A PLANT-WAREHOUSE SYSTEM WITH VARIABLE LEAD-TIMES AND VARIABLE RE-ORDER LEVELS

(The Cost Optimization - COPT - System)

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General Foods Corp.

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1. Introduction

An analyst, in approaching the design of an integrated factory warehouse decision system, finds out that existing operations research theory concentrates on the rigorous solution of only limited and selected segments of the complex relationship between production and distribution. The fixed or economic order quantity re-ordering practice most frequently discussed in O/R literature results in an undesirable fluctuation in orders at the plant. If the manufacturer owns both the plants and the warehouses, he must incorporate an order smoothing decision rule into his system which must necessarily modify the size of the economic order quantity.

The fixed re-order point (or trigger point) is likewise an undesirable restriction on the operation of a system attempting to optimize both factory and distribution costs. At the times when the sales rate is below the rate of production a particular re-order point may not be reached at all. Conversely, at times of high sales, the re-order point may be reached repeatedly with the ultimate consequence of lengthening the lead times at the plant.

Whether to design the system on the assumption of fixed or statistically varying lead times is another dilemma. In an integrated system, the imposition of a short fixed lead time on a factory by a warehouse is not realistic because the urgency of supply varies depending on the phase of the sales cycle. Unduly liberal fixed lead times, on the other hand, penalize the system by excessive permanent safety stocks. A statistical model based on sampled actual lead times is also difficult to justify. The shape of a particular lead time distribution function has a causal basis in the inter-relationships between warehouse ordering practices and plant production patterns. Calculating safety stocks on the basis of these lead time distributions, which include transactions having varying degrees of priority, results in heavy inventories.

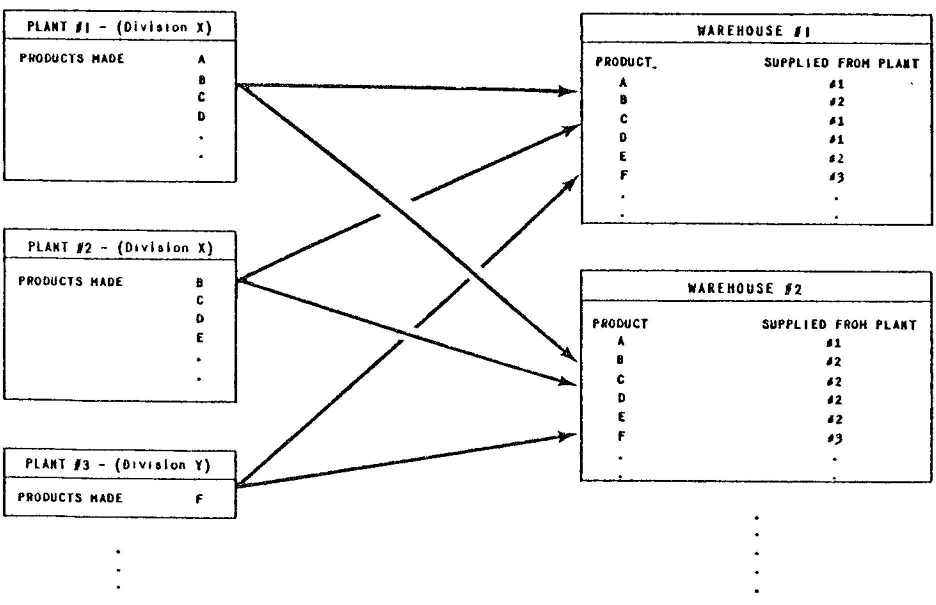
The question of selecting an optimal production scheduling and inventory decision (or review) period must be also answered. The necessity of examining inventory levels and fixing production schedules varies from time-to-time, from product-to-product and is clearly related to policies adapted with respect to order quantities, re-order points and lead times. A number of secondary relationships affecting the design of the system place important restrictions on the design of an integrated system. These are:

(a) Shipment Consolidation—Regardless of order quantity or reorder point, such things as the product mix, frequency of shipments and predictability of economic shipment quantities may govern the plant to warehouse movements.

(b) Economic Production Lot Size—Superimposed on ordering patterns of individual warehouses are the effects of aggregate order quantities and the cyclical or counter-cyclical peaking of demand for products manufactured on joint facilities.

(c) Organization Limitations—The organizational status of warehouse administration, raw materials procurement, managerial control over cascaded (or subassembly) steps in the process, availability of computer facilities, sales promotional practices, strength of divisional vs. plant production planning staffs are significant limitations which must necessarily dictate the feasible operating features of an integrated system.

This paper describes design features of a decentralized plant-warehouse inventory system operating successfully and providing decision rules for ordering, producing and shipping well over $250,000,000 worth of relatively low cost grocery products from over 10 plants to 16 nationally located distribution centers. The product line consists of over 250 items, most of which are distributed nationally. Individual plants report operationally to different divisions. All warehouses are administered by a single division. Due to the large volume and bulk of products, all warehousing is done as close as possible to the ultimate sales des-



SCHEMATIC OUTLINE OF MULTI-DIVISIONAL, MULTI-PLANT and MULTI-WAREHOUSE DISTRIBUTION SYSTEM

EXHIBIT I

tination, with insignificant amounts held at the factory level. Hence, the problem of inventory management is inseparable from the problem of production and traffic scheduling and any statements about cost savings can be made from the point of view of minimizing warehousing plus transportation plus production plus customer service costs. This requirement is reinforced by placing the total cost responsibility for manufacturing and distribution with the producing divisions. Consequently, the warehouse managers do not make ordering decisions. Exhibit I describes diagrammatically the distribution system.

2. Allocation of Warehouses to Plant for Service

Two principal considerations led to fixing (for a stipulated planning period of one year) the "service responsibility" for supplying a given warehouse with a specific product for items manufactured in a number of plants. If the "service responsibility" was not assigned in advance, each supply decision would have to be made by referring all demands to a centralized scheduling staff. Apart from the costliness of such an arrangement in terms of personnel, communications and "noise" generated, all system transactions would be penalized by 3–4 additional days of lead time. A simple, worksheet simulation identified both the "steady state" effect (on safety stocks) and "dynamic effect" (on response characteristics to instantaneous sales peaks) of the two system design alternatives and substantiated the recommendation to eliminate functions performed by a centralized staff of order dispatchers. Another consideration for fixing the "service responsibility" was the appreciation of the fact that short-term transfers of demands from borderline warehouses back and forth among plants to meet short-term demands actually results in oscillations of aggregate production levels while total long-term demand remains constant. The system now provides for a routine allocation of warehouses to plants using the Ford-Fulkerson method on an IBM 704. The allocation decision is scheduled to be made about four months prior to start of a fiscal year and prior to each plant submitting next year's standard manufacturing costs (the latter being based on the volume of production allocated each plant). The allocation decision is then rechecked about two weeks before the start of the fiscal year using latest standard variable cost data.

Despite the fixed assignment of "service responsibility" the desirable flexibility of centralized order dispatching has been retained by distributing to all plants information concerning weekly stock status, sales and supply urgency for all warehouses storing products for which a plant has production facilities. Using this information, the plant planning manager may, at critical times, request inter-warehouse trans-shipments from a borderline location serviced by another plant. The man hour production equivalents of such transfers are later reconciled among plants themselves. Only rare instances of conflict concerning priority in expediting are referred to the central production planning staff.

3. Seasonal Planning

Inasmuch as most grocery products exhibit seasonal sales patterns, the decision period for long run smoothing of production levels is one year. Two weeks

SEASONAL EMPLOYMENT STABILIZATION POLICIES

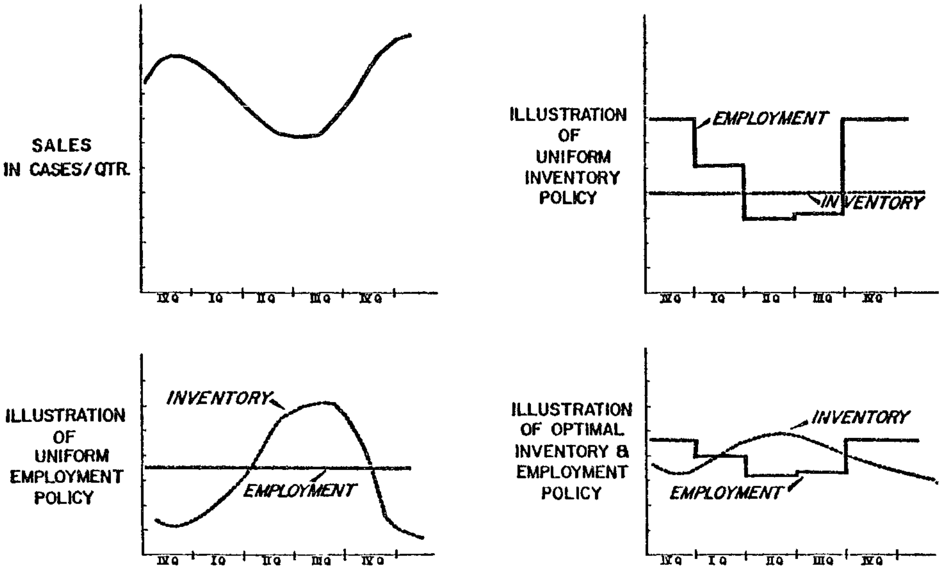


EXHIBIT II

before the start of each fiscal year, each plant submits a formal inventory and production plan proposal for four fiscal quarters ahead. The annual plan is based on moving average projections of past sales for product groups, by sales districts, as modified by latest marketing and operational plans.

Exhibit II illustrates the basic approach to seasonal employment stabilization. Extreme employment (uniform employment) and inventory (uniform inventory) policies are set forth and their consequences priced out for each plant separately. The least cost inventory and employment policy is then calculated and a feasible annual production plan is set forth meeting a number of additional restrictions such as vacation shut-downs, process limitations, crop and sales season requirements, etc.

To arrive at a cost of smoothed employment, each plant represents a unique production smoothing problem due to peculiarities of the product mix assigned to it, amplitude and phasing of the aggregate seasonal sales curve, labor contents of its product line as well as distinctly non-continuous increments in the operating scale of various departments. This non-homogeneity immediately ruled out analytic approaches.[1] Instead, each plant prepares two "Manpower Balances", one for a variable and the other for a uniform employment plant. The "Manpower Balance" concept is outlined in Exhibit III. The uniform employment plan balances manpower from quarter-to-quarter so that plant employment remains constant. The labor man-shifts for each product are converted into

[1] Such as Holt, Modigliani, Muth and Simon's: "Planning Production, Inventories, and Work Force", Prentice Hall, 1960.

Plant ______ #.

FY '62 MANPOWER BALANCE Prepared By JOHN DOE Date 4/5/61

Uniform Employment Plan

PRODUCT GROUP or PRODUCT DEPARTMENT	63 JUNE QUARTER Operating Days					48 SEPTEMBER QUARTER Operating Days					61 DECEMBER QUARTER Operating Days					63 MARCH QUARTER Operating Days				
			MAN SHIFTS					MAN SHIFTS					MAN SHIFTS					MAN SHIFTS		
	MEN	SHIFTS	SCHED	AVAIL	DIFF	MEN	SHIFTS	SCHED	AVAIL	DIFF	MEN	SHIFTS	SCHED	AVAIL	DIFF	MEN	SHIFTS	SCHED	[illegible]	[illegible]
Product A Pkg.	4	47	188	252	+64	4	44	176	192	+16	4	50	200	244	+44	4	57	228	252	+24
" B "	4	42	168	0	-168	4	4	16	0	-16	4	11	44	0	-44	4	6	24	0	-24
" C "	2	23	46	63	+17	2	24	48	48	0	2	18	36	61	+25	2	19	38	63	+25
" A,B,C	6	63[1]	378	378	0	6	46[2]	276	288	+ 12	6	59[3]	354	366	+12	5	63[3]	378	378	0
Product D Pkg.	3	30	90	189	+99	3	48	144	144	0	3	61	183	183	0	3	63	189	189	0
" E "	5	58	153	189	+ 36	5	80	208	144	-64	3	51	153	183	+30	3	63	189	189	0
" (process) D,E	6[4]	37	222	378	+156	6[4]	48	288	288	0	6[4]	54	324	366	+42	6[4]	64	384	378	0
Less Overtime Shift																6	-1	-6		
Product F (6)	8	15	120	0	-120															
Supervision	4		218			4		179			4		236			4		250		
Service & Handle			84	0	-84				52	+52			109		-109			25		-25
Total Man Shifts			1667		Σ 0			1335		Σ 0			1639		Σ 0			1699		Σ 0
Employment			27					28[5]					27					27		
#1 - 8 5 hr. Day																				
#2 - 10.0 hr. Day																				
#3 - 8.0 hr. Day																				
#4 - shift operation																				
#5 - hire 1 girl for special																				
assignment																				
#6 - Controlled by plant																				

EXHIBIT III

anticipated production volumes using standard shift production rates corresponding to the particular shift levels (or machine configuration) chosen and are then compared to corresponding quarterly sales volume projections, as shown in Exhibit IV.

The variable employment "Manpower Balance" shows the extent of fluctuation in plant labor, in terms of men, to meet the aggregate seasonal sales curve. Sub-totals can be used to identify (by department and/or labor skill) manpower fluctuations, the feasibility of scaling up or down production levels and the interchangeability of personnel. Net employment additions or deletions are then multiplied by approved employment fluctuation unit costs reflecting the seniority level of personnel involved, projected duration of the seasonal layoff or other peculiarities of the local labor market (such as availability of a skilled labor pool not desiring year-round employment).

The formulation and approval of a cost scale for employment variation is resolved well in advance of the annual planning process at the management level, the scale being set separately for each plant. In many instances, a feasible variable employment "Manpower Balance" of necessity results in some accumulation of seasonal inventories. The variable costs of such inventories must then be added to the priced out cost of employment variation. Similarly, fluctuation in

Plant: #1
FY '62

SEASONAL INVENTORY ACCUMULATION SCHEDULE

Sheet ____ of ____
Prepared By: JOHN DOE
Approved By. ____

[X] UNIFORM EMPLOYMENT PLAN
[ ] VARIABLE EMPLOYMENT PLAN - TRIAL # ____

Product		Current Inventory Accumulation MARCH Qtr	PLANNED DATA: JUNE Qtr	SEPT. Qtr.	DECEMBER Qtr.	MARCH Qtr.	TOTAL
A	Sales Volume		110,000	86,850	100,650	113,550	411,050
	Scheduled Production		94,000	88,000	100,000	114,000	396,000
	Inventory Change		- 16,000	+ 1,150	- 650	+ 450	
	Cum Inventory Change	+ 16,200	+ 200	+ 1,350	+ 700	+ 1,150	
	Cost of Cum Inv Change		$ 12.00	$ 81.00	$ 42.00	$ 69.00	$ 204.00
B	Sales Volume		7,640	9,500	7,000	7,100	31,240
	Scheduled Production		21,000	2,000	5,500	3,000	31,500
	Inventory Change		+ 13,360	- 7,500	- 1,500	- 4,100	
	Cum Inventory Change	0	+ 13,360	+ 5,860	+ 4,360	+ 260	
	Cost of Cum Inv Change		$ 334.00	$ 146.00	$ 109 00	$ 7 00	$ 596 00
C	Sales Volume		9,418	9,768	7,027	7,832	34,235
	Scheduled Production		9,418	9,768	7,027	7,832	34,235
	Inventory Change		0	0	0	0	
	Cum Inventory Change	0	0	0	0	0	
	Cost of Cum Inv Change		0	0	0	0	$ 0
D	Sales Volume		30,189	95,250	91,897	108,881	326,217
	Scheduled Production		52,800	76,800	97,600	100,800	328,000
	Inventory Change		+ 22,611	- 18,450	+ 5,703	- 8,081	
	Cum Inventory Change	0	+ 22,611	+ 4,161	+ 9,864	+ 1,783	
	Cost of Cum Inv Change		$ 1,355	$ 250	$ 592	$ 107	$ 2,304
E	Sales Volume		133,224	161,500	158,124	198,822	651,670
	Scheduled Production		118,400	153,600	163,200	201,600	636,800
	Inventory Change		- 14,824	- 7,900	+ 5,076	+ 2,778	
	Cum Inventory Change	+ 30,857	+ 16,033	+ 8,133	+ 13,209	+ 15,987	
	Cost of Cum Inv Change		$ 1,603	$ 813	$ 1,321	$ 1,599	$ 5,336
	Sales Volume						
	Scheduled Production						
	Inventory Change						
	Cum Inventory Change						
	Cost of Cum Inv Change		PRODUCT	INV.	CARRY COST PER	QTR.	
	Sales Volume		A		.06	per case	
	Scheduled Production		B		.025 "	"	
	Inventory Change		C		-	-	
	Cum Inventory Change		D		.06 "	"	
	Cost of Cum Inv Change		E		.10 "	"	

EXHIBIT IV

production levels in phase with seasonal variation of sales may increase variable production costs by forcing departures from optimal process or machine load configurations. Such costs are additive to the cost of employment variation The computation of the least cost seasonal employment is performed as follows:

Given: A = Cost of employment fluctuation

a_1 = Minimum feasible cost of seasonal inventories corresponding to A

a_2 = Loss in efficiency due to non-optimal scheduling

B = Cost of inventory accumulation corresponding to level employment

$f(x)$ = Inventory accumulation function with a lower limit of 0 (no employment stabilization inventory accumulation) and an upper limit of 1 (maximum inventory accumulation possible).

We can assume that

$$Y_u = \text{cost of uniform employment} = f(x) = (B - a_1)\cdot x + a_1$$

and that

$$Y_v = \text{cost of variable employment} = f(x) = (A + a_1 + a_2)\cdot(1 - x)^2$$

Inasmuch as the values of A; a_1; a_2 and B cannot be derived analytically, they are established empirically using trial and error techniques partially illustrated in Exhibits III and IV.

The quadratic approximation of the cost of variable employment has been shown to give a reasonably close representation of factory cost relationships. Incremental costs for small changes in output levels are relatively small. As fluctuations in seasonal output levels become larger, the number of people affected as well as their seniority rapidly increases. The non-linearity of the variable employment curve is then due both to cut-backs in indirect labor in addition to variable labor (assumed as linear) as well as due to steeply increasing employment variation unit costs. Seasonal planning costs will be then:

$$TC = Y_u + Y_v = (B - a_1)\cdot x + a_1 + (A + a_1 + a_2)(1 - x)^2$$
$$= Bx - a_1x + a_1 + (A + a_1 + a_2)(1 - 2x + x^2)$$

as shown in Exhibit V.

To find minimum seasonal planning costs

$$\frac{d(TC)}{dx} = B - a_1 - 2(A + a_1 + a_2) + 2x(A + a_1 + a_2) = 0$$

then

$$x_{\text{opt}} = 1 - \frac{B - a_1}{2(A + a_1 + a_2)}$$

Due to limits on value of $0 \leqq X \leqq 1$ a compromise solution between extreme employment or inventory policies exists only if:

$$B - a_1 < 2(A + a_1 + a_2)$$

SEASONAL PLANNING COST RELATIONSHIPS

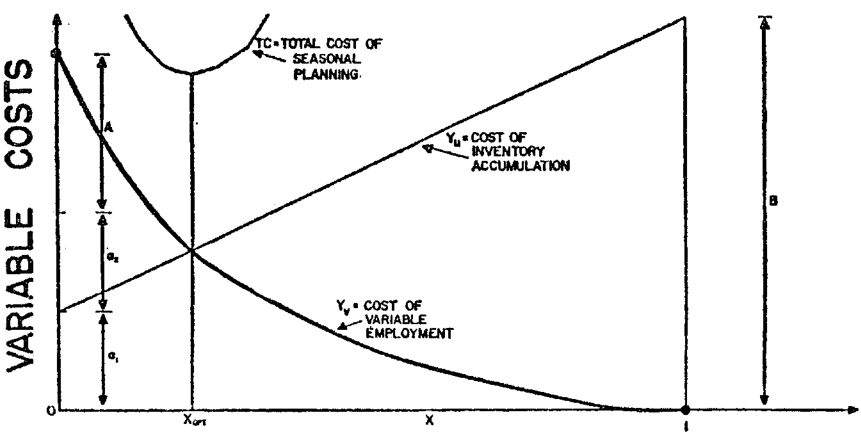


EXHIBIT V

This means that if the incremental cost of accumulating seasonal inventories is more than twice the total cost of employment variation, the latter policy should be preferred in all cases.

The allocation of optimum seasonal inventory accumulations to individual products is finally accomplished by re-working the "Manpower Balance" and "Seasonal Inventory Accumulation Schedule" to assure that high labor contents products are scheduled preferentially into seasonal inventory surplus, that shelf life and frequent packaging changes do not conflict with the accumulation plan and that economic scheduling of incremental production levels is feasible.

4. Setting the Availability Standard

Since the size of safety inventories, which are necessary to maintain availability (service) at warehouses are an important factor in short-term production planning, the criteria and techniques for determining their size become a matter of primary concern in the plant-warehouse system design. Standard references on the question of valuation of an out-of-stock occurrence or setting an arbitrary availability percentage were found to be inadequate treatments of a phenomenon of considerable complexity for the following reasons:

1. Due to large volumes of goods moved representing a relatively small number of individual items, a completely mechanized machine tabulating system at each warehouse generates daily inventory status of all items. Availability is reviewed daily and out-of-stocks are anticipated in the light of the local marketing situation by the warehouse order clerk who may initiate a series of expediting actions before there is any tangible evidence of an out-of-stock condition. Application of human intelligence to call for advance action is particularly effective in cases of extreme sales demands and is an important factor in keeping actual out-of-stocks in the range required by an exceedingly keen competitive market. (e.g. substantially better than 99 % availability). Consequently, the size of safety inventories is determined to an important extent by "expediting costs" such as:

a. Inter-warehouse trans-shipments;

b. Less than carload or less than truckload shipments;

c. Cost penalties arising from departures from an optimum plant production schedule;

d. Overtime;

e. Uneconomic procurement practices for raw and packaging materials

2. The duration of a particular out-of-stock condition is of great importance. The prevailing practice of assigning a unit cost to an out-of-stock occurrence has not been found to be satisfactory. The fact that it is virtually impossible to obtain agreement on the cost of a "customer non-service" occurrence testifies clearly that this approach is not meaningful. Distributors of grocery products do not necessarily expect full and continuous service out of a distribution warehouse instantaneously, for all products and at all times. The availability of stocks in the customer's own distribution channels and the relative importance of being fully stocked at the grocery shelf level results in most cases in a penalty to the

manufacturer's sales organization only if over a period of time promised delivery deadlines are not met.

3. The relative priority to maintain a fixed availability standard varies from time-to-time and changes depending on product involved, location and condition of sale (such as a "promotion", market test or new product introduction). Furthermore, an out-of-stock occurrence at the warehouse (distribution center) level does not necessarily result in lost sales to ultimate customers inasmuch as a large portion of shipments from a warehouse go to distributors and not to retail stores.

In order to cope with the restrictions discussed above, the following system policies have been adopted:

1. Each product group or location is assigned an agreed upon "delivery standard" in days. If this standard is, for instance, two days, a least cost expediting action must be taken to assure delivery within two days after the out-of-stock is reported. All out-of-stocks are tabulated daily and counted daily until the item becomes available. For instance, 100 items reported as being out-of-stock for three days would be tallied as 300 out-of-stock occurrences.

2. All expediting actions taken within a month are costed out, classified and reported to the central production planning staff.

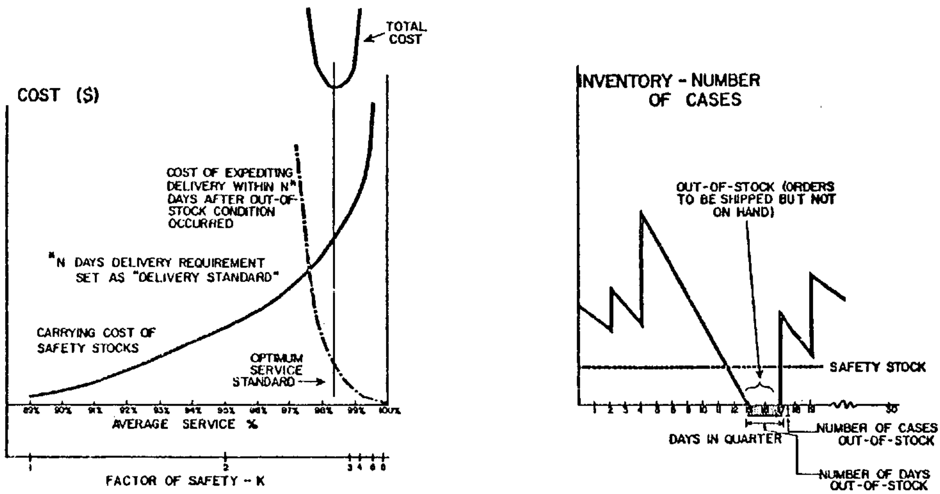
3. Charts similar to ones used in quality control are maintained to aid in identification of local out-of-control situations and to aid the central staff in evaluation of plant scheduling performance. Consistent above-or-below standard out-of-stock experiences are reviewed to identify their cause and to aid in taking corrective actions.

The information obtained as a result of the above policies is then used to calculate the optimum system factors of safety (K) for each product group and/or warehouse location.[2] Exhibit VI portrays the technique used. The approach differs in many respects from the conventional treatment of the problem. First, the costs of a lost sale or loss of good will are hidden in the expediting costs which are a function of the "delivery standard". Although this is not an explicit way of identifying the extent of penalty due to item inavailability, operationally this represents a method which lends itself to clear communication of relative service priorities. Changing an item from two to three day delivery standard can be understood, administered and measured easier than increasing the "service standard", for instance from 99.75 to 99.90%. Secondly, individual expediting occurrences may be measured and analyzed to yield significant information for improving the performance of the system and for taking corrective actions where human error can be easily hidden by phenomena presumed to be "statistical"

The fundamental premise on which this approach is based is the observed fact that out-of-stocks do not occur only because demand and lead times are statistically variable. Failure to communicate marketing developments, hesitancy on the part of the plant to alter schedules or take corrective action that may ad-

[2] The factor of safety is used here in the same sense as outlined by R. G. Brown in "Statistical Forecasting for Inventory Control"—McGraw-Hill Book Company.

SERVICE STANDARD DETERMINATION



OUT-OF-STOCK COUNT = NUMBER OF CASES OUT-OF-STOCK × NUMBER OF DAYS OUT-OF-STOCK

$$\text{SERVICE \%} = \left(1 - \frac{\text{OUT-OF-STOCK COUNT DURING QUARTER}}{\text{TOTAL SHIPMENTS FOR QUARTER}}\right) \times 100\%$$

SAFETY STOCK = FACTOR OF SAFETY × STANDARD DEVIATION OF FORECAST ERRORS

Exhibit VI

versely affect manufacturing costs, hold-up of raw material supplies by quality control due to poor vendor performance, delays by advertising in releasing approved copy for change of packaging, etc. ultimately account for a large share of "forecasting errors" and "lead time variations" causing out-of-stocks. Unless a mechanism is developed for making the variable system costs causally traceable, the extreme ranges of the statistical distributions of lead time and of error in sales forecast will be incorporated uncritically into various inventory safety levels. The long-term consequence of such an approach will be the embalmment of the status quo into theoretically correctly computed safety parameters. The other important difference in approach to system design is that the optimum availability standard, computed as illustrated in Exhibit VI and defined as

$$\text{Availability (\%)} = \frac{\text{Orders (in units)} - \text{out-of-stock count (cumulative method)}}{\text{Orders (in units)}} \times 100$$

is attributed solely to the statistical distribution of forecast errors. This assumption holds true in a system where lead time is a controllable system element due to the following policies:

1. Weekly, plants receive forecasts of detailed production and shipping requirements, by week, eight weeks ahead.[3] Hence, availability of equipment capacity and transportation means can be planned well in advance and plans reviewed as the day of action approaches.

[3] For detail see section 7 of this paper.

2. The reliability of the transportation system is known reasonably well and the actual routing of shipments is subject to continuous monitoring.

3. A daily warning signal is generated as a matter of routine and as a by-product of the warehouses' daily perpetual stock record updating. Such a signal is originated if a warehouse reaches an availability point where action can be taken only on an expedited basis. To make sure that a plant knows how to respond to such a "warehouse minimum" message, each plant establishes quarterly warehouse minimum levels at which the warehouse is required to originate a teletype message. As a rule, the warehouse minimum level is higher than that of the warehouse safety stock and is computed using the least re-supply time which may be economical for a particular plant-warehouse configuration.

4. Although the plant's production schedule can be planned ahead reasonably in advance (up to eight weeks) and raw materials availability has been designed to satisfy availability criteria for finished goods, the plant is specifically prohibited from finalizing production schedules until the latest sales and re-supply priority computations arrive at the plant two to three days before the start of the production week.[4]

5. Cost of Carrying Inventories

The application of a single percentage figure (usually ranging from 10%–30%) to the value of an inventoried item, as a method of pricing out the cost of carrying inventory per annum, is the most frequently quoted approach currently in use. If there are relatively few items in a product line, the lack of correlation between the size of an item and its value as well as the general bulkiness of grocery products per unit justify a more rigorous treatment of this parameter which affects a large number of system relationships. The cost of carrying inventory is defined as:

(a) Warehousing Cost (warehousing cost per sq. ft. per annum reduced to cost per case per annum). Unless a company already owns substantial amounts of vacant warehousing space, the warehousing cost used in computations should be the marginal cost for additional space at prevailing commercial rates.

(b) Taxes and insurance, per case.

(c) Net variable cost of capital tied up in inventories—For purposes of inventory valuation in a distribution decision system only direct variable costs should be used to measure the amount of funds tied up in inventories. Fixed charges and factory overhead should be subtracted from the cost-of-goods used for valuation for accounting purposes. Similarly, if the manufacturing process involves a conversion from raw materials which are purchased in substantial supply regardless of the short term requirements of the conversion process (such

[4] Design criteria for a factory raw materials inventorial policy shall be discussed in a separate paper. There are significant relationships between ratios of finished goods inventories at the distribution warehouse, plant warehouse levels and raw materials inventories at the plant and supplier warehouses. Attempts to minimize inventories at any of these four levels in a plant-warehouse logistic system may seriously penalize the system as a whole

as in the case of purchasing an annual crop or buying a substantial supply of a raw material as protection against a price increase or supply failure) the inclusion of such raw materials in the valuation of inventories is incorrect. The timing of the conversion of raw materials into finished goods (creation of inventories) should not be affected by the fact that the raw material will remain available regardless of actions taken.

Another problem arises when an interest rate must be selected representing the percentage per annum costs of funds employed in inventories. The divisional controllers are confronted with conflicting considerations if inventories represent a large portion of total funds employed. Invariably, they will tend to select the interest rate applicable to the divisional return on investment of funds employed which leads to obviously fallacious inventory decisions.[5] The correct approach is to use a return on investment rate for an investment having a risk comparable to creation of inventories. For a staple product, this rate would approach the cost of long-term corporate borrowing. For new products, promotional items, merchandise subject to sudden price decline, obsolescence or spoilage, etc., the investment in inventories should be based on a discounted valuation of probabilities that inventory losses will take place in the future.

6. Quarterly Planning

Since fiscal and marketing objectives are re-appraised quarterly, adjustments in the annual plan are easiest to accomplish during the first two weeks of each quarter. At this time over-fulfillment or underfulfillment of last quarter's sales targets has been identified and detailed product promotional activities for the current quarter have been communicated to plants.

At the end of the first two weeks of each quarter, each plant submits for approval to the divisional production planning staff a formal quarterly production and inventory accumulation plan illustrated partially as Exhibits VII and VIII. A minimum cost production and inventory plan is found by pricing out inventory accumulations and comparing this cost with the cost of varying production levels which would eliminate increases in inventories.[6] This is illustrated in Exhibit IX The quarterly planning process is completed by determining the minimum and maximum levels for inventories to apply during the next planning period, as follows:

(a) Minimum Inventory--This amount is read off the computer run described in section 7 of this paper and represents K standard deviations of forecast errors for the lead time of one week. If the review period increases, such as during plant shut-down for vacations, the minimum inventory corresponding to the shut-down period (in weeks) would be used.

(b) Manufacturing Cycle or Shipping Frequency—Upon completion of a

[5] See article by John Dearden in the Harvard Business Review, May–June, 1961, page 76

[6] Due to cycling of a large number of products through identical equipment, the technique outlined in Magee's "Production Scheduling and Inventory Control", McGraw-Hill, New York, 1958, pages 58, 59, 310–312, was found particularly helpful.

QUARTER: JUNE QTR. FY 62

PLANT: #1
PREPARED BY: JOHN DOE APPROVED: ______ PLANT MANAGER
APPROVED: ______ DATE: ______

PLANNED PRODUCTION REQUIREMENTS

		(1)	(2)	(3)	(4) = (1)+(2)+(3)	(5)	(6)		(7)	(8)	(9)	(10) = (5) + (6) + (7)+(8)+(9)	(11) = (10) − (4)	(12)	(13) = (12 + (11)
PRODUCT CODE	PRODUCT DESCRIPTION	LAST QUARTER-END INVENTORIES				NEXT QUARTER-END INVENTORIES							INVENTORY ADJUSTMENT	WAREHOUSE SHIPMENT FORECAST	QUARTER PRODUCTION REQUIREMENTS
		WAREHOUSE	TRANSIT	PLANT	TOTAL	WAREHOUSE SAFETY	WHSE PROTECTION ADJ. WEEKS	WHSE PROTECTION ADJ. QUANTITY	SEASONAL ACCUMULATION	PROJECTED IN-TRANSIT	PROJECTED PLANT	PLANNED TOTAL			
	Product A	54,326	16,453	3 451	74,230	38,030	–	–	+ 200	16,000	4,000	58,230	−16,000	110,000	94,000
	Product B	5,780	100	70	5,950	5,250	–	–	+13,360	700	–	19 310	+13,360	7,640	21 000
	Product C	0	0	494	494	0	–	–	+ 0	–	494	494	0	9,418	9,418
	Product D	15,347	2,370	178	17,895	13 351	–	–	+22,611	4,000	544	40,506	+22 611	30,189	52,800
	Product E	32,293	18,190	5,006	55,489	20,034	0 4	4,598	+16,033	–	–	40,665	−14,824	133,224	118,400

EXHIBIT VII

QUARTER: JUNE QTR FY 62

PRODUCTION PLAN

PLANT: #1

PREPARED BY: JOHN DOE APPROVED ______ PLANT MANAGER

APPROVED: ______ DATE ______

WEEK IN QUARTER

PRODUCT CODE	PRODUCT ON REQUIREMENTS	1 MACH SHFTS	1 PRODUCTION	2 MACH SHFTS	2 PRODUCTION	3 MACH SHFTS	3 PRODUCTION	4 MACH SHFTS	4 PRODUCTION	5 MACH SHFTS	5 PRODUCTION	6 MACH SHFTS	6 PRODUCTION	7 MACH SHFTS	7 PRODUCTION
A	94 000	4	8,000	4	8,000	4	8,000	4	8,000	3	6,000	3	6 000	3	6,000
B	21,000	4	2,000	4	2,000	4	2,000		0		0		0	5	2,500
C	9,418—80# Bags	2	800	2	800	2	800		0	1	400	2	800	2	800
D	52,800	5	8,000	5	8,000	4	6,400		0		0		0	4	6 400
E	118,400	5	16,000	5	16 000	4	12 800		0		0		0		0

PRODUCT CODE	8 MACH SHFTS	8 PRODUCTION	9 MACH SHFTS	9 PRODUCTION	10 MACH SHFTS	10 PRODUCTION	11 MACH SHFTS	11 PRODUCTION	12 MACH SHFTS	12 PRODUCTION	13 MACH SHFTS	13 PRODUCTION	TOTAL PRODUCTION SCHEDULED	NEXT QUARTER 1st Week MACH SHFTS	NEXT QUARTER 1st Week PRODUCTION	NEXT QUARTER 2nd Week MACH SHFTS	NEXT QUARTER 2nd Week PRODUCTION
A	4	8,000	4	8,000	4	8,000	4	8,000	3	6,000	3	6,000	94,000	5	10,000	5	10,000
B	4	2,000	4	2,000	4	2,000	4	2,000	5	2,500	4	2,000	21,000		0		0
C	2	800	2	800	2	800	2	800	2	800	3	1,200	9 600	2	800	2	800
D	4	6,400	4	6 400	4	6,400	3	4,800		0		0	52 800	5	8,000	5	8,000
E		0	3	9 600	5	16,000	5	16,000	5	16,000	5	16,000	118,400	5	16,000	5	16,000

EXHIBIT VIII

QUARTERLY TRIAL PRODUCTION PLAN COMPUTATION

Plant: #1 **Prepared by:** JOHN DOE **Date:** 4/5/61

PRODUCT GROUP: D

WEEK NO.	NO. OF SHIFTS	☐ UNIFORM ☒ TRIAL PRODUCTION PLAN (1)	QUARTERLY CYCLE FACTOR (2)	VARIABLE PROD. PLAN (SHIPMENTS) (3)	INVENTORY ACCUMULATION (1) - (3)	TOTAL [illegible] INVENTORY ACCUMULATION	COST OF TRIAL PROD. PLAN
Carry-Over, Seasonal or Cycle Inventory					0	0	
1	5	3,000	0.8	1,855	+ 6,145	+ 6,145	$ 28
2	5	8,000	0.8	1,855	+ 6,145	+12,290	$ 57
3	4	6,400	1.0	2,320	+ 4,080	+16,370	$ 75
4	0	0	1.0	2,320	- 2,320	+14,050	$ 65
5	0	0	0.7	1,625	- 1,625	+12,425	$ 57
6	0	0	1.0	2,320	- 2,320	+10,105	$ 47
7	4	6,400	1.0	2,320	+ 4,080	+14,185	$ 65
8	4	6,400	1.0	2,320	+ 4,080	+ 18,265	$ 84
9	4	6,400	1.0	2,320	+ 4,080	+22,345	$ 104
10	4	6,400	1.0	2,320	+ 4,080	+ 26,425	$ 122
11	3	4,800	1.0	2,320	+ 2,480	+ 28,905	$ 134
12	0	0	1.3	3,019	- 3,019	+ 25,886	$ 120
13	0	0	1.4	3,275	- 3,275	+22,611	$ 104
QTR. TOTAL	33	52,800	13.0	30,189	-	+ 22,611	$1,062
1							
2							

COMMENTS:

Exhibit IX

production lot, the size of warehouse inventories will be determined either by the frequency of the manufacturing cycle (in week's supply) or by the frequency of economic shipments to the particular warehouse location. For instance, if product Q is manufactured once every three weeks at plant X, but the most economic shipping method (by rail) to warehouse #4 allows scheduling of car-lot deliveries only once every five weeks, the "shipping frequency" shall govern in determination of the maximum inventories at warehouse #4 for a product made at X. Similarly, if shipments are made weekly, the "manufacturing cycle frequency" would govern.

(c) Seasonal and Quarterly Cycle Inventories—Allowances for these accumulations are made and the value of the maximum inventory level raised accordingly.

(d) Additional Protection—For a number of reasons, such as accumulation for a promotion, anticipation of price changes, equipment modifications, etc., management may wish to raise the allowable maximum inventory levels by providing additional supplies of specific items.

A tabulation of the maximum and minimum factors in terms of weeks' supply is then made which is translated into maximum case limits. At the same time, a computation is made of "warehouse minima" by taking the minimum inventory levels (from the plant's point of view) and increasing them by a time factor representing plant to warehouse lead time on an expedited basis. The "warehouse minima" are inserted into the perpetual inventory records maintained by IBM tabulating equipment at each warehouse and reviewed daily. If the quantity available is less than the "warehouse minimum" this fact is immediately reported by teletype to the plant. It should be noted that this communication allows for reaction on an expedited basis only and is not used to make the routine replenishment decision. The primary significance of the daily "warehouse minimum" signal on an exception basis is that it allows reduction of safety levels even further than theoretically deemed feasible by a weekly review frequency. The decision rules discussed under the minimum-maximum concept above are summarized in a graphical form as Exhibit X, which indicates how plants are given considerable latitude in optimizing their short-run inventory, production, transportation and customer service costs subject to the following restrictions:

(a) Plants shall always schedule shipments to warehouses so that the actual

THE MIN.-MAX. INVENTORY CONTROL CONCEPT

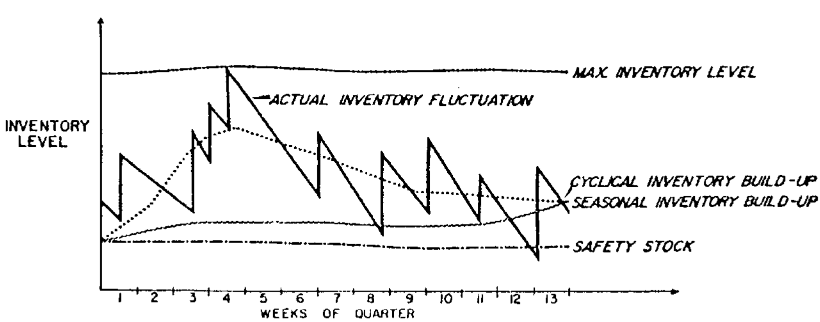


EXHIBIT X

inventory, projected one review period ahead, shall not fall below in the minimum inventory level.

(b) Plants shall always schedule shipments to warehouses so that the actual inventory shall not exceed the *maximum* inventory level.

The practical consequences of these decision rules is that plants are allowed to re-allocate instantaneously (without divisional action) production capacity and manpower to items experiencing short-term sales increases even if such sales are substantially in excess of budgeted amounts. As a corollary, plants are not allowed to produce in amounts which would result in inventories excess of the maximum limit if sales slow down even though the planned production levels have been set for the anticipated sales levels. Divisional approval is necessary only if the aggregate effect of short-term sales fluctuations require a modification of the annual plan.

7. Weekly Planning

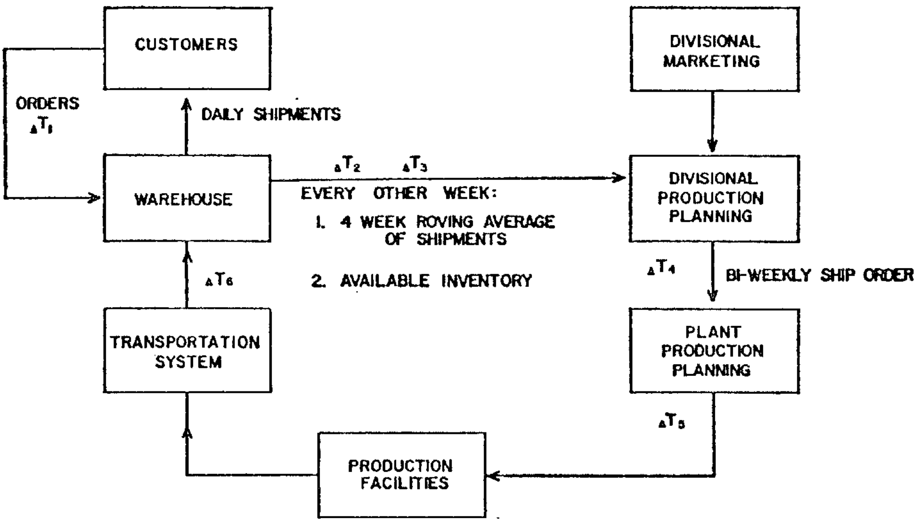
The plant's decision to produce and ship is postponed to the latest time period possible. This rule is theoretically justifiable because both the age of information on which decisions are made, as well as the frequency of decisions, have a significant influence on the aggregate lead time and response characteristics to transient disturbances built into the system. Applying techniques of "industrial dynamics" to the old inventory system (outlined in Exhibit XI), the average lead time of six weeks (with an upper range of 12.3 weeks) was reduced by changing to the information system shown in Exhibit XII. The major differences between the new and the old information loops are:

1. Orders placed for future delivery are "phased out" by date and automatically deducted from available inventories.
2. The four weeks moving average has been replaced by an exponentially weighted moving average forecasting function,[7] which is believed to eliminate the lagging features of the moving average and makes allowance for seasonal and trend components of sales curves.
3. Shortening the review frequency from two weeks to one week.
4. Eliminating the lead time component attributable to the procurement of raw materials establishing a raw materials forecasting system consistent with management of finished goods inventories.
5. Eliminating the warehouse to division reporting lag (see paragraph 2 of the paper).

These measures have reduced the average lead time from six weeks to three weeks. But the most significant element in reducing inventories has been the reduction of the upper range of lead times from twelve weeks to four weeks. Since it is the unpredictability of the range of demand rather than the demand average that determines the size of safety stocks each system element must be carefully analyzed for maximum delays which are generated by it. This experience has demonstrated that the first step in the design of an integrated inventory produc-

[7] See Peter R. Winters, "Forecasting Sales by Exponentially Weighted Moving Averages", Management Science, Volume VI, Number 3.

PRODUCTION — INVENTORY MANAGEMENT SYSTEM



DELAYS IN OLD SYSTEM

DELAY	EXPLANATION	AVERAGE DURATION (Weeks)	RANGE	CUMULATIVE VALUE (Weeks)
ΔT_1	ORDERS PLACED FOR FUTURE DELIVERY	0.6	0.2 – 2.0	0.6
ΔT_2	SENSITIVITY OF 4 WEEKS MOVING AVERAGE	2.0	0 – 4.0	2.6
ΔT_3	REPORTING LAG – WAREHOUSE TO DIVISION	0.5	0.5 – 0.8	3.1
ΔT_4	PRODUCTION SCHEDULING TIME	0.2	0 – 0.5	3.3
ΔT_5	PRODUCTION TIME	1.7	0.2 – 3.0	5.0
ΔT_6	TRANSIT TIME	1.0	0.5 – 2.0	6.0
	TOTAL	6.0	1.4 – 12.3	

Exhibit XI

tion scheduling decision making system should be a detailed flow chart of the logic and time elements of the existing system. This is to be followed by evaluation of institutional, communication and data processing limitations which determine the lowest attainable levels of lead time.

The new communication system provides for teletype transmission of information about sales and stocks to a central location where a report illustrated as Exhibit XIII is prepared and mailed (over the weekend) to each plant. The sig-

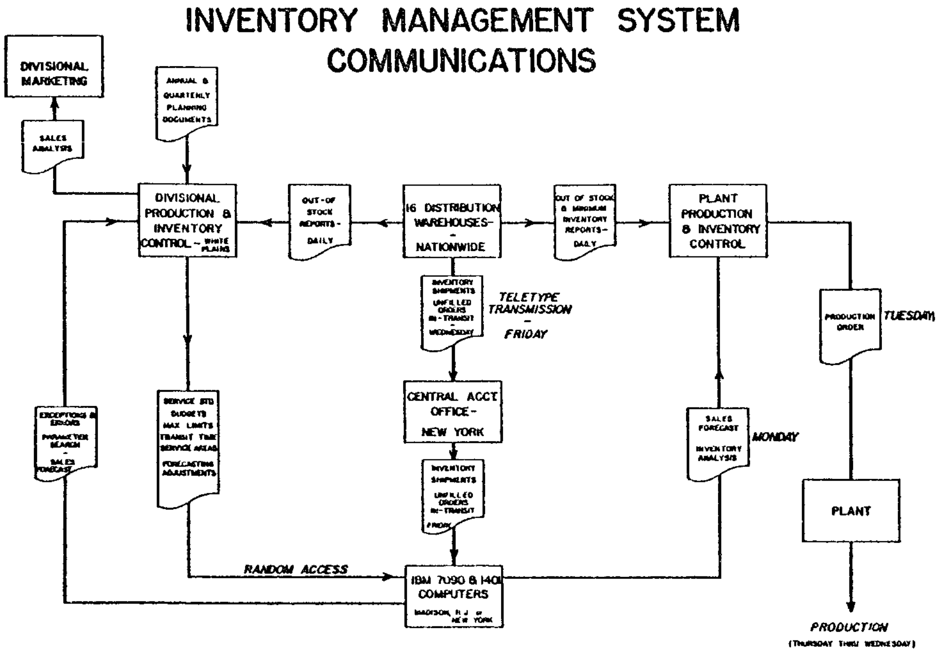


EXHIBIT XII

nificance of the various elements on the computer run is explained as Exhibit XIV.

The forecasts shown on the computer output are made cumulatively, one through eight weeks ahead, each week of a 13 week quarter. This means that at the end of the fifth week in a quarter, the first projection of quarter-end sales can be made by adding actual for quarter-to-date plus an eight week sales forecast.

This process is repeated weekly with improved accuracy inasmuch as the quarter-end forecast includes an ever increasing fraction of actual sales, providing thereby significant information for sales analysis purposes. The forecasting equations are based on Winter's paper (op. cit.) and are used to compute cumulative forecasts F, at time for n periods ahead where $1 \leqq n \leqq 8$. Then

$$F_{t,n} = \tilde{S}_{t,1} + \tilde{S}_{t,2} + \cdots + \tilde{S}_{t,n}$$

where $\tilde{S}_{t_1 n}$ is forecast shipments in period $(t + n)$. Similarly, the cumulative actual shipments, A, during these periods are given by

$$A_{t,n} = S_{t,1} + \cdots + S_{t,2}$$

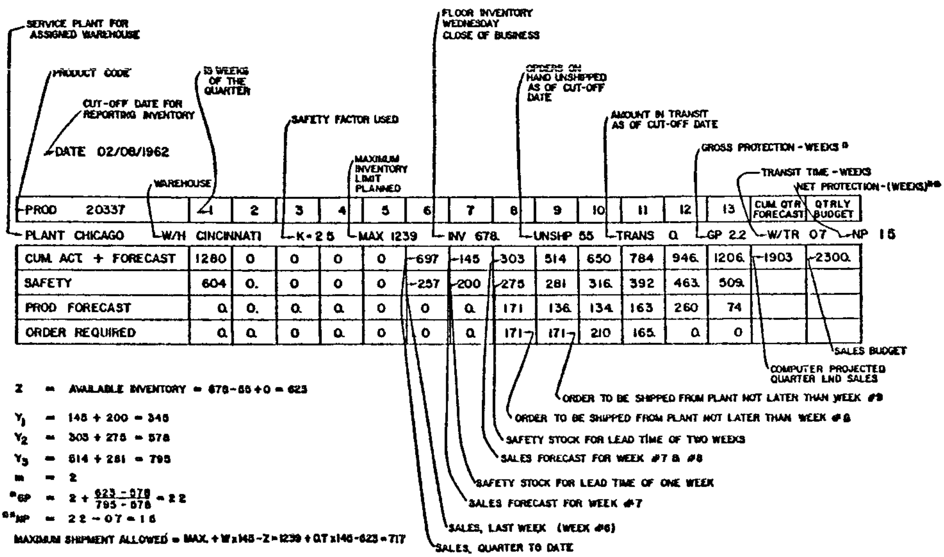
The difference between cumulative forecast shipments and cumulative actual shipments is represented by $E_{t,n}$ where

$$E_{t,n} = F_{t,n} - A_{t,n}$$

DATE 02/08/1962														CUM QTR	QTRLY.
PROD. 20337	1	2	3	4	5	6	7	8	9	10	11	12	13	FORCAST	BUDGET
PLT CHICAGO	W/H CINCINNATI		K= 2.5	MAX 1239.		INV 678.		UNSHP 55		TRANS 0.		GP 2.2	W/TR 0.7	NP 1.5	
CUM ACT+FORCST	1280.	0.	0.	0.	0.	697.	145.	303.	514.	650.	784.	946.	1206.	1903.	2300
SAFETY	604.	0.	0.	0.	0.	257.	200.	275.	281.	316.	392.	463.	509.		
PROD. FORECAST	0.	0.	0.	0.	0.	0.	0.	171.	136.	134.	163.	260.	74.		
ORDER REQUIRED	0.	0.	0.	0.	0.	0.	0.	171.	171.	210.	165.	0.	0.		
PLT HOBOKEN	W/H CLIFTON		K= 2.5	MAX 900.		INV 603.		UNSHP 96		TRANS 0.		GP 1.8	W/TR 0.1	NP 1.7	
CUM ACT+FORCST	1098.	0.	0.	0.	0.	536.	137.	251.	400.	561.	743.	845.	1016.	1552.	1410
SAFETY	638.	0.	0.	0.	0.	140.	200.	293.	418.	468.	584.	586.	624.		
PROD. FORECAST	82.	0.	0.	0.	0.	0.	0.	38.	148.	162.	181.	102.	171.		
ORDER REQUIRED	0.	0.	0.	0.	0.	0.	0.	38.	273.	96.	0.	0.	0.		
PLT CHICAGO	W/H DETROIT		K= 2.5	MAX 1193.		INV 988.		UNSHP 60		TRANS 0.		GP 3.5	W/TR 0.6	NP 2.9	
CUM ACT+FORCST	1175.	0.	0.	0.	0.	676.	150.	315.	475.	611.	773.	889.	1098.	1774.	1990
SAFETY	770.	0.	0.	0.	0.	214.	184.	263.	339.	430.	522.	619.	701.		
PROD. FORECAST	0.	0.	0.	0.	0.	0.	0.	0.	113.	162.	115.	210.	76.		
ORDER REQUIRED	0.	0.	0.	0.	0.	0.	0.	0.	113.	242.	0.	0.	0.		
PLT CHICAGO	W/H CHICAGO		K= 2.5	MAX 2205.		INV 778.		UNSHP 173		TRANS 0.		GP 1.0	W/TR 0.1	NP 0.9	
CUM ACT+FORCST	2200.	0.	0.	0.	0.	1246.	320.	590.	863.	1131.	1370.	1634.	2067.	3311.	4100
SAFETY	1322.	0.	0.	0.	0.	301.	308.	491.	645.	788.	961.	1084.	1218.		
PROD. FORECAST	133.	0.	0.	0.	0.	0.	23.	270.	273.	268.	239.	264.	633.		
ORDER REQUIRED	0.	0.	0.	0.	0.	0.	23.	454.	426.	411.	318.	0.	0.		
PLT CHICAGO	W/H YOUNGSTOWN		K= 2.5	MAX 1850.		INV 1017.		UNSHP 178		TRANS 0.		GP 2.3	W/TR 0.7	NP 1.6	
CUM ACT+FORCST	1522.	0.	0.	0.	0.	985.	207.	407.	634.	812.	1021.	1203.	1452.	2437.	3340
SAFETY	1143.	0.	0.	0.	0.	215.	294.	325.	440.	556.	724.	859.	1025.		
PROD. FORECAST	0.	0.	0.	0.	0.	0.	0.	234.	179.	209.	182.	249.	70.		
ORDER REQUIRED	0.	0.	0.	0.	0.	0.	0.	234.	295.	377.	250.	0.	0.		
PLT CHICAGO	W/H ATLANTA		K= 2.5	MAX 2008.		INV 1553.		UNSHP 51		TRANS 0.		GP 2.7	W/TR 0.9	NP 1.8	
CUM ACT+FORCST	2485.	0.	0.	0.	0.	1199.	354.	640.	971.	1258.	1616.	1886.	2326.	3525.	3570
SAFETY	1182.	0.	0.	0.	0.	624.	337.	503.	666.	733.	847.	953.	1078.		
PROD. FORECAST	0.	0.	0.	0.	0.	0.	0.	135.	287.	358.	270.	440.	158.		
ORDER REQUIRED	0.	0.	0.	0.	0.	0.	0.	135.	354.	336.	0.	0.	0.		
CHICAGO	0.	0.	0.	0.	0.	0.	138.	1313.	1901.	2003.	1226.	0.	0.	ORDER SUM	
	200.	0.	0.	0.	0.	0.	138.	1033.	1402.	1469.	1449.	2542.	1368.	PROD. SUM	
HOBOKEN	0.	0.	0.	0.	0.	0.	0.	38.	381.	814.	383.	193.	0.	ORDER SUM	
	82.	0.	0.	0.	0.	0.	0.	38.	256.	691.	572.	785.	356.	PROD. SUM	

Exhibit XIII

EXPLANATION OF COMPUTER OUTPUT



PROD 20337	1	2	3	4	5	6	7	8	9	10	11	12	13	CUM QTR FORECAST	QTRLY BUDGET
CUM. ACT. + FORECAST	1280	0	0	0	0	697	145	303	514	650	784	946.	1206.	1903	2300.
SAFETY	604	0.	0	0	0	257	200	275	281	316.	392	463.	509.		
PROD FORECAST	0.	0.	0.	0.	0	0	0.	171	136.	134.	163	260	74		
ORDER REQUIRED	0.	0.	0	0.	0	0	0.	171	171	210	165.	0.	0		

EXHIBIT IV

Since for any value of n we have p different error estimates (where p depends on the number of data in the computer and internal Q_2 over which the forecast has been simulated), the standard deviation for an n period forecast is computed from the root-mean-square of these p estimates as follows:

$$\sigma_n = \sqrt{\frac{(\Sigma E^2)_n}{p}}$$

The program computes σ_n for $n = 1, 2 \cdots 8$ and saves the results for multiplication by the safety factor K which can be chosen individually for each product warehouse location. The safety stock in each of the cumulative forecasts is then $X_n = K \cdot \sigma_n$ and the total inventory requirement Y_n is given by

$$Y_n = F_{t,n} + X_n$$

Due to the scarcity of input data in the proper format, the system was started up initially with only 26 sales data intervals (two cycles of 13 weeks each) per time series for each of the 4,000 time series involved. Although this amount of data is an absolute minimum it represented such a vast improvement over the existing four weeks moving average that the cost of additional input data for the system start-up was not considered practical.

The computer operations are classified according to the "pilot" or "production" mode. During the "pilot" mode initial values of the trend, seasonal factors and smoothed shipments are computed. Then simulation without forecasting takes place over an interval Q_1 to test out the effect of three weighing factors (smoothing constants) on the system. Another simulation, over an interval Q_2 simulates the exponential smoothing equations to arrive at reasonable values of the standard deviation of forecast errors. A further option may be exercised wherein as many as six different values may be supplied for each of the weighing factors to determine one combination which would minimize the standard deviation of forecast errors n periods ahead. Inasmuch as only one forecasting period can be selected for the criterion of optimality, the minimum value of σ_3 has been selected because the production lead time of three weeks (from the date of the data) represents closest the existing planning horizon of the plants. In the "production mode", no simulation takes place and maximum advantage is taken of the exponentially moving average equations to up-date the time series with a minimum of historical data. The economies of exponential smoothing are apparent from the following data:

1. Compute time on IBM 7090: 4.4 minutes per 1,000 time series in "production mode"[8]

2. Input edit time on IBM 1401: 4 minutes per 1,000 time series. The order computation by the computer is based on the concept of "Gross Protection" which is analogous to the widely used concept of "weeks of supply" except that the length of time over which the existing stocks will suffice takes into account both the shape of the short-term sales forecast curve and the forecast requirements for safety stocks. The order computations are based on the following method:

If Z = amount available at the warehouse = inventory plus intransit less unshipped order at time t

W = weeks-in-transit, plant-to-warehouse using most economical means of transportation

R_i = order required (outbound shipment from plant to warehouse) at time $t = i$

m = number of the last forecast in which Z exceeds Y_n

GP = Gross Protection (number of weeks' existing supply would last with a confidence implicit in the $K \cdot \sigma_n$ safety stocks

NP = Net Protection (the number of the week in which the first replenishment shipment must leave the plant in order to maintain inventories at the warehouse above safety stocks)

then

$$GP = m + \frac{Z - Y_m}{Y_{m+1} - Y_m}$$

and

$$NP = GP - W$$

The "order" amounts are then determined as follows:

$$R_i = 0 \qquad \text{for } i \leq m$$

[8] The program efficiency is due to work by the Computer Usage Company of New York and their Senior Analyst, J. H. G. Kelly.

$$R_i = Y_i - Z \qquad \text{for } i = m + 1$$

$$R_i = Y_i - Y_i - 1 \qquad \text{for } i \geqq m + 2$$

The R_i values are shifted on the computer output on the line "Order Required" in accordance with the lowest value of NP to calendarize the outbound shipment into its proper production week. Due to the restriction, however, that inventory shall not exceed a planned maximum (see par. 6), the R_i values are truncated so that

$$\sum R_i \leqq \text{Maximum inventory} - Z + \bar{S}_{t,n} \cdot W$$

The usefulness of the output format is manifold as illustrated by the following cases:

1. The plant totals of R_i values lend themselves to quick determination of order requirements, by item, up to eight weeks ahead. This allows improved short-term manpower scheduling.
2. The NP values act as true "priority indexes" for action. NP's which are negative or less than one are expedited. Code locations having NP's larger than one can be ranked according to priority of shipment, lowest values of NP having the highest urgency. For all practical purposes, items with GP in excess of eight ($GP = OVR$) are disregarded.
3. When sales trail behind production output, the surplus inventories can be distributed with uniform risk by equalizing result NP's up to the allowable maximum inventory level. Conversely, when sales exceed current production levels, the NP index allows uniform spreading of the out-of-stocks risks.
4. The plant summary labelled "production forecast" totals are used for raw materials management and procurement. Scheduled production one, two and three weeks ahead is key punched into cards, converted into ingredients requirements by the materials "explosion" technique, compared against available stocks and safety requirements to yield a phased out raw materials ordering schedule.
5. The increase in safety stocks with lengthened lead times is used in computations to influence diverse system decisions such as:

(a) Optimum economic order quantities using non-linear relationships of inventory costs as a function of batch size.

(b) Optimum length of vacation shut down or equipment changeover.

(c) Production requirements for promotions.

8. Concluding Remarks

The system described in this paper has been successfully operational since the Spring of 1961 and is generally known as the COPT system (abbreviation for *C*ost *Opt*imization). Less than eight months were spent designing and installing the features discussed. The primary reason for the rapid introduction and relatively low development costs can be found in the close cooperation between the production scheduling personnel and the operations research consultant. The inadequacies and contradictory tendencies of the old scheduling system confronted the operating personnel daily. Consequently, they were in a position to set forth the fundamental criteria for measures which should eliminate the identified problems. The major difficulty encountered was in education of personnel on the clerical level who actually make the majority of production scheduling, shipping and inventorial decisions. The concepts of making decisions which optimize costs of the overall system rather than minimize individually factors such as out-of-stock, inventory investment, warehouse floor space, realization of in-transit privileges, etc., were exceedingly difficult to get across. A partial answer to this was found by writing a detailed procedural manual which outlines in sequential format individual decision-making steps which have to be taken by each individual operating the system.