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MANAGEMENT SUPPORT SYSTEM EFFECTIVENESS: FURTHER EMPIRICAL EVIDENCE[1]

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ABSTRACT

Modern research has engendered frameworks, such as the management support system (MSS), that are designed to provide comprehensive and integrated support for the decision making process. While one recent study has empirically measured the effects of these frameworks on decision making, there have been few, if any, corroborating or deprecating investigations. This article offers further empirical evidence on MSS effectiveness.

[1]Both authors contributed equally to this paper.

The paper begins with a brief overview of the previous research. Next, it assesses the influences of the MSS on the process and outcomes of business policy decision making. The paper also examines the implications of the analyses for information systems research and management practice.

Keywords: business policy, decision making processes, decision support systems, decision outcome measures, decision process measures, management support systems

I. INTRODUCTION

Modern decision making, particularly business decision making, is an art that can be enhanced with science and technology. Decision support, expert, and executive information systems can be used to provide the artistic, scientific, and technological support needed for effective decision making. A variety of studies have provided empirical verifications of this notion. Table 1 summarizes a small sample of recent empirical studies.

While each of the individual systems can bolster a separate segment of the process, no one system by itself is designed to render entire decision making support. Comprehensive support will require a consolidation of the separate decision support system, expert system, and executive information system functions and an effective delivery of the integrated capabilities (El-Najdawi and Stylianou 1993; Fazlollahi 1997; Forgionne 1991; Gottinger and Weimann 1992). Integrating the standalone functions can enhance the quality and efficiency of the segmented support, create synergistic effects, and augment decision making performance and value (Potter et al. 1992; Silverman 1994).

A high level of integration can be achieved by embellishing a decision support system with executive information and expert systems to form a "management support system (MSS)." In theory, such a system provides more problem-specific information and knowledge, and thereby offers more support for decision making, than less integrated systems. Improvement should be reflected in the process of, as well as the outcomes from, decision making.

Table 1. A Sample of Recent Empirical DISS/ES/EIS Studies

AUTHORS	RESEARCH OBJECTIVES	RESULTS
Clements (1993)	Assess the effects of a creativity-enhancing DSS on decision making	The creativity-enhancing DSS significantly improved the decision making process of novice and experienced users
Forgionne and Kohli (1995)	Assess the effects of MSS (DSS enhanced with ES and EIS) on the process and outcome of healthcare decision makers	MSS had significant effect on the subjects' ability to recognize problems, generate and evaluate alternatives, and choose the final alternative. Subjects also rated the system as effective in decision making
Lamberti and Wallace (1990)	Assess the effects of knowledge presentation and decision performance between high and low skill decision makers	High skill subjects performed faster and more accurately and reported higher confidence than low skill decision makers
Leidner and Elam (1993-94)	Assess the effects of EIS on decision making	EIS facilitates selected decision making tasks for users
Lipshitz and Bar-Ilan (1996)	Assess that the DSS users follow the perspective or descriptive six-phase probabilistic problem-solving model	In both types of cases, the location of phases in the problem-solving process was consistent with the sequence prescribed by the model, and the order of consecutive phases, irrespective of location in the sequence, was also consistent with the model
Mackay and Elam (1992)	Assess the effects of decision aid on experts and novices, in functional and task domain, problem solving	Decision aid expertise is required to successfully apply functional expertise
Newman (1993)	Assess the effects of DSS on organizational performance	Net income increased significantly for DSS over non-DSS users
Tan and Benbasat (1993)	Assess the influence of graph types on information extraction effectiveness	Graph type influences decision task performance
Todd and Benbasat (1991)	Assess the effects of DSS and model features on decision strategies	Decision makers tend to adapt their strategy selection to the type of decision aid to reduce effort
Sainfort et al. (1990)	Assess the effects of a DSS and video tape on conflict resolution between couples	Subjects with DSS generated more alternative solutions and reported a higher perceived progress in the resolution of the problem

NOTE: In this table, DSS = decision support system, ES = expert system, EIS = executive information system, and MSS = management support system.

Recently, the theory has been tested empirically through a series of health-care experiments (Forgionne and Kohli 1995). In these experiments, clinicians and administrators used a DSS and a MSS to help make strategic decisions for a simulated hospital. Both the DSS and MSS were tailored to the specific needs of hospital decision-makers. By comparing DSS- and MSS-assisted results, it was possible to measure the MSS's influence on hospital decision making. The test results generally supported the hypotheses that the MSS improved both the process of, and outcomes from, the simulated decision making.

Although the MSS showed promise, the concept needed further research. Among other things, the application base should be expanded beyond hospitals. Also, MSS effects on novices, as well as experts, should be evaluated. To date, however, there have been no other follow-up studies reported in the literature.

This article presents an additional empirical investigation designed to assess the effectiveness of management support systems (MSS) on strategic decision making. It reports the research plan, details of the experiment, and experimental findings. Then, the paper discusses these findings and examines the implications for information systems research and management practice.

II. BUSINESS POLICY EXPERIMENT

To realize strategic business objectives, executives will need complete, integrated, and systematic analyses and sharing in real time of marketing, finance, and marketing information and knowledge (West and Courtney 1993). There are information technologies to support selected strategic decision making tasks, including individual (stand-alone) decision support systems (Parsaye and Chigell 1993) and separate expert systems (Spangler 1991; Tyran and George 1993). Since the separate systems focus on individual department tasks, however, they cannot deliver the organization-oriented information or knowledge needed to optimize business performance.

By providing organization modeling, data access and reporting, and knowledge delivery, a management support system, in theory, can help executives make decisions that better achieve the strategic policy objectives of a business. Improvements should be observed in both the outcomes from, and the process of, strategic business decision making. An experiment was developed to test this theory.

SUBJECTS

As in many previous DSS, EIS, and ES studies, the business policy experiment utilized students as subjects. The original design called for a single sample involving a representative mix of undergraduate and graduate students. For budgetary and logistical reasons, the participants were students in a cross-listed Decision Support and Expert System course taught by one of the authors. This course was both an upper-division requirement for undergraduates and a core obligation for graduate students in a major public university's information systems programs. Students taking the course as undergraduates were not allowed to repeat the course as graduate students. Because of teaching assignments, there was about a two-year period that elapsed between the time that the author offered the undergraduate and graduate versions of the course.

Budgetary, logistical, and timing considerations, then, necessitated an experiment that consisted of two independent samples. Table 2 briefly describes these samples and summarizes the modal characteristics of their volunteer subjects.

While the program restrictions should have excluded Experiment UG enrollees from the Experiment G course, it is possible that some students may have circumvented the rules. To check for such a possibility, the two class rosters were compared. This roster check revealed that none of the Experiment UG students participated in the experiments again as students in Experiment G. On a related issue, the university's undergraduates are generally full-time, day students, while the graduate students have tended to be part-time, evening students. This disparity in student populations plus the approximately two-year time spread between experiments made it unlikely that the subjects from the first experiment shared information with the subjects of the later experiment.

Table 2. Business Policy Experiments

Experiment	Subjects (Number)	Demographics					
		Age (Years)	Sex	Major	GPA (Mean)	Work Experience (in Years)	Field of Experience
IS 93 Experiment (UG). Undergraduate information systems students enrolled in a core DSS course	18	24.23	45% Female 55% Male	Info. Systems	3.168	3.26	36% Business
IS 95 Experiment (G). Graduate information systems students enrolled in a core DSS course	16	28.35	47% Female 40% Male 3% not reported	Info. Systems	3.469	5.42	43% Information Systems

Student subjects were solicited by the participating course professor. All class members participated in return for (1) feedback on their competitive performance, (2) exposure to decision technologies, and (3) as part of the learning experience in the courses. As an added incentive, the financial performance of the simulated organizations affected the students' final grades in the course. Students managing the top performing organizations received sufficient additional points to improve their grades substantially, and participants were well informed about, and well aware of, this incentive. In the UG experiments, five students earned the incentive, while four students earned the incentive in the Experiment G. Experiments were conducted during hours usually allocated as lab sessions in the courses and competitive feedback was provided one week after the completion of the experiments.

RESEARCH PLAN

Each experiment followed a research plan adapted from schemes applied successfully in related studies (Adelman 1991; Creswell 1994; Elam and Mead 1990; Gardner et al. 1993). Figure 1 outlines this plan.

Preliminaries. Subjects were introduced to the study through an oral presentation and a supplemental summary document. At a later date, a formal lecture

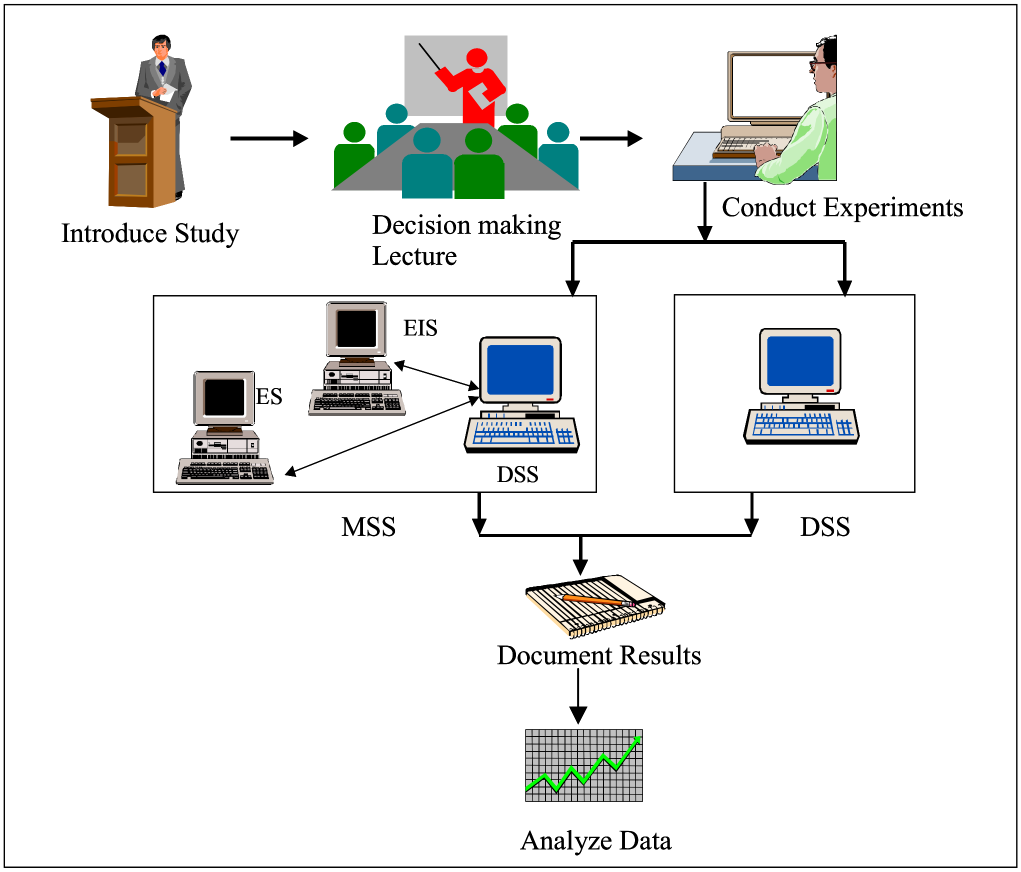

Figure 1. Research Plan

was given about the business policy simulation, the variable to outcome relationships, the decision making process, and the role of information systems in the process. The lecture was augmented with written instructions. Next, a questionnaire was used to collect data on the subjects' demographic characteristics and experience levels and subjects were given practice in using the simulation software to solve several hypothetical, but realistic, strategic decision making problems. The practice sessions continued throughout most of the semester, with the professor available to answer questions about the problems, decision environment, software usage, and other concerns of the participants. Subjects were told, and were well aware, that the practice results would be strictly for learning purposes and would not affect their grades. During the training sessions, it was apparent from the questions and software usage that none of the Experiment UG or Experiment G subjects were initially familiar with the problems, the software, the decision environment, or the decision process.

By the end of the training sessions, the reduction in question quantity and complexity and software usage improvements indicated that significant learning had occurred. All subjects in both experiments had become accustomed to, and comfortable with, the problems, the software, the decision environment, and the decision process.

At this point (toward the end of the semester), students were informed, and were well aware, that the last two lab sessions in the courses would constitute the recorded experiments, with results counting toward their grades. All subjects were given a new problem, similar to but different from the problems they had been working on previously. Both the control and experimental groups were given that same new problem. Initially, the information system was a basic DSS (and the subjects were designated as the control group), and later a MSS was available to facilitate decision-making (and the same subjects were denoted as the control group).

As in previous related studies, this investigation utilized a within-subjects research design. Such a design has been shown to offer superior control for subject heterogeneity, or individual subject differences (Keppel 1982; Maxwell and Delaney 1990, p. 487). A within-subjects design also will yield more data points for analysis than a between-subjects design. For example, by dividing an initial sample into two groups, there would be half as many observations in each group than in the initial sample. This data-point efficiency is particularly important in relatively small-sample investigations such as this study.

The within-subjects design does create a need for stringent learning effect controls (Cook and Campbell 1979). Otherwise, it would be difficult to isolate treatment from time, problem experience, and other learning effects. This investigation provided a variety of the necessary controls. First, the training sessions and the course materials ensured that all subjects were completely familiar with strategic decision making, representative problems, appropriate decision tools, the software (which actually formed the basic DSS), the decision environment, and the decision process. Second, there was a one-week time spread between the use of the basic DSS and the MSS. This time lapse between treatments served to dissipate any learning by subjects about the experimental problem. Third, the decision situation, the data capture methodology, and the nature of the information systems rendered the first to second period knowledge transfers unlikely and ineffective.

Decision Situation. As in previous DSS and EIS studies, subjects were challenged with a complex, semi-structured management problem. The problem involves a market in which an organization competes for a product's four-quarter total market potential on the basis of price and marketing (McLeod 1986). Demand for the organization's product will be influenced by (1) its actions, (2) a major competitor's behavior, and (3) the economic environment. In both the experimental and control groups, every subject was instructed to utilize available information with her/his experience, judgment, and knowledge in developing a business policy that would generate as much total profit as possible over the four-quarter planning period. Policy making required the subject to

(1) set the levels of four decision variables, including the product price, marketing budget, research and development expenditures, and plant expansion investment; and

(2) forecast the levels of four key uncontrollable variables, consisting of the competitor's price and marketing budget, a seasonal product-sales index, and an index of general economic conditions.

These eight variables jointly influenced the profitability of the simulated business organization. Twelve additional variables, including plant capacity, raw materials inventory, and finished goods inventory, were fixed from trial to trial or implied from the policy making variables (could not be altered by the subject) and thereby became the scenario for decision making.

As is the case in a competitive business environment, this problem is dynamic in nature, i.e., a decision made in one quarter affects decisions and outcomes in the current and subsequent quarters. In this dynamic environment, it also is difficult to recover from initially poor decision strategies within the simulated time frame. Further, simplistic strategies, such as reacting to the competitor's current actions or linearly extrapolating current patterns without considering other conditions, are penalized in the simulation. This problem situation has been used to educate a variety of undergraduate, graduate, and executive and continuing education students in representative strategic decision making at various universities and institutions.

An information system was provided to support the decision making. By using this system, a subject could input decisions and uncontrollable variable forecasts and get an instant report on the resulting profit (or loss) and other key situation outcomes. Written instructions were given on the use of the information system and assistants were available to help subjects operate the computer hardware and software. Subjects competed against each other and they were aware of the competition. Participants were allowed to run as many trials as desired in a single 90-minute session, but only the end-of-simulation (last 10 trial) results were recorded for, and counted in, the competition and statistical testing. Subjects were conscious of these rules.

Data Capture. At the start of the experiment, every subject in each group was given a four part questionnaire that requested: (1) demographic data, (2) computer, information system, and work experience levels, (3) a record of the time expended, number of problems and opportunities identified, and the number of alternatives considered during the simulations, and (4) the subject's ratings, on a 10-point Likert scale with least helpful to most helpful anchors, of the information system's usefulness in supporting the user's ability to perform the steps of decision making. Parts (1) and (2) were completed by the students before they ran trials; part (3) was completed at the end of each trial; and part (4) was completed after all trials were completed. An item analysis on the questionnaire's decision-making step components verified (with a Cronbach's $\alpha = .85$) that the instrument reliably measured the subjects' self-ratings.

At the end of each trial (run of the simulation), the subject immediately directed the results to the printer. While still at the computer terminal, and without delay, the subject also recorded, on the questionnaire, the time expended, the number of problems and opportunities identified, and the number of alternatives considered during the trial. Subjects had full access to the information system, their final inputs (including decisions), and the results as they completed the questionnaire.

The computer printout recorded the respondent's name, the final input values, final results (including profit), and the time of day when the results were directed to the printer. A comparison of computer-recorded with subject-reported times indicated that the participants were very accurate in their self-reporting. The software logged the final decision set, but it did not log all the problems/opportunities identified or all alternatives considered. Thus, there was no way to verify the correctness of the self-reported values for these measures. Nonetheless, the self-reported numbers of problems/opportunities and alternatives were likely to be accurate for the following reasons:

(1) the subjects probably remembered the correct values, because each trial typically consumed only two or three minutes;

(2) since subjects knew they were being judged only on the financial performance of the simulated organization, there was no incentive for misreporting other measures; and

(3) problem/opportunity and alternative quantities were self-recorded at the same time as the expended time, and participants were accurate in self-reporting the expended time.

Immediately after the 90-minute session, end-of-simulation results for all trials were printed in hard copy form and submitted to the instructor. Subjects were not allowed to keep notes of their effort or to keep the hard copy printouts. These prohibitions effectively precluded subjects from studying the problem and their actions between the first and second periods of experimentation. The complicated nature of the problem also made it unlikely that student recollections from the first period would be of much specific value to the participants during the second period of experimentation.

Statistical Summaries. Collected outcome data were metric, but demographic data were categorical (nonmetric), and experience levels were ordinal (nonmetric), in nature. The gathered process data (subjects' Likert-scaled self-ratings) data were arguably interval-scaled and thereby metric in character (Creswell 1994; Emory and Cooper 1991). Nonmetric data were summarized with frequency distributions and cross-tabulations. Chi-square, Fisher's test, and Spearman correlation analyses of the cross-tabulated data were used to test the hypotheses that the two (IS 93 or UG and IS 95 or G) samples had the same background (age, experience, gender, and GPA) composition. The metric data were summarized with measures of central tendency and dispersions; multivariate analyses were used to test the hypotheses that the outcome and process measures were each independent of the study group. The *SPSS for Windows* computer package was used to perform the descriptive and inferential statistical analyses (Norusis 1992).

INFORMATION SYSTEMS

Each subject in the control group was given a decision support system (DSS), delivered through the Academic Information System's (AIS) software package to support the simulated strategic decision making. AIS's software package is useful in illustrating how the computer can be used in problem solving (McLeod 1986). Although the software is tailored specifically for strategic management, AIS is similar in architecture and usage to the decision support systems utilized in previous DSS studies. This strategic-management-specific DSS has (1) a database that captures and stores internal organizational and external competitive and environmental data and (2) a model base of mathematical expressions that describes the relationships between the decision and uncontrollable variables and profit. The mathematical expressions are hidden from the DSS user.

By making selections from display screen menus, subjects could input the decision variables, forecast the uncontrollable variables, obtain profit status reports, and perform sensitivity analyses. Such analyses and evaluations assist users in arriving at a recommended policy (set of decision variables) for the simulated business organization. However, the system does not guide the user toward accurate uncontrollable variable forecasts or recommended policies, nor does the DSS provide any explanation or justification for the results.

Subjects in the experimental group were provided with a management support system (MSS). In this MSS, the AIS-based DSS was enhanced with Windows-based executive information (EIS) and expert (ES) systems. Since AIS is a DOS program, the MSS could not take advantage of Windows's dynamic data exchange (DDE) feature to “hotlink” the components. Instead, subjects utilized *Windows*'s task-switching and Clipboard capabilities to move among the components.

Still, the MSS had the same look and feel to the user as the DSS. That is, inputs were entered, and reports were generated and formatted, identically in both the DSS and MSS. While the MSS had pushbutton links to the EIS and ES components, the component processing was transparent to the user. To the MSS user, the pushbuttons merely elicited guidance in setting some inputs for the problem analysis and evaluation. Both systems utilized the same mathematical expressions to perform the analysis and evaluation, and both systems supported decision making in a consistent manner. If MSS users followed the same decision process and supplied identical inputs as DSS users, both groups would obtain the same results from each system.

EIS Component. The executive information system component was delivered through the popular EIS product *Forest & Trees*. Like the executive information systems in previous EIS studies, this *Forest & Trees*-delivered EIS allowed subjects to access and report data pertinent to the management problem's decisions. In the simulated business organization situation, these data included (1) statistical-modeling-based forecasts for the seasonal and economic indexes and (2) estimates of the competitor’s price and marketing budget over the upcoming four-quarter planning period. By selecting a topical *folder*, the subject could quickly search for the desired summary information. Each folder had further linked *views* that enabled the user to drill-down to supporting detail in tabular or graphic form. An explanation about the relevance of the selected variable and about the source of the provided data was available through a Clipboard icon in the EIS.

ES Component. The expert system component was delivered through the popular ES development shell *Level 5 Object*. Like the expert systems in previous ES studies, this *Level 5 Object*-delivered ES acted as an electronic counselor to the user. A hybrid object-production rule knowledge base captured and stored strategic decision making expertise elicited from the professor instructions and underlying computer code for the AIS-based policy game. Upon entrance, the ES prompted the subject for information about her/his specified scenario. Completed responses triggered the ES's chaining-based inference engine to display professional advice on some (but not all) of the decision variables. The advice consisted of the recommended (1) prices and (2) marketing budgets for the forthcoming four-quarter planning period. By selecting the ES's *Expand* menu item, the user could get an explanation for the prompts and ensuing recommendations.

Decision Making Support. The MSS supports all phases of the decision making process in the simulated business organization situation. The embedded EIS helps users discern pricing and marketing problems or opportunities and gather pertinent environmental information (intelligence). Users can utilize the information with the base DSS (with the aid of the embedded ES and EIS) to generate price and marketing alternatives and to establish the environmental variable levels for the simulation model (design). These operationalized models can be used with the base DSS and the embedded ES to help decision makers evaluate the alternatives and select the best alternative (choice). The EIS and ES can provide explanations to help users gain confidence in, and execute, the decision (implementation). After the decision is implemented on a trial basis, the user will want to observe the new reality and follow through with intelligence, design, choice, and implementation. The interactive feedback loops of the MSS make it relatively easy for the user to perform the consequent sensitivity analyses and other post-trial evaluations.

The MSS was designed to offer the support in an integrated and complete, rather than separate and fragmented, manner. No one component offered knowledge sufficient for the entire decision-making process. Users could obtain forecasts for some, but not all, uncontrollable inputs from the EIS, and some, but not all, controllable inputs from the ES. The rest of the controllable and uncontrollable inputs had to be supplied by the user, presumably from her or his insight, judgment, and experience. All inputs were needed to generate a simulated financial outcome, and such an outcome could be obtained only through the basic DSS.

SYSTEM SESSIONS

The DSS user accesses the system by clicking the Pricing Model selection on the desktop's displayed pull-down menu. This selection places the user in the DSS input (data entry form) window shown by example in Figure 2. By entering the controllable and uncontrollable inputs on the entry form and selecting the END command, the DSS user will generate the corresponding simulated profit, as shown by example in Figure 3. DSS users also can drill down to the details behind the summary report.

The MSS user accesses the system in the same manner as the DSS user, by clicking the Pricing Model selection on the desktop's displayed pull-down menu. Once again, inputs are entered on Figure 2's data entry form and simulated results are shown on Figure 3's report screen. Unlike the DSS users, however, MSS users had access to an EIS and ES. Access to the EIS or ES was achieved by task switching to the desktop's displayed pull-down menu and selecting the Pricing Model EIS or ES button.

By selecting the EIS button, the MSS user would access a window, shown by example in Figure 4, that displayed forecasts for key uncontrollable inputs in the simulated decision making. If desired, the MSS user also could obtain view notes for any of the forecasted inputs by selecting the thumbnail icon in the index's window. Figure 5 gives an example view note.

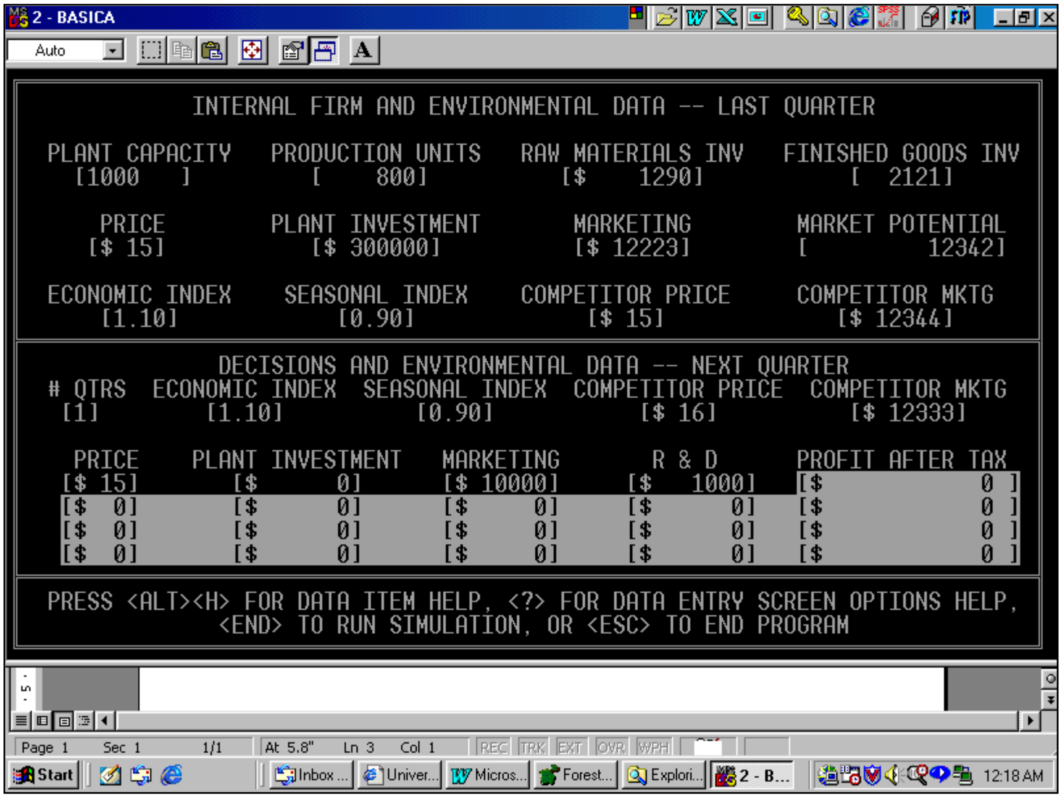

Figure 2. Example Input Form in the AIS-based DSS

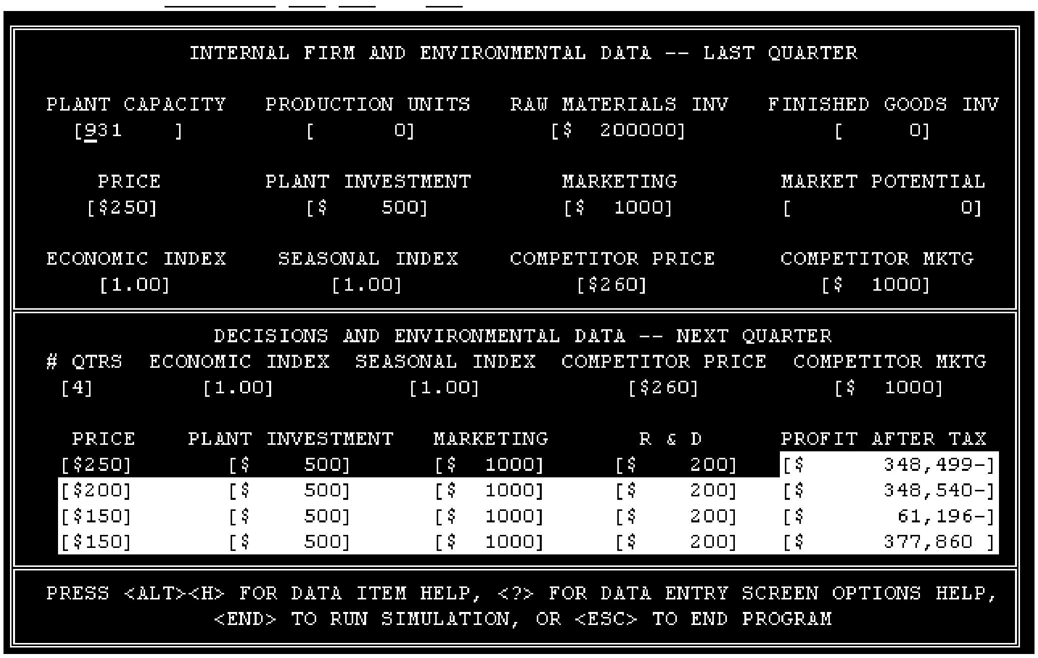

Figure 3. Example Profit Status Report in the AIS-based DSS

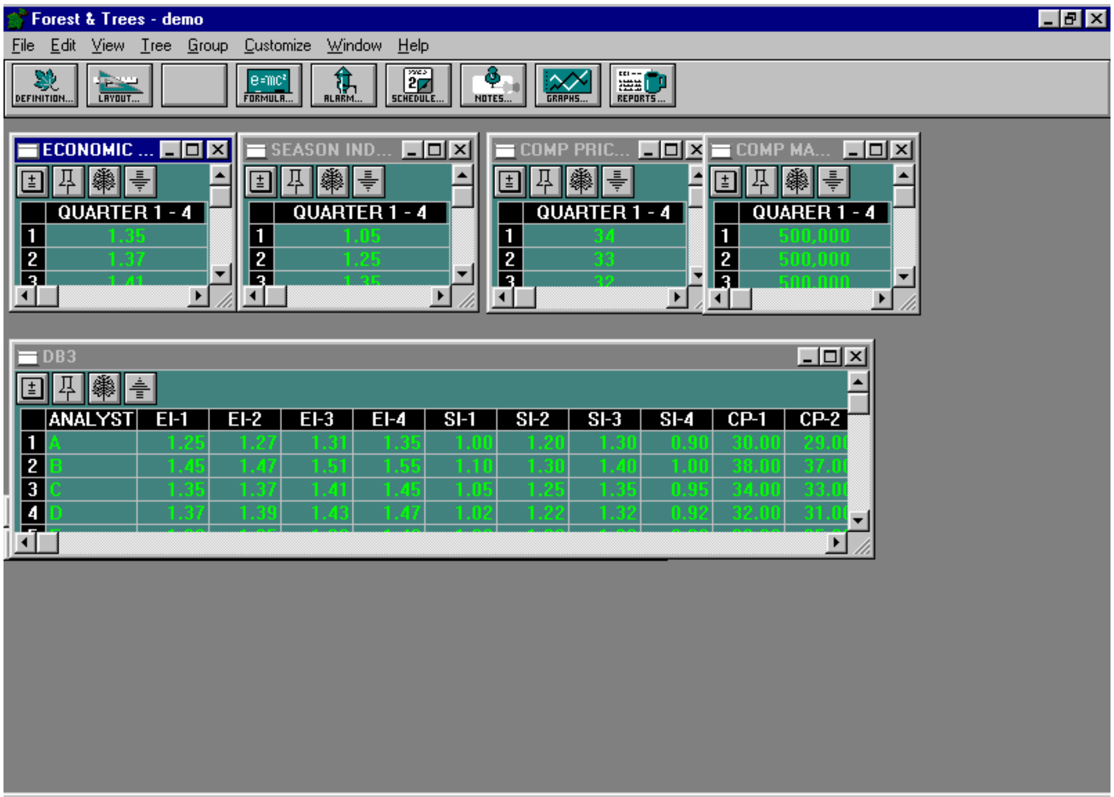

Figure 4. Example EIS Display

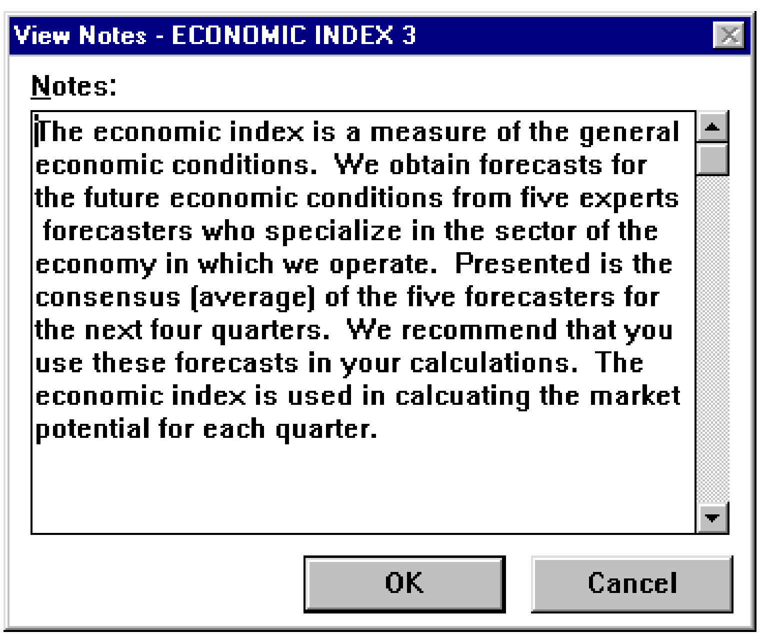

Figure 5. Example EIS View Notes

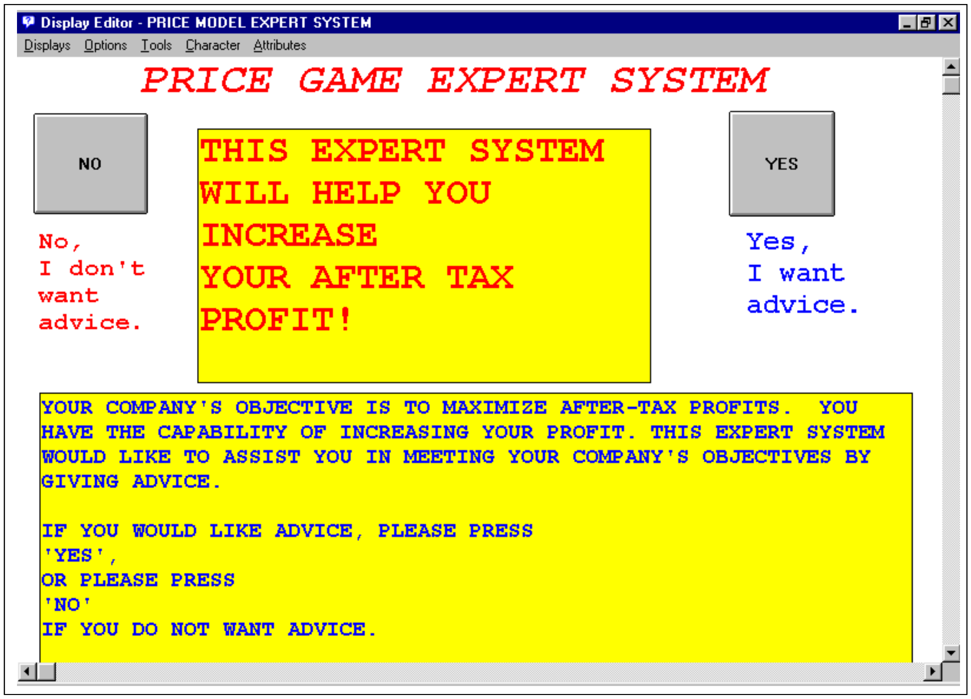

Figure 6. ES Welcome Screen

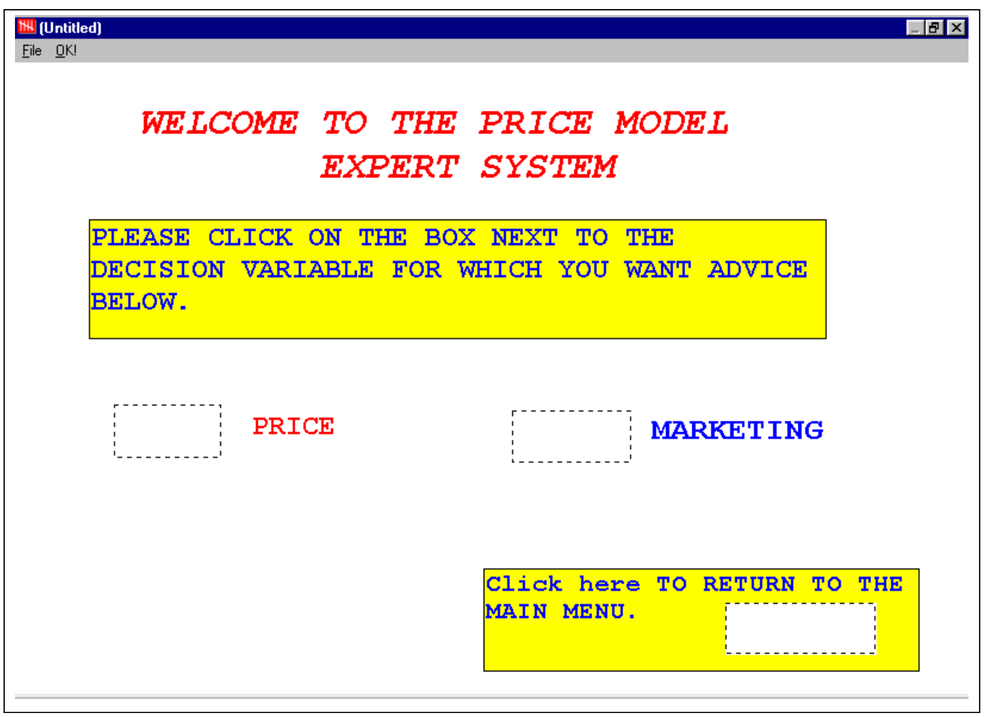

Figure 7. Decision Variable Screen

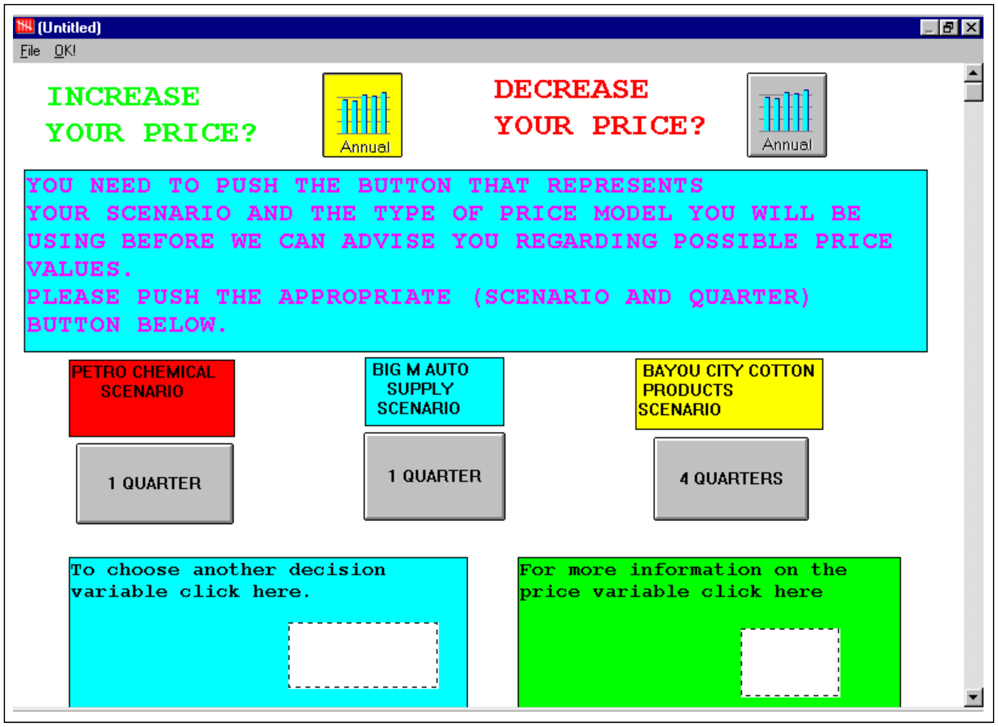

Figure 8. ES Application Screen

Selecting the ES button would put the MSS user in the ES welcome window shown in Figure 6. As this figure demonstrates, the MSS user would have to affirmatively seek decision advice. By doing so, he or she would access a screen that focuses the advice on the desired decision variable, as shown in Figure 7. A selection from the decision variable screen (Figure 7) would put the MSS user in a window, shown by example in Figure 8, that focused the advice on the desired application. If desired, the user could also obtain an explanation about the selected decision variable. By selecting an application, the user would be placed in a screen, shown by example in Figure 9, that recommended a strategy for the selected decision variable and application. If desired, users could get an explanation for the recommendation.

MSS users could access the EIS and ES anytime during the simulation. Since the simulation was dynamic in nature, however, it was preferable to seek assistance before entering uncontrollable inputs and decision variables on the data entry screen (Figure 2).

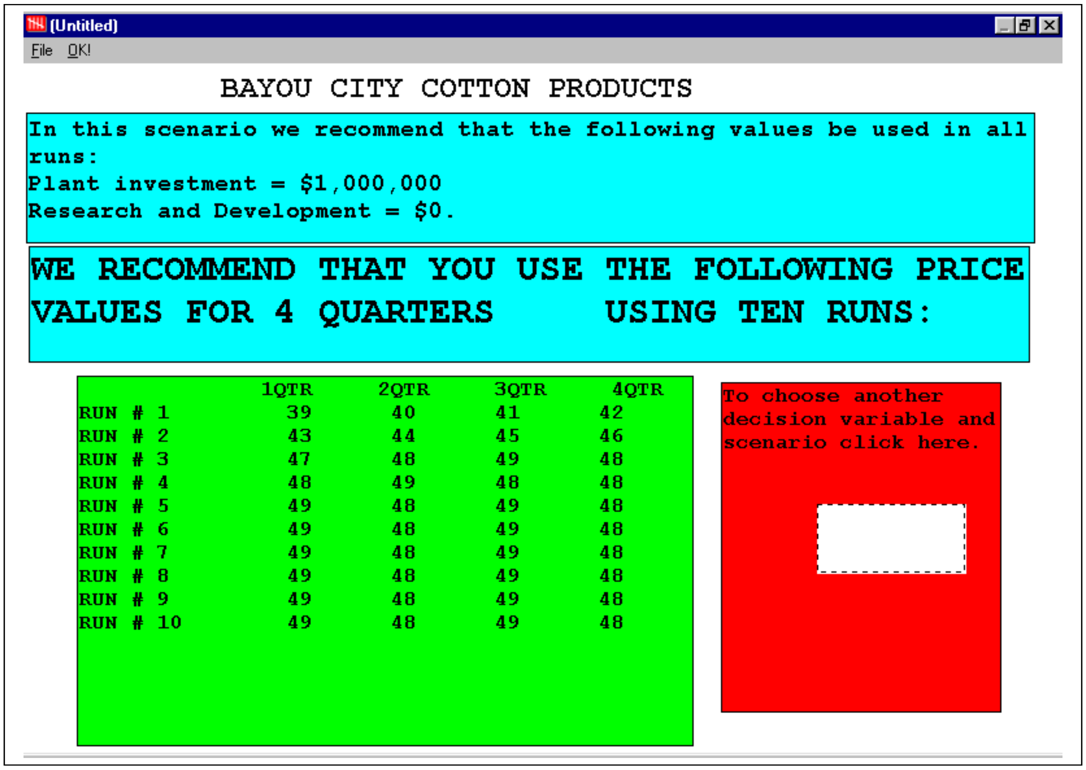

Figure 9. ES Recommendation Screen

DECISION VALUE

The outcome from, and the process of, decision making are interrelated. Enhanced outcomes will be the result of improvements in the process of decision-making (Dean and Sharfman 1996). Indeed, outcome enhancements cannot be reliably credited to DSS or MSS usage without explaining how the system improved the decision making process. Assessing DSS or MSS value, then, will be a multiple criteria problem that should include valid process, as well as outcome, measures (Forgionne and Kohli 1996).

Outcome improvements from using the DSS or MSS can include (1) gains in organization performance, such as an increase in return or a decrease in cost (DeLone and McLean 1992; Sethi and King 1991), and (2) the maturation of the user as a decision maker, as would occur when there is progress in the person's (or group's) understanding of the current problem and solution or a gain in the person's (or group’s) general problem-solving skills (Forgionne and Kohli 1996; Li 1997). Process improvements involve enhancements in the users' ability to perform the phases and steps of decision making (Udo 1992). As in previous DSS, EIS, and ES studies, decision value was assessed by the system's separate effects on the outcomes from, and the process of, decision making.

Outcomes. Business organization performance was assessed with total profit (O_PROFIT). A mature strategic decision maker will expend considerable effort on, and be capable of, defining the management problem, exploring the interpretation's relationship to alternative views, and generating alternative clinical and administrative solution concepts. Effort was assessed by the time (in minutes) spent on the simulated decision making (O_TIME). In the original plan, capability was to be measured by the numbers of opportunities and problems (O_PROB) identified during the simulation and the number of alternatives considered during the simulation (O_ALT). Unfortunately, such variables were not recorded consistently in the IS 93 (UG) experiments. To avoid potential data comparability problems, the plan was modified to exclude the capability measures.

Process. The decision making process was described to subjects as a step-augmented adaptation of the intelligence-design-choice-implementation paradigm. Self-ratings assessed the usefulness of the system in supporting the subject's ability to perform the identifying objectives (P_OBJ), recognizing problem or opportunity (P_PRB), gathering qualitative data (P_QUAL), gathering quantitative data (P_QUANT), generating alternatives (P_GENALT), establishing criteria (P_CRTRIA), evaluating alternatives (P_EVLALT), choosing the most preferable alternative (P_CHSALT), decision confidence (P_MKDEC), system effectiveness (P_EFECTV), and implementing the final choice (P_IMPLCH) steps of this adaptation.

III. EXPERIMENTAL RESULTS

Experimental results were used to assess the management support system's impact on the outcomes from, and process of, simulated strategic decision making.

As in related studies, separate hypotheses were examined for outcome and process effects.

RESEARCH QUESTIONS AND HYPOTHESES

The fundamental research question and corresponding hypotheses for outcome effects can be stated as follows:

> **Question: Can the MSS improve decision making outcomes relative to the DSS?**
>
> **Null: The MSS and DSS outcomes are the same.**
>
> **Alternative: The MSS results in different outcomes than the DSS.**

The fundamental research question and corresponding hypotheses for process effects can be stated as follows:

> **Question: Can the MSS improve the decision making process relative to the DSS?**
>
> **Null: Process ratings are the same from MSS and DSS users.**
>
> **Alternative: Process ratings are different for MSS than DSS users.**

OUTCOME AND PROCESS FUNCTIONS

Neither information system generated a computer log that could be checked for feature usage during simulation trials. However, an examination of the end-of-simulation computer printouts showed that

(1) all subjects in the control group utilized the DSS,

(2) all subjects in the experimental group used the DSS, EIS, and ES components of the MSS, and

(3) all subjects in the experimental group asked for, and virtually all accepted, the EIS and ES recommendations.

Hence, it was unnecessary to distinguish experimental group subjects by their feature usage.

Since the groups differed only by the information systems provided to the subjects, the control group served as a proxy for the DSS and the experimental group was a surrogate for the MSS. Outcome and process effects then were functions of the group (GROUP) and any other moderating factors, or

Outcomes = f(GROUP, Moderating Factors)

and

Process Ratings = f(GROUP, Moderating Factors)

and the hypotheses could be tested through the statistically estimated parameters of the pertinent functions.

MODERATING FACTORS

In this study, demographics and experience levels were the only surveyed factors that can moderate the influence of the information systems on outcomes and process ratings. Within each experiment, all subjects used both the DSS and MSS. Consequently, within-sample control and experimental groups had equivalent demographic characteristics and experience levels. While the small sample sizes precluded definitive statistical testing, it seemed reasonable to assume that the subjects' backgrounds would have no moderating effects on outcomes or process ratings within each experiment.

The remaining factor was the type of the student (undergraduate or graduate). Each experiment had a different student composition and the participants' backgrounds were significantly different between the experiments (IS 93 or UG versus IS 95 or G). Student type and background, as proxied by the sample number (EXP_NUM), then, could have a moderating effect on the dependent variables, or

Outcomes = f(GROUP, EXP_NUM, EXP_NUM by GROUP)

and

Process Ratings = f(GROUP, EXP_NUM, EXP_NUM by GROUP)

Namely, outcomes and process ratings were functions of group (and thereby the information system provided to the subjects), the type of student, and any interaction between the student type and the provided information system.

HYPOTHESIS TESTING

Since outcomes and process ratings were metric, MANOVA seemed to be an appropriate procedure to statistically test the hypotheses. Several diagnostics were conducted to ensure that this procedure was appropriate for the experiment.

Diagnostics. Bartlett-Box F and Cochran C univariate tests indicated that the homogeneity-of-variance assumption was valid with respect to (1) most (but not all) of the outcome variables and (2) most (but not all) of the process step variables. The Bartlett test for sphericity demonstrated that there were significant correlations (1) among the outcome variables and (2) among the process step variables. Box M multivariate tests suggested that the homogeneity-of-variance assumption was valid with respect to the outcome and process step variables.

According to the diagnostics, there were some variations from the equal variance assumption. Yet, MANOVA is reasonably robust with respect to minor assumption variations, and the procedure is more powerful (and generates more information) statistically than its nonparametric counterparts (Kanji 1993; Tatsuoka 1988). For these reasons, the hypotheses were tested with MANOVA.

As a precaution, the outcome and process variables were recoded into nonmetric categories and these recoded variables were cross-tabulated against GROUP and EXP_NUM for hypothesis testing purposes. Loglinear analyses and Chi-square goodness-of-fit tests of the cross-tabulated data yielded results that were essentially the same as the MANOVA findings.

MANOVA Tests. Pillais, Wilks, Roy, and Hotelling T^2 statistics were used to test for the multivariate equality of mean outcomes. The same statistics were used to perform analogous multivariate process step tests. In every case, the Pillais, Wilks, Roy, and Hotelling tests yielded identical results. Bonferroni simultaneous confidence intervals and Roy-Bargman stepdown F statistics were used to isolate separate dependent variable differences. Each of these analyses generated the same results.

Sample Size and Other Potential Problems. Both the undergraduate and graduate experiments involved small sample sizes (18 in the undergraduate and 16 in the graduate groups). These samples are consistent with the sizes used in previous, related experiments (Adelman 1991; Creswell 1994; Elam and Mead 1990; Gardner et al. 1993). Moreover, each subject performed repeated measures of the experiment, so that there were more than 100 observations for many measures of performance. Nevertheless, other measures had observations equal only to the number of subjects in the experiments. Such small sample sizes potentially could affect the statistical analyses involving these other measures and thereby must be acknowledged as a limitation of the study. While the ideal solution would be to increase the sample size, budgetary, logistical, and timing (longitudinal) considerations precluded the implementation of this solution.

Another potential problem involved a few MSS users. As in real-life, users were free to disregard the system recommendations and suffer the consequences. A couple of MSS users requested, but ignored, EIS and ES recommendations. Such nonacceptance may be an unmeasured moderating factor that could have affected the statistical analyses. Yet, nonaccepting MSS users obtained significantly inferior outcomes than the other MSS users. Hence, the potential unmeasured moderating would have a dampening effect on MSS results, thereby leading to a type II error (accepting the null hypothesis when it was false). Since the number of nonaccepting MSS users was very small, there is little chance for the error. For these reasons, the potential, and unlikely, error was not viewed as a serious threat to the integrity of the study.

FINDINGS

Hotelling and Roy-Bargman statistics, with significance levels in parentheses, are reported in Table 3 for the outcome variables and in Table 4 for the process step variables. Group means for all outcome and process step variables are given in Table 5.

Outcome Differences. Table 3's statistics indicate that

(1) the information system provided to the subjects (GROUP) and the subject's student type (EXP_NUM) had significant independent and joint effects on outcomes;

(2) the information system provided to the subject (GROUP) and the subject's student type (EXP_NUM) had significant independent and joint effects on profit (PROFIT); and

(3) the information system provided to the subject (GROUP) and the subject's student type (EXP_NUM) had significant independent and joint effects on decision effort (TIME).

In summary, organization performance and decision maturity were different for MSS than DSS users. These findings generally support the hypothesis that the MSS results in different outcomes than the DSS.

Table 3. MANOVA Outcome Statistics

OUTCOME VARIABLE	FACTOR		
	GROUP	EXP_NUM	EXP_NUM by GROUP
MULTIVARIATE	120.911 (.000)	53.185 (.000)	14.115 (.000)
Profit (PROFIT)	229.023 (.000)	49.791 (.000)	19.312 (.000)
Decision effort (TIME)	6.955 (.009)	53.282 (.000)	9.805 (.000)
NOTES: The multivariate row reports the F score of Hotelling T^2 for multivariate significance, while the other rows show the Roy-Bargman stepdown F tests for the individual outcome variable significance. In each case, the significance level is shown in parentheses below the reported statistic.			

Table 4. MANOVA Process Step Statistics

PROCESS VARIABLE	FACTOR		
	GROUP	EXP_NUM	EXP_NUM by GROUP
MULTIVARIATE	10.317 (.000)	12.329 (.000)	16.815 (.000)
Choosing the final alternative (P_CHSALT)	15.654 (.000)	26.187 (.000)	41.802 (.000)
Establishing criteria (P_CRTRIA)	5.062 (.025)	15.979 (.000)	1.080 (.299)
System effectiveness (P_EFECTV)	9.286 (.002)	7.467 (.001)	2.218 (.137)
Evaluating alternatives (P_EVLALT)	2.020 (0.156)	10.698 (.000)	6.003 (.015)
Generating alternatives (P_GENALT)	30.635 (.000)	36.454 (.000)	10.966 (.001)
Implementing the final choice (P_IMPLCH)	0.125 (.724)	18.787 (.000)	1.037 (.309)
Confidence in decision making (P_MKDEC)	0.090 (.764)	53.292 (.000)	0.392 (.531)
Identify objective of decision making (P_OBJ)	18.780 (.000)	8.468 (.000)	4.427 (.036)
Identify problems (P_PRB)	1.617 (.204)	1.924 (.147)	0.403 (.526)
Ability to gather qualitative data (P_QUAL)	2.517 (.113)	22.091 (.000)	62.049 (.000)
Ability to gather quantitative data (P_QUANT)	1.145 (.285)	3.728 (.024)	1.960 (.162)

NOTES: The multivariate row reports the F score of Hotelling T^2 for multivariate significance, while the other rows show the Roy-Bargman stepdown F tests for the individual outcome variable significance. In each case, the significance level is shown in parentheses below the reported statistic.

Process Step Differences. Table 4's statistics indicate that

(1) the information system provided to the subjects (GROUP) and the subjects' student type (EXP_NUM) had significant independent and joint effects on process step ratings;

(2) the information system provided to the subjects (GROUP) and the subjects' student type (EXP_NUM) had independent and joint effects on the identifying objective (P_OBJ), generating alternatives (P_GENALT), choosing the final alternative (P_CHSALT) steps of their decision making process;

(3) the information system provided to the subjects (GROUP) and the subjects' student type (EXP_NUM) had significant independent effects on the establishing criteria (P_CRTRIA) and system effectiveness (P_EFECTV) steps of their decision making process; and

(4) the interaction between the provided information system and student type (GROUP by EXP_NUM) had a significant effect on the evaluating alternatives (P_ EVLALT) and gathering qualitative data (P_QUAL) steps of the subjects' decision making process.

In summary, subject self-ratings on seven (out of 11) decision-making steps were different for MSS than DSS users. These findings generally support the hypothesis that process step ratings are different for MSS than DSS users.

Decision Value. Table 5's statistics indicate that

(1) MSS users had a larger mean profit (PROFIT) than DSS users in both experiments;

(2) MSS users had a larger mean effort (TIME) during simulated decision making than DSS users only in the case of graduate (IS 95 or G) students;

(3) MSS users had larger mean self-ratings than DSS users for the establishing criteria (P_CRTRIA) and generating alternatives (P_GENALT) decision-making steps in both experiments;

(4) MSS users had larger mean self-ratings than DSS users for the evaluating alternatives (P_EVLALT) decision-making step only in the case of graduate (IS 95 or G) students; and

(5) MSS users had larger mean self-ratings than DSS users for the choosing the final alternative (P_CHSALT) and gathering qualitative data (P_QUAL) decision-making steps only in the case of under-graduate (IS 93 or UG) students.

In summary, the results show that the MSS clearly improved organization performance (PROFIT) and at least two decision making steps (P_CRTRIA and

P_GENALT). These results plus the MANOVA conclusions support the general finding that the MSS results in better decision value (superior outcomes from, and an improved process of, simulated strategic decision making) than the DSS. The implications of all results are examined in the following discussion.

Table 5. Group Means for Outcome and Process Variables

EXPERIMENT	Experiment G		Experiment UG	
Outcomes	DSS	MSS	DSS	MSS
Profit (O_PROFIT in $)	- 57,469.64	6,452,701.39	-3,806,022.57	2,638,990.42
Decision Effort (O_TIME in minutes)	2.20	2.81	1.54	1.13
Process Steps				
Choosing the final alternative (P_CHSALT)	8.50	6.76	7.58	8.00
Establishing criteria (P_CRTRIA)	6.35	6.92	7.32	7.66
System effectiveness (P_EFECTV)	8.14	7.38	8.09	7.83
Evaluating alternatives (P_EVLALT)	6.64	7.23	7.68	7.50
Generating alternatives (P_GENALT)	6.85	8.30	7.44	8.16
Implementing the final choice (P_IMPLCH)	6.64	6.76	7.42	7.16
Confidence in decision making (P_MKDEC)	6.92	7.07	7.88	7.83
Identify objective of decision making (P_OBJ)	8.35	7.38	7.50	7.50
Identify problems (P_PRB)	6.64	6.53	7.10	7.10
Ability to gather qualitative data (P_QUAL)	7.57	5.76	6.50	8.16
Ability to gather quantitative data (P_QUANT)	7.92	7.53	8.10	8.16

DISCUSSION

In assessing the additional costs that an organization might incur from development and usage time in implementing a MSS vis-à-vis a DSS, it may be helpful to conduct a cost-benefit analysis. Following is a brief cost-benefit analysis we conducted for our experiments. A summary of the cost benefit analysis is also presented in Table 6.

Costs. Both simulation software tools were delivered through a Windows interface, thereby becoming the DSS, and the MSS. The MSS and DSS were developed by three graduate students, none of whom were subjects in Experiment UG or Experiment G. It took these students a total of about three person hours to develop the DSS and a total of approximately 40 person hours to develop the MSS. Assigning a $50 per hour expense for the development time, the MSS then cost

(40 – 3) x $50 = $1,850

more to develop than the DSS. All development software was donated by the vendors for the study. If purchased, this software would have cost a total of $995, and $935 of the expense would have been for MSS-specific development software. Thus, the fixed cost was

$1,850 + $935 = $2,785

higher in total for MSS, than for DSS, development.

The same hardware and system software was utilized to run the MSS and DSS, and the computer processing time was virtually identical for both systems. Hence, both systems consumed virtually identical computing resources. Another variable cost that may occur is the maintenance expense. Since MSS and DSS models and data were internalized, both systems were self-maintaining systems. As the Decision Effort (Time) data in Table 5 indicates, a MSS user spent approximately

(2.81 – 2.20) x 10 = 6.1 minutes

more than a DSS user during the 10 runs of the simulation in the Experiment G but

(1.13 – 1.54) x 10 = -4.1 minutes

or 4.1 minutes less than a DSS user in Experiment UG. Assigning a $120 per hour, or $2 per minute, expense for the users' time, the MSS then had a variable cost that was

[($2 x 6.1) x 16 subjects]– [($2 x 4.1) x 18 subjects] = $47.60

more than the DSS for the simulated decision making.

The computations, then, show that the MSS cost a total of about

fixed cost + variable cost = $2832.60

more than the DSS.

Benefits. According to the data in Table 5, when compared to the DSS user, this investment enabled the MSS user to increase simulated profit by approximately

($6,452,701 – (-$57,469)) x 10 runs x 16 subjects = $1,041,627,200

in Experiment G and

($2,638,990 – (-$3,806,022) x 10 runs x 18 subjects = $1,160,102,160

in Experiment UG. Consequently, the MSS increased users' simulated profit by a net of more than $2 billion.

Breakeven Analysis. In addition to the cost-benefit analysis, the decision to invest in a MSS can be viewed also in the context of the time it would take to recover the costs of developing and implementing the MSS. This factor could be a consideration for small and medium-size business where the IT expenditures have to be weighed against other competing needs. A breakeven analysis can help identify the duration in which the system would pay for itself.

An MSS could cost more than our experimental system. The extent of costs incurred and benefits resulting from the implementation of MSS within an organization are dependent, among other factors, upon the complexity of decisions, the number of decision-makers, the technology used and expected payoff from the decisions, and training and acquisition costs. These factors, however, were recognized and incorporated in the cost-benefit analysis presented in Table 6. The expenses and profits in Table 6 demonstrate that MSS users earned approximately $6.5 million more than DSS users in the 90 simulated minutes of decision making. Consequently, MSS users would recover the additional $2,832.60 development cost in about

$2,832.60/($6.5 million/90) = 0.03922 minutes

or about 2.35 seconds of simulated decision making.

Improvement Mechanisms. These significant simulated net monetary gains were achieved in different ways for various MSS users. One difference involves the nonuniform effects of the MSS on the level of users' decision making maturity. Graduate (IS 95 or G) students used the MSS to increase the effort (TIME) expended on simulated decision making, while undergraduate (IS 93 or UG) MSS users had a

Table 6. A Summary of the Cost-benefit Analysis of MSS and DSS

	DSS		MSS		MSS-DSS
COSTS					
Fixed Costs					
Development Cost @$50/hour	(3 hours x $50) =	$150	(40 hours x $50) =	$2,000	
Software Costs		$60		$995	
Difference in Development Costs	($2000 - $150)				$1,850.00
Difference in Software Costs	($995 - $60)				$935.00
Variable Costs					
Decision Time - G (minutes)	2.2		2.81		
Decision Time – UG (minutes)	1.13		1.54		
Time Difference – G	2.81 - 2.2 = 0.61 (min)				
Time Difference – UG	1.54 - 1.13 = 0.41 (min)				
10 runs for 16 subjects – G	(.61 X 10 x16) x $2/min	$195.20			
10 runs for 18 subjects – UG	(.41 x 10 x 18) x $2/min	$147.60			
Difference in Time Costs (G – UG)	$195.20 - $147.60				$47.60
Total Costs					**$2,832.60**
BENEFITS					
Simulated Profit – G per run	$ (57,469)		$6,452,701		
Simulated Profit – UG per run	$ (3,806,022)		$2,638,990		
Benefit Difference – G	$ 6,510,170				
Benefit Difference – UG	$ 6,445,012				
10 runs 16 subjects – G	$ 6,510,170 x10 x16				$1,041,627,200
10 runs for 18 subjects – UG	$ 6,445,012 x10 x18				$1,160,102,160
Total Benefits					**$2,201,729,360**

decreased decision time. One explanation is that maturity may have been expressed differently between the groups and these expressions could have been confounded within the TIME variable. For example, undergraduates may have been most concerned with personal efficiency (reducing the time needed to perform individual decision steps), while graduate students may have focused on personal productivity (increasing the amount of pertinent information, knowledge, and wisdom gained during decision making). Such a theory could have been tested had the IS 93 (UG) experiment consistently captured the capability measures (the number of problems identified and alternatives considered).

Another difference involves the process results. Graduate (IS 95 or G) students had a different perception of the MSS decision making process support than did the undergraduates. For example, the MSS was better than the DSS for undergraduates in gathering qualitative data and choosing the final alternative, while the MSS was better than the DSS for graduate students in evaluating alternatives. One explanation is that different groups had varying decision perspectives and the MSS was better suited to particular viewpoints. For example, the undergraduates may have an intelligence and final choice focus and they may have found that the MSS was better suited than the DSS to these decision making phases. On the other hand, the graduate students may have an early choice phase orientation and they may have found that the MSS was better suited to that decision making phase. A related explanation is that different groups had varying (real or perceived) support needs, and the MSS was better suited than the DSS to particular needs. For example, undergraduates may have needed strong intelligence support and they found that the MSS was better suited to this need. On the other hand, the graduate students may have needed strong early choice support and they found that the MSS was better suited to this need.

Nevertheless, the MSS evidently supported the relevant steps of both the undergraduate and graduate students' decision making process. Even with the DSS, neither student type was able to earn a profit in the simulated strategic decision making. With the MSS, both student types were able to earn substantial profits. The empirical testing helps to pinpoint the linkages between this performance and the MSS support. For undergraduates, the profit improvement can be derived from the MSS support for establishing criteria, gathering qualitative data, generating alternatives, and choosing the final alternative. For graduate students, the profit improvement was educed from the MSS support for establishing criteria, generating alternatives, and evaluating alternatives. Such pinpointing can be used to enhance future system design and development.

IV. CONCLUSIONS

The results of this study confirm the previous research and continue to indicate that a management support system (MSS) can significantly improve both the outcomes from, and process of, strategic decision making. This MSS is a workstation-based combination of decision support, executive information, and expert system functions that

(1) provides central repositories for decision data, models, and knowledge;

(2) incorporates a user-extensible knowledge-representation scheme that links information, knowledge, and models;

(3) delivers models that support an organization-oriented view of strategic decision making;

(4) assists staff in understanding business decision making tasks, events, and processes; and

(5) serves as a learning tool for future business policy decision makers.

Results, provided in desired vivid detail, can be used to explain, justify, and communicate the information and knowledge to colleagues in a real-time, very user-friendly manner.

By delivering comprehensive decision making support effectively, a MSS can serve as an important strategic weapon for business organizations. Adaptations of the MSS can deliver the same benefits to executives and managers in diverse public and private sector enterprises.

Although the MSS continues to show promise, the concept needs additional research. Enhancements can be made to the MSS that will provide more pervasive support than the empirical prototypes for all steps in the strategic decision making process. The application base can be expanded further. A higher-level integration strategy can be adopted to test the research questions. Experiments can be designed that will comparatively evaluate the decision value of each management support system (MSS) component. For example, it would be useful to isolate the impact of the DSS, ES, and EIS components on decision-making outcomes and process. If properly designed, such an experiment would also enable the researcher to compare the decision value of executive support (ESS = DSS + EIS), intelligent DSS (DSS + ES), MSS (DSS + EIS + ES), and other integration strategies. A composite indicator can be developed that will measure joint, rather than separate, impacts of process and outcome on decision making value. Large and broad-based samples with stringent moderating factor designs can be used to confirm the original, and test the additional, hypotheses.

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