RESTSIM

A Simulation Model that Highlights Decision Making Under Conditions of Uncertainty

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Phenomena in the business world are characterized by uncertainty; and computer simulation can be used as a vehicle for expressing and studying this uncertainty. In the most general sense, simulation is the act of creating a complex model which resembles a real process or system, and then running and experimenting with the model in the hope of learning something about the real system. Simulation helps make assumptions explicit, thus assisting the user in thinking through a decision situation.

MODEL

We have developed a simulation model to accomplish the following three objectives:

(1) to gain insights into the subtleties of restaurant operation;
(2) to expose managers to simulation as a decision support technique and to demonstrate how this technique can be used to solve marketing problems;
(3) to teach managers about strategic planning.

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THE PROBLEM

When an investor is considering the opening of a new restaurant, one of the most important questions which must be answered is: How big should the restaurant be? This is not a problem with a simple answer. During the first three years of a restaurant's existence—a critical period—there is an inverse correlation between restaurant size and business success. That is, the smaller the place, the more likely it is to succeed. Larger establishments, on the other hand, that serve the same cuisine at the same prices, are more likely to fail. This phenomenon might come about because smaller restaurants look more crowded, are thought to be serving better food, and therefore draw bigger crowds. On the other hand, a restaurant does not want to start out too small because this would limit future profits if the restaurant does become popular. Thus, in the first years, it is critical for a restaurant to be just the right size.

We have developed an interactive simulation program—RESTSIM—which helps users to make this decision about restaurant size. The simulation is equally useful for the individual entrepreneur and for the owners of a restaurant chain when the time comes to decide how large a new franchise should be. For both clients, RESTSIM can also provide insight concerning where the new restaurant should be located as it allows for the possibility of comparing profit streams from several different locations.

RESTSIM is useful for solving an important problem in the business world; but it also provides an effective means for introducing naive users to simulation as a decision support technique. Specifically, RESTSIM exposes managers to simulation in three important ways. First, the program demonstrates the use of simulation as a market planning tool. Second, RESTSIM demonstrates the importance of using sensitivity analysis and decision rules to evaluate simulation output. And third, the simulation allows users to explore restaurant operation in order to determine where the money is made in that business.

THE MODEL

If an entrepreneur is going to open a new restaurant, it is necessary to decide on the size of the restaurant. The heart of RESTSIM is a computer simulation which has been constructed to model restaurant operation. By interacting with the simulation, the manager can directly observe the impact of alternative restaurant sizes on profits. Specifically, the manager is able to experiment with the number of bar stools and the number of dining tables in a hypothetical restaurant. On each simulation run (lasting approximately one minute, real time) the user is able to "build" a restaurant of specified proportions.

Each run of the simulation models one evening's activities at the new restaurant. Customers arrive, enter the bar, move to a restaurant table, dine, and depart. At the evenings' end, summary statistics describing restaurant operations are outputted. Both interactive and batch versions are available.

The simulation program is written in PL/1 and GPSS/H. The PL/1 program prompts the user for input and checks to make sure that the input is numeric and within the proper range. The GPSS/H program models restaurant operation. A flow chart of the GPSS/H program is represented in Figure 1.

Basically, the simulation model operates as follows. Customer groups (ranging in size from one to eight) are generated and attempt to enter the restaurant. If the bar (and restaurant) is full, 85% of the arriving groups depart. People do not want to eat in an empty restaurant, but they do not like to stand in line to eat in a restaurant either. It would be more realistic to represent the 85% departure rate as a distribution rather than a point estimate; but to do so would involve adding an additional stochastic element to the simulation and would require additional input (seed value) from the user. We have experimented with versions of RESTSIM which allow the user to specify both a departure rate and a departure distribution; but we have found that RESTSIM is most successful when the number of inputs is kept at a minimum.

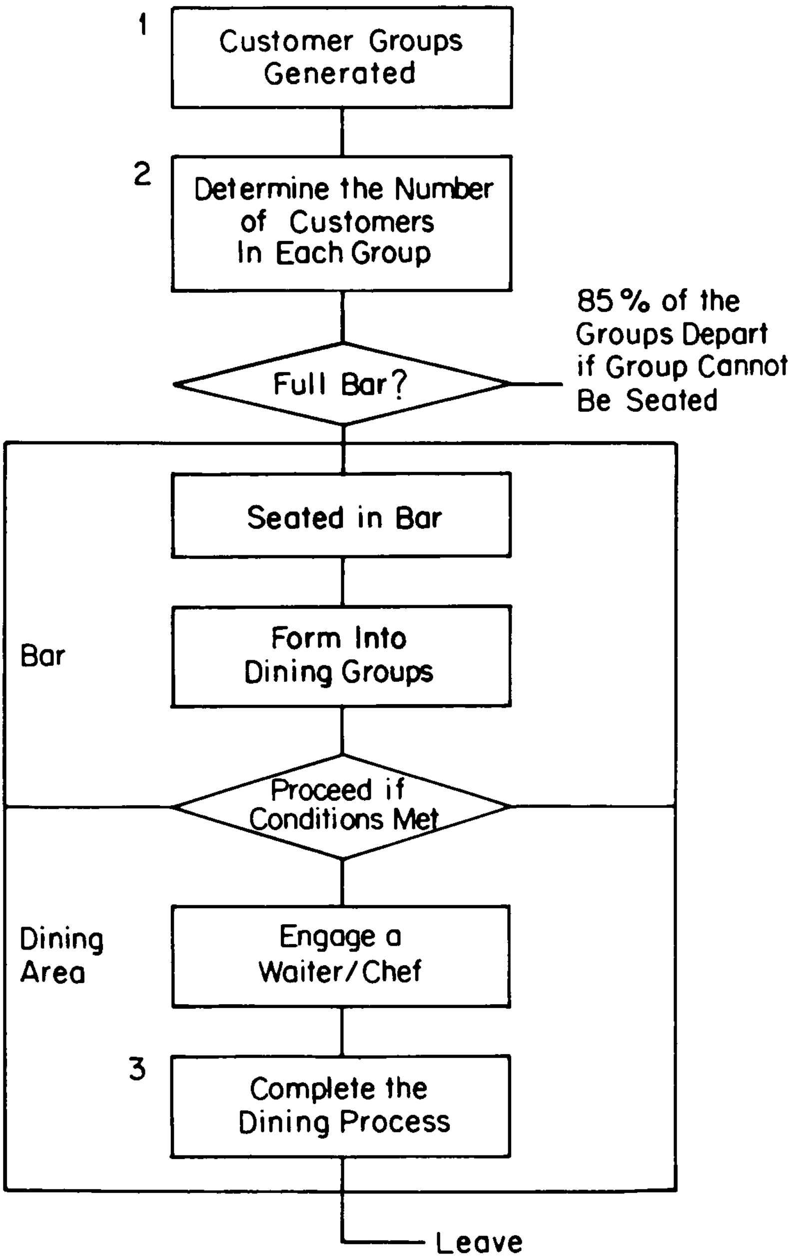

Figure 1. Model Design

Customers are seated if all of the following conditions are met:

I. There is a waiter/chef available, and

II. There is a table available, and

III. At least <u>one</u> of the below is true:

a. There are four or more waiting customers;

b. Any member of the party has been waiting for more than forty minutes;

c. It is almost closing time.

Figure 2. ***Matre d'* Logic**

The customers who stay find seats in the bar and are formed into dining groups. Customers are seated if all of the conditions in Figure 2 are met. Thus, it is possible for a customer to spend zero time in the bar and to proceed directly to the dining room, if conditions are right (i.e., if the dining room is not full when the customer arrives). The dining process is completed in 60 + 5 minutes. If the bar begins to fill up, the waiter/chefs begin to work faster. Other realistic aspects of the model are outlined below.

Customers arrive at differing rates, depending on the time of the evening. Between 5:00 and 5:30 p.m. business is slow; between 5:30 and 7:30 p.m. business picks up; and from 7:30 to 9:00 p.m. (closing time) business slows down again. Customers are seated according to a complex group of decision rules (see Figure 2). In fact, much GPSS logic is devoted to the "simulation" of an active and concerned maitre d'. Waiter/chefs work faster and more efficiently as the bar fills to capacity. However, as can be seen in Figure 2, a single arriving customer will not be seated immediately if a dining group of four cannot be formed. This is done to maximize the amount of time that the customer spends in the bar (where profit margins are high) and to allow for more efficient use of the waiter/chef's time. No customer is allowed to wait more than 40 minutes if a table is available.

The model operates in seconds. Customer arrival rates are Poisson-distributed. Thus interarrival times are exponentially distributed. There are four stochastic processes in the model; these include: customer arrival times, the number of customers in each arriving party, the determination of which arriving customer parties will leave when the bar is full, and actual dining times.

One of the advantages of RESTSIM is that it is easily understood by users. For example, Figure 1 clearly illustrates each stage of restaurant operation. Users are readily able to observe the importance and consequences of the marketing decision variables which are highlighted in restaurant operation. Partly this is due to the power of the GPSS programming language wherein a small effort is required to model a complex system. Since GPSS/H operates interactively in a time-sharing environment, it is possible to design GPSS models that can be run by users who have no knowledge of the underlying language.

Not only is the simulation model itself easily comprehended, but the input variables are fairly straightforward. The profitability of a proposed restaurant can be captured by two important input variables: restaurant size and customer arrival-time assumptions. Since there is such a small number of input variables, users readily observe the tradeoffs which are made as the restaurant varies in size. This, in turn, invites greater interactive experimentation with the model. In the two sections below, RESTSIM is positioned relative to other existing simulation models, and general methods for analyzing outputs from the model are discussed in more detail.

COMPARING RESTSIM TO OTHER SIMULATION MODELS

Customer simulation involves the construction of a simulation model, the purpose of which is to generate a population of customers with certain characteristics. This population is then faced with a decision; usually, a product is offered for sale. The members of the population can either buy or not buy. Thus, it is possible to observe purchase behavior over time and to estimate expected market shares for various brands. Customer simulations differ depending on the sophistication of this customer decision process and can operate on four different levels. These levels are outlined in Table 1; examples of each level are also included.

RESTSIM represents a model of a complex decision situation. It is not possible, through the use of hand calculations, to determine the optimum size of a new restaurant and to address all of the long-range planning issues associated with that new restaurant. RESTSIM provides the user with a means to grasp a complex situation; and yet, the user is able to accomplish this through the manipulation of relatively few decision variables. The third column of Table 1 outlines the number of input decision variables in the various simulation models represented. Notice that RESTSIM involves the fewest input variables of any of the listed models. In addition, RESTSIM is extremely user-friendly in that the user is provided with multiple opportunities to supply input that is properly numeric and within the proper range. An illustration of the user interface is shown in Table 2, where an interactive terminal session is reproduced.

ANALYZING SIMULATION OUTPUT

RESTSIM suggests several methods by which participants can evaluate and organize simulation results. Table 3 represents one way that output from the simulation model can be summarized. The number of restaurant tables is listed on the abscissa while the number of bar stools is listed on the ordinate axis. Entries in the cells represent average net profit before taxes. By examining Table 3, the simulation user can get a feel for the response surface. In this case, the optimum restaurant configuration seems to consist of five tables and 22 bar stools as this results in the highest net profit before taxes—$169 per night.

Simulation is only one entry on a long list of decision-making tools. It is a valuable aid in evaluating decision options and in understanding the structure of a decision problem. However, it is

TABLE 1
Levels of Customer Simulations

Level	Example	Number of Decision Variables
1. Customer Decision Process	Hinesbury Mills	11
2. The Individual Firm	RESTSIM	3
3. An Entire Industry	MarkStrat	8
4. An Economy	A Microanalytic Population Simulation of Alberta	10

not a replacement for managerial knowledge, experience, and intuition which can be used to interpret and augment simulation results. One way that decision style can be incorporated into the choice process is through the use of Maximin, Maximax, Minimax Regret, Laplace, or Expected Value Criterion to evaluate simulation results. In this way, managers can explicitly evaluate their attitudes toward risk, given the decision situation.

Table 4 presents a payoff matrix that was constructed by one user of RESTSIM. The entries in the table refer to the net profit before taxes that can be expected each day under different restaurant configurations (in terms of number of tables and number of bar stools). Under each configuration, six profit estimates are given. These profit estimates are expected to cover the following conditions:

(1) Pessimistic/Conservative Estimate—uses a pessimistic estimate of customer arrival rates at the restaurant and a conservative estimate of expected restaurant profitability;
(2) Pessimistic/Liberal Estimate—uses a pessimistic estimate of arrival rates and a liberal estimate of profit margins;
(3) Most Likely/Conservative Estimate—uses a most likely estimate of customer arrival rates and a conservative estimate of restaurant profitability;

TABLE 2

Inputting Data to the Interactive Simulation

```
                    (Optional introductory material)

     This is a simulation to investigate the ideal bar/restaurant configura-
tion for a restaurant.  After each question, type in the data requested,
followed by a "carriage return."  Type input data starting in column 1; hit
"attn" or "break" key if you want to bail out.  Note that negative numbers are
not allowed; also note that all values should be expressed as integers.

     A marketing research study is available which predicts an average
customer interarrival time, Poisson distributed.  This marketing research
study provides three estimates for customer interarrival time:

          1.   Most optimistic    -----    4 minute interarrival time
          2.   Most likely        -----    6 minute interarrival time
          3.   Most pessimistic   -----    8 minute interarrival time

     The following simulation has been designed to approximate restaurant
operation.  You are cordially invited to experiment.

How big should the restaurant be?

          (Inputting data:  user responses are underlined)

Which marketing research estimate do you want to use?

          1.   Most optimistic
          2.   Most likely
          3.   Most pessimistic

Type in "1", "2", or "3"

1.
Type in the number of bar stools
23
Type in the number of dining tables;
Each table seats 8 customers.
8
Do you want to supply seeds for the 2 random number generators?
Type "Y" or "N"
N
(Next, the program supplies a summary of the input and displays the results of
the simulation)
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(4) Most Likely/Liberal Estimate—uses a most likely estimate of customer arrival rates and a liberal estimate of profitability;
(5) Optimistic/Conservative Estimate—uses an optimistic estimate of arrival rates and a conservative estimate of profit margins;
(6) Optimistic/Liberal Estimate—uses an optimistic estimate of arrival rates and a Liberal estimate of profit loyalty.

The pessimistic, most likely, and optimistic assumptions can be obtained either by interviewing potential customers (survey

TABLE 3
Average Profit per Night Under Different Restaurant Configurations

Number of Bar Stools	3	4	5	6	7	8	9	10	11	12	13	14
31												
30			160									-230
29			161									
28			162									-229
27			164									
26			164									-227
25	53		165			101						
24			166									-226
23	82	146	167	113								
22		147	◯169	114		56		-25		-158		-225
21		122	159	114		55		-26		-160		
20			147									-223
18					86							-221
17												
16												
15												
14					62							
13			103		57		0		-67		-142	-218

Number of Tables

◯ = optimum configuration

research) or by performing simple hand calculations based on different assumptions about customer loyalty.

Table 4 represents an example of raw simulation output. Subsequently, it is necessary to use managerial judgment or experience to evaluate this raw output. One way to start this process is to eliminate possibilities which produce unfeasible or intolerable results. In this particular case, several alternatives are

TABLE 4

Payoff Matrix (net profit before taxes per day)

# of Tables	# of Stools	Pessimistic Cons*	Pessimistic Lib**	Most Likely Cons	Most Likely Lib	Optimistic Cons	Optimistic Lib
7	45	$54	$110	--	--	--	--
8	45	39	104	57	142	--	--
9	65	37	104	51	136	78	190
10	50	25	82	48	133	71	180
11	30	29	85	48	133	67	180

-- Indicates not feasible due to too many customers being turned away at the door.
* Conservative
** Liberal

eliminated because, under these conditions, the restaurant would be forced to turn away too many customers due to overcrowding.

Table 5 represents the way that the expected profit figures from the various configurations can be represented under the various decision-making criteria—Maximin, Maximax, Minimax Regret, Laplace, and Expected Monetary Value. A brief explanation of each of these decision strategies is also contained in Table 5.

The decision tree necessary for calculating the expected monetary value criterion is presented in Figure 3. Note that different restaurant configurations appear optimal when different decision criteria are used. This serves to underscore the importance of using managerial experience and managerial judgment to evaluate simulation results.

Simulation is a computational technique for measuring parametric sensitivity. A problem common to all models is how to determine the effect of variations in input data and/or structural parameters on output results. One reason for doing this is to compensate for inaccurate data, to see how the output would be affected by alternative estimates. Another reason is that initial conditions in a simulation are often arbitrary, and it is important to determine whether the output is significantly affected by different starting conditions. Sensitivity analysis is an especially good technique for analyzing RESTSIM output, since it highlights the changes in output (in this case, profits) that occur as inputs to

TABLE 5

Decision-Making Criteria

The optimum restaurant configuration under each decision criterion is indicated by a [ ] and is summarized in parentheses after the description of each criterion.

		Tables	NPBT/DAY
I.	MAXIMIN CRITERION:	7	$ [54]
		8	39
	Maximize the minimum payoff for each configuration.	9	37
		10	48
		11	48
	(7 tables, 45 bar stools)		
II.	MAXIMAX CRITERION:	7	$ 110
		8	142
	Maximize the maximum payoff for each configuration.	9	[190]
		10	184
		11	181
	(9 tables, 65 bar stools)		
III.	MINIMAX REGRET:	7	$ [56]
		8	103
	Considers greatest opportunity loss for each configuration, then minimizes it. The opportunity loss = greatest payoff - least payoff in each configuration.	9	153
		10	136
		11	133
	(7 tables, 45 bar stools)		
IV.	LAPLACE CRITERION:	7	Not
		8	Possible
	Maximize the average expected value. Equal probabilities assigned to each payoff.	9	$ [101]
		10	92
		11	92
	(9 tables, 65 bar stools)		
V.	EXPECTED MONETARY VALUE CRITERION:	7	Not
		8	Possible
	Use subjective probabilities and maximize expected value. See Figure 4.	9	$ [89]
		10	82
		11	82
	(9 tables, 65 bar stools)		

the system change. Specifically, the effect of different restaurant sizes and different customer arrival assumptions on profit streams can be scrutinized.

For example, once a user has determined the "optimum" restaurant configuration, a sensitivity analysis can be performed to observe the impact on profit of adding (or subtracting) one bar

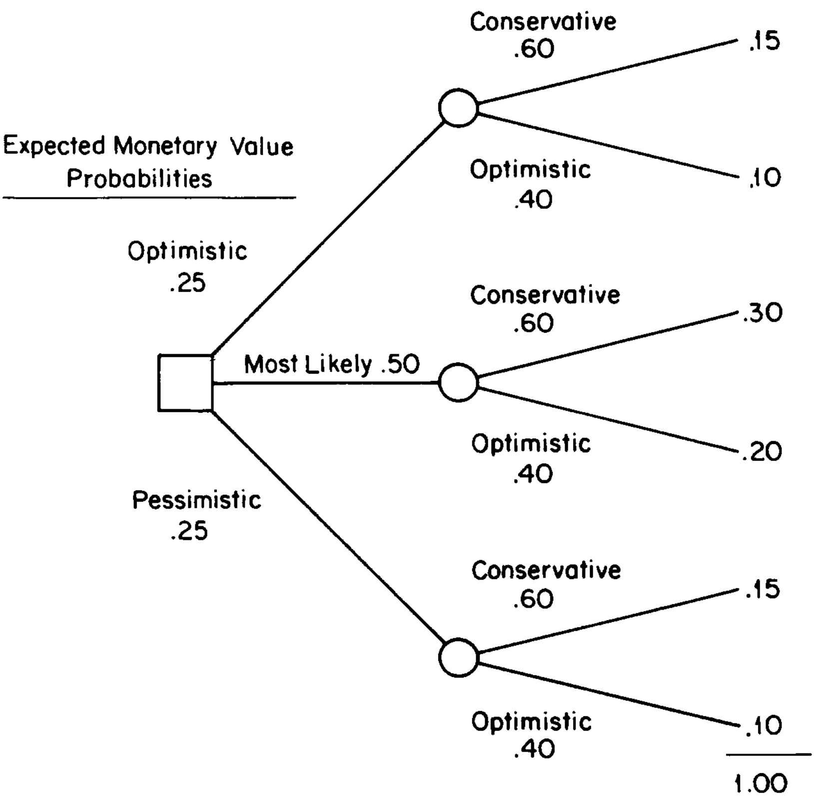

Figure 3. Decision Tree

stool or one dining table. RESTSIM can also be operated in batch mode to facilitate such analysis. Alternatively, after identifying the two "best" restaurant configurations, the user can perform a t-test in order to determine if profit streams differ significantly under the two configurations. Again, a batch mode can be employed to generate a sample of profit streams. Further, if a manager wishes to compare more than two configurations simultaneously, then the Scheffe method of simultaneous inference can be employed. Through repeated simulation runs, a user can put confidence intervals around profit streams and in this manner deal with uncertainty in a quantifiable and rational manner.

ADMINISTERING RESTSIM IN THE CLASSROOM

We have found that it is best to expose students to RESTSIM using a five-step process. The first and last stages take place in class, while the intervening stages happen outside of class as take-home assignments. RESTSIM can stand on its own as a case and simulation exercise, or it can be used in conjunction with other restaurant cases such as Benihana of Tokyo. The procedures for implementing and administering RESTSIM as a stand-alone case are briefly outlined below.

As a first step, students are introduced to some of the problems which arise when a new restaurant is planned; this introduction can take place in class, as lecture material. At the second step, students are given a handout to read which further highlights restaurant planning problems and which introduces users to the simulation model. This handout outlines the decision situation, contains detailed instructions for operating the simulation model, and includes guide questions to help the user analyze simulation output. Third, students are given an opportunity to interact with the simulation by following instructions contained in the handout.

At the fourth stage, as an assignment, students answer guide questions from the aforementioned handout. Answers to these questions can be gleaned from a careful examination of simulation output. These assigned questions concern such topics as: "What is the expected profitability under different restaurant configurations?" "Where is the money made in the restaurant industry?" "What is the optimum restaurant size?" At the final stage, in class, students can discuss their experiences with the simulation model and discuss the answers to the guide question. The instructor can highlight such issues as assumptions of the simulation model, methods for analyzing simulation output, and the role of simulation as a decision support technique. In addition, it is possible to set up student presentations on some of these topics.

COURSES WHICH MIGHT BENEFIT FROM RESTSIM

RESTSIM is appropriate both for graduate courses and for advanced undergraduate courses; adoption may be considered when the instructor desires to introduce students to the use of computer simulation in a business setting. Our personal experience with RESTSIM includes use in introductory marketing courses (both undergraduate and graduate) and use in a graduate course in planning and strategy. Other courses which may be appropriate are introductory management, policy and control, retailing, operations research, or services marketing. For all of these courses, RESTSIM can be used to demonstrate the proper procedure for interacting with a decision support system and to highlight specific elements of restaurant operation. For example, users can directly observe the impact that different assumptions about repeat customers have on restaurant profitability. From a close examination of simulation output, users can also determine which aspects of restaurant operation are most profitable (e.g., profit margins are higher on drinks than food). Sensitivity analysis can be employed to highlight the changes in output that occur as inputs to the system change. In this way, managers can come to make better decisions when using the simulation model; this is especially apparent in this situation where paper and pencil calculations are not able to capture the dynamics of arriving customers and restaurant operation. The process of using the simulation and thinking about the assumptions of the model seem to cause the user to understand the restaurant business better; this, in turn, seems to lead to a more thorough analysis of the decision problem.

Again, RESTSIM can be adopted whenever the instructor may want to introduce students to the use of decision support systems. The exercise teaches students how to interact with a decision support system, how to scrutinize the assumptions of a simulation model, and how to analyze inputs and outputs. For introductory courses, the instructor may want to emphasize the assumptions of the model and emphasize the procedure for interacting with the model. For more advanced students, the instructor can emphasize the importance of sensitivity analysis and can explore some of the advanced statistical procedures which are available for examining simulation models.

SUMMARY

Here we have described a simulation exercise that can be used to introduce users to a decision support technique which is designed to aid in the solution of a real world problem. This customer simulation requires no prior experience on the part of the users with either simulation modeling or simulation languages; but the exercise can also benefit more sophisticated users by providing a vehicle for studying the various statistical procedures which exist for evaluating simulation output.

In our experience, RESTSIM has proven to be an interesting and useful pedagogical tool to introduce managers to both services marketing and computer simulation. In any simulation model, assumptions have to be made. If used properly, simulation can help managers make their assumptions more explicit. RESTSIM provides one vehicle for managers to evaluate the validity of their assumptions. Additionally, RESTSIM makes potential managers more aware of the methods which exist for analyzing simulation input and for evaluating simulation output. As managers begin to feel more comfortable within a simulation setting, they become better prepared to function in today's computer-oriented business environment.