Proceedings of the 1987 Winter Simulation Conference
A. Thesen, H. Grant, W. David Kelton (eds.)

A LOGISTICS APPLICATION OF SIMULATION TO DETERMINE DISTRIBUTION COSTS RESULTING FROM A FORWARD WAREHOUSE OPERATION

Edmund W. Schuster
Welch Foods, Inc
Westfield, New York 14787

ABSTRACT

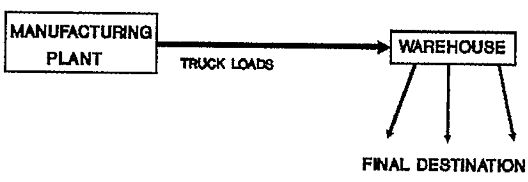
Often it is difficult to compute the cost of a forward warehouse operation given uncertain demand and complex billing systems. The simulation to be presented serves as a decision support system which aids logistics management in determining distribution costs associated with a forward warehouse based on transportation, warehouse and inventory considerations. A unique aspect of the simulation is that it is a microcomputer spreadsheet application using technology common to many business environments. Practical uses of the simulation include such corporate policy issues as warehouse location, cost increase evaluation, customer service projections and analysis of different billing systems.

1. INTRODUCTION

The activity to be simulated is best visualized as a pull distribution system with flow of five stock keeping units (SKU) originating at the manufacturer, moving through a forward warehouse, to the eventual consumer (Figure 1). Truck load quantities of product are shipped to a forward warehouse for storage while smaller quantities of product are shipped from stock, located at the forward warehouse, to the final consumers. This fanning-out distribution arrangement has proven an efficient method to deal with small customer orders, manufacturing leadtimes and demand uncertainty.

FIGURE 1

DISTRIBUTION NETWORK



System costs related to the movement of product from the manufacturer to the consumer include transportation, warehousing and inventory charges. The sum of these charges is defined as the distribution cost of the system. Common to the entire distribution network is the CWT unit of measure (1 CWT = 100 pounds). Every leg of product flow involves CWT and all distribution charges are on a CWT basis. The simulation of distribution costs involves measuring CWT at equally spaced time intervals and assessing the proper charges.

An important characteristic of the simulation is demand uncertainty. The major simulation assumption is that weekly demand patterns for outbound shipments of a particular SKU from a forward warehouse can be expressed as a probability distribution with a mean and standard deviation that is stationary. It is reasonable that the aggregate demand behavior of numerous customers placing small orders on a central warehouse will approximated a Normal Distribution for most SKU's. Due to market forces, however, some SKU's may exhibit demand behavior uncharacteristic of the Normal Distribution. Of the five SKU's to be simulated, four will have demand patterns expressed as Normal Distributions, with different means and standard deviations, and one SKU will have a demand pattern expressed as a Weibull distribution.

Finally, forward warehousing is widely employed by manufacturing concerns that are involved in "make to stock" operations, defined by The American Production and Inventory Control Society (APICS) as a strategy of producing finished goods prior to customer orders arriving. Countless retail stores in the United States draw consumer goods, produced by "make to stock" manufactures, from large central warehouses often owned by third parties. Some classes of consumer products require special low temperature storage conditions resulting in high distribution costs linked with refrigerated storage and transportation. For this reason the simulation to be discussed has greatest application in the refrigerated food industry where distribution cost is a main consideration and must be aggressively controlled. Examples listed below all deal with forward refrigerated warehousing though the simulation can also be applied to similar problems experienced by forward non-refrigerated warehousing operations.

2. PUBLIC REFRIGERATED WAREHOUSE COSTS

Due to the high cost of refrigerated warehouse construction, and inability to ship Less Than Truckload (LTL) orders direct from the manufacturer, it is common practice in the frozen food industry for manufacturers to use refrigerated warehouses owned by another party. These third party operations, often termed Public Refrigerated Warehouses, are used for storage and distribution of finished product to retail outlets. Public Refrigerated Warehouse charges consist of the following:

1. Handling
2. Storage
3. Inbound Transportation
4. Outbound Transportation

A HANDLING charge is assessed when finished product is shipped into a public refrigerated warehouse. It is a one time only charge to cover labor and equipment needed to move product in and out of the warehouse. The initial charge covers both in and out handling.

STORAGE is charged on a monthly basis for product that resides in the facility. Two types of billing systems dominate the refrigerated storage industry; SPLIT MONTH and ANNIVERSARY DATE.

SPLIT MONTH billing is defined by a major public refrigerated warehouse as follows:

> A storage month will be split with a full months storage applied to product received from the 1st through the 15th and 1/2 the monthly storage rate applied to product received from the 16th to the last day of the month with all rebills applied to the first of each subsequent month.

ANNIVERSARY DATE billing, in contrast to SPLIT MONTH, can be defined as follows:

> All charges for storage are on a month-to-month basis. Charges for any lot shall begin upon receipt in storage of the first unit of that lot and shall continue and include the storage month during which the last unit of that lot is delivered. Storage charges shall be assessed on the maximum number of units or weight in any particular lot in store during a storage month.

INBOUND TRANSPORTATION is the responsibility of the manufacturer and is usually accomplished by refrigerated truck or rail car. Often full truck loads of finished product are shipped to Public Refrigerated Warehouses but occasionally LTL quantities may be delivered as a stopoff on a truck in route to a another destination.

OUTBOUND TRANSPORTATION is performed by the Public Refrigerated Warehouse and is charged to the shipper. Small orders are consolidated, with products from other manufacturers, into truckload quantities. Generally, Public Refrigerated Warehouses offer consolidated outbound distribution service for areas spanning many hundreds of miles.

With complex billing systems and uncertain demand, it becomes difficult to evaluate the cost of competing Public Refrigerated Warehouses. To cope with this intricate problem, a simulation programmed on a microcomputer can be a valuable tool.

3. PARAMETERS OF THE SIMULATION

Several parameters must be inputted into the microcomputer, for each SKU, prior to running the simulation. These inputs are outlined in Table 1. In Table 2, the parameter values for the 5 SKU's to be simulated are listed. The data represents an actual situation, experienced by Welch Foods, dealing with distribution of frozen fruit juice concentrate to retail stores.

Table 1: Simulation Parameters
WAREHOUSING COSTS
Handling ($/CWT)
Storage ($/CWT)
Inbound Transportation ($/CWT)
Outbound Transportation ($/CWT)
PROBABILITY DISTRIBUTION PARAMETERS
MeanDemand (pounds/week)
Standard Deviation (pounds/week)
INVENTORY PARAMETERS
Re-Order Quantity (weeks supply)
Customer Service (% level)
INVENTORY CARRYING COSTS
Cost Per Pound ($/pound)
Carrying Cost (annual %)

Warehousing Costs originate directly from the Public Refrigerated Warehouse. Quotes can usually be obtained on short notice through phone contact.

Probability Distribution Parameters deal with the demand pattern desired for the simulation and pertains only to those SKU's which have Normally Distributed demand (Weibull distribution is addressed in section 5.2). The Mean Demand corresponds to the expected average CWT per week to be shipped from the warehouse. Since demand is considered probabilistic, a small Standard Deviation will cluster demands, generated by the simulation, close to the mean while a large Standard Deviation will result in demands widely dispersed from the mean. Historical time series demand data for a particular geographical area serves as a valid guide on which to base the Mean and Standard Deviation.

Inventory Parameters define the flow rate of product from the manufacturer, through the refrigerated warehouse to the final consumer. Re-Order Quantity indicates the supply of product to be shipped from the manufacturer to the warehouse when an order is placed to re-stock the warehouse. Supply is expressed in terms of weeks of average demand. Customer Service refers to the probability that stock will be available at the warehouse for shipment to final consumers. A high service level is desired for high volume SKU's, characterized as "A" items, and a lower service level is desired for lower volume SKU's, characterized as "B" & "C" items. The reason for this strategy is that low service levels for "A" items will mean increased lost sales while the impact of a low service levels for slow moving "B" or "C" items, in terms of sales losses, is much less.

Finally, Inventory Carrying Cost allows for financial analysis of inventory value based on the estimated Cost Per Pound and established Carrying Cost. The estimated Cost Per Pound is obtained by dividing the standard cost of an SKU by its weight. Carrying Cost is calculated using the industry Weighted Average Cost of Capital and represents the opportunity cost of holding a SKU as finished product inventory.

4. APPLICATIONS OF THE SIMULATION

Though there are numerous uses for the simulation, perhaps the most powerful group of applications involve manipulation of the Simulation Parameters to identify intricate cost relationships. These applications include warehouse location, cost increase evaluation, customer service projections and analysis of different billing systems. The following examples demonstrate the benefits of these applications by simulating the distribution costs for the five SKU example listed in Table 2.

4.1. Warehouse Location

If an Analyst has to determine the cheapest way to distribute frozen product manufactured in Erie, Pennsylvania to final destinations in densely populated Eastern metropolitan areas, where should the refrigerated warehouse be located to store the goods? Common sense dictates that the cheapest alternative would be a location close to population centers but it is often difficult to evaluate quotes from several warehouses with different locations and billing systems. For example, in Table 3, two candidate warehouses list their charges for serving a major Eastern metropolitan region (New England, New York State, Pennsylvania, Delaware, Maryland and Virginia) from Erie, Pennsylvania.

Table 3: Foreward Warehouse Charges

	ALTERNATIVE 1 SYRACUSE, N.Y.	ALTERNATIVE 2 SECAUCUS, N.J.
HANDLING	.70 /CWT	.86 /CWT
STORAGE	.40 /CWT	.60 /CWT
INBOUND	1.57 /CWT	2.19 /CWT
OUTBOUND	3.55 /CWT	3.29 /CWT
BILLING	SPLIT MONTH	ANNIVERSARY

Which is the least cost location? Even though Syracuse has a lower Storage/Handling rate than Secaucus, which is located only a few miles outside New York City, billing is on a split month basis. Inbound transportation is cheaper between Erie and Syracuse but outbound transportation is cheaper from Secaucus.

To answer this question a simulation was run to determine the least cost alternative. The results indicate that for a five month period, total cost equals $39,800 for Syracuse and $45,600 for Secaucus. By using Syracuse, rather than Secaucus, $5,800 can be saved.

4.2. Cost Increase Evaluation

Another useful application of the simulation is evaluation of proposed cost increases. An important part of negotiation strategy is analyzing the sensitivity of individual cost increases. Please note Table 4.

Table 4: Cost Increase Comparison

	BASE	4% INCREASE
HANDLING & STORAGE	$39,800	$39,900
TRANSPORTATION	$39,800	$41,400

Table 2: Simulation Parameters

	AVERAGE DEMAND	STANDARD DEVIATION	RE-ORDER QTY	CUSTOMER SERVICE	ABC CLASS	COST/LB	ICC	PROBABILITY DISTRIBUTION
PRODUCT 1	3190	EST	2 WKS	98.00 %	B	$0.44	15.00%	WEIBULL
PRODUCT 2	20900	5000	2 WKS	99.99 %	A	$0.30	15.00%	NORMAL
PRODUCT 3	6044	638	2 WKS	98.00 %	B	$0.34	15.00%	NORMAL
PRODUCT 4	728	130	2 WKS	97.00 %	C	$0.48	15.00%	NORMAL
PRODUCT 5	316	98	2 WKS	97.00 %	C	$0.44	15.00%	NORMAL

A 4% increase in Handling and Storage charges results in only a $100 increase in distribution cost while a 4% increase in Inbound and Outbound Transportation results in a distribution cost increase of $1600. This simple example demonstrates that the best negotiation approach is to intensely bargain for small increases in Inbound and Outbound Transportation but perhaps accept larger percentage increases in Handling and Storage.

4.3. Customer Service Projections

Nothing is more frustrating for the retail trade than to order merchandise from a central warehouse and experience an "out of stock" situation. On the other hand, it is not economical for manufactures to keep enough inventory in a forward warehouse to eliminate all out of stock's. The cost of maintaining each increment of customer service becomes a critical question which can be answered through simulation. By reducing customer service for each of the five SKU's the following distribution costs were obtained (Table 5):

Table 5: Cost of Customer Service

CUSTOMER SERVICE	DISTRIBUTION COST
BASE	$39,800
-1%	$39,500
-2%	$39,200
-3%	$38,600

A 3% decrease in customer service results in a reduction of $1200 in distribution costs. Cost savings estimates such as this can be compared to the loss of customer goodwill, allowing management a better criteria on which to make judgements regarding customer service levels.

4.4. Analysis of Different Billing Systems

A final application of the simulation involves testing Public Refrigerated Warehouse billing systems to determine if one billing system offers a consistent cost advantage. As noted in section 2.0, Split Month and Anniversary billing systems are very popular in the refrigerated warehousing industry but they differ drastically in terms of billing procedures. Given identical rates, could one form of billing be cheaper?

The simulation offers a quick answer. Under identical conditions the simulation was run ten times for both Split Month and Anniversary billing systems. A small sample t-test was performed on the mean cost of the two samples of ten to determine if the sample means were statistically equal.

Though Anniversary billing seems slightly more expensive than Split Month billing, under the conditions tested, there is not enough statistical evidence to conclude that the sample means are unequal ($\alpha = .05$). Thus there is no cost advantage to be obtained by employing one billing system rather than another.

5. TECHNICAL ASPECTS OF THE SIMULATION

Hardware and software required to run the simulation include an IBM - AT and the integrated spreadsheet package for microcomputers, Symphony. The first step in simulating distribution costs is to develop a method of generating patterns of weekly demand based on a predetermined probability distribution. Because demand is uncertain, it would be useless to design a simulation based on average demand per week. A better approach is to treat demand as probabilistic and use a monte carlo simulation to generate weekly demand. By using this technique, demand will more closely reflect actual week to week fluctuations experienced by a warehouse.

5.1. Generating Normally Distributed Demand

The essential aspect of monte carlo simulation is calculating random numbers for use in a function that will generate variates based on a desired probability distribution. As mentioned previously, the Normal Distribution was selected as a suitable approximation of weekly demands expected to be placed on a warehouse for four of the five SKU's.

The Log & Trig Method (Mihram, p. 130) of generating Normally Distributed Z values was employed. The formula is expressed as:

$$Z = [-2 * \ln(U(1)]^{1/2} \times \cos(2 \times \pi \times U(2))$$

U(1) & U(2) are independent, uniformly distributed random variables

As a value of Z is calculated it is translated into product demand using the following relation:

$$Z = (x - \mu)/\sigma$$

μ = mean
σ = standard deviation

Solving for x:

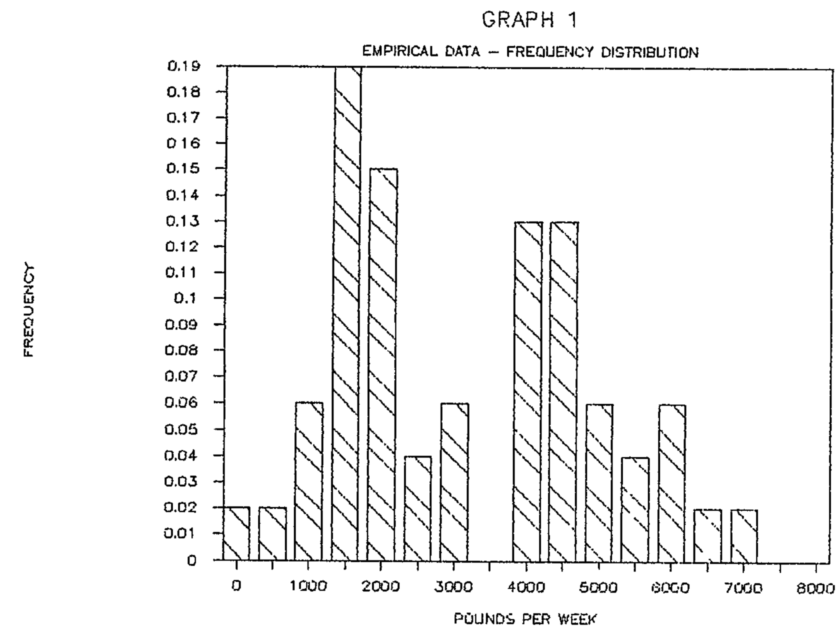
$$x = u + Z\sigma$$

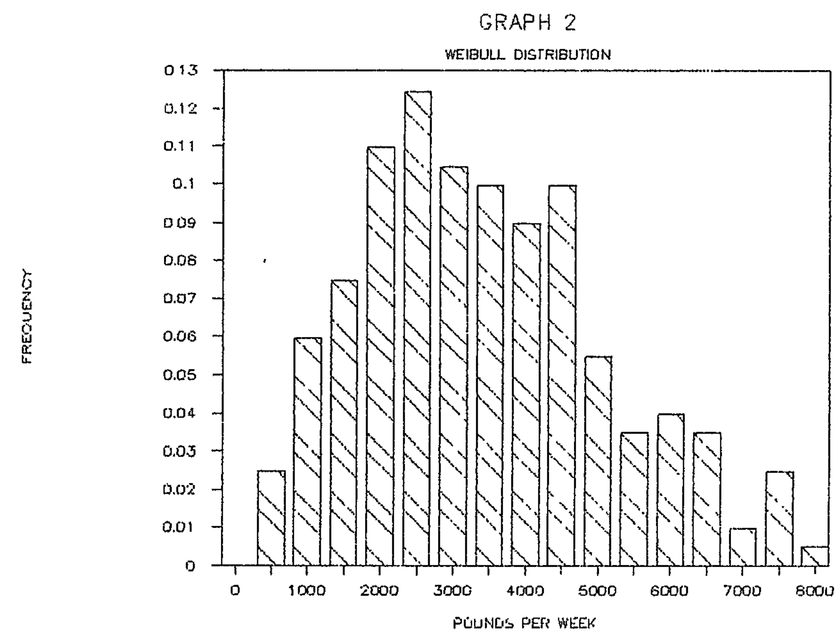
The values for mean and standard deviation are stipulated as part of the input to the simulation. Thus x represents demand, in terms of pounds per week, randomly generated from a Normal Distribution specified by inputted mean and standard deviation values.

5.2. The Weibull Distribution

Due to market forces, such as promotions and competitive position, demand history for some SKU's cannot be expressed as a Normal Distribution. Please note Graph 1 which represents empirical data obtained from a SKU distributed by Welch Foods though a forward refrigerated warehouse operation.

Clearly the frequency distribution of time series demand indicated in Graph 1 is not a Normal Distribution. It has a peculiar bimodal nature with a peak at 1500-2000 and another peak at 4000-5000. Giauque reports that the Weibull distribution with a scale


GRAPH 1
EMPIRICAL DATA – FREQUENCY DISTRIBUTION
FREQUENCY
0.19
0.18
0.17
0.16
0.15
0.14
0.13
0.12
0.11
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0
1000
2000
3000
4000
5000
6000
7000
8000
POUNDS PER WEEK


GRAPH 2
WEIBULL DISTRIBUTION
FREQUENCY
0.13
0.12
0.11
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0
1000
2000
3000
4000
5000
6000
7000
8000
POUNDS PER WEEK

parameter (defined as β) of 3620.00, a shape parameter (α) of 1.81391 and a location parameter (lp) of -41.6667 best fits the empirical data. Graph 2 is a frequency distribution of the Weibull with the above parameters.

The Weibull has a cumulative frequency distribution given by:

$$F(x) = 1 - \exp \quad -((x-lp/\beta)^{\alpha}$$

This is easily inverted to give:

$$x = \beta * (-\ln RN)^{(1/\alpha)} + lp$$

RN is a random number between zero and one, and x is the demand for this random draw. The appropriate spreadsheet cell entry value to give a random value for demand would be:

```
@MAX(0,+3620.00*
        (-@LN(@RAND))^(1/1.81391)-41.6667)
```

The @MAX truncates the demand distribution at zero to avoid a very slight chance of negative demand.

5.3. Spreadsheet Configuration

Columns 1 & 2 of Figure 2, which is a printout of sample spreadsheet simulation for a single SKU (Normal Distribution), represent U(1) and U(2). Column 3 represents the calculation of Z by a cell entry of the Log & Trig formula. Demand, which appears in column 6, is calculated by a cell formula that references the inputted Mean and Standard Deviation as well as the calculated Z value. In the case of the Weibull distribution, the cell formula for demand, listed in section 5.2, is entered in column 6. It should be noted that the demand appearing in the upper half of Figure 2 (SPLIT MONTH billing) matches the demand in the lower half of Figure 2 (ANNIVERSARY DATE billing). The common demand patterns were used so that fair comparison of the two billing systems can be made.

Now that probabilistic demand has been established, the flow of finished product through the warehouse on a weekly basis can be simulated by subtracting weekly demand from inventory to arrive at a balance. The balance is compared to the Re-Order Point. If the balance is less than the Re-Order Point, the Re-Order Quantity is added into the following week (leadtime = 1 week; constant for the entire 24 week period). A two week supply of inventory is assumed to begin the simulation (Week 1, Month A--Column 5). Symbolically, the above can be represented as:

Inv(n) - Demand(n) = Balance(n)

If Balance < Re-Order Point, then Re-Order Quantity + Inv(n+1)

IF Balance > R.P., then 0 + Inv(n+1)

n is equal to the first week of the simulation

The Re-Order Point (Figure 2, Column 8) is calculated using a standard safety stock formula which incorporates service level:

R.P. = (u)(t) + S.S.

R.P. = Re-Order Point
(u) = demand per week
(t) = leadtime
S.S. = Safety Stock = K * σ

Since the leadtime is one week, the first part of the above formula is equal to the average demand per week as inputted into the simulation. The amount of safety stock is dependent on the desired service level (Krupp, p. 35) which is also an inputted value.

As an example of the weekly replenishment cycle, in the upper half of Figure 2 the demand for week 1 of month A (19,179--Column 6) is subtracted from the beginning inventory (41,800--Column 5), equaling a balance (22,621--Column 7). Since the balance is less than the Re-Order Point (22,621--Column 7 is less than 31,150--Column 8), the Re-Order Quantity (41,800) is added to week 2 of month A (Column 5). In week 2 of month A the balance is greater than the Re-Order Point triggering a Re-Order Quantity of 0 (Column 9) to be added to the beginning inventory of week 3 of month A. The cycle continues for the 24 week period.

Costs per week are calculated based on the defined billing system stipulations. For SPLIT MONTH billing, upper half of Figure 2, handling is charged as finished product is moved into the warehouse (Column 10). Storage is also assessed when the product is moved into the warehouse (Column 11). If the product moves into the warehouse between the 1st and 15th of the month, a full month's storage is applied. If product enters the warehouse between the 15th and the 30th, 1/2 month's storage is charged. Product that remains in inventory at the begining of a new month is billed one month storage. Inbound and outbound charges are recorded as product moves in and out of the warehouse (Columns 13 & 14). Total cost and annual turn rate appear at the conclusion of the 24 week period.

ANNIVERSARY DATE billing is a slightly different situation. If finished product moves into the warehouse on the 15th of the month, billing for 1 month's storage applies to the following month on the 15th. Any inventory remaining past the 15th is rebilled for an additional months storage. Handling, Inbound & Outbound Transportation are calculated the same as the split month example.

Referring to the bottom half of Figure 2, product is charged one month storage (Column 11) as it moves into the warehouse. If the product does not turn from inventory in the course of a month, a rebill is charged equal to 1 months storage on the remaining quantity (column 12). The quantity to be rebilled is calculated by subtracting the most recent 4 weeks of demand from the inventory level recorded one month previous. If this calculation is negative, the product has turned from inventory. If it is positive, demand has not been high enough to turn the product from inventory in one months time and a rebill needs to be applied to the quantity remaining.

FIGURE 2

COLUMN #	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
				SPLIT MONTH BILLING						WAREHOUSE COSTS			TRANSPORTATION COSTS		
	U(1)	U(2)	Z	WEEK	INV	DEMAND	BALANCE	F.P.	QUANTITY	HANDLING	STORAGE		INBOUND	OUTBOUND	INVENTORY CARRYING COSTS
	0.8464	0.3516	-0.3441	1A	41800	19179	22621	31150	41800	$0	$0		$0	$0	$0
	0.0371	0.5941	-2.1303	2A	64421	10245	54175	31150	0	$0	$0		$0	$0	$0
	0.8692	0.8762	0.3772	3A	54175	22786	31389	31150	0	$0	$0		$0	$0	$0
	0.7966	0.6479	-0.4034	4A	31389	18683	12506	31150	41800	$0	$0		$0	$0	$0
	0.2237	0.0686	1.5722	1B	54306	28761	25545	31150	41800	$293	$384		$656	$1,021	$47
	0.0573	0.5825	-2.0774	2B	67345	10513	56832	31150	0	$0	$0		$0	$373	$58
	0.0721	0.5580	-2.1427	3B	56832	10186	46645	31150	0	$0	$0		$0	$362	$49
	0.0889	0.9883	2.1941	4B	46645	31870	14775	31150	41800	$293	$84		$656	$1,131	$40
	*	*	*	*	*	*	*	*	*	*	*		*	*	*
	*	*	*	*	*	*	*	*	*	*	*		*	*	*
	0.4951	0.4965	-1.1855	4F	62041	14973	48068	31150	0	$0	$0		$0	$532	$55
				TOTAL		495332 LBS			501600 LBS	$2,926	$1,447		$6,563	$15,060	$916

TOTAL COST FOR 3 MONTH SIMULATION $26,912
****

TURNS PER YEAR 19.2
***

COLUMN #	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
				ANNIVERSARY MONTH BILLING						WAREHOUSE COSTS			TRANSPORTATION COSTS		
				WEEK	INV	DEMAND	BALANCE	R.P.	QUANTITY	HANDLING	STORAGE	REBILL	INBOUND	OUTBOUND	INVENTORY CARRYING COSTS
				1A	41800	19179	22621	31150	41800	$0	$0		$0	$0	$0
				2A	64421	10246	54175	31150	0	$0	$0		$0	$0	$0
				3A	54175	22786	31389	31150	0	$0	$0		$0	$0	$0
				4A	31339	18883	12506	31150	41800	$0	$0		$0	$0	$0
				1B	54306	28761	25545	31150	41800	$293	$167		$656	$1,021	$47
				2B	67345	10513	56832	31150	0	$0	$0		$0	$373	$58
				3B	56832	10186	46645	31150	0	$0	$0		$0	$362	$49
				4B	46645	31870	14775	31150	41800	$293	$167		$656	$1,131	$40
				*	*	*	*	*	*	*	*		*	*	*
				*	*	*	*	*	*	*	*		*	*	*
				4F	63041	14973	48068	31150	0	$0	$0	$0	$0	$532	$55
				TOTAL		495332 LBS			501600 LBS	$2,926	$1,672	$72	$6,563	$15,060	$916

TOTAL COST FOR 3 MONTH SIMULATION $27,229
****

TURNS PER YEAR 19.2
***

MONTH = A,B,C,D,E,F
WEEK = 1,2,3,4
* MONTHS C,D,E ARE ABRIDGED
NOTE: UNLESS OTHERWISE STATED, ALL VALUES ARE IN POUNDS/WEEK.

Column 15 contains the calculation of Inventory Carrying Costs. The formula employed is:

$$ICC = CC \times CP \times IL$$

CC = Carrying Cost
CP = Cost per Pound
IL = Inventory Level

Both Carrying Cost and Cost Per Pound are inputted values. Inventory Level is referenced from Column 5 and represents the beginning of the week inventory for each of the 24 weeks included in the simulation.

Even though the duration of the simulation is 24 weeks, distribution costs are not calculated for the first four weeks of data (Month A). This is to allow the simulation to achieve a steady state inventory condition before costs are assessed. Distortions resulting from costs calculated early in the simulation are avoided.

For each of the five SKU's, a simulation, as pictured in Figure 2, was programmed into a single spreadsheet. The simulation was run ten times for each SKU with the help of Symphony command language. Results of the ten simulation runs per SKU are captured and recorded automatically. An average system cost for each billing type is calculated from the ten runs and serves as the primary basis of comparison.

As a check of simulation validity, a one tailed t-test was performed on two successive independent sample means of ten simulation runs to determine if the means were statistically equal. The test results indicate that the two means were equal ($\alpha =$ .05). This demonstrates that the output of the simulation, under identical parameter settings, can be duplicated in successive runs with a high statistical confidence level.

ACKNOWLEDGMENTS

The author would like to thank Dr. Giauque of Brigham Young University and Dr. Kliorys & Dr. Wellington of Gannon University for their comments and helpful suggestions. In addition the author would like to thank Welch Foods, Inc. for cooperation and support of this paper.

REFERENCES

The American Production and Inventory Control Society, Falls Church, VA.

Giauque, William C., Graduate School of Management, Brigham Young University.

Mihram, G., Arther, SIMULATION: STATISTICAL FOUNDATIONS AND METHODOLOGY, Academic Press, Inc (1972).

Krupp, James, A., EFFECTIVE SAFETY STOCK PLANNING, Production and Inventory Management, Vol 23, Number 3.

AUTHOR'S BIOGRAPHY

EDMUND W. SCHUSTER is an Inventory Analyst at Welch Foods, located in Westfield, New York. He has a B.S. in Food Technology from The Ohio State University and a Masters of Public Administration from Gannon University. An active member of The American Production and Inventory Control Society, Ed serves on the Process Industry Steering Committee and as Executive Vice President of the Erie, Pennsylvania Chapter. Ed's research interests include decision support systems and modeling production & inventory control systems.

Edmund W. Schuster
Welch Foods, Inc
2 South Portage Street
Westfield, New York 14787
(716) 326-5188