A STUDY OF MIS DESIGN VARIABLES:
DECISION STYLES AND DECISION
AIDING STRATEGY

DISSERTATION

Presented in Partial Fulfillment of the Requirements for
the Degree Doctor of Philosophy in the Graduate
School of The Ohio State University

By

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* * * * *

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1978
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# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACKNOWLEDGEMENT.</td>
<td>ii</td>
</tr>
<tr>
<td>VITA</td>
<td>iii</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td>vii</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td>ix</td>
</tr>
<tr>
<td>Chapter</td>
<td></td>
</tr>
<tr>
<td>I. INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>Background</td>
<td>3</td>
</tr>
<tr>
<td>Purpose and Rationale for the Study</td>
<td>3</td>
</tr>
<tr>
<td>Definitions</td>
<td>5</td>
</tr>
<tr>
<td>Organization of the Report</td>
<td>6</td>
</tr>
<tr>
<td>II. CONCEPTUAL ISSUES IN THE DESIGN OF MIS</td>
<td>8</td>
</tr>
<tr>
<td>A Conceptual Model</td>
<td>16</td>
</tr>
<tr>
<td>MIS Decision Maker Interactions</td>
<td>20</td>
</tr>
<tr>
<td>MIS Decision Task Interactions</td>
<td>23</td>
</tr>
<tr>
<td>MIS Organizational Structure Interactions</td>
<td>26</td>
</tr>
<tr>
<td>Summary</td>
<td>30</td>
</tr>
<tr>
<td>III. LITERATURE REVIEW</td>
<td>33</td>
</tr>
<tr>
<td>Review of MIS Research</td>
<td>33</td>
</tr>
<tr>
<td>Conclusions and Discussions of MIS Literature</td>
<td>41</td>
</tr>
<tr>
<td>Review</td>
<td>43</td>
</tr>
<tr>
<td>Review of Decision Aiding Strategies</td>
<td>54</td>
</tr>
<tr>
<td>Review of Decision Style Constructs</td>
<td>67</td>
</tr>
<tr>
<td>The Research Questions</td>
<td></td>
</tr>
<tr>
<td>IV. RESEARCH METHODOLOGY</td>
<td>71</td>
</tr>
<tr>
<td>Hypotheses to be Tested</td>
<td>71</td>
</tr>
<tr>
<td>Research Methodology</td>
<td>76</td>
</tr>
</tbody>
</table>
Experimental Design .................................................. 76
Experimental Subjects ............................................... 77
Experimental Task .................................................... 78
"FACTORY: 2" Simulation ............................................. 80
Research Variables .................................................... 83
Operationalization of Variables .................................... 84
Independent Variables .............................................. 84
Dependent Variables .................................................. 91
Control Variables ..................................................... 93
Experiment Administration and Procedures ...................... 93
Pre-experimental Session ............................................. 94
First Experimental Session ......................................... 95
Second Experimental Session ....................................... 96
Post experiment and Debriefing ..................................... 97
Summary .................................................................. 97

V. ANALYSIS OF EXPERIMENTAL RESULTS ...................... 99
Statistical Methods ..................................................... 99
Chi-Square Test ........................................................ 100
Two-Way Analysis of Variance ...................................... 101
Preliminary Analysis ................................................... 103
Statistical Results and Test of Hypotheses ....................... 105
Performance Variables ............................................... 105
User Attitude Variables .............................................. 110
Usage Variable ........................................................ 116
Summary .................................................................. 118
VI. DISCUSSION AND CONCLUSIONS. .............................................. 119

Discussion and Interpretation of Research Findings. 119

Discussion of Significant Results. 119
Discussion of Non-significant Results. 127

Limitations of Research . 128
Practical Implication of the Research . 129
Summary and Conclusions . 129
Directions for Future Research. 132

APPENDIXES

A. "FACTORY:2" Case Description. ............................................. 137
   Post-Experimental Questionnaire ............................................. 159
   Subject Sign-Up Sheet .......................................................... 166
   Subject Consent Form ......................................................... 166

B. FORTRAN Listing of "FACTORY:2". .......................................... 169

C. The Linear Decision Rules for "FACTORY:2" ......................... 194

D. Supportive Statistics ......................................................... 205
# LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. U. S. Computer Census</td>
<td>2</td>
</tr>
<tr>
<td>2. Summary of Results and Variables Investigated in Some Experiments at the University of Minnesota MIS Research Center</td>
<td>35</td>
</tr>
<tr>
<td>3. Product Moment Correlations of Importance of Information with Ambiguity Tolerance</td>
<td>38</td>
</tr>
<tr>
<td>4. The Experimental Factors and Factor Levels</td>
<td>77</td>
</tr>
<tr>
<td>5. The Two-Way Analysis of Variance Table</td>
<td>103</td>
</tr>
<tr>
<td>6. Mean Decision Time Data</td>
<td>106</td>
</tr>
<tr>
<td>7. Mean Profit Data</td>
<td>106</td>
</tr>
<tr>
<td>8. Analysis of Variance Results for Decision Time</td>
<td>109</td>
</tr>
<tr>
<td>9. Analysis of Variance Results for Profits</td>
<td>109</td>
</tr>
<tr>
<td>10. Mean User Satisfaction Data</td>
<td>111</td>
</tr>
<tr>
<td>11. Mean &quot;Ease of Use&quot; Data</td>
<td>111</td>
</tr>
<tr>
<td>12. Mean &quot;Importance&quot; Data</td>
<td>112</td>
</tr>
<tr>
<td>13. Mean &quot;Willingness&quot; Data</td>
<td>112</td>
</tr>
<tr>
<td>14. Analysis of Variance Tables for Satisfaction Scores</td>
<td>113</td>
</tr>
<tr>
<td>15. Analysis of Variance Table for &quot;Ease&quot; Scores</td>
<td>113</td>
</tr>
<tr>
<td>16. Analysis of Variance Table for &quot;Importance&quot; Scores</td>
<td>114</td>
</tr>
<tr>
<td>17. Analysis of Variance Table for &quot;Willingness&quot; Score</td>
<td>114</td>
</tr>
<tr>
<td>18. Frequency of Usage of Decision Aids</td>
<td>117</td>
</tr>
<tr>
<td>Table</td>
<td>Page</td>
</tr>
<tr>
<td>-------</td>
<td>------</td>
</tr>
<tr>
<td>19. Frequency of Usage of Decision Aids</td>
<td>117</td>
</tr>
<tr>
<td>20. Summary of Statistically Significant Effects by Dependent Variables</td>
<td>121</td>
</tr>
<tr>
<td>21. The Spearman Rank Correlation Coefficients</td>
<td>208</td>
</tr>
<tr>
<td>22. Usage of Decision Aids for Different Levels of Experience</td>
<td>209</td>
</tr>
<tr>
<td>23. Frequency of Usage Presented in Terms of Decision Aids</td>
<td>210</td>
</tr>
<tr>
<td>24. Frequency of Usage Presented in Terms of Decision Styles</td>
<td>211</td>
</tr>
<tr>
<td>25. Frequency of Usage of LDRS for the Four Decision Styles</td>
<td>212</td>
</tr>
<tr>
<td>26. Calculations of Confidence Intervals for Decision Time</td>
<td>214</td>
</tr>
<tr>
<td>27. Confidence Intervals for Satisfaction Scores</td>
<td>215</td>
</tr>
<tr>
<td>28. Confidence Intervals for &quot;Importance&quot; Scores</td>
<td>216</td>
</tr>
<tr>
<td>29. Significant Confidence Intervals for Satisfaction Means</td>
<td>217</td>
</tr>
<tr>
<td>30. Significant Confidence Intervals for Willingness Means</td>
<td>218</td>
</tr>
</tbody>
</table>
# LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Anthony's Normative Information Characteristics</td>
<td>10</td>
</tr>
<tr>
<td>2.</td>
<td>Bariff and Lusk's MIS Design Framework</td>
<td>11</td>
</tr>
<tr>
<td>3.</td>
<td>Simon's Classification of Decision Tasks</td>
<td>12</td>
</tr>
<tr>
<td>4.</td>
<td>Locus' MIS Design Framework</td>
<td>14</td>
</tr>
<tr>
<td>5.</td>
<td>Mason and Mitroff's Taxonomy of MIS Design Variables</td>
<td>15</td>
</tr>
<tr>
<td>6.</td>
<td>Leavitt's Model of Organizational System</td>
<td>17</td>
</tr>
<tr>
<td>7.</td>
<td>A Conceptual Model of MIS Design Variables</td>
<td>17</td>
</tr>
<tr>
<td>9.</td>
<td>Information Requirement by Decision Category</td>
<td>25</td>
</tr>
<tr>
<td>10.</td>
<td>General Incongruity Adaptation Level (GIAL) as a Dimension of Decision Style</td>
<td>57</td>
</tr>
<tr>
<td>11.</td>
<td>McKenny and Keen's Dimensions of Decision Styles</td>
<td>64</td>
</tr>
<tr>
<td>12.</td>
<td>Driver and Mock Decision Style Model</td>
<td>66</td>
</tr>
<tr>
<td>13.</td>
<td>The Experimental Variables</td>
<td>70</td>
</tr>
<tr>
<td>14.</td>
<td>A Flow Diagram of the Simulation Program</td>
<td>81</td>
</tr>
<tr>
<td>15.</td>
<td>The Infinite System of Linear Equations to be Solved for the LDR</td>
<td>86</td>
</tr>
<tr>
<td>16.</td>
<td>The Production LDR for Product 1</td>
<td>87</td>
</tr>
<tr>
<td>17.</td>
<td>An Example of Subject Regression Model</td>
<td>91</td>
</tr>
</tbody>
</table>
CHAPTER I
INTRODUCTION

Background

In the span of twenty years, computer anchored information systems (defined as information systems that use computer capabilities for collection, storage, processing, or dissemination of information) have become important to a large number of organizations and are becoming increasingly more important as suggested and projected in Table 1. A great deal of effort and resources have been spent on development of so-called Management Information System(s) (MIS) to aid the management processes. But many MIS users express dissatisfaction with the benefits resulting from these systems. McKinsey and Company (74) conducted a survey of thirty-six large computer users to investigate their computer practices and achievements. The analysis of data collected in this and other similar surveys has indicated that computer expenditures were not being matched by rising economic returns, and that the underlying reason is essentially behavioral in nature (13,23). Research has also indicated that for many users, management information systems are considered unresponsive, inflexible, and not worth the effort and expense of development (61). One of the basic reasons for this dissatisfaction is said to be lack of sufficient knowledge about the relationships between the performance and
Table 1: U. S. Computer Census (23)

<table>
<thead>
<tr>
<th>Year</th>
<th>General Purpose</th>
<th>Dedicated</th>
<th>Total</th>
</tr>
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<tbody>
<tr>
<td>1955*</td>
<td>1,000</td>
<td>0</td>
<td>1,000</td>
</tr>
<tr>
<td>1960</td>
<td>5,000</td>
<td>500</td>
<td>5,500</td>
</tr>
<tr>
<td>1965</td>
<td>20,000</td>
<td>2,500</td>
<td>22,500</td>
</tr>
<tr>
<td>1970</td>
<td>45,000</td>
<td>25,000</td>
<td>70,000</td>
</tr>
<tr>
<td>1975</td>
<td>75,000</td>
<td>150,000</td>
<td>225,000</td>
</tr>
<tr>
<td>1980</td>
<td>125,000</td>
<td>575,000</td>
<td>700,000</td>
</tr>
<tr>
<td>1985</td>
<td>175,000</td>
<td>925,000</td>
<td>1,100,000</td>
</tr>
</tbody>
</table>

*1955 data is uncertain.
effectiveness of MIS and their contextual variables (user characteristics, decision problems, and organizational factors)\(^{4,6,63,66}\). This research is aimed at exploring the nature of association and inter-relationships between some contextual variables (user characteristics) and performance of some alternative MIS configurations.

A review of MIS conceptual design frameworks, in terms of key authors, indicates that consideration of decision tasks, behavioral aspects, and organizational factors in the development of management information systems has been strongly emphasized. Despite this emphasis at the conceptual level however, little empirically derived knowledge about the relationships between the MIS characteristics and these key variables exist. At a conference of the Society for Management Information Systems held at the University of Minnesota, management information systems professionals were asked to rank twenty-six potential research projects. The two projects receiving the highest ranking were:

1- development of methods for determining what the content of an information system should be, and

2- investigation into the characteristics of decision makers which affect MIS design.

The latter is the topic of interest and investigation of this research.

**Purpose and Rationale for Research**

The primary objective of this study is to investigate the influence of alternative MIS structure and user decision style on the use and performance of management information systems.
The literature in human information utilization and in management and accounting information systems is likely to lead one to the notion of tailored information systems (i.e., information systems designed according to the user characteristics). For instance, Revsine (36) has agreed that accounting information systems should be designed according to some consideration of user's cognitive information processing characteristics. McKenney and Keen suggest that decision aids "must be designed to 'fit' the managers' decision styles" and that "... the central factor determining whether a manager will use a model to reach a decision is the extent to which it 'fits' his style of thinking" (73). Mason and Mitroff have offered the following rationale for studying the individual characteristics of decision makers:

"What is information to one type of decision maker will definitely not be information to another. Thus, as designers of MIS, our job is not to set (or force) all types conform to one, but give each type the kind of information he is psychologically attuned to and will use most effectively (69, pp. 487)."

Driver and Mock (29) stated that an underlying reason for failure and ineffectiveness of majority of MIS is that, "MIS systems themselves show no concern for user personality."

Thus, the notion of tailored information systems and explicit consideration of user decision style is strongly suggested in the literature. But how do the systems designers go about implementing these suggestions? How and where the user decision style influence use and performance of MIS? This research, by investigating these variables and their interactions will lead to some knowledge
concerning how more effective management information systems should be designed.

Definitions

Management Information Systems

There is not a unique definition for the term information systems in the literature. Due to largely semantic debates on what a management information system really is,¹ it is necessary to present the MIS definition adapted in this study. A management information system is a system for collection (storage), processing, and dissemination of information for improving the management decision processes. This definition is compatible with other definitions of MIS (see 69) and is particularly well-suited for the purposes of this study in that in addition to information processing activities of MIS, it emphasizes the aspect of interest to this research, the MIS decision support activities.

Decision Aiding Strategies

The term decision aiding strategy is used to refer to any specific procedure used for purposes of enhancing effectiveness of managerial decision making. Throughout this report, the terms

¹As an example of the semantic issue in the area of MIS, see (46, pp. 90-99), and the responses that this article stimulated such as (22) and many responses in the "Letters to the Editor" column of the Harvard Business Review, Vol. 50, No. 3.
decision aiding strategy, decision aiding technique, and decision aiding approach have been used interchangeably.

Organization of the Report

In Chapter II, the conceptual issues of the design of management information systems have been addressed. Some conceptual MIS design frameworks are first described. Then drawing upon Leavitt's model of organizational system, a conceptual model of MIS design variables is developed. This conceptual model provides the research framework for this study.

Chapter III, the literature survey, consists of two distinct but interrelated parts. Part 1 contains the review of research in the area of MIS-user characteristics in terms of key studies and researchers. Conclusions concerning the significance of previous empirical works and their implications for further research are drawn and presented at the end of Part 1. Part 2 consists of the review of literature from related fields (behavioral sciences and decision theory), relevant to variables under study. Discussion of research questions and the experimental framework and the specific treatment levels are presented at the end of Chapter III.

Chapter IV presents a detailed explanation of the methodology used in this study. The hypotheses are listed and the procedures for the experimental task are given at length. This chapter also contains the discussion of the procedures for operationalization of the independent variables (decision style and decision aiding strategies) and dependent variables (MIS performance variables).
Chapter V is concerned with statistical analyses of the data. The statistical results and conclusions of the study are presented in this chapter.

Chapter VI summarizes the research findings and presents the researcher's interpretation of these findings and the implications of the results for the design of management information systems. This chapter also includes a discussion of limitations of this work and suggestions for further research.
CHAPTER II

CONCEPTUAL ISSUES IN THE DESIGN OF MIS

The MIS contemporary literature suggests the emergence of a contingency approach to design of management information systems versus prescription of "ideal" or "universal" MIS configurations. For example, Anthony noted the relationships between the nature of decision task and the characteristics of the management information system (1). He categorized the managerial decisions into three groups.

1- Strategic planning: "The process of deciding on objectives of the organization, on changes in these objectives, on the resources used to attain these objectives and on the policies used to attain these objectives, and on the policies that are to govern the acquisition, use and disposition of these resources (1, p. 16)."

2- Management control: "is the process by which managers assure that resources are obtained and used effectively and efficiently in the accomplishment of the organization's objectives (1, p. 17)."

3- Operational control: "is the process of assuring that specific tasks are carried out efficiently and effectively (1, p. 18)."
Anthony argued that different categories of decision tasks require different MIS configurations because they each require different types of information (Figure 1).

Bariff and Lusk stated that successful and effective development of management information systems should explicitly involve the psychological disposition of the user. They further stated that to construct management information systems which correspond to the user requirements, the system designer should also consider the nature of the decision problem. Their framework for design and development of MIS (demonstrated in Figure 2) is primarily based on development of user behavioral profiles.

The design framework developed by Chervany, Dickson and Kozar (15) stresses the relationship between the characteristics of MIS, individual decision styles and the nature of decision problem. In their framework the key design variables consist of the decision maker, decision environment (characterized in terms of decision task) and the characteristics of the information system. The authors suggest that since the objectives of designing and implementing a management information system is to improve the quality of decisions made using the system, then an "investigation of these variables and their interactions will lead to knowledge concerning how a management information system should be designed."

Simon's (93) framework of MIS design, illustrated in Figure 3, is directed toward description of decision making process and presents two categories of decision making: programmed and non-programmed. These categories are viewed to form the extremes of
<table>
<thead>
<tr>
<th>Operational Decisions</th>
<th>Managerial Decisions</th>
<th>Strategic Planning Decisions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very detailed data related to specific task</td>
<td>Moderately detailed data related to achievement of the organization's objectives</td>
<td>Aggregated data relates to establishing broad policies</td>
</tr>
<tr>
<td>Frequently reported historical data internally generated very accurate</td>
<td>Regularly reported historical and predictive mostly internally generated accurate within decision bounds</td>
<td>Infrequently reported predictive externally generated accurate in magnitude only</td>
</tr>
<tr>
<td>Repetitive often non-financial</td>
<td>exception reporting mainly financial</td>
<td>unique to problem under consideration often non-financial</td>
</tr>
</tbody>
</table>

Figure 1: Anthony's Normative Information Characteristics
<table>
<thead>
<tr>
<th>Development of User Behavioral Profiles</th>
<th>Design of Report Format and Implementation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Selection and administration of psychological tests</td>
<td>System analyst interpretation</td>
</tr>
<tr>
<td>Statistical analysis performed</td>
<td>Guidelines for report design and implemention</td>
</tr>
<tr>
<td>User behavioral profiles developed</td>
<td>Creation of report formats &amp; implemention scheduled</td>
</tr>
<tr>
<td></td>
<td>User report formats and implemention procedures generated</td>
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</table>

Figure 2: Bariff and Lusk's MIS Design Frameworks
<table>
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<tr>
<th>Type</th>
<th>Characteristics</th>
<th>Decision making techniques</th>
<th>MODERN</th>
</tr>
</thead>
</table>
| Programmed      | Routine, repetitive organization develops specific procedures to handle them | 1. habit  
2. clerical routines  
3. organizational structure | 1. OR models  
2. computer simulation |
| Non-programmed  | one-shot, ill structured novel, handled by general problem solving procedures | 1. judgment, intuition and creativity  
2. rules of thumb | heuristic problem solving  
(a) training human decision makers  
(b) computer heuristic programs |

Figure 3: Simon's Classification of Decision Tasks
a continuum. The author suggests that different decision making techniques are appropriate for different decision types. The implications of this framework are similar to those of Anthony (1), the designer should explicitly consider the relationship between the nature of decision problem and the MIS characteristics when designing information systems.

The MIS design framework developed by Locus (63) stresses the relationship between information systems and the contextual variables such as user decision styles, situational factors, etc. A simplified version of this model is illustrated in Figure 4. The objective of this framework as stated by the author is "to stimulate and guide researchers to undertake empirical studies of information systems in organizations." This model has a broad perspective and demonstrates the variety of factors affecting the development of management information systems. Due to lack of explicit definitions and measurement techniques, it is difficult to operationalize the full model.

Mason and Mitroff (69) have provided the following structural definition of a management information system: "... consists of at least one person of a certain PSYCHOLOGICAL TYPE who faces a PROBLEM within some ORGANIZATIONAL CONTEXT for which he needs EVIDENCE to arrive at a solution (i.e., to select some sources of action) and that the evidence is made available to him through some MODE of PRESENTATION (69)." They provide a taxonomy of states for each of the variables in the model (Figure 5) and argue that much of the previous research and developmental work in MIS has assumed "only one underlying psychological type, one class of problems, one or two
Figure 4: Locus' MIS Design Framework
1. Psychological type
   a) thinking - sensation
   b) thinking - intuition
   c) feeling - sensation
   d) feeling - intuition

2. Class of problems
   a) structured
      1. decision under certainty
      2. decisions under risk
      3. decisions under uncertainty
   b) un-structured, wicked decisions

3. Method of evidence generation
   a) Lockean (data based)
   b) Leibnitzian (model based)
   c) Kantian (multiple models)
   d) Hegelian (conflicting models)
   e) Singerian-Churchmanian (learning systems)

4. Organizational context
   a) strategic planning
   b) managerial control
   c) operational control

5. Modes of presentation
   a) personalistic
      1. drama-role plays
      2. art graphics
      3. one-to-one contact, group interaction
   b) impersonalistic
      1. company report
      2. abstract models

Figure 5: Mason and Mitroff's Taxonomy of MIS Design Variables
methods of generating evidence, and finally one mode as method of presentation."

The framework developed by Mock (76) notes the psychological, organizational and environmental variables that are relevant to design of information systems. This framework primarily focuses on relationship between the decision maker and the information system structure. The author states that, "selection of an information system is dependent on the behavioral factors of the manager who will receive messages. An understanding of the behavioral aspects will then enhance the management information system designer’s choice of selecting a satisfactory of even an optimal structure(s)."

A number of MIS design frameworks were reviewed here. We next provide a conceptual model of MIS design variables which integrates and expands on parts of the reviewed works to formulate a general conceptual framework for design of management information systems.

A Conceptual Model

In formulation of our conceptual model we have drawn upon Leavitt's model of organizations (59). The four elements of Leavitt's model (Figure 6) provide entry points into an organizational system. In this model "task" refers to the organizational transformation function (defined as the process of changing the raw materials to the end products and services) as well as task performed by the individuals. "Technology" applies to the programs and techniques as well as tools and machines used by the individuals.
Figure 6: Leavitt's Model of Organizational System

Figure 7: A Conceptual Model of MIS Design Variables
"Structure" refers to grouping of positions and activities as well as patterns of control and decision making (59). In our work we have applied this model to identify the key MIS contextual variables and to establish and analyze their interactions.

In the context of Leavitt's model MIS may be viewed as a "technology" in that it is a system designed for enhancing the effectiveness of organizational decision processes and support of individual decision tasks. The conceptual model emerging under this view is demonstrated in Figure 7. Notice that this model of MIS design is compatible with all the previous approaches discussed earlier. Furthermore, it provides for their integration in that it contains all the design elements and their possible interactions. For example, Anthony's design framework (emphasizing the relationship between the decision task and MIS characteristic) can be combined with Bariff and Lusk's framework (emphasizing relationships between the individual and MIS characteristics) in the context of our model. The integrative power of this model will become more evident once it is described in more detail in the following section. The simplicity of this model is a valuable attribute. Each of the elements, decision task, MIS, organizational structure and decision maker, may be viewed as a "black box" or may be examined in greater detail in terms of the variable and dimensions associated with it. The relationships between these elements, and the variable sets associated with them, may be examined in the context of the specified interactions. Each component of the model interacts with the other three components. This implies that in any given situation each
element should be considered in relation to all the other components. Based on the objective and interests of this research however, only the main interactions among MIS and other elements will be addressed here and the paths among organizational structure, task and individuals will not be explicitly discussed. These interactions have been extensively studied in the organization behavior literature and have been subject of many studies in this field and the area of organization design.

The MIS element in our conceptual framework may be characterized in terms of its inputs, outputs and decision support processes. Inputs and outputs of MIS may be further characterized in terms of medium, modes, methods and informational structure. Informational structure refers to information source, frequency, aggregation (detail) level, collection and dissimination frequency and report format. Decision support processes refer to the decision aiding techniques incorporated in the system for enhancing the effectiveness of user decision making. The following section presents a discussion of interactions between the MIS (conceptualized in terms of its inputs, outputs and decision processes) and the other elements of our model. The discussions are based on some limited empirical work in MIS field and research in other related areas (e.g., human information processing and organization behavior) and the conceptual works of some key researchers in the MIS field. The discussions serve to demonstrate both the need for undertaking scientific studies of MIS and the strength and richness of our conceptual model as a framework for such research.
MIS-Decision Maker Interactions

In our discussions of MIS-decision maker interactions we have primarily drawn on the domain of psychology and the studies of human information processing. Alternative theories and models of Human Information Processing (HIP) have been developed. For example, the HIP model developed by Simon and Newell (92) may be best characterized as structural in nature. In this model man is characterized as a serial information processor with limited short-term memory, infinite long-term memory and capable of undertaking heuristic approaches to problem solving and information search. The main thrust of this approach deals with how the human information processor internally represents task environments. Simon and Newell call this internal representation a problem space. It is the problem space against which the stored programs (operators) are applied. Behavior to resolve a task, as the task is portrayed in the problem space, can be best defined as a tree-like search; that is, the decision maker can widen the search for alternative paths or deepen the search down a particular branch until he arrives to a dead end or a solution. This model has important implications for MIS design in terms of obtaining an effective division of labor between the human decision maker and the MIS. For example, remembering large quantity of data and involved calculations are more effectively and efficiently handled by the MIS components. On the other hand, decision situations requiring heuristic approaches and processing a wide range of data types which cannot be predefined will be more effectively undertaken by the human decision maker.
Some HIP experiments undertaken by Miller revealed that the capacity of human to accept and retain information inputs and produce outputs is limited to 5-9 symbols with average of 7 (the magical number 7+2). Hence, individuals are easily subjected to information overload. This finding has two important implications for design of MIS informational structures and decision aiding strategies.

1- The MIS input to human decision maker and response requirements from the user should be kept below the information overload.

2- In situations of information overload, the effectiveness of human decision maker may be enhanced by filtering some of the information elements coming to him and hence reducing or eliminating the information overload.

Studies on human capability for processing and providing probabilistic data have indicated that humans are poor intuitive statisticians and they have rather limited intuitive capabilities for dealing with probabilistic data. This implies that in probabilistic decision making situations an effective way of improving the design maker's performance may be through probabilistic information processing techniques (e.g., Bayes' theorem) and techniques for obtaining more accurate probability estimates.

Other user attributes, for example psychological characteristics, are also relevant to design of management information systems. For example, user decision style has been considered an important user attribute affecting the MIS design (1, 27, 69, 77). Different classifications of individuals by decision making types or styles have
been proposed (4, 27, 69). These classifications all imply that individuals have different concepts of information and different approaches to analysis and problem solving. Based on this one may conclude as McKenny and Keen did that design of "good" and effective management information systems is also a matter of compatibility and comfort, i.e., a fit between how the user approaches problem solving and information gathering and the extent that the MIS allows him to do so.

As our discussions indicate the user characteristics can affect the design of MIS in terms of informational characteristics (quantity, type, etc.) and selection of decision aiding strategies. This is not a one-way interaction and as indicated in our conceptual model, the MIS characteristics can also affect the user. It has been found that based on age, sex and position in the organization, the individuals react differently to a MIS (64). In an organization information is power and it affects an individual's authority, status, career and visibility (64). If we adopt Thompson's view of power that "power is based in interdependence (97, p. 62)," we realize that a MIS by modifying information flows and interdependencies may result in shift in individual power bases. Thus, one may conclude as Dickson and Simmons have that dysfunctional reactions to installation of MIS (ranging from failure to use the system to outright sabotage) are based on the individual's defensive responses such as aggression, projection and avoidance (25, 64). It is important to anticipate the positive and negative aspects of changes that will be created by the MIS. It may be simple to change some informational characteristics
and decision aiding aspects of MIS to reduce the negative impact on
the user. Mumford and Ward (80) provide detailed planning for the
potential impact of MIS on individuals.

Some aspects of MIS-decision maker interactions were dis-
cussed. Our discussions were primarily based on implications drawn
from the research in the human information processing literature.
Little systematic research has been done on mapping the relation-
ships between MIS and user characteristics.

MIS-Decision Task Interactions

Since extensive and complete discussions can be found in the
literature (1, 36, 93), the MIS-decision task interactions will be
discussed only briefly. We base our discussion of MIS-decision task
relationships on a framework developed by Corry and Scott-Morton (36).
They combined Anthony's category of decisions (operational control,
management control and strategic planning) with Simon's decision
types (structured, semistructured and unstructured) into a matrix
(Figure 8). Categorizing management decision processes along these
two dimensions, they argued that MIS characteristics would systemat-
ically vary with the level and structuredness of the decision task in
that each category has different information requirements (Figure 9).
Furthermore, different types of decision tasks have different require-
ments in terms of design of decision aiding strategies. For example,
an effective decision aiding strategy for a structured decision task
in the area of operational control may consist of a mathematical model
whereas the effective decision aiding strategy for an unstructured
<table>
<thead>
<tr>
<th></th>
<th>Operational control</th>
<th>Management control</th>
<th>Strategic planning</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Structured</strong></td>
<td>accounts receivable</td>
<td>budget analysis</td>
<td>warehouse location</td>
</tr>
<tr>
<td></td>
<td>orders entry</td>
<td>short-term forecasting</td>
<td>location</td>
</tr>
<tr>
<td><strong>Semi-structured</strong></td>
<td>inventory control</td>
<td>variance analysis</td>
<td>mergers and requisitions</td>
</tr>
<tr>
<td></td>
<td>production scheduling</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Unstructured</strong></td>
<td>cash management</td>
<td>budget preparation</td>
<td>new product planning</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>R &amp; D planning</td>
</tr>
</tbody>
</table>

*Figure 8: Gorry and Scott-Morton's Framework of Decision Tasks*
<table>
<thead>
<tr>
<th>Characteristics of Information</th>
<th>Operational Control</th>
<th>Managerial Control</th>
<th>Strategic Planning</th>
</tr>
</thead>
<tbody>
<tr>
<td>source</td>
<td>largely internal</td>
<td>well defined, narrow</td>
<td>external</td>
</tr>
<tr>
<td>scope</td>
<td>well defined, narrow</td>
<td>very wide</td>
<td>aggregate</td>
</tr>
<tr>
<td>aggregation level</td>
<td>detailed</td>
<td>aggregate</td>
<td></td>
</tr>
<tr>
<td>time horizon</td>
<td>historical</td>
<td>future</td>
<td></td>
</tr>
<tr>
<td>currency</td>
<td>highly current</td>
<td>quite old</td>
<td></td>
</tr>
<tr>
<td>required accuracy</td>
<td>high</td>
<td>low</td>
<td></td>
</tr>
<tr>
<td>frequency of use</td>
<td>very frequent</td>
<td>infrequent</td>
<td></td>
</tr>
</tbody>
</table>

Figure 9: Information Requirement by Decision Category
decision task at strategic level may be to improve the decision maker's appreciation.\textsuperscript{2} The approaches and information stimuli required to improve appreciation are undoubtedly different from those required for development and solving mathematical models.

Gorry and Scott Morton's model demonstrated in Figure 8 may also be used to describe the impact of MIS on the decision tasks. The major impact of management information systems on the decision tasks so far has been in the upper left-hand corner of this framework (i.e., the category of operational control and structured decisions). This implies that the future trend in the development of MIS will be to move toward less structured decisions made at management control and strategic levels. Therefore, effects of unstructured decision tasks on management information systems and vice versa should be investigated.

\textbf{MIS-Organizational Structure Interactions}

Organizational Structure is defined by Thompson as "internal differentiation and patterning relationships (97)." Ford and Slocum (32) define structure in terms of four dimensions.

1- Internal differentiation: defined in terms horizontal, vertical, spatial and personal differentiation.

2- Formalization: specification and adherence to rules.

\textsuperscript{2}The term "appreciation" was coined by Sir Geoffery Vickers (69, p. 46C) to describe the processes by which the decision maker reaches "judgments of fact about the 'state of the system' both internally and in its external relations" and "judgments about the significance of these facts to the appreciator or to the body for whom the appreciation is made."
3- Centralization: locus of formal authority and power.
4- Administrative intensity: number and kind of administrative or supportive components.

A management information system may potentially impact structure along one or more of these dimensions. For example, in terms of structural differentiation one may argue that MIS using on-line and tele-processing capabilities have facilitated the spatial differentiation and geographical dispersion of some organizations. In terms of effects of MIS on organizational personnel, it may be argued that delegation of routine repetitive and well-structured tasks to MIS has decreased the potential growth in the number of clerical personnel in some of the organizations. On the other hand, it is likely that there will be an increase in the number of personnel with MIS related expertise (e.g., information technologists, computer programmers, management scientists, etc.) for development, operation and maintenance of these systems.

Increase in the information processing capacity of organizations as result of installation of MIS can have potential effects on the patterns of departmentalization. One primary effect may be aggregation of different departmental information collection, processing and dissemination activities into an information system or data processing department. As a result a reduction in size of some departments may occur. The reduction in size may in turn result in consolidation of these departments to economize on the supervision and management resources. Also in organization with a functional departmentalization in which the departments are set up to perform
sequential functions on the work flow of the organizations (e.g., in organizations operating serial technologies such as automobile manufacturing), a broader scope and "reach" of information across the work flow may make it feasible or desirable to define the departments more broadly. This change may cause consolidation of some of the existing departments. A management information system may also decrease the tendency toward the creation of self-contained subunits. An underlying reason for creation of self-contained departments (departments which have all the necessary resources for creation of a product or service) is to reduce the organizational information processing requirements (34). Self-contained units usually have the problem of suboptimization associated with them. Increasing the information processing capability of the organization through MIS, potential problems of suboptimization and economics of functional departmentation may decrease the tendency toward the creation of self-contained subunits.

The effects of MIS on organizational centralization was empirically investigated by Whisler (103). He concluded that in the organizations under study, the implementation of information systems increased centralization of control. But his study was inconclusive in terms of impact of the MIS on centralization of decision making authority. Hence in analysis of effects of MIS in this area, one should consider where the information is provided for current decision-making and how it is to be provided under the new or modified management information system. The important question to ask and answer is: do the information flows and locations for decision making
correspond to management goals for centralization of decision making authority? To improve the chances of successful implementations the impact of MIS along different dimensions or organizational structure (formalization, internal differentiation, and administrative intensity) should be explicitly considered.

In discussing the effects of organizational structure on the design of MIS, Mason and Mitroff state that, "there are a large, if not infinite, number of ways that one can discuss the influence of organizational structure on the design of MIS. This is because an organization's structure and its information systems are in reality just two sides of the same coin (69, p. 483)." To demonstrate the type and nature of considerations, it will be useful to discuss one possible way.

The elements of structure described above are common to all organizations. That is, all organizations have patterns of authority, task allocation and degrees of centralization (or decentralization) of decision and formalization. These elements affect the information collection, processing and flow in organizations. Wilensky has shown that hierarchy, specialization and centralization tend to create "information pathologies" (e.g., secrecy, distortion, blockage, etc.) in organizations (69). However, there are many alternative patterns of hierarchy, and differentiation, different degrees of formalization and different types of administrative intensity that an organization can employ. How do each of these affect the MIS characteristic? Does it make a difference? To our knowledge despite their importance these questions have not been systematically investigated.
Summary

The objectives of designing management information systems is to improve the quality of decisions made using the system. Therefore we need to investigate what variables and how they affect the MIS characteristics and performance. Knowledge of the key design variables and the nature of their association with MIS performance will provide a basis for design and development of more effective systems.

Our conceptual model based on Leavitt's model of organizational system identified four categories of key design variables:

1- variables associated with the organizational structure,
2- variables associated with the decision task,
3- variables associated with the user, and
4- variables associated with the MIS.

In the content of this model many questions in regard to the relationships between these design components and MIS characteristics may be formulated. For example, consider the following:

1- What organizational structure variables and how do they affect the design of MIS?

   How do alternative patterns of organizational hierarchy affect the MIS design and vice versa?

   How do alternative patterns of differentiation affect the design of management information systems?

2- How does the nature of decision task influence the MIS design?

   How does the nature of the decision task affect the performance of alternative MIS configurations?
How does the nature of the decision task affect the selection or design of MIS decision aiding strategies?

3- What is the nature of the relationships between the user and MIS characteristics?

Does the performance of alternative MIS configurations significantly vary for different types of users?

Understandably this research will not intend to provide an answer to all these questions. For the purposes of this study we will investigate the relationships between the decision maker (user) and MIS characteristics. The reason for focusing on the MIS-decision maker path versus other interactions in our conceptual model is that despite great emphasis placed on consideration of human characteristics in the design of MIS at the conceptual level, very few empirical studies have been conducted in this area. In this regard Sackman states that:

"Although the enhancement of the human intellect with computers has been the subject of much speculation, remarkably little valid scientific work has been done in man-computer problem solving. The humanistic lag in the application of computers to social affairs goes hand in hand with the experimental lag in man-computer communication (87, p. 3)."

Also as Jenkins argues as information systems are being implemented at higher levels of management, greater attention is being paid to fitting the system to the user as opposed to the "train the user to fit the system" mentality that was associated with most clerical level systems.
To develop an adequate experimental framework for studying the user-MIS relationships we next review the empirical work in this area. This review will provide the basis for selection of specific user and MIS variables for investigation in this study. In addition, literature relevant to the variables under consideration (decision style and decision aiding strategies) will be reviewed. Review of this literature will facilitate understanding of the issues under consideration.
CHAPTER III
LITERATURE SURVEY

Our survey of literature consists of two parts. In the first part some key empirical studies in the area of MIS are individually examined and reviewed. This review provided the basis for development of the specific research question investigated in this study. The second part of this chapter contains the review of literature from related fields (e.g., behavioral sciences and decision analysis) relevant to the variables of interest in this study. This review provided the basis for selection of specific treatment levels and measurement techniques employed in this work.

Review of MIS Research

The previous empirical work in the area of management information systems has primarily focused on the MIS informational characteristics (in terms of report format and information and feedback structure) and the decision aiding techniques of MIS have been to a great extent ignored. This section consists of a description of some key MIS studies in the area of MIS informational characteristics.

A large number of MIS empirical studies have been conducted at the Management Information Systems Research Center at University of Minnesota. Different variables related to user characteristics
and management information systems have been investigated in these studies. Table 2 provides a list of some of the independent and dependent variables and the results of the studies at University of Minnesota. As demonstrated in Table 2, the MIS characteristics investigated in these studies all relate to informational and input/output characteristics of the management information systems. For example, Kozar investigated the effects of MIS media (CRT versus hard copy) on cost, time and decision confidence (56). The experiment indicated a significant relationship between MIS media and decision time (CRT users has a long decision time). No significant relationships between media and decision confidence and cost was indicated.

In a simulation production planning experiment using thirty-two graduate business students Tiessen tested the following hypothesis: "Higher functional area knowledge subjects (more experienced subjects) will have a lower production cost performance, take less time to make a decision, and use less reports and report elements than lower functional area knowledge subjects (less experienced subjects) (98)."

This hypothesis was supported. However, the effects seemed to change during experiment Tiessen reported that, "functional area knowledge formed statistically significant relationships with these dependent variables only in the first decision period. In the latter periods functional area knowledge was an insignificant explanatory factor."
The variables and results of some other experiments conducted at University of Minnesota are listed in Table 2.
Table 2: Summary of Results and Variables Investigated in Some Experiments at the University of Minnesota MIS Research Center

<table>
<thead>
<tr>
<th>User Characteristics</th>
<th>MIS Characteristics</th>
<th>Performance</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Independent variable</td>
<td>media (56)</td>
<td>decision time</td>
<td>CRT users took more time</td>
</tr>
<tr>
<td>Kozar</td>
<td>media (35)</td>
<td>decision time</td>
<td>CRT users took less time</td>
</tr>
<tr>
<td>Prokop and Brooks</td>
<td>media (89)</td>
<td>decision time, report use</td>
<td>CRT users took less time, used fewer reports</td>
</tr>
<tr>
<td>Senn</td>
<td>media (14)</td>
<td>task time</td>
<td>CRT users took more time</td>
</tr>
<tr>
<td>Carlisle</td>
<td>media (101)</td>
<td>task time</td>
<td>CRT users took less time</td>
</tr>
<tr>
<td>Walther</td>
<td>Wynne</td>
<td>decision quality</td>
<td>more explicit goals produced better decisions</td>
</tr>
<tr>
<td>goal specification</td>
<td>Tiessen</td>
<td>decision quality</td>
<td>more experienced subjects made better decisions</td>
</tr>
<tr>
<td>(105)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>experience * (98)</td>
<td>Smith</td>
<td>decision quality</td>
<td>more experienced subjects made better decisions</td>
</tr>
<tr>
<td>experience (95)</td>
<td></td>
<td>decision quality</td>
<td>more experienced subjects made better decisions</td>
</tr>
<tr>
<td>experience (6)</td>
<td>Benbasat</td>
<td>report use</td>
<td>more experienced subjects used fewer reports</td>
</tr>
</tbody>
</table>

*Experience has been defined in different ways by the researchers; refer to the text for details.
Bariff and Lusk (4) proposed and implemented a procedure for the design of MIS user reports using two sets of user behavioral variables (cognitive style and implementation apprehension) in the context of a community health service organization. To measure cognitive styles, the Witkin Embedded Figures Test (which measures one's analytical ability) and the modified Bieri Cognitive Complexity Test were used. Implementation apprehension was defined in this study as resistance to change (measured by the Dogmatism scale), defense mechanism (measured by the Defense Mechanism Invenstoty Tests) and stress level (measured by Manifest Anxiety and Tolerance for Ambiguity). Report formats differing in data content (raw versus percentage data) and data format (tabular versus graphic) were evaluated by the users on four dimensions:

readability,
completeness,
ability to locate and abstract data, and
amount of data.

The researchers concluded that the direction of the user preference for report formats were all consistent with the psychological test results. One implication of this study was that some of user behavior variables are relevant to the design and acceptance of report presentation styles and hence, "... use of psychological tests eliciting indirect inferential systems insights provide potentially more useful report design information than direct response to interviews (4, p. 821)."

Dermer (24) in a field study investigated if the cognitive characteristics of a manager (defined in terms of intolerance of ambiguity) affect his perception of what information is important. The following two hypotheses were tested in this study:

"1- individuals intolerant of ambiguity will tend to perceive more information to be important than those tolerant of ambiguity, and

2- individuals intolerant of ambiguity manifest a preference for readily interpretable stimuli. Thus individuals intolerant of ambiguity will tend to judge as important information that is well defined, familiar and certain (24)."

Intolerance of ambiguity was measured by the questionnaires developed by Budner (24). Information types were defined in terms of twelve characteristics (listed in Table 3).

The first hypothesis of this study was supported. The second hypothesis as demonstrated in Table 3 was partially supported (i.e., some correlation coefficients between information types and perceived importance were significant and in the expected direction).

The findings of this research have important implications for report design in terms of information content and quantity. The results indicate that utility and perceived importance of a particular type of information cannot be effectively evaluated apart from the users of that information. For example, a report containing financial forecast data or human performance (behavioral) information may be of little utility to MIS users whose cognitive make-up is such that they will tend to ignore it.
Table 3: Product Moment Correlations of Importance of Information with Ambiguity Tolerance ($\phi_4$).

<table>
<thead>
<tr>
<th>Type of Information</th>
<th>Product Moment Correlations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Totals</td>
<td></td>
</tr>
<tr>
<td>future</td>
<td>.027*</td>
</tr>
<tr>
<td>external</td>
<td>.06</td>
</tr>
<tr>
<td>financial</td>
<td>.05</td>
</tr>
<tr>
<td>behavioral</td>
<td>-.25*</td>
</tr>
<tr>
<td>Twelve Classifications</td>
<td></td>
</tr>
<tr>
<td>future internal operational</td>
<td>.08</td>
</tr>
<tr>
<td>future internal behavioral</td>
<td>-.27*</td>
</tr>
<tr>
<td>current external operational</td>
<td>.02</td>
</tr>
<tr>
<td>current internal operational</td>
<td>.29**</td>
</tr>
<tr>
<td>future external financial</td>
<td>-.06</td>
</tr>
<tr>
<td>current internal behavioral</td>
<td>-.28*</td>
</tr>
<tr>
<td>future internal financial</td>
<td>-.22</td>
</tr>
<tr>
<td>future external operational</td>
<td>.11</td>
</tr>
<tr>
<td>future external behavioral</td>
<td>-.15</td>
</tr>
<tr>
<td>current external financial</td>
<td>.05</td>
</tr>
<tr>
<td>current internal behavioral</td>
<td>.19</td>
</tr>
<tr>
<td>current internal financial</td>
<td>.027*</td>
</tr>
</tbody>
</table>

*p < 0.10

**p < .05
In a study conducted by Doktor and Hamilton (27) the relationships between the user cognitive styles and report format (independent variables) and the acceptance of OR/management science recommendations (dependent variable) were investigated. The results of this study indicated that the user acceptance of the recommendations was significantly different for various report formats and user cognitive styles and that the highest acceptance was in those cases where there seemed to be a "fit" between the user cognitive styles and the report format.

Cognitive style in this study was defined as, "the characteristic, self-consistent way of functioning that an individual exhibits across perceptual and intellectual activities (27, p. 885)." The particular cognitive style of interest to their research was field independence/dependence (measured by Witkin's Embedded Figures Test).

A major implication of the findings of this study was that since user acceptance is a necessary (but not sufficient) condition for successful implementation, explicit consideration of user cognitive style in design and presentation of reports enhances implementation.

Information structure experiments conducted by Driver and Mock are a series of studies in the value of alternative information structures within a business game setting. These experiments have investigated information structures differing in terms of timelines (Mock, 1969), explicit budget feedback (Mock, 1973) and
decision styles (Mock, Estrin and Vasarhelyi, 1973 and Mock and Driver, 1975) (29).

The decision style construct used in these studies was based on Human Information Processing Systems (HIPS) model proposed by Driver and Mock (29). This model is in turn based on an earlier formulation of human information processing proposed by Schroder, Driver and Streufert (88) and Driver and Streufert. The new formulation of HIPS emphasizes habitual differences in use of information and focus (i.e., the number of solutions generated). Using these two dimensions, four basic decision styles (Decisive, Flexible, Hierarchic and Integrative) were developed. In addition to these four basic styles the model also postulated some mixed style patterns. The most pervasive is a mix of Integrative and Hierarchic, which was termed the complex style.

The effects of decision styles as described above (and operationalized through Integrative Style Test (IST) on a variety of interesting and potentially relevant MIS parameters have been studied. For example, Driver and Mock (29) found that information purchase and decision making time were related to decision approaches. In another study these researchers investigated whether or not the informational amount and complexity of an MIS affect each decision style's performance differently. The results of this experiment indicated the following.

1- The Decisive style performs best with the less complex information system.
2- The Flexible style seems indifferent to complexity of information systems.

3- The Integrative and Complex styles performed best with complex information systems.

The basic conclusion drawn from the series of information structure experiments was that tailored information systems would lead to improved decisions and more successful implementation.

The discussion of the conclusions drawn from the literature survey is presented in the following section.

Conclusions and Discussions of
MIS Research Review

Review of previous research indicated that different facets of MIS user characteristics, MIS structures, and MIS performance and their interrelationships have been investigated. These investigations are all potentially useful in that they have resulted in insight and some accumulation of knowledge concerning the MIS report design and informational configuration. On the other hand, as management information systems assume more of a decision supporting role in addition to their traditional data processing and informational support activities, selection and design of effective decision aiding techniques are becoming an increasingly more challenging design aspect. Therefore, a need for conduct of empirical investigation in the area of MIS decision support activities is created. In addition, the variety and diversity of existing decision aiding strategies
(discussed in the following section) further enhances the need for undertaking research and comparative studies in this area.

Our survey of MIS research also indicated that a variety of user characteristics such as experience, occupation, age, motivation, goal specificity, etc. have been found to influence MIS performance and utilization. Although many user characteristics may be relevant here, this work stresses modes of thought (as reflected in decision styles) as central. This is based on the following reasons. Some studies have shown that the future trend in the development of MIS will be to move toward support of less structured management decisions \(^{29,36}\). The crucial element in these types of decisions is the human decision maker (in contrast to structured or programmed decisions) whose judgements are needed to define data requirement and formulate solutions. This implies that some of the current research efforts in the MIS area should be directed toward investigation of user characteristics, in particular user decision styles (the way the decision maker acquires information and uses the information to make decisions). Furthermore, the arguments presented by Argyris \(^{2}\), Churchman \(^{16}\), Huysman \(^{45}\) and Driver and Mock state that ineffectiveness and management resistance to MIS and other OR/management science recommendations are primarily due to the distance between the managers and scientists thought processes and that managers are threatened by thought processes alien to their own. Therefore, in this study, user decision style is selected for investigation over other user characteristics. Different decision style constructs
will be reviewed and the construct employed in this research will be identified. We next undertake the review of decision aiding strategies.

Review of Decision Aiding Strategies

The topic of decision aiding has been studied in a variety of disciplines such as behavioral sciences, economics, decision theory, etc. In this part we discuss decision aiding strategies in terms of a classification based on their primary functions instead of the traditional paradigms. It is believed that this approach to classification of decision aids will provide new perspectives that have higher potential applications.

Decision aiding strategies based on their primary functions (most serve multiple functions) can be divided into:

1- alternative (solution) generation and testing,
2- complexity reduction,
3- conflict management,
4- decision analysis,
5- enhancing intuitive functioning,
6- evaluationary strategies, and
7- information collection and processing.

In the following section we will provide a brief description for each category and a review of some basic and commonly used techniques within some of the categories.
Alternative Generation

This group of decision aids are primarily useful in situations where the decision maker is uncertain about the available courses of action. Some techniques for enhancing alternative generation are group processes and morphology.

Group Processes. Group processes such as brain storming, brain writing and nominal groups use group participation to facilitate information and alternative generation. In order to encourage individuals to participate, group processes are usually conducted under three conditions:

1- ideas are freely expressed without considering their quality,
2- group members are encouraged to modify and combine the previously expressed ideas, and
3- the ideas are not evaluated until they are all expressed.

Experiments have shown that asking the participants to avoid criticism and to be creative seems to increase the quantity and not necessarily the quality of information and alternatives generated (72). In decision situations calling for innovative and novel solutions a useful approach may be the synectic approach. In this approach a carefully selected and trained group led by an experienced leader is formed (35,84). This group process involves viewing the decision problem in various ways and consists of eight "phases" from problem statement through problem solution. It however requires extensive selection and training procedures.
Morphology. Morphology provides a structured procedure for systematically relating combinations of elements to form new alternatives (102). This technique is based on the assumption that psychological set of decision makers constraints them in combining decision elements into new (unfamiliar) alternatives. This technique usually results in a relatively large number of potential solutions. The first step in this approach involves identification of the key dimensions of the solution space. The next step consists of examination of all possible combinations of the solution dimensions. This technique usually results in formulation of an exhaustive set of alternatives and reduces the likelihood of leaving out important elements in a decision problem.

Complexity Reduction Strategies

Experiments have shown that complexity is a major obstacle to effectiveness of decision making (72). Complexity in a decision situation usually stems from multiplicity of the factors to be considered and the interconnections among these factors. Decision aiding strategies devised for complexity reduction draw upon understanding of human information processing and decision making behavior. A variety of techniques such as input/output models (60), use of decomposable matrices (92), means-ends analysis (72), information chunking and aggregation (93), etc. have been devised. To demonstrate the basic approach and the nature of this group of decision aids, we very briefly discuss the following two techniques.
**Input/Output Models.** The modeling approach involving input/output models was developed by Leontieff (60) for macro-economic planning. These models have been successfully applied to analyze production and sales pattern and organizational information flows. The input/output models have provided a convenient way to model complex situations by systematically representing the interrelationships between the inputs and outputs of a system. A major weakness of these models is their underlying linearity assumption. These models assume a stable pattern of linear relationships between the various subsystems that they represent which may not necessarily hold in all the applications. Therefore, providing additional data on the sensibility of the model to assumptions has been suggested (60).

**Decomposable Matrices.** To effectively deal with complex decision systems, Simon (92) proposed their decomposition into the semi-independent components corresponding to their functional parts. Such an use of decomposable matrices is based on his view of complex systems as a hierarchy of levels in which the operation of the system at each level can be defined by describing its components functions. The technique may be effectively applied to a large number of decision environment that interactions among subsystems are weak but not negligible. These decision environments can be represented as hierarchies of components. This reduces their complexity with relatively little loss of information. By reducing the complexity of decision problems through this technique, the information processing
requirements of the decision problem is brought closer to the information processing capacity of the decision maker.

Conflict Management Strategies

Conflict in a decision situation may arise when:

1- there exists multiple parties,

2- the actions of one person can affect the outcomes of others, and

3- the parties have different preference ordering on the outcomes.

A large number of decision aiding strategies for conflict management stem from the game theory literature (97). Recently the decision situations under the conflict have attracted a good deal of attention from behavioral scientists, and a body of descriptive empirical literature dealing with what has generally been called "interpersonal accommodations" has developed (91). Here we present a brief description of some of the most frequently used conflict management techniques.

Bargaining. Bargaining involves interaction among the conflicting parties. This conflict management approach is particularly suitable for mixed motive decision situations in that the conflicting parties neither have to agree upon a formal rule for settling the conflict beforehand nor do they have to completely agree on all the desired outcomes (72). Although the conflicting parties may not
agree on some aspects of the decision situation, there should be sufficient common interest among the parties to start and continue the bargaining process.

Different approaches to bargaining may be taken. One approach is bargaining in the presence of an acceptable third party (the mediator) who assists the conflicting parties in resolving their differences. The primary role of mediator is to bring the parties together by use of persuasion and compromise. It has been demonstrated that in practical applications, bargaining is an effective approach to conflict management (72).

Market Mechanism. When conflicting interests among different suppliers, different demanders and suppliers and demanders exist, market mechanisms may be used to resolve the conflict and obtain cooperation. In addition to conflict resolution, the objectivity of "letting the market decide" can decrease antagonism among the parties involved (51). Davis and Kamien (21) provide a discussion of situations in which market mechanisms may break down.

For an extensive review of conflict management strategies, refer to MacCrimmon and Taylor.

Decision Analysis

The most general approach for systematically evaluating the alternative actions is decision analysis. Decision analysis involves developing a model of the decision situation and assessing the probability of relevant contingencies, obtaining user preferences and
finally assessing the value or utility of each decision alternative. Modeling involves identifying the decision variables and systematizing the information about these variables. Models provide possibility of a variety of decision aiding through generation of optimal or alternative solutions and providing information through sensitivity analysis.

In decision situations in which the uncertain decision variables occur over time, but the decision maker does not know what values it will take on, the decision analysis involves search for patterns and applications of different forecasting techniques. For example, yearly sales rates usually change in systematic ways that can be realized. A variety of techniques such as moving average which weighs a set of the most recent observations and exponential smoothing method which gives more weight to recent observations, for dealing with time series data exist. Chambers, Mullick and Smith (14) provide discussions of more general methods.

In decision situations which deal with unique events and the decision maker has some beliefs about the events which may occur, decision analysis involves externalizing the decision maker's beliefs by assigning subjective probabilities of events. These subjective probabilities are then used as inputs to different models. Subjective probabilities should be checked for consistency and biases. Various biases have been found in the assignment of subjective probabilities. For example, decision makers are usually too confident in their beliefs and use too narrow a distribution of values (30). They also usually tend to overestimate the probability of rare events and
underestimate the probability of likely events (31). Subjective probabilities may be assessed through direct or indirect methods. In direct assessment methods the decision maker is asked to assign a probability value to the event of interest. In the indirect methods the event is associated with some partition of a random device such as a lottery ticket or a probability wheel.

Enhancing the Intuitive Functioning

The basic decision aiding strategy here is to seek ways of permitting the intuition of the manager to function most effectively. The effectiveness of intuitive functioning decreases under physical stress (e.g., fatigue and time pressure) and psychological pressures (e.g., frustration and anxiety). Therefore the primary functions of decision aids in this group is eliminating, coping with or avoiding those conditions that degrade the decision maker's intuitive effectiveness (e.g., frustration coping, anxiety coping, relieving time pressure, etc.). One of the basic decision aiding of this group is bootstrapping.

**Bootstrapping.** Bootstrapping is a technique designed to aid the decision maker that is based on his or her own judgement of decision situations. It involves development of mathematical models which given the same information that the individual has will accurately reproduce or predict his or her judgement. A large number of studies have shown that these models "perform" better than the human decision maker in the sense of predicting some criterion or
implementing the decision maker's personal values. This technique enhances the intuitive effectiveness of the decision maker by eliminating the inconsistency in his or her decision making process.

Goldberg has noted:

"He 'has his day': Boredom, fatigue, illness, situational and interpersonal distractions all plague him, with the result that his repeated judgments of the exact same stimulus configuration are not identical. He is subject to all these human frailties which lower the reliability of his judgments below unity. And, if the judge's reliability is less than unity, there must be error in his judgments--error which can serve no other purpose than to attenuate his accuracy. If we could ... (eliminate) the random error in his judgments, we should thereby increase the validity of the resulting predictions."

While research in this area is being conducted at a number of different institutions, one of the major ones is the Institution of Behavioral Science of the University of Colorado. The research at this institution is primarily concerned with improvement of the decision process by developing explicit mathematical models of this process. The mathematical and statistical strategies for building such models are grounded in both Bayesian analysis and regression analysis. For a detailed discussion of these two approaches, refer to Slovic and Lichtenstein (94).

Evolutionary Decision Aiding Strategies

The underlying premise of evolutionary decision aiding strategies is that awareness of one's own decision process is most likely to become an effective basis for change and improvement in that process. The evolutionary decision aiding approaches are primarily concerned with:
1- development of self-consciousness and self awareness and providing the decision maker with self insight into his or her decision making process, and

2- suggestion of more or less specific ways of enhancing that style.

The concept of evolutionary decision aiding strategies is a new concept and has seldom been used in design of actual management information systems.

Information Collection and Processing

This strategy is the basic strategy incorporated in the design of majority of management information systems. Behavioral scientists have generated a large body of literature on human information processing and utilization. This literature is primarily descriptive and findings of empirical studies in this area have been specially used in the area of report generation (in terms of aggregation level, format, etc.). The normative information collection and processing approaches that may be used in the design of information systems are Bayesian approach and team theory.

**Bayesian Approach.** Bayes' theorem is frequently used to determine optimal revision of probabilities upon receipt of additional information in uncertain decision environments. Research in psychology has shown that actual information acquisition and processing behavior of individuals deviates systematically from the Bayesian strategy. This deviation has been attributed to individuals'
tendency toward "conservatism." When additional information is received, the subjects do usually revise their posterior probability estimates in the direction specified by Bayes' theorem. But the revision is smaller than the amount prescribed by the theorem (31). Conservatism and other limitations on human information processing capacity has lead to construction and use of probabilistic information processing systems (PIP). The PIP are computer based information systems in which the decision maker supplies the subjective probabilities and the computer aggregates these across data and hypotheses using Bayes' theorem. The PIP systems, on experimental basis, have been successfully used in military decision making, probation decision making and in medicine (72).

Team Theory. Optimal team strategy is a well-developed normative strategy of information processing in multi-person situations in uncertain environments (66). It extends expected utility theory to a multiple-person situation where no conflict of goals and interests exists among the individuals. This strategy focuses on three issues:

1- how organizational members should collect information on the uncertain organizational environments,

2- what channels and messages should be used for communication of the information, and

3- what action the member should take upon receipt of information.

In simple situations team theory provides the optimal strategies for dealing with communication in uncertain environments. In more complex
settings it offers a conceptual framework for monitoring behavior and avoiding information communication fallacies (67).

The decision aiding techniques briefly described here by no means provide a complete list of all existing decision aids. Also we note here that these strategies are not mutually exclusive and in a given situation a combination of two or more of these techniques may be used. Some of these strategies (e.g., team theory) are difficult to apply to real organizations at this point and in complex situations they only offer conceptual approaches and orientation. Given this and the variety and multiplicity of decision aiding strategies the need for comparative study of these approaches and devising criteria for selection and implementation of decision aiding strategies is demonstrated.

Review of Decision Style Constructs

A definition of decision style is the individual's characteristic and self-consistent decision making behavior. Different dimensions of decision style corresponding to psychological processes underlying decision making such as perception and information processing have been developed. To demonstrate the variety and sometimes overlapping sets of dimensions of decision style that have been proposed, a review of some classic works in this area will be presented here. Some approaches to decision style are uni-dimensional and others are two-dimensional. We first undertake discussion of uni-dimensional representations of decision style.
Uni-Dimensional Representation of Decision Styles

1. Field Dependence/Independence. This dimension primarily corresponds to perceptual processes underlying decision making. Witkin et al. (104) categorized individuals as field dependent or field independent on the basis of their ability to differentiate an object from its context. This characteristic is measured in terms of observed influence of the field on the individual's perception of the object within it. The tests originally used by Witkin (104) to measure this dimension were: "Body Adjustment Tests," "Rod and Frame Test," and "Embedded Figures Test."

Field dependence/independence is reflective of decision styles in that it indicates the source of important cues for the decision maker. It reveals the extent to which the individual relies on memory or experience as a source for information or procedures for decision making. This dimension of decision style is used in one form or another in all the two-dimensional approaches described in this section.

2. General Incongruity Adaptation Level (GIAL). Driver and Streufert (88) proposed the General Incongruity Adaptation Level as a means of describing an individual's reaction to a decision situation. This approach concerns two basic issues involved in decision situations:

1. information load (the quantity of information confronted by the individual) and
2- incongruity of the information with previous experience of the decision maker. 

These essential features of GIAL approach are shown in Figure 10, for two persons who display different characteristic reactions to information load and incongruity. GIAL method suggests that there is an optimal level of information load and incongruity for each individual. Furthermore, this level varies among the individuals (e.g., in Figure 10, Person A is shown to have a higher optimal level of load and incongruity compared to Individual B). This approach further suggests that when the environmental information load and incongruity level is not at the decision maker's optimal level, he will seek to adjust the environmental load to his optimal level through selective attention to information items and engaging in information search. Since GIAL suggests a characteristic reaction of individuals to the decision environments, it provides a measure of decision styles.

3. Conceptual Structure. Conceptual structure of individuals is defined along a continuum ranging from "abstractness" at one extreme to "concreteness" at the other extreme. "Concreteness" is characterized by the use of a few dimensions of information and a simple integrating approach. "Abstractness" refers to a tendency to process many dimensions of information and to use a complex integrative approach.

Conceptual structure attribute may be used to explain some characteristic information acquisition and processing behavior of an individual in decision making situations. Schroeder, Driver and
Figure 10: General Incongruity Adaptation Level (GIAL) as a Dimension of Decision Style \( ^{(39)} \)
Struerefert (83) proposed that "abstract" decision makers are more information oriented and would typically process more information in complex decision environments. "Concrete" decision makers on the other hand, would typically tend to process less information and reach the state of information overload at lower levels. The research finding has generally supported this proposition. Research findings have further demonstrated that concrete decision makers in simple decision environments need more information to reach a decision than do abstract decision makers. The information seeking behaviors of groups of four abstract decision makers were less affected by changes in the amount of information presented to them as an information base than were the information seeking behaviors of groups of four concrete decision makers (83). This dimension of decision style is at least implicitly dealt with in all the two-dimensional approaches discussed below.

Risk-Taking Propensity. Theoretical and experimental works have shown that risk-taking behavior can account for some differences in behavior among decision makers (9, 96). For example, Bruner et al. (9) found that risk-taking propensity influences information seeking strategies used by decision makers. Taylor and Dunnette (96) observed the risk-seeking decision makers make relatively rapid decisions based on little information, but process each item of information more slowly and judge its value for the decision more accurately than do risk-converse decision makers. A variety of
approaches such as utility functions, and mean-variance criterion have been developed to measure risk-taking propensity.

Intolerance for Ambiguity. Budner (24) defined the concept of intolerance for ambiguity as the "tendency to perceive or interpret ambiguous situations as sources of threat." Ambiguity is defined as uncertainty of meaning, and ambiguous situations are those which cannot be adequately structured or categorized by the decision maker. Situations that are new or have contradictory and many cues (24). Intolerance for ambiguity manifests itself in the way that particular phenomenon is evaluated by the individual. Decision making involves evaluation of information items. Therefore, the decision maker's disposition to ambiguity influences his information evaluation process. As such, this dimension represents a characteristic reaction to decision situations.

Two-Dimensional Descriptions of Decision Style

Jungian Personality Typology. Jung's description of personality characteristics has been used to describe decision style (69,82). Two particular dimensions of the Jungian Personality System used to describe decision making are:

1. perceptual orientation, i.e., the kind of "input-data" an individual characteristically prefers to take in from the environment, and

2. Other dimension of the Jungian Personality Typology is Extrovert-Introvert dimension which is not used in the description of decision styles.
2- decision making orientation: the individual's preference for
the kind of "decision making process" that he characteristi-
cally brings to bear upon the preferred kind of input data.

According to Jung, individuals can take in data from their
environments by either sensation or intuition. Sensation-type refers
to those individuals who typically take in information via the
senses, who are most comfortable when attending to the details and
specifics. In contrast, intuition-type refers to individuals who
typically take in information by means of their imagination, by
seeing the whole of any situation. These individuals typically pre-
fer the hypothetical possibilities in any situation to the "actual"
facts. The sensation and intuition modes of perception are antitheti-
tical and as a result individuals tend to develop a preference for
one or the other (82).

Jung described the two extremes of decision orientation as
thinking and feeling. Thinking is defined as the process of reaching
a decision that is based on impersonal and analytical modes of
reasoning. Thinking is the function that seeks to explain things in
scientific and theoretical terms independent of human needs and con-
cerns. Feeling is the process of reaching a decision that is based
on personalistic, value judgements that may be highly unique to par-
ticular decision maker. Thinking and feeling modes are also anti-
theitical and consequently individuals develop a preference for one or
the other and not both simultaneously.

Thus, however one takes in data (either by sensation or intu-
ition) an individual may come to a conclusion about the data by either
 impersonal analysis (thinking) or by subjective, personal processes (feeling). Since these two dimensions are independent of each other, they may be combined in all possible ways to get the following four personality types:

1- sensing-thinking or ST's,
2- sensing-feeling or SF's,
3- intuition-feeling or NF's, and
4- intuition-thinking or NT's.

According to Jung, for most individuals, over time, one personality type will become dominant. Figure 10 illustrates Jungian dimensions of decision styles.

McKenny and Keen Dimensions of Decision Style. The decision style dimensions proposed by McKenny and Keen (73) are similar to Jungian dimension and concerns information gathering gathering and information evaluation processes.

Information gathering relates to essentially preceptual processes by which the mind organizes the variety of visual and verbal stimuli it encounters (73). Along this dimension, McKenny and Keen distinguished between preceptive and receptive individuals. Preceptive individuals are described as bringing to bear concepts to filter data and as focusing on relationships between items. They tend to look for deviations from or conformities with their expectations. Receptive individuals on the other hand, have been characterized as being more sensitive to the stimulus itself. They focus on details rather than relationships and try to derive the attributes of the
Feeling (F)
- aware of others and their feelings,
- reached decisions that are based on personalistic judgments

Intuition (N) perceptual orientation Sensation (S)
- takes in information by means of their imagination.
- seeks the whole of the situations.
- takes long-range view of situation
- takes in information via senses,
- attends to details and specifics,
- prefers hard and impersonal facts

Thinking (T)
- reaches a decision that is based on impersonal, analytical facts

Figure 10: The Jungian Typology
information from direct examination of it instead of from fitting it to their precept (73).

Information evaluation refers to analysis of gathered information and to processes commonly classified under problem solving. Along this dimension distinctions are made between systematic and intuitive individuals. Systematic individuals tend to approach a decision by structuring it in terms of some method, which if followed through leads to a likely solution. The intuitive individuals at the other extreme, are characterized by alternative testing and trial and error approaches to decision making. They usually tend to discard information and are sensitive to cues that are not easily verbalized. Figure 11 illustrates the McKenny and Keen's dimension of decision style.

**Driver and Mock Decision Style Model.** Driver and Mock's (29) dimensions of decision style refer to the amount of information used and the focus of the decision maker on the number of solutions that are generated. Their model is a two-dimensional model which emphasizes habitual differences in information utilization and focus. The information utilization dimension distinguishes between an information maximizer at one extreme who uses all relevant information and an information satisfier at the other extreme who uses just enough information to make an acceptable decision. The second dimension concerns how information is structured into solutions. At one extreme is a style in which all data is used to develop a single convergent answer. The other extreme is a style in which information is used to
Figure 11: McKenny and Keen's Dimensions of Decision Styles
formulate a variety of answers. Using these two dimensions, Driver and Mock developed four basic decision styles (Figure 12):

"The Decisive Style is seen as one prizing speed, efficiency and consistency. Just enough data is used to generate an adequate decision. Decisions are made quickly with few backward glances.

Flexible Style shares the decisive habit of focus on action. This style uses minimal data but sees solution as changing consistently over time. It however relies more on intuition than facts.

Hierarchic Style is the style which strives to attain one best solution. Rigor extends to method as well as results.

Integrative Style shares the high data bias of the Hierarchic but generates multiple solutions rather than one. It is a style which likes information for its own sake and seems most creative (29, p. 6)."

In addition to four basic styles this model postulates some mixed style patterns. The most pervasive is complex style which is a mix of Integrative and Hierarchic styles. The complex style demonstrates the characteristics of Integrative style in initial phases of decision making and usually shifts to Hierarchic style in later phases. Driver and Mock's experiments showed that each individual demonstrates a "dominant style" under moderate environmental load but under conditions of overload or underload, a "back-up style," usually Decisive or Flexible was displayed.

A Concluding Note

Some attempts have been made to relate some cognitive attributes (e.g., intelligence, intellectual efficiency) to decision making behavior. These dimensions are not discussed here because they seem to primarily influence information handling and judgemental versus stylistic aspects of decision making. For example, they appear
<table>
<thead>
<tr>
<th>Amount of information used</th>
<th>Degree of focus in use of data</th>
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<tbody>
<tr>
<td>multiple solution</td>
<td>Flexible</td>
</tr>
<tr>
<td>one solution</td>
<td>Decisive</td>
</tr>
</tbody>
</table>

Figure 12: Driver and Mock Decision Style Model
to influence retaining information in short term memory. The dimensions discussed here (intolerance for ambiguity, risk-taking propensity, etc.) seem to primarily relate to and reflect idiosyncratic aspects of decision making (e.g., the amount and type of information sought).

The review of MIS research, decision aiding strategies and the decision style paradigms provided the basis for the formulation of the research question presented in the following section.

The Research Question

This research investigates whether or not the MIS performance variable (dependent variables) vary for different user decision styles and under alternative MIS decision aiding strategies (independent variables). More specifically this study aims at investigation of:

1- whether or not MIS performance is affected by the decision aiding strategies incorporated in the system,

2- whether or not MIS performance is affected by the user decision styles, and

3- whether or not interactions between decision aiding strategies and decision styles will influence the MIS performance.

The variable set associated with performance consists of: decision quality (defined in terms of decision cost or profitability and decision time); usage of the decision aiding strategy and user attitudes and opinions concerning the satisfaction with the system.
Jungian personality typology will be used to describe decision styles. One reason for selection of this two-dimensional model over the uni-dimensional models is that as Keen has put it, "The weakness of any uni-dimensional model of human thought processes is simply that it seems unlikely that it can do justice to the complexity of human thinking. To fit the immense range of capacity and responses that any capable adult demonstrates over a variety of settings into a single polarized dimension is inevitably to limit the applicability of the model in question (69, p. 16)." Another reason for selection of Jungian representation of decision style is that the instrument used to operationalize this construct, Myers-Briggs type indicator, is a simple paper and pencil instrument with high degree of validity\(^3\) and reliability.\(^4\)

The decision aiding strategies selected for investigation in this study are:

1- analytical models,
2- enhancing intuitive functioning (bootstrapping), and
3- evaluationary techniques.

There are several reasons for selecting these decision aiding techniques. Formal mathematical models are widely used decision aids and thus improvement of their effectiveness may result in increased

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\(^3\)Validity, minimization of systematic error, indicates the extent to which a given test measures an underlying psychological construct (4).

\(^4\)Reliability, minimization of random error, indicates the stability of the test measure (a) over repeated measures under similar conditions, (b) over alternating test forms, or (c) over subsets of items within the same test (4).
utilization and user satisfaction. Due to substantial intuitive content and nature of many management decisions (78), obtaining empirically based knowledge on the performance of decision aids aimed at enhancing the intuitive functioning will be valuable in achieving more favorable MIS cost-benefit ratios. Finally it is felt that investigation of evolutionary strategies is valuable due to meager number of empirical studies in this area.

The experimental variables are demonstrated in Figure 13. The dependent and independent variables and their operationalization procedures will be discussed in detail in the next chapter. The next chapter also includes the listing of the hypotheses and a detailed description of the research methodology and procedures employed in this experiment.
<table>
<thead>
<tr>
<th>Independent Variables</th>
<th>Dependent variables</th>
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<tr>
<td><strong>User element</strong></td>
<td><strong>MIS element</strong></td>
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<tr>
<td>Jungian decision styles</td>
<td>Decision aiding strategies</td>
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<td></td>
<td>• bootstrapping</td>
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<td>• mathematical models</td>
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<td>• evolutionary strategies</td>
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*Figure 13: The Experimental Variables*
In order to clearly present the research methodology employed in testing relationships between the user and MIS characteristics, this chapter is divided into three major sections:

1- hypotheses to be tested,
2- detailed statement of the methodology, and
3- description of the experimental procedures.

The statement of methodology includes the description of the experimental design, the subjects, experimental task, variables and variable operationalization.

**Hypotheses to be Tested**

The following hypotheses were posed to investigate whether or not user performance, attitudes and utilization of the decision aid (dependent variables) are significantly affected by the decision styles and their interactions with the decision aiding strategies.

The Jungian decision style construct discussed in the previous chapter, formed the theoretical basis for postulating hypotheses 1 and 2 and the subordinate hypotheses listed in this section. This construct indicates some important differences in the ways in which
individuals of particular styles approach problem solving and information processing. The following descriptions summarize the main characteristics of each style

ST type: "prefers (a) to break all problems, simple and complex, down into manageable parts, (b) to work on the parts independently of one another, and (c) to utilize or apply an existing well-developed theoretical model or a well-understood body of knowledge plus a set of facts about the specific problem at hand to derive a single, unambiguous optimal ("best") solution (plan, course of action) to the decision problem."

NT type: "prefers (a) to conceptualize all problems, simple and complex, in the broadest possible theoretical terms and form the most diverse points of view, (b) to work on all aspects of the problem (the whole problem) simultaneously, and (c) to develop new conceptual ideas and theoretical models to propose (discover) as many possible new and different solutions to the original problem as well as invent (discover) entirely new theoretical problems."

NF type: "prefers (a) to conceptualize all problems, simple and complex, the broadest possible human terms and from the most diverse point of view, (b) to work on all aspects of the problem (the whole problem) simultaneously, and (c) to develop new conceptual ideas and human possibilities to propose (discover) as many possible new and different
solutions to the original problem as well as invent (discover) entirely new human problems (possibilities)."

SF type: "prefers (a) to break all problems, simple and complex, down in the manageable parts, (b) to work on the parts independently of one another, and (c) to utilize or apply an existing well-understood personal body of knowledge plus a set of personal facts about the specific at hand to derive a single, unambiguously "best" subjective solution to the problem."

Decision style construct implies that individuals are psychologically attuned to different and characteristic ways of information collection and processing. This further suggests that not only decision tasks exist that are suited to particular decision styles but also that the individual prefers and searches out those decision and problem solving approaches that are compatible with her/his decision style ( 73 ). Therefore, it was postulated that:

Hypothesis 1. Decision performance is affected by the user decision styles.

Hypothesis 2. Interactions between the decision styles and decision aiding strategies have significant effects on utilization and user attitudes concerning evaluation of the decision aids.

Furthermore two subordinate hypotheses concerning the interactions of the decision styles and the decision aiding strategies were postulated. Analytic decision aid provides an explicit, systematic and structured approach to solution of the decision task. It involves
structuring the problem in abstract and theoretical terms, reducing the unknowns, defining very explicitly all the constraints in the situation and producing a single "best" solution. Thus based on the compatibility and "fit" between attributes of the analytic model and the ST type (refer to the characteristics of the ST type listed above), it was postulated that:

**Sub-hypothesis 1.** Sensing-Thinking (ST) type will be most satisfied with the analytic model.

**Sub-hypothesis 2.** Utilization of the analytic model will be highest for the ST type compared with the other decision styles.

The work of the MIS designer, beyond the creation of the information system, involves its implementation (defined as the actual sustained use of the system by the decision maker (78)). In the contemporary MIS design and implementation literature several authors (37,49,53,78) have advocated evolutionary approaches to design and implementation of the information systems and management science models. Karash and Urban (49) stated that a major advantage of the evolutionary approaches to decision aiding and model building is increased managerial understanding and acceptance of the decision aid. King and Cleland (53) proposed that introduction of normative models as an evolutionary development of simple and descriptive to more complex and theoretical facilitates user participation and will hence foster managerial acceptance and use of the model. This study investigated the implementation and user attitudes toward evolutionary decision aiding approaches.
In the context of this research evolutionary decision aiding approach involved:

1- development of subject's self-awareness and self-knowledge in regard to her/his decision process through development of descriptive decision models, and
2- using the descriptive models as a basis for introduction and presentation of normative and theoretical decision model.

The following hypotheses concerning the utilization and user attitudes toward the evolutionary approach were formed.

Hypothesis 3. User satisfaction with the decision aid is highest in the evolutionary approach across all decision styles.

Hypothesis 4. The usage of decision aid is highest in the evolutionary approach across all the decision styles.

In addition to the hypotheses listed above, this research investigated the main and interaction effects of the independent variables on all the dependent variables under study based on the following reason. From the MIS designer's perspective, it is useful to know how a given MIS configuration performs under different user decision styles. Furthermore, it will be more useful to know how the performance and user attitudes may be affected by manipulating the characteristics of the decision aiding strategies incorporated in the system. This investigation will provide some empirically derived guidelines for selection of effective decision aiding strategies and their successful implementation.
Research Methodology

The research methodology is discussed under the following main headings:

1- experimental design,
2- experimental subjects,
3- experimental task, and
4- variables under study (independent, dependent and control) and their operationalization.

The selection of an experimental design is largely influenced by the phenomena of interest to the researcher (47). Since both main and interaction effects are considered important in this study, a factorial design was selected. A factorial design is one in which all levels of a given factor are combined with all levels of every other factor in the experiment. Kirk lists three major advantages of factorial experiments:

1- "All subjects are used in evaluating the effects of two or more treatments. The effects of each treatment are evaluated with the same precision as if the entire experiment had been devoted to that treatment alone. Factorial experiments thus permit efficient use of resources.
2- Effects can be evaluated over a wide range of experimental conditions with maximum efficiency.
3- Permits interaction effects to be evaluated (54, pp. 243)."

The two factors in this experiment are MIS user decision style (consisting of four levels corresponding to the four categories of Jungian typology) and the decision aiding strategy incorporated in
the MIS. The factor levels of this experiment are listed in Table 4. Factor A, the user decision style is a subject-specific characteristic (classification or attribute factor). Hence it is measured but not manipulated in the experiment. Factor B, the decision aiding strategy is the treatment factor in the experiment and the subjects are randomly assigned to the three levels of this factor. Factor levels and their operationalization will be discussed in detail in the following sections.

**TABLE 4**

**THE EXPERIMENTAL FACTORS AND FACTOR LEVELS**

<table>
<thead>
<tr>
<th>Number</th>
<th>Factors Description</th>
<th>Designation</th>
<th>Factor Levels</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>decision style</td>
<td>A</td>
<td>ST</td>
</tr>
<tr>
<td>2</td>
<td>decision aiding</td>
<td>B</td>
<td>analytic</td>
</tr>
<tr>
<td></td>
<td>strategy</td>
<td></td>
<td>model</td>
</tr>
</tbody>
</table>

Experimental Subjects

The subjects of this research were drawn from the graduate and undergraduate student population of the College of Business Administration at The Ohio State University. This subject population was

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5Pilot studies indicated that 8-10 hours of subject time would be required to complete the total experiment. These costs in subject time (given the exploratory nature of the research) were felt to be too high to use managers as subjects.
used in order to obtain a homogeneous group of subjects who would find role playing in a business simulation to their liking in terms of values and motivation. All subjects had at least one course in production planning in their backgrounds. Some subjects participated in the experiment on voluntary basis and some subjects were drafted for the experiment (as a part of requirements for a production planning course). Volunteer subjects were paid $20 for their participation in the experiment. All subjects competed for cash prizes. The cash prizes offered to the drafted subjects were higher than the one's offered to volunteer subjects. The prizes were awarded on the basis of average profit made over the number of decision cycles. All subjects seemed highly motivated throughout the experiment.

Post-study analysis indicated no significant and systematic differences in performance and attitudes (dependent variables of the study) between the graduate and undergraduate and volunteer and drafted subjects.

Experimental Task

The experimental task was a controlled laboratory task involving aggregate work force and production scheduling decisions in a simulated factory environment. Each subject assumed the responsibility of a production manager in the simulated factory. The primary task of the production manager was to make periodic (weekly) work force and production decisions for the ten finished products based on knowledge of current inventory levels, present size of work force and forecasted demand over a 12 period horizon. Due to lead time
requirements for raw materials and parts, a planning horizon of 5 weeks was used. The objective of the production manager was to minimize total "long-run" costs, i.e., cost over the entire number of decision periods in the experiment. The cost included hiring and firing, idle time, overtime, finished goods inventory carrying and shortage costs. A case description provided the subjects with all of the essential information required concerning the corporate environment. It described the key characters and the circumstances leading up to the hiring of the subject. The description of the subject's position (production manager) contained detailed information on her/his functions, responsibility and objectives. Further, the written description coupled with the examples of management reports illustrated the information that was available to the production manager on continuous basis. The case contained the description of the exact conditions that existed in the production department when the subject assumed her/his position with the firm. (A case description of "FACTORY: 2" is presented in Appendix A.)

Two primary reasons justify selection of this particular experimental task. First, the task can be solved intuitively or analytically and hence allowing development of "bootstrapping" and analytical approaches to decision aiding. Second, the sequential and repetitive nature of the task was compatible with and satisfied the requirements of evolutionary and bootstrapping approaches. A brief description of the logic, content and basic features of the simulation model is presented below.
"FACTORY: 2" Simulation Model. A flow diagram of the version of "FACTORY: 2" simulation program used in this study is shown in Figure 14. The simulation is written in FORTRAN IV programming language (the FORTRAN listing is presented in Appendix B.)

Referring to Figure 14, the program is divided into seven major stages of execution (identified by letters A through G). Stage A is the run initialization stage at which time data and control parameters are read from the input files and initial conditions for inventory, production, and sales are established. At this stage, a 24-week sales history is also generated. Stage A is only executed for the initial run of the simulation and is skipped in all the subsequent runs.

Stage B involves re-initialization of the variables and parameters by the data saved from previous runs and stored on direct access files. The direct access files are indexed by a unique identifier, i.e., the subject's social security numbers. This configuration allowed multiple access and execution of the simulation program. Stages A and B are mutually exclusive and a run control parameter assures that they are not both executed at the same run.

Stage C of execution consists of the simulation of the production operations for a week. Within the actual weekly production run, Stage D occurs which involves calls to the forecast and detail planning sub-routines. The outputs of the forecasting sub-routine is

---

6The original version of the simulation program was developed at the graduate school of Industrial Administration at the University of Pittsburgh. This original version was extensively modified to meet the needs and requirements of this research.
Figure 14: A Flow Diagram of the Simulation Program.
a 12-week sales (demand) forecast for the ten final products. This sub-routine does not use any of the subjects' input data. Therefore, all the subjects received identical sales forecast throughout the experiment. The detail planning sub-routine requires the subjects' aggregate work force and production plans for the finished products. Output of this sub-routine is the production plan for sub-assemblies and parts and disaggregated work force schedules. The subjects' input data is obtained by execution of a sub-routine which prompts the subjects for their input decisions. The subject data was entered via time share terminals (Digital DEC-Writer II).

At Stage E of execution weekly demand is generated stochastically for each of the final products and product sales are released from the finished goods inventories.

Stage F computes the weekly accounting data on operations and generates management reports. On this experiment five management reports were printed out (for a report description, please refer to the case description in Appendix A).

Stage G, the final stage of execution involved "freezing" the simulation program by saving all the values and parameters on the direct access files. This feature provided the simulation with a re-start capability so that the simulation could be executed in an on-line mode while the subjects could make their decisions away from the terminals and on their own time.
Research Variables

The independent variables of this research are decision style and decision aiding strategy. Decision style being a user-specific variable is measured but not manipulated. The treatment variable is the decision aiding approach incorporated in the MIS. Three alternative decision aiding approaches are used: analytic, bootstrapping, and evolutionary.

Control variables in this research are: subject's experience, and subject's previous familiarity with the decision aiding approaches supplied to them. Control or confounding variables are those variables which might help explain differential responses among subjects if the responses are not in the hypothesized direction.

The dependent variables of the study fall into three major categories:

1- user performance variables,
2- user attitudes concerning evaluation of and satisfaction with the decision aid, and
3- user utilization of decision aid.

The variables associated with the user performance are: decision quality and decision making time. The variable set associated with the user attitudes are: ease of use, satisfaction with the decision aid, importance of the decision aid in arriving at the production decisions and willingness to use a similar decision aid in a similar decision environment in the future.
The operationalization of independent, dependent and control variables is discussed in the following section.

**Operationalization of Variables**

**Independent Variables**

*Decision Style.* The decision style construct used in this research is Jungian typology. This construct is operationalized through Myers-Briggs Type Indicators (in this study the long form was used). Based on her/his scores on Myers-Briggs questionnaire, each subject was assigned to one of the four categories of Jungian decision style. These four categories are: intuitive-Thinking (NT), Sensing-Thinking (ST), Sensing-Feeling (SF), and intuitive-Feeling (NF). For a description of these categories, please refer to (82).

*Decision Aiding Strategies.* The analytic, mathematical decision aiding approach used in this study is the Linear Decision Rule (LDR) model. LDR was originally developed by Holt, Modigliani and Simon (11) as a means of making aggregate employment and production rate decisions. It is based on the development of a quadratic cost function of the following general form:

\[
C_N = \sum_{t=1}^{N} \left[ (C_1 w_t) + C_2 (w_t - w_{t-1})^2 + C_3 (p_t - C_4 w_t)^2 \\
+ C_5 p_t - C_6 w_t + C_7 (I_t - C_8 - C_9 t)^2 \right].
\]
where, by definition, the excess of production over orders affects net inventory as follows:

\[ P_t - F_t = I_t - I_{t-1} \quad t = 1, 2, 3, \ldots N. \]

In this function \( C_N \) refers to the total cost of production over \( N \) periods, \( w_t \) is the work force at period \( t \), \( P_t \) is the production at period \( t \), and \( I_t \) is the net inventory at period \( t \). The cost components in the above formula are made up of: regular payroll costs \((C_1w_t)\), hiring and firing costs \([C_2(w_t - w_{t-1})^2]\), overtime costs \([C_3(P_t - C_4w_t)^2 + C_5P_t - C_6w_t]\) and inventory carrying costs \([C_7(I_t - C_8 - C_9I_{t-1})^2]\).

In the applications, the cost coefficients \((C_i)'s\) in the quadratic cost function are estimated based on the historical data of the production activities. In this study the "historical" data for "FACTORY: 2" simulation was obtained by running the simulation for several periods. The cost coefficients were then estimated by fitting the corresponding cost curves to the historical data using SAS statistical package. The next step in the development of the LDRS involves differentiating the quadratic cost function with the respect to the decision variables \( w_t \) and \( P_t \) for \( t = 1, 2, \ldots N \), and setting these partial derivatives equal to zero. This results in an infinite set of linear simultaneous equations of the form illustrated in Figure 15. This system of linear equations may be solved by a variety of techniques. The approach used in this research was the one based on development of auxiliary equations, described by Holt, Modigliani and Muth (10). Using this approach a FORTRAN program was
Figure 15: The Infinite System of Linear Equations to be Solved for the LDR
written to develop ten linear decision rules for production and work force planning for the 10 final products of "FACTORY: 2" case. The production linear decision rule developed for Product 1 is shown in Figure 16

\[
P_t = 882.5 + \sum \left[ \begin{array}{c}
0.149543 F_{t+1} \\
0.105065 F_{t+2} \\
0.067415 F_{t+3} \\
0.038495 F_{t+4} \\
0.018102 F_{t+5} \\
0.004961 F_{t+6} \\
-0.002588 F_{t+7} \\
-0.006179 F_{t+8} \\
-0.007210 F_{t+9} \\
-0.006760 F_{t+10} \\
-0.005598 F_{t+11}
\end{array} \right] + 0.1954 (F_t - I_{t-1}) + 5.41 w_{t-1}
\]

Figure 16: The Production LDR for Product 1

Where \( P_t \) is the prescribed production level for period \( t \), \( F_t \) through \( F_{t+11} \) are the forecast of sales for the next 12 periods, \( w_{t-1} \) is the size of the work force at the end of previous period and \( I_{t-1} \) is the previous period's ending inventory.

The linear decision rules for the remaining products in "FACTORY: 2" case are presented in Appendix D.
"Bootstrapping." A popular approach to bootstrapping is regression analysis. Regression analysis provides a quantified description of the way that a decision maker weights and combines information elements. Regression analysis is applicable in repetitive types of decision situations, where the factors considered by the decision maker are treated as the independent variables in a linear regression of the form:

\[ Y = B_0 + B_1 X_1 + B_2 X_2 + \ldots + B_n X_n. \]

From the decision maker's past choices, coefficients of the variables are estimated using standard regression techniques. The magnitude of the coefficients are assumed to reflect the relative importance of each factor considered by the decision maker. The "paramorphic" model that results can then be used to predict the decision maker's choice in future decisions. It has been shown that due to inconsistencies in the decision maker's behavior the regression models often outperform the decision maker (8, 57, 79). This suggests that the model may be used by the decision maker to "bootstrap" his way up to better decision making (in some cases even better than an "optimal" model developed in traditional OR fashion (57, 79)). Hence, regression analysis may be used to enhance the decision maker's intuitive functioning by primarily eliminating inconsistencies in his decision process. In attempting to describe the subject choice process, it is essential to begin with a theory or hypothesis about his/her decision behavior (choosing the model from a set of arbitrary functions which best fits the data set is wrong). Our hypothesis was
that subjects' production decisions at time period \( t \) were based on
last period's work force \( (w_{t-1}) \), the requirements for the immediate
forthcoming period \( (F_t - I_{t-1}) \), where \( F_t \) is the forecast of demands and
\( I_{t-1} \) is the previous period's ending inventory), and given future
forecasted demands beyond the immediate period \( (F_{t+1}, F_{t+2}, \text{etc.}) \).
In other words, the form of the subjects' regression models was hypo-
thesized to be identical to that of the mathematically derived LDRS,\(^7\)
i.e.,

\[ P_t = a_0 + a_1 w_{t-1} + a_2(F_t - I_{t-1}) + a_3 F_{t+1} + a_4 F_{t+2} \ldots \]

Other two basic assumptions underlying regression analysis are:

1- significant instabilities do not occur in the decision
environment, and

2- adequate performance feedback be given to the decision
maker (57, 79).

In this study the controlled simulation task created a stable deci-
sion environment and the five management reports printed at the end
of weekly simulations provided the subjects with adequate and timely
performance feedback.

Two major problems in developing the open ended regression
forms described above were encountered.

1- the sales forecasts \( (F_t, F_{t+1}, F_{t+2}, \ldots) \) were highly
correlated, and

\(^7\)The statistical goodness of fit tests using the coefficient
of multiple regression \( R^2 \) indicated that this assumption was in fact
a reasonable one.
due to a large number of independent variables in the open ended model, a very large number of data points (approximately 65 production decisions) would be required. Therefore, the regression models were simplified by replacing the forecasts beyond the forthcoming period by a variable called forecast Trend ($T$). The modified form of the regression model is:

$$P_t = a_0 + a_1 T + a_2 (P_t - I_{t-1}) + a_3 w_{t-1}.$$ 

The coefficient of the Trend variable was interpreted as: the relative importance of the long-term forecasts of demands in the production decision of the forthcoming period. Regression model coefficients were estimated by a FORTRAN program using an ordinary least square method. This program was interfaced with the "FACTORY: 2" simulation via a small FORTRAN sub-routine. The interfacing sub-routine passed the subjects' production plans and other pertinent data from the simulation to the regression program. This configuration allowed the rapid development and display of the regression models to the subjects. For "FACTORY: 2" case 10 regression models corresponding to 10 final products were developed. An example of a subject's regression model for Product 1 is illustrated in Figure 17. The numbers in the figure correspond to the trend, Forecast-Inventory and work force coefficients. R-SQ, the coefficient of multiple regression, is a measure of statistical goodness of fit.

Evolutionary Approach. In the evolutionary approach the previous two approaches, the linear decision rule and regression analysis were combined in the following manner. The regression models using
the same variables described above were first developed. These regression models were then used as a basis for introduction and discussion of the Linear Decision Rule (LDR) models. The regression models were used to provide the subjects with learning and insight into her/his decision behavior. By comparing the terms and coefficients in the regression and LDR models, the subjects were made aware of the cost implications of their decision behaviors, their decision biases (misperceiving the decision variables and their relative importance) and their inconsistencies (deviating from their average behavior). The procedures for using the LDR models were then discussed.

Would you like the regression models (Y or N)?

Product 1 Regression Results:

\[ R^2 = 0.922 \]

\[ Y \text{ intercept} = 715.312 \quad \text{Trend} = 1.370 \]

Forecast-Inventory = 0.960  Workforce = 3,877

Figure 17: An Example of Subject Regression Model

The Dependent Variables

**Decision Performance.** The performance variables are average decision time and average dollar profits made over the decision cycles. The decision time was selected as one of the dependent variables of this research because a management information system which reduces decision time is always desirable, since it provides more
managerial time, which has economic value, for other managerial activities. Subjects were not given any time constraints in this experiment. They were told to work at their own pace. The decision time was measured from the time the management reports were printed for the subject until the subject had coded his new set of work force and production decisions on the work sheets. Notice that the decision time measured in this fashion does not include the data entry time.

Profit performance was selected as one of the dependent variables of this study because the economic dimension of decision quality is usually a very important dimension in any measure of decision effectiveness. The profit figures were computed in each weekly simulation and displayed to the subject in a weekly income statement report.

User-Attitude Variables. A post-study questionnaire was used to obtain data on user attitudes concerning evaluation of the decision aids incorporated in the management information system. All the elements of the variable set associated with the user attitudes (satisfaction with the decision aid, ease of use, importance of the decision aid in arriving at the production decisions and willingness to use a similar decision aid in a similar decision situation) were measured on a seven-point Likert type scale. The post-study questionnaire measuring user attitude variables is presented in Appendix A.
Usage of Decision Aiding Strategy. In this study the utilization, usage, or use (of the decision aiding strategy) was defined to refer to the inclusion of the data generated by the decision aid by the subject in her/his decision making process. This variable was measured on a qualitative scale (1 indicating that the decision aid was used in arriving at the decisions and 0 indicating that the decision aid was not used). The data on the utilization of the decision aid was obtained by the post-experimental questionnaire and examining the subjects' input decisions.

Control Variables. Subjects' previous familiarity with the decision aids was measured on seven point Likert scales. Experience was defined as the subject's knowledge of the functional area (production planning). Experience defined in this fashion was measured by the number of production courses in the subject's background and previous work experience involving production planning activities.

Experimental Procedures

In this section the experimental process is described temporally in the order that it occurred for each subject. The subjects participated in the experiment individually. To minimize learning effects, the experiment was run in two sessions. The subjects took three and a half to four and a half to complete each session. To avoid subject boredom and fatigue and to facilitate scheduling of the sessions, they were run on two different days. No two sessions were more than three days apart.
Pre-Experimental Session

The initial meeting between the subjects and the experimenter was the pre-test and orientation meeting. At these meetings following a brief overview of the experiment and the discussion of monetary prizes and the payments, a case description of "FACTORY: 2" was distributed among the subjects. The subjects were told that the objectives of the experiment were to:

1- compare students' and managers' performances on the simulation game, and
2- evaluate the simulation as a teaching aid for the production courses.

In addition, the following instruments were administered in the pre-experimental session.

First, the subject sign-up sheets (demonstrated in Appendix A) were distributed. This form provided the researcher with the information needed to schedule subject's experimental sessions. Second, the subjects read and signed the subject consent form as shown in Appendix A. The written consent was required by The Ohio State University's Committee on the Use of Human Subjects in Research.

Finally, the long-form of Myers-Briggs Type Indicators was administered.

The pre-experimental session took from thirty to forth minutes. Within a few days following this meeting the subjects were notified of the time and dates of the experiment.

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8. This questionnaire was not administered to the drafted subjects because the experiments were run during the two and one half hours of regularly scheduled classes.
Experimental Sessions

Prior to subject's arrival the simulation program and the time-sharing terminals were made ready. Depending on the size of the group in the experimental session, three to eight terminals were reserved for the subjects' use. Also prior to the experimental session, after identifying each subject's decision style, he or she was randomly assigned to one of the experimental groups. Each group received only one of the experimental treatments (the decision aids). Pilot studies indicated that having the subjects make their work force and production decisions at the terminals, in a real time mode, put considerable time pressure on them. Therefore, the simulation program was given restart capabilities so that program execution and input/output processes would take place in real time mode and the actual decisions could be made off-line. Upon obtaining the management reports subjects were directed to the designated areas (reserved classrooms) to make their next set of decisions on their own time. To facilitate data entry into the computer and to decrease possibilities of error, the subjects were asked to code their answers on a subject work sheet depicted in Appendix A.

First Experimental Session. The first experimental session was for learning and orientation purposes. No data for analysis was collected in this session and the subjects did not compete for the prizes. The main purpose of this session was to provide the subjects with some experience with the experimental task. First, any questions the subjects had concerning the case material or the forthcoming
experiment were answered. The subjects were told that they were to complete three decision cycles\textsuperscript{9} during the session. After completing two decision cycles, the decision aid was introduced and explained. After all the questions concerning the decision aid were answered, the subjects were required to use the decision aid in the prescribed manner in making their third set of decisions. This was to assure that the subjects understood the decision aid and at least used it once during the course of the experiment. It was believed that this would put the subjects in a better position to evaluate the decision aid in the post-experimental session. At the end of the third decision cycle, after answering all the questions concerning the simulation, the decision aid, and the experimental task the first experimental session was terminated.\textsuperscript{10}

**Second Experimental Session.** Prior to the second experimental session the random number generator seed in the simulation program was changed so that a different history, forecast and demand would be generated during the second experimental session. Except for this modification, all the other experimental conditions were similar in the two sessions. In this session the subject completed three decision cycles. Subjects were not informed as to the number of the decisions that they would be required to make. This was done to avoid any

\textsuperscript{9}This number of decision cycles was selected based on the observations made during the pilot study.

\textsuperscript{10}The subjects were encouraged to stay longer and play the simulation game for more decision cycles if they did not feel comfortable with it.
attempt on the subjects' parts to "end play" the simulation. At the beginning of the session the subjects were told that the use of the decision aid was optional. The data collected during this session was analyzed and the subjects competed for prizes.

Post-Test and Debriefing

After completing her/his three decision cycles, the subject was directed to a classroom to meet with the researcher for the post-study and debriefing session. The purpose of these meetings was to answer any questions the subjects might have and to obtain information on the subjects' attitudes and opinions concerning the experiment.

First, the post-study questionnaire was administered (refer to Appendix A for a copy of the questionnaire). The subjects took between fifteen and twenty-five minutes to complete this questionnaire. Second, the subject received her/his scores on Myers-Briggs Type Indicators administered during the pre-test session and a written description of her/his decision style. The post-study session concluded when all the questions the subject had were answered.

Summary

This chapter and the referenced materials in the appendices present a detailed description of the methods and procedures employed in this study. The experimental design, experimental task, the subjects, the research variables and their operationalizations are discussed. The discussions of the experimental task includes a brief
description of the simulation programs employed in this research. A temporal description of the experimental procedures is presented. It begins with the pre-experimental session, continues through the two experimental sessions and concludes with the post-study and debriefing session.
CHAPTER V

ANALYSIS OF EXPERIMENTAL RESULTS

This chapter presents the results of the statistical analysis on the data collected during this simulation experiment. Statistical analysis consisted of two phases:

1- preliminary analysis of data, and
2- investigation of the relationships between the independent and dependent variables under consideration and test of the research hypotheses.

In this chapter only the results of the statistical analysis without any consideration of their implications are presented. The explanation, interpretation and operational significance of these relationships are discussed in the following chapter.

Statistical Methods

The major statistical methods used to analyze the data can be grouped by:

1- analysis of the decision aid utilization data, and
2- analysis of the user performance and attitude variables.

The reason for this breakdown is in the differences in the measurement scales for these two types of data. The usage of the decision aid was measured on a nominal scale (1 if the decision aid supplied
was used and 0 if it was not used). When the dependent variable is qualitative, Chi-square tests of independence or discriminant analysis procedures are appropriate. In comparison, the user performance and evaluation data are measured on quantitative scales. In this case, the appropriate statistical methods are analysis of variance or regression (E3, pp. 441).

Chi-Square Test

To investigate the effects of treatment level (analytic, bootstrapping and evolutionary decision aiding approaches) and the decision aiding styles on the usage variable, Chi-square tests of association were performed. The formal model is:

\[
\begin{align*}
H_0: \quad & E(O_{ij}) = E_{ij} \quad \text{for all } i \text{ and } j \\
H_1: \quad & E(O_{ij}) \neq E_{ij} \quad \text{for all } i \text{ and } j
\end{align*}
\]

where \( O_{ij} \) = observed frequency of use for \( j \)th treatment (or decision style) present,
\( E_{ij} \) = expected frequency of use for \( j \)th treatment (or decision style) present.

The test statistics for this model is:

\[
x^2 = \sum \frac{a b (O_{ij} - E_{ij})^2}{E_{ij}} \quad \text{with degrees of freedom of } (a - 1)(b - 1).
\]

If the null hypothesis \( H_0 \) is rejected, it is inferred that the usage of the decision aid is influenced by the decision aid supplied (or decision style present). The only assumption necessary for this
The statistical test is that the expected frequencies for each $ij$ combination be at least 5.

The sample size in this research did not allow for simultaneously testing the relationship between decision aids and decision styles and the usage variable. The limiting factor being the requirement on the size of the expected frequencies.

Analysis of Variance Model

A fixed-effect two-way analysis of variance model was fitted to the data for all the quantitative depend variables of the study. The formal analysis of variance model is (83):

$$y_{ijk} = \mu + \alpha_i + \beta_j + (\alpha \beta)_{ij} + \epsilon_{ik}$$

where $y_{ijk}$ = the observation taken under the $i$th level of factor A (decision style) and the $j$th level of factor B (decision aiding approaches) in the $k$th replicate,

$\mu$ = the overall mean effect,

$\alpha_i$ = the true effect of the $i$th level of factor A; $i = 1, 2, 3, 4$,

$\beta_j$ = the true effect of the $j$th level of factor B; $j = 1, 2, 3$,

$(\alpha \beta)_{ij}$ = the effect of the interaction between $\alpha_i$ and $\beta_j$,

$\epsilon_{ik}$ = random error component.

Since both factors are fixed, $\Sigma \alpha_i = 0$ and $\Sigma \beta_j = 0$. Similarly the $a$ $b$

\[ a \]
\[ i \]

\[ b \]
\[ j=1 \]

\[ i \]

\[ 11 \] The statistical technique for this test is multiple contingency table.
interaction effects are fixed and defined so that \( \sum_{i}^{a} (\alpha\beta)_{ij} = \sum_{j}^{b} (\alpha\beta)_{ij} = 0. \)

The assumptions for this model are that \( \varepsilon_{ijk} \) are independent \( \mathcal{N}(0, \sigma^2) \). Random assignment of subjects to experimental treatments and independent participation of the subjects in the experiment insured that the independence assumption was satisfied. The preliminary analysis of the sample data supported the normality and equal variance assumptions.

F tests were used to test the significance of effects. The hypotheses tested with this model were:

\[
\begin{cases}
H_0: (\alpha\beta)_{ij} = 0 \\
H_1: (\alpha\beta)_{ij} \neq 0,
\end{cases}
\begin{cases}
H_0: \alpha_i = 0 \\
H_1: \alpha_i = 0, \text{ and}
\end{cases}
\begin{cases}
H_0: \beta_j = 0 \\
H_1: \beta_j \neq 0.
\end{cases}
\]

The null hypotheses \( H_0 \) state that the independent variables and their interactions have no effect on the dependent variable. The analysis of variance table for the two-way classification, fixed effect model is presented in Table 5. In this study SAS statistical package was used to construct the analysis of variance tables.
### TABLE 5

**THE TWO-WAY ANALYSIS OF VARIANCE TABLE**

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Sum of Squares</th>
<th>Degrees of Freedom</th>
<th>$F_0$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor A (decision style)</td>
<td>$SS_A$</td>
<td>$a - 1$</td>
<td>$SS_A / SS_E$</td>
</tr>
<tr>
<td>Factor B (decision aid)</td>
<td>$SS_B$</td>
<td>$b - 1$</td>
<td>$SS_B / SS_E$</td>
</tr>
<tr>
<td>interaction effect</td>
<td>$SS_{AB}$</td>
<td>$(a - 1)(b - 1)$</td>
<td>$SS_{AB} / SS_E$</td>
</tr>
<tr>
<td>error</td>
<td>$SS_E$</td>
<td>$N - ab$</td>
<td></td>
</tr>
<tr>
<td>total</td>
<td>$SS_T$</td>
<td>$N - 1$</td>
<td></td>
</tr>
</tbody>
</table>

*In this study $a = 4$, $b = 3$, $3 < n < 5$ and $N = 45$.

**Preliminary Data Analysis**

The preliminary analysis consisted of first examining the sample data for equal variance assumption as required by the analysis of variance model. Second, the effects of the potentially confounding variables on the dependent variables of the study were investigated. The test statistics of the preliminary analysis are presented in Appendix D.

Several formal tests are available for examining whether or not two or more populations have equal variances. Due to unequal cell sizes, the Bartlett test (83) was used in this research. The results of Bartlett test indicated that equal variance assumption as required by analysis of variance model holds for the sample data.
Correlation analysis was initially used to examine the relationships between the "experience" and "familiarity" with the dependent variables of the study. Experience was defined in this study as the knowledge of functional area (production planning). It was measured in terms of subject's previous work experience involving production activities and number of formal production courses taken. The post-experimental questionnaire indicated that none of the subjects participating in the experiment had any previous work experience involving production planning activities. In terms of number of production courses, the subject population was grouped into two categories:

1- the subjects who had taken two production courses (graduate students), and

2- those subjects who had taken one production course (undergraduate students).

Subject's previous familiarity with the decision aid was measured on a seven-point Likert type scale (1 indicating no previous familiarity and 7 indicating very familiar). On average all of the subjects were below average in terms of familiarity with the decision aids supplied (grand sample mean = 3.2 on a seven-point scale).

Correlation analysis (using Pearson's correlation coefficient) of the experience and familiarity variables and the dependent variables of the study indicated no significant association between these variables. The correlation results did not justify any further analysis (e.g., analysis of covariance) of the effects of experience and familiarity. It was concluded that experience and familiarity as
defined and measured in this study did not present any significant sources of variation in the sample data.

Statistical Results and Tests of the Hypotheses

This section presents the results of the analysis of effects of decision aiding strategies and decision styles (independent variables) and their interactions on the dependent variables of the study. The interpretation of these results in terms of support of the hypotheses stated in the previous chapter is also presented. This presentation is structured on the dependent variables and is organized into three parts:

1- decision performance variables,
2- user attitude variables, and
3- utilization variable.

Decision Performance Variables

Summary data on performance measures (average decision making time and average profits) is presented in Tables 6 and 7. The following verbal interpretation of Table 6 is typical for tables presenting the summary data and therefore is presented only for this first instance.

Table 6: presents the mean for average decision time where:

\[ Y_{11} \] equals 36.4, which is the mean decision time (in minutes) for subjects from the sample population who were classified as ST decision type and who were given the analytic model (LDR) treatment.
### TABLE 6

**MEAN DECISION TIME DATA**

<table>
<thead>
<tr>
<th>Decision styles</th>
<th>ST</th>
<th>NT</th>
<th>NF</th>
<th>SF</th>
</tr>
</thead>
<tbody>
<tr>
<td>LDR</td>
<td>Y_{11}.</td>
<td>Y_{12}.</td>
<td>Y_{13}.</td>
<td>Y_{14}.</td>
</tr>
<tr>
<td></td>
<td>36.4</td>
<td>27.2</td>
<td>29.6</td>
<td>28.66</td>
</tr>
<tr>
<td>regressions</td>
<td>Y_{21}.</td>
<td>Y_{22}.</td>
<td>Y_{23}.</td>
<td>Y_{24}.</td>
</tr>
<tr>
<td></td>
<td>34.5</td>
<td>30.25</td>
<td>27.33</td>
<td>28.33</td>
</tr>
<tr>
<td>evolutionary</td>
<td>Y_{31}.</td>
<td>Y_{32}.</td>
<td>Y_{33}.</td>
<td>Y_{34}.</td>
</tr>
<tr>
<td></td>
<td>35.25</td>
<td>27.4</td>
<td>27.66</td>
<td>30.66</td>
</tr>
<tr>
<td>Y_{1}.</td>
<td>Y_{2}.</td>
<td>Y_{3}.</td>
<td>Y_{4}.</td>
<td>Y_{..}</td>
</tr>
<tr>
<td></td>
<td>35.38</td>
<td>28.28</td>
<td>28.19</td>
<td>29.19</td>
</tr>
</tbody>
</table>

### TABLE 7

**MEAN PROFIT DATA**

<table>
<thead>
<tr>
<th>Decision styles</th>
<th>ST</th>
<th>NT</th>
<th>NF</th>
<th>SF</th>
</tr>
</thead>
<tbody>
<tr>
<td>LDR</td>
<td>Y_{11}.</td>
<td>Y_{12}.</td>
<td>Y_{13}.</td>
<td>Y_{14}.</td>
</tr>
<tr>
<td></td>
<td>49321.2</td>
<td>51835.2</td>
<td>52731.66</td>
<td>49404.33</td>
</tr>
<tr>
<td>regressions</td>
<td>Y_{21}.</td>
<td>Y_{22}.</td>
<td>Y_{23}.</td>
<td>Y_{24}.</td>
</tr>
<tr>
<td></td>
<td>48708.</td>
<td>47905.25</td>
<td>49743.66</td>
<td>51266.66</td>
</tr>
<tr>
<td>evolutionary</td>
<td>Y_{31}.</td>
<td>Y_{32}.</td>
<td>Y_{33}.</td>
<td>Y_{34}.</td>
</tr>
<tr>
<td></td>
<td>51279.5</td>
<td>49383.2</td>
<td>49011.</td>
<td>52050.</td>
</tr>
<tr>
<td>Y_{1}.</td>
<td>Y_{2}.</td>
<td>Y_{3}.</td>
<td>Y_{4}.</td>
<td>Y_{..}</td>
</tr>
<tr>
<td></td>
<td>49769.56</td>
<td>49707.88</td>
<td>50495.4</td>
<td>50906.99</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>50219.95</td>
</tr>
</tbody>
</table>
$Y_{12}$. equals $27.2$, which is the mean decision time for subjects from the sample population who were classified as NT decision type and who were given the analytic model (LDR) treatment.

$Y_{13}$. equals $29.6$, which is the mean decision time for subjects from the sample population who were classified as NF decision type and who were given the LDR treatment.

$Y_{14}$. equals $28.66$, which is the mean decision time for subjects from the sample population who were classified as SF and who were given the LDR treatment.

$Y_{21}$. equals $34.5$, which is the mean decision time for subjects who were classified as ST decision types and who were given the bootstrapping (regression models) treatment.

$Y_{22}$. equals $30.25$, which is the mean decision time for the subjects who were classified as NT decision types and who were given the bootstrapping treatment.

$Y_{23}$. equals $27.33$, which is the mean decision time for the subjects who were classified as NF decision type and who were given bootstrapping treatment.

$Y_{24}$. equals $28.33$, which is the mean decision time for the subjects classified as SF decision type and who were given the bootstrapping treatment.

$Y_{31}$. equals $35.25$, which is the mean decision time for the subjects who were classified as ST type and were given evolutionary decision aid (regressions and LDR models).
$Y_{32}$ equals 27.4, which is the mean decision time for the subjects who were classified as NT type and who were given the evolutionary treatment.

$Y_{33}$ equals 27.66, which is the mean decision time for the subjects who were classified as NF type and who were given the evolutionary treatment.

$Y_{34}$ equals 30.6, which is the mean decision time for the subjects who were classified as SF type and who were given the evolutionary treatment.

The two-way analysis of variance results for decision time and profit variables are given in Tables 8 and 9.

**Main Effects.** Analysis of variance results indicated no significant relationships between the decision aiding strategies supplied and any of the performance variables. Also no significant relationship between the decision styles and average profits was observed. Decision styles however, had a significant main effect on the decision time.

**Interaction Effects.** Based on the analysis of variance results, it was concluded that interaction between decision styles and the decision aiding strategies had no significant effect on any of the decision performance variables.

**Test of Related Hypotheses.** Hypothesis 1 of this study corresponds to performance variables. This hypothesis stated that: performance is affected by the user decision styles. The statistical results presented here indicate that this hypothesis is
### Table 8

**Analysis of Variance Results for Decision Time**

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Sum of Squares</th>
<th>Degrees of Freedom</th>
<th>( F_0 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>decision style</td>
<td>417.78</td>
<td>3</td>
<td>3.15*</td>
</tr>
<tr>
<td>decision aid</td>
<td>16.61</td>
<td>2</td>
<td>.19</td>
</tr>
<tr>
<td>style * aid</td>
<td>147.22</td>
<td>6</td>
<td>.55</td>
</tr>
<tr>
<td>error</td>
<td>1459.03</td>
<td></td>
<td></td>
</tr>
<tr>
<td>total</td>
<td>2055.91</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Significant at \( \alpha = .037 \) level

### Table 9

**Analysis of Variance Results for Dollar Profits**

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Sum of Squares</th>
<th>Degrees of Freedom</th>
<th>( F_0 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>decision styles</td>
<td>137899840.78</td>
<td>3</td>
<td>.25</td>
</tr>
<tr>
<td>decision aids</td>
<td>20140327.06</td>
<td>2</td>
<td>.54</td>
</tr>
<tr>
<td>styles * aids</td>
<td>76853458.13</td>
<td>6</td>
<td>.69</td>
</tr>
<tr>
<td>error</td>
<td>612110452.81</td>
<td>33</td>
<td></td>
</tr>
<tr>
<td>total</td>
<td>725152493.2</td>
<td>44</td>
<td></td>
</tr>
</tbody>
</table>
partially supported. The profit performance was not influenced by the decision styles where the decision time was significantly (at significance level of $\alpha = .037$) affected by the decision styles. Bonferroni (83) multiple comparison intervals were calculated for the decision time means of the four decision styles (the statistics and calculations are presented in Appendix D). The statistical results (at family $\alpha$ level of $.12$) indicated that mean decision time for ST type was longer than mean decision time for other types. No other significant differences among the decision time means was observed.

User Attitude Variables

Data on user attitude variables (satisfaction, ease of use of decision aid, importance of decision aid in arriving at the decisions, and willingness to use a similar decision aid in future) is presented in Tables 10 through 13, respectively. The analysis of variance results are given in Tables 14 through 17.

Main Effects. Decision aids had a significant main effect on "satisfaction" and "importance" variables (at significance levels of $.075$ and $.043$). No significant main effects between decision aiding strategies and other attitude variables (ease of use, understanding, and willingness to use the decision aid again) were observed. As indicated by the analysis of variance tables, no significant main effects between the decision styles and any of the attitude variables were present.

Interaction Effects. The interaction between decision styles and decision aiding strategies had significant effects on user
### TABLE 10
MEAN USER SATISFACTION DATA

<table>
<thead>
<tr>
<th>Decision styles</th>
<th>ST</th>
<th>NT</th>
<th>NF</th>
<th>SF</th>
</tr>
</thead>
<tbody>
<tr>
<td>LDR</td>
<td>4.4</td>
<td>4.25</td>
<td>3.33</td>
<td>3.93</td>
</tr>
<tr>
<td>regressions</td>
<td>3.25</td>
<td>4.25</td>
<td>4.</td>
<td>4.33</td>
</tr>
<tr>
<td>evolutionary</td>
<td>5.5</td>
<td>4.8</td>
<td>4.66</td>
<td>5.</td>
</tr>
</tbody>
</table>

### TABLE 11
MEAN "EASE OF USE" DATA

<table>
<thead>
<tr>
<th>Decision styles</th>
<th>ST</th>
<th>NT</th>
<th>NF</th>
<th>SF</th>
</tr>
</thead>
<tbody>
<tr>
<td>LDR</td>
<td>4.</td>
<td>3.4</td>
<td>4.</td>
<td>3.33</td>
</tr>
<tr>
<td>regressions</td>
<td>3.50</td>
<td>3.75</td>
<td>3.66</td>
<td>3.66</td>
</tr>
<tr>
<td>evolutionary</td>
<td>4.25</td>
<td>3.4</td>
<td>4.33</td>
<td>4.66</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Y.1.</th>
<th>Y.2.</th>
<th>Y.3.</th>
<th>Y.4.</th>
<th>Y...</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.38</td>
<td>4.35</td>
<td>4.</td>
<td>4.44</td>
<td>4.29</td>
</tr>
<tr>
<td>Y.1.</td>
<td>Y.2.</td>
<td>Y.3.</td>
<td>Y.4.</td>
<td>Y...</td>
</tr>
<tr>
<td>3.92</td>
<td>3.52</td>
<td>4.</td>
<td>3.88</td>
<td>3.88</td>
</tr>
</tbody>
</table>
### TABLE 12
MEAN "IMPORTANCE OF DECISION AID" DATA

<table>
<thead>
<tr>
<th>Decision aids</th>
<th>ST</th>
<th>NT</th>
<th>NF</th>
<th>SF</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>LDR</td>
<td>Y_{11. 4.25}</td>
<td>Y_{12. 4.}</td>
<td>Y_{13. 3.33}</td>
<td>Y_{14. 3.66}</td>
<td>Y_{1. 3.81}</td>
</tr>
<tr>
<td>regressions</td>
<td>Y_{21. 4.}</td>
<td>Y_{22. 3.5}</td>
<td>Y_{23. 3.16}</td>
<td>Y_{24. 3.33}</td>
<td>Y_{2. 3.69}</td>
</tr>
<tr>
<td>evaluating</td>
<td>Y_{31. 5.25}</td>
<td>Y_{32. 4.8}</td>
<td>Y_{33. 5.33}</td>
<td>Y_{34. 4.33}</td>
<td>Y_{3. 4.93}</td>
</tr>
<tr>
<td></td>
<td>Y_{.1. 4.5}</td>
<td>Y_{.2. 4.18}</td>
<td>Y_{.3. 4.11}</td>
<td>Y_{.4. 3.77}</td>
<td>Y_{... 4.14}</td>
</tr>
</tbody>
</table>

### TABLE 13
MEAN "WILLINGNESS" DATA

<table>
<thead>
<tr>
<th>Decision aids</th>
<th>ST</th>
<th>NT</th>
<th>NF</th>
<th>SF</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>LDR</td>
<td>Y_{11. 4.8}</td>
<td>Y_{12. 4.2}</td>
<td>Y_{13. 4.33}</td>
<td>Y_{14. 4.33}</td>
<td>Y_{1. 4.42}</td>
</tr>
<tr>
<td>regressions</td>
<td>Y_{21. 3.75}</td>
<td>Y_{22. 4.5}</td>
<td>Y_{23. 5.}</td>
<td>Y_{24. 4.66}</td>
<td>Y_{2. 4.48}</td>
</tr>
<tr>
<td>evolutionary</td>
<td>Y_{31. 5.75}</td>
<td>Y_{32. 5.55}</td>
<td>Y_{33. 5.}</td>
<td>Y_{34. 4.33}</td>
<td>Y_{3. 5.15}</td>
</tr>
<tr>
<td></td>
<td>Y_{.1. 4.77}</td>
<td>Y_{.2. 4.73}</td>
<td>Y_{.3. 4.78}</td>
<td>Y_{.4. 4.44}</td>
<td>Y_{.5. 4.68}</td>
</tr>
</tbody>
</table>
### Table 14
Analysis of Variance Table for Satisfactory Scores

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Sum of Squares</th>
<th>Degrees of Freedom</th>
<th>F₀</th>
</tr>
</thead>
<tbody>
<tr>
<td>decision style</td>
<td>4.24</td>
<td>3</td>
<td>.53</td>
</tr>
<tr>
<td>decision aid</td>
<td>16.27</td>
<td>2</td>
<td>2.79*</td>
</tr>
<tr>
<td>style * aid</td>
<td>33.72</td>
<td>6</td>
<td>2.44**</td>
</tr>
<tr>
<td>error</td>
<td>76.06</td>
<td>33</td>
<td></td>
</tr>
<tr>
<td>total</td>
<td>130.31</td>
<td>44</td>
<td></td>
</tr>
</tbody>
</table>

*Significant at α = .075
**Significant at α = .046 level

### Table 15
Analysis of Variance Table for "Ease" Scores

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Sum of Squares</th>
<th>Degrees of Freedom</th>
<th>F₀</th>
</tr>
</thead>
<tbody>
<tr>
<td>decision style</td>
<td>5.930</td>
<td>3</td>
<td>.64</td>
</tr>
<tr>
<td>decision aid</td>
<td>5.580</td>
<td>2</td>
<td>.90</td>
</tr>
<tr>
<td>style * aid</td>
<td>6.335</td>
<td>6</td>
<td>.34</td>
</tr>
<tr>
<td>error</td>
<td>102.23</td>
<td>33</td>
<td></td>
</tr>
<tr>
<td>total</td>
<td>120.07</td>
<td>44</td>
<td></td>
</tr>
</tbody>
</table>
### TABLE 16

**ANALYSIS OF VARIABLE TABLE FOR "IMPORTANCE" SCORE**

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Sum of Squares</th>
<th>Degrees of Freedom</th>
<th>$F_0$</th>
</tr>
</thead>
<tbody>
<tr>
<td>decision style</td>
<td>6.74</td>
<td>3</td>
<td>.70</td>
</tr>
<tr>
<td>decision aid</td>
<td>15.8282</td>
<td>2</td>
<td>3.97*</td>
</tr>
<tr>
<td>style * aid</td>
<td>26.34</td>
<td>6</td>
<td>1.36</td>
</tr>
<tr>
<td>error</td>
<td>65.784</td>
<td>33</td>
<td></td>
</tr>
<tr>
<td>total</td>
<td>114.692</td>
<td>44</td>
<td></td>
</tr>
</tbody>
</table>

*Significant at $\alpha = .043$ level

### TABLE 17

**ANALYSIS OF VARIABLE TABLE FOR "WILLINGNESS" SCORE**

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Sum of Squares</th>
<th>Degrees of Freedom</th>
<th>$F_0$</th>
</tr>
</thead>
<tbody>
<tr>
<td>decision style</td>
<td>5.0368</td>
<td>3</td>
<td>1.01</td>
</tr>
<tr>
<td>decision aid</td>
<td>5.5872</td>
<td>2</td>
<td>1.69</td>
</tr>
<tr>
<td>style * aid</td>
<td>3.1472</td>
<td>6</td>
<td>2.58*</td>
</tr>
<tr>
<td>error</td>
<td>6.7091</td>
<td>33</td>
<td></td>
</tr>
<tr>
<td>total</td>
<td>20.4803</td>
<td>44</td>
<td></td>
</tr>
</tbody>
</table>

*Significant at $\alpha = .036$ level
satisfaction and willingness to utilize a similar decision aid in future (at significance levels of .046 and .036, respectively). No significant interaction effects on other attitude variables were indicated.

Tests of Related Hypotheses. Hypothesis 2 (and its sub-hypotheses) and hypothesis 3 correspond to the user attitude variables. Hypothesis 2 stated that: interactions between the decision styles and decision aiding strategies have significant effects on the user attitudes. The results presented here indicated that this hypothesis is supported for satisfaction and willingness variables.

Hypothesis 3 stated that: user satisfaction with the decision aid is highest in the evolutionary approach across all decision styles. The analysis of variance indicated a significant main effect between the decision aids and the user satisfaction. To further investigated this effect, the Bonferroni multiple comparison intervals for the mean satisfaction scores for each of the decision aiding strategies across all the decision styles ($\mu_1$, $\mu_2$, $\mu_3$) were calculated (refer to Appendix D). At family significance level of .12 it was indicated that mean satisfaction scores for the evolutionary treatment was larger than the mean satisfaction scores for the LDR and bootstrapping treatments. Hence, hypothesis 3 of the research was supported.

The subordinate hypothesis in regard to interaction effects stated that: sensing-thinking type will be most satisfied with the analytic model. To test this hypothesis, the Scheffé's multiple comparison intervals for satisfaction scores of ST types across all
decision aiding strategies were calculated (refer to Appendix E). The confidence intervals indicated that at family significance level of .1, the mean satisfaction scores of the ST types who were supplied with the analytic models were higher than the ST types who were supplied with the bootstrapping decision aid. No significant differences between the satisfaction means of ST types who were given LDR treatment and those ST subjects who were given the evolutionary treatment was observed.

Usage Variable

Tables 17, and 18 present the data on the frequency of use the decision aids in terms of decision aids and decision styles. As mentioned before, the simultaneous test of the effects of two independent variables on the usage was not possible with the given sample size. The results of $X^2$ tests (presented in Appendix E) indicated that utilization was independent of the decision styles. On the other hand, utilization was significantly (at significance level of .05) affected by the decision aiding approach that was supplied.

Tests of the Related Hypotheses. Hypotheses 4 and 4a correspond to the effects of the independent variables on the utilization of the decision aids. Hypothesis 4 stated that: usage of decision aid is highest in the evolutionary approach across all the decision styles. The results of Chi-square analysis (presented in Appendix D) supported this hypothesis. It was further hypothesized (sub-hypothesis 4a) that utilization of the analytic model is highest for the ST types. This sub-hypothesis was tested for the 31 subjects who were supplied
### Table 18

**Frequency of Usage of Decision Aids**
*(Presented in Terms of the Decision Aids)*

<table>
<thead>
<tr>
<th>Decision aids</th>
<th>LDR</th>
<th>Bootstrapping</th>
<th>Evolutionary</th>
<th>Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td>used</td>
<td>6</td>
<td>5</td>
<td>12</td>
<td>23</td>
</tr>
<tr>
<td>not used</td>
<td>10</td>
<td>9</td>
<td>3</td>
<td>22</td>
</tr>
<tr>
<td>totals</td>
<td>16</td>
<td>14</td>
<td>15</td>
<td>45</td>
</tr>
</tbody>
</table>

### Table 19

**Frequency of Usage of Decision Aids**
*(Presented in Terms of the Decision Styles)*

<table>
<thead>
<tr>
<th>Decision aids</th>
<th>ST</th>
<th>NT</th>
<th>NF</th>
<th>SF</th>
<th>Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td>used</td>
<td>8</td>
<td>7</td>
<td>4</td>
<td>5</td>
<td>24</td>
</tr>
<tr>
<td>not used</td>
<td>5</td>
<td>7</td>
<td>5</td>
<td>4</td>
<td>21</td>
</tr>
<tr>
<td>totals</td>
<td>13</td>
<td>14</td>
<td>9</td>
<td>9</td>
<td>45</td>
</tr>
</tbody>
</table>
with the analytic model. The results of Chi-square test (presented in Appendix E) indicated that this sub-hypothesis was not supported.

Summary

This chapter presented the statistical method and analysis of the data obtained from the experiment. The results and findings of the preliminary data analysis were first presented. The main and interaction effects of the independent variables on the dependent measures were then investigated using two-way analysis of variance and Chi-square test of association. The implications of the statistical results in terms of the support of the a priori hypotheses of the research were discussed. The interpretation and implications of the findings are presented in the next chapter.
CHAPTER VI
DISCUSSION AND CONCLUSIONS

The first section of this chapter interprets the statistical findings presented in the previous chapter. The interpretation of the significant results is presented first followed by a discussion of nonsignificant results and their implications.

The second section first describes possible limitations to the research. It discusses the possible implications of these limitations for the external validity (generalizability) of the findings and provides the researcher's thoughts on the importance of these limitations. Second, the practical implications of this study are described. Next, a brief summary and conclusions of this work are presented. Finally, the directions for future research are discussed.

Discussion and Interpretation of Research Findings

This section summarizes the research findings and presents the researcher's interpretation of these findings. First, the statistically significant results are analyzed in the context of the dependent variables of the study. Second, the statistically non-significant results and their implications are discussed.

Discussion of Significant Results

A tabular summary of the statistically significant results in
terms of the dependent variables is presented in Table 20 to provide an overview for the following discussion. The significant findings are individually discussed in the same sequence as the dependent variables are presented in Table 20. The discussion in this part proceeds in the following manner. First, a verbal description of the statistical findings presented in the previous chapter is presented. Second, an interpretation and explanation of the findings in relation to theory and previous MIS research is provided. In examining the research findings in the light of previous experimentations, no direct comparisons were possible based on the following reason. Of the limited number of previous studies which investigated the MIS-user interactions, very few examined or reported on the interactions and effects of the variables investigated in this study. Therefore, the comparisons made are general and brief.

**Utilization of Decision Aids.** A significant association between the usage of the decision aids and the treatment levels (the decision aiding strategies provided) was observed. From the set of 16 subjects who were provided with the LDR models, six subjects used the model (37.5%). From the set of 14 individuals who were provided with the regression models, 5 individuals used the models (35.7%). From the set of 15 individuals who were given the LDR models in an evolutionary manner, however, 12 individuals used the LDR's (80.0%). No significant association between the usage of the decision aids and decision styles was indicated. The following is a verbal description of this finding. Independent of the decision styles, the usage of
### Table 20
Summary of Statistically Significant Effects by Dependent Variables

<table>
<thead>
<tr>
<th>Dependent Variables</th>
<th>Independent Variables</th>
<th>Main Effects</th>
<th>Interaction Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Utilization</td>
<td>decision aids</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&quot;Importance&quot;</td>
<td>decision aids</td>
<td></td>
<td></td>
</tr>
<tr>
<td>User Satisfaction</td>
<td>decision aids</td>
<td></td>
<td>decision styles X</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>decision aids</td>
</tr>
<tr>
<td>&quot;Willingness&quot;</td>
<td>decision styles X</td>
<td>decision aids</td>
<td></td>
</tr>
<tr>
<td>Decision Time</td>
<td>decision aids</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
the decision aid that was presented in an evolutionary fashion was highest.

This finding is consistent with the contemporary MIS design and implementation literature (37, 53, 78, 106). For example, King and Cleland stated that the introduction of normative decision models as an evolutionary development of simple and descriptive models enhanced the usage of and user satisfaction with the normative models (53). Karash and Urban (49) in a field study, concluded that the evolutionary approaches to decision aiding and model building resulted in increased acceptance and usage of the decision aid. The following theoretical explanation is offered for this result.

In the evolutionary approach, the development and presentation of the descriptive decision model (regression models) resulted in increased user self-knowledge and self-insight into his/her decision process. The introduction of LDR's, on the other hand, provided a "standard" or measure of "reasonableness" for the user decisions. Based on the comparison of one's own decision process and the "standard" (LDR's), a need for "improvement" was perceived and established which in turn motivated the individuals to use the prescribed decision aids.

This finding however should be viewed tentative. Reported empirical work concerning evolutionary decision aiding strategies are very few (if not non-existent). Much more research and investigation on design and implementation of evolutionary strategies is needed before any general conclusions can be drawn.
**Importance of the decision aid.** The only significant effect involving the decision aid was the direct effect of the type of decision aids supplied. Bonferroni confidence intervals indicated that the mean importance scores for the subset of subjects who were given the evolutionary decision aid was significantly higher than the mean scores for the subsets of subjects who were supplied with the regression and LDR models. Based on this result, it was inferred that independent of decision styles, the importance of the LDR's in arriving at decisions was higher when they were presented in an evolutionary manner. Also, independent of decision styles, the LDR's presented in an evolutionary manner were more important in arriving at decisions than the regression models.

The user's rating of the importance of the information generated by the decision aid to the decisions made is a measure closely associated with the utilization and the extent of usage of the decision aid. Hence this finding is consistent with the previous finding indicating a higher utilization of the evolutionary approach.

**Satisfaction with the Decision Aid.** The user's satisfaction with the decision aid provided in this experiment was not significantly different across the decision styles.

The user's satisfaction was directly affected by the decision aids supplied. Pairwise comparison of the satisfaction means for the three decision aids indicated the mean satisfaction score of the evolutionary decision aid was significantly larger than the mean satisfaction of regression and LDR models. The following is a verbal description of the findings. Users, independent of their decision
styles, were more satisfied with the evolutionary decision aiding approach compared to LDR and bootstrapping approaches. This result is consistent with the findings in terms of utilization and importance of the decision aids in that the highest usage and satisfaction are associated with the same decision aiding approach namely, the evolutionary technique.

The interaction of the decision styles and decision aids also produced a strong relationship with the satisfaction variable. This implied that user satisfaction was affected by the decision aid provided, contingent on his/her decision style. A pairwise comparison of the mean satisfaction scores across the cells indicated that satisfaction of the ST types who were provided with the regression models (bootstrapping approach) was significantly less than the satisfaction scores of those ST types who were provided with the LDR's and evolutionary approach. That is the sensing-thinking types were more satisfied with the analytic LDR models than the intuitive enhancing regression models.

This finding is compatible with the findings of Barkin (3) and Doktar and Hamilton (27). Barkin, using the cognitive style construct developed by McKenny and Keen (73), found that "analytic" and "intuitive" decision types used his computer system in differing ways with analytic users favoring the traditional quantitative operation research models more than the intuitive users. Doktar and Hamilton found that analytic decision makers favored the "detailed" and "specific" versus "general" MIS reports. The higher satisfaction of ST types with the analytic LDR models may be explained
in terms of Jungian decision style construct. The LDR is an analytic decision aid that provided an explicit, systematic and structured approach to solution of the decision task. It involved structuring the problem in abstract and theoretical terms, defining explicitly all the constraints in the given situation, and producing a single "best" solution. The sensing-thinking decision types in Jungian typology are characterized by a preference for well-developed theoretical approaches and a well-understood body of knowledge to derive a single, unambiguous optimal ("best") solution to the decision problem. The close "fit" between the attributes of the LDR's and the characteristics of ST decision types as described above resulted in high satisfaction of this type with the LDR's. Typical of statements made by ST subjects provided with the LDR's in the post-experiment questionnaire were:

I liked the LDR because it seemed very complete - very detailed. It seemed logical and reliable.

I liked the LDR because it was a mathematical technique that allowed me to obtain optimum results for the specified cost function. I also like it because it was easy to use due to its iterative properties.

It (LDR) was a very concise and understandable decision aid.

User willingness. The direct effects of decision styles and decision aids supplied on user willingness to use a similar decision aid in future were insignificant. On the other hand, the interaction effect of the independent variables was significant. Thus, the user's willingness to use a similar decision aid in the future was affected by the decision aids supplied, but only contingent on his/her decision
style. The willingness scores for the ST types who were supplied with the analytic decision aid was significantly higher than the mean willingness scores of the ST types who were provided with the regression models. That is for the ST decision types, the willingness to use the analytic model in the future was greater than their willingness to use the bootstrapping technique. This finding is consistent with the findings on the satisfaction variable. That is the ST types more satisfied with the analytic LDR models are also more willing to use similar decision aids in the future.

In this researcher's opinion, the preference of the ST types for the LDR technique is also attributed to the close fit between the characteristics of the linear decision rule technique and characteristic and stylistic aspects of decision making approaches of ST types as discussed above for the satisfaction variable.

Decision making time. Average decision time was not significantly affected by the interaction of decision styles and decision aiding strategies supplied to the users. Decision styles had a direct effect on decision time. Pairwise comparison of mean decision time of the four decision styles, using Bonferroni confidence intervals indicated that sensing-thinking types took longer to make their decisions compared to the other three decision styles. On the other hand, no significant differences in terms of average decision time were indicated among the intuitive-thinking (NT), intuitive-feeling (NF), and sensing-feeling (SF) types.

Decision time has been studied in a different number of MIS empirical studies (56, 85). None of these studies, however,
reported a relationship between the decision time and the user decision styles. The decision style construct provided the theoretical basis for explanation of this finding. The characteristic approach of ST types to information processing and evaluation involves the systematic search for a "best" answer, direct examination of information attributes and focusing on the detail rather than relationships among information items. The approach coupled with the variety of information items provided in the experimental decision environment resulted in longer decision making time for ST types.

Discussion of Non-Significant Results

The analysis of variance results indicated no statistically significant relationships between the independent variables of the study (decision aiding strategies and decision styles) and the dependent variable average profit performance. This implies that the experimental task, the production planning decision, was not biased toward any specific decision aid or decision style. This is a desired situation in that the nature and characteristics of the experimental task did not have a confounding effect on the experimental results. The other dependent variable of this study that was not significantly affected by any of the independent variables of the study was user's evaluation of the ease of usage of the proposed decision aids. In this researcher's view, this is attributed to the first experimental session in which the subjects were given the opportunity for "learning" and to practice with the decision aids.
This implies that the learning effects were minimized in this study and did not produce any systematic variation in the experimental results.

Limitations of the Research

The approach taken in this research was a laboratory experimental gaming. Given the lack of theoretical knowledge in the MIS field and the small number of empirical work in this area, laboratory experimentation appeared to be the most appropriate method for research at this stage in the development of MIS theory, primarily because of the controls it offers the researcher. The major limitation of this experiment is the one normally associated with laboratory experimental gaming, using surrogate subjects: low external validity. Care must be taken in generalizing the findings of this experiment to different populations, settings, and situations. The second limitation of this study concerns the nature of the treatment variables (the decision aiding strategies) and their operationalization. Three categories of decision aiding approaches were investigated: analytic quantitative models, intuitive enhancing, and evolutionary approaches. There are different techniques within each nominal category. This research does not offer a test of the categories in general, but the test of the best state of the art in each of these categories. This implies that care must be taken in interpreting the findings of this study in terms of other techniques. This is particularly important for the evolutionary strategies in that at the present state of the art, no well defined and generally
agreed upon approach to operationalization of evolutionary strategies exists.

Practical Implication of the Research

This section presents what the researcher believes are the major implications of this research finding for the design and implementation of management information systems from a practitioner's perspective.

This research indicated that interaction of user decision styles and the characteristics of the decision aids incorporated in the MIS have significant effects on the user attitudes and utilization of the system. The existence of these interactions imply that care should be taken not to place great emphasis on any single factor in the user-system interface. This further implies that explicit consideration of the user decision styles may be required to achieve improved levels of satisfaction and more favorable user attitudes. The significant main effect of the decision aids on the attitudes and utilization of the decision aids suggests that "logic", "optimality" and "technical sophistication" of the decision aid are not sufficient conditions for successful implementation. Implementation seems to be more affected by user attitudes and his/her perception of need for change. Our findings in terms of the evolutionary decision aiding approach has significant implications for implementation of theoretical, quantitative OR/MIS models.

Summary and Conclusions

A conceptual model of MIS design variables based on Leavitt's
model of an organizational system was presented in Chapter II. The model identified four categories of MIS design variables.

1. Variables associated with the structure of MIS host organization such as centralization and degree of formalization.

2. Variables associated with the decision task such as task structuredness and information requirements.

3. Variables associated with the decision maker such as decision styles, age and experience.

4. MIS characteristics such as informational structure and decision aiding strategies.

This study focused on the MIS-user interface and empirically investigated the relationships and nature of association between the decision maker and the MIS variables: decision styles and decision aiding strategies.

The development of experimental framework for studying the user-MIS relationship and selection of the specific variables for investigation was based on a review of theoretical and empirical literature in MIS and other related fields (decision analysis and psychology). (The literature review was presented in Chapter III). Jungian decision style construct and three categories of decision aiding strategies: quantitative models, intuitive enhancing and evolutionary approaches were selected. These variables constituted the independent variables of the study. The dependent variables of the study were: decision quality (decision making time and profits), user attitudes concerning evaluation of and satisfaction with the decision
aids and utilization of the decision aids supplied to the users. The hypotheses formulated in terms of specific relationships between these variables were presented at the beginning of Chapter IV. These hypotheses were tested using 15 student subjects making production and work force decisions in a simulated factory environment. The findings of this investigation were as follows:

1. Evolutionary approaches enhance the implementation and the extent of usage of theoretical and analytical decision aiding models.

2. Evolutionary decision aiding approaches result in increased user satisfaction.

3. User's satisfaction with and evaluation of decision aiding techniques is contingent upon his/her decision styles.
   3A - Sensing-thinking (ST) types are more satisfied with the mathematical analytic models than intuitive enhancing decision aids.
   3B - Sensing-thinking (ST) types are more willing to use the mathematical and analytic models than intuitive enhancing techniques.

4. Decision making time is affected by the user decision style.
   4A - Sensing-thinking types took longer to make their decisions compared to the other decision styles.

Replication is necessary both to substantiate existing findings and to seek explanations for these findings. In addition to
experimentation in the MIS field, there is a need for improved research and theoretical frameworks especially in terms of mapping the experimental findings. The lack of a strong theoretical base in this field greatly reduces the ability to explain the research findings. It is believed that the findings presented in this study are reinforcing of theories and beliefs of individuals recognized as knowledgeable in the field. But complete reliance on any single empirical work is folly. As Herman Bondi stated, "It is not the purpose of any scientific theory to be infallible or final or true. It's purpose is to be fertile, to suggest new observations that suggest new ramifications of the subject (8)." The approach taken in this study and the findings, however, hold promise for advancing our present level of understanding and knowledge of user-MIS interface and design of more effective management information systems.

**Directions for Future Research**

Several lines of investigation suggest themselves. This study did not generate any information in terms of interaction and main effects and preferences for more intuitive and less analytic decision styles (NF, NT and SF types). The researcher believes that this is due to lack of a close "fit" between the decision aiding techniques used in this study and the characteristics and stylistic aspects of decision making approaches of these types (for a description of these styles, refer to Chapter III). Hence, one area for future research is investigation and development of decision aiding techniques for "intuitive" versus "systematic" and "feeling" versus "analytic"
decision makers.

A second area of research is that dealing with other types and categories of decision aiding strategies. A variety of categories and techniques of decision aiding were discussed in Chapter III. To obtain empirically based criteria and guidelines for selection and design of effective management information systems under different environmental conditions, future research should be directed toward comparative study and development of other decision aiding techniques.

A third line of investigation concerns the relationships between other dimensions of decision style and performance and effectiveness of alternative MIS configurations. Different dimensions of decision style such as tolerance for ambiguity, field dependence/independence etc., were discussed in Chapter III. Some interesting research questions in this context are the following. What dimensions of decision style seem to influence performance and implementation of management information systems the most? Are there several interacting dimensions or different dimensions can be collapsed to a few underlying dimensions in relation to the design of management information systems? Furthermore, the relationship between other user characteristics such as age, experience and organizational role and performance and attitudes toward MIS may be investigated.

Future research may also be directed toward the study of the nature of association and interactions of decision task and MIS characteristics. For example, the effects of task structuredness on the performance of alternative MIS configurations may be studied. Or the impact of interactions of task characteristics and decision
style on the effectiveness and user preferences for different decision aiding approaches may be investigated.
APPENDIX A

"FACTORY: 2" CASE DESCRIPTION
POST STUDY QUESTIONNAIRE
SUBJECT SIGN UP SHEET
SUBJECT CONSENT FORM
TABLE OF CONTENTS

1. Case Description
   1.1 Company Background
   1.2 The Production Technology
   1.3 Work Force Data
   1.4 Manufacturing Costs
   1.5 Production Demand
   1.6 Plant Manager Responsibilities

11. Subject Instructions
   2.1 Input Specification and Procedures
   2.2 Sample Subject Work Sheet and Time Sharing Dialogue
I. Case Description for "Factory 2"

1.1 Company Background

The "FACTORY: 2" Company has been in business for almost 35 years. It was founded shortly after World War II by four veterans who became close friends while serving in the Navy. Carl Negus, the President and chief-executive-officer, and Art Hertz, Vice-President of Manufacturing Operations, are the two surviving founders and also the majority stockholders—owning 35% and 20%, respectively. Hertz's only son-in-law, Paul Turner, is Vice President of Finance and holds an additional 10% of the equity. The remaining equity is divided among management personnel and treasury stock. As might be expected, the company is tightly controlled and major decisions on policy matters are dominated by the influence of Negus and Hertz. A company organization chart and a year end balance sheet are provided in Figures 1 and 2.

From humble beginnings as a small custom quality job shop, the "FACTORY: 2" Company has matured into a well-respected manufacturer of special purpose air-moving equipment with annual sales approached $18 million. Company headquarters is in Dearborn, Michigan, adjacent to the sole production facilities, a relatively modern factory built within the past ten years. The company's marketing effort is directed by Jim Rhodes who employs a modest force
Figure 1. Company Organization Chart
<table>
<thead>
<tr>
<th>Assets</th>
<th>Liabilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cash</td>
<td>Accounts payable</td>
</tr>
<tr>
<td>Securities</td>
<td>Notes payable</td>
</tr>
<tr>
<td>Accounts receivable</td>
<td>Short term debt</td>
</tr>
<tr>
<td>Inventory</td>
<td>Accrued expenses</td>
</tr>
<tr>
<td>Other current assets</td>
<td>Other current liabilities</td>
</tr>
<tr>
<td>Total current assets</td>
<td>Total current liabilities</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>$</th>
<th>$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cash</td>
<td>$1,035</td>
<td>Accounts payable</td>
</tr>
<tr>
<td>Securities</td>
<td>216</td>
<td>Notes payable</td>
</tr>
<tr>
<td>Accounts receivable</td>
<td>2,907</td>
<td>Short term debt</td>
</tr>
<tr>
<td>Inventory</td>
<td>3,688</td>
<td>Accrued expenses</td>
</tr>
<tr>
<td>Other current assets</td>
<td>785</td>
<td>Other current liabilities</td>
</tr>
<tr>
<td>Total current assets</td>
<td>$8,631</td>
<td>Total current liabilities</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>$</th>
<th>$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant (at cost)</td>
<td>$5,470</td>
<td>Long term debt</td>
</tr>
<tr>
<td>Equipment</td>
<td>6,120</td>
<td></td>
</tr>
<tr>
<td>Allowance for depr.</td>
<td>(-1,483)</td>
<td>Stockholder's equity</td>
</tr>
<tr>
<td>Net Plant and Equipment</td>
<td>$10,089</td>
<td>Retained earnings</td>
</tr>
<tr>
<td>Other fixed assets</td>
<td>617</td>
<td>Other liabilities</td>
</tr>
<tr>
<td>Total Assets</td>
<td>$19,337</td>
<td>Total Liabilities</td>
</tr>
</tbody>
</table>

$2,349

Figure 2. Company Balance Sheet (in $ thousands)
of direct contact salesmen. Although sales have been rising in recent years, top management has been concerned that, in their opinion, profit margins are not rising proportionately. As one move to correct the situation Hertz is considering hiring a new plant manager for FACTORY: 2.

1.2 Production Technology

FACTORY: 2 markets 10 final products which range in price from $16.25 to $41.25 per unit. The plant is organized around work flow into three main operating departments: final assembly, sub-assembly, and raw materials and parts. The current product line requires 7 sub-assembly groups, 15 parts categories, and 8 classifications for raw materials; work flow and inventories are controlled within the factory according to this breakdown. Manufacturing lead times within factory departments are nominally 1 week. (For example, referring to Figure 3 transfer of raw materials in Department 3 or final products in Department 1 require one week lead time.) Lead times from raw material suppliers are 1 and 2 weeks, respectively, depending upon the particular item group required.

As indicated above there are forty item categories involved in factory operations. The factory employs the following "codes" for item identification: items numbered 1 to 10 represent "finished products"; items numbered 11 to 17 represent "sub-assemblies"; items numbered 18 to 32 represent "parts"; items numbered 33 to 36 represent "raw materials (1 week lead time)" and those numbered 37 to 40 represent "raw materials (2 weeks lead time)."
Figure 3. Schematic of Factory Organization and Work Flow
1.3 Work Force Data

The factory currently employs 247 skilled workers in direct labor. The work force is unionized and the existing average wage per worker (including fringe benefits) is $4.50/hour. Under the present union contract the hiring cost per man which includes training is estimated at $350.00 plus a loss in productive time of 32 hours per man hired during the week hired; layoff cost per man including severance pay is estimated at $360.00. The company incurs a penalty in lost productivity and downtime when workers are transferred between departments within the factory; accounting estimates the loss in productivity to be 16 hours per man week transfer (i.e., 2 days downtime per man). The union contract restricts overtime operations on a weekly basis to 140% of regular time, so that the maximum allowed hours per man in any work week is 56 hours. The wage rate for overtime operations is "time and a half" (i.e., 1.5 times the rate for regular time) up to 48 hours and "double time and a half" for the balance up to the maximum per week. Plant Industrial Engineering has synthesized (and rated) time standards for manufacturing in conjunction with the local union; these time standards in manhours by stock item are listed in Table 1.
Table 1: Standard time requirement for manufacturing

<table>
<thead>
<tr>
<th>Item number</th>
<th>Set-up time (man hours)</th>
<th>Run time/unit (man hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10</td>
<td>.1</td>
</tr>
<tr>
<td>2</td>
<td>16</td>
<td>.6</td>
</tr>
<tr>
<td>3</td>
<td>20</td>
<td>.3</td>
</tr>
<tr>
<td>4</td>
<td>40</td>
<td>.4</td>
</tr>
<tr>
<td>5</td>
<td>12</td>
<td>.2</td>
</tr>
<tr>
<td>6</td>
<td>20</td>
<td>1.</td>
</tr>
<tr>
<td>7</td>
<td>24</td>
<td>.5</td>
</tr>
<tr>
<td>8</td>
<td>8</td>
<td>.15</td>
</tr>
<tr>
<td>9</td>
<td>14</td>
<td>.3</td>
</tr>
<tr>
<td>10</td>
<td>80</td>
<td>.7</td>
</tr>
</tbody>
</table>

1.4 Manufacturing Costs

In addition to the labor costs noted above, the plant accounting observes several conventions in establishing manufacturing cost for a production item. Current practice is based on a full cost system which assigns a standard 15% loading as a burden rate on all direct labor hours (at regular time). Inventory stock is valued at total cost using FIFO by quarters (12 weeks) and the inventory carrying charge includes 0.3% per week on the full-value investment.

Final Product Operating data is summarized by stock item category in Table 2. Due to the nature of the business, no quantity discounts are involved in the final product sales prices shown in Table 2. Work force productivity estimates in Table 2 were determined by plant industrial engineers on the basis of departmental time standards and historical data.
Table 2: Final Product Operating Data

<table>
<thead>
<tr>
<th>Final Product item number</th>
<th>Price ($)</th>
<th>Initial inventory stock (units)</th>
<th>Estimated work force productivity (Units/man week)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>16.25</td>
<td>3000</td>
<td>195.75</td>
</tr>
<tr>
<td>2</td>
<td>21.67</td>
<td>1500</td>
<td>32</td>
</tr>
<tr>
<td>3</td>
<td>20.75</td>
<td>60</td>
<td>64</td>
</tr>
<tr>
<td>4</td>
<td>29.70</td>
<td>600</td>
<td>48</td>
</tr>
<tr>
<td>5</td>
<td>36.11</td>
<td>900</td>
<td>95.7</td>
</tr>
<tr>
<td>6</td>
<td>42.67</td>
<td>225</td>
<td>19.25</td>
</tr>
<tr>
<td>7</td>
<td>36.00</td>
<td>1500</td>
<td>38.5</td>
</tr>
<tr>
<td>8</td>
<td>25.54</td>
<td>2250</td>
<td>128</td>
</tr>
<tr>
<td>9</td>
<td>27.04</td>
<td>600</td>
<td>64</td>
</tr>
<tr>
<td>10</td>
<td>41.25</td>
<td>120</td>
<td>27.4</td>
</tr>
</tbody>
</table>

*Based on "average" work week of 45 hours.

An example income statement for the factory is shown in Figure 4a. The corresponding manufacturing statement and labor report for the same week are shown in Figures 4b and 4c. These are three of the reports provided to the factory management for monitoring operations. Factory accounting of costs employs the following procedures:

1. Inventory book values are computed according to the FIFO (by quarter) valuation method. The number of units of the item produced in any week is added to the stock item volume on hand.

2. When any item is manufactured the total cost of the production run for that item is the sum of: the value of the components used in the item (each at FIFO inventory...
### SALES

<table>
<thead>
<tr>
<th>Item</th>
<th>Amount</th>
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</thead>
<tbody>
<tr>
<td>MATERIALS</td>
<td>239701.</td>
</tr>
<tr>
<td>DIRECT LABOR</td>
<td>45518.</td>
</tr>
<tr>
<td>OTHER EXPENSES</td>
<td>39468.</td>
</tr>
</tbody>
</table>

**OPERATING PROFIT** 67787.

**Figure 4a. Income Statement for the Last 1 Week(s) as of Week 1**

### MANUFACTURING COSTS

<table>
<thead>
<tr>
<th>Item</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>DIRECT LABOR</td>
<td></td>
</tr>
<tr>
<td>REGULAR</td>
<td>44100.</td>
</tr>
<tr>
<td>OVERTIME</td>
<td>1418.</td>
</tr>
<tr>
<td>TOTAL</td>
<td>45518.</td>
</tr>
<tr>
<td>DIRECT MATERIALS</td>
<td></td>
</tr>
<tr>
<td>REGULAR</td>
<td>215759.</td>
</tr>
<tr>
<td>EXPEDITED</td>
<td>0.</td>
</tr>
<tr>
<td>TOTAL</td>
<td>215759.</td>
</tr>
<tr>
<td>OVERHEAD</td>
<td></td>
</tr>
<tr>
<td>HIRING</td>
<td>0.</td>
</tr>
<tr>
<td>FIRING</td>
<td>720.</td>
</tr>
<tr>
<td>INVENTORY CARRYING COST</td>
<td>2564.</td>
</tr>
<tr>
<td>VARIABLE OVERHEAD</td>
<td>36183.</td>
</tr>
<tr>
<td>TOTAL OVERHEAD</td>
<td>39468.</td>
</tr>
<tr>
<td>COST OF GOODS MANUFACTURED</td>
<td>300744.</td>
</tr>
<tr>
<td>ADD BEGINNING INVENTORY</td>
<td>881299.</td>
</tr>
<tr>
<td>LESS ENDING INVENTORY</td>
<td>857355.</td>
</tr>
<tr>
<td>COST OF GOODS SOLD</td>
<td>324688.</td>
</tr>
</tbody>
</table>

**Figure 4b. Manufacturing Statement for the Last 1 Week(s) as of Week 1**
<table>
<thead>
<tr>
<th>DEPT.</th>
<th>AVAILABLE HOURS</th>
<th>REGULAR TIME</th>
<th>OVER TIME</th>
<th>PAYROLL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4440.</td>
<td>3726.</td>
<td>0.</td>
<td>19980.</td>
</tr>
<tr>
<td>2</td>
<td>2720.</td>
<td>2358.</td>
<td>0.</td>
<td>12240.</td>
</tr>
</tbody>
</table>

TOTAL WORK FORCE 245

HIRED 0
FIRED 2
TRANSFERRED 4

Figure 4c. Labor Report for the Last 1 Week(s) as of Week 1
value per unit) direct labor cost at regular time (and overtime if any), and a 90% burden rate on direct labor.

(3)"Materials" during the week (see Figure 4a) is the total cost of goods sold at finished good inventory value per unit less the direct labor cost of total production man-hours during the week and "other expenses."

(4)"Director labor" is total cost for the week at regular time and overtime, if any. (An example of the supporting detailed report for direct labor costs by department is shown in Figure 4c).

(5)"Other expenses" (where applicable) including hiring and firing costs, inventory, and "variable overhead."

(6)"Operating profit" before taxes is total weekly sales revenue minus materials cost, direct labor, and other expenses.

1.5 Product Demand

Market demand for the ten final products is reasonably stable, as industrial markets go, and is not overly sensitive to advertising expenses or unusual promotional activities. The product line enjoys a favorable reputation for quality and reliability and is priced competitively. However, customers are responsive to the availability of items and supply performance over time. Thus, the factory maintains inventory stock to protect market position for all final products, since these items are "standard" and do not involve custom manufacturing. Historical data has shown that in out-of-stock situations for
a particular product, some fraction of the excess-demand-customers will backorder sales; however, this fraction of reliable customers depends upon factory performance in meeting sales over time. That is, under continuing out-of-stock conditions the number of customers willing to backorder decreases successively if the situation perpetuates itself over time. Similarly, stock-outs influence total product demand as the reputation for "poor supply performance" spreads within the market place. On the other hand, as performance is improved and stock-outs approach zero, all conditions will converge to "normal."

Published surveys on the industry, including an economic analysis of market data, strongly suggests that product demand is influenced by trend and seasonal factors.

1.6 The Plant Manager Responsibilities

The major responsibility of the plant manager is to prepare the total work force and production plans for the 10 finished products. Due to the lead time requirements for subassemblies, parts and raw materials, production planning horizon of 5 weeks is used in the factory. In the interest of cost economy, the expedite option is not exercised in the factory.

Detailed schedules for sub-assemblies, parts and raw materials are obtained from the planned production decisions for the final products. Detailed production and work force planning and scheduling activities and ordering raw materials and parts are performed by a different department in the plant. Requirements generation for stock
stock item inventory control is based entirely on the extrapolation of the final product production plans over the planning horizon and the bill of materials explosion. Inventory safety stock, where they exist, have been established implicitly on the basis of historical performance (nominally, a week and a half supply).

Although every attempt is made to meet the planned production levels, the planned production levels for the final products are not always met. This is due to production problems such as machine breakdowns, labor absenteeism and delay in delivery of raw materials. Deviations from the planned production for the final products are reported to the factory manager in a problem report (Figure 5).

As noted under section 3, the plant manager is also provided with income statement, manufacturing cost and labor report on weekly, monthly, quarterly, and yearly basis. In addition to the above reports, the following reports are generated and made available to the plant management:

* Cumulative forecast deviation report for each final product forecast (Figure 6). This report is generated regularly on weekly, monthly, quarterly, and annual basis.

* Detailed status report on finished goods production (Figure 7). This report provides information on sales, actual and desired production levels for finished goods, inventory levels and inventory values and is generated regularly on weekly, monthly, quarterly, and annual basis.

Data on operating performance of the factory is collected on six categories of operations: gross profits, material costs, direct
PRODUCTION OF 3 REDUCED TO 30 BECAUSE OF PROBLEM CODE 13
PRODUCTION OF 4 REDUCED TO 588 BECAUSE OF PROBLEM CODE 14
PRODUCTION OF 5 REDUCED TO 795 BECAUSE OF PROBLEM CODE 15
PRODUCTION OF 6 REDUCED TO 180 BECAUSE OF PROBLEM CODE 16
PRODUCTION OF 8 REDUCED TO 3395 BECAUSE OF PROBLEM CODE 11
PRODUCTION OF 10 REDUCED TO 6 BECAUSE OF PROBLEM CODE 32
PRODUCTION OF 13 REDUCED TO 1579 BECAUSE OF PROBLEM CODE 22
PRODUCTION OF 17 REDUCED TO 637 BECAUSE OF TIME SHORTAGE

Figure 5. Problem Report for the Last 1 Week as of Week 1

560 962 1008 458 103 28 402 435 10 25

Figure 6. Cumulative Forecast Deviations for the Last, 1 Weeks as of Week 1
<table>
<thead>
<tr>
<th>PRODUCT NUMBER</th>
<th>FORECAST SALES</th>
<th>DESIRED PROD.</th>
<th>ACTUAL PROD.</th>
<th>ACTUAL SALES</th>
<th>BACKORDERS ON HAND</th>
<th>INVENTORY UNITS</th>
<th>COST OF GOODS SOLD</th>
<th>INVENTORY DOLLARS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3014</td>
<td>3004</td>
<td>3004</td>
<td>2890</td>
<td>0</td>
<td>3106</td>
<td>35870.7</td>
<td>38667.4</td>
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<td>2</td>
<td>2428</td>
<td>2798</td>
<td>2798</td>
<td>2648</td>
<td>0</td>
<td>1621</td>
<td>54563.6</td>
<td>33501.9</td>
</tr>
<tr>
<td>3</td>
<td>1621</td>
<td>2363</td>
<td>2363</td>
<td>2011</td>
<td>0</td>
<td>696</td>
<td>31414.5</td>
<td>10905.1</td>
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<td>4</td>
<td>748</td>
<td>941</td>
<td>941</td>
<td>1191</td>
<td>119</td>
<td>0</td>
<td>32205.3</td>
<td>.0</td>
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<td>1236</td>
<td>1471</td>
<td>1471</td>
<td>1411</td>
<td>0</td>
<td>664</td>
<td>39666.7</td>
<td>18722.7</td>
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<td>6</td>
<td>301</td>
<td>389</td>
<td>389</td>
<td>368</td>
<td>0</td>
<td>142</td>
<td>14486.3</td>
<td>5606.6</td>
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<tr>
<td>7</td>
<td>1795</td>
<td>1959</td>
<td>1959</td>
<td>1889</td>
<td>0</td>
<td>1377</td>
<td>56158.4</td>
<td>41059.9</td>
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<tr>
<td>8</td>
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<td>558</td>
<td>0</td>
<td>838</td>
<td>13767.7</td>
<td>19232.0</td>
</tr>
<tr>
<td>10</td>
<td>435</td>
<td>459</td>
<td>459</td>
<td>435</td>
<td>0</td>
<td>337</td>
<td>13313.9</td>
<td>10345.4</td>
</tr>
</tbody>
</table>

Figure 7. Finished Goods Production Report for Last 1 Weeks as of Week 1
labor cost, regular time manhours, overtime manhours, and inventory turnover. Operating performance data is also available on monthly, quarterly, and yearly basis. The factory performance during a "recent" five-year history is summarized in Figure 8.

II. Subject Instructions

2.1 Input Specification and Procedures

Now that you have read the case, you will be asked to assume the role of the new FACTORY: 2 plant manager. Your major responsibility as described in the case is making weekly aggregate workforce and production plans for the ten final products. Remember that due to lead time requirements for raw materials and parts, the planning horizon is 5 weeks. Furthermore, the planning activities are conducted on weekly basis. That is at the end of each week you are asked to prepare a new aggregate plan for the next 5 weeks. For your initial plan, in addition to the data provided in the case description, you will be provided with a 24-week sales history and a 12-week forecast of sales for the finished products. For each subsequent week, you will be provided with the factory's operating data and a new 12-period forecast. You will input your aggregate workforce and production plans into a simulation program of FACTORY: 2 in an interactive mode via a time sharing terminal. Specifically the simulation program will proceed to ask for the following information in the described order:
<table>
<thead>
<tr>
<th>YEAR</th>
<th>GROSS PROFIT</th>
<th>DIRECT MATERIAL COST</th>
<th>DIRECT LABOR COST</th>
<th>MANHOURS REGULAR</th>
<th>MANHOURS OVERTIME</th>
<th>INV. TURNOVER</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$3,238,994</td>
<td>$9,690,323</td>
<td>$2,252,425</td>
<td>440,560</td>
<td>36,827</td>
<td>11.44</td>
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<tr>
<td>2</td>
<td>3,645,741</td>
<td>10,470,565</td>
<td>2,439,780</td>
<td>470,240</td>
<td>43,974</td>
<td>12.69</td>
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<tr>
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<td>4,174,823</td>
<td>11,563,102</td>
<td>2,622,207</td>
<td>520,920</td>
<td>39,218</td>
<td>13.27</td>
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<tr>
<td>4</td>
<td>4,534,546</td>
<td>12,637,260</td>
<td>2,980,116</td>
<td>565,440</td>
<td>45,641</td>
<td>13.58</td>
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<tr>
<td>5</td>
<td>4,913,968</td>
<td>13,410,771</td>
<td>3,019,644</td>
<td>605,120</td>
<td>42,922</td>
<td>13.65</td>
</tr>
</tbody>
</table>

Figure 8. Summary of Year End Performance (Consecutive 5-year History)
* Your social security number: your social security number should be entered as a string of 9 digits with no blanks or other special characters.

* The run number: the run number corresponds to the week that is to be simulated. It should be input as a 2-digit number. For example, for the first week simulation you input 01, for the second week 02, etc.

* Total planned work force for the next five weeks: total work force refers to the work force required for the production of all the 10 finished products. Work force should be entered as a 4 digit number.

* The planned production levels for the 10 final products: you are asked to input the planned production levels for the finished products on weekly basis. That is, the program first asks you to input the 10 production levels for period 1 (week 1). After verifying your input numbers you are asked to enter production levels for period 2 (week 2), etc. Your last production level inputs will correspond to period 5 (week 5). Notice that all your input numbers should be 4 digits long. For example, a production level of 72 units should be entered as 0072.

After receiving the above information items the program prints your input production and work force levels in a tabulated form and proceeds to simulate the factory operations for one week. At the end of each weekly simulation 5 management reports (income statement, manufacturing cost report, forecast deviations, labor report and
final products production report) are printed out. The end of simulation run is indicated by an "end of weekly simulation" message.

To facilitate input procedures, you are asked to code your input numbers on the subject worksheets furnished to you at the beginning of the experiment. A sample subject worksheet and time sharing dialogue is presented in the following section.
**SAMPLE WORKSHEET**

**SOCIAL SECURITY #:** [ ]

**_TRIAL #:** [ ]

**TIME IN:** __________

**TIME OUT:** __________

**AGGREGATE WORK FORCE LEVELS FOR THE NEXT FIVE WEEKS:**

<table>
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<th>WEEK</th>
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<th>3</th>
<th>4</th>
<th>5</th>
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<td></td>
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**PRODUCTION LEVELS FOR:**

<table>
<thead>
<tr>
<th>PRODUCT 1:</th>
<th>WEEK 1</th>
<th>WEEK 2</th>
<th>WEEK 3</th>
<th>WEEK 4</th>
<th>WEEK 5</th>
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<table>
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<th>WEEK 2</th>
<th>WEEK 3</th>
<th>WEEK 4</th>
<th>WEEK 5</th>
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</thead>
<tbody>
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<th>WEEK 4</th>
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<th>WEEK 3</th>
<th>WEEK 4</th>
<th>WEEK 5</th>
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<tbody>
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<table>
<thead>
<tr>
<th>PRODUCT 5:</th>
<th>WEEK 1</th>
<th>WEEK 2</th>
<th>WEEK 3</th>
<th>WEEK 4</th>
<th>WEEK 5</th>
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<tbody>
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<tr>
<th>PRODUCT 6:</th>
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<table>
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<th>WEEK 5</th>
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<table>
<thead>
<tr>
<th>PRODUCT 10:</th>
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<th>WEEK 2</th>
<th>WEEK 3</th>
<th>WEEK 4</th>
<th>WEEK 5</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
SAMPLE TIME - SHARE DIALOGUE

PLEASE ENTER YOUR SOCIAL SECURITY NUMBER.
276563290

IS 276563290 WHAT YOU ENTERED (Y OR N)?

INPUT THE 2-DIGIT RUN NUMBER.
01
PLEASE TYPE IN YOUR TOTAL WORK FORCE FOR THE NEXT FIVE PERIODS. YOUR INPUTS SHOULD BE 4-DIGITS LONG.

0245
0245
0245
0245
0245

YOU ENTERED
245
245
245
245
245

DO YOU WISH TO REENTER THE NUMBER? TYPE IN Y OR N.
INPUT PRODUCTION LEVELS FOR 10 FINISHED PRODUCTS.  
ALL INPUT NUMBERS SHOULD BE 4-DIGITS LONG.  

INPUT PRODUCTION LEVELS FOR THE PRODUCTS FOR PERIOD 1

2677
1886
2036
0607
0090
0220
1558
3849
0594
0586

YOU ENTERED THE FOLLOWING NUMBERS

2677
1886
2036
607
890
220
1558
3849
594
585

DO YOU WISH TO REENTER THE NUMBERS? ENTER Y OR N.

INPUT PRODUCTION LEVELS FOR THE PRODUCTS FOR PERIOD 2

2575
1912
2141
0609
0667
0218
1576
4249
0522
0623

YOU ENTERED THE FOLLOWING NUMBERS

2575
1912
2141
609
887
710
1576
4249
592
623
POST-EXPERIMENT QUESTIONNAIRE

Name:__________________________  Major Field:___________

Social Security No.:______________  Minor Field:___________
(if any)

Age:______________
PART A

1. Please place a check mark next to the number of formal production courses you have had as a part of your educational training:

   a. none________
   b. 1 or 2________
   c. more than 2________

2. Have you ever had a job involving production planning activities?

   a. Yes________        b. No________
   c. If yes, how long did you hold the job?____________________

PART B

In the following statements, please indicate your feeling or attitude by placing a check mark in the appropriate box.

Example

"Computerized data processing is necessary to the modern organization."

Strongly disagree [ ] [ ] [x] [ ] [ ] Strongly agree

1. Did you find the work force and production planning task challenging?

   No challenge [ ] [ ] [ ] [ ] [ ] Very challenging

   at all  [ ] [ ] [ ] [ ] [ ]

2. Did you find the work force and production planning task complex?

   Not at all complex [ ] [ ] [ ] [ ] [ ] Very complex
3. Did you understand how the decision aid could be used to support your decisions?

No understanding [ ] [ ] [ ] [ ] [ ] Complete understanding

4. How difficult was it to work with and use the decision aid?

Very difficult [ ] [ ] [ ] [ ] [ ] Very easy

5. Please rate your overall satisfaction with the decision aid.

Very dissatisfied [ ] [ ] [ ] [ ] [ ] Very satisfied

6. How willing would you be to have a decision aid (like the one used) developed to aid in the decision problems you now (or may in the future) face?

Not at all willing [ ] [ ] [ ] [ ] [ ] Very willing

7. How important were the specific numbers generated by the decision aid in arriving at your particular production decisions?

Not important to decision [ ] [ ] [ ] [ ] [ ] Completely determined the decision

8. How familiar were you with the suggested decision aid?

Not familiar at all [ ] [ ] [ ] [ ] [ ] Very familiar

9. How easily do you work with numbers?

With much difficulty [ ] [ ] [ ] [ ] [ ] Very easily
10. How well do you like to work on problems involving quantitative data?

Strongly dislike [ ] [ ] [ ] [ ] [ ] Strongly like [ ] [ ] [ ] [ ] [ ]

11. In analyzing problems with both quantitative and qualitative information, how much emphasis do you tend to give to analyzing the quantitative data?

Little emphasis [ ] [ ] [ ] [ ] [ ] Great emphasis [ ] [ ] [ ] [ ] [ ]

The following questions are aimed at describing your personal decision style.

12. My personal decision style is primarily intuitive and implicit as opposed to analytical and explicit.

Strongly disagree [ ] [ ] [ ] [ ] [ ] Strongly agree [ ] [ ] [ ] [ ] [ ]

13. I try to look mostly at the immediate short term, near-at-hand consequences of a choice. I do not get involved in looking way ahead into the distant future.

Strongly disagree [ ] [ ] [ ] [ ] [ ] Strongly agree [ ] [ ] [ ] [ ] [ ]

14. As a decision maker I am creative and experimental as opposed to habitual, conventional, and routine.

Strongly disagree [ ] [ ] [ ] [ ] [ ] Strongly agree [ ] [ ] [ ] [ ] [ ]
PART C

1. Do you give permission to the experimenter to obtain your grade point average (this information will be kept confidential)?

   Yes __________
   No __________

2. Did you at all use the decision aid to help you make your decisions on the second session of the experiment?

   Yes __________
   No __________

   If yes, explain your procedure for using it.
3. Briefly discuss the features (if any) of the decision aid that you like the best.
4. Briefly discuss the features (if any) of the decision aid that you liked the least.
Subject Sign-Up Sheet

Subject Consent Form
Please fill in the information requested below. This information is necessary to schedule your participation in the experiment.

NAME:__________________________________________________________

ADDRESS:_______________________________________________________

TELEPHONE NUMBER:____________________________________________

Every effort will be made to schedule your experimental session at your convenience. To assist in scheduling these sessions, please indicate your preference below by circling the appropriate day and time.

<table>
<thead>
<tr>
<th>DAY</th>
<th>TIME</th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td>8-12 a.m. 1-5 p.m. 6-10 p.m.</td>
</tr>
<tr>
<td>T</td>
<td></td>
</tr>
<tr>
<td>W</td>
<td></td>
</tr>
<tr>
<td>TH</td>
<td></td>
</tr>
<tr>
<td>F</td>
<td></td>
</tr>
</tbody>
</table>

Is there any day of the week that is unacceptable to you? _________

______________________________________________________________
RESEARCH INVOLVING HUMAN SUBJECTS
CONSENT TO SERVE AS A SUBJECT IN RESEARCH

BEHAVIORAL AND SURVEY RESEARCH FORM

I consent to serve as a subject in the research investigation entitled:

The nature and general purpose of the research procedure have been explained to me. This research is to be performed by or under the direction of Dr. ________________, who is authorized to use the services of others in the performance of the research.

I understand that any further inquiries I make concerning this procedure will be answered. I understand my identity will not be revealed in any publication, document, recording, video-tape, photograph, computer data storage, or in any other way which relates to this research. Finally, I understand that I am free to withdraw my consent and discontinue participation at any time following the notification of the Project Director.

Signed ____________________
(Subject)

Date ____________________ A.M.
Time ____________________ P.M.

Witness - (Auditor) ____________________

Investigator ____________________

PA-027
APPENDIX B

FORTRAN LISTING OF MODIFIED "FACTORY:2"
C COMPUTE THE MAXIMUM AMOUNT OF TIME AVAILABLE TO THE DEPARTMENT

C EVENTS

TTAHPRT(1) - HPRT

TTATIM(11) - TIME

C ZERO THE "TIME USED" COUNTER

ATTIM(10) = 0

C LOOP FOR SIMULATION OF EACH PRODUCT IN THE CURRENT DEPARTMENT

C PRODUCE PRODUCTS IN THE ORDER SPECIFIED BY THE PRIORITY ARRAY

C TEST THAT THE PRODUCT SPECIFIED IS IN THE DEPARTMENT BEING SIMULATED

C IF (PRIORITY(IP)) = 1, then...

C TEST FOR TIME CONSTRAINT AND REDUCE THE DESIRED LEVEL OF PRODUCTION

C IF NEEDED

C IF (EVENTS(1)) = 1170 + 1170 + 1050

C IF (EVENTS(1)) = 1050 + 1070 + 1080

C IF (EVENTS(1)) = 1050 + 1052 + 1052

C IF (APMNT(1)) = 1

C IF (APMNT(1)) = 1

1015 FORMAT(15,1X,"PROBLEM REPORT FOR THE LAST 1 WEEK")

1017 FORMAT(15,1X,"1st AS OF WEEK *13/71")

1061 APPOINT

1062 IF (APMNT(1)) GO TO 1063

1063 IF (APMNT(1)) = 1170 + 1170 + 1050

1065 FORMAT(15,1X,"PRODUCTION OF +12,149 REDUCED FROM +15,847 TO +16")

1070 END OF TIME

1072 APPOINT

C TEST FOR MATERIAL CONSTRAINT AND REDUCE THE DESIRED LEVEL OF PRODUCTION

C IF NEEDED

C IF (EVENTS(1)) = 1120 + 1120 + 1090

C IF (EVENTS(1)) = 1120 + 129 + 1120

C IF (APMNT(1)) = 1

C IF (APMNT(1)) = 1

1105 IF (EVENTS(1)) = 1129 + 1120 + 123

C EXCISE IF SHORTAGE OCCURS AND EXCISE OPTION IS ELECTED

1110 IF (EVENTS(1)) = 1129 + 1120 + 123

1115 IF (EVENTS(1)) = 1129 + 1120 + 123

1117 IF (EVENTS(1)) = 1129 + 1120 + 123

1119 IF (EVENTS(1)) = 1129 + 1120 + 123

1121 IF (EVENTS(1)) = 1129 + 1120 + 123

1123 IF (EVENTS(1)) = 1129 + 1120 + 123

1125 IF (EVENTS(1)) = 1129 + 1120 + 123
C FUNCTION OF REPORTS
DO 26 I=1,6
   DO 26 K=I+4
26   IF(I+K.LE.41) GO TO 27
JFR=1.0
DO 27 J=1,4
   IF(J.GE.5.0) GO TO 127
ERR(J)=1.0
DO 127 K=5 TO 127
   ERR(J)=ERR(J)+1.0
   IF(K.GE.1.0) ERR(J)=ERR(J)*K
IF(K.LE.1.0) ERR(J)=ERR(J)*K
127 CONTINUE
C INSERT "TIME SLED" HERE
C PERMUTATION OF MIXED COEFFICIENTS ACROSS FINAL PRODUCTS
CALL SRAP(MIX(2))
CALL SRAP(MIX(3))
CALL SRAP(MIX(4))
C SET LOGIC SWITCHES TO CALL DESIRED TEACH OR STUDENT SUBROUTINES
SW1=5
SW2=5
SW3=5
SW4=5
SW5=0
SW6=5
SW7=5
SW8=5
SW9=5
SW10=0
SW11=0
SW12=0
105 IF SW1.EQ.5
   106 IF SW2.EQ.5 ST 127
   127 SW1.EQ.127
C GENERATE TEL OF MATERIALS MATRICES
DO 100 J=1,13
   DO 100 I=1,13
      PT(I,J)=0
100   P(I,J)=1
C TEST LOWER 30% TRENDS ON PLANNING HORIZON
IF NORE=1 125 125 106
105 IF NORE=5
   106 IF NORE.GT.121 HUPZ=12
C GENERATE TEL OF MATERIALS MATRICES
DO 100 J=1,13
   DO 100 I=1,13
      PT(I,J)=0
100   P(I,J)=1
C TEST LOWER 30% TRENDS ON PLANNING HORIZON
IF NORE=1 125 125 106
105 IF NORE=5
   106 IF NORE.GT.121 HUPZ=12
C GENERATE TEL OF MATERIALS MATRICES
DO 100 J=1,13
   DO 100 I=1,13
      PT(I,J)=0
100   P(I,J)=1
C TEST LOWER 30% TRENDS ON PLANNING HORIZON
IF NORE=1 125 125 106
105 IF NORE=5
   106 IF NORE.GT.121 HUPZ=12
C GENERATE TEL OF MATERIALS MATRICES
DO 100 J=1,13
   DO 100 I=1,13
      PT(I,J)=0
100   P(I,J)=1
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105 IF NORE=5
   106 IF NORE.GT.121 HUPZ=12
C GENERATE TEL OF MATERIALS MATRICES
DO 100 J=1,13
   DO 100 I=1,13
      PT(I,J)=0
100   P(I,J)=1
C TEST LOWER 30% TRENDS ON PLANNING HORIZON
IF NORE=1 125 125 106
105 IF NORE=5
   106 IF NORE.GT.121 HUPZ=12
C GENERATE TEL OF MATERIALS MATRICES
DO 100 J=1,13
   DO 100 I=1,13
      PT(I,J)=0
100   P(I,J)=1
C TEST LOWER 30% TRENDS ON PLANNING HORIZON
IF NORE=1 125 125 106
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   106 IF NORE.GT.121 HUPZ=12
C GENERATE TEL OF MATERIALS MATRICES
DO 100 J=1,13
   DO 100 I=1,13
      PT(I,J)=0
100   P(I,J)=1
C TEST LOWER 30% TRENDS ON PLANNING HORIZON
IF NORE=1 125 125 106
105 IF NORE=5
   106 IF NORE.GT.121 HUPZ=12
C GENERATE TEL OF MATERIALS MATRICES
DO 100 J=1,13
   DO 100 I=1,13
      PT(I,J)=0
100   P(I,J)=1
C TEST LOWER 30% TRENDS ON PLANNING HORIZON
IF NORE=1 125 125 106
105 IF NORE=5
   106 IF NORE.GT.121 HUPZ=12
C GENERATE TEL OF MATERIALS MATRICES
DO 100 J=1,13
   DO 100 I=1,13
      PT(I,J)=0
100   P(I,J)=1
C TEST LOWER 30% TRENDS ON PLANNING HORIZON
IF NORE=1 125 125 106
105 IF NORE=5
   106 IF NORE.GT.121 HUPZ=12
C GENERATE TEL OF MATERIALS MATRICES
DO 100 J=1,13
   DO 100 I=1,13
      PT(I,J)=0
100   P(I,J)=1
C TEST LOWER 30% TRENDS ON PLANNING HORIZON
IF NORE=1 125 125 106
105 IF NORE=5
   106 IF NORE.GT.121 HUPZ=12
C GENERATE TEL OF MATERIALS MATRICES
DO 100 J=1,13
   DO 100 I=1,13
      PT(I,J)=0
100   P(I,J)=1
C TEST LOWER 30% TRENDS ON PLANNING HORIZON
IF NORE=1 125 125 106
105 IF NORE=5
   106 IF NORE.GT.121 HUPZ=12
C GENERATE TEL OF MATERIALS MATRICES
DO 100 J=1,13
   DO 100 I=1,13
      PT(I,J)=0
100   P(I,J)=1
C TEST LOWER 30% TRENDS ON PLANNING HORIZON
IF NORE=1 125 125 106
105 IF NORE=5
   106 IF NORE.GT.121 HUPZ=12
C GENERATE TEL OF MATERIALS MATRICES
DO 100 J=1,13
   DO 100 I=1,13
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DO 100 J=1,13
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C TEST LOWER 30% TRENDS ON PLANNING HORIZON
IF NORE=1 125 125 106
105 IF NORE=5
   106 IF NORE.GT.121 HUPZ=12
C GENERATE TEL OF MATERIALS MATRICES
DO 100 J=1,13
   DO 100 I=1,13
      PT(I,J)=0
100   P(I,J)=1
C TEST LOWER 30% TRENDS ON PLANNING HORIZON
IF NORE=1 125 125 106
105 IF NORE=5
   106 IF NORE.GT.121 HUPZ=12
C GENERATE TEL OF MATERIALS MATRICES
DO 100 J=1,13
   DO 100 I=1,13
      PT(I,J)=0
100   P(I,J)=1
C PRODUCTION PRIORITY ARRAY
DO 4 I=1,32
4 IMPRTII=1
INTT=0
JCTP
IPR=IP*32
DO 6 J=1,IPR
6 CONTINUE
C MIKE PRIORITY ARRAY
DO 7 I=1,32
7 IMPRTII=1
INTT=0
TP=
IP=IP
DO 8 J=1,IP
8 CONTINUE
C CALCULATE MIKE & 2 TRANSFER WORKERS IN EACH DEPARTMENT
C 0 DEC1(1) DEC1(2) DEC1(3)
LDEC(1) LDEC(2) LDEC(3)
LEC1
IF(I1=5350) 5350, 5350, 5370
5370 UJ 5370 T=1,3
JMPRTII
INR3SI1=DECU(1)+DECU(2)+DECU(3)
5350 IF(1=1) 6,4,0) TRANSA1(0)
5370 UJ 5370 T=1,3
JMPRTII
IF(REJ1=1) 401+LFLF1J1
5370 UJ 5370 T=1,3
JMPRTII
IF(REJ1=1) 401+LFLF1J1
5370 UJ 5370 T=1,3
JMPRTII
530 UJ T=1,3
CONTINUE
C LUPT FOR PROJECTION "SIMULATIONS" BY DEPARTMENT "SEQUENCE": DEPT = 1
C DEPT = 2, DEPT = 3
VO=6,6
VY=6,6
CONTINUE
C SET UP MINIMUM PRODUCTION NUMBERS AS THE LIMITS FOR THE CURRENT
C DEPARTMENT "SIMULATIONS"
C 0 0 0 0 30
1130 RESNFIN1.120APR1VVE
1131 IFREJ-1VVE(11) 1140.1140,1140
C 400 EXPEDITING COSTS TO THE VALUE OF THE PRODUCT'S INVENTORY IF ANY
C MATERIALS COST EXPEDITED
1147 FACTV3LX="T" IF I1V3LX="T" 1147V3LX="T" 1147
C ACCUMULATE AN JURIS OF MATERIALS EXPEDITED
1150 EXPD(1Z)JRT-1V3LX+EXPED1Z 1151
1152 I1V3LX JRT 1151 GO TO 1154
1154 ITAL+1V3LX 0.0 1155
VALR=VALR+1V3LX 1156
6234 CONTINUE
1157 I1V3LX 0.0 1158
1159 JRT=JRT 1159
1160 JMAX=JMAX 1161
1161 V3LX+1V3LX 1162
1162 I1V3LX 1163
JRT I1V3LX 1164
GO TO 1150
1165 JMAX=JMAX 1165
1166 JRT=JRT 1166
1167 IFIREG,1V3LX-1V3LX+JRT 1167 GO TO 1151
1168 I1V3LX=I1V3LX+1 1169
1169 V3LX+V3LX 1170
1170 I1V3LX+1V3LX 1171
1171 ITAL=ITAL+1 1172
1172 V3LX+1V3LX 1173
1173 JRT=JRT 1174
VALR=VALR+1V3LX 1175
GO TO 1157
1176 JMAX=JMAX 1176
1177 JRT=JRT 1177
1178 DD 1155 1=JRT 1178
V3LX+V3LX 1179
1179 I1V3LX+1V3LX 1180
1180 DD 1155 1=JMAX 1181
1181 JRT=JRT 1182
1182 GO TO 1150
1183 V3LX+V3LX 1184
1184 I1V3LX=I1V3LX+1 1185
1185 V3LX+V3LX 1186
1186 I1V3LX+1V3LX 1187
1187 REU=REU+1V3LX 1188
1188 ITAL=ITAL+1 1189
1189 V3LX+V3LX 1190
1190 I1V3LX+1V3LX 1191
1191 ITAL=ITAL+1 1192
1192 VALR=VALR+1V3LX 1193
1193 GO TO 1152
1194 JRT=JRT 1195
1195 GO TO 1153
1196 C ACCOUNT FOR THE TIME USED TO MAKE THE PRODUCT
1197 TIME=TIME+TIME 1198
1198 DD 1155 1=TIME 1199
1199 JRT=JRT 1200
C ACCUMULATE JURIS AND UPDATE INVENTORIES
1202 I1V3LX+1V3LX 1203
1203 VALR=VALR+1V3LX 1204
1204 GO TO 1150
IF(IHR,3,47)GOTO1161
IMAX=I1/2(I1+1)

1161 J=J+1
VWIM,J+1,VW(J+1,J+1)+VAL(T(J+1,J)+0.0+TEMPI)
VWIM,J+1,VW(J+1,J)+VW,J+1,J+1

IF(VWIM,J+1,1=0)+1.DO+TEMPI
IF(VWIM,J+1,1=0)+1.DO+TEMPI

KCTIM(1)=KCTIM(1)+1.DO
IF(KTIM,111,112,1190)

1170 Ti=0.DO
C END OF NTH DEPARTMENT ANY PRODUCT LOOPS
1190 CONTINUE

DO 1171 Ti=33.45
IF (DECI(12)) 1192,1191,1171

1172 DECI(12)
1191 CONTINUE

C ORDER RAW MATERIALS
DO 1200 Ti=33.36
IF (Ti=0) GO TO 1193
JMAX=112+1

1193 JMAX=1
VWI2,J+1=CI(J)+DEC(J)+VW(J+1,J)
VTIM(VW,J+1,J)+VTIM(VW,J)
IN(TI)=IN(TI)+DEC(J)

1207 VWI2,J+1=VWI2,J+1+DEC(J)
C CREDIT RAW MATERIAL INVENTORIES WITH PREVIOUSLY ORDERED RAW MATERIALS
DCU1210 Ti=33.40

C ADD RAW MATERIAL COSTS TO RAW MATERIAL INVENTORIES

1210 FCU2=DEC(J)

C CALCULATE ALL OF HFTC AND ALL OF OVERTIME

1219 FCU3=FCU2

DC 1211 J=1,3
1211 FTIM=DEC(J)
DO 1212 J=1,3
1212 ALLOC(J)=J/J
DO 1213 J=1,9
1213 ALLOC(J)=J/J
DO 1215 J=1,7
1215 ALLOC(J)=J/J
C COMPUTE LABOUR COSTS

HFTC=0.0
FCC=0.0
HFTCI=0.0

IF (DEC(I)=DEC(J))=DEC(I)
LT=LLF(J)+LLF(J)+LLF(J)

C=LLF(J)

4010 MCCI=0.0
4020 FC=0.0
4030 CV=0.0
C UPDATE THE TIME CLOCK USED FOR THE DEMAND GENERATOR
TIME=+1.0
C (2) COMPUTE COUNTERS FOR WEEKLY SALES AND COST OF GOODS SOLD
TOTALED = 0
TOTALS = 0
TOTALED = 0
C LOOP FOR DEMAND GENERATION OF FINAL PRODUCTS
DO 1274 J = 1, 10
CGSI(11) = 0.0
C COMPUTE DEMAND DUE TO PREVIOUS BACKORDER CONDITIONS
DEMT(1) = CGSI(11) + CGSI(11) + (CGSI(11) + J)
C GENERATE RANDOM ERROR TERM IN DEMAND FUNCTION
REL = 0
GO TO 1240
INIT = INIT + 1.0
IV = 1
IF (INIT .GT. 1250) INIT = 1.0
1239
REL = INIT
1240 PEER = (+CT / 1075241823.5) - 1
EPS = CYM(11) + CGSI(11) + ITBM(11) / 2.0 + REL
CGSI(11) = CGSI(11) + J
C COMPUTE DEMAND AS REDUCED BY PREVIOUS BACKORDERS
DEMT(1) = CGSI(11) + (CGSI(11) + J)
IF (DEMT(1) .GT. 1250) DEMT(1) = 0
ZDEMT(1) = DEMT(1) - J
IF (ZDEMT(1) .LE. EPS) THEN
C ESTIMATE DECREASED DEMAND FOR DEMAND
TOEM(11) = TOEM(11) + EPS(11) + CGSI(11) + J
C ADJUST ACCOUNTS AND INVENTORIES TO RECORD SALES FOR BOTH
1.0
C TOE AND SHORTAGE CONDITIONS
IF (TOEM(11) .GT. 1250) TOEM(11) = 0
1257 SALES(11) = TOEM(11)
1257 TUER = TOEM(11)
IF (TUER .EQ. EPS) THEN
JMAX = JMAX
1257 IF (DEMT(1) .GT. EPS + CT) GO TO 1251
VADDX = M + EPS
JMAX = JMAX + EPS
VADDX = EPS + M
CGSI(11) = EPS
IF (JMXX .EQ. EPS) GO TO 1253
JMAX = JMAX
1257 GO TO 1255
JMAX = JMAX
1255 GO TO 1255
1255 JMAX = JMAX + 1
1255 GO TO 1255
1255
TOFM = TDC - VM - VM*VM
JM = JM + 1
GO TO 1252
1253 VM1 = VM1 + CG11
INVT1 = VM1
VM1 = 0
GO TO 1270
1250 SVAE1 = INVT1
JMA = JMA + 1
GO 1263
CONTINUE
INVT1 = JMA - 1
VM1 = VM1 + 1
CONTINUE
1261 VM1 = 0
1262 INVT1 = CG11
CONTINUE
C ACCUMULATE TOTAL WEEK'S SALES AND COST OF GOODS SOLD
1270 TOTSALE = SALES11 + PRIC11 * TOTSALE
TOTCGS = TOTCGS + CG11
C SALES HISTORY
IF (WEEK <= 264) HISTSA11 = WEEK * SALES11
IF (WEEK = LE + 1) GO TO 1260
DO 5260 J = 1, 263
5260 HISTSA11 = HISTSA11 + SALES11
5290 CONTINUE
1274 CONTINUE
C COMPUTE EXPEDITING, INVENTORY CARRYING, PAYROLL, MATERIAL, OVERHEAD
C EXPENSES AND COSTS
INVT = 0.0
CEX = 0.0
CL = (10 * DEC1411 + DEC242 + DEC421) * 0.05 * TOTCT + TOTCT * TOTCT / 100
C = CL = CL + 1
ZZ = 0.0
RATIO11 = 16.25
RATIO21 = 7.50
RATIO31 = 12.50
RATIO41 = 36.25
RATIO12 = 35.0
RATIO22 = 30.5
RATIO32 = 28.75
RATIO42 = 32.75
RATIO13 = 42.5
RATIO23 = 40.5
RATIO33 = 42.5
RATIO43 = 35.5
RATIO14 = 142.5
RATIO24 = 127.5
RATIO34 = 132.5
RATIO44 = 147.5
C = CEX * EXP11 + REXT11
JMA = JMA + 1
GO TO 3001
3001 VM = VM1* MV 3002
IF (VM1 < VM) GO TO 3112
C = C14 + VM1* M12* VM + VM1* VM1* VM1* VM1
IF (VM1 < VM) GO TO 3112
C  INITIALIZE CUMULATIVE VARIABLES TO ZERO

183
CALL TEACH "STUDENT REPORT GENERATOR" SUBROUTINES
IF (.NOT.STS.4) CALL TCHECK
CALL TREPORT
IF (WEEK.GT.11) GO TO 3855
DO 3853 IT=1,3
CLIT1=0.0
CLIT2=0.0
SLS11=0.0
SLS12=0.0
3853 AIT(I)=Q0
3855 CONTINUE
RMPF(I)=RMPF(I)+R(EC(I)+R(EC(I+1)+R(EC(I+2)+R(EC(I+3)))
SUM(I)=SUM(I)+SLS(I)
SLS11=SLS11*SLS11
CLIT1=CLIT1+CM11
CLIT2=CLIT2+CM21
DO 3205 I=1,40
3205 AIT(I)=AI(I)+11
C END OF WEEKLY SIMULATION
C FIF0 CONTROL
NGES=NGES+1
IF (NGES.GT.31) NGES=1
C PRINT MONTHLY AND WEEKLY PERFORMANCE REPORT IF NEEDED
IF (WEEK.GT.11) GO TO 3300
IF (WEEK.LE.11) GO TO 3300
IF (WEEK.LE.11) GO TO 3300
WRITE (6,101) M11,CLIT1,CM11,CM21,AM11,AM21,AM31
WRITE (6,101) M12,CLIT2,CM12,CM22,AM12,AM22,AM32
WRITE (6,101) M13,CLIT3,CM13,CM23,AM13,AM23,AM33
WRITE (6,101) M14,CLIT4,CM14,CM24,AM14,AM24,AM34
WRITE (6,101) M15,CLIT5,CM15,CM25,AM15,AM25,AM35
WRITE (6,101) M16,CLIT6,CM16,CM26,AM16,AM26,AM36
WRITE (6,101) M17,CLIT7,CM17,CM27,AM17,AM27,AM37
WRITE (6,101) M18,CLIT8,CM18,CM28,AM18,AM28,AM38
WRITE (6,101) M19,CLIT9,CM19,CM29,AM19,AM29,AM39
WRITE (6,101) M10,CLIT10,CM10,CM210,AM10,AM210,AM310
3210 PRINT, ("MONTHLY PERFORMANCE REPORT FOR MONTH ", I, " ")
PROFIT1 = PROFIT(1) + PROFIT(2)

QVH(1) = QVH(2) + QVH(1)

ATT(1) = ATT(2) + AT1(1)

CL(2) = CL(2) + CL(1)

CM(2) = CM(2) + CM(1)

SLS(1) = SLS(2)

PKOF(11) = 0.0

RHE(1) = 0.0

ATT(3) = 0.0

CL(1) = 0.0

CM(1) = 0.0

SLS = SLS(3) + SLS(2) + SLS(1) + SLS(3)

3230 QUART = QUART + 1

IF (QVH < 3) GOTO 3210, 3230

3240 FORMAT (3, /, 3x) PERFORMANCE REPORT FOR QUARTER 1

WRITE (6, 3240) QUART

3241 SLS(1) = SLS(3) + SLS(2) + SLS(1)

PKOF(1) = PKOF(1) + PKOF(2)

QVH(1) = QVH(3) + QVH(2)

ATT(1) = ATT(3) + ATT(2)

CL(1) = CL(3) + CL(2)

CM(1) = CM(3) + CM(2)

SLS(1) = SLS(3) + SLS(2) + SLS(1)

PKOF(1) = PKOF(1) + PKOF(2)

RHE(1) = 0.0

ATT(2) = 0.0

CL(2) = 0.0

CM(2) = 0.0

3250 YEAR = YEAR + 1

WRITE (6, 3250) YEAR

3260 FORMAT (3, /, 3x) PERFORMANCE REPORT FOR YEAR 1

WRITE (6, 3260) YEAR

3270 PROFIT(5) = PROFIT(1) + PROFIT(2)

QVH(1) = QVH(3) + QVH(2)

ATT(1) = ATT(3) + ATT(2)

CL(1) = CL(3) + CL(2)

CM(1) = CM(3) + CM(2)

SLS(1) = SLS(3) + SLS(2) + SLS(1)

PROFIT(5) = PROFIT(1) + PROFIT(2)

RHE(1) = 0.0

ATT(2) = 0.0

CL(2) = 0.0

CM(2) = 0.0

3420 FORMAT (3, /, 3x) PERFORMANCE REPORT FOR PERIOD ENDING IN WKR 13 1/1

WRITE (6, 3420) WKR

3421 FORMAT (3, /, 3x) PERFORMANCE REPORT FOR PERIOD ENDING IN WKR 12 2/1

WRITE (6, 3421) WKR

3430 FORMAT (3, /, 3x) PERFORMANCE REPORT FOR PERIOD ENDING IN WKR 11 3/1

WRITE (6, 3430) WKR

3440 FORMAT (3, /, 3x) PERFORMANCE REPORT FOR PERIOD ENDING IN WKR 10 4/1

WRITE (6, 3440) WKR

3450 FORMAT (3, /, 3x) PERFORMANCE REPORT FOR PERIOD ENDING IN WKR 09 5/1

WRITE (6, 3450) WKR

3460 FORMAT (3, /, 3x) PERFORMANCE REPORT FOR PERIOD ENDING IN WKR 08 6/1

WRITE (6, 3460) WKR

3470 FORMAT (3, /, 3x) PERFORMANCE REPORT FOR PERIOD ENDING IN WKR 07 7/1

WRITE (6, 3470) WKR

3480 FORMAT (3, /, 3x) PERFORMANCE REPORT FOR PERIOD ENDING IN WKR 06 8/1

WRITE (6, 3480) WKR

3490 FORMAT (3, /, 3x) PERFORMANCE REPORT FOR PERIOD ENDING IN WKR 05 9/1

WRITE (6, 3490) WKR

3500 FORMAT (3, /, 3x) PERFORMANCE REPORT FOR PERIOD ENDING IN WKR 04 10/1

WRITE (6, 3500) WKR

3510 FORMAT (3, /, 3x) PERFORMANCE REPORT FOR PERIOD ENDING IN WKR 03 11/1

WRITE (6, 3510) WKR

3520 FORMAT (3, /, 3x) PERFORMANCE REPORT FOR PERIOD ENDING IN WKR 02 7/1

WRITE (6, 3520) WKR

3530 FORMAT (3, /, 3x) PERFORMANCE REPORT FOR PERIOD ENDING IN WKR 01 7/1

WRITE (6, 3530) WKR
101  **DEF:INIT/2147483649*I**  
**K**  
**PEFAR**  
**ARI**  
**AKAI**  
**ARK**  
**AR**  
**CONTINUE**  
**RETURN**  
**END**  
**SUBROUTINE FCST**  
**C DECLARATIONS**  
**COMMON/CCS/ISTTA10,ISTT20,FPET210,ISTT10,ISTT210**  
**INTEGER**  
**CONTINUE**  
**RETURN**  
**END**  
**SUBROUTINE AGGR**  
**C DECLARATIONS**  
**COMMON/CCS/ISTTA10,ISTT20,FPET210,ISTT10,ISTT210**  
**INTEGER**  
**CONTINUE**  
**RETURN**
APPENDIX C

The Production and Work force
Linear Decision Rules (LDR)
for "FACTORYS 2" Final Products
Linear Decision Rules for Work Force
and Production Planning

Product 1:

\[
P_t = \Sigma \begin{pmatrix}
.149543 F_{t+1} \\
.105065 F_{t+2} \\
.067415 F_{t+3} \\
.038495 F_{t+4} \\
.018102 F_{t+5} \\
.004961 F_{t+6} \\
.002588 F_{t+7} \\
.006179 F_{t+8} \\
.007210 F_{t+9} \\
-.007210 F_{t+10} \\
-.006760 F_{t+11} \\
-.005598 F_{t+11}
\end{pmatrix} + 5.41 W_{t-1} + 882.5 + .1954 (F_t - I_{t-1})
\]

\[
W_t = .07 W_{t-1} + 5.65 - .0012 F_{t-1} - I_{t-1} + \Sigma \begin{pmatrix}
.001090 F_{t+1} \\
.000850 F_{t+2} \\
.000608 F_{t+3} \\
.000398 F_{t+4} \\
.000234 F_{t+5} \\
.000116 F_{t+6} \\
.000039 F_{t+7} \\
.000027 F_{t+8} \\
.000020 F_{t+9} \\
.000038 F_{t+10} \\
.000037 F_{t+11}
\end{pmatrix}
\]
Product 2:

\[
P_t = \sum \begin{pmatrix} 
.094734 & F_{t+1} \\
.076982 & F_{t+2} \\
.059727 & F_{t+3} \\
.044140 & F_{t+4} \\
.030830 & F_{t+5} \\
.020003 & F_{t+6} \\
.011595 & F_{t+7} \\
.005373 & F_{t+8} \\
.001022 & F_{t+9} \\
.001807 & F_{t+10} \\
.003452 & F_{t+11} 
\end{pmatrix} + 5.04 \ W_{t-1} + 302.21 + .111 \ (F_t - I_{t-1})
\]

\[
W_t = .13 \ W_{t-1} + 4.21 + .0015 \ F_t - I_{t-1} + \sum \begin{pmatrix} 
.00145 & F_{t+1} \\
.001258 & F_{t+2} \\
.001039 & F_{t+3} \\
.000818 & F_{t+4} \\
.000615 & F_{t+5} \\
.000438 & F_{t+6} \\
.000292 & F_{t+7} \\
.000177 & F_{t+8} \\
.000090 & F_{t+9} \\
.000028 & F_{t+10} \\
.000013 & F_{t+11} 
\end{pmatrix}
\]
Product 3:

\[ P_t = \sum \left( \begin{array}{c}
.077726 F_{t+1} \\
.065947 F_{t+2} \\
.053842 F_{t+3} \\
.041485 F_{t+4} \\
.030671 F_{t+5} \\
.021414 F_{t+6} \\
.013845 F_{t+7} \\
.007924 F_{t+8} \\
.003506 F_{t+9} \\
.000385 F_{t+10} \\
.001667 F_{t+11}
\end{array} \right) + 3.63 W_{t-1} + 158.48 + .087118 (F_t - I_{t-1}) \]

\[ W_t = .06 W_{t-1} + 1.88 + .0010 F_{t-I_{t-1}} + \sum \left( \begin{array}{c}
.000978 F_{t+1} \\
.000856 F_{t+2} \\
.000714 F_{t+3} \\
.00057 F_{t+4} \\
.000435 F_{t+5} \\
.000316 F_{t+6} \\
.000215 F_{t+7} \\
.000134 F_{t+8} \\
.000072 F_{t+9} \\
.000026 F_{t+10} \\
-.000005 F_{t+11}
\end{array} \right) \]
Product 4:

\[
P_t = \sum \begin{pmatrix} 
0.135974 F_{t+1} \\
0.099731 F_{t+2} \\
0.066589 F_{t+3} \\
0.039747 F_{t+4} \\
0.020005 F_{t+5} \\
0.006785 F_{t+6} \\
-0.001138 F_{t+7} \\
-0.005153 F_{t+8} \\
-0.006543 F_{t+9} \\
-0.006354 F_{t+10} \\
-0.00536 F_{t+11} 
\end{pmatrix} + 1.44 W_{t-1} + 152.2 + .1684 (F_t - I_{t-1})
\]

\[
W_t = .037 W_{t-1} + 2.789982 + .0031 (F_t - I_{t-1}) + \sum \begin{pmatrix} 
0.002677 F_{t+1} \\
0.002069 F_{t+2} \\
0.001457 F_{t+3} \\
0.00093 F_{t+4} \\
0.000521 F_{t+5} \\
0.000232 F_{t+6} \\
0.000047 F_{t+7} \\
0.000057 F_{t+8} \\
0.000104 F_{t+9} \\
0.000114 F_{t+10} \\
0.000103 F_{t+11} 
\end{pmatrix}
\]
Product 5:

\[
P_t = \Sigma \begin{pmatrix}
.16895 & F_{t+1} \\
.111057 & F_{t+2} \\
.063596 & F_{t+3} \\
.029768 & F_{t+4} \\
.008538 & F_{t+5} \\
-.002909 & F_{t+6} \\
-.007690 & F_{t+7} \\
-.008488 & F_{t+8} \\
-.007288 & F_{t+9} \\
-.005381 & F_{t+10}
\end{pmatrix}
+ 1.87 W_{t-1} + 306.28 + .226 (F_t - I_{t-1})
\]

\[
W_t = .035 W_{t-1} + 3.67 + .0027 (F_t - I_{t-1}) + \Sigma
\]

\[
\begin{pmatrix}
.002228 & F_{t+1} \\
.00158 & F_{t+2} \\
.000987 & F_{t+3} \\
.000528 & F_{t+4} \\
.000218 & F_{t+5} \\
.000033 & F_{t+6} \\
.000059 & F_{t+7} \\
.000091 & F_{t+8} \\
.000089 & F_{t+9} \\
.000071 & F_{t+10} \\
.00005 & F_{t+11}
\end{pmatrix}
\]
Product 6:

\[
P_t = \Sigma \begin{pmatrix}
0.083818 F_{t+1} \\
0.070446 F_{t+2} \\
0.056065 F_{t+3} \\
0.042285 F_{t+4} \\
0.030060 F_{t+5} \\
0.019852 F_{t+6} \\
0.011777 F_{t+7} \\
0.005726 F_{t+8} \\
0.001456 F_{t+9} \\
-0.001335 F_{t+10} \\
-0.002965 F_{t+11}
\end{pmatrix} + 0.667 W_{t-1} + 31.90 + 0.093 (F_t - I_{t-1})
\]

\[
W_t = 0.025 W_{t-1} + 1.03 + 0.003 (F_t - I_{t-1}) + \Sigma \begin{pmatrix}
0.002832 F_{t+1} \\
0.002424 F_{t+2} \\
0.001962 F_{t+3} \\
0.001505 F_{t+4} \\
0.001091 F_{t+5} \\
0.000739 F_{t+6} \\
0.000456 F_{t+7} \\
0.00024 F_{t+8} \\
0.000085 F_{t+9} \\
-0.000019 F_{t+10} \\
-0.000083 F_{t+11}
\end{pmatrix}
\]
Product 7:

\[
P_t = \sum \begin{bmatrix} 
.173625 F_{t+1} \\
.112230 F_{t+2} \\
.064513 F_{t+3} \\
.031117 F_{t+4} \\
.010024 F_{t+5} \\
-.011735 F_{t+6} \\
-.007100 F_{t+7} \\
-.008523 F_{t+8} \\
-.007822 F_{t+9} \\
-.006214 F_{t+10} \\
-.004433 F_{t+11} 
\end{bmatrix} + 2.957 W_{t-1} + .2427 (F_t - I_{t-1})
\]

\[
W_t = .097 W_{t-1} + 7.3821 + .0032 (F_t - I_{t-1}) + \sum 
\begin{bmatrix} 
.002761 F_{t+1} \\
.002055 F_{t+2} \\
.001383 F_{t+3} \\
.000835 F_{t+4} \\
.000436 F_{t+5} \\
.000174 F_{t+6} \\
.000020 F_{t+7} \\
-.000058 F_{t+8} \\
-.000085 F_{t+9} \\
-.000085 F_{t+10} \\
-.000071 F_{t+11} 
\end{bmatrix}
\]
Product 8:

\[
P_{t} = \sum \begin{bmatrix}
.195094 & F_{t+1} \\
.114295 & F_{t+2} \\
.056487 & F_{t+3} \\
.020265 & F_{t+4} \\
.000643 & F_{t+5} \\
.007887 & F_{t+6} \\
.009935 & F_{t+7} \\
.008794 & F_{t+8} \\
.006518 & F_{t+9} \\
.004220 & F_{t+10} \\
.002379 & F_{t+11}
\end{bmatrix} + 4.48 \, W_{t-1} + 1116.1 + .291 \, (F_{t} - I_{t-1})
\]

\[
W_{t} = .071 \, W_{t-1} + 7.36 + .0019 \, (F_{t} - I_{t-1}) + \sum \begin{bmatrix}
.001541 & F_{t+1} \\
.001060 & F_{t+2} \\
.000638 & F_{t+4} \\
.000129 & F_{t+5} \\
.000017 & F_{t+6} \\
.000034 & F_{t+7} \\
.000049 & F_{t+8} \\
.000045 & F_{t+9} \\
.000035 & F_{t+10} \\
.000023 & F_{t+11}
\end{bmatrix}
\]
Product 9:

\[
P_t = \sum \left( \begin{array}{c}
.151549 F_{t+1} \\
.106007 F_{t+2} \\
.066043 F_{t+3} \\
.035419 F_{t+4} \\
.014453 F_{t+5} \\
.001713 F_{t+6} \\
-.004864 F_{t+7} \\
-.007313 F_{t+8} \\
-.007318 F_{t+9} \\
-.009115 F_{t+10} \\
-.004514 F_{t+11}
\end{array} \right) + 1.359 W_{t-1} + 174.51 + .193 (F_t - I_{t-1})
\]

\[
W_t = .028 W_{t-1} + 2.65 + .0029 (F_t - I_{t-1}) + \sum \left( \begin{array}{c}
.002467 F_{t+1} \\
.001820 F_{t+2} \\
.001201 F_{t+3} \\
.000697 F_{t+4} \\
.000333 F_{t+5} \\
.000099 F_{t+6} \\
-.000034 F_{t+7} \\
-.000093 F_{t+8} \\
-.000107 F_{t+9} \\
-.000097 F_{t+10} \\
-.000076 F_{t+11}
\end{array} \right)
\]
Product 10:

\[ P_t = \sum_{i=0}^{11} \begin{bmatrix} .136562 \, F_{t+1} \\ .100157 \, F_{t+2} \\ .066475 \, F_{t+4} \\ .03917 \, F_{t+5} \\ .019204 \, F_{t+6} \\ .005994 \, F_{t+7} \\ -.001756 \, F_{t+8} \\ -.005526 \, F_{t+9} \\ -.006672 \, F_{t+10} \\ -.006285 \, F_{t+11} \end{bmatrix} + .869 \, W_{t-1} + 91.06 + .167 \left( F_t - I_{t-1} \right) \]

\[ W_t = .25 \, W_{t-1} + 2.04 + .0038 \left( F_t - I_{t-1} \right) + \xi \]

\[ \xi \begin{bmatrix} .003247 \, F_{t+1} \\ .002477 \, F_{t+2} \\ .001711 \, F_{t+3} \\ .001062 \, F_{t+4} \\ .000567 \, F_{t+5} \\ .000227 \, F_{t+6} \\ .000016 \, F_{t+7} \\ -.000096 \, F_{t+8} \\ -.000140 \, F_{t+9} \\ -.000142 \, F_{t+10} \\ -.000122 \, F_{t+11} \end{bmatrix} \]
APPENDIX D

SUPPORTIVE STATISTICS

BARTLETTE TEST
CORRELATION ANALYSIS
CHI SQUARE TEST
CONFIDENCE INTERVALS
Bartlett Test

Bartlett test is used for studying whether or not the sample populations have equal variances, as required by the analysis of variance model. Bartlett (B) statistics is:

\[ B = \frac{2.302585}{C} (n_t-r) (\log_{10} \text{MSE} - \log_{10} \text{GMSE}) \]

where \( n_t \) = total number of observations,
\( r = \) number of populations,
\( \text{MSE} = \frac{1}{n_t-r} \sum_{j=1}^{r} (n_j-1) S_j^2 \) is mean square error,
\( \text{GMSE} = \left[ (S_1^2)^{n_1-1} (S_2^2)^{n_2-1} \ldots (S_r^2)^{n_r-1} \right]^{1/(n_t-r)} \) is the weighted geometric average of the \( S_j^2 \), and

\[ C = 1 + \frac{1}{3(r-1)} \left[ \sum_{j=1}^{r} \frac{1}{n_j-1} - \frac{1}{n_t-r} \right]. \]

The above formulat for \( B \) reduces to:

\[ B = \frac{2.302585}{C} [(n_t-r) \log_{10} \text{MSE} - \sum_{j=1}^{r} (n_j-1) \log_{10} S_j^2] \]

where the term 2.302585 is a factor to convert logarithms on the base 10 to logarithms on the base e. The following hypotheses are tested by the Bartlette Statistic:

\[ \begin{cases} H_0 : \sigma_1 = \sigma_2 = \ldots = \sigma_r \\ H_1 : \text{not all } \sigma_j \text{ are equal.} \end{cases} \]

Statistic \( B \) is approximately distributed as \( X^2 \) with \((r-1)\) degrees of freedom when \( H_0 \) holds. Hence the appropriate decision rule for controlling the risk of Type I error at \( \alpha \) is:

if \( B \leq X^2 (1-\alpha; r-1) \), conclude \( H_0 \)

if \( B > X^2 (1-\alpha; r-1) \), conclude \( H_1 \).
The following B statistics for the dependent variables of this study were calculated using the above formulas.

- decision time $43.8186$
- dollar profits $49.921$
- satisfaction $33.731$
- ease $40.029$
- willingness $35.920$
- importance $36.284$

The risk of Type I error was controlled at .05. Therefore the above B statistics were compared with $X^2 (0.95, 11) = 55.76$.

The decision rules were:

- if $B \leq 55.76$ conclude $H_0$
- if $B > 55.76$ conclude $H_1$

Since the B values above are all less than 55.76, it was concluded that the population variances for the dependent measures were all equal.

**Correlation Analysis**

The association between the user familiarity and experience with the dependent variables of the study: decision time, profits, satisfaction, ease, willingness and importance were measured with the Spearman rank correlation coefficient (also called rho statistics). The Spearman rank correlation coefficient $r_s$ is calculated by:

$$r_s = 1 - \frac{6 \sum d_i^2}{N^3 - N}$$
where \( d_i = X_i - Y_i \) is the difference between the two measures in the \( i \)th observation; and \( N \) = total number of observations.

The Spearman correlation coefficients were calculated using SAS statistical package. The \( r_s \) values are presented in Table 21.

Table 21
The Spearman rank correlation coefficients

<table>
<thead>
<tr>
<th>Variables</th>
<th>familiarity</th>
<th>experiment</th>
</tr>
</thead>
<tbody>
<tr>
<td>time</td>
<td>0.10282</td>
<td>0.01054</td>
</tr>
<tr>
<td>profits</td>
<td>0.01869</td>
<td>0.28768</td>
</tr>
<tr>
<td>satisfaction</td>
<td>0.10853</td>
<td>0.04284</td>
</tr>
<tr>
<td>ease</td>
<td>0.11082</td>
<td>0.26156</td>
</tr>
<tr>
<td>willingness</td>
<td>-0.10341</td>
<td>0.18762</td>
</tr>
<tr>
<td>importance</td>
<td>-0.21111</td>
<td>-0.06931</td>
</tr>
</tbody>
</table>

Usage variable being a dichotomous variable was not entered into the correlation analysis. Instead, the means of familiarity scores at different levels of the dichotomous variable were examined. The mean familiarity score for subjects who used the decision aids was 3.15 and the mean score for the subjects who did not use the decision aids was 3.25, which was not significantly different. The data on the usage of the decision aids for the subjects with different levels of experience is presented in Table 22. Chi-square test statistics indicated no significant association between the user experience and usage of the decision aids.
### Table 22

usage of decision aids for different levels of experience.

<table>
<thead>
<tr>
<th>Experience</th>
<th>1 course</th>
<th>2 courses</th>
<th>Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 course</td>
<td>22</td>
<td>11</td>
<td>45</td>
</tr>
<tr>
<td>2 courses</td>
<td>23</td>
<td>12</td>
<td>35</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td><strong>45</strong></td>
<td><strong>23</strong></td>
<td><strong>68</strong></td>
</tr>
</tbody>
</table>

* Calculated $X^2 = .0698$

---

**Chi-Square Test of Association.**

Chi-square test of association was used to study the effects of the treatments (decision aids) and decision styles on the usage of decision aiding strategies. Tables 23 and 24 present the observed and expected frequencies for usage and decision aids and decision styles.

**Effects of decision aids on usage.**

The following hypotheses were tested:

\[
\begin{align*}
H_0 &: E(o_{i,j}) = E_{i,j} \\
H_1 &: E(o_{i,j}) \neq E_{i,j}
\end{align*}
\]

If the null hypothesis ($H_0$) is rejected, it is concluded that the usage of the decision aid is influenced by the decision aid supplies. The calculated $X^2$ is:
\[ X^2 = \sum \sum \left( \frac{\text{E}_{ij} - \text{O}_{ij}}{\text{E}_{ij}} \right)^2 \]

\[ = \left( \frac{8.18-6}{8.18} \right)^2 + \left( \frac{7.16-5}{7.16} \right)^2 + \left( \frac{7.67-12}{7.67} \right)^2 + \left( \frac{10-7.82}{7.82} \right)^2 \]

\[ + \left( \frac{9-6.84}{6.84} \right)^2 + \left( \frac{7.33-3}{7.33} \right)^2 \]

\[ X = 7.52 \text{ with two degrees of freedom.} \]

Therefore, \( H_0 \) is rejected at significance level \( \alpha = .05 \).

**TABLE 23**

Frequency of usage presented in terms of decision aids

<table>
<thead>
<tr>
<th>decision aid usage</th>
<th>LDR</th>
<th>regression</th>
<th>evolutionary</th>
<th>totals</th>
</tr>
</thead>
<tbody>
<tr>
<td>used</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>23</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>5</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td></td>
<td>8.18</td>
<td>7.16</td>
<td>7.67</td>
<td></td>
</tr>
<tr>
<td></td>
<td>E</td>
<td>E</td>
<td>E</td>
<td></td>
</tr>
<tr>
<td>not used</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>9</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>7.82</td>
<td>6.84</td>
<td>7.33</td>
<td></td>
</tr>
<tr>
<td></td>
<td>E</td>
<td>E</td>
<td>E</td>
<td></td>
</tr>
<tr>
<td>totals</td>
<td>16</td>
<td>14</td>
<td>15</td>
<td>45</td>
</tr>
</tbody>
</table>
### Table 24

Frequency of usage presented in terms of decision styles

<table>
<thead>
<tr>
<th>decision styles</th>
<th>usage</th>
<th>ST</th>
<th>NT</th>
<th>NF</th>
<th>SF</th>
<th>totals</th>
</tr>
</thead>
<tbody>
<tr>
<td>used</td>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6.06</td>
<td>6.5</td>
<td>4.20</td>
<td>4.20</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>E</td>
<td>E</td>
<td>E</td>
<td>E</td>
<td></td>
</tr>
<tr>
<td>not used</td>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7.46</td>
<td>4.48</td>
<td>4.48</td>
<td>4.8</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>E</td>
<td>E</td>
<td>E</td>
<td>E</td>
<td></td>
</tr>
</tbody>
</table>

|               |       | 13 | 14 | 9  | 9  | 45     |

**Effects of Decision Styles on Usage.**

The following hypotheses were tested.

\[
\begin{align*}
H_0 : & \quad E(0_{ij}) = E_{ij} \\
H_1 : & \quad E(0_{ij}) \neq E_{ij}
\end{align*}
\]

If the null hypothesis \(H_0\) is rejected, it is inferred that there is no association between the decision styles and usage of decision aiding strategies. The calculated \(X^2\) is:

\[
X^2 = \frac{2}{I} \sum_{i,j} \frac{(E_{ij} - O_{ij})^2}{E_{ij}}
\]

\[
X^2 = \frac{(6.06-5)^2}{6.06} + \frac{(7-6.5)^2}{6.5} + \frac{(5-4.2)^2}{4.2} + \frac{(4.20-4)^2}{4.2} \\
+ \frac{(8-6.93)^2}{6.93} + \frac{(7.46-7)^2}{7.46} + \frac{(4.8-4)^2}{4.8} + \frac{(5-4.8)^2}{4.8}
\]

\[
X^2 = 2.29 \text{ with three degrees of freedom.}
\]
Therefore, $H_0$ is not rejected. That is, there is no association between the decision styles and usage. The frequency of use of the LDRS for the ST, NT, NF and SF types is indicated in Table 25. Chi-square test indicated no significant relationship between the decision styles and the usage.

Table 25

Frequency of use of LDRS for the four decision styles

<table>
<thead>
<tr>
<th>decision styles</th>
<th>ST</th>
<th>NT</th>
<th>NF</th>
<th>ST</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>9</td>
<td>10</td>
<td>6</td>
<td>6</td>
<td>31</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>5</td>
<td>3</td>
<td>3</td>
<td>16</td>
</tr>
</tbody>
</table>

Bonferroni multiple comparisons.

Bonferroni multiple comparison method was used in this study to unequal cell sizes. In this method a $(1-\alpha)$ family of confidence intervals for mean responses at different levels of factors A and B (decision styles and decision aiding strategies) is given by:

$$ \hat{L}_{i} - Bs (\hat{L}_{i}) < \hat{L}_{i} < \hat{L}_{i} + Bs (\hat{L}_{i}) \quad i = 1, \ldots, s.$$  

where: $B = t (1-a/2) s, \eta_i = ab$,

$s =$ number of statements in the family

$\hat{L}_{i} = \Sigma c_i Y_i \ldots$ is an estimate of contrast among the factor level means $\mu_i$ and $c_i = 0$

$s (\hat{L}_{i}) = \frac{MSE}{a} \frac{t}{2} (c_{ij}/n_{ij})$ is the unbiased estimator of $\hat{L}_{i}$'s variance and $n_{ij} =$ observation/cell.
Confidence Intervals for decision styles and decision time.

The analysis of variance indicated a significant main effect of decision style on decision time (Table 8). The confidence intervals for the following contrasts were calculated:¹²

\[ \hat{L}_1 = M_1 - M_2 \]
\[ \hat{L}_2 = M_1 - M_3 \]
\[ \hat{L}_3 = M_1 - M_4 \]

The unbiased estimators for the above contrasts are:

\[ \hat{L}_1 = Y_{.1} - Y_{.2} = 7.10 \]
\[ \hat{L}_2 = Y_{.1} - Y_{.3} = 7.19 \]
\[ \hat{L}_3 = Y_{.1} - Y_{.4} = 6.19 \]

From Table 8 we have: MSE = 1459.03/33 = 44.2130, and \( a = 3 \).

We also have \( s = 6 \). The calculation of multiple intervals are indicated in Table 26.

¹² The Confidence intervals for \( \mu_{.2} - \mu_{.3} \), \( \mu_{.2} - \mu_{.4} \) and \( \mu_{.3} - \mu_{.4} \) all contained zero. Hence, the calculations for these confidence intervals are not shown.
TABLE 26

Calculations of confidence intervals for decision time

<table>
<thead>
<tr>
<th>$\hat{L}_1$</th>
<th>$S^2(\hat{L}<em>1) = \frac{\text{MSE} \sum C</em>{ij}^2}{n_i j}$</th>
<th>$S(\hat{L}_1)$</th>
<th>$S(\hat{L}_1) \cdot B = S(\hat{L}_1) \cdot t(.99,33)$</th>
<th>Confidence Intervals</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.10</td>
<td>4.9126(1.35)</td>
<td>2.5753</td>
<td>6.0520</td>
<td>[1.0480,13.152]</td>
</tr>
<tr>
<td>7.19</td>
<td>4.9126(1.7)</td>
<td>2.8899</td>
<td>6.7912</td>
<td>[.3988,13.9812]</td>
</tr>
<tr>
<td>6.19</td>
<td>4.9126(1.56)</td>
<td>2.7683</td>
<td>6.5056</td>
<td>[.3156,12.6956]</td>
</tr>
</tbody>
</table>

Confidence Intervals for Satisfaction Scores.

Analysis of variance results (Table 14) indicated a significant main effect between the decision aids provided and the user satisfaction. Mean satisfaction scores for the three decision aids using Bonferroni method calculated for:

$L_1 = \mu_1 - \mu_2$, estimated by $\hat{L}_1 = Y_{1..} - Y_{2..} = -.03$

$L_2 = \mu_1 - \mu_3$, estimated by $\hat{L}_2 = Y_{1..} - Y_{3..} = -1.06$

$L_3 = \mu_2 - \mu_3$, estimated by $\hat{L}_3 = Y_{2..} - Y_{3..} = -1.03$

The following values were used:

$b = 4 \quad a = 3 \quad s = 3$ and MSE = .4096

The calculations are presented in Table 27.
TABLE 27
Confidence intervals for satisfaction scores

<table>
<thead>
<tr>
<th>( \hat{L}_1 = )</th>
<th>( S^2(\hat{L}_1) = )</th>
<th>( S(\hat{L}_1) )</th>
<th>( S(\hat{L}_1) \times B = )</th>
<th>Confidence Intervals</th>
</tr>
</thead>
<tbody>
<tr>
<td>EC_i Y_i</td>
<td>( \frac{\text{MSE}}{b^2} \sum \frac{C_{ij}^2}{n_{ij}} )</td>
<td>( S(\hat{L}_1) )</td>
<td>( S(\hat{L}_1) \times t(0.9833) )</td>
<td></td>
</tr>
<tr>
<td>-.033</td>
<td>.0256(2.0333) = .0520</td>
<td>.22815</td>
<td>.4791</td>
<td>[-.5091, -.4491]</td>
</tr>
<tr>
<td>-.106</td>
<td>.0256(2.183) = .0559</td>
<td>.23642</td>
<td>.4964</td>
<td>[1.5564, -.5635]</td>
</tr>
<tr>
<td>-.103</td>
<td>.0256(2.283) = .0585</td>
<td>.24177</td>
<td>.5077</td>
<td>[-1.5377, -.5223]</td>
</tr>
</tbody>
</table>

Confidence Intervals for "importance" scores.

Analysis of variance results indicated a significant main effect between the decision aids and "importance" scores. Hence confidence intervals for the following contracts involving the pairwise comparison of means were calculated for:

\[
L_1 = \mu_1 - \mu_2 \quad \text{estimated by} \quad Y_{1\cdot} - Y_{2\cdot} = .12
\]

\[
L_2 = \mu_1 - \mu_3 \quad \text{estimated by} \quad Y_{1\cdot} - Y_{3\cdot} = -1.12
\]

\[
L_3 = \mu_2 - \mu_3 \quad \text{estimated by} \quad Y_{2\cdot} - Y_{3\cdot} = -1.24
\]

The following values were used in the calculations.

\[
\text{MSE} = .124592, \quad a = 3 \quad b = 4 \quad S = 3.
\]

The confidence intervals are presented in Table 28.
### TABLE 28
Confidence intervals for "importance" scores

<table>
<thead>
<tr>
<th>( \hat{L}_1 )</th>
<th>( S^2(\hat{L}_1) = )</th>
<th>( S(\hat{L}_1) \ast B = )</th>
<th>Confidence Intervals</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \Sigma c_{ij}^{2} \Sigma \frac{n_{ij}}{b^2} )</td>
<td>( \frac{MSE}{b^2} )</td>
<td>( S(\hat{L}_1) \ast t(.98,33) )</td>
<td>(</td>
</tr>
<tr>
<td>( .12 )</td>
<td>( .12459(2.233) = ) ( .2782 )</td>
<td>( .52745 )</td>
<td>( 1.1076 )</td>
</tr>
<tr>
<td>( -1.12 )</td>
<td>( .12459(2.183) = ) ( .2720 )</td>
<td>( .52152 )</td>
<td>( 1.0951 )</td>
</tr>
<tr>
<td>( -1.24 )</td>
<td>( .12459(2.283) = ) ( .2720 )</td>
<td>( .5333 )</td>
<td>( 1.1199 )</td>
</tr>
</tbody>
</table>

**Scheffe Multiple Comparison Intervals**

When analysis of variance results indicated significance interaction effects, Scheffe's multiple comparison procedure was used here because the number of contracts involving the pairwise comparison of means was higher than the number of factor levels.

Scheffe's joint confidence intervals are:

\[
\hat{L} - Ss(L) < L < \hat{L} + Ss(\hat{L})
\]

where

\[
\hat{L} = \Sigma c_{ij}^{2} y_{ij}, \Sigma c_{ij}^{2} = 0
\]

\[
\hat{L} = \Sigma c_{ij} y_{ij}.
\]

\[
s^{2}(\hat{L}) = \frac{MSE}{n_{ij}}\Sigma c_{ij}^{2} \text{ and}
\]

\[
S^{2} = (ab-1) F (1-\alpha; \, ab-1; \, N_{j} - ab).
\]
Confidence Intervals for interaction effects.

The analysis of variance results indicated significant interaction effects for satisfaction and willingness dependent variables. Using the Scheffe's method, the cell means were compared for these variables. The significant differences and the corresponding calculations are presented in Tables 29 and 30.

**TABLE 29**

Significant confidence intervals for satisfaction means

<table>
<thead>
<tr>
<th>$S (\hat{L}_1)$</th>
<th>$S^2 (\hat{L}_1)$</th>
<th>$S(\hat{L}_1)$</th>
<th>$S(L)*S = S(L)*F(.9, 11, 33)$</th>
<th>Confidence Intervals</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Sigma c_{ij} \frac{Y_{i}j}{n_{ij}}$</td>
<td>$\Sigma \frac{c_{ij}}{n_{ij}}$ MSE</td>
<td>.4088(.45) = .184</td>
<td>.4044</td>
<td>1.1102</td>
</tr>
<tr>
<td>$Y_{11} - Y_{21} = 1.15$</td>
<td>$Y_{21} - Y_{31} = 2.25$</td>
<td>.4088(.5) = .2044</td>
<td>.4521</td>
<td>1.4648</td>
</tr>
</tbody>
</table>
### TABLE 30

Significant confidence intervals for willingness means

<table>
<thead>
<tr>
<th>$S \left( \hat{L}_1 \right)$</th>
<th>$S^2 \left( \hat{L}_1 \right)$</th>
<th>$S(\hat{L}_1)$</th>
<th>$S(\hat{L}_1) \times S = S(\hat{L}_1) \times F$</th>
<th>Confidence Intervals</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\sum c_{ij} \bar{Y}_{ij}$</td>
<td>$\frac{S^2 \left( \hat{L}_1 \right)}{MSE}$</td>
<td>$\frac{S(\hat{L}<em>1)}{n</em>{ij}}$</td>
<td>$\left( .9, 11, 33 \right)$</td>
<td></td>
</tr>
<tr>
<td>$Y_{11} - Y_{21} = 1.05$</td>
<td>$.2033(.75)$</td>
<td>$.3025$</td>
<td>$.98$</td>
<td>$[.07, 2.03]$</td>
</tr>
<tr>
<td>$Y_{31} - Y_{21} = 2$</td>
<td>$.2033(.5)$</td>
<td>$.3188$</td>
<td>$1.033$</td>
<td>$[.967, 3.033]$</td>
</tr>
</tbody>
</table>
BIBLIOGRAPHY


