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ANALYSIS OF LOW DEMAND ITEMS,(U)
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by

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USAF Procurement Research Office Project 75-11

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INTRODUCTION

At the start of the Spring semester of 1974-75, the cadets in Management 462, a Systems Analysis course, were required to accomplish a term project. The thrust of the project was to work on a real-life problem rather than an artificially contrived one. Teams of four to five cadets were formed. This particular team worked with Air Force Logistics Command (AFLC) in studying a more efficient way to manage low demand items in the inventories of the Air Logistics Centers (ALC). The Air Force Logistics Command has five ALC's. Each of these centers manages an enormous inventory and is tasked with supporting the Air Force's operational equipment in a geographic area. Furthermore, demands on their inventories are made from outside of the Air Force as well.

The U.S. has entered into many military treaties around the globe. In the course of these treaties, the U.S. has given away many billions of dollars worth of military equipment. The recipient nations of this equipment seldom have the means to repair and maintain it, and thus, the U.S. is expected to come to their aid. This support usually comes in the form of a request to an ALC inventory of a part that has not been used by the operational Air Force in twenty years. For example, many South American countries still fly

B-25's, and parts for these planes must still be kept in stock. These requests for outdated equipment obviously greatly compound the problems that AFLC has to work with. Hopefully, we have given the manager of these items a few small tools in coping with one of the biggest stocking headaches they have, the low demand item.

THE SYSTEMS ANALYSIS TECHNIQUE

In the systems analysis technique of problem analysis and solution there are, essentially, three problems which much be considered. These are the "problem as given", the "problem as understood", and the "problem to be solved".. In our case, the "problem as given" was to provide to the Air Logistics Centers a more efficient method of predicting the demand for low demand items.

Presently, these centers use an eight quarter moving average to predict ninth quarter demand. This, of course, led us to our "problem(s) as understood". Before beginning any type of prediction analysis, we would have to define what the term "low-demand item" meant to us as analysts. Having agreed on this definition, and further using available data, our next step would be to find a way to more accurately predict the ninth quarter demand of these low demand items.

Knowing the type of data available and its possible limitations, we agreed to what we perceived as our "problem to be solved". First, we would define a low demand item based on eight quarters of demand history recorded on a computer tape. Second, we would determine through data graphs and research into past work in this area which probability distribution would most accurately predict the occurrence of demand for these low demand items. A clearer look at exactly how we perceived our problem is given in the next section.

THE PROBLEM

Given the basic problem area of working with low demand items (LDI) in inventories of AFLC, we felt we should address this problem on two fronts initially. First, we read every research report and paper we could obtain on the subject of managing LDI. Luckily, we found a wealth of information in this area. Many reports were published on this subject by the RAND Corporation and other private as well as DOD agencies. The second area of study we undertook was that of the AFLC itself and the present methods they employ in stocking their inventories.

Out of this research two points surfaced. First, we found that the nonrepairable item requirements system was very complex. It is a complicated system which includes such variables as production lead time, administrative lead time, a predicted demand for the future, and many other factors. This predicted demand for the future is obtained by summing a history of eight previous quarters on an item and then dividing by eight to get an average. This average is the predicted value for the ninth quarter.

The second point that came to our attention out of our initial research was that the value obtained from the requirement system is not the driving factor in the amount of items that is usually purchased. Ideally, the requirement system yields an optimum number which should be purchased by the Item Manager (an individual in charge of a number of items in the inventory). This number, however, is seldom followed for LDI. The reason for this is that for LDI the requirement system will give a very low number to purchase. This number is usually too small for the manufacturer to economically bid on. For example, if the requirement system states that nine bolts should be procured for a B-25, the item manager may find that the manufacturer will not produce less than 1000. Only this larger number will bring the factory owner a profit! Thus the driving factor in the number of items procured is usually the amount the manufacturer is willing to produce and not the output of an economic order quantity (EOQ) formula.

With these two facts in mind, we defined the problem. The one factor in the requirements system where we felt we could make a significant improvement was in predicting demand. The present method of simply averaging eight quarters of information to get a ninth quarter of predicted demand appears to be a very simplistic approach. We felt there was a better prediction technique. Thus, we narrowed the problem to working with only one input of the requirements system, that of predicting demand for low demand items.

Once we decided on the problem, we subdivided this problem into four tasks that were to be accomplished. These tasks were as follows. First, we felt it was necessary to quantitatively define what was meant by a low demand item. Second, once this definition was obtained, we needed to analyze exactly what the low demand was. Hopefully, these items would fall into some sort of a frequency distribution. Third, we needed to develop a new prediction technique for low demand items. In order to show that we would be predicting demand better than the present method, we would also need to develop a measuring device to test which prediction technique was actually better. Fourth, we then have to give this new prediction technique to the Item Manager in some form he can readily use.

In summary, the rest of the report will be a breakdown of each of these four tasks. They were accomplished in an ALGOL computer program. Fortunately, in this program we had a computer tape which had 5000 randomly picked items which contained sixteen quarters of past history, the cost, stock number and other information on each of these items. (There were no new items in this sample). It would have been impossible to accomplish this program without this data.

PART 1: DEFINING A LOW DEMAND ITEM

In managing LDI it was obvious we needed a quantitative definition of what a LDI was. We felt we could arbitrarily pick a value such as 2 or 3 demands per month or less and not really worry where the line was actually drawn. This was apparently done in some of the studies we had read. The important point to remember is not where you draw the cut-off line, but to have some way to distinguish whether an item is low demand or not.

We chose to find a mean rate of the 5000 data items over eight quarters and put these rates into various levels of a histogram. The results are illustrated in Figure 1. Each level of the histogram was a breakdown of demand per month. The first level was the number of items with 0 to 1 demands per month, the second level of the histogram was from 1 to 2 demands, and so on. The final level of the histogram shows all items with 10 or more demands per month.

Clearly, as shown in Figure 1, there was a demand break present between the first and the second level of the histogram. Therefore, we decided to define LDI as those items that fell into the first level of the histogram. More precisely, a LDI was any item that had an eight quarter history of less than one demand per month or less that three demands per

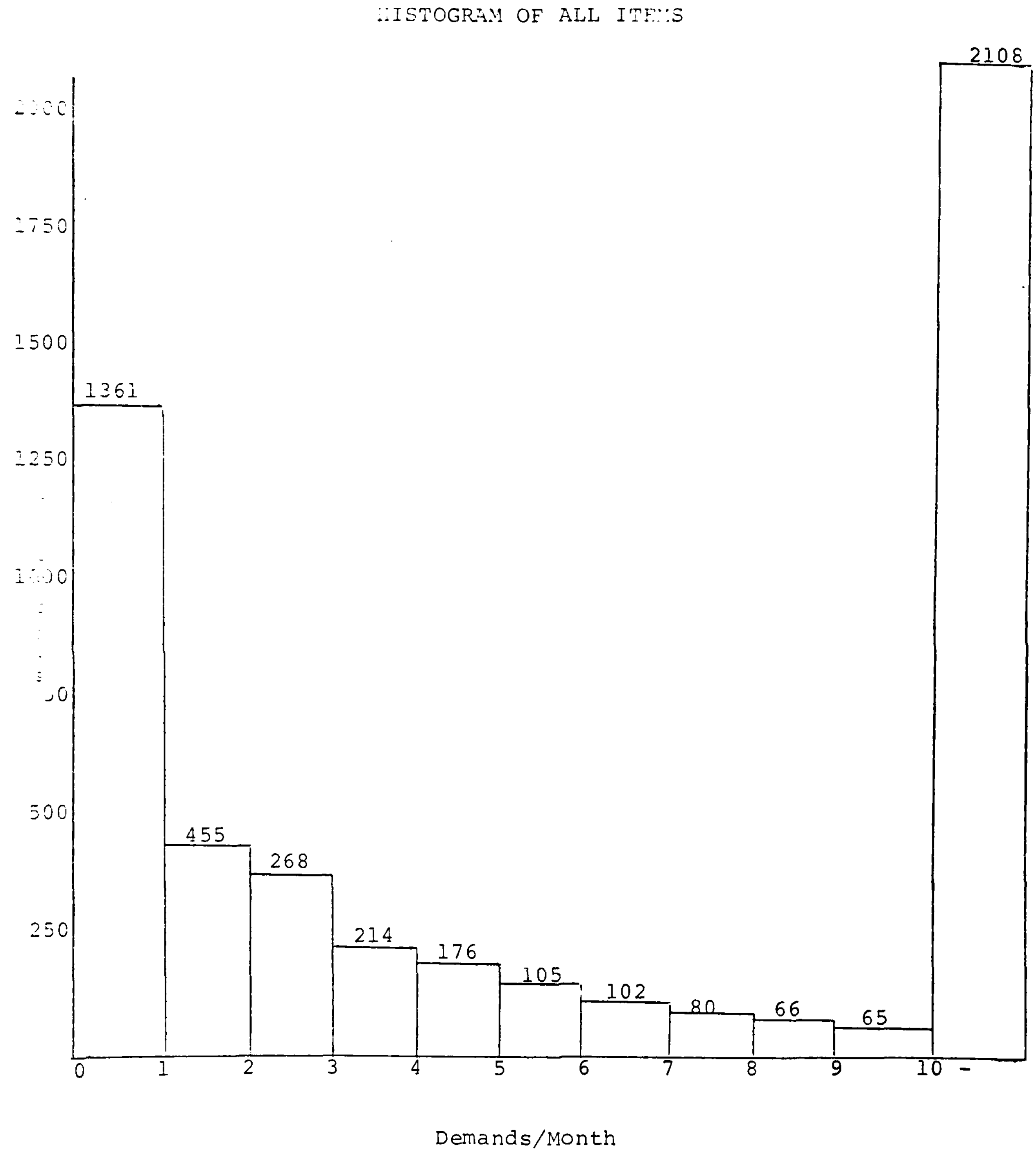

HISTOGRAM OF ALL ITEMS
2108
1750
1500
1361
1250
500
455
268
250
214
176
105
102
80
66
65
0
1
2
3
4
5
6
7
8
9
10 -
Demands/Month

FIGURE 1

quarter. With this as a starting point, we were able to work with low demand items in earnest.

PART 2: ANALYSIS OF LOW DEMAND ITEMS

For the 5000 item sample in the inventory of the Air Logistics Center, we found that 1361 of these items fell into the category of zero to one demand per month. We took these items and further broke them down in increments of .2 demands per month (Figure 2). Of course, since this was not a random sampling of the items, but rather a histogram of the 1361 low demand item population, we could draw no valid conclusion concerning the possible distributions which these items might have followed.

Our next concern was what value in percent of total cost these low demand items represented. Our computer run stated that these items represented 20.6% of the value of the total population. We considered this to be a substantial portion of the total cost. In number of items, our low demand items accounted for 27.2% of the total number of items on the data tape. Over one quarter of the items in the total population fit into our definition of low demand items. These numbers are illustrated in Figure 3.

There were various factors which had to be considered in the choice of a distribution which we believed could most accurately predict future demand of low demand items. The demand for these items was, historically, very erratic and

HISTOGRAM OF ONLY LOW DEMAND ITEMS

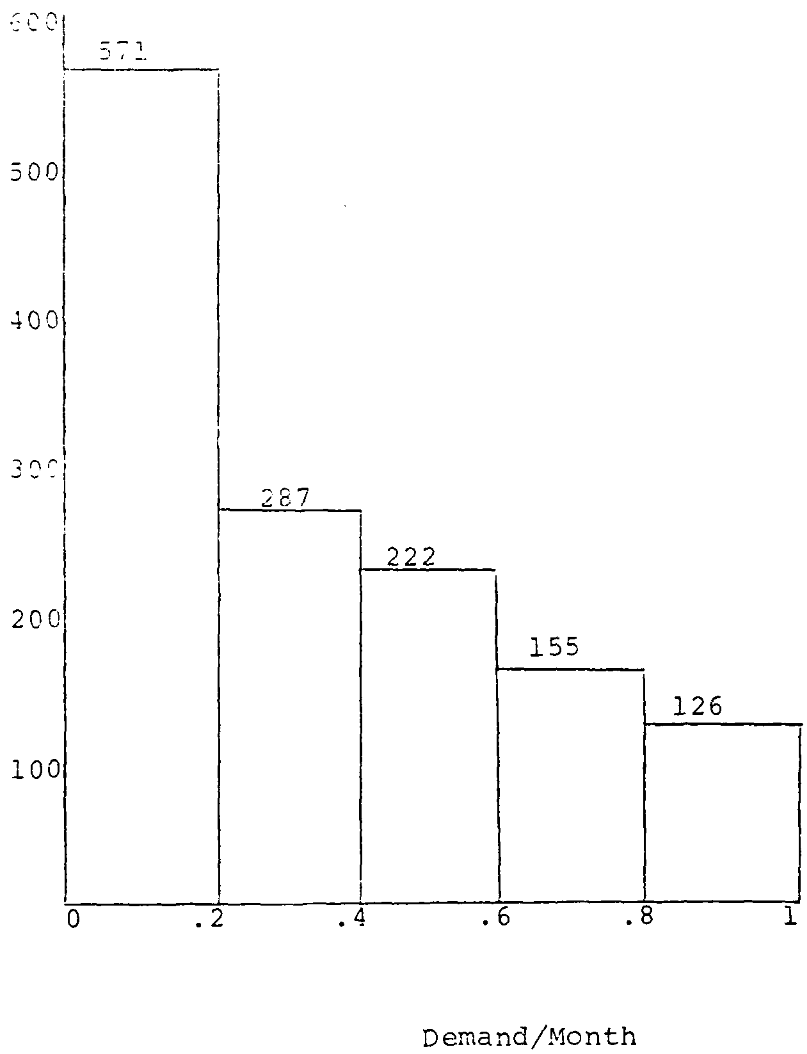
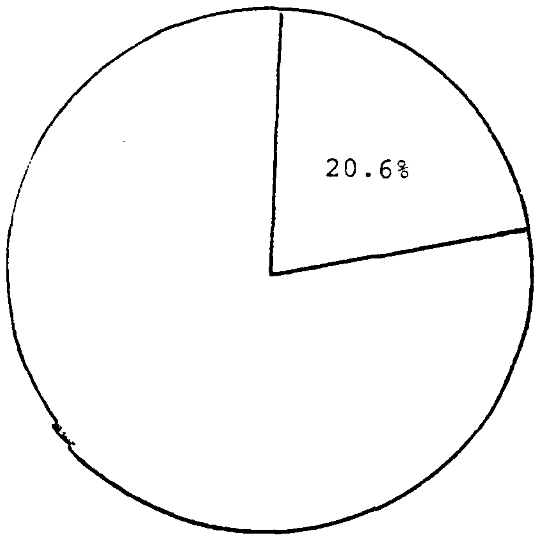


FIGURE 2

Total $ Value of Low Demand Items

(LDI Cost/Total Cost of Items)



Total % of Low Demand Items

(No. of LDI's/Total No. of Items Examined) = 1361/5000

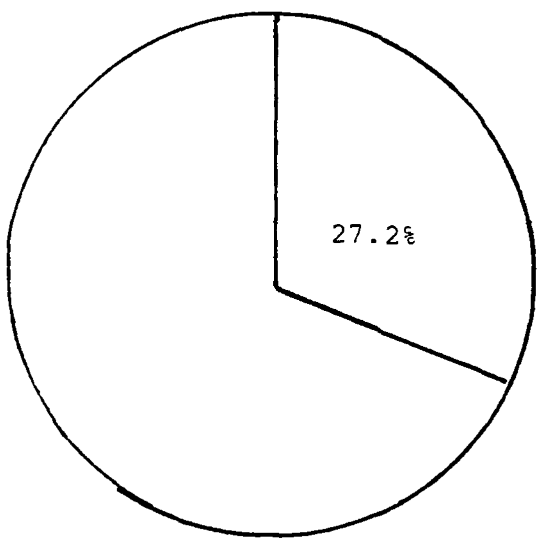


FIGURE 3

in some cases very rare. These two factors alone would have been enough to lead us to examine the Poisson distribution as a possible predictor. Also, almost all of our preliminary research pointed toward the Poisson distribution, as it is very often used to predict rare events.

The equation which we used for the Poisson is as follows: $P(x=n) = \frac{e^{-\lambda}(\lambda)^n}{n!}$; where "n" is the number of demands predicted for the ninth quarter given eight quarters of demand history.

It became evident to us in our analysis that "n" would have to take on values between zero and one in our program. Thus, the factorial in the denominator of the Poisson equation could have presented a problem. To remedy this situation, we used a factorial approximation knows as Sterling's Formula. The equation for it is the following: $n! = n^n e^{-n} \sqrt{2\pi n}$ This proved to ba an effective approximation in our computer analysis.

PART 3: THE SIMULATION

This was the most important part of the program. Having defined and analyzed LDI we were ready to use a Poisson distribution to predict low demand. This, we felt, would be more accurate than the present eight quarter moving average the system presently employs.

In order to measure which prediction technique was more effective we had to develop a thermometer or measuring device to test both the status quo and the Poisson. This thermometer took two forms: First, a total percent miss, high or low; and second, a total percent miss, high or low, times cost. Let's examine the latter first.

It would be best to follow along Figure 4, as this is being discussed. In using the status quo prediction technique we added eight quarters of data, then divided by eight to get the prediction. The actual demand was simply the next or ninth quarter. We subtracted the actual from the predicted value to get a miss difference. Then we separated our low and high predictions to get two separate values. The difference was divided in both cases by the predicted value to give us a percent miss. This percent high or low miss was then multiplied by cost to give a percent cost high or low miss factor. This factor was then incremented by each

STATUS QUO-EXAMPLE CALCULATIONS

Actual Steps Used In Getting Calculated Values

$\sum_{1}^{8}$ Qtrs of Data/8 = Prediction

Actual Demand = 9th Qtr of Data

START: Miss Difference = Predicted - Actual Demand

If Miss Diff. > 0 Then go to High

Percent Miss Low = Miss Diff./Predicted

Percent Miss Low Cost = Percent Miss Low * Cost of Item

HIGH: Same Four Calculations Only Stored In Different Variables.

FIGURE 4

new LDI.[1]

As can be seen in the first histogram, we had 1361 out of 5000 LDI on our tape. But instead of using only the first eight quarters on our tape for each LDI we slid the prediction over a period of one year. In other words, for the first prediction we used quarters one through eight for a prediction with actual demand being quarter nine. Then we slid everything one quarter using quarters two through nine for the prediction and quarter ten as the actual demand. In this way we followed each LDI for one year and received four values from it.

The Poisson miss high and low factors were done almost exactly the same. Here the reader should follow along Figure 5. We used the formula: $P[X=x] = (e^{-x})(\lambda^{x})/x!$, however to get our predicted value. Lambda (λ) was obtained by averaging eight quarters worth of information. We also slid these eight quarters over a year for LDI. Little "x" was our prediction value. But notice this formula yields probability of X being "x". Thus we stepped through different

---

[1]This $\Sigma \left(\frac{\text{Predicted-Actual}}{\text{Predicted}}\right)$ cost might well be a faulty use of a ratio since the absolute values are lost. Using the median of the distribution appears to be more valid rather than the mode. ed.

POISSON-EXAMPLE CALCULATIONS

Sample Data on an Item

Demands/Quarter

/DATA/---/---/---/---/---/---/---/---/---/---/---/---/

~~1 2 3 4 5 6 7 8 9 10 11 12~~

Poisson Formula: $P\ [X=x] = \dfrac{e^{-\lambda}\ \lambda^{x}}{X!}$

Lambda (λ) $= \sum_{1}^{8}$ Quarters of Data/8

Variable x x = Our predicted value (ranges from .2, .4, →3)

Probabilities)(X=x) = yields a probability, not a value for x

X	x
Probability	.2
"	.4
"	
"	↓
"	
"	3

- The highest probability associated with little x is our predicted value!!!
- Actual demand obtained by looking at next quarters' demand.
- From this point on you can go to START to get the rest of the calculated values.

NOTE: x! of .2, .4, etc. approximated by Sterling's formula.

FIGURE 5

"x" values at increments of .2 from .2 to 3. This yielded 15 probabilities. The highest probability associated with x was our predicted value! From this point on the rest of calculating the actual value and the high and low miss cost values were exactly the same as for the status quo.

Two more points should be mentioned. First, when we were incrementing "x" by .2 to get 15 values (.2, .4, .6, etc. to 3) notice that "x" in the Poisson formula is in the form x factorial. In order to estimate the factoral of a fraction we used Sterling's formula which is: $n!=n^n e^{-n} 2\pi n$. The second point that should be made is that "x" was incremented up to 3 since this is the highest number of demands an LDI may have in one quarter. Remember LDI is defined as any item with a past eight quarter history of one demand per month or less, or three demands per quarter or less.

The second yardstick we used was similar to the first except it added only a high and low percent miss. It did not multiply this value to the cost of the item. Where we stopped to get this figure is clearly marked on Figure 4.[2]

Advisor Comment: Normally in a Poisson distribution, lambda will also be the value of the "x" with the highest probability if lambda is an integer. Therefore, there should be no difference between the forecasted value of the Poisson and the moving average since lambda is the moving average. However,

---

[2] This measure of effectiveness $[\Sigma(\frac{\text{Predicted-Actual}}{\text{Predicted}})]$ ignores differences in the cost of items, presenting a serious question as to the meaningfulness of such a measure. ed.

SUMMARY OF SIMULATION

	Variables	High	Low	Total
STATUS QUO	Total % Miss With Cost Over 8 Quarters	2.0832×10^5	8.3798×10^4	2.9212×10^5
STATUS QUO	Total % Miss Without Cost Over 8 Quarters	5.9250×10^2	3.9133×10^2	9.8383×10^2
STATUS QUO	Total % Miss With Cost Over 4 Quarters	5.4038×10^2	3.8155×10^5	3.8209×10^5
POISSON	Total % Miss With Cost Over 8 Quarters	6.4476×10^4	5.8890×10^4	1.2336×10^5
POISSON	Total % Miss Without Cost Over 8 Quarters	2.3050×10^2	2.2915×10^2	4.5966×10^2

FIGURE 6

the researchers found a significant difference particularly on the high side. This disparity is probably caused by a combination of two factors. First, as the researchers note, the Sterling's formula is only an approximation. Second, when lambda is not an integer--as would normally be true in this case--the highest probability will occur somewhere between λ-1 and λ. Since the lambda's in this project are never greater than 3, this characteristic exerts a strong downward bias on the data. Therefore, results of this simulation should be viewed with skepticism.

However, other researchers[3] have found that the Poisson distribution does describe the demand patterns of low demand items. Therefore, the conclusions of this report are probably correct.

---

[3]Guthoehrlein, R.A. and Faiola, R.A., "Inventory Levels for Low Demand Items"., Research Report of the Navy Fleet Materiel Support Office, 1971, and

Hadley, G., "A Model for Procurement, Allocation, and Redistribution for Low Demand Items", Naval Research Logistics Quarterly, December 1961.

PART 4: TABLE FOR THE ITEM MANAGER

We have now shown that the Poisson formula is a better predictor of demand than the present eight quarter moving average. We must now use this prediction technique to improve the present procurement process. This can be done in two ways.

First, as a predictor of the next quarter's demand for an item it can be used as an input to the requirements system rather than the old predictor of a moving average. You may recall we found that the output of the EOQ formula was seldom used as a number of items purchased since this low number was seldom economically profitable to the manufacturer. Nevertheless, a more accurate value being inputted to the requirements system should improve the output of the formula when it is used.

The second area where the Poisson prediction technique could help the Item Manager is by giving him information directly. This could be done by giving the Item Manager a table that breaks down by quarter, for the next eight quarters, the probability that the present assets on hand will fulfill future demands. An illustration of this table is given in Figure 7. In short, at the top of the table is given the item (by stock number) and the present number of units in the inventory (i.e. assets). On the left hand side of the

TABLE FOR ITEM MANAGER

Stock Number	Assets = some number
Future Quarters (1 - 8)	Probability Assets Demanded
1	.004
2	.01
3	.25
4	.4
5	.6
6	.72
7	.84
8	.96
	(fictitious probabilities)

FIGURE 7

margin are the numbers one through eight which stand for the future quarters and on the right hand side are the probabilities associated with stockouts of that item given the assets on hand at some future time frame. The formula used to predict these values was a variation of the Poisson given as: $P[X=x] = \frac{e^{-\lambda t}(\lambda t)^x}{x!}$. The only new variable "t", obviously stands for the time increment you wish to insert into the formula.

In summary, these two applications of our Poisson predictor should aid the Item Manager in stocking his inventories. The second approach, that of a table of future stockout possibilities, should be especially helpful in giving the Item Manager valuable new information in managing the low demand item.

BIBLIOGRAPHY

Lapin, Lawrence L., Statistics for Modern Business Decisions. New York: Harcourt Brace Jovanovich, Inc. 1973.

Rudwich, Barnard H., Systems Analysis for Effective Planning: Principles and Cases. New York: John Wiley & Sons, Inc. 1969.

Standard Mathematical Tables. Cleveland: The Chemical Rubber Co. 1970.

APPENDIX

COMPUTER PROGRAM

PART-1 DEFINING A LOW DEMAND ITEM

```
THIS IS THE 1  LEVEL OF THE HISTOGRAM 126[illegible]
THIS IS THE 2  LEVEL OF THE HISTOGRAM  455
THIS IS THE 3  LEVEL OF THE HISTOGRAM  24[illegible]
THIS IS THE 4  LEVEL OF THE HISTOGRAM  2[illegible]
THIS IS THE 5  LEVEL OF THE HISTOGRAM  17[illegible]
THIS IS THE 6  LEVEL OF THE HISTOGRAM  10[illegible]
THIS IS THE 7  LEVEL OF THE HISTOGRAM  10[illegible]
THIS IS THE 8  LEVEL OF THE HISTOGRAM   [illegible]
THIS IS THE 9  LEVEL OF THE HISTOGRAM   [illegible]
THIS IS THE10  LEVEL OF THE HISTOGRAM   65
THIS IS THE11  LEVEL OF THE HISTOGRAM 210[illegible]
```

PART-2 ANAYSIS OF LOW DEMAND ITEMS

THIS HISTOGRAM ONLY BREAKS DOWN LOT

```
THIS IS THE 0  LEVEL OF THE HISTOGRAM  57[illegible]
THIS IS THE 1  LEVEL OF THE HISTOGRAM  28[illegible]
THIS IS THE 2  LEVEL OF THE HISTOGRAM  2[illegible]
THIS IS THE 3  LEVEL OF THE HISTOGRAM  155
THIS IS THE 4  LEVEL OF THE HISTOGRAM  1[illegible]
```

THE TOTAL PERCENT VALUE OF DEMAN IS 0.20[illegible]

THE TOTAL PERCENT OF LOW DEMAND IS 0.27[illegible]

PART-3 THE SIMULATION

****** STATUS QUO ******

TOTAL PERCENT HIGH AND LOW MISS COST FACTORS OVER 8 QTRS

HIGH-MISS 2.08318E 05
LOW MISS 8.37982E 04

TOTAL PERCENT HIGH AND LOW MISS FACTORS WITHOUT COST OVER 8 QTRS

HIGH-MISS 5.92500E 02
LOW MISS 3.91333E 02

TOTAL PERCENT HIGH AND LOW MISS COST FACTOR OVER 4 QTRS

HIGH-MISS 5.40380E 02
LOW MISS 3.81553E 05

****** POISSON ******

TOTAL PERCENT HIGH AND LOW MISS COST FACTORS OVER 8 QTRS

HIGH-MISS 6.44761E 04
LOW MISS 5.[illegible] 04

TOTAL PERCENT HIGH AND LOW MISS FACTORS WITHOUT COST OVER 8 QTRS

HIGH-MISS 2.30500E 0[illegible]
LOW MISS 2.2915[illegible]

PART-4 TABLE FOR THE ITEM MANAGER

FUTURE QUARTERS(1-8)	PROBABILITY ASSETS DEMANDED
1	0.0000
2	0.0004
3	0.0017
4	0.0047
5	0.0102
6	0.0187
7	0.0305
8	0.0460