D. and Peter G. W. Keen. "Organizational Strategies for Personal Computing in Decision Support Systems," Management Information Systems Quarterly, Volume 5, Number 3, September 1981, pp. 21-27.

Hair, Joseph F. Jr., Rolph E. Anderson, Ronald L. Tatham, and Bernie J. Grablowsky. Multivariate Data Analysis: With Readings. Tulsa: Petroleum Publishing Company, 1979.

Hammer, William, Jr. "Systems Design in a Data Base Environment," Journal of Systems Management, Volume 33, Number 11, issue # 259, November 1982, pp. 24-29.

Hammond, K.R. "Toward Increasing Competence of Thought in Public Policy Formation," in Hammond, Kenneth R., ed., Judgment and Decision in Public Policy Formation, AAAS Selected Symposium, Boulder, Colorado, 1980.

Hammond, Robert and Patrick McCullagh. Quantitative Techniques in Geography: An Introduction. Oxford: Oxford University Press, 1974.

Hayden, F. Gregory. "A Geobased National Agricultural Policy For Rural Community Enhancement, Environmental Vitality, and Income Stabilization," Journal of Economic Issues, Volume 18, Number 1, March 1984, pp. 181-221.

Hayden, F. Gregory. "Integration of Social Indicators Into Holistic Geobased Models," Journal of Economic Issues, Volume 17, Number 2, June 1983, pp. 325-334.

Hayes, Robert H. "Why Japanese Factories Work," Harvard Business Review, Volume 59, July-August 1981, pp. 57-66.

Hayes, Robert H. and William J. Abernathy. "Managing Our Way to Economic Decline," Harvard Business Review, Volume 58, July-August 1980, pp. 67-77.

Hayes, Robert and Steven C. Wheelwright. Restoring Our Competitive Edge: Competing Through Manufacturing. New York: John Wiley & Sons, 1984.

Hayes-Roth, F., D. Waterman, and D. Lenat, eds. Building Expert Systems, Volume I, London: Addison-Wesley Publishers, 1983.

Heller, N. B., R. E. Markland, and J. A. Brockelmeyer. Partitioning Police Districts into Optimal Patrol Beats Using a Political Districting Algorithm: Model Design and Validation. University of Missouri-St. Louis School of Business Administration, working paper, 1971.

Henderson, John C. "Integrated Approach for Manpower Planning in the Service Sector," OMEGA, Volume 10, Number 1, 1980, pp. 61-73.

Henderson, John C. and David A. Schilling. "Design and Implementation of Decision Support Systems in the Public Sector," Management Information Systems Quarterly, Volume 9, Number 2, June 1985, pp. 157-168.

Hirouchi, Tetsuo and Takeshi Kosaka. "An Effective Database Formation for Decision Support Systems," Information and Management, Volume 7, 1983, pp. 183-195.

Hogarth, Robin M. Judgement and Choice: The Psychology of Decision, New York: John Wiley & Sons, 1980.

Hogarth, Robin M., ed. Question Framing and Response Consistency. San Francisco: Josey-Bass Inc., 1982.

Hoover, Edgar M. The Location of Economic Activity. New York: McGraw-Hill, 1948.

Horwitt, Elisabeth. "DSS: Effective Relief for Frustrated Management," Business Computer Systems, Volume 3, Number 7, July 1984, pp. 44-56.

Hughs, Jesse W. "MIS for State and Local Governments," Journal of Systems Management, November 1984, pp. 25-31.

Isard, Walter. Location and Space-Economy. Cambridge, Mass.: MIT Press, 1956.

Isard, Walter. Methods of Regional Analysis. Cambridge, Mass.: MIT Press, 1960.

Jobson, J. D. and Rodney Schneck. "Constituent Views of Organizational Effectiveness: Evidence from Police Organizations," Academy of Management Journal, Volume 25, Number 1, 1982, pp. 25-46.

Jurkovich, R. "A Core Typology of Organizational Environments," Administrative Science Quarterly, Volume 19, 1974, pp. 380-394.

Keen, P.G.W. "Adaptive Design for DSS," Database, Volume 12, Numbers 1 and 2, Fall 1980, pp. 15-25.

Keen, Peter G. W. and M. S. Scott Morton. Decision Support Systems: An Organizational Perspective. Reading, Mass.: Addison-Wesley, 1978.

Kendall, Kenneth E. "A Decentralized Information and Control System for Blood Management," The Journal of Systems and Software, Volume 1, 1980a, pp. 299-306.

Kendall, Kenneth E. "Multiple Objective Planning for Regional Blood Centers," Long Range Planning, Volume 13, August 1980b, pp. 98-104.

Kendall, Kenneth E. and Julie E. Kendall. "STROBE: A Structured Approach to Observation of the Decision-Making Environment," Information and Management, Volume 7, 1984a, pp. 1-11.

Kendall, Kenneth E. and Julie E. Kendall. "Structured Observation of the Environment: A Reliability and Validity Assessment, Decision Sciences, Volume 15, Number 1, Winter 1984b, pp. 107-118.

Kendall, Kenneth E. and Charles H. Kriebel. "Contributions of the Management Sciences to the Evolution of Management Information Systems," Data Base, Fall 1982, pp. 13-18.

Kendall, Kenneth E. and Merrill E. Warkentin, "A Contingency Model for Selecting Successful MIS Implementation Strategies," presented at the 1985 Conference of the American Institute of Decision Sciences.

Kendall, Kenneth E., Merrill E. Warkentin, and Leon Cederlind, The Nebraska State Patrol Manpower Allocation Model: A Spatial Decision Support System for Traffic Law Enforcement, Nebraska State Patrol, July 1986.

Kilmann, R.H. and I.I. Mitroff. "Qualitative versus Quantitative Analysis for Management Science: Different forms for Different Psychological Types," Interfaces, Volume 6, 1976, pp. 17-27.

Kole, Michael A. "Going Outside for MIS Implementation," Information and Management, October 1983, Number 5, pp. 261-268.

Kosaka, Takeshi and Tetsuo Hirouchi. "An Effective Architecture for Decision Support Systems," Information and Management, Volume 5, 1982, pp. 7-17.

Leary, Edward. J. "Decision Support Systems Aid in Management of Operations, Resources, and Finances," Industrial Engineering, Volume 17, Number 9, September 1985, pp. 26-34.

Leblibici, H. and G. R. Salancik, "Effects of Environmental Uncertainty on Information and Decision Processing in Banks," Administrative Science Quarterly, Volume 26, 1981, pp. 578-596.

Lee, S. M. and M. Bird. "A Goal Programming Model for Sales Effort Allocation," Business Perspectives, Volume 6, Number 4, Summer 1970, pp. 17-21.

Lee, S. M., L. S. Franz, and A. J. Wynne. "Optimizing State Patrol Manpower Allocations," Journal of Operational Research Society, Volume 30, Number 10, October 1979, pp. 885-896.

Lewin, K. "Group Decision and Social Change." In Readings in Social Psychology, edited by Maccoby, E., Newcomb, T. M., and Hartley, E. L. New York: Holt, Rinehart and Winston, 1947, pp. 197-211.

Lillesand, Thomas M. and Ralph W. Kiefer. Remote Sensing and Image Interpretation, New York: John Wiley & Sons, 1979.

Linstone, H.A. and M. Turoff, eds. The Delphi Method, Reading, Mass.: Addison-Wesley, 1975.

Little, J.D.C. "Decision Support Systems for Marketing Managers," Journal of Marketing, Volume 43, Number 3, Summer 1979, pp. 9-26.

Littlefield, J. E. "On the art of locating new banks," The Bankers Magazine, Autumn 1968, 151, 94-102.

Lloyd, P. E. and P. Dicken. Location in Space: A Theoretical Approach to Economic Geography, 2nd edition. London: Harper and Row, 1977.

Lord, J. D. and D. B. Wright. "Competition and Location Strategy in Branch Banking: Spatial Avoidance or Clustering," Urban Geography, 1981, pp. 189-200.

Losch, August. The Economics of Location, translated by W. H. Woglom from Die raumliche Ordnung der Wirtshaft (1940), New Haven, Conn.: Yale University Press, 1940.

Louviere, Jordon J. "Information Processing Theory and Functional Form in Spatial Behavior," in Golledge, Reginald G. and Gerald Rushton, eds. Spatial Choice and Spatial Behavior: Geographic Essays on the Analysis of Preferences and Perceptions. Columbus: Ohio State University Press, 1976, pp. 211-248.

Love, D. O. and J. A. Deichert. Locating financial branch facilities: A guide to techniques and literature. Lincoln, NE: Bureau of Business Research, University of Nebraska-Lincoln, September 1983.

Lucas, Henry C., Jr. "Empirical Evidence for a Descriptive Model of Implementation," Management Information Systems Quarterly, Volume 2, Number 3, August 1978, pp. 27-41.

Lucas, Henry C., Jr. Implementation: The Key to Successful Information Systems. New York: Columbia University Press, 1981.

Lundsten, L. L. Market share forecasting for banking offices. UMI Research Press, 1978.

McManis, Gerald L. and William C. Parker. Implementing Management Information Systems in Colleges and Universities. Littleton, Colorado: Ireland Educational Corporation, 1978.

Mann, Robert I. and Hugh J. Watson. "A Contingency Model for User Involvement in DSS Development," Management Information Systems Quartely, March 1984, pp. 27-37.

Markus, M. Lynne. "Power, Politics, and MIS Implementation," Communications of the ACM, Volume 26, Number 6, June 1983, pp. 430-444.

Marble, Duane F., Hugh W. Calkins, and Donna J. Peuquet. Basic Readings in Geographic Information Systems. Williamsville, N.Y.: SPAD Systems, Ltd., 1984.

Martin, Merle P. "Determining Information Requirements for DSS," Journal of Systems Management 33:12, issue #260, December 1982, pp. 14-21.

Marx, Robert W. "Automating Census Geography for 1990," American Demographics, June 1983, pp. 30-33.

Massey, D. B. "A Critical Evaluation of Industrial Location Theory," in Hamilton, R. E. I. and G. J. R. Linge, eds., Spatial Analysis, Industry and the Industrial Environment. Volume 1, Industrial Systems. Chicester: John Wiley, 1979, pp. 57-72.

Mastrofski, Stephen. "Police Knowledge of the Patrol Beat as a Performance Measure," in Whitaker, Gordon P.,ed., Understanding Police Agency Performance, U. S. Department of Justice, Washington, D.C., February 1984.

Matthews, John A. Quantitative and Statistical Approaches to Geography: A Practical Manual. Oxford: Pergamon Press, 1981.

Meador, C. Lawrence, Martin J. Guyote, and Peter G. W. Keen. "Setting Priorities for DSS Development," Management Information Systems Quarterly, Volume 8, Number 3, June 1984, pp. 117-129.

Meehan, E. J. Explanation in Social Science: A System Paradigm. Homewood, Ill.: The Dorsey Press, 1968.

Menkus, Belden. "Practical Considerations in Decision Support System Design," Journal of Systems Management, Volume 34, Number 6, Issue #266, June 1983, pp. 32-33.

Miller, James R. and Mason Haire. "MANPLAN: A Micro-Simulator for Manpower Planning," Computers in Behavioral Science, 1969, pp. 515-522.

Minshull, Roger. An Introduction to Models in Geography. London: Longman Group Limited, 1975.

Mittra, Sitansu S. "Information Systems Analysis and Design," Journal of Systems Management, Volume 34, Number 4, issue # 264, April 1983, pp. 30-34.

Mittra, Sitansu S. "Quantification: An Essential Part of Systems Analysis," Journal of Systems Management, Volume 34, Number 6, issue # 266, June 1983, pp. 26-28.

MGT of America, Inc. Human Resource Assessment: A Report to the Florida Department of Community Affairs, Florida State Patrol, September 1980.

Mockler, Robert J. Information Systems for Management. Columbus, Ohio: Charles E. Merrill Publishing Company, 1974.

Murdick, Robert J. and Ross, Joel E. MIS in Action. St. Paul: West Publishing Company, 1975.

Nebraska Department of Labor. Work trends, 1977 and 1983.

Nebraska Department of Revenue. Annual report, 1976 and 1982.

Nebraska Department of Roads, Selected Highway Statistics, various years.

Nebraska State Patrol, Office Automation Study: Findings and Recommendations, March 1985.

Nebraska State Patrol, Policing By Objectives: Troop C Project, 1983.

Neft, David S. Statistical Analysis for Areal Distributions. Monograph Series Number Two, B.H. Stevens, ed. Philadelphia: Regional Science Research Institute, 1966.

Nemec, John. "Information Systems Analysis. Journal of Systems Management, Volume 33, Number 1, issue # 249, January 1982, pp. 24-26.

Olsen, L. M. and J.D. Lord. "Market area characteristics and branch bank performance," Journal of Bank Research, 1979, 10, 102-110.

Perrow, C. "Three types of effectiveness studies," in Goodman, P.S. and J.M. Pennings, eds. New Perspectives on Organizational Effectiveness. San Francisco: Jossey-Bass, 1977, pp. 96-105.

Pred, A. Behavior and Location: Foundations for a Geographic and Dynamic Location Theory, Part 1. Lund Studies in Geography, Series B, 27, 1967.

Preble, John F. "The Selection of Delphi Panels for Strategic Planning Purposes," Strategic Planning Journal, Volume 5, 1984, pp. 157-170.

Price, W. L., A. Martel, and K.A. LEwis. "A Review of Mathematical Models in Human Resource Planning," OMEGA, Volume 8, Number 6, 1980, pp. 639-645.

Price, W. L. "Solving Goal-Programming Manpower Models using Advanced Network Codes," Journal of Operational Research Society, Volume 29, Number 12 (December 1978), pp. 1231-1239.

Raub, Richard A. Allocating A Police Force Throughout A State or Large Geographic Area, Illinois Department of Law Enforcement, Division of Administration, 1985.

Raub, Richard A. Description of the Microcomputer Program: MANPOWER, Illinois Department of Law Enforcement, Division of Administration, 1984.

Rengert, G. F. "Spatial Aspects of Criminal Behavior," in Georges-Abeyie and K. D. Harries, Crime: A Spatial Perspective, New York: Columbia University Press, 1980.

Ritter, Duane J. Nebraska State Patrol Manpower Allocation Study: Step I -- Purpose and Design, Nebraska State Patrol, 1983.

Roberts, Edward B. "Strategies for Effective Implementation of Complex Corporate Models," _Interfaces_, November 1977, Volume 8, Number 1, pp. 26-33.

Rockart, John and Adam D.Crescenzi. "Engaging Top Management in Information Technology," _Sloan Management Review_, Volume 25, Number 4, Summer 1984, pp. 3-16.

Rudd, Howard F., James W. Vigen, and Richard N. Davis. "The LMMD Model: Choosing the Optimal Location for a Small Retail Business," _Journal of Small Business Management_, April 1983, pp. 45-57.

Sack, Robert David. _Conceptions of Space in Social Thought: A Geographic Perspective_. Minneapolis: University of Minnesota Press, 1980.

Saladin, B. A. "Goal Programming Applied to Police Patrol Allocation," _Journal of Operations Management_, Volume 2, Number 4, August 1982, pp. 239-249.

Schein, E. H. "Management Development as a Process of Influence," Industrial Management Review, Spring 1961, Volume 2, Number 2, pp. 59-77, Number 1, pp. 11-20.

Schiffman, Susan S., M. Lance Reynolds, and Forrest W. Young. Introduction to Multidimensional Scaling: Theory, Methods, and Applications New York: Academic Press, Inc., 1981.

Schniederjans, M.J., N.K. Kwak, and M.C. Helmer. "An Application of Goal Programming to Resolve a Site Location Problem," Interfaces, Volume 12, Number 3, June 1982, pp. 65-72.

Schonberger, Richard J. "The Implementation Process: A Change Approach," Management Information Systems Quarterly, Volume 4, Number 1, March 1980, pp. 13-20.

Schuiteman, John G. Proposed Allocation of Virginia State Troopers, Virginia State Police Planning Unit, January 1985.

Schuldt, Barbara A. A Field Experiment Comparing the Decision Support Systems Structure to the Decision Making Effectiveness of the Nebraska State Patrol's Investigative Services Division, unpublished doctoral dissertation, University of Nebraska-Lincoln, 1986.

Scott, R.W. "Effectiveness of organizational effectiveness studies," in Goodman, P.S. and J.M. Pennings, eds. New Perspectives on Organizational Effectiveness. San Francisco: Jossey-Bass, 1977, pp. 63-95.

Senter, R. J. Analysis of Data, Glenview, Ill.: Scott, Foresman and Company, 1969.

Sharif, Nawaz and Pakorn Adulbhan, eds. Systems Models For Decision Making. Bangkok: Asian Institute of Technology, 1978.

Siegel, Sidney. Nonparametric Statistics for the Behavioral Sciences, New York: McGraw-Hill Book Company, 1956.

Simon, H. The New Science of Management Decision, New York: Harper and Row, 1960.

Sloan, J. V. "How one bank tried to make its branch site selection scientific," ABA Banking Journal, May 1981, 73, pp. 205-206.

Slovic, P., and S. Lichenstein. "Comparison of Bayesian and Regression Approaches to the Study of Information Processing in Judgment," Organizational Behavior and Human Peformance, Volume 6, 1971, pp. 649-744.

Shanahan, Donald T. Patrol Administration: Managing by Objectives, second edition. Boston: Allyn and Bacon, Inc., 1975.

Silk, John. Statistical Concepts in Geography. London: George Allen & Unwin Ltd., 1979.

Smith, August W. Management Systems: Analysis and Applications. Chicago: The Dryden Press, 1982.

Soenen, L. A. "Locating bank branches," Industrial Marketing Management, Volume 3, 1974, pp. 211-228.

Spiegler, Israel. "MIS and DBMS: Where Does One End and the Other Start?" Journal of Systems Management, Volume 34, Number 6, issue # 266, June 1983, pp. 34-42.

Sprague, Ralph H., Jr. "A Framework for the Development of Decision Support Systems," Management Information Systems Quarterly, Volume 4, Number 4, December 1980, pp. 1-26.

Sprague, Ralph H., Jr., and E. D. Carlson. Building Effective Decision Support Systems. Englewood Cliffs, N.J.: Prentice-Hall, 1982.

Taylor, B. W., L. J. Moore, and E. R. Clayton. "R & D Project Selection and Manpower Allocation with Integer Nonlinear Goal Programming," Management Science, Volume 28, Number 10, October 1982, pp. 1149-1158.

Taylor, Peter J. Quantitative Methods in Geography: An Introduction to Spatial Analysis. Boston: Houghton Mifflin Company, 1977.

Thompson, J. D. Organizations in Action, New York: McGraw-Hill Book Company, 1967.

Thrift, Nigel J. On Time in Geography: An Exploration of Temporal Awareness and Perception and a Bibliography on Time. Series A: Number 25. Bristol, England: Department of Geography, University of Bristol, 1974.

Tornqvist, G. Contact Systems and Regional Development, Lund Studies in Geography, Series B, 35, 1970.

U.S. Department of Commerce, Bureau of the Census. The Dime Geocoding System. Report No. 4. Census Use Study. Washington, D.C.: Government Printing Office, 1970.

U.S. Department of Commerce, Bureau of the Census. County business patterns. Washington, D.C.: Government Printing Office, 1981a.

U.S. Department of Commerce, Bureau of the Census. 1980 Census of the Population (and related materials and computer tapes). Washington, D.C.: Government Printing Office, 1981b.

Uehling, Larry L. Nebraska State Patrol Manpower Allocation Study: Step II -- History and Critique, Nebraska State Patrol, 1984.

Waldrop, M. Mitchell, "Why do we like music?" Science, March 1985, p.36.

Walsh, James A. Information Theory and Classification in Geography. Discussion Paper No. 4. Hamilton, Ontario: Department of Geography, McMaster University, 1976.

Warkentin, Merrill E. and Thomas H. Parker, "Environmental Uncertainty and its Impact on Strategic Information System Design," Proceedings of the 1985 Conference of the American Institute of Decision Sciences.

Watkins, Paul R. "Perceived Information Structure: Implications for Decision Support System Design," Decision Sciences, Volume 13, 1982, pp. 38-59.

Watkins, Paul R. "Preference Mapping of Perceived Information Structure: Implications for Decision Support Systems Design," Decision Sciences, Volume 15, 1984, pp. 92-106.

Watson, Hugh J. and Marianne M. Hill. "Decision Support Systems or What Didn't Happen with MIS," Interfaces, Volume 13, Number 5, October 1983, pp. 81-88.

Weber, A. Alfred Weber's Theory of the Location of Industries, translated by C. J. Friedrich from Uber den Standort der Industrien (1909). Chicago: University of Chicago Press, 1929.

Wedley, William C. and Richard H. G. Field. "A Predecision Support System," Academy of Management Review, Volume 9, Number 4, 1984, pp. 696-703.

Welsch, Gemma M. "Successful Implementation of Decision Support Systems: The Role of the Information Transfer Specialist," Proceedings of the American Institute for Decision Sciences, Vol. 1, 1981, pp. 206-208.

Wheelwright, Steven C. "Manufacturing Strategy: Defining the Missing Link." Strategic Management Journal,Volume 5, 1984a, pp. 77-91.

Wheelwright, Steven C. "Strategic Management of Manufacturing." In Lamb, Robert, ed. Advances in Applied Business Strategy, Volume 1, Greenwich, Conn.: JAI Press Inc., 1984b, pp. 1-15.

White, Rodney. The Measurement of Spatial Perception. Series A: Number 8. Bristol, England: Department of Geography, University of Bristol, 1967.

Wiest, J.D. "A Heuristic Model for Scheduling Large Projects with Limited Resources," Management Science, Volume 13, 1967, pp. 359-377.

Winkler, David L. Nebraska State Patrol Manpower Allocation Study: Step III -- Documentation: Progress, Recording Methods, Implementation, Nebraska State Patrol, 1985.

Wright, W.F. "Properties of Judgment Models in a Financial Setting," Organizational Behavior and Human Performance, Volume 23, 1979, pp. 73-85.

Wrigley, N., ed. Statistical Applications in the Spatial Sciences. London: Pion Limited, 1979.

Wrigley, N. and R. J. Bennet. "Spatial and Temporal Analysis: Spatial Time Series," Quantitative Geography: A British View. London: Routledge and Kegan Paul, 1981, pp. 97-103.

Zanakis, S. H. and M. W. Maret. "A Markovian Goal Programming Approach to Aggregate Manpower Planning, Journal of the Operational Research Society, Volume 32, Number 1, January 1981, pp. 55-63.

Zanakis, Steve H., Sushil K. Gupta, and Jerzy Kyparisis. "Manpower Prediction and Allocation for Florida Highway Patrol Troopers," Florida International University, Department of Decision Sciences, working paper, September 1985.

Zmud, Robert W. "Design Alternatives for Organizing Information Systems Activities," Management Information Systems Quarterly, Volume 8, Number 2, June 1984, pp. 79-93.

Wrigley, N., ed. Statistical Applications in the Spatial Sciences. London: Pion Limited, 1979.

Wrigley, N. and R. J. Bennet. "Spatial and Temporal Analysis: Spatial Time Series," Quantitative Geography: A British View. London: Routledge and Kegan Paul, 1981, pp. 97-103.

Zanakis, S. H. and M. W. Maret. "A Markovian Goal Programming Approach to Aggregate Manpower Planning, Journal of the Operational Research Society, Volume 32, Number 1, January 1981, pp. 55-63.

Zanakis, Steve H., Sushil K. Gupta, and Jerzy Kyparisis. "Manpower Prediction and Allocation for Florida Highway Patrol Troopers," Florida International University, Department of Decision Sciences, working paper, September 1985.

Zmud, Robert W. "Design Alternatives for Organizing Information Systems Activities," Management Information Systems Quarterly, Volume 8, Number 2, June 1984, pp. 79-93.

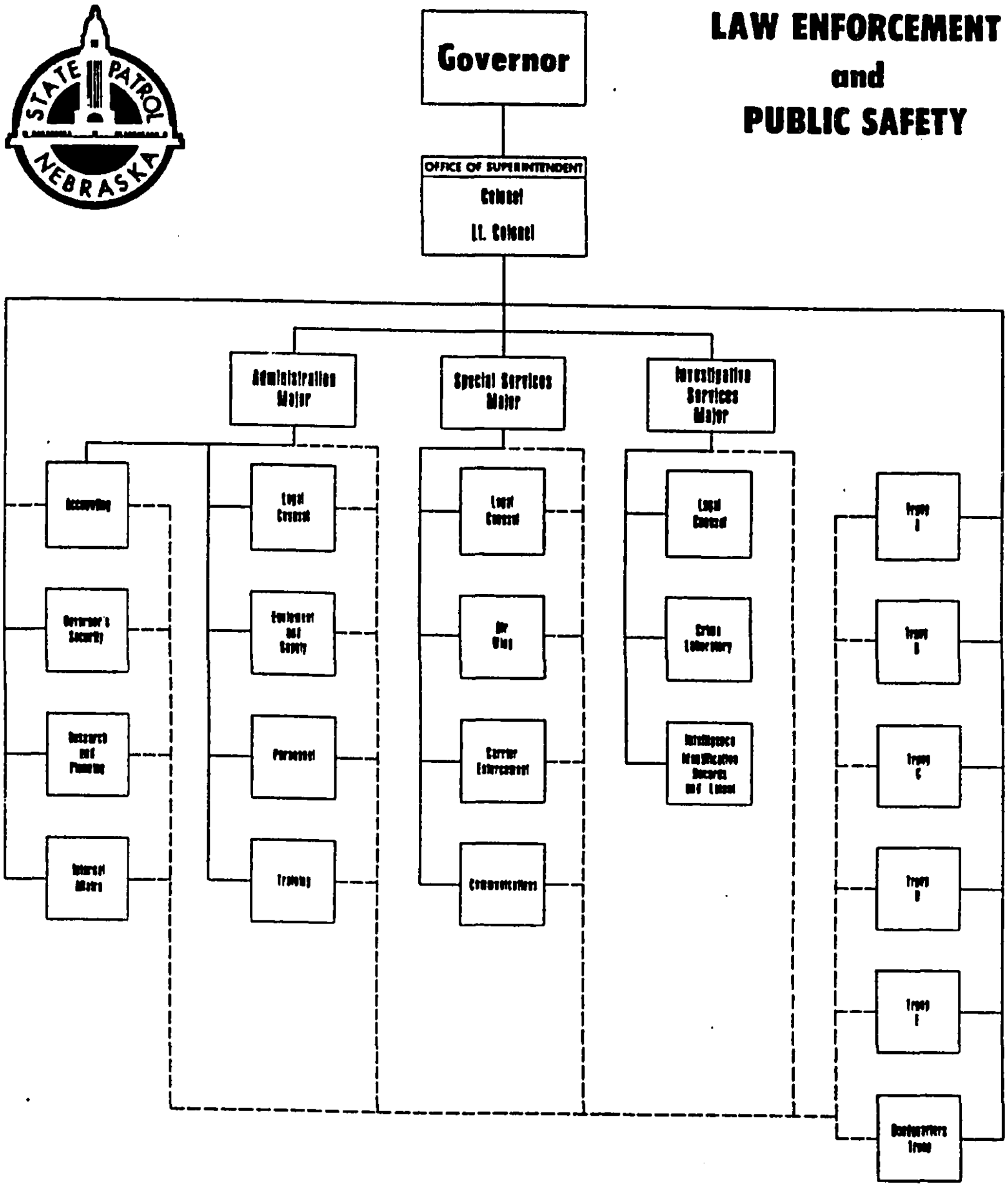
Zmud, Robert W. Information Systems in Organizations. Glenview, Illinois: Scott, Foresman and Company, 1983.

Zmud, Robert W. and James F. Cox. "The Implementation Process: A Change Approach," Management Information Systems Quarterly, June 1979, Volume 3, Number 2, pp. 35-44.

APPENDIX A

Nebraska State Patrol Organizational Chart

LAW ENFORCEMENT and PUBLIC SAFETY



LEGEND:

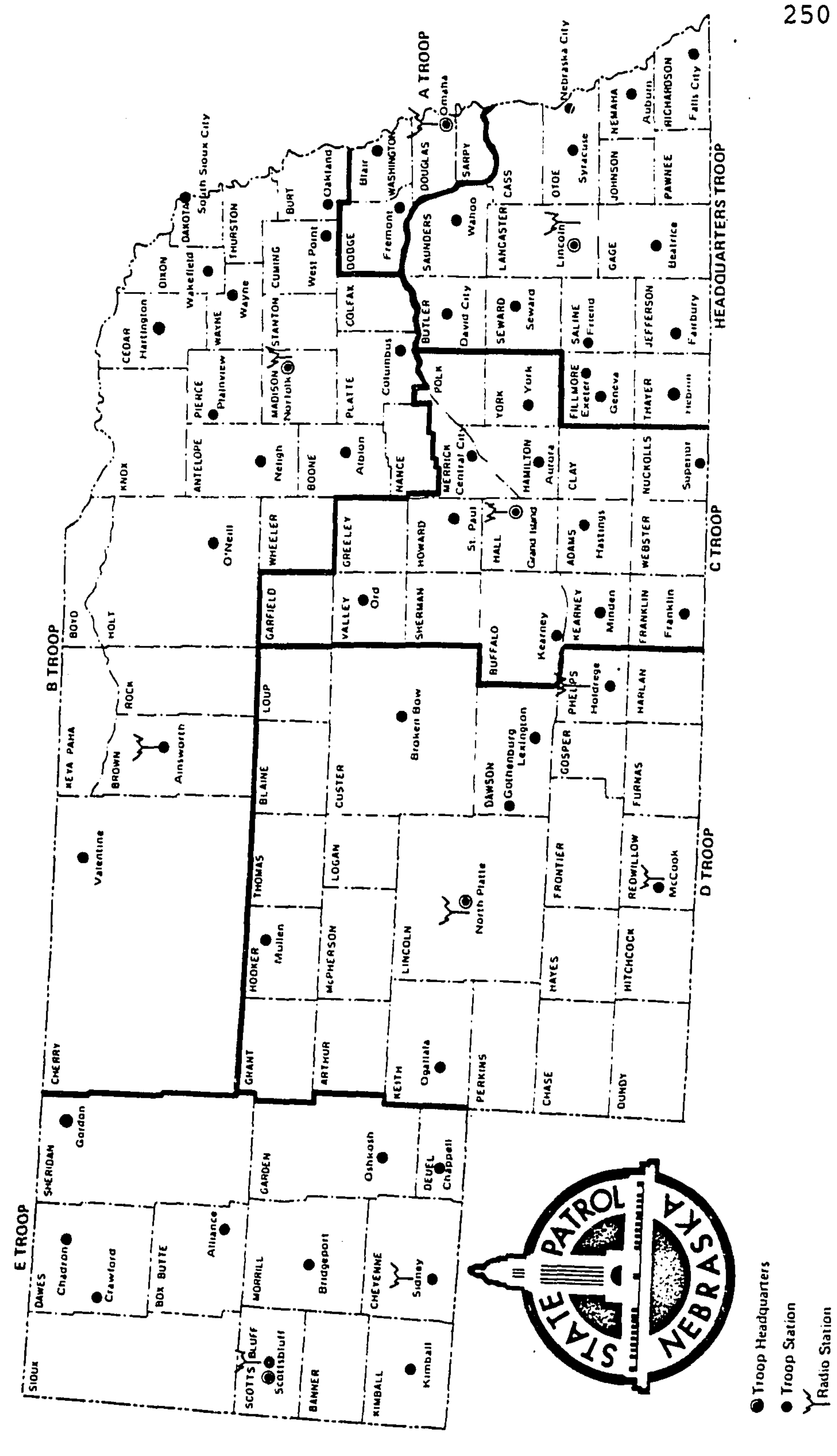
Line of Authority ———

Line of Information - - - -

July 1985

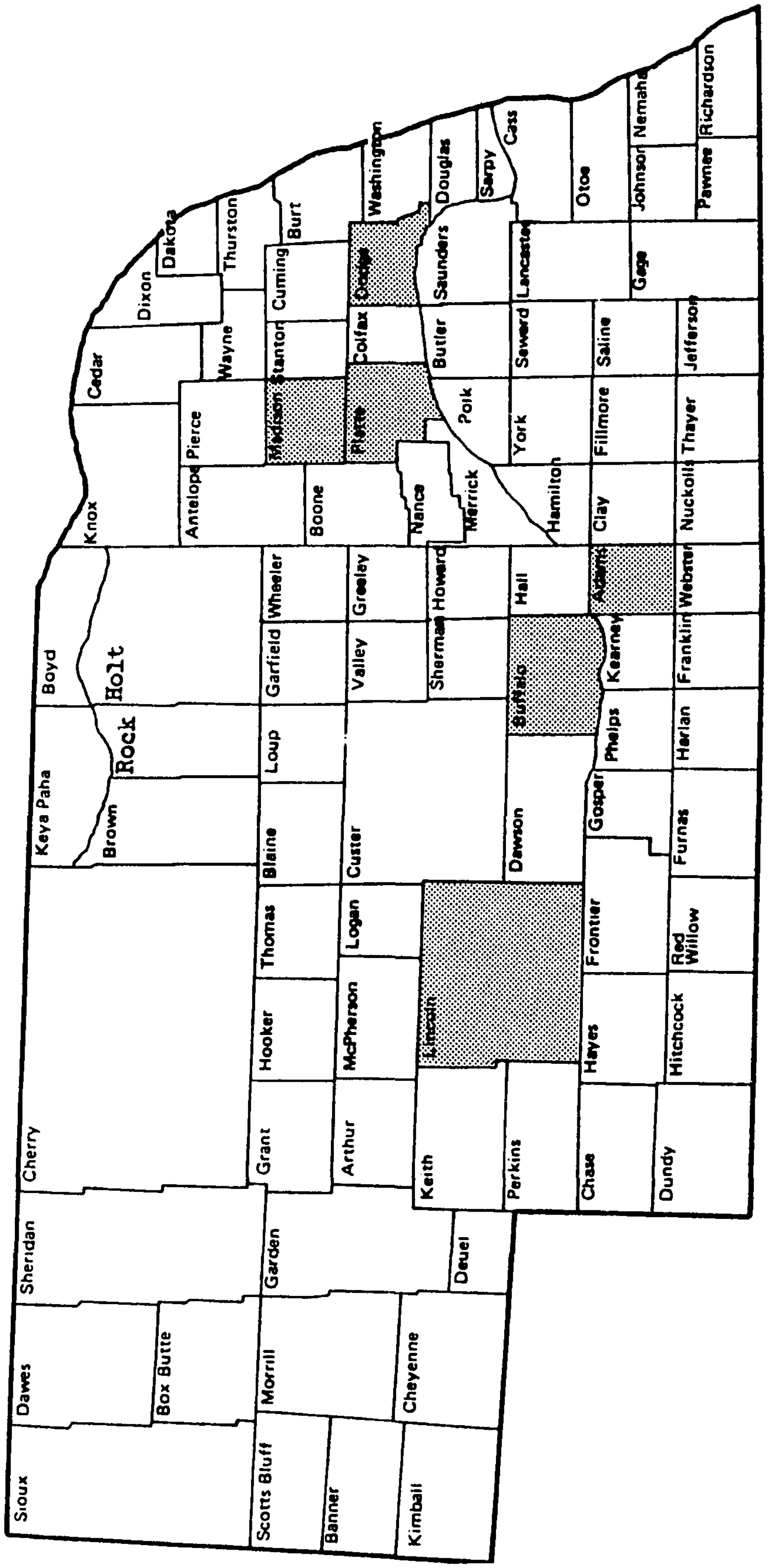
APPENDIX B

Nebraska State Patrol Troop Areas


A TROOP
B TROOP
C TROOP
D TROOP
E TROOP
HEADQUARTERS TROOP
NEBRASKA STATE PATROL
Troop Headquarters
Troop Station
Radio Station

APPENDIX C

Savings and Loan Branch Site Alternatives


Sioux
Dawes
Box Butte
Sheridan
Cherry
Scotts Bluff
Banner
Kimball
Morrill
Cheyenne
Garden
Deuel
Grant
Arthur
Keith
Perkins
Chase
Dundy
Hooker
McPherson
Lincoln
Hayes
Hitchcock
Thomas
Logan
Frontier
Red Willow
Blaine
Custer
Dawson
Gosper
Furnas
Loup
Phelps
Harlan
Keya Paha
Brown
Rock
Holt
Boyd
Garfield
Valley
Sherman
Buffalo
Kearney
Franklin
Wheeler
Greeley
Howard
Hall
Adams
Webster
Knox
Antelope
Boone
Nance
Merrick
Hamilton
Clay
Nuckolls
Cedar
Pierce
Madison
Platte
Polk
York
Fillmore
Thayer
Dixon
Wayne
Stanton
Colfax
Butler
Seward
Saline
Jefferson
Dakota
Thurston
Cuming
Dodge
Saunders
Lancaster
Gage
Burt
Washington
Douglas
Sarpy
Cass
Otoe
Johnson
Nemaha
Pawnee
Richardson

APPENDIX D

Incident Report Data Sheet

DATE-REC	DAY	TIME	EVENT	CO.	REQ-BY	REF-TO	ASSIGNED	ARRIVED	COMPLETED
06-15-85	6	17:43	4	28	3	02-N	17:43	17:50	17:59
06-15-85	6	18:07	4	08	6	01-N	18:09	18:20	19:59
06-15-85	6	21:48	6	08	1	00-N	:	:	:
06-15-85	6	23:45	1	08	6	02-N	23:51	00:07	01:07
06-16-85	7	00:04	6	08	3	02-N	00:04	00:07	01:05
06-16-85	7	01:25	3	17	1	01-N	01:25	01:32	02:44
06-16-85	7	02:38	1	09	4	01-N	:	02:38	03:17
06-16-85	7	06:29	3	08	1	01-N	06:30	06:56	07:08
06-16-85	7	07:04	5	14	2	02-N	07:10	08:41	09:38
06-16-85	7	09:39	6	08	6	01-N	09:41	09:52	10:04
06-16-85	7	15:51	4	08	3	01-N	15:53	:	16:10
06-16-85	7	16:49	3	28	3	01-N	16:51	:	17:44
06-16-85	7	17:07	6	09	1	01-N	17:44	:	:
06-16-85	7	17:24	6	46	3	01-N	17:26	18:38	18:52
06-16-85	7	17:29	6	14	3	01-N	17:30	17:49	18:17
06-16-85	7	19:47	2	09	3	01-N	19:47	19:56	20:04
06-16-85	7	20:15	6	09	3	01-N	20:15	20:25	20:40
06-16-85	7	22:53	1	46	6	01-N	22:55	23:09	23:25
06-17-85	1	00:20	4	28	3	02-N	00:20	00:29	00:33
06-17-85	1	07:19	1	47	4	01-N	:	07:19	07:49
06-17-85	1	07:29	4	28	3	01-N	07:30	07:40	07:41
06-17-85	1	07:44	1	08	1	01-N	07:44	07:51	08:37
06-17-85	1	14:38	1	17	5	01-N	14:38	14:46	16:57
06-17-85	1	16:35	4	28	5	01-N	16:35	17:02	17:10
06-17-85	1	22:47	6	56	3	01-N	22:49	:	23:08
06-17-85	1	23:07	4	08	1	01-N	23:08	24:00	00:00
06-18-85	2	08:14	2	08	1	03-N	08:16	08:44	11:41
06-18-85	2	13:32	4	16	3	01-N	13:36	:	13:55
06-18-85	2	16:32	6	08	1	01-N	16:51	:	18:10
06-18-85	2	20:20	4	09	3	00-N	20:25	:	:
06-18-85	2	22:23	4	46	4	01-N	22:24	:	00:18
06-19-85	3	10:05	6	08	5	02-N	10:06	10:08	10:45
06-19-85	3	10:10	1	08	1	00-P	10:10	:	:
06-19-85	3	12:10	2	18	4	01-N	12:21	12:21	:
06-19-85	3	12:31	6	14	3	01-N	12:32	12:49	13:06

APPENDIX E

Nebraska State Patrol PBO Notice

You have been contacted by a Nebraska State Trooper on a highway that has been targeted for accident reduction. Statistical data indicates this is a high-accident area.

This accident reduction program called "Policing by Objectives" (PBO) was initiated by the State Patrol to allow personnel to concentrate their efforts toward those causative factors which contribute to the accidents on this highway. Since accident reduction is a primary goal of the Patrol, PBO offers the flexibility of utilizing both equipment and personnel at times and places which will offer the best results.

Your voluntary compliance with traffic laws in the future will contribute greatly to the success of this program. Lives will be saved, injuries reduced, and millions of dollars in property damage will be conserved.

Please do your part to help us reduce accidents. **THANK YOU.**

YOUR NEBRASKA STATE PATROL

NSP-411