AN INVENTORY MANAGEMENT SIMULATION GAME

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ABSTRACT

The inventory management simulation is a multiechelon, multiproduct computer simulation of the Bell System inventory loop which can be controlled over a series of time periods. In the simulation the inventories, material flows, and accounting procedures of the inventory system are modeled in detail. The simulation was designed as a tool for teaching and illustrating inventory management concepts. Each period decisions must be made to control the flow of items throughout the loop. At the end of each period, stock information reports and financial statements are available to evaluate the decisions and the system's behavior. In this paper, the inventory system modeled in the simulation is described. In addition to the general operation and features, the education and research uses of the simulation are also presented.

INTRODUCTION

Two Bell System inventory management simulations have been developed. The first was used as part of an AT&T sponsored Executive Seminar on Inventory Management Principles which was offered at the Bell System Center for Technical Education. This simulation designed by A. B. Hoadley (1) was effective in illustrating to high level executives that good inventory management can improve the financial performance of the company. As a result of the success of the first simulation, a more detailed simulation of the Bell System supply pipeline was developed for use in a new course, Inventory Management Fundamentals, which is offered to middle level Bell System managers. This new simulation more closely approximates the actual telephone company inventory system and is designed to develop the user's ability to make actual operational decisions. It is this second simulation that is described in this paper.

OVERVIEW OF THE FLOW DIAGRAM

Figure 1 is a flow diagram of the simulation. It models the inventory loop of a single telephone company. This flow diagram is appropriate for any class of telephone company equipment that can be recycled. The design was motivated in particular by station apparatus such as telephones and data sets.

The computer simulates the movement of units from one inventory location (denoted by a box) to another. The allowable flows (indicated by arrows) are controlled either by the player through his decisions (indicated on the diagram by valve symbols), or by the computer through parameters uniquely identified with the product. Associated with some of the flows are fixed delays (indicated by saw-toothed symbols).

The inventory loop has four main components. These are the Western Electric Company (WE) factory, the telephone company central stock, the service center repair process and the work locations (the part of the loop inside the dashed box). In practice, many of these work locations (WL) are served by a single central stock. In the simulation there may be three work locations.

All inventory units enter the inventory loop at central stock. Items may be either purchased new from Western Electric stock, or purchased used from other telephone companies. Central stock is also supplied with recycled items from the service center repair process. If the inventory level at central stock gets too high, units may be disposed of through sales to other telephone companies.

In the work locations, customer demand must be met. The revenue producing box contains all items of the product that are in service, i.e., on the customer premise and producing revenue. Here, the simulation is driven by service orders that cause equipment to move in and out of revenue producing (RP). Three classes of equipment enter RP: inward movement (items for new service), changes-in

(replacements at the customer's request), and failures-in (replacements for defective equipment).

Central stock supplies the work locations with items. Two types of inventory may be kept in the WL for meeting demand for items into RP. Maintenance spares can only be used for replacing failed items in service. Work location stock is used for meeting the other demands. If no maintenance spares are available, an emergency replacement is shipped from central stock. If there are no items in work location stock and if the play has allowed for quick response shipments (generally at a higher cost), an item is ordered from central stock. If such shipments have not been allowed, then the customer demand becomes backordered. Work location stock is supplied also by items that have been turned around in the field. If too many items accumulate in WL stock, they may be returned to central stock.

Three classes of items leave RP: outward movement (items associated with disconnection of service), changes-out and failures-out. In order to disconnect service, it is assumed that no visit to the customer premise is required. Items that are no longer producing revenue, but have not yet been removed from the customer's premise, are contained in the awaiting recovery box. Some of these items may be lost. The player controls the removal rate for such items. The recovered items are candidates for field turnaround, which is assumed to be cheaper than service center repair but results in a higher failure rate.

Items not sent through field turnaround plus the failures are returned to the service center. Some items are visibly damaged and thus junked. Others may be junked at the player's request. Of the rest, the player may choose to repair some. When repair is completed, the items are returned to central stock for reuse.

DEFINITION OF A GAME

A game is defined to be a set of parameters that describe the specific products and inventory system to be simulated. By appropriately choosing values for these parameters, different products and portions of a product's life cycle can be modeled. The simulation can store up to six games in memory.

The game parameters are of five types: 1) Structure defining parameters such as length of simulation, number of products, number of work locations, delays, and available manhours. 2) Flow rates such as failure rates, junk rates, loss rates, reconnect rates, fraction of lost items becoming unauthorized equipment, and percentage of lost sales. 3) Financial items such as ordering and shipping costs, prices, of new items, repair charges, labor rates, revenues, inflation rates, interest rate, and tax rate. 4) Initializations of inventories and depreciation rates. 5) Demands represented by service orders for connecting or disconnecting service.

FORMAT OF PLAY

The length of the simulation is divided into several major time intervals called decision periods. A decision period is divided into minor time intervals called simulation cycles. At the beginning of each decision period the user inputs his inventory control decisions such as how much to order, junk, remove, and repair. The computer simulates the flow of items and the financial activities for each simulation cycle in the decision period. At the end of the period, operating results which are a series of performance measures are printed. Figure 2 is an example of the operating results report. There are ten information reports that contain more detailed information on the system's behavior and may be selectively requested by the user as needed. These reports include income statement, balance sheet, service level distributions, inventory levels, movement of items. Figure 3 and 4 are examples of reports.

In a classroom environment, the students will be grouped into teams. In a single computer session up to six teams can play. All teams are independent in the sense that 1) each team can play at its own speed, 2) the results of any team depend only on its decisions and not on the decisions of any other team, and 3) each team can play a different game.

FEATURES OF THE SIMULATION

Some of the features included to make using the simulation both realistic and interesting are described below.

1) Service order demands for each cycle can be input manually or randomly generated. When random the demands are generated from a truncated normal distribution according to distributional parameters input by the user. The same parameters apply to the demands in all work locations, but because of the randomness they result in different particular series for each work location. Seasonal fluctuations can be incorporated into the random series.

2) One or two products can be controlled in the same simulation game. Substitution between the two products when meeting demand can be allowed.

3) Associated with the inventory system is a cradle-to-grave accounting system. This means an item remains on the books from time of purchase until final disposal. The values of these accounts are computed according to Bell System accounting rules.

4) The simulation includes the equations to compute an income statement for the inventory system. The sources of revenue are the fixed installation charge and the continuing revenue from items in service. The expenses that are affected by inventory management are itemized. These are service center repair cost, field turnaround, transportation and ordering, service maintenance, and depreciation accruals.

5) If orders cannot be met on time, they become backordered and must be met in some later cycle. As a penalty for not meeting customer demand on time, a fraction of the in-service orders that are backordered will become lost sales.

6) There are two ways in which each inventory control decision can be input to the simulation: by quantity or by rule. As an example, consider the decision of ordering items for maintenance spares. If the decision is made by quantity, the user specifies the number of items to be ordered during the decision period. In the other method, the computer determines the quantity according to a rule input by the player. For maintenance spare orders, the quantity ordered each cycle is determined so as to keep the number of maintenance spares at a level set by the user. The rules that must be determined by the player are similar to decisions that must be made when managing telephone company inventory.

7) In addition to the information reports, the detailed time series of certain key variables in the simulation are available. This facility of being able to examine the cycle-to-cycle fluctuations of inventories and flows was included in the design for research applications.

8) The effects of inflation can be considered. There are three separate inflation rates: one affects new purchases from Western Electric, one affects revenues, and the last affects labor rates and all other costs.

9) The number of items that fail each cycle from RP items is randomly generated from a Poisson distribution. The mean failure rate depends upon the amount of field turnaround that is done. The assumption is made that items repaired locally are not repaired as thoroughly as items repaired in the service center. Thus, inventory strategy will affect the failure rate and thus the maintenance expense.

10) A mathematical model of the factory is included in order to demonstrate certain characteristics of its real counterpart. The factory production rate should be able to provide central stock with a specific objective level of service. The cycle-to-cycle fluctuation in factory output should be small, since production capacity in a real factory cannot change abruptly. The model uses past orders to forecase future orders on Western Electric from central stock. The production rate that will provide the objective level of service is computed, and exponential smoothing is used to reduce the cycle variation in factory output.

11) The mathematical model of the service center repair process incorporates several realistic features of a repair shop. Although the repair rate cannot change abruptly, it does depend on the number of items in the repair queue. The repair rate is chosen to meet an objective average delay through the repair process; the delay for each item is random.

EDUCATIONAL TOOL

Over 1000 Bell System managers have been exposed to the inventory management simulation in the Inventory Management Fundamentals course. The simulation is used as a full-day exercise to reinforce the inventory theory that has been presented in lectures. Students and instructors are enthusiastic about the simulation. Some of the things they learned playing it are:

1) Although a manager may be responsible for controlling only one part of inventory loop, he must be aware of how his decision will affect other parts of the system.

2) Optimal inventory decisions change as a product progresses through its life cycle.

3) Utilization, the percent of inventory producing revenue, is not the only measure of good inventory management. Capital expenditures, rate of return, and service level to the customer are also important.

RESEARCH TOOL

The simulation has been used to aid in the study of the Bell System inventory loop. The recycling of items creates dependencies between the components of the loop. Although analytic results are often difficult to obtain, the simulated system gives insight to the behavior of the actual system and can be used to test inventory control algorithms.

BIBLIOGRAPHY

1. Hoadley, Bruce and Showers, Janet, "An Inventory Management Simulation/ Game of the Bell System Inventory Loop," Talk at ORSA/TIMS Miami Joint National Meeting, ORSA/TIMS Bulletin, No. 2, November 3-5, 1976.

FIGURE 1

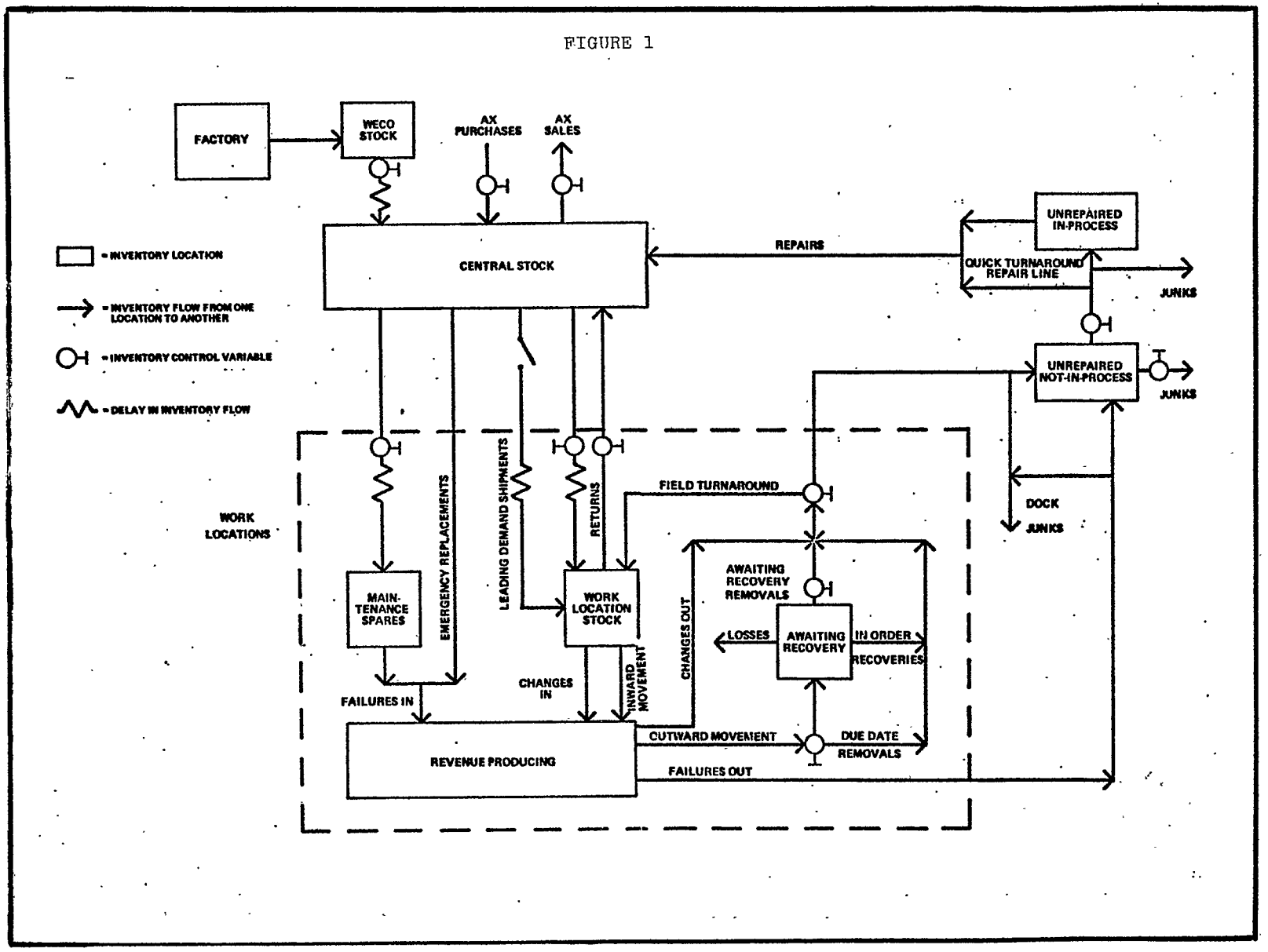
FACTORY
WECO STOCK
AX PURCHASES
AX SALES
CENTRAL STOCK
REPAIRS
UNREPAIRED IN-PROCESS
QUICK TURNAROUND REPAIR LINE
JUNKS
UNREPAIRED NOT-IN-PROCESS
JUNKS
= INVENTORY LOCATION
= INVENTORY FLOW FROM ONE LOCATION TO ANOTHER
= INVENTORY CONTROL VARIABLE
= DELAY IN INVENTORY FLOW
WORK LOCATIONS
MAIN-TENANCE SPARES
EMERGENCY REPLACEMENTS
LEADING DEMAND SHIPMENTS
RETURNS
FIELD TURNAROUND
DOCK
JUNKS
WORK LOCATION STOCK
AWAITING RECOVERY REMOVALS
LOSSES
AWAITING RECOVERY
IN ORDER
RECOVERIES
CHANGES OUT
FAILURES IN
CHANGES IN
INWARD MOVEMENT
OUTWARD MOVEMENT
DUE DATE REMOVALS
REVENUE PRODUCING
FAILURES OUT

FIGURE 2

OPERATING RESULTS — TEAM 2 — PERIOD 1

CUMULATIVE RATE OF RETURN		14.071
CURRENT RATE OF RETURN		14.071
OPERATING INCOME		129803
AVERAGE NET PLANT		922483
BUDGET:	SPENT TO DATE	% OF BUDGET
EQUIPMENT	381273	58.66
REPAIR	121138	48.46
		PRODUCT 1
CONSTRUCTION EXPENDITURES		
EQUIPMENT		381273
CONNECTIONS OR PIOC		404866
* TOTAL		786139
UTILIZATION		87.74
REPAIRS&TURNAROUND PER 100 TOTAL DEMAND		59.12
REPAIRS&TURNAROUND PER 100 TOTAL OUTS		87.20
OUT ORDER RECOVERIES PER 100 OM		87.84
LOSSES PER 100 OM		2.89
JUNKS PER 100 OM		11.43
ANNUAL FAILURES PER UNIT RP		.06
LOST SALES AS % OF TOTAL SALES		.87
DELAY THRU REPAIR SHOP IN CYCLES		6.24
SERVICE LEVELS:	% MET ON TIME	
PRODUCT 1:		
WECO STOCK	65.89	
CENTRAL STOCK	89.58	
CUSTOMER	91.54	

FIGURE 3

MOVEMENT DATA: CENTRAL STOCK AND SERVICE CENTER — TEAM 2 — PERIOD 1

	PRODUCT 1
AX PURCHASES	728
AX SALES	0
NEW PURCHASES	3153
REPAIR COMPLETIONS	4289
JUNKS	685
SHIPMENTS OUT OF CENTRAL STOCK	8279
RETURNS TO UNREPAIRED	4891
RETURNS TO CENTRAL STOCK	0

FIGURE 4

SERVICE LEVEL DISTRIBUTIONS — TEAM 2 — PERIOD 1

	DELAY	% DEMAND MET AT		
		CUSTOMER	CENTRAL STOCK	WECO STOCK
PRODUCT: 1				
	0	91.54	89.58	65.89
	1	8.06	9.60	16.71
	2	.40	.83	9.87
	3	.00	.00	7.52
	4	.00	.00	.00
	>= 5	.00	.00	.00