CASE STUDY (CS 3)

SOLVING AUDIT PROBLEMS WITH COMPUTER SIMULATION:

A CASE STUDY

DIVISION OF FINANCIAL AND GENERAL MANAGEMENT STUDIES

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Contents

CHAPTER		Page
1	COMPUTER MODELS AND SIMULATION	1
2	GPO INVENTORY SYSTEM AND MANAGEMENT POLICY	3
	GPO inventory system	3
	GPO inventory management policy	5
3	GAO ANALYSIS OF GPO INVENTORY DATA	6
	Design of model	9
	Validation of model	13
	Simulation of GPO inventory operations	13
4	EVALUATION OF SIMULATION	16

CHAPTER 1

COMPUTER MODELS AND SIMULATION

This General Accounting Office (GAO) case study presents a detailed discussion of the procedures used in modeling and simulating inventory operations at the Government Printing Office (GPO). It is intended to illustrate the advantages that can be gained by using these techniques in conjunction with regular audit procedures. It supplements an earlier study entitled "Case Studies of Auditing in a Computer-Based Systems Environment" (B-115369, June 1971).

Although mathematical models have been known since the sixth century B.C., they are a relatively new technique for the auditor. A model is generally defined as a mathematical representation of a process, device, or concept. As computer technology advanced, man's capacity for invention quickly led him to combine two elements, computers and modeling, to form a new technique--computer simulation. Computer simulation is a powerful technique with a broad range of applications in audit activities. As used by the auditor, simulation can assist in identifying an optimum solution to a difficult problem, as it did at GPO. Assuming that a computer model is valid, in that it accurately represents the system or operation functions and measures what it is supposed to measure, it is an inexpensive, efficient, rapid device for analyzing and evaluating systems or operations. However, developing a model is only half the battle. The other half is using it in simulation to search for an improved solution.

The problem of searching for an improved solution can be compared with that of finding the peak of a mountain. Perhaps a better analogy for the auditor is finding the peak of a range of mountains of nearly equal height on a foggy day under conditions where landslides and earthquakes keep shifting the terrain. With simulation the auditor is able to describe the shape of the mountain and can take advantage of certain of its properties so that, by going from ridge to ridge, his search always proceeds uphill in an efficient way to the peak. In some instances, he may not know the shape of the mountain or any particular property of its surface and therefore he must simply search around for the peak. Sometimes he can take advantage of the fact that he can tell uphill from downhill and that the peak is always on the uphill side.

Basically all that is required is that a simulation predict the relative effects of alternative actions with sufficient accuracy to permit the auditor to make a sound decision. It is of critical importance that the results of the simulation be within statistically acceptable confidence limits. Thus, when using simulation the auditor should predetermine the confidence limits he is willing to accept. A major advantage of simulation is in studying a problem and proposed or related solutions without incurring the costs or risks of actual implementation. It was this advantage which led to the development of the inventory model used to simulate inventory operations at GPO.

CHAPTER 2

GPO INVENTORY SYSTEM AND MANAGEMENT POLICY

GPO INVENTORY SYSTEM

GPO is a Government agency whose primary responsibility is to provide printing and binding services for the Congress and for Government departments and agencies. To meet these responsibilities GPO maintains and stores about 600 different types of paper with an estimated value of $8.5 million.

GPO obtains most of its paper from contractors under 3-month contracts. Such a contract contains descriptions, including testing specifications, of all types of paper GPO plans to use during the term of the contract. The contract also contains a listing of terms and conditions to be met by the contractor and by GPO. For example, the contract contains provisions which set forth the allowable variance in the quantities delivered. The allowable variance between the quantity ordered and the quantity delivered is not to exceed 30 percent. Depending on the quantity ordered, the allowable variance may range from 2 to 30 percent. The contract also requires that shipment of an order be made within 35 calendar days (plus or minus 5 days) after the order is placed. If this requirement is not met, any additional costs (greater than $15) incurred by GPO are to be charged to the contractor.

In addition, paper not meeting GPO specifications must be replaced within 14 calendar days after receipt of the notice of rejection, unless other action is authorized by the Public Printer. Further, the contract stipulates that, unless shipments of less than carload lots are specified by GPO, additional freight charges for less than carload lots will not be paid by GPO.

GPO's current inventory system, although partially automated, relies almost entirely on nonautomated procedures for inventory decisions. For the most part the automated part of the system performs a recordkeeping function. The major product of this automated part of the system is a biweekly Inventory Detail Listing. This listing provides day-to-day information on all transactions involving every type of paper maintained by GPO. This information can be used only in this form, because the computer tapes from which the listing is prepared are not retained for later use. In addition, the automated part of the system also produces a daily listing which contains the quantities of each paper on hand and on order. All other aspects of the ordering procedure are performed manually and are based on the personal judgment and experience of GPO officials.

To establish minimum inventory levels, GPO gives each line item of paper a month factor. This month factor indicates the number of months' supply to be maintained in inventory (the quantity on hand plus the quantity on order) of each line item of paper used by GPO. This factor varies greatly for different items and ranges from two to six. The month factor is determined by the Chief of the Paper and Materials Control Section on the basis of his experience in paper procurement and his professional judgment rather than of historical data. He also estimates the quantity of paper that will be ordered, taking into consideration the average monthly use for the preceding 6 months. If the estimate is unrealistic, he will increase it and thereby increase the minimum inventory level for that item. Next he prepares a minimum ordering level document summarizing this information for all items.

The minimum quantity of paper to be maintained in inventory (the month factor multiplied by the average monthly use) is also the reorder point; when the inventory level reaches this point, an order is placed. The quantity ordered is equal to 1 month's average use. This means that the 2- to 6-month supply maintained for each line item of paper is the minimum level, and the actual inventory quantity will at most times be considerably higher.

GPO INVENTORY MANAGEMENT POLICY

Due to its responsibility for quickly providing printing and binding services to the Congress and to Government departments and agencies, GPO has established an inventory management policy that is intended to insure that it will always have an adequate supply of paper on hand to meet its needs. GPO does not tolerate an out-of-stock condition for any of the paper it uses.

CHAPTER 3

GAO ANALYSIS OF GPO INVENTORY DATA

The objective of GAO's analysis was to develop an efficient and effective method of analyzing the experience of GPO. This experience was represented by a large volume of historical data on the many line items of paper GPO stocked. The GAO audit staff believed that simulation could help solve this problem, because it would provide an independent and accurate method of evaluation and could be used to ascertain the probable future effect of any procedural changes.

In this study, as is true in similar studies, the analysis of historical data was mandatory, difficult, and time consuming. However, this task was simplified because of the excellent records maintained by GPO. It maintained complete records, for a 3-year period, on the dates and quantities of each line item of paper purchased, the dates and quantities received, and the dates and quantities used in filling printing and binding orders. The quality and quantity of the data indicated two things: first, the data would be extremely useful in providing accurate and useable study results, because the patterns of ordering, receiving, and use could be readily determined and second, the data would be susceptible to analysis by a computer.

As a starting point for our analysis, two basic documents were used--the Division of Purchase Control Card and the biweekly Inventory Detail Listing.

The basic document used to administratively control orders and receipts of paper is the Division of Purchases Control Card. This card shows all pertinent information concerning orders and deliveries: the property number of the line item ordered, the date of the order, the quantity ordered, the total price, and the delivery instructions. The back of the card lists the shipments received that make up the entire order. Included in this list is the date the shipment is received, the quantity received, and the date that the shipment is accepted. The difference between the date the shipment is received and the date it is accepted (1 to 3 weeks) is due to the testing procedures carried out by GPO to insure that the paper meets the required specifications.

To get an overview of this information, we analyzed all information from the control cards for each order for a 3-year period. Comparisons of the GPO requested deliveries with the actual deliveries showed that the contractors were shipping paper in carload lots under their own schedules and were disregarding GPO delivery specifications. However, delivery on this basis conformed with the contract terms which required the contractor to ship in carload lots. For this reason, delivery time was considered to be a variable factor in the inventory operations. Further analysis revealed that the number of elapsed days between deliveries could be broken down into 10-percent increments for each order since these increments approximated carload lots. We also calculated the mean and the standard deviation[1] associated with each increment. Use of this data was necessary in constructing schedules during the simulation. This data, which is summarized in the table on page 8 for property 205, white writing paper, was used to simulate GPO inventory operations.

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[1] A measure of the degree of spread among a set of values; a measure of the tendency of individual values to vary from the mean value (GAO Glossary for Systems Analysis and Planning-Programming-Budgeting).

Table 1

Analysis of Elapsed Days

percent of order received	mean number of days required to receive each increment	standard deviation
10	49	21
20	51	25
30	54	24
40	57	24
50	62	22
60	66	26
70	68	27
80	71	28
90	72	28
100	76	29

To continue our analysis, we used all available Inventory Detail Listings covering an approximately 3-year period. To properly analyze the use data, we had to separate the use entries from all other entries. After extracting this information, we first summarized it on a daily basis and then on a monthly basis. We needed these two summaries later in the simulation.

The development of the model is illustrated using one line item (property 205, white writing paper). However, the procedure could be used for any of the 600 line items stocked by GPO.

DESIGN OF MODEL

Our preliminary analysis of GPO's inventory operations for a 3-year period suggested a strong possibility that minimum inventory levels could be substantially reduced and still insure that GPO would always have a supply of paper available to meet its needs. Further, the GAO audit staff believed that a model of the GPO inventory system should provide answers to the following questions.

1. What inventory procedures could be changed to bring about reductions in inventory levels?

2. What effect could these changes be expected to have on future inventory operations?

3. What procedures should be used to determine the extent of the changes? and how could the effect on future operations be determined?

Our analysis indicated that the procedures affecting inventory levels that could be changed were those used to determine the reorder point, the reorder quantity, the average monthly use, and the month factor. After thoroughly considering the procedures used to determine each of these values, the staff concluded that the month factor, which was determined solely on the basis of professional judgment and experience, appeared to be the most likely candidate for change. Also, since the month factor is one of the prime factors in determining the minimum inventory (reorder point), a small change in the month factor would result in a sizable change in the inventory level.

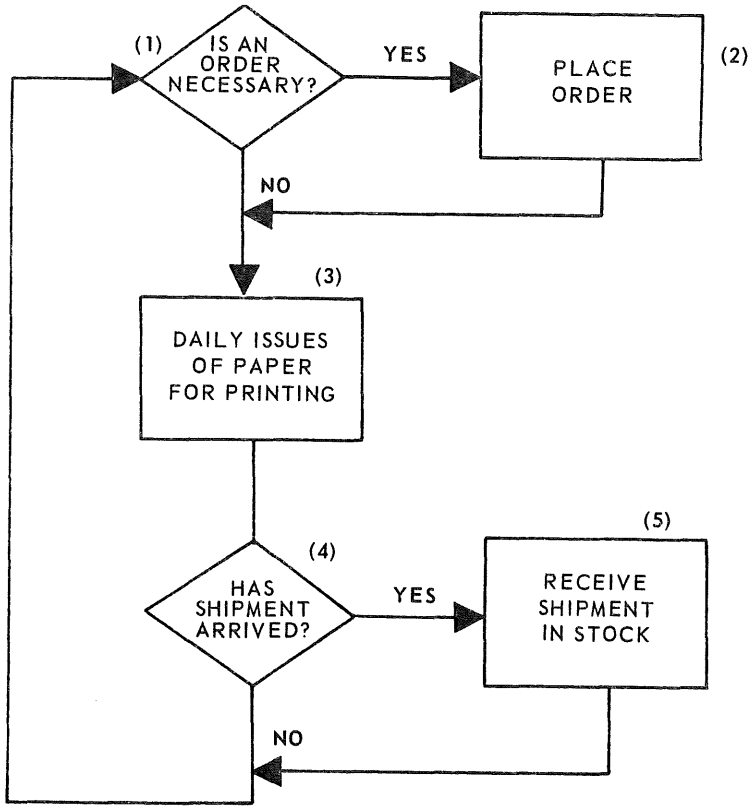
During the actual design phase, it was absolutely necessary to be certain:

1. To include all the factors involved in the inventory operations.

2. To retain all the proper relationships between the various factors.

The basic operation of the model used is shown in figure 1.

FIGURE 1



The five blocks in figure 1 above were expanded by adding the appropriate values and mathematical relationships, as follows.

1. <u>Is an order necessary?</u> This necessity is determined by comparing the reorder point to the quantity on hand plus the quantity on order. If the reorder point is greater than or equal to the quantity on hand plus the quantity on order, an order is necessary and the model proceeds to block 2. If the reorder point is less than the quantity on hand plus the quantity on order, an order is not necessary and the model proceeds to block 3.

2. Place order. Since GPO's current ordering procedure was not changed, the quantity ordered is equal to 1 month's average use. The order is placed in block 2, and the quantity is added to the quantity on order. When the order is placed, it is necessary for the model to determine when the order will be delivered. Because the model is to simulate actual experienced conditions, the order is broken into 10-percent increments. The number of elapsed days between ordering and delivery for each 10-percent increment is normally distributed; each 10-percent increment is assigned a normally distributed random number with a mean and a standard deviation reflecting the values in table 1. The model now proceeds to block 3.

3. Daily issues of paper for printing. The determination of daily issues of paper presents a problem different from that for the delivery of paper. The fact that the range in the quantities of daily use for property 205, white writing paper (zero to 402,278 sheets), is wide and the fact that the values are widely scattered throughout this range makes the use of averages impossible. The only other method available is to use actual data and make it subject to random selection.

   Therefore if the table was loaded with the daily use values from the 3-year historical data, each time the model entered block 3 it would randomly select one value from the table of historical data to be used as the current daily use. The model would also subtract this amount from the total amount on hand. This method assumes that past trends and patterns could be expected to continue. This, in turn, means that any future day's use is as likely to be predicted by the model as it was likely to occur in the 3-year period. The model now proceeds to block 4.

4. Has shipment arrived? The model searches the delivery schedules, and if the shipment is subtracted from the quantity on order and added to the quantity received. The model them proceeds to block 5. If no shipment is due to arrive, the model returns to block 1 and begins the next day's operations.

5. Receive shipment in stock. When a shipment is received, the model determines when the quantity received is available for use. It generally takes GPO 1 to 3 weeks to test a shipment to insure that it meets GPO's specifications. This condition was included in the model by using actual data and making it subject to random selection. Accordingly, if a table were loaded with these values, each time the model entered block 5 it would randomly select one value from the table. The quantity received would not be made available for use in block 2 until this value, representing the testing period, had expired. Following these determinations, the model returns to block 1.

This model is designed and run on a time-sharing system. The language used to do the computer programming is "A Programming Language/360 (APL/360)."[2] This language, originally designed by International Business Machine Corporation (IBM), lends itself to simulation because of its mathematical orientation. The reason this language has been selected for the model is that it has the following favorable characteristics.

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[2] This model could also have been programmed in other mathematically oriented languages, such as Fortran, Simscript, or Algol.

1. It can easily be learned and used by an auditor.

2. It can easily manipulate large tables.

3. It handles large volumes of data with relative ease.

4. It has the capability of generating different types of random numbers and of randomly selecting values from tables at high speed.

The terminal used is an ITEL terminal, which is very similar to an IBM Selectric typewriter but which has special APL/360 characters.

VALIDATION OF MODEL

To establish the validity of the model and to be sure that it contains all pertinent variables and appropriate relationships, It has been validated by testing and re-designing it until it produces results nearly identical to those actually experienced by GPO. That it represents reality within some statistically acceptable confidence intervals is of critical importance to any model. Once the model has been validated, the simulation can begin.

SIMULATION OF GPO INVENTORY OPERATIONS

The inventory model has been designed to continuously make small changes to the month factor and, after each change, to determine the effect of the change on future inventory operations. Thus the simulation, in effect, subjects the model to known but random occurrences which represent actual operations. This allows the model to periodically change the month factor and, through the day-to-day simulation, determine the effect of the change on inventory.

The simulation technique, which is used to determine the number of months' supply of paper that is needed to meet needs with minimum stockage, is performed in two parts. First, the month factor is gradually reduced to a feasible optimum point. Second, this new month factor is tested over a long period.

GAO began its simulation with a month factor of 4. This was the month factor currently used by GPO. The simulation reduced the month factor by 0.25--an amount equal to 1 week's use--after every 150 days. (This was considered as accurate as needed for this GAO simulation.) In addition, the simulation recalculated, after every 180 days, the average monthly usage and all other values contingent upon it, as was GPO's policy. The simulation continued to reduce the month factor until an out-of-stock condition occurred during the 150-day test period. Since an out-of-stock condition is unacceptable to GPO, the model then raised the month factor by 0.25. The results of this part of the simulation indicated that the month factor could be reduced to 2.25, which would reduce the inventory level to well below the 300,000-pound minimum maintained by GPO but would insure GPO's never running out of stock. To assure the GAO audit staff that this new, reduced month factor of 2.25 was indeed reasonable, the model went into the second phase of the simulation and tested the month factor of 2.25 for 1,825 days (5 years). The simulation continued for the full 5-year period without ever reaching an out-of-stock condition. This indicated that GPO could use a month factor of 2.25 instead of 4 with high confidence that it would not run out of stock.

The simulation was designed to represent the GPO inventory operations previously described and to reduce the month factor to a minimum. Before running the simulation it was necessary to store in the computer the daily use data from the 3-year listing. All other required data was requested from the user during the simulation. This procedure made the model flexible for use with any other inventory item.

The model requests the user to provide the following information.

1. The property number.

2. The average monthly use (the statistic currently used by GPO). The simulation will calculate this statistic from this point on.

3. The inventory on hand, including any partially undelivered orders.

4. The initial amount on order, which must be zero at the start of the simulation. (Any quantity on order at the start of the simulation is considered to be on hand, because a delivery schedule cannot be developed for this quantity.)

5. The number of days to be simulated.

6. The data on the average number of elapsed days to receive each 10-percent increment of an order. (See table 1.)

7. The 10 standard deviations associated with each order.

8. The month factor for the line item being simulated (the factor currently used by GPO).

A flow chart of the inventory model and a listing of the program can be obtained from the Financial and General Management Studies Division.

By letter dated October 29, 1971, GAO informed the Public Printer that the simulation had indicated that GPO could reduce its inventory levels by about $2 million worth of paper by changing the procedure used to calculate the month factor. GPO officials agreed to test the model and simulation results. When testing the model GPO plans to operate it simultaneously with its present system.

CHAPTER 4

EVALUATION OF SIMULATION

The GAO work at GPO showed that computer simulation is a powerful technique with a broad range of applications to the audit activities of GAO. In this instance, it was a tool which provided the GAO audit staff with answers to questions that arose during the analysis of inventory operations. The large volume of historical data and its intricate interrelationships did not lend itself to analysis by other techniques.

GPO inventory operations consisted of four primary variables: the reorder point, the reorder quantity, the average monthly use and the month factor. However, these variables were influenced significantly by the contractors' shipping schedules and by GPO's testing procedures. For example, each GPO contract provides that the order be filled within 35 days (plus or minus 5 days). However, inventory records showed the orders for white writing paper could be filled in a minimum of 47 days, could take as long as 105 days, and averaged 76 days. (Similar conditions occurred with the other items simulated at GPO.) In addition, it took GPO 7 to 21 days to make the quantities received available for use. Thus it could take as many as 126 days for GPO to receive and accept an entire order. It was relationships such as this that had to be maintained during GAO's analysis of GPO inventory operations.

On the basis of GAO's experience in simulating GPO inventory operations, it can be concluded that:

1. The simulation technique should be applied when there is reasonable assurance that the operation being evaluated can be successfully simulated. Sufficient data on the operation must be available to give realism to the model and to make a successful simulation possible.

2. The technique should be used whenever an exceptionally large volume of computations is necessary. Some problems cannot be solved manually because of the sheer size of the computational requirements alone. The application of high-speed computers has made it possible to solve huge, complex problems that would otherwise be impossible to solve in a reasonable time.

3. The technique should be applied whenever the mere process of constructing a simulation of a system can, in itself, be a beneficial learning experience of the system process. This can provide an experience that cannot be gained in any other way.

The GAO audit staff found that many standard computer models for analyzing inventory and transportation systems already existed. An already-existing model could be modified to meet the constraints of the system being studied. An audit team having mathematical, statistical, and computer skills can perform these modifications and can use simulation in a variety of audits.

The GPO audit simulation provided several advantages over other audit procedures. First, it was possible to study inventory operations occurring over months and years by operating a computer simulation for seconds and minutes. Second, it provided a means for maintaining complex interrelationships within statistically acceptable confidence limits. Third, it provided a means for determining the possible effects of alternative future actions without incurring the risk or cost of actual implementation. This final advantage is the principal benefit of simulation and the one which made the results of the GAO audit work acceptable to GPO.

1811