THE USE OF SIMULATION AND GAMING IN INFORMATION SYSTEMS RESEARCH

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by

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THE USE OF SIMULATION AND GAMING IN INFORMATION SYSTEMS RESEARCH

Research in management information systems and in information, communication or intelligence systems in general has grown significantly within the past decade. Yet although significant work is evident at both the theoretical level with the development of information economics and statistical decision theory and at the technical level as is evidenced by the development of complex on-line networks and advanced information storage and retrieval systems, little research which has focused upon information systems has utilized gaming and simulation techniques. Such techniques have been used by the authors in a series of related studies into information systems and decision processes. The use of simulation and gaming in this information systems context is critically examined and exemplified in this paper. As will be demonstrated, simulation techniques are useful for the analysis of complex decision models in which information alternatives are examined and for controlled empirical (experimental) analysis of information alternatives. The paper begins with a summary of a series of information economics experiments and the use of gaming therein. Within this context, discreet event simulation is utilized to estimate the value of more timely information in a fifteen period decision process which contains four random environmental variables. The second main part of this paper considers the use of less controlled gaming for the investigation of an on-line directive planning system.
THE USE OF SIMULATION AND GAMING IN INFORMATION SYSTEMS RESEARCH

GAMING AND SIMULATION APPLIED TO INFORMATION ECONOMICS

The first set of applications of simulation in information systems research to be discussed involves a set of information economics studies. As will be seen, this research permitted one to estimate both the value of differences in the timeliness of information and the value of an information system based upon the management control process of budget feedback.

When these particular studies were initiated*, the conceptual foundation of information economics had been developed by Marshak [3] and others, but little had been done in terms of empirically or pragmatically testing information value notions. Part of the difficulty in applying these notions lay in the complex decision processes within which extant information systems derive their value and part lay in the lack of methodology in which to analyze information systems differences. In the studies to be described, simulation and gaming techniques proved to be the key to resolving such difficulties.

SPECIFIC RESEARCH OBJECTIVES

The specific research focus is founded upon the perspective of the information system designer. From this point of view, a decision problem may be formulated which involves selection of an information system which optimizes the net utility for the entity of interest. In information

*Mock [4]
economics, this design problem is developed in terms of basic decision theory and is seen to rely upon:

1. a decision maker,
2. a set of relevant states-of-the-world,
3. the decision maker's prior expectations concerning such states,
4. a set of feasible decision alternatives, and
5. a utility or payoff function defined on the possible outcomes which are a function of the alternative chosen and the state-of-the-world which occurs.

Within such a model, the role of information is to alter the decision maker's prior expectations such that chosen alternatives can be conditional upon the world-states that occur or upon the "real" prior probabilities.

Based upon the above decision theoretic view of analyzing information systems, but conditioned with the knowledge that pragmatic decision making is based upon more complex behavioral foundations, a set of business game experiments were designed to consider:

1. The predictive validity of estimates of information value based upon information economics.
2. The usefulness of gaming and simulation as a methodology for empirical estimation of cost and value of information.
3. The role of behavioral and pragmatic complexity factors such as learning and decision approach in information systems analysis.

In addition, discreet-event simulation was found to be a useful analytical methodology for the estimation of information values in a complex but well-defined decision model.
THE UNDERLYING MODEL AND INFORMATION DIFFERENCES TESTED

In order to investigate two sets of alternative information systems, a business game was developed, validated, optimized and implemented at three different universities. The actual implementations are summarized in Exhibit 1 which contrasts the information differences tested and technical implementation features. As is evident in this exhibit, two distinct experiments were conducted. The first experiments permitted subjects to reach decisions based upon real-time information (Information System I₁) or one-period lagged information (Information System I₂) about relevant environmental parameters such as input costs and external demand. A second set of business games (conducted both at UCLA and Ohio State University) were based upon two different information systems — a budget variance system (Information System I₃) and a system based upon conventional income statement feedback. A common decision model and set of environment parameters was the basis for all experiments. Its mathematical structure is as follows:
Maximize: \[ \Pi_t = P_t Q_t - C_t \]

Subject to:

1. \[ P_t = \beta_t - .03 Q_t + 95 A_t - A_t^2 \]  
2. \[ C_t = \alpha_t + c_t (.0075 Q_t^2 - .075 Q_t) + 5000 A_t \]  
3. \[ 1 = 2 (M_t L_t)^{1/2} \]  
4. \[ c_t = P_{Lt} L_t + P_{Mt} M_t \]  
5. \[ M_t, L_t > 0 \]  
6. \[ Q_t \geq 10 \]  
7. \[ 0 \leq A < 75 \]

\( \alpha_t, \beta_t, P_{Lt}, \) and \( P_{Mt} \) are stochastic parameters which were fixed for each \( t \) and greater than 0, where for each period \( t \):

- \( \Pi_t \) = profit
- \( P_t \) = selling price
- \( Q_t \) = quantity produced and sold
- \( C_t \) = total cost
- \( A_t \) = advertising units purchased
- \( M_t \) = material input
- \( L_t \) = labor input
- \( c_t \) = input cost per standard unit produced
- \( P_{Mt} \) = cost of materials
- \( P_{Lt} \) = cost of labor

*Decision variables
### EXHIBIT 1
Summary of the Three Experiments Conducted

<table>
<thead>
<tr>
<th>University Site</th>
<th>Information Differences</th>
<th>Decision Variables</th>
<th>Simulation Environment</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. U.C., Berkeley</td>
<td>Timing: Real-Time Versus Lagged ($I_1$ vs. $I_2$)</td>
<td>Production Quantity, Production Inputs</td>
<td>Management Science Laboratory, Individual Cubicles, Teletype Interface with PDP 5/6 Specialized, ECL Language</td>
</tr>
<tr>
<td>Ohio State</td>
<td>&quot;</td>
<td>&quot;</td>
<td>Individual Cubicles, 2741 Interface, CPS Language under TSO</td>
</tr>
</tbody>
</table>
Decision variables

\[ p_L^c = \text{cost of labor} \]
\[ p_M^c = \text{cost of materials} \]
\[ c = \text{input cost per standard unit produced} \]
\[ I = \text{labor input} \]
\[ M = \text{material input} \]
\[ V = \text{average selling price per unit purchased} \]
\[ c = \text{total cost} \]
\[ q = \text{quantity produced and sold} \]
\[ p = \text{selling price} \]
\[ \Pi = \text{profit} \]

\( t > 0, \) where for each period:

1. \( A > 0 \)
2. \( 0 < I < 10 \)
3. \( 0 < M < q \)
4. \( q = \frac{3}{2} p + \frac{3}{2} n \)
5. \( n = 2 \left( \frac{M + p}{2} \right) \)
6. \( A = q \times 0.075 - 0.075 A^2 + 0.00000095 + 5000 A^2 \)
7. \( \text{subject to:} \)
   \[ p = c - c_A - c_B - c_C + c_E \]
   \[ \text{Maximize:} \]
   \[ \Pi = c_A - c_B - c_C \]
This model was communicated to each subject by means of a scenario. Essentially the decision maker faced a series of decisions of selecting \( Q, A, \) and \( M \) each period depending upon the (expected) state of uncontrollable environmental parameters \( (P_L, P_M, \) and \( \beta \) being relevant to the decision maker). Values of these parameters were generated as random walks and were the same for each experimental subject.

MODEL OPTIMIZATION

The above decision model is based upon a homothetic production function so that theoretically the system may be optimized by first minimizing period input cost and then, using the derived inputs, maximizing profits. The cost minimizing material input is

\[
M_t^* = 0.5 \left( \frac{P_L}{P_M} \right)^{1/2}
\]

Labor input is then uniquely determined given equation (3).

Profit maximization results in the first order conditions:

\[
0 = \beta_t - 0.06Q_t + 95A_t - A_t^2 + 0.075c^* - 0.015c^*Q_t
\]

\[
0 = 95Q_t - 2A_tQ_t - 5000
\]

where \( c^* \) = minimum unit input cost.

A proper selection of parameters according to second order conditions and according to the constraints of the decision model insure that a unique solution exists for each decision period.
One will note that optimization of such a system is dependent upon a
number of important decision maker assumptions and upon available information
concerning input costs ($P_{Lt}$, $P_{Mt}$) and the demand index $\beta_t$. Under the first
information system $I_1$, subjects received real-time information concerning
these parameters, and thus they could have conceivably reached overall
optimal decisions. Under information system $I_2$, messages concerning these
parameters were lagged one period, thus expected profits was less. The
differences in expected profits which may be derived from information
economics notions, is then hypothesized as the expected value of the more
timely information.

**Deviation**

**DEVIAITON OF THE EXPECTED VALUE OF INFORMATION; AN ANALYTICAL AND**

**A SIMULATION APPROACH**

Within the above decision problem two notions of information value
are evident. First, one might ask what is the expected value of $I_1$ over
$I_2$ given the actual set of environmental conditions that existed in the 15
periods for the experiment. Let us call this the *ex post value of
information* as it can be calculated only after actual parameters are
known.

Second, one might ask what the value of more timely information would
be at the beginning of the experiments ($t=0$). At this point the decision
maker is facing a very large number of possible environments as each of the
four parameters may take on a large number of values dictated by a random
walk process for each of the 15 decision periods. The value of
information for this problem is known as the *ex ante value of information*. 

The former information value (ex post) may be calculated using straight analytical techniques and is given in Table 1.

**TABLE 1**

The (ex post) Value of Information Structure I₁ (real time) Compared to I₂ (lagged information)

<table>
<thead>
<tr>
<th>Period</th>
<th>Optimal Attainable Profits Given I₁</th>
<th>I₂</th>
<th>Difference (Value of I₁ over I₂)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>146279</td>
<td>146244</td>
<td>35</td>
</tr>
<tr>
<td>2</td>
<td>149026</td>
<td>149003</td>
<td>23</td>
</tr>
<tr>
<td>3</td>
<td>166695</td>
<td>166695</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>204102</td>
<td>201636</td>
<td>2466</td>
</tr>
<tr>
<td>5</td>
<td>229461</td>
<td>229301</td>
<td>160</td>
</tr>
<tr>
<td>6</td>
<td>237119</td>
<td>234260</td>
<td>2859</td>
</tr>
<tr>
<td>7</td>
<td>213661</td>
<td>212415</td>
<td>1246</td>
</tr>
<tr>
<td>8</td>
<td>208328</td>
<td>208063</td>
<td>265</td>
</tr>
<tr>
<td>9</td>
<td>179113</td>
<td>178974</td>
<td>139</td>
</tr>
<tr>
<td>10</td>
<td>252329</td>
<td>246907</td>
<td>5422</td>
</tr>
<tr>
<td>11</td>
<td>305518</td>
<td>300083</td>
<td>5435</td>
</tr>
<tr>
<td>12</td>
<td>351448</td>
<td>350006</td>
<td>1442</td>
</tr>
<tr>
<td>13</td>
<td>270056</td>
<td>268305</td>
<td>1751</td>
</tr>
<tr>
<td>14</td>
<td>304562</td>
<td>301353</td>
<td>3209</td>
</tr>
<tr>
<td>15</td>
<td>299706</td>
<td>298973</td>
<td>733</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>25,185</td>
</tr>
<tr>
<td>Average periods 1-15</td>
<td></td>
<td></td>
<td>1,592</td>
</tr>
<tr>
<td>Average periods 4-15</td>
<td></td>
<td></td>
<td>2,094</td>
</tr>
</tbody>
</table>

In the actual experiments, realized profit differences were obtained and contrasted to those that were theoretically attainable [$2,094 average per period for periods 4 to 15. Note that periods 1 to 3 were set aside for learning purposes.].

The estimation of the ex ante value of information turned out to be a much more difficult analytical problem and indeed a problem that was a prime prospect for simulation techniques. To our knowledge, this represents one of the few applications of simulation to an information economics question.
A SIMULATION STUDY OF THE 15 PERIOD MODEL

Using APL/360, a simulation model of the above decision problem was programmed and validated. The simulation itself utilized variance reduction techniques and consisted of two basic modules.

1. Random variates, antithetic and correlated, were generated for the 15 periods for each environmental parameter.

2. A decision module conditioned on available information \((I_1\ or\ I_2)\) generated optimal decisions which resulted in profits attained and estimates of information value.

BASIC RESULTS -

The simulator was run many times - 15 periods each - for both types of information structures — real-time and lagged time. Based upon the average profits for each 15 period run, standard deviations were calculated. The results for one 40 run sample which were validated by other runs are summarized as follows:

<table>
<thead>
<tr>
<th></th>
<th>Mean Profit</th>
<th>Standard Deviation of</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Average Profits</td>
</tr>
<tr>
<td>Real-Time ((I_1))</td>
<td>$180,320</td>
<td>$28,118</td>
</tr>
<tr>
<td>Lagged-Time ((I_2))</td>
<td>175,514</td>
<td>27,785</td>
</tr>
<tr>
<td>Difference</td>
<td>3,706</td>
<td>912</td>
</tr>
</tbody>
</table>

According to these results, the ex ante profit differential due to the real-time system is $3,706 per period. Before a decision maker or the
system designer would be willing to invest that amount, the distribution of values around the expected value should be examined. The value of the real-time information system is clearly positive since all values are greater than zero. But the standard deviation is $912 giving some indication of the amount of risk.

Note that the mean ex ante information value exceeds the so-called ex post value. Thus a "rational" (expected value maximizer) decision maker could have paid more for real time information at the beginning of the business game than it turned out to be worth. Clearly, the actual experimental environment was less variable than one would expect given the underlying distributions of stochastic parameters. Before closing this section, it should be noted that the simulation approach solved a problem that was virtually impossible to attack analytically, an approach which proved unfruitful for over three years. The main reason why simulation was an appropriate methodology for estimating ex ante information value was that it leads itself to quantifying the underlying decision, payoff, information and environmental functions within a stochastic analysis.

OVERALL GAMING RESULTS

Given the preceding estimates of information value and the underlying economic game, the two sets of information alternatives (I₁ vs. I₂ and I₃ vs. I₄) were implemented. Although the experiments resulted in data which contributed evidence concerning a number of information-decision process variables, such as learning patterns and decision approach effects,
this paper focuses upon insights gained with respect to information systems
questions.*

THE EXPERIMENTAL VALUE OF INFORMATION: TIMING DIFFERENCES (I₁ versus I₂)

The initial set of experiments utilized a real-time versus a one-period
lagged information system as the experimental treatment. In these games,
72 subjects including 25 full-time businessmen participated in 15 decision
periods where the first three were utilized as "learning periods." In
Table 2, the basic results of these experiments are given. In addition
these data are plotted in Exhibit 1 so that one may observe the basic
patterns of the results. Observe that actual profit differences were in the
directions predicted (e.g., the more timely information was functional to
improved decision maker performance) but that such differences are
significantly larger than expected (both of these differences are statistically
significant). It is also evident that decision makers were unable to realize
optimal profits (Exhibit 1, Part C) and that little learning occurred after
decision period 3. Subsequent analysis of the data* showed that behavioral
factors such as decision approach and learning did not explain variations
in observed profits but that the amount of time utilized by I₁ and I₂ subjects
was significantly different. Thus one is uncertain to what extent the more
timely information (I₁) or the additional decision time spent resulted in the
excess profits realized by I₁ subjects.

* For a more complete exposition of behavioral and other considerations
  see Mock [5 & 7] and Mock, Estrin and Vasarhelyi. [6]
TABLE 2

Average Profits and Profit Differences Realized for I₁ and I₂ Decision Makers

Average Profits

<table>
<thead>
<tr>
<th>Period</th>
<th>I₁ Subjects</th>
<th></th>
<th>I₂ Subjects</th>
<th></th>
<th>Actual Profit Difference</th>
<th>Theoretical Profit Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dollars</td>
<td>Percent of Optimal</td>
<td>Dollars</td>
<td>Percent of Optimal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>60737.</td>
<td>0.415</td>
<td>51624.</td>
<td>0.353</td>
<td>9113.</td>
<td>35.</td>
</tr>
<tr>
<td>2</td>
<td>-279752.</td>
<td>-1.877</td>
<td>28860.</td>
<td>0.194</td>
<td>-308612.</td>
<td>23.</td>
</tr>
<tr>
<td>3</td>
<td>100863.</td>
<td>0.605</td>
<td>73507.</td>
<td>0.441</td>
<td>27356.</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>145534.</td>
<td>0.713</td>
<td>143771.</td>
<td>0.713</td>
<td>1763.</td>
<td>2466.</td>
</tr>
<tr>
<td>5</td>
<td>159779.</td>
<td>0.696</td>
<td>115517.</td>
<td>0.504</td>
<td>44262.</td>
<td>160.</td>
</tr>
<tr>
<td>6</td>
<td>177607.</td>
<td>0.749</td>
<td>150001.</td>
<td>0.640</td>
<td>27606.</td>
<td>2859.</td>
</tr>
<tr>
<td>7</td>
<td>120892.</td>
<td>0.566</td>
<td>143935.</td>
<td>0.678</td>
<td>-23043.</td>
<td>1246.</td>
</tr>
<tr>
<td>8</td>
<td>112156.</td>
<td>0.538</td>
<td>139838.</td>
<td>0.672</td>
<td>-27682.</td>
<td>265.</td>
</tr>
<tr>
<td>9</td>
<td>116036.</td>
<td>0.648</td>
<td>101359.</td>
<td>0.566</td>
<td>14677.</td>
<td>139.</td>
</tr>
<tr>
<td>10</td>
<td>189072.</td>
<td>0.749</td>
<td>178467.</td>
<td>0.723</td>
<td>10605.</td>
<td>5422.</td>
</tr>
<tr>
<td>11</td>
<td>224626.</td>
<td>0.734</td>
<td>186593.</td>
<td>0.622</td>
<td>37669.</td>
<td>5435.</td>
</tr>
<tr>
<td>12</td>
<td>246165.</td>
<td>0.700</td>
<td>213304.</td>
<td>0.609</td>
<td>32861.</td>
<td>1442.</td>
</tr>
<tr>
<td>13</td>
<td>171862.</td>
<td>0.636</td>
<td>159742.</td>
<td>0.595</td>
<td>12120.</td>
<td>1751.</td>
</tr>
<tr>
<td>14</td>
<td>196641.</td>
<td>0.646</td>
<td>192458.</td>
<td>0.639</td>
<td>4183.</td>
<td>3209.</td>
</tr>
<tr>
<td>15</td>
<td>199739.</td>
<td>0.666</td>
<td>193914.</td>
<td>0.649</td>
<td>5825.</td>
<td>733.</td>
</tr>
</tbody>
</table>
EXHIBIT 1

Plots of Average Profits (A), Profit Differences (E), and Relative Profits (C) (Actual divided by optimal) for I₁ and I₂ Decision Makers

A. Average Profits I₁ Subjects ○

Average Profits I₂ Subjects *
EXHIBIT I

B. Actual Profit Differences

Hypothetical Profit Differences

Dollars of Profit Differences

50000

25000

0

-25000

-50000

0 | 5 | 10 | 15 | Period

C. Relative Profits $I_1$ Subjects

Relative Profits $I_2$ Subjects

Percent of Optimal

0.75

0.50

0.25

0.00

-0.25

0 | 5 | 10 | 15 | Period
EXHIBIT 2

Plots of Profit Differences (A) and Relative (Realized Profits divided by Optimal) Profits (B) of $I_3$ and $I_4$ Decision Makers

A. Difference in Realized Profits for $I_3 - I_4$ Subjects

\$ 750.0

\$ 500.0

\$ 250.0

\$ 0

-\$ 250.0

0 5 10 Period
EXHIBIT 2

E. Relative Profits Earned I\(_3\) Subjects  
Relative Profits Earned I\(_4\) Subjects
An examination of these data indicate that budgetary feedback information was functional to improved decision maker performance to the tune of $12,520 per period for periods 2 to 10.*

An examination of the learning curves for both subject groups indicates that learning was evident for both groups. Yet rates of learning were not significantly different, although I, subjects exhibited the higher rate. A complete analysis of variance of the experiments indicated that information system, motivation, learning and individual differences each accounted for the observed variance in the experimental data.

As the overall preceding evidence indicates, if one considers available methodologies for information system research, simulation and gaming are among the most useful and feasible methodologies. Such experiments exhibit the necessary degree of internal control to permit statistical inference and a realistic degree of external validity. Most subjects found the experiments interesting and evidence points towards sufficient motivation and effort.

In the following section, the reader will find an even more complex and realistic use of simulation in information systems research. In these studies, experimental control is relaxed in order to investigate a series of information and decision maker variables within the context of a strategic planning problem which is aided by an online directive planning system.

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* The second experiments were conducted for only 10 periods. Period one is not considered as feedback occurs only after period one.
SIMULATION OF PLANNING SYSTEMS*

Objectives and Problem Relevance

Thus far the studies considered have concentrated on the reactions of decision makers to different information structures. Also of importance is the entire communication system, including the problem of man-machine interaction.

The study of complex management systems involving men and machines in symbiotic interaction requires complex methodologies. For example, real-life observation of events often fails to discriminate between events and their causes due to the complexity of the environment. Therefore a study which has a main objective of examining the behavior of managers in man-machine interaction requires a more controlled laboratory or gaming environment. Such an environment would increase control but should not become trivial or deterministic in nature.

The quest for validity of a surrogate environment (and system) in forthcoming management information systems requires online characteristics and a relevant management problem such as planning. Therefore the dual objectives of behavioral and information systems research led to a philosophy of information systems design as suggested by Vasarhelyi [10]. This section of the paper examines the utilization of simulation and gaming for the above objectives.

Simulation in this case is not used as a closed system but as an environment for man-machine interaction.

**MODEL DESCRIPTION**

As too little is known about basic man-machine interaction factors, within an online planning environment, this study focused on three main areas: behavioral factors (decision approach, information utilization and decision speed), man-machine utilization factors (affinity for computers, "power", flexibility, difficulty with...) and secondary factors (sex and recruitment).

**The Simulation Model**

In order to examine these three areas, a simulated environment was created with a history and a problem situation described in a case. A decision tool was also provided in the form of an interactive planning system with an inbuilt database which contained the firm's history. This decision tool, which in essence was a directive Interactive Planning Simulator (IPS), led the user (manager) through a sequence of planning steps:

1. Objective setting
2. Problem formulation
3. Alternative generation
4. Alternative evaluation
5. Alternative choice
6. Feedback

Steps 1 to 3 provided the user with direction in his planning process while step 4 provided O.R. and simulation aids for decision making. Step 4
involved financial ratio calculations of financial statements and a financial planning simulation for the firm. This simulation allowed the decision maker to examine the expected impact of his actions (e.g., issuing bonds or factoring accounts to provide cash) and policy changes (e.g., increase the cash/accounts receivable ratio, decrease the level of borrowing) throughout the planning process of the simulated enterprise. Therefore the overall organizational simulation of man-machine interaction also included a financial simulation module. Such a simulation within a simulation game facilitated the measurement of the man's reaction towards the modeling of financial systems as well as the overall research objectives of measuring the individual's behavior.

**IMPLEMENTATION FEATURES**

**Language Selection**

APL was clearly the language to be used as it was the most powerful language available and its conversational features were especially useful for man-machine interaction. Its major shortcoming — limited workspace size — was bypassed when SNSC Plusfile was made available. This facilitated access to files larger than the basic APL workspaces. Also as the nature of this research was mainly developmental with a small production/development ratio, the interpretative nature of the language was not a significant drawback in terms of cost.
The results of the research indicate that analytic decision makers should have systems tailored to:

1. Emphasize quantitative data
2. Permit ease of usage

Yet rapid response time was less important for such subjects. On the other hand, heuristic decision makers require systems which

1. Emphasize qualitative data
2. Are flexible in nature
3. Facilitate rapid interaction

Finally, analysis of attitude changes indicates that interaction with a system such as the IPS will improve users' attitude towards computers both for experienced and inexperienced computer users.

**Findings in the Pre-Implementation Testing of Software Systems**

In addition to the behavioral findings mentioned above this study added further evidence as to the functionality of simulation as a tool for long-scale software systems development. During the design phases, major problems within the simulation were discovered. These findings could easily be generalized to a real-life software development project. The programming phase identified a series of factors that in a simulation situation are easy to correct but are very serious in nature if they occur in a real life development. For example, in the original IPS, files had not been dimensioned adequately. Thus trace matrixes became too large and
resulted in "WS Full" errors during execution. A segmenting routine easily corrected this problem.

Most of all the experimental part led to user preferences, feedback and performance under simulated conditions. Such evidence would undoubtedly lower overall development costs in large-scale software systems while producing a more adequate system from the user's standpoint.

For example, upon examining user feedback it became clear that the need of making a very clear dialogue with the user was necessary. However, redundant instructions made the system too verbose and repetitive for the user after some utilization. A real life implementation could benefit from this experience and provide different levels of dialogue for the different stages of system utilization.

**Overall Results and Implications**

This paper has emphasized the use of simulation and gaming in information systems research. In contrast, the preponderance of traditional research in this field is pragmatic knowledge, field studies, and theoretical studies such as decision theory. The main obstacle to basic research in this field is the complexity of the variable inter-relationships and the number of factors involved in large systems. The two main sections of this paper discussed studies which deal with these problems by using a laboratory approach with simulation and gaming. These studies relied on similar approaches and dealt with key factors in information systems research. The first set of information-decision process studies dealt with information
economics, while the second with information utilization and behavioral factors in information systems. Figure IV.1 compares the two experiments with respect to overall features. Both experiments were performed in simulated environments using surrogate populations. These populations were carefully observed and timed as they performed a well-defined task. This task led to quantitative decision in the first experiment and quantitative-based decisions in the second. The analysis of results led to similar conclusions concerning manager's decision styles, where in all experiments the heuristic/analytic decision approach (cognitive style) framework was shown to be discriminative. This implied that advantages could be obtained by tailoring information systems to the behavioral characteristics of decision makers. Findings related to ways of supplying information, desirable characteristics for man-machine decision makers and others were also obtained. Each of these is possibly another step towards the comprehension of information. Much is still to be accomplished especially in the study of the interrelations between basic variables. Such a comprehension only can be reached through the laboratory approach and the utilization of simulation and gaming.

The utilization of simulation in information systems research requires a different emphasis than normal discrete-event simulation studies. Verisimilitude, control and sequential dependence must be emphasized instead of traditional simulation criteria such as representativeness, stochastic validity and structural analogy. Barton [1, p. 58] defines "verisimilitude, which means that, while simulation is obviously an artificial representation, it has the quality of being true to life or to human experience." Control,
### FIGURE IV.1
**COMPARATIVE TABLE**

<table>
<thead>
<tr>
<th>Feature</th>
<th>Information Economics Study</th>
<th>Behavioral Planning Study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Language Implemented</td>
<td>APL, CPS</td>
<td>APL</td>
</tr>
<tr>
<td>Number of Subjects</td>
<td>112</td>
<td>50</td>
</tr>
<tr>
<td>Location of Studies</td>
<td>Berkeley, UCLA, Ohio State</td>
<td>UCLA</td>
</tr>
<tr>
<td>Emphasis</td>
<td>1. Information Structure</td>
<td>1. User attitudes</td>
</tr>
<tr>
<td></td>
<td>2. Value of Information</td>
<td>2. Information Utilization</td>
</tr>
<tr>
<td></td>
<td>3. Decision Approach</td>
<td>3. Decision Approach</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4. User background</td>
</tr>
<tr>
<td>Number of APL Workspaces</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Time Spent per Subject</td>
<td>2 - 3 hours</td>
<td>2 - 6 hours</td>
</tr>
<tr>
<td>Method of Evaluation of performance</td>
<td>Comparison with Optimal Values</td>
<td>Judge Rating</td>
</tr>
<tr>
<td>User Response Timing</td>
<td>Automatic</td>
<td>Automatic</td>
</tr>
<tr>
<td>Nature of Subjects</td>
<td>Managers and Graduate Students</td>
<td>Managers and Graduate Students</td>
</tr>
</tbody>
</table>
BIBLIOGRAPHY


