PRODUCTION LEAD TIME FORECASTING

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FINAL REPORT
JANUARY 1972

BY
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INSTITUTE FOR LOGISTICS RESEARCH

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Fort Lee, Virginia

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13. ABSTRACT

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The study covers analysis of the performance of the present method for estimating lead times and an attempt to formulate improved methodology based on relationships existing between lead times and variables readily available to the item manager.

It was found that the present methodology results in considerable forecast error. Stepwise regression was then used to develop modifications to the present methodology that gave better forecasts, but significant forecast error remains.

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TABLE OF CONTENTS

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The study covers analysis of the performance of the present method for estimating lead times and an attempt to formulate an improved methodology based on relationships existing between lead times and variables readily available to the item manager.

It was found that the present methodology results in considerable forecast error. Stepwise regression was then used to develop modifications to the present methodology that gave better forecasts, but significant forecast error remains.

ACKNOWLEDGEMENT

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A number of IRO personnel were of assistance to the author in accomplishing this work. This would include Alan Kaplan, Martin Cohen and Bruce Kirkpatrick.

SUMMARY

1. Problem and Background

Methodology now being used by Army National Inventory Control Points for computation of variable (statistical) safety levels assumes that the length of the Production Lead Time is known and that only the variability of demand within this time need be considered in the Variable Safety Level computation. This assumption was questioned, however, when the ALPHA system was under development so the Inventory Research Office undertook this study to determine the validity of the assumption and, if invalid, to develop improved forecasting methodology.

2. Purpose & Objectives

a. Part I of Study

(1) Examine presently used techniques of forecasting Production Lead Time (PLT).

(2) Statistically determine forecast error of present system.

b. Part II of Study

(1) Develop, if possible, a new method of forecasting PLT that would give better accuracy.

3. Scope and Methods

a. Part I of Study

Computer records of the U.S. Army Aviation Systems Command containing the actual time till first significant delivery and the deviation (+ or -) of this time from the forecast PLT were used as the basic raw data. Statistical analysis was done of these transactions to determine if these deviations were significant enough to warrant further study.

b. <u>Part II of Study</u>

Since Part I showed large forecast errors, several alternative forecasting models were formulated and then tested on the same data, using stepwise regression techniques. An important constraint on this study was that only models incorporating easily available data were considered, since feasibility of implementation was of paramount interest.

4. <u>Findings</u>

a. <u>Part I of Study</u>

The presently used method of forecasting production lead time is to average, by FSN, lead times experienced in the past. A <u>statistical</u> bias of 25.5 days was observed; i.e., the average estimate of lead time was 25.5 days less than the average lead time actually experienced for the contracts included in the sample data. This by itself is not significant. (See Section 3.7).

Of significance is that even after the estimates were corrected for bias, average error was <u>87</u> days. What this means is that the difference between estimate and actual varied greatly from contract to contract with the estimate sometimes being much larger than actual, and sometimes much smaller. If the differences between actual and estimate are averaged, without regard to whether the cause was a low estimate or a high estimate, the average difference is 87 days.

Standard deviation of error was 122.6 days. The distribution of error, excluding outliers, was plotted and was close to the Normal distribution in appearance.

b. Part II of Study

A new method of forecasting PLT that gives significantly better forecast accuracy was found. This method

(1) supplements the completed procurement data available for a given FSN with available currently completed procurement data for other items in the catalog.

(2) stratifies the data into procurement method (PM) codes.

(3) uses stepwise regression technique to determine how the FSN data and the catalog data are to be weighted to give the best forecast of the PLT for the FSN. This is done for each PM code grouping of the data and for all data ungrouped.

(4) uses the results of step (3) for one of the PM groupings in projecting PLT when the type of contract is known in advance. Uses the ungrouped results of step (3) above to project PLT when there is no prior knowledge about the type of contract.

The models developed require annual updating. A program for monitoring forecast accuracy and providing input to the model update program could be incorporated in ALPHA. The model update program already exists and could be run off-line.

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CHAPTER I

DATA SOURCE AND BASIC ANALYSES

1.1 Source

The data base used in this study was originally in the form of magnetic tapes from U.S. Army Aviation Systems Command Master Data Record containing sector 0 (fixed sector) and sector 07 on all items in procurement at a particular point in time (April 19, 1970).

1.2 Contents

The pertinent fixed sector data includes FSN, Procurement Lead Time Estimate and Standard Unit Price. Procurement Lead Time Estimate (PROLT) is the total of Estimated Production Lead Time (ELT), Estimated Delivery Lead Time and Estimated Administrative Lead Time. Standard estimates are used for administrative lead time (90 days)* and delivery lead time (30 days) making ELT = PROLT - 120.

Sector 07 contains data on orders currently in the procurement process; data includes size of order, and actual delivery dates. Completed contracts are dropped from sector 07. However, at any given time, sector 07 will contain multi-delivery contracts waiting for completion of delivery schedules; it also can contain single delivery contracts which have been completed but which are waiting for update to sector 09 of the AVSCOM FSN Master Data Record. In both cases, actual production lead times can be computed; for multiple delivery contracts production lead time is defined as time till first significant delivery. The data base reflects a high proportion of high dollar (HDV) items, for which multiple deliveries are used.

*After this work was completed, it was brought to light by Mr. W. Higgins, USAMC Headquarters, that there is an error in this statement. The error and its impact on our results are discussed in Section 3.7.

Complete historical data found in Sector 09 was not used in this study because it was impossible to examine the error of estimate on each past procurement. Since the estimated Production Lead Time is continually updated, we were unable to determine what the estimates corresponding to past procurements were. Even using the data in Sector 07 did not completely avoid this problem as the estimate in the Fixed Header is updated as soon as a delivery date is computed, except for items bought sole source. This indicates that the conclusions made in this report may be understated, with errors larger than reported, and the value of models to supplement past experience would thus be more important.

An extract program was written to create an easily accessible data base. The resulting data base includes 145 different FSC groups with a total sample size of 2039 procurement actions.

1.3 Analysis

a. Basic data analysis consisted of computing various statistics on actual production lead times, estimated production lead times, and variables readily accessible to an item manager (e.g. standard unit price). The statistical results of this analysis are shown in the first column (total sample column) of Table 1 with the variable designated as follows:

PLT = Actual Production Lead Time

ELT = Estimated Production Lead Time

SUP = Standard Unit Price

QTY = Quantity of Order

EXT = SUP x QTY, that is extended price of order, a measure of economic importance of order.

VARLOG = Logarithm of whatever variable is specified, e.g., SUPLOG.

For the total sample column in Table 1 note the high variability of PLT, and the low correlations with PLT for all variables but ELT.

b. In an attempt to find indications of underlying relationships, possibly non-linear in nature, scatter diagrams were plotted, first of PLT vs ELT (figure 1), then of PLT vs the logarithms of Standard Unit Price, Quantity of contract, and Extended Price of contract (figure 2-4). As can be seen, all plots exhibit a high degree of scatter, but figure 1 shows the least scatter of all. This is consistent with the correlation statistics shown in the first column of Table 1.

1.4 Stratification Analysis

Further analysis was done in an effort to find an explanation for the high variability in the data by stratifying the data base by procurement method. The contracts in the data base were classified as follows:

Procurement Method Code 1: Already Competitive
2: 1st Time Competitive
3: Already Direct Purchase Mftr.
4: 1st Time Direct Purchase Mftr.
5: Non-Competitive (Sole Source)

The same statistical analysis as described in Section 1.3(a) was done on each of the five groups. These results are also shown in Table 1. Again we noted poor correlations and high variability of PLT, but it is easy to see that the five groups are different in the range of variability. PM Code 5 (sole source) exhibits the most variable behavior.

Of particular importance are the sizeable differences in average PLT between PM Codes 1, 2, 4 vs PM Code 3 vs PM Code 5.

CHAPTER II

PRESENT FORECASTING TECHNIQUES

2.1 Computation of ELT

Estimated Production Lead Time (ELT) is computed by AVSCOM as an average of past experienced lead times on contracts for the same item.* Contracts completed more than 2 years past are excluded from the average, and generally provisioning buys and expedited deliveries are excluded. For multiple delivery contracts, estimates are based on time till first (non-expedited) delivery. For other than sole source contracts, the ELT is updated as the new information becomes available. For sole source contracts, only manual updates are made, and for any item, regardless of procurement method, a manual update can override the computer update.

When no applicable history of procurement exists, the ELT may be entered as the minimum time allowed as follows:

AVSCOM FORECAST LIMITS

Unit price	Minimum PLT Mos.	Maximum PLT Mos.
$ 0.01 to 100.00	3	12
100.01 to 1,000.00	4	14
1,000.01 to 3,000.00	6	16
3,000.01 to 5,000.00	7	18
5,000.01 to 7,500.00	8	19
7,500.01 to 10,000.00	10	21
over 10,000.00	11	24

*The description of Section 2.1 is based on specifications for PLT updating given AVSCOM ADP by AVSCOM Directorate of Materiel Management (17 May 69) as well as direct personal contact with AVSCOM personnel.

An inquiry was made to AVSCOM for a list of constraints on ELT giving group type and parameter set. Only one constraint was found to exist; FSC group 53XX with a CDC classification GA has a maximum of 240 days ELT. Our data sample only contained 27 of this group (1.3%) so the possibility of constraints significantly affecting performance was not further considered.

2.2 Performance Statistics

Three performance statistics are used in this report.

Let

PLT_i = actual production lead time for the i^{th} contract

EST_i = estimated production lead time for the i^{th} contract*

n = number of contracts for which statistic is computed

Then

(1a) Mean Error (ME) $= \frac{1}{n} \times \sum_{i=1}^{n} (PLT_i - EST_i)$

(1b) Mean Absolute Deviation of Error (M.A.D.) =

$$\left(\frac{1}{n}\right) \times \sum_{i=1}^{n} \left| (PLT_i - EST_i) - ME \right| =$$

$$\frac{1}{n} \times \sum_{i=1}^{n} \left| PLT_i - (EST_i + ME) \right|$$

(1c) Standard Deviation of Error (S.D.) $= \sqrt{\left(\frac{1}{n-1}\right) \times \sum_{i=1}^{n} (PLT_i - EST_i - ME)^2}$

* For analysis of Chapter 2, $EST_i = ELT_i$ (i.e. the AVSCOM historical estimate).

Mean error was termed "statistical bias" in the report summary, and mean absolute deviation was termed "average error" - in order to keep the summary non-technical. Note that mean absolute deviation and standard deviation, in effect, compare PLT_i to (EST_i + ME), so that errors are computed after adjustment for bias, i.e., after ME is added to EST_i.

2.3 Performance Achieved

The performance statistics were computed for all contracts in the data base, treating all data as one sample, and then stratifying the data into five samples by PM code. Results are given in Table 2.

Additional statistics were then tabulated. A frequency distribution of error was set up by subtracting ELT from PLT and putting the resultant deviation into 30 day classes (-early, + late)*. Results are shown in Figure 5. Analysis was also done on the relative error with respect to the actual lead time ($\frac{PLT-ELT}{PLT}$). A frequency distribution was formed and the results are shown in Figure 6.

*Distribution was truncated to eliminate outliers; all error values outside of the range ± 300 days were excluded.

CHAPTER III

NEW FORECASTING MODELS

3.1 Approach

Technique

Regression analysis was used in the search for an improved methodology for forecasting production lead times. A regression analysis provides a relationship between a dependent variable (e.g. PLT) and one or more independent variables (e.g. standard unit price, quantity on order, etc.). Since there were several independent variables, stepwise regression was used in which the regression program (BMD 02R)* proceeds in a stepwise fashion forming successive regression analyses. A single variable is added to the regression equation with each step — the variable which gives the greatest improvement in estimate — and this continues as song as statistically significant improvement can be made. Improvement is measured in terms of minimizing the "standard error of estimate" and statistical significance is indicated by an "F" test. For the regression equations, Standard Error of Estimate (S.E.) is essentially equal to the Standard Deviation of the error distribution (equation 1c), Section 2.2).** The stepwise regression program also computes Multiple Coefficient of Correlation ("Multiple R").

Experimental Design

The data base was first separated into five data segments by

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* BMD 02R Stepwise Regression Program, version of May 16, 1968. Described in detail in Biomedical Computer Programs; University of California Press, Berkeley and Los Angeles, 1968.

**The denominator has number degrees of freedom instead of (n-1). In current context they are very close.

PM code, and the regression technique was then used to explore each segment individually. The data analysis of Section 1.4 (Table 1) and performance analysis of Chapter 2, summarized in Table 2, indicated that such a stratification was meaningful.

Next, for completeness and possible ease of implementation, groupings were considered. That is, combinations of data segments and the data base as a whole were also subjected to the regression analysis. From the results to the above, prospective models were chosen and their performance compared to that of ELT.

3.2 Regression

For the reader's convenience, abbreviations for variables used in the regression equations are repeated here:

PLT = Actual Production Lead Time

ELT = AVSCOM Estimate of Production Lead Time

SUP = Standard Unit Price

QTY = Quantity of Contract

EXT = SUP × QTY

VARLOG = Logarithm of whatever variable is specified,

e.g. SUPLOG.

Regression results were quite promising, both with stratification by PM code (Table 3) and by groupings (Table 4). In PM codes 1, 2, and 4, the Multiple Correlation Coefficient (R) was brought to over .7 and the significance level (F-test) was over 99% in each case. PM codes 3 and 5 have somewhat lower Multiple R.

Regression results for groupings of PM codes were not as good but still showed some promise. When all PM codes are grouped together, a Multiple R of over .5 was still achieved along with standard error of 113 days. To refer to the four groupings in Table 4, use the following:

PM Codes Grouped

1 & 2 - Competitive

3 & 4 - Direct Purchase Mftrs.

1 & 3 - Already in the Classification

2 & 4 - 1st Time in the Classification

It is somewhat surprising to note that better results come from the "competitives" than from the "Direct purchase Mftrs." But even more notable is the fact that models for items already in a classification showed substantially less promise than did the models for the "1st time" item category.

3.3 Model Formulation

The models chosen for further accuracy testing are designated by an asterisk (*) in Tables 3 and 4. Up to three models per PM code or grouping were selected. These include:

"Simple" - Forecast model uses a constant plus ELT variable only.

"Price" - Forecast model uses a constant, ELT, SUP and SUPLOG variables only (may not include both SUP and SUPLOC).

"Complex" - Most promising complex equation for the PM code or grouping. Might include any of the variables studied.

"Price" equations were examined in hope that they could achieve approximately the accuracy of the complex models, but with a uniform set of variables for all PM codes. It was noted that unit price and log of unit price tended to be statistically significant as demonstrated by their inclusion, in most cases when using the automated stepwise regression. Their contribution, however, in reducing error was relatively small as compared with ELT.

3.4 Model Testing

The mean error (ME), mean absolute deviation of error (M.A.D.) and standard deviation of error (S.D.) were used to compare the AVSCOM ELT estimate and the various regression models designated for testing. Results are given in Table 5. (%) denotes % improvement of regression model vs use of estimate equal to ELT only.

Not shown in Table 5 is that mean error was reduced to essentially zero. While this is to be expected when using a regression equation on the same data from which it was derived, we believe it likely that use of the models would reduce mean error in a real world context.

In nearly all cases, significant improvement was found in both Standard Deviation and Mean Absolute Deviation of Error. These improvements over ELT are legitimate improvements in that both performance measures were defined (cf. Section 2.2) to be unaffected by the size of mean error.

In Table 5 even the simple model showed worthwhile improvement over use of ELT as the estimate; e.g., when the simple model is applied to the data base as a whole, improvement is in the 5-6% range, apart from potential reduction in bias (mean error). The more complex models, however, when applied by PM code, performed better than the simple models, with percent improvements in the range of 7.4% (PM Code 5) to 15.4% (PM Code 4). When the PM code is not known in advance, the complex model offers small improvement over the simple model (cf results for "all" grouping).

When the stepwise regression program did not include the price variables for a particular PM code or grouping, the program was run with a special feature by which these variables could be forced into the equations. The results of such runs are not shown because in no case did the "price" equation thus developed show real improvement over the corresponding simple equation.

3.5 Analysis of Simple Model

The simple model is of the form:

(2) $$\text{Estimate} = a + b \times \text{ELT}$$

where a, b are constants determined by regression. Since no variables are used other than ELT, the question arises as to why the estimates obtained should be better than those obtained by setting estimate = ELT.

It is shown at the end of this section that the regression model computes a and b so use of Equation 2 is equivalent to use of:

(3) $$\text{Estimate} = (1-\alpha)\,\mu + \alpha\,(\text{ELT}+\text{B})$$

where

μ = mean production lead time for all contracts in sample
B = (sample) bias in use of ELT as estimate of PLT
$\alpha = b$

By equivalence is meant that equations (2) and (3) always have the same value. An interpretation of the simple model is suggested by equation (3).

Two different unbiased estimates of production lead time would be:

Estimate = ELT+B

*Estimate = μ

Furthermore, the two estimates are statistically independent. ELT is based on past experience for one FSN, while μ is essentially independent of that history since it is a sample mean based on the current experience for a large number of FSNs. Now, it is a well known statistical property that a weighted average of unbiased independent estimators can always be found which is superior (has smaller variance) to either estimator used alone. The simple model is a weighted average of unbiased, independent estimators, although this is not obvious in the form of equation (2). In other words, use of the simple model is equivalent to modifying the estimate based on ELT by the contract experience for other FSNs.

Proof of Equivalence of equations (2) and (3)

(i) $b = \alpha$; by definition

(ii) $\mu = a + b \times \overline{ELT}$; where $\overline{ELT}$ is, for all contracts in sample, mean ELT. This is a well known property of linear regression.

(iii) $\mu = \overline{ELT} + B$; by definition of B.

*μ is unbiased in that if used as an estimator for an item selected randomly, expected mean error would be zero.

(iv) $a = \mu - b \times \overline{ELT}$; from (ii), by algebra.

(v) $a = \mu - \alpha \times (\mu - B) = \mu \times (1-\alpha) + \alpha \times B$; substituting (i), (iii), (iv) into (ii)

(vi) $a + b \times ELT = \mu \times (1-\alpha) + \alpha \times B + \alpha \times ELT = (1-\alpha)\mu + \alpha (ELT+B)$; substituting (i), (v) into (2)

Q.E.D.

3.6 Conclusions

a. Significant error exists about the forecast mean; this forecast error should be taken into account in NICP Safety Level computations.

b. Forecast error can be reduced by combining the individual FSN's past experience with that of the other FSNs in the catalog. Even better improvement can be had if the Procurement Method is known in advance. Stepwise regression techniques are useful for determining both the independent variables to use and the form of the regression equations.

c. Since conditions affecting the length of Production Lead Times are subject to change, analyses like those done in this project should be done periodically, say annually. The ALPHA system should incorporate a program for extracting data needed for analysis. The actual BMD 02R stepwise regression analysis can be done off-line.

d. An "order of magnitude" analysis was made to estimate the significance of a 5% reduction in procurement lead time forecast error. It was concluded that total NICP safety levels could be reduced in the range of 0.5% to 4.0% with no loss of supply performance, given a 5% reduction in procurement lead time forecast error. Since total NICP apportionment year safety level requirements were 176.8 million dollars, based on FY 71 "Strat",* even a 0.5% reduction is significant. It should be recognized, of course, that this figure is used just to determine whether it is worth implementing the improved forecasting method. It has no operational significance since other factors such as the manner in which statistical safety level techniques are applied, the supply performance targets to be met, etc., have to be considered in deciding on quantitative changes in safety level investment. In general, it suffices to say that improvement in the accuracy of the PLT forecast will enhance the accuracy of prediction of supply performance one expects to achieve from a given investment and that the degree of improvement offered by the new methodology is sufficiently large to make its adoption worthwhile.

3.7 Validity of Results

The process for calculating ELT discussed in section 1.2 was based on the belief that AVSCOM used a 90 day standard for administrative lead time. In fact, as pointed out by W. Higgins of AMC Headquarters, the average estimate used was about 75 days; subsequent conversation with AVSCOM personnel indicated that the 90 day standard was used only for the sole source items (PM code 5).

What this means is that for PM codes 1-4, the values which

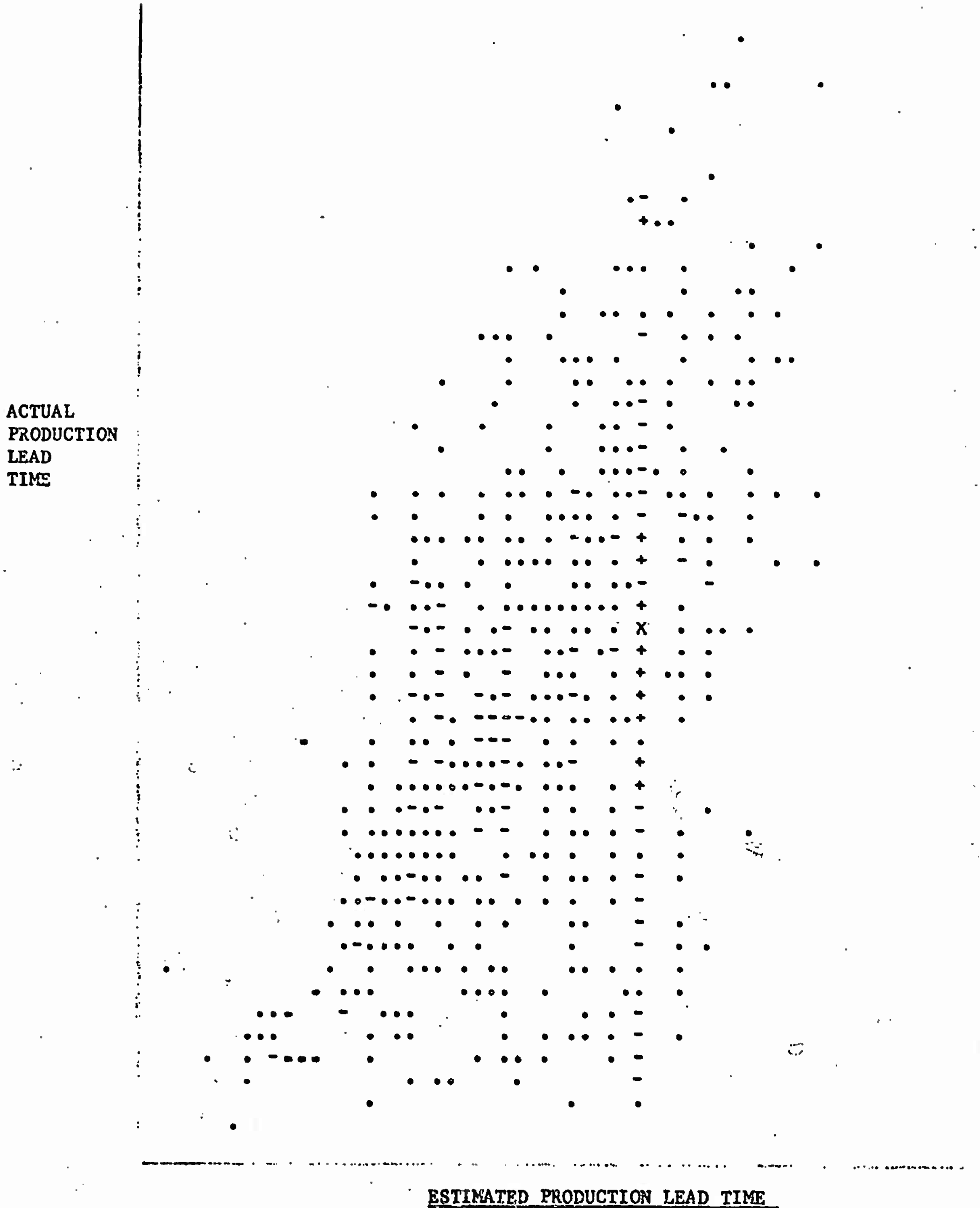
*Figures furnished by Mr. W. Higgins, AMC.

should have been used for ELT in this study were an average of something over 15 days greater than the values actually used. It is very unlikely that this error significantly affected the results since in evaluating performance all ELT's used were first upward adjusted anyway to remove statistical bias (section 2.2), and since average error after adjustment was 87 days.

In general, since the sample used was not random — having a predominance of multi-delivery items — and since the sample represented only one NICP, at one point in time, exact numerical results should not be extrapolated to other context. Thus, these particular regression coefficients should not be used at other NICPs or, for that matter, at the same NICP without periodic updating. The general applicability of the methodology, however, is not affected by the special characteristics of the particular data base used in this analysis and the conclusions of section 3.6 are considered valid.

FIGURE 1

SCATTER DIAGRAM (PLT VS ELT)



Note: Density Represented As Follows:

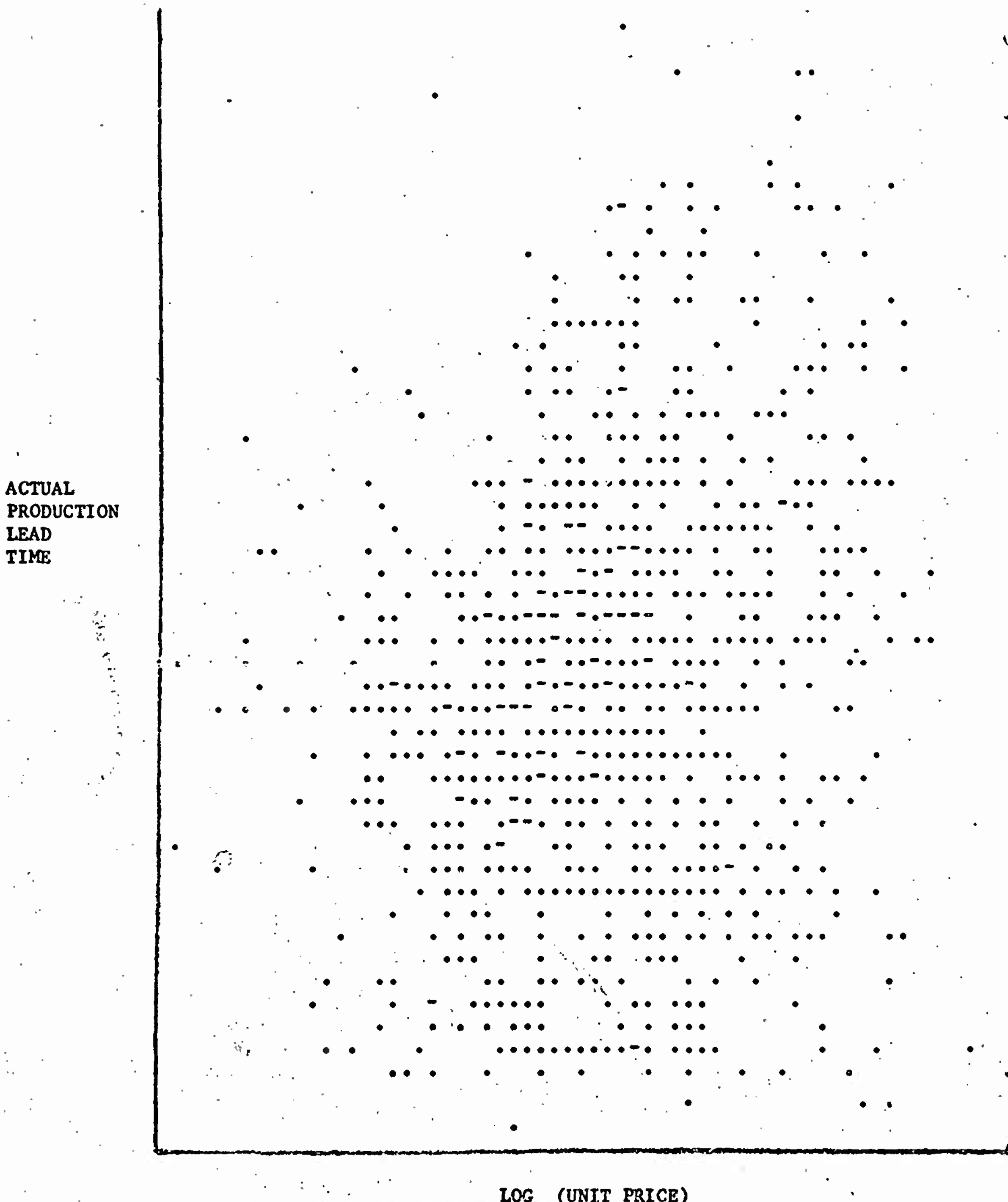
. = 1-3 points   + = 12-32

- = 4-11   x = > 32

16

FIGURE 2

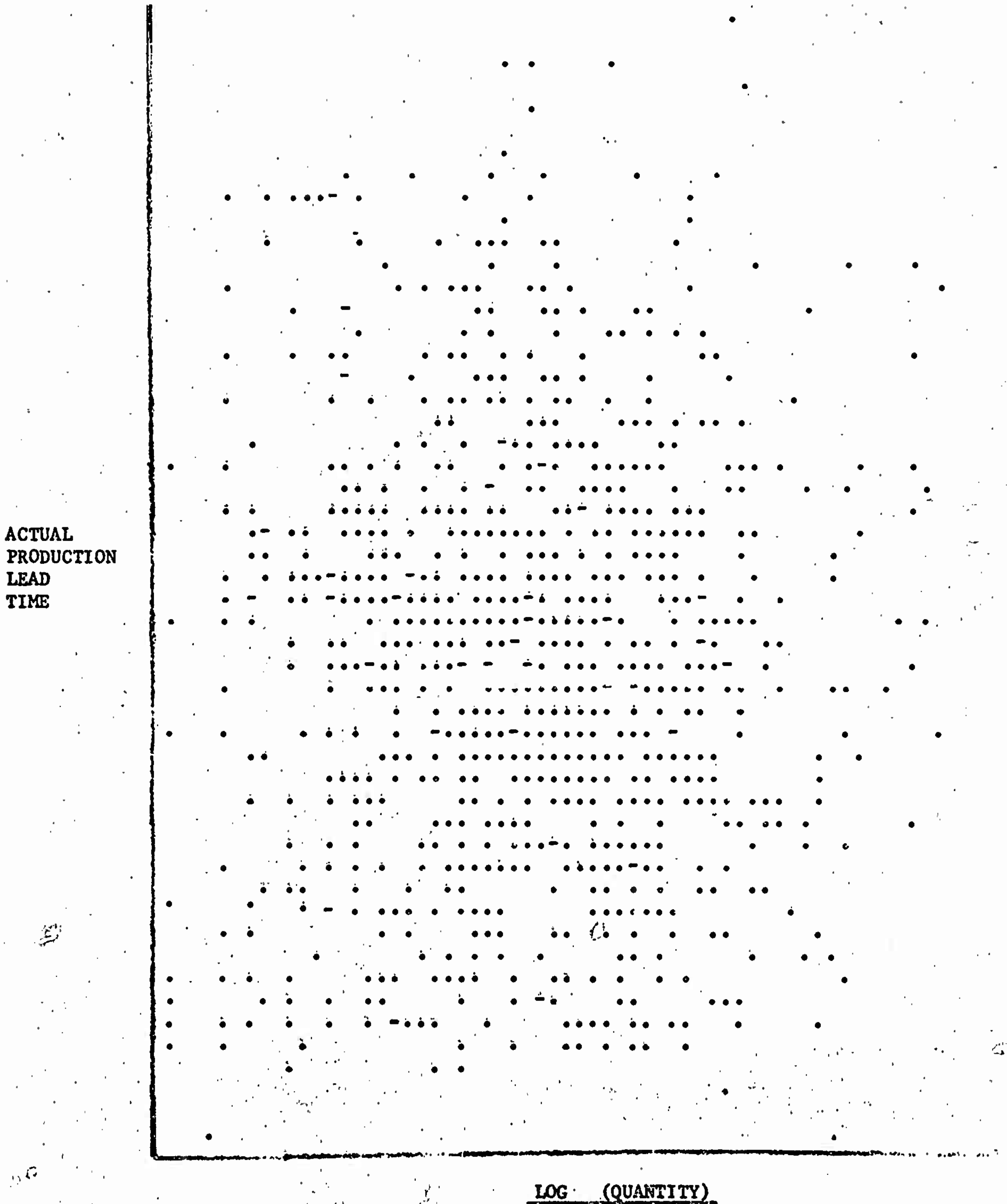
SCATTER DIAGRAM (PLT VS LOG(UP))



Note: Density Represented as follows:
. = 1-3 points + = 12-32
- = 4-11 x > 32

FIGURE 3

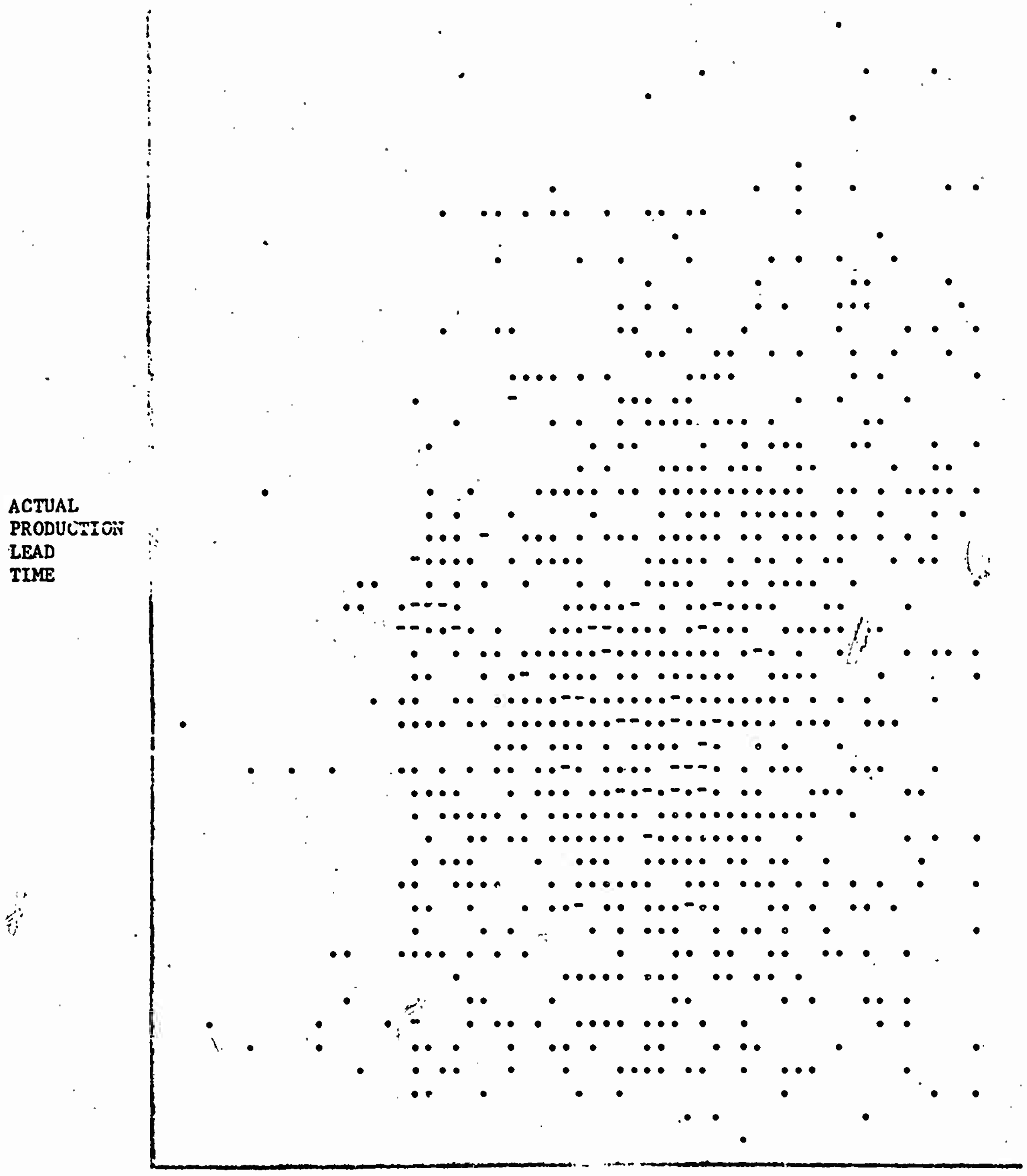
SCATTER DIAGRAM (PLT VS LOG (QTY))



Note: Density Represented as follows:
. = 1-3 points + = 12-32
- = 4-11 x > 32

FIGURE 4

SCATTER DIAGRAM (PLT VS LOG (UP * QTY))



Note: Density Represented as follows:

. = 1-3 points   + = 12-32

- = 4-11   x > 32

FIGURE 5

FREQUENCY DISTRIBUTION OF FORECAST ERROR (ACTUAL MINUS ESTIMATE LEAD TIME)

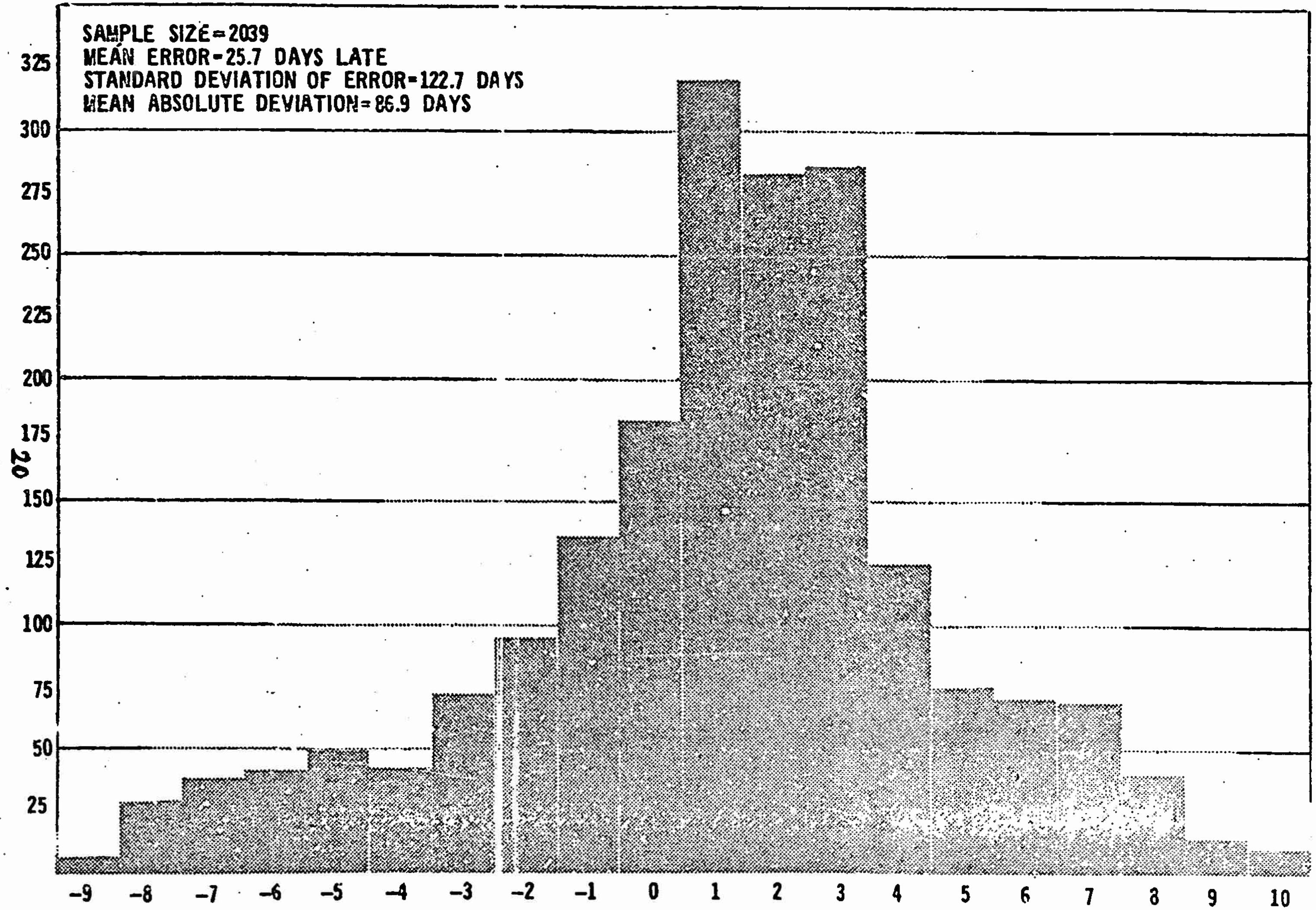
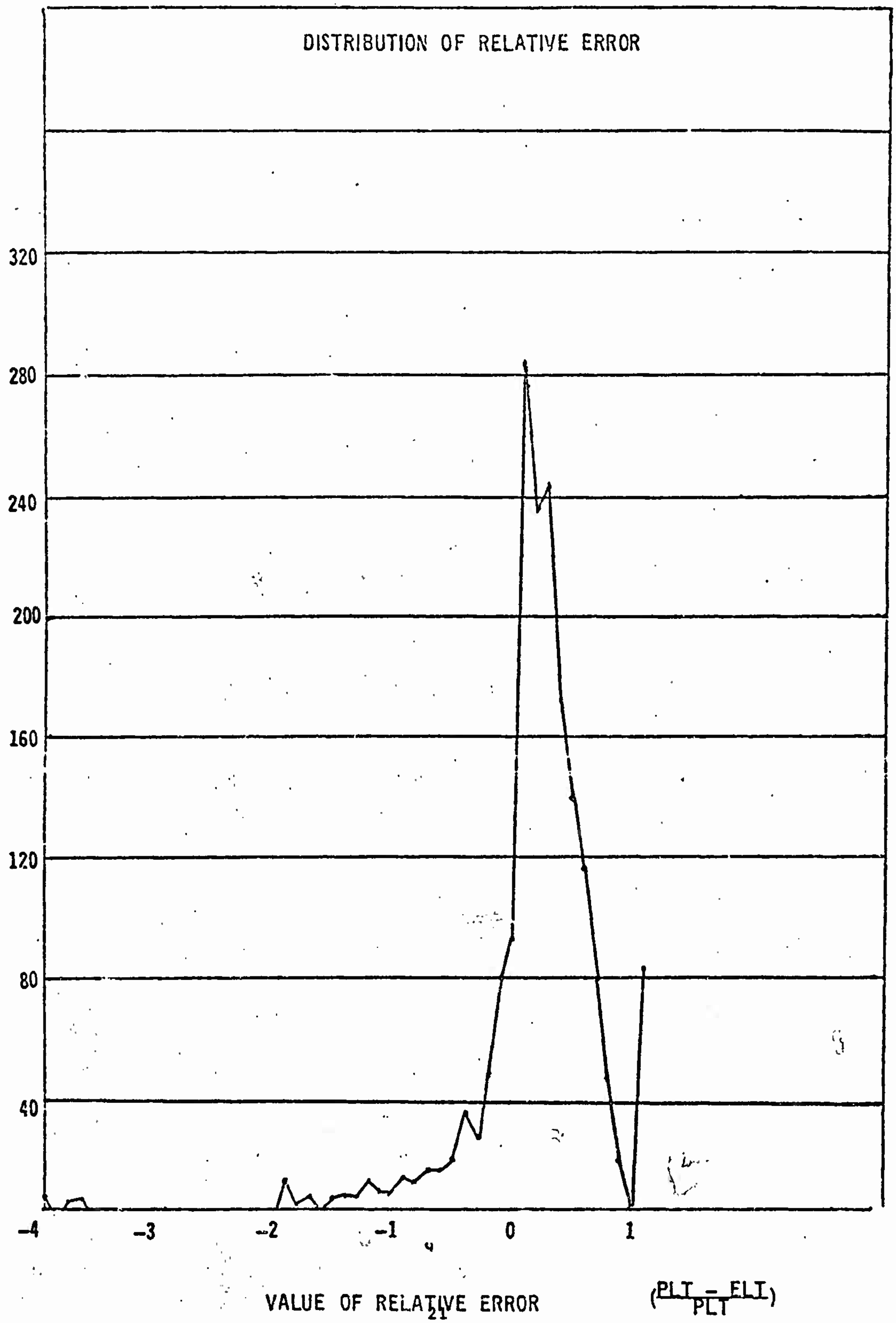


FIGURE 6



DISTRIBUTION OF RELATIVE ERROR
320
280
240
200
160
120
80
40
-4
-3
-2
-1
0
1
VALUE OF RELATIVE ERROR
(PLT - ELT / PLT)

TABLE 1

SUMMARY OF ANALYSIS OF VARIABLES

	Total Sample	By Procurement Method (PM)				
		PM 1 Already Compet	PM 2 1st Time Compet	PM 3 Already Direct Purch	PM 4 1st Time Direct Purch	PM 5 Sole Source
No. FSN's	2039	159	105	1176	317	282
PLT (days)						
Mean	226	161	183	238	161	301
Std Dev	134	111	91	113	106	201
ELT (days)						
Mean	201	143	164	216	143	247
Correlation Coefs						
PLT vs ELT	.510	.688	.661	.427	.693	.318
PLT vs SUP	.021	.625	.230	.019	.111	.243
PLT vs SUPLOG	.275	.412	.466	.191	.124	.388
PLT vs QTY	.025	.080	.151	.007	.048	.032
PLT vs QTYLOG	.028	.083	.234	.036	.319	.010
PLT vs EXT	.175	.234	.117	.091	.242	.208
PLT vs EXTLOG	.053	.154	.328	.045	.315	.075

TABLE 2

SUMMARY OF ERROR STATISTICS BY PROCUREMENT METHOD CODE

PM CODE	MEAN[1] ERROR OF ESTIMATE	MEAN[2] ABSOLUTE DEVIATION	STAND.[2] DEVIATION OF ERROR
All	26	86.9	122
1	18	59.0	84
2	18	50.3	71
3	22	87.0	114
4	18	62.2	90
5	55	148.2	196

(1) Expressed in days late.

(2) Expressed in days.

TABLE 3

RESULTS TO EMD - STEPWISE REGRESSION

INDIVIDUAL PM-CODES

PM	STEP	MULT. R	EQUATION	STD. ERROR	F RATIO
1	1	.688	*PLT = 54.28 + .74 ELT	80.64	141.43
1	2	.750	PLT = 74.18 + .53 ELT + .10 SUP	73.76	100.32
1	3	.761	*PLT = 54.94 + .52 ELT + .08 SUP + 7.85 SUPLOG	72.61	71.01
2	1	.661	*PLT = 60.01 + .75 ELT	68.78	79.84
2	2	.683	PLT = 57.95 + .64 ELT + 8.2 SUPLOG	67.24	44.65
2	3	.697	*PLT = 47.86 + .67 ELT - .02 SUP + 11.7 SUPLOG	66.34	31.84
2	4	.708	PLT = 88.27 + .70 ELT - 02 SUP + 9.47 SUPLOG - 6.34 QTYLOG	65.68	25.12
2	5	.716	*PLT = 123.46 + .68 ELT - .03 SUP + 7.9 SUPLOG - 7.6 QTYLOG - 3.3 EXTLOG	65.25	20.83
3	1	.427	*PLT = 132.81 + .49 ELT	102.39	261.64
3	2	.443	PLT = 45.12 + .30 ELT + 25.0 ELTLOG	101.56	143.13
3	3	.454	PLT = 27.04 + .25 ELT + 26.9 ELTLOG +5.86 SUPLOG	100.95	101.62
3	4	.456	*PLT = 27.18 + .26 ELT + 26.8 ELTLOG - .001 SUP + 5.9 SUPLOG	100.37	77.03
4	1	.693	*PLT = 74.37 + .61 ELT	76.51	290.55
4	2	.719	PLT = 38.22 + .57 ELT + 9.57 QTYLOG	73.78	168.54
4	3	.737	PLT = 2.78 + .55 ELT + 8.96 QTYLOG + 7.05 EXTLOG	71.88	124.33
4	4	.755	*PLT = .05 + .53 ELT + 7.6 QTYLOG + .00012 EXT + 8.45 EXTLOG	69.88	103.46
4	5	.758	PLT = 4.3 + .52 ELT - .01 QTY + 10.1 QTYLOG + .00012 EXT + 8.2 EXTLOG	69.63	84.01
5	1	.318	*PLT = 159.22 + .58 ELT	191.01	31.42
5	2	.436	*PLT = 99.69 + .38 ELT + 27.44 SUPLOG	181.58	32.79
5	3	.450	*PLT = - 63.64 + .09 ELT + 43.88 ELTLOG + 28.03 SUPLOG	180.53	23.54

* Equations tested further

TABLE 4

RESULTS TO BMD - STEPWISE REGRESSION

PM-CODE GROUPING

M	STEP	MULT. R	EQUATION	STD. ERROR	F RATIO
.11	1	.510	*PLT = 100.95 + .624 ELT	115.52	71.5
	2	.529	*PLT = 82.37 + .575 ELT + 9.25 SUPLOG	114.02	39.5
	3	.537	*PLT = 24.35 + .411 ELT + 17.92 ELTLOG + 9.86 SUPLOG	113.31	27.5
	4	.539	PLT = 26.32 + .40 ELT + 18.06 ELTLOG + 8.85 SUPLOG + .00003 EXT	113.17	20.8
1&2	1	.684	*PLT = 56.07 + .75 ELT	75.92	23.0
	2	.710	*PLT = 40.35 + .67 ELT + 10.08 SUPLOG	73.42	13.3
3&4	1	.525	*PLT = 109.07 + .56 ELT	98.77	56.6
	2	.540	PLT = 47.44 + .36 ELT + 20.47 ELTLOG	97.65	30.7
	3	.545	*PLT = 34.60 + .34 ELT + 21.71 ELTLOG + 4.24 SUPLOG	97.32	31.0
	4	.547	PLT = 24.30 + .34 ELT + 20.64 ELTLOG + 5.07 SUPLOG + 2.58 QTYLOG	97.22	15.9
1&3	1	.486	*PLT = 115.09 + .55 ELT	101.12	41.1
	2	.496	*PLT = 105.56 + .52 ELT + 5.83 SUPLOG	100.51	21.7
	3	.506	*PLT = 36.14 + .37 ELT + 17.40 ELTLOG + 6.12 SUPLOG	99.87	15.2
2&4	1	.687	*PLT = 73.49 + .63 ELT	74.77	37.5
	2	.701	*PLT = 72.98 + .61 ELT + .00011 EXT	73.43	20.3
	3	.710	PLT = 49.04 + .60 ELT + .00012 EXT + 4.20 EXTLOG	72.66	14.1
	4	.715	PLT = 33.15 + .59 ELT + 4.15 QTYLOG + .00011 EXT + 3.91 EXTLOG	72.15	10.9
	5	.719	*PLT = 30.07 + .59 ELT - .003 QTY + 5.26 QTYLOG + .00011 EXT + 4.08 EXTLOG	71.82	8.9

Groupings - (1&2) = Competitives, (3&4) = Dir Purch Mftr.
(1&3) = Alreadies, (2&4) = 1st Times

* Equations Tested Further

TABLE 5

REDUCTION IN ERROR BY TYPE MODEL

PM	AVSCOM ELT ESTIMATE			PERCENT REDUCTION IN ERROR					
				SIMPLE MODEL		PRICE MODEL		COMPLEX MODEL	
	ME (days)	MAD (days)	SD (days)	MAD	SD	MAD	SD	MAD	SD
1	17.9	59.0	84.02	6.3 %	4.9 %	11.5 %	14.7 %	- %	- %
2	18.4	50.3	71.1	2.2	4.2	5.4	8.4	9.3	10.7
3	22.2	87.0	114.2	10.8	10.4	-	-	13.0	11.8
4	18.0	62.2	89.9	13.2	15.1	-	-	15.4	22.9
5	54.6	148.2	196.1	0.1	3.0	6.7	7.9	7.4	8.6
All	25.5	86.9	122.6	5.6	5.8	5.6	7.1	6.9	7.7
1&2	18.1	55.5	79.3	5.0	4.7	5.9	7.6	-	-
3&4	21.3	81.5	109.5	9.3	9.9	-	-	11.4	11.2
1&3	21.7	83.6	111.0	9.1	9.0	9.3	9.5	10.9	10.2
2&4	18.1	59.2	85.6	10.6	12.9	-	-	11.7 11.3	14.5 16.2