AUTOMATIC CANNON MANUFACTURING COST ESTIMATING RELATIONSHIP

TECHNICAL REPORT

PREPARED BY

OFFICE OF THE COMPTROLLER
COST ANALYSIS DIVISION
JO E. McCLURE

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ABSTRACT

This report presents a Cost Estimating Relationship (CER) to be used for predicting automatic cannon manufacturing theoretical first unit cost and learning slope. Physical and performance characteristics were examined as possible independent variables. The CER presented is based on gun weight, boresize and projectile mass.

ACKNOWLEDGEMENTS

This study is the result of guidance and support from a large number of people. Those people who made outstanding contributions are:

Mr. Robert L. Henderson for data collection and guidance.
Miss Kathleen Keleher for statistical assistance and guidance.
Mrs. Linda Helms for typing patience.
Mr. James F. Goodall for data analysis.

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1. INTRODUCTION

This study was performed by the Cost Analysis Division, Comptroller, US Army Armament Materiel Readiness Command. The cost estimating relationship was developed to estimate the automatic cannon manufacturing costs for the Division Air Defense System Independent Parametric Cost Estimate (DIVAD IPCE) (January 1977). It is presented here with supporting data for use in other similar type studies.

2. PURPOSE

The purpose of this study is to:

a. Present methodology which may be used in estimating automatic cannon manufacturing costs.

b. Present supporting data such as gun characteristics and historical cost data which may be used to determine applicability of this cost estimating relationship.

3. SCOPE OF THE STUDY

The automatic cannon manufacturing costs included in this study consist of those costs included in the reference g cost element 2.02, Production, and include contractor costs of manufacturing, recurring engineering, quality control, sustaining tooling, and other recurring production costs incurred under cost element 2.02 and which are properly changable to the Government. General and Administrative (G&A) and Profit ~~have been~~ excluded, but can be added as factors.

The weapons used in this study are identified to include the basic gun, including drive unit if applicable; feeder; and recoil. Ancillary equipment is not included.

4. GENERAL APPROACH

a. Assumptions.

The basic assumption of this study is that learning is a characteristic of automatic cannon production. The dependent variables used are derived from learning curve theory. Theoretical first unit cost and learning curve slope are the outputs of the cost estimating relationship.

Secondly, it was assumed that the physical and performance characteristics of the gun can be used as independent variables to determine theoretical first unit cost and slope. The problem then is to determine which characteristics most accurately project cost.

b. Variables.

This study was initiated to provide an automatic cannon manufacturing cost estimate for the DIVAD IPCE. Therefore, sixteen guns were chosen which were generically similar to the proposed DIVAD gun and which had readily available procurement cost history or validated cost estimates. For each gun a theoretical first unit cost and learning slope was then calculated for use as dependent variables (see Section A of Annex).

Nine physical and performance characteristics were used as independent variables. These were chosen on the basis of availability and reasonableness. These characteristics are: gun weight, boresize, number of barrels, number of components, number of equivalent "D"-sized drawings, maximum range, muzzle velocity, kinetic energy, and projectile weight (see Section B of Annex).

Preliminary analysis indicated that learning slope cannot be directly determined using these gun characteristics. The equation, $\text{Log}_e Y = \text{Log}_e A + B\ \text{Log}_e X$ 1/, was applied to calculate the cost of an arbitrarily chosen unit (the 500th) on each of the input learning curves. This five hundredth unit cost provided a satisfactory dependent variable in place of the learning slope (see Section A of Annex).

1/ Where: A = Theoretical First Unit Cost
B = Learning Slope (exponential form)
X = Unit Number
Y = Unit Cost

c. Regression Analysis.

An extensive regression analysis was performed using the Stanford University Biomedical Computer Program. In the search for a "good" relationship, the nine independent variables were regressed (singly and in combinations of up to five independent variables) against each of the two input costs, theoretical first unit cost and 500th unit cost. Nonlinear relationships (using the natural logarithm of one or more variables), as well as strictly linear relationships, were examined for statistical acceptability. The "best" statistically acceptable equation was then chosen; one for theoretical first unit cost and one for 500th unit cost.

Gun weight, boresize, and projectile weight proved to yield the "best" relationship for both costs. The equation form was chosen on the basis of highest coefficient of determination, lowest standard error of estimate, and the range of the absolute value of the partial correlation coefficients. The t-test was used to test the significance of the slopes at a 99% level of confidence.

5. STUDY RESULTS

The manufacturing cost of a given lot of automatic cannon production can be estimated using these two relationships and learning curve equations. All costs are expressed in FY 76 dollars.

a. Theoretical First Unit Cost Estimating Relationship

$$Z = -(7.804\text{x}10^3) + (2.068\text{x}10^2)W + (1.450\text{x}10^3)X - (9.625\text{x}10^4)Y$$

where: W = gun weight (lbs)
X = boresize (mm)
Y = projectile weight (lbs)
Z = theoretical first unit cost (FY 76 $'s)

Statistics:

Coefficient of Determination = .9213

Standard Error of the Estimate = $1.002\text{x}10^4$

Partial Correlation Coefficients: ZW.XY = .9394
ZX.WY = .7355
ZY.WX = .8610

b. Five-hundredth Unit Cost Estimating Relationship

$$Z' = -(1.699\text{x}10^3) + (5.895\text{x}10^1)W + (5.049\text{x}10^2)X - (2.606\text{x}10^4)Y$$

where: W = gun weight (lbs)
X = boresize (mm)
Y = projectile weight (lbs)
Z' = five-hundredth unit cost (FY 76 $'s)

Statistics:

Coefficient of Determination = .9094

Standard Error of the Estimate = $3.426\text{x}10^3$

Partial Correlation Coefficients: Z'W.XY = .9161
Z'X.WY = .7417
Z'Y.WX = .8015

6. USE OF THE CER

The Automatic Cannon Manufacturing CER should be used when gun weight, boresize, and HE projectile mass is available either as engineering estimates or actual hard data. The data should be checked to see that it is within the following range of data used as input to the development of the CER:

Range of Independent Variables

Variable	Range
Gun Weight (lbs)	22.5 to 1000
Boresize (mm)	7.62 to 40
Projectile Weight (lbs)	.0215 to 1.9600

The next step in using the CER is to solve the equations for Theoretical First Unit Cost and Five-hundredth Unit Cost. The following equation can then be used to determine the Learning Slope: 2/

$$B = \frac{\mathrm{Log}_e\, Y - \mathrm{Log}_e\, A}{\mathrm{Log}_e\, 500}$$

where: A = Theoretical First Unit Cost
Y = Five-hundredth Unit Cost
B = Learning Slope

Finally, to calculate given lot values, use the following learning curve equation. This equation can be derived from the equation used to find the algebraic lot midpoint.

$$\text{Total Lot Cost} = A \times \frac{((L + .5)^{B + 1} - (F + .5)^{B + 1})}{B + 1}$$

where: A = Theoretical First Unit Cost
B = Learning Slope
F = First Unit in Lot
L = Last Unit in Lot

An example calculation can be found in Section D of Annex.

2/ This calculation yields the Learning Slope in exponential form which is the form used in the next calculation. For presentation purposes, the percentage form (expressed as B%) may be calculated as follows:

$$B\% = \mathrm{Antilog}_e\, (B \times \mathrm{Log}_e 2 + \mathrm{Log}_e 100)$$

7. REFERENCES

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e. Muriel L. Slevin, Data Processing Systems Office Information Report, "BMDS - The Biomedical Computer Programs Available at Picatinny Arsenal," Picatinny Arsenal, Dover, New Jersey, 1971.

f. Department of the Army, Comptroller of the Army, Directorate of Cost Analysis, "Cost Estimating Relationship for Theoretical First Unit Cost for Medium Bore Guns (10-40mm)," 1976.

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ANNEX

Automatic Cannon Manufacturing
Cost Estimating Relationship

SECTION A

Dependent Variables

The source of cost data for each weapon system used in the CER is included in this section. It is important to note that estimates have been used as input data. The author recognizes the danger of including estimates; however, to obtain a sufficient data base, this practice was considered necessary.

Table 1 presents a summary of the input costs. The 500th Unit Cost is calculated as noted in paragraph 4b of this report.

Table 1

DEPENDENT VARIABLES

	GUN	THEORETICAL FIRST UNIT COST (FY 76$)	LEARNING SLOPE PERCENT	FIVE-HUNDREDTH UNIT COST (FY 76$)
1.	MAG 58	$ 1,654	98.0	$ 1,380
2.	M60	618	99.8	616
3.	M73	12,296	90.0	4,781
4.	M129	7,031	90.0	2,734
5.	M134	21,333	88.0	6,781
6.	M85	19,946	90.0	7,739
7.	M2	16,904	90.0	6,572
8.	XM230	19,973	90.5	8,161
9.	XM140	42,610	91.0	18,293
10.	M139	23,849	91.0	10,237
11.	XM188	19,314	98.0	16,114
12.	M197	43,294	87.2	12,680
13.	Bushmaster	34,925	90.0	13,579
14.	M61A1	32,300	90.0	12,684
15.	GAU-8	132,690	87.7	40,906
16.	M2A1	66,074	90.0	25,691

1. Mag 58, 7.62MM, Machine Gun - Based on an FY 77 DRSAR-PPW-SA pre-contract estimate provided for 1400 units having an average unit cost of $1,788.66. A learning slope of 98 percent was assumed based on M60 Machine Gun history. Theoretical first unit cost calculates to $1,654 (FY 76$'s) excluding 11.8 percent for G&A and 10 percent for profit.

2. M60, 7.62MM, Machine Gun - Cost data was extracted from Army Weapons Command Pamphlet 37-2 (Dec 72), "Financial Administration Cost Data." This data is based on contract values and learning calculations found in the M60 data base file (DRSAR-CPE-D).

3. M73, 7.62MM, Machine Gun - Cost is based on three lots totaling 3,130 units. The contractor estimated a learning slope of 90 percent. This was necessary due to the extensive Government furnished equipment provided to the contractor. The theoretical first unit cost is then calculated to be $12,296 based on the 90 percent slope and the average unit value of the 3,130 units.

4. M129, 40MM, Grenade Launcher - This cost is based on a contract for 756 M129's. This contract showed an average unit cost (FY 76 $'s) of $3023.01, less G&A and Profit. Projected using an assumed 90 percent learning slope provides a theoretical first unit cost of $7,031.

5. M134, 7.62MM, Gatling Gun - Theoretical first unit cost and slope based on contract data for eleven lots with a total procurement of 9,502 units. The calculated values are $21,333 and 88 percent.

6. M85, 12.7MM, Machine Gun - Cost is based on contract data for three lots for a total buy of 2,098 units. The contractor estimated a learning slope of 90 percent (see No. 3), and using the average unit value for the 2,098 units, the theoretical first unit cost is calculated to be $19,946 (FY 76 $).

7. M2, 12.7MM, Machine Gun - Based on an FY 76 DRSAR-PPX-P estimate dated 7 Oct 76 for 2000 weapons having an average unit cost of $6,273.92. A 90 percent learning slope was assumed. The theoretical first unit cost is $16,904 (FY 76 $).

8. XM230, 30MM, Chain Gun - Theoretical first unit cost and slope are based on an analogy with the XM140 30MM gun estimates. A complexity factor of 1/2.5 was applied to the XM140 gun (less barrel costs) based on a parts comparison. When combined with barrel theoretical first unit cost and slope the XM230 gun values become $19,973 and 90.5 percent. (see "Area Weapon Subsystem and Aerial Rocket Subsystem Design-to-Cost Update for the Advanced Attack Helicopter," January 1975, for further explanation of these value derivations).

9. XM140, 30MM, Automatic Gun - Based on estimate developed by Government cost personnel who extensively reviewed the contractor's budgetary and planning estimates for the gun. The contract was in the negotiation phase when the Cheyenne program was terminated so there is no actual contract data. The Government cost personnel estimated a theoretical first unit cost of $42,610 (FY 76 $) and a slope of 91 percent.

10. M139, 20MM, Automatic Gun - Contract data was available for two lots totaling 2330 units. The US production was a modification of the Swiss HS820 so the learning slope was estimated as 91 percent. Using the average unit value for the 2330 units the theoretical first unit cost is $23,849 (FY 76 $).

11. XM188, 30MM, 3-Barrel Gatling Gun - Based on data extracted from the Advanced Attack Helicopter (AAH) Baseline Cost Estimate Update, dated Aug 76. The AAH estimates are based on engineering estimates and analogies with the M197, and M61A1, and XM140 guns.

12. M197, 20MM, Gun - The M197 20mm 3-barrel gun cost was based on actual contract costs for the gun, delinking feeder, and barrels. A total of 460 M197 weapons and M89E1 delinking feeders have been procured. These data were plotted using learning curve analyses to arrive at a learning slope and theoretical first unit cost. They are 87.2 percent and $39,768, respectively. Historically, the 20mm barrel has had a learning slope of 88 percent. For convenience, the 87.2 percent slope was used to cost 1500 barrels (500 weapons). This data was combined with the weapon and delinking feeder data to result in an overall M197 weapon system theoretical first unit cost of $43,294 and a slope of 87.2 percent.

13. Bushmaster, 25MM, Gun - This estimate was developed by the MICV-PM personnel from a CER developed by DRSAR-CPE-S for the MICV program. This CER, based on the M85, M73, M139, M140 and M42A1, provided a theoretical first unit cost of $34,925 with an assumed learning slope of 90 percent.

14. M61A1, 20MM, Gun - The theoretical first unit cost and slope were calculated from four years of procurement cost history data extracted from the M61A1 gun data base files maintained in DRSAR-CPE-D.

15. GAU-8, 30MM, Gatling Gun - This estimate was developed based on Cost Performance Reports provided by the A10 Special Project Office at Wright Patterson Air Force Base, Ohio. From the data for four contracts totaling 95 units a theoretical first unit cost of $132,690 and a learning slope of 87.7 percent was calculated. The raw data is on file in the GAU-8 data base maintained in DRSAR-CPE-D.

16. M2A1, 40MM, Cannon - The majority of actual contract data for the M2A1 is unavailable. This cost is based on a contract totaling 978 units of which actual data was available for a lot of 678 units. An engineering estimate determined the slope to be 91 percent. The theoretical first unit was calculated based on the average unit cost for the 678 units with a prior quantity of 300 units.

SECTION B

Independent Variables

A summary of physical/performance characteristic data is presented in this section. Table 2 lists those characteristic values which were used in developing the recommended CER. Table 3 lists characteristics which were examined in the regression analysis, but were not used in the preferred CER.

The source of this data is widely varied. Most of the weapon data was extracted from technical characteristic sheets which can be found in the DRSAR-CPE-D data base files. The number of equivalent "D"-sized drawings was extracted from the "Producibility Engineering and Planning" Technical Report (Jan 77) prepared by DRSAR-CPE. Technical data was also obtained from system offices by telephone contact. Projectile data was obtained from HQ, ARMCOM, Technical Report DRSAR-CPE 76-4, Ammunition Cost Research Study, June 1976; AMCP 700-3-2, Complete Round Charts Ammunition through 20 Millimeter, December 1973; and HQ, ARRCOM, Logistics Engineering Directorate technical personnel.

Standard units of measure for the independent variables are used. Projectile weights that were expressed in grains or grams were converted to pounds by dividing the given weight by the appropriate physical relationship of 7,000 grains per pound or 454 grams per pound.

Table 2

INDEPENDENT VARIABLES USED IN PREFFERED CER

	Gun	Weight (lbs)	Boresize (mm)	Projectile Weight (lbs)
1.	MAG 58	22.5	7.62	.0215
2.	M60	23.2	7.62	.0215
3.	M73	35.0	7.62	.0215
4.	M129	44.0	40.	.5108
5.	M134	56.0	7.62	.0215
6.	M85	65.0	12.7	.1014
7.	M2	82.0	12.7	.1014
8.	XM230	104.0	30.	.4359
9.	XM140	150.0	30.	.4359
10.	M139	161.0	20.	.2687
11.	XM188	169.0	30.	.4359
12.	M197	172.0	20.	.2229
13.	Bush.	247.0	25.	.3965
14.	M61A1	255.0	20.	.2229
15.	GAU-8	804.0	30.	.7996
16.	M2A1	1000.0	40.	1.9600

Table 3

INDEPENDENT VARIABLES CONSIDERED BUT NOT USED IN PREFERRED CER

Gun	Number of Barrels	Number of Components	Equivalent "D"-Sized Drawings	Maximum Range (M)	Muzzle Velocity (FPS)	Kinetic Energy (1/2 mv^2)
MAG 58	1	233	98*	3,700	2,800	2,619
M60	1	373	159	3,700	2,800	2,619
M73	1	263	178	3,700	2,800	2,619
M129	1	116	104	2,098	800	5,076
M134	6	146	63	3,200	2,850	2,713
M85	1	319	142	6,548	2,840	12,699
M2	1	364	152*	6,714	2,930	13,5167
XM230	1	399	168*	4,066	2,200	32,760
XM140	1	800	237	4,066	2,200	32,760
M139	1	400	144	4,541	3,444	49,491
XM188	3	689	289*	4,066	2,350	37,379
M197	3	310	130*	4,451	3,400	40,009
BUSH.	1	185	77*	2,500	3,600	79,795
M61A1	6	419	168	4,541	3,380	39,540
GAU-8	7	**	**	4,000	3,450	147,781
M2A1	1	496	208*	8,527	2,870	250,690

* Estimated at 42 percent of number of components-based on the other weapons' drawing and component data.

** This information was unavailable at the time of the study.

SECTION C

Regression Analysis

This section contains the output of the Stanford University Biomedical Computer Program - Multiple Regression with Case Combination. It is presented here for information purposes and can be used to determine the statistical reliability and confidence limits of the relationships recommended in this report.

Some explanations are necessary to relate this output to the data presented in Section A and B of this Annex.

1. Due to the limitations of the program's format, dependent variables were adjusted by powers of ten to that at least four significant digits were printed. The following table is a listing of variable numbers and the transpositions performed:

Variable Number	Variable (With Transposition)
1	Gun Weight
2	Boresize
3	Projectile
5	(Five-hundredth Unit Cost) x 10^{-3}
6	(Theoretical First Unit Cost) x 10^{-3}

2. The observation number in the "Table of Residuals" can be identified to the specific weapon system by referring to Tables 1, 2, and 3 in Sections A and B of this Annex. The weapon systems were numbered on those tables solely for this purpose.

SELECTION NO. 2-21

SAMPLE SIZE 16
NO. OF VARIABLES 4 NO. OF VARIABLES DELETEO 2 (FOR VARIABLES OELETEO, SEE BELOW)
DEPENDENT VARIABLE IS NOW NO. 5

COEFFICIENT OF DETERMINATION 0.9213
MULTIPLE CORR. COEFFICIENT 0.9598

SUM OF SQUARES ATTRIBUTABLE TO REGRESSION 14100.9336
SUM OF SQUARES OF DEVIATION FROM REGRESSION 1205.29297

VARIANCE OF ESTIMATE 100.44107
STO. ERROR OF ESTIMATE 10.02203

INTERCEPT (A VALUE) -7.80403

ANALYSIS OF VARIANCE FOR THE MULTIPLE LINEAR REGRESSION

SOURCE OF VARIATION	O.F.	SUM OF SQUARES	MEAN SQUARES	F VALUE
DUE TO REGRESSION............	3	14100.9336	4700.30859	46.7967
DEVIATION ABOUT REGRESSION...	12	1205.29297	100.44107	
TOTAL...	15	15306.2266		

VARIABLE NO.	MEAN	STD. DEVIATION	REG. COEFF.	STD.ERROR OF REG.COE.	COMPUTEO T VALUE	PARTIAL CORR. COE.	SUM OF SQ. AODED	PROP. VAR. INCREMENT
1	211.85625	281.66064	0.20678	0.02179	9.49038	0.93938	10631.4961	0.69459
2	21.30499	11.30603	1.44957	0.38547	3.76051	0.73550	16.71359	0.00109
3	0.37362	0.47817	-96.25049	16.41631	-5.86310	-0.86096	3452.75024	0.22558
5	30.92566	31.94394						

COMP. CHECK ON FINAL COEFF. -96.25038

VARIABLES OELETEO... 4 6

SELECTION NO. 2-21

CORRELATION COEFFICIENTS

ROW 1	1.000	.5693	.8898	.8334
ROW 2	.5693	1.000	.7661	.4473
ROW 3	.8898	.7661	1.000	.5745
ROW 4	.8334	.4473	.5745	1.000

INVERSE OF CORRELATION COEFFICIENT MATRIX

ROW 1	5.624	1.529	-6.176
ROW 2	1.529	2.837	-3.534
ROW 3	-6.176	-3.534	9.202

TABLE OF RESIDUALS

OBSERVATION	Y VALUE	Y ESTIMATE	RESIDUAL
1	1.65400	5.82486	-4.17086
2	0.61800	5.96961	-5.35161
3	12.29600	8.40961	3.88639
4	7.03100	10.11238	-3.08138
5	21.33299	12.75198	8.58102
6	19.94598	14.28639	5.65960
7	16.90399	17.80162	-0.89763
8	19.97299	15.23259	4.74040
9	42.60999	24.74446	17.86552
10	23.84898	28.61639	-4.76741
11	19.31400	28.67326	-9.35927
12	43.29399	35.29926	7.99474
13	34.92499	41.34650	-6.42151
14	32.29999	52.46196	-20.16197
15	132.68999	124.97202	7.71797
16	66.07399	68.30730	-2.23331

TEST OF EXTREME RESIDUALS

RANGE OF RESIDUALS................ 38.027
RANGE / STD. ERROR OF ESTIMATE.... 3.794

SELECTION NO. 2-22

SAMPLE SIZE 16
NO. OF VARIABLES 4 NO. OF VARIABLES DELETED 2 (FOR VARIABLES DELETED, SEE BELOW)
DEPENDENT VARIABLE IS NOW NO. 6

COEFFICIENT OF DETERMINATION 0.9094
MULTIPLE CORR. COEFFICIENT 0.9536

SUM OF SQUARES ATTRIBUTABLE TO REGRESSION 1414.52637
SUM OF SQUARES OF DEVIATION FROM REGRESSION 140.89746

VARIANCE OF ESTIMATE 11.74146
STD. ERROR OF ESTIMATE 3.42658

INTERCEPT (A VALUE) -1.69928

ANALYSIS OF VARIANCE FOR THE MULTIPLE LINEAR REGRESSION

SOURCE OF VARIATION	D.F.	SUM OF SQUARES	MEAN SQUARES	F VALUE
DUE TO REGRESSION............	3	1414.52637	471.50879	40.1576
DEVIATION ABOUT REGRESSION...	12	140.89746	11.74146	
TOTAL...	15	1555.42383		

VARIABLE NO.	MEAN	STD. DEVIATION	REG. COEFF.	STD.ERROR OF REG.COE.	COMPUTED T VALUE	PARTIAL CORR. COE.	SUM OF SQ. ADDED	PROP. VAR. INCREMENT
1	211.85625	281.66064	0.05895	0.00745	7.91339	0.91607	1152.77368	0.74113
2	21.30499	11.30603	0.50486	0.13179	3.83068	0.74171	8.63514	0.00555
3	0.37362	0.47817	-26.06065	5.61282	-4.64306	-0.80151	253.12199	0.16274
6	11.80924	10.18307						

COMP. CHECK ON FINAL COEFF. -26.06062

VARIABLES DELETED... 4 5

SELECTION NO. 2-22

CORRELATION COEFFICIENTS

ROW 1	1.000	.5693	.8898	.8609
ROW 2	.5693	1.000	.7661	.5514
ROW 3	.8898	.7661	1.000	.6565
ROW 4	.8609	.5514	.6565	1.000

INVERSE OF CORRELATION COEFFICIENT MATRIX

ROW 1	5.624	1.529	-6.176
ROW 2	1.529	2.837	-3.534
ROW 3	-6.176	-3.534	9.202

TABLE OF RESIDUALS

OBSERVATION	Y VALUE	Y ESTIMATE	RESIDUAL
1	1.38000	2.91387	-1.53387
2	0.61600	2.95514	-2.33914
3	4.78100	3.65076	1.13024
4	2.73400	7.77733	-5.04333
5	6.78100	4.88874	1.89226
6	7.73900	5.90176	1.83724
7	6.57200	6.90393	-0.33193
8	8.16100	8.21771	-0.05671
9	18.29298	10.92945	7.36353
10	10.23700	10.88662	-0.64962
11	16.11400	12.04953	4.06447
12	12.68000	12.72866	-0.04867
13	13.57900	15.15018	-1.57118
14	12.68400	17.62160	-4.93760
15	40.90599	40.00523	0.90076
16	25.69099	26.36751	-0.67651

TEST OF EXTREME RESIDUALS

RANGE OF RESIDUALS................ 12.407
RANGE / STD. ERROR OF ESTIMATE.... 3.621

SECTION D

Example Application of CER

The following example is to assist the estimator in using the CER. This example is an ideal case and is of a purely fictional weapon system. Any variation from the stated conditions such as prior US production would require methodology other than that presented in this report.

1. A new automatic cannon weapon system is desired to be mounted on the Fictional Attack Tank (FAT). One of the weapons being considered is the Z1, a 25 mm automatic gun being developed by a foreign manufacturer. If selected, the Z1 will be manufactured in the US. The Z1 has already been selected for a helicopter system, but production will not start until shortly before the FAT system production is scheduled to begin. The problem is to estimate the armament manufacturing cost for the FAT system if the Z1 is chosen.

2. The foreign engineers have published a fact sheet on their Z1 gun. This fact sheet contains physical and performance characteristic data and recommends the types of ammunition to be used. One of the physical characteristics listed is that the automatic cannon weighs approximately 200 pounds. The recommended ammunition of the High Explosive (HE) type is a US round which has been in production for several years. The HE Projectile weight is 175.5 grams, which equates to 0.387 pounds.

3. These values are then used in the Theoretical First Unit Cost Relationship and the Five-hundredth Unit Cost Relationship as follows:

Theoretical First Unit Cost (A)

$$= -(7.804 \times 10^3) + (2.068 \times 10^2)(200) + (1.450 \times 10^3)\ (25) -$$

$$(9.625 \times 10^4)(0.387)$$

$$= \$32,557.25$$

and,

Five-hundredth Unit Cost

$= -(1.699 \times 10^3) + (5.895 \times 10)(200) + (5.049 \times 10^2) \quad (25) -$

$(2.606 \times 10^4 \ (0.387)$

$= \$12,628.28$

where: Weight (lbs) = 200
Boresize (mm) = 25
Projectile Weight (pounds) = 0.387

4. The Learning Slope calculation is then performed:

$$B = \frac{\text{Log}_e(12,628.28) - \text{Log}_e(32,557.25)}{\text{Log}_e\ 500}$$

$= -.152393$

where: Theoretical First Unit Cost = \$32,557.25
Five hundredth Unit Cost = \$12,628.28

5. Finally, the total lot cost must be calculated. To perform this calculation, more information is necessary.

a. How many Z1's are needed for the operational FAT? (Note that prototypes, etc. are not included - this CER estimates only those weapons funded by the Procurement Appropriation during the Investment phase of the systems's life cycle).

b. How many Z1's (for the helicopter system) will have been produced by the time the FAT Z1 goes into production?

c. What are other contributing factors which would affect FAT Z1 production? Will there be a break in production between the helicopter A1 buy and the FAT Z1 buy? Has there been prior US production of the Z1 (other than for the helicopter)? Is the FAT Z1 significantly different from the helicopter Z1?

The project manager for FAT provided the following answers to these questions:

a. Three hundred Operational FAT systems will be produced. Therefore, 300 Z1's will be needed.

b. A buy of 140 Z1's is planned for the helicopter system.

c. Production will be continuous. There are no significant differences between the Z1 to be mounted on the helicopter and the FAT Z1. There is no known US production other than for these two systems (Note that the answers in paragraph 3 are the ideal situation. Methods of handling factors such as significant changes in the gun and breaks in production are not addressed in this report.)

The total lot cost can now be calculated as follows:

Total Lot Cost

$$= (32{,}557.25) \times \frac{(440 + .5)^{-.152393 + 1} - (141 + .5)^{-.152393 + 1}}{-.152393 + 1}$$

$= \$4{,}135{,}489.66$

where: Theoretical First Unit Cost = $32,557.25
Learning Slope = -.152393
First Unit in Lot = 141 (Units 1 thru 140 are in helicopter lot)
Last Unit in Lot = 440

6. The total manufacturing cost for a lot of 300 Z1's to be mounted on FAT systems is $4,135,489.66. The estimated average manufacturing unit cost of the Z1, given the assumptions listed in this Section, is $13,784.97.

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13. ABSTRACT

This report presents a Cost Estimating Relationship (CER) to be used for predicting automatic cannon manufacturing theoretical first unit cost and learning slope. Physical and performance characteristics were examined as possible independent variables. The CER presented is based on gun weight, boresize, and projectile mass.

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