SIMULATION-FRONT END SCHEDULING

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The author discusses the use of computer simulation technique to solve checkout personnel allocation problems.

I will approach the discussion on the use of simulation in the management of the front end of the supermarket from two basic perspectives. The first is to explain why I believe computer simulation is a technique applicable to the solving of checkout personnel allocation problems. The second is to give some idea of the general approach to using simulation as it applies to the front end of the supermarket. For illustrations I will use preliminary results from research that I am conducting.

To begin, there is not anything magic with the technique of simulation. Many examples of simulation are found all around us - in nature where the tree frog camouflages itself by simulating the object on which it rests, to research where wind tunnels simulate actual air turbulence, to the military where war games simulate actual combat. These are examples of the many ways that something may be simulated, such as through unrelated physical material, scaled down physical analogues, an exact duplicate of the object itself, combinations of actual parts and hypothesized behavior, word descriptions, or mathematical formulae. It is this last method that is of most interest to us today, the use of computer simulation to imitate the relevant characteristics of the front end of the supermarket.

Why might simulation techniques have to be applied to the problem of front end scheduling? First of all, although there is an elegant mathematical body of queuing theory, the complexity of multichannels, varying arrival and service rates, and other store parameters precludes exact solution by mathematical procedures.

Second, is the importance of the problem itself. While supermarket gross margins as a percentage of sales have remained relatively constant for the last five years, payroll expenses have definitely increased. According to the latest Progressive Grocer - Cornell report, labor expenses have risen from 49% of gross margin to 53% of gross margin for chains and from under 44% gross margin for independents to over 46% of gross margin. This continuing profit squeeze is putting increased pressure on supermarkets to make maximum use of their resources, including proper allocation of their personnel. The answer is not to simply cut back on service, for already over three-fourths of shoppers think the wait at the checkout line is too long, but instead to more efficiently allocate personnel.

A third reason for simulation work, is the seeming lack of satisfactory methods being used currently. In a survey of 116 of the 330 largest supermarket chains, independents, and wholesalers, there was found to be quite a bit of dissatisfaction with the way their front end operations

were being managed. Top management personnel were asked about the methods they employed to allocate front end help. They were then asked to indicate on a scale their level of satisfaction with the method employed. About 25% of those using computers or some form of models expressed some dissatisfaction while over 50% of those relying on managerial judgment were dissatisfied. The main reason given by those not using more sophisticated techniques was because they did not know of any good model or better technique. Thus good methods available now seem to be proprietary and not accessible to everyone. With the size of stores continuously rising and the number of checkouts likewise increasing, it can only be assumed that the level of dissatisfaction with managerial judgment will also increase.

Lastly, simulation more than simply allows for a determination of the correct number of queues to have or how many checkouts should be open at any given time. It also allows for testing hypotheses, decision rules and alternate systems of operation under a variety of assumed conditions. Thus, the implications of no, one, or two express lanes, of varying numbers of baggers, of different service policies, as well as numerous other decisions may be tested with little risk and still afford the manager a degree of confidence about the outcomes. Training new managers and evaluations are two further uses for which this technique may be utilized.

These are some of the reasons for and advantages of using computer simulation to help solve the front end scheduling problem. Next I would like to discuss a general procedure for problem solving through simulation. This discussion should not be thought of as a procedure that automatically develops simulations capable of reducing complex problems into simple solutions. Instead, it should be viewed as a general guideline to aid the individual in an orderly progression of steps aimed at minimizing duplication and unnecessary work in developing a workable model. These steps will be discussed in relation to the front end scheduling problem. I should also like to share with you some preliminary results of my simulation work in the area as illustrations.

The first step is the definition of the problem in terms of the objectives to be achieved. In the front end allocation problem, the maximum utilization of front end facilities might be desired, within the restraint of providing a stated level of customer service. This could also be posed in other ways, which may result in slightly different allocations. For example, maximizing customer service at a given level of expense or minimizing front end expenses, etc., could have been chosen. In any case, the key is the dual requirement of cost consideration versus level of customer service. It was this requirement that led me to approach the problem with two closely related simulations rather than one. The first gives the optimal number of servers with a given level of service and the second determines the effect the store's actual fluctuating arrival rate will have on this service. I will go into this in a little more depth later.

The second step is the identification of relevant variables and parameters. These would be such things as the pertinent distributions, identification of store parameters, external constraints, etc. This is done to determine the various facets of the front end and their relationships. One useful way of categorizing these variables is whether or not they are inputs (exogenous to the model) or outputs (endogenous to the model). Some of the important input variables are: arrival distribution and rate, purchase distribution, time in the store, service rate, number of baggers, etc. Some of the outputs would be: arrival rate to checkout, time spent in line, time of service, checker utilization, and number of checkouts to have open.

A next step would be to take the overall model of the supermarket and break it down into logical subsystems that can be described and modelled. This is done because it is much easier to determine relationships, significant variables, and

processes for each subsystem than it is for the system as a whole. These subsystems would then be combined as a flow chart that would show the logical sequence of activities of the system.

Figure 1 shows a flowchart of my overall model itself. Broken down, it consists of six subsections:

Main program: This initializes the values of various store parameters for that particular run.

Evnts: This determines which of the various other subroutines will be called next. This is needed to organize and sequence the happenings taking place.

Arrvl: This is the first of the actual store subroutines. In this one the arrival rate of customers is determined, whether they are major shoppers or simply supplemental, how many items they will purchase, and when they will conclude shopping.

Enshp: This subroutine determines what happens after shopping is completed. If a checkout is free the customer is directed to it. If not, the customer is placed in the appropriate queue (i.e., the shortest one). Also, statistics on the customer's shopping are collected here (i.e., no purchases, time shopping, etc.).

Ckout: In this subroutine the customer is checked out. Statistics on his wait in line and service time are collected along with some on the servers too - such as percent time busy, number waiting, etc.

Endsm: This subroutine ends the simulation. All statistics are updated, service is completed, and reports are printed out.

This logic can now be programmed in a language that is selected. I chose FORTRAN, for use with the simulation language GASP. This simulation language was chosen because of its versatility, its simplicity, and particularly its applicability to queuing situations.

The next step is one of the most difficult parts of the use of simulation, that of the estimation of distributions of variables and parameters. In addition to the problems of observation inaccuracy, determination of sampling, unknown interaction of the variables, and other miscellaneous errors, there are also the practical problems of economics (i.e., how much can be afforded for collection) and disruption of normal store operations to be considered. In my simulation, a large supermarket in the Cleveland area was studied in detail for several weeks. In addition, data on their operations for other time periods was also obtained. Because of time and expense limitations, only Tuesday through Friday of each week was studied. On this particular store Tuesday and Wednesday were almost identical as were Thursday and Friday. These were the ways computer runs were then made.

The last step to be discussed is that of validation of the model. Validation itself can be a complex and multilevel problem. We will now examine a few facets of it. The first and simplest level is that of face validity. This is examining the model for internal logic flow (i.e., is the model simulating what it is supposed to?). Another way of looking at it is how well the model intuitively coincides with the real world process being analyzed.

There can also be statistical validation of the various distributions and estimations used in the model. A comparison of the sample store's customer arrivals with those simulated, while not perfectly coinciding, is close enough to be judged a good fit, both by observation and also by statistical testing. Likewise, the time in store distribution, service rate distribution, and any other estimations should be evaluated, actual versus that determined by the model.

Another level of validation is comparing those values actually determined or calculated by the model, with actual samples from the store. These figures are formed by interaction of several of the input variables. An example of this would be how well the model could combine input of

arrivals, purchases, and shopping time to calculate the distribution of customers arriving at the checkout counters.

Another level of validation is how well the model can reproduce the overall results of its total system based on historical data. Here past observations are used to determine input on all facets of the system. The model should be able to approximately reproduce their underlying distributions. Of special importance is determination of how well the model reproduces key results that are the aggregate of interactions of as many of the variables as possible. In the case of the front end of a supermarket, the distribution of the length of time customers spend at the checkout counter, both waiting and also being served would be a good example. In other words, arrival rate, number of purchases, time in the store, and service rate would all affect the time spent at the checkout counter. Comparing the actual versus simulated checkout times, results are both observationally and statistically good.

The validity tests up to now are all good and necessary in evaluating the model. However, their real purpose was to aid in the development of the model and develop confidence in the results of the simulation. The real test of validity of this model is how well it predicts -- how well the solution determined operate under future conditions. To test this aspect the two simulation programs must be utilized. The number and allocation of checkouts are first determined as output of the first program by specifying a certain level of customer service. These decisions on number of checkouts operating are then used as input in the second program, and the arrival rate allowed to vary to replicate the actual future arrival distribution to the store. For example, for the Thursday-Friday simulation, the actual number of customers for four weeks following the observations varied from 1520 to 1727 customers with an average of 1625. The simulated, or predicted number of customers, for the same period had a range from 1498 to 1788 customers, with an average of 1608. Thus, the simulated values fully encompassed the actual values for the time period covered. The results were similar for the Tuesday-Wednesday comparison.

The final part of this test was how well the model predicted number of checkouts fared against the actual number of checkouts used. The average number of customers served per clerk hour was 30.0 for the model predicted values and 26.5 for the actual number of clerks used or a 13% increase. At the same time, the average customer service time did not significantly vary, being 3.92 minutes for the actual number of checkouts and 4.03 for the predicted, a 2 1/2% increase in waiting time. It must be admitted at this point that there was some variation depending on the count of the actual day, the predicted number being definitely superior on the lower and average number of customer days and giving slower service times on the higher than average days.

This aspect of the simulation technique, that of forecasting results based on the predicted values is still very much under study. Computer runs are being made with data obtained from other stores to see how applicable the model is in forecasting under varying circumstances. For it is only through success on this point will the method be worth anything from a practical standpoint.

I hope I have shown, albeit in a rather cursory manner, an overview of the computer simulation method of problem solving as it relates to managerial decision making. I hope I have also demonstrated more specifically that for cost and flexibility reasons, also for the overall potential benefits, why I believe that computer, simulation can play a very important and useful role in helping to solve the allocation problem of front end personnel in the supermarket.

FIGURE 1

FLOWCHART - SUPERMARKET SIMULATION