# SIMULATION OF COMPUTER PROGRAM DISTRIBUTION

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## Summary

A computer program library is essentially a "job shop" which accepts and processes requests for computer programs. Such processing usually results in an initial delivery of the program package to the requestor, followed later by deliveries of maintenance packages to him.

Packages usually consist of documentation and machine readable material (cards, tapes, disks, etc.). The latter is prepared on data processing equipment installed in the shop.

Simulation of this preparation process has proved to be a useful tool in the short and long range planning of the shop's facilities.

The GPSS/360 model constructed simulates both the management's supervisory decision process as well as the resulting activity of machine readable material preparation. It produces a suggested equipment installation schedule, accompanied by statistics on equipment utilization, service times, costs, etc. based on that schedule.

## Introduction

A recent discussion on the merits and shortcomings of "Industrial Dynamics" (1) included an interesting evaluation of the purposes of simulation in general.

While one school argues that a sufficient reward for the efforts invested in simulating a system is the acquisition of knowledge on the system's general nature (i.e. tendencies of its state variables to fluctuate, frequencies and magnitudes of peaks and lows, correlations between variables, etc.), others feel that the true purpose is the prediction of the system's state at some given time points in the future.

While everyone accepts the desirability of the latter objective, those who do not attempt to attain it claim that it is unattainable. Their position is well taken for most cases in which prediction with great accuracy is insisted upon. Very often, however, such accuracy is neither expected nor required. For these cases, predictive simulation is purposeful and useful.

The model presented here is an example of such a case. The predictions it produces, although approximate, are effectively used as a basis for a 5 year plan and for placement of orders for computers, which constitute the "production facilities" of the simulated system.

## The Simulated System

The model simulates certain activities within a computer program library (more appropriately called a Program Distribution Center, or PDC). The "production facilities" are computers used for duplication of the machine readable portion of the programs and for verification of the readability and correctness of the copies made. The distribution media for the machine readable material are magnetic tapes, disks, punched cards or paper tapes.

The following is a brief description of the PDC's operation:

The PDC is essentially a job shop receiving orders for programs from various users. The orders received are batched and placed in queue for processing in the computer room. Orders are processed in the sequence received.

Every user's order is also recorded in the Users' File for the purpose of subsequently sending him maintenance for the program ordered.

Maintenance is in two forms:

1. Partial Replacement. The user receives a package which partially replaces his previous one. Delivery of these packages is initiated immediately upon release of the Partial Replacement.

2. Total Replacement. A card is mailed to the user, notifying him that a new version of the program is available, obsoleting the one he has. The program is at the same time removed from the Users' File, to be re-entered there only after

the user has reordered the program, by mailing back the notification card. The user thus receives no further maintenance unless and until he reorders the program.

It is noteworthy that the two types of maintenance account for 85% of the PDC's activity.

The simulation model pertains to those programs which must be duplicated by a computer of the type on which they run (e.g. the System/360 Model 20 Disk Programming System, 1130 Disk Resident Programs etc.).

## The Problem

Since delivery time for computers may be a year, equipment requirements must be forecast well in advance and orders for computers placed accordingly. The obvious objective is to keep the amount of equipment at the minimum level necessary for attaining a desired service level.

In order to define the service level let us introduce the following notation:

W is random variable denoting the order's waiting time in queue for a computer (an "order" is either the initial request for a program or a subsequent request for a total replacement).

L is the "Service Level" constant

Pr denotes Probability

A service level L is attained if

$$Pr\ (W \leq L) \geq .95$$

A reasonable value for L is 4 days. The above expression then means that at least 95% of the orders will wait in queue for program duplication by a computer, no longer than 4 days.

The waiting time depends on the rate of order arrivals and on the number of computers available. As the arrival rate increases additional computers must be installed in order to maintain the service level.

The problem is, thus, to determine the minimal installation schedule for a given type of computer such that the predetermined service level is assured for programs which are duplicated on that type of computer.

## The Model

The simulation model consists of two cycles. The weekly management decision cycle and the daily production cycle, (where "production" is the program duplication activity). In the management cycle decision is reached on the number of new computers (if any) to install in the current week. The decision is based on a comparison between the available computer capacity and the anticipated weekly load. This load is defined as the computer time necessary for handling the backlog from previous weeks (i.e. the queue) and the orders due to arrive in the current week. Only initial deliveries and total replacements are included in this load calculation. Partial replacements are excluded because they are automatically delivered rather than ordered by the user and are therefore not subject to service level considerations. They are however included in the production cycle.

The rule used is to install additional computers until a capacity of at least one half the weekly load is reached. The factor of one half has been empirically found to assure, in most cases, the desired service level of four days. It is, however, easily altered if so desired.

In the daily production cycle initial orders arrive, partial and total replacements are released and responses to total replacements are received. All are placed in queue and are eventually processed. Statistics on waiting times, queue lengths, computer utilization etc. are collected and tabulated.

The model is written in the GPSS/360 language (2).

The order arrival rate is determined on the basis of the following inputs:

1. The expected number of users for each program (i.e. the "Market Forecast") in each year of the simulation period, (between 1 and 25 years - normally 5 years).

2. The expected "Maintenance Schedules", i.e. the weeks in which Partial or Total Replacements will be released for each program, in the simulation period.

3. The "Response Functions" i.e., for each program, the % of existing users who respond to the notification on the

availability of a Total Replacement in the 1st, 2nd, 3rd, etc. week following the mailing of the notification. The total response varies greatly among programs and has been observed to lie between 40% and 100%. All responses arrive within 8 weeks following notification.

The computer capacity is determined on the basis of the following inputs:

1. The number of computers initially available (normally 0).

2. The number of "productive" hours per computer per week (e.g. 110 hours on a 3 shift basis).

3. For each program, the number of computer minutes necessary for duplication of a partial and of a total replacement package. (The latter applies to initial packages as well).

These three inputs can be changed in the course of the simulation, if for instance a faster I/O unit becomes available later, or a second working shift is introduced etc. In particular, the number of computers is increased by the management decision cycle when the work load grows, as was previously explained.

The model is thus modifiable by "management decision" during the simulation run. It can be regarded as being a "feedback" model, because the decisions depend to some extent on backlog (queue) accumulations, which, in turn, are affected by a decision to install more equipment. Nevertheless, the major factor considered, in deciding on equipment installation, is the order arrival rate which is pre-determined by the inputs and is thus unaffected by what happens in the shop.

The output is printed out "yearly" and consists of a variety of statistics as normally provided by GPSS, containing among others, the following items (at decreasing order of importance):

1. The computer installation schedule.

2. Computer utilization, for each installed computer.

3. Queue statistics for Total and Partial Replacements

   -Maximum lengths
   -Average lengths
   -Total entries (i.e. total number of orders processed)
   -Number and percentage of zero-wait entries
   -Average waiting times

4. Two tables showing the distributions of waiting times for Total and Partial Replacements.

By inspecting the table for Total Replacements one determines whether or not the desired service level has been attained. If not, the rule for installing computers is altered and the simulation rerun. Similarly, if the level has been exceeded the rule can be altered so as to install fewer computers, thereby increasing their utilization.

The attached 3 pages contain selected parts of a run's input and output, as edited by the GPSS/360 Output Editor.

The run covered the distribution and maintenance of 2 programs, the 1st over 5 years and the 2nd over 4 1/2 years (i.e. starting 26 weeks later).

TRPL and PRPL denote the queue (backlog) of Total and Partial Replacements, respectively. ("Total Replacements" include initial orders).

The input data are fictitious and represent no particular programs or computer.

Disregard the lines "Matrix Halfword etc." in the report.

The following inputs are not shown in the report:

1. The initial number of computers is 0.

2. The response to total replacement notification for both programs is:

| Week # (following notification) | % of users who respond |
|---|---|
| 1 | 4.6 |
| 2 | 17.1 |
| 3 | 11.8 |
| 4 | 7.8 |
| 5 | 4.6 |
| 6 | 1.2 |
| 7 | 1.0 |
| 8 | 0.8 |
| 9 up | 0 |

3. The maintenance schedule includes 27 total replacements and no partials for program #1; 15 totals and 21 partials for program #2. The weeks in which replacements occur are specified by 2 GPSS Functions.

## Conclusions

The simulation model has been successfully used to establish 5 year installation schedules for several types of computers at IBM's Program Distribution Centers in the U. S. (Hawthorne, New York) and in Europe (Paris, France).

The indicated installation times fell almost invariably in the second week following the release of some Total Replacement of some program. This is due to the fact that the response functions always showed the highest response in the second week. It follows that the installation schedule produced is highly sensitive to variations in the maintenance schedule, especially to changes in the timing of Total Replacements. This sensitivity can, however, be expected in any predictive simulation model, as explained in the introduction. It can be remedied here by allowing a few extra weeks when ordering the equipment.

The other output statistics are estimates of the expected service levels, backlog accumulations, computer utilization, (and hence, computer time available for other jobs), total production, etc. These are used for estimating total cost and for planning additional (second priority) assignments for the equipment.

In summary, the model described here is a predictive, partial feedback, moderately accurate simulation model with some "built in" rules for decision making. It is a useful tool for planning the facilities of the simulated system and in estimating their utilization.

## References


1. Ansoff, H.I. and Slevin, D.P., An Appreciation of Industrial Dynamics, Management Science, March 1968.

2. General Purpose System Simulation System/360, IBM Corp., Publication H20-0304, 1967.


YEAR NO. 5

1. INPUT

2 PRODUCTS
5 YEARS SIMULATED
110 PRODUCTION HOURS PER COMPUTER PER WK

MARKET FORECAST MATRICES (1 MATRIX PER PRODUCT):
ROWS REPRESENT YEARS.
COLUMN 1 IS THE NUMBER OF WEEKS IN THE YEAR.
COLUMN 2 IS THE NUMBER OF NEW USERS.
COLUMN 3 IS THE NUMBER OF USERS AT YEAR'S END.

MATRIX HALFWORD SAVEVALUEFRCST

| | COL. | 1 | 2 | 3 |
|---|---|---|---|---|
| ROW | 1 | 52 | 750 | 700 |
| | 2 | 52 | 1150 | 1755 |
| | 3 | 52 | 1600 | 3195 |
| | 4 | 52 | 945 | 3955 |
| | 5 | 52 | 300 | 3965 |

MATRIX HALFWORD SAVEVALUE 2

| | COL. | 1 | 2 | 3 |
|---|---|---|---|---|
| ROW | 1 | 26 | 400 | 380 |
| | 2 | 52 | 1600 | 1900 |
| | 3 | 52 | 2100 | 3700 |
| | 4 | 52 | 1950 | 5200 |
| | 5 | 52 | 1750 | 5400 |

MISCELLANEOUS DATA MATRIX:
ROWS REPRESENT PRODUCTS.
COLUMN 1 IS TOTAL REPLACEMENT TIME PER 10 PACKAGES, IN MINUTES
COLUMN 2 IS PARTIAL REPLACEMENT TIME PER 100 PACKAGES, IN MINUTES
COLUMN 3 IS THE DELAY IN INITIAL DELIVERY WITH RESPECT TO PROD. 1
DISREGARD COLUMNS 4,5 AND 6.

MATRIX HALFWORD SAVEVALUE MISC

| | COL. | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| ROW | 1 | 500 | 500 | 0 | 6 | 0 | 2 |
| | 2 | 300 | 300 | 26 | 34 | 0 | 8 |

THE REPLACEMENT SCHEDULES (FUNCTIONS 1,2,3,...) AND THE USER RESPONSE (FUNCTIONS 11,12,13,...) ARE LISTED WITH THE PROGRAM ON THE FIRST PAGES.

2. OUTPUT

COMPUTER INSTALLATION SCHEDULE AND UTILIZATION:
EACH ROW REPRESENTS ONE COMPUTER.
COLUMN 1 GIVES THE YEAR OF INSTALLATION.
COLUMN 2 GIVES THE WEEK OF INSTALLATION IN THAT YEAR.
COLUMN 3 GIVES THE UTILIZATION IN PARTS PER THOUSAND.

MATRIX HALFWORD SAVEVALUE INST

| | COL. 1 | 2 | 3 |
|---|---|---|---|
| ROW 1 | 1 | 1 | 567 |
| 2 | 2 | 4 | 544 |
| 3 | 2 | 38 | 500 |
| 4 | 3 | 41 | 414 |
| 5 | 4 | 39 | 232 |
| 6 | 4 | 39 | 216 |
| 7 | 0 | 0 | 0 |
| 8 | 0 | 0 | 0 |
| 9 | 0 | 0 | 0 |
| 10 | 0 | 0 | 0 |
| 11 | 0 | 0 | 0 |
| 12 | 0 | 0 | 0 |
| 13 | 0 | 0 | 0 |
| 14 | 0 | 0 | 0 |
| 15 | 0 | 0 | 0 |
| 16 | 0 | 0 | 0 |
| 17 | 0 | 0 | 0 |
| 18 | 0 | 0 | 0 |
| 19 | 0 | 0 | 0 |
| 20 | 0 | 0 | 0 |
| 21 | 0 | 0 | 0 |
| 22 | 0 | 0 | 0 |
| 23 | 0 | 0 | 0 |
| 24 | 0 | 0 | 0 |
| 25 | 0 | 0 | 0 |

BACKLOG STATISTICS (FOR TOTAL & PARTIAL REPLACEMENTS):

| | MAXIMUM BACKLOG | AVERAGE BACKLOG | TOTAL PRODCTN | NO-WAIT PACKAGES # | NO-WAIT PACKAGES % |
|---|---|---|---|---|---|
| TRPL | 1220 | 65.198 | 68350 | 17660 | 25.8 |
| PRPL | 4600 | 62.855 | 49000 | 1500 | 3.0 |

AVERAGE WAIT IN SHOP (TOTAL REPLACEMENTS) 1 DAYS 5 HOURS.
AVERAGE " " " (PARTIAL " ) 1 DAYS 15 HOURS.

TABLE TRPL
ENTRIES IN TABLE 6835 MEAN ARGUMENT 1636.889 STANDARD DEVIATION 1729.000

| DAYS | UPPER LIMIT | OBSERVED FREQUENCY | PER CENT OF TOTAL | CUMULATIVE PERCENTAGE |
|---|---|---|---|---|
| 0 | 0 | 1766 | 25.83 | 25.8 |
| 1 | 1320 | 2003 | 29.30 | 55.1 |
| 2 | 2640 | 1353 | 19.79 | 74.9 |
| 3 | 3960 | 819 | 11.98 | 86.9 |
| 4 | 5280 | 589 | 8.61 | 95.5 |
| 5 | 6600 | 269 | 3.93 | 99.4 |
| 6 | 7920 | 36 | .52 | 100.0 |

REMAINING FREQUENCIES ARE ALL ZERO

Notes:
1. This table provides the frequency distribution of the queuing time of Initial and Total Replacement Orders. (In minutes)
2. ENTRIES IN TABLE AND OBSERVED FREQUENCY represent 10s of orders.
3. Since the input defines a working week (5 days) as 110 hours, a working day consists of 1320 minutes.
4. 95.5% of the orders waited 4 days or less.