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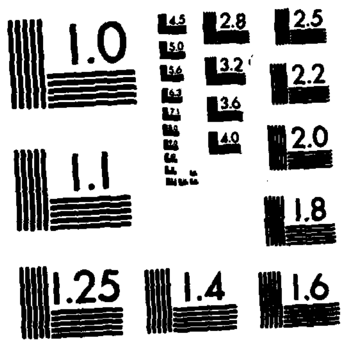

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AMMUNITION COST RESEARCH STUDY

VOLUME I

U.S. ARMY
ARRCOM

TECHNICAL REPORT

JANUARY 1983

COST ANALYSIS DIVISION (DRSAR-CPE)
HQ, US ARMY ARMAMENT MATERIEL READINESS COMMAND
ROCK ISLAND, ILLINOIS 61299

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ABSTRACT

This report presents statistically developed tools to estimate ammunition production costs at the component level-of-detail. These tools include learning rates and cost estimating relationships/ cost factors applicable during early life cycle cost estimating.

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I. INTRODUCTION

A BACKGROUND

Preparation of cost estimates for new ammunition proposals as well as for ammunition in production is always difficult because of the acquisition environment, the advancing technology and the trend in recent years for ammunition costs to escalate at a greater rate than inflation estimates. To compound the difficulty, availability of statistically reliable cost estimating methodology has been confined to relatively narrow bands of components or complete rounds. The major comprehensive study to address the problem and develop methods for estimating ammunition costs early in the life cycle was the ammunition cost research project initially chartered by the Cost Analysis Directorate of the Office of the Comptroller of the Army in April 1975. Responsibility for performing the study was assigned to the Cost Analysis Division Headquarters US Army Armament Command (ARMCOM) and results were published in June 1976 (Ref 1).

The results of that study have been widely used since that time in solving ammunition cost estimating problems However the data base has since aged, ammunition production technology has steadily improved and new concepts in materials and configurations have combined to mitigate the usefulness of that initial research study. Therefore, the need became apparent for updating the earlier work and improving and expanding it to help the defense community solve existing and anticipated cost estimating problems in the ammunition field. Hence this study was undertaken by the Cost Analysis Division at Headquarters US Army Armament Materiel Readiness Command in late 1981. This study supersedes the June 1976 study.

B. PURPOSE AND GENERAL APPROACH

The primary purposes of this study are to improve upon and broaden the scope of existing ammunition recurring investment cost estimating methodologies. These methodologies must be applicable to prevalent types and calibers of ammunition produced at various program quantities so that wide ranges of ammunition can be estimated easily and independently. The results of this study are intended to support decision making early in the acquisition process as well as during the annual budgetary cycles in the investment phase of the life cycle.

The intent was to develop tools featuring cost predictors at the component level-of-detail which can statistically predict costs based upon physical and performance characteristics. Cost behavior in response to experience curve theory was examined. Also relationships were investigated to determine quantitative measures of workload impacts on costs at the Army ammunition plants (AAP's). In addition an attempt was made to assess the impact of improved manufacturing technology on production costs and develop means to account for this in the estimating process.

Data collection priority was placed on the use of historical ammunition procurement data. These data were selected because they represent actual and anticipated ammunition procurement practices. Efforts were also made to collect data on friendly foreign developed/produced ammunition through various collection channels. However, it was found that only limited cost data were available and these were not suited for purposes of this study. Plant workload and production base support data were gathered from various monthly AAP summary records. Ammunition technical data were collected from appropriate technical manuals, engineering drawings and similar sources in the armament technical community.

C. SCOPE

This study specifically addresses the following:

1. Production cost estimating methodologies for the types of ammunition shown at Table I. As can be seen, methodology development was focused at the component level-of-detail except for small arms ammunition. The cost addressed by these methodologies is the production cost incurred by the producer and specified by cost element 2.02 in DA Pamphlet 11-3 (Ref 2).

2. Methodology to measure the impacts of manufacturing technology and manufacturing plant workload on ammunition production cost.

II. STUDY RESULTS

A. GENERAL ESTIMATING METHODOLOGIES

The primary approach pursued by this study for developing ammunition cost estimates was through the application of parametric tools at the component level-of-detail. The study results demonstrate that component level development of cost models should be used, given availability of data rather than attempting to prepare such models at the complete round level. While the component approach does not eliminate difficulties when advances in ammunition technology are incorporated into a new ammunition proposal, structuring the estimate at the component level limits these problems to the components involved in the change. When using total round level cost models and when faced with a new kind of component, such as a telescoped cartridge case, the estimator should reduce the reliability of the total estimate or abandon use of the model entirely. With component cost models, the estimator need only adopt alternate estimating techniques for the components that are unique.

This section of the study presents a summary of the cost model development with details of each model provided in Section III. The costs addressed in this study are confined to the contractor costs, and excluded in-house support costs. A deterrent to preparing estimating statistics covering support costs is the absence of an accounting system which collects in-house support costs allocated to the procurement of specific complete rounds and components. However, the support costs are not usually a significant portion of the acquisition cost and are, therefore, not a particular problem for the estimator.

1. Learning Rates. Learning rates, based on unit experience curve theory have been developed by ammunition component, and are presented in detail at Table IV. These rates vary from the previous research study since they are based on generally larger samples, and production data attributed to decreasing workload conditions have been excluded from this analysis. Learning rates for small arms ammunition were not developed due to the unavailability of the early historical production data.

2. Cost Estimating Relationships/Cost Factors. Table I presents a summary of recommended ammunition production cost estimating methodologies. The methodologies include cost estimating relationships (CER's) and cost factors. In this study, the dependent variable for all CER's is average unit production cost whereas the dependent variable for some CER's in the 1976 study was the theoretical first unit production cost. The theoretical first unit cost was not considered as a dependent variable in this study due to it's high sensitivity to changes in production-lot data. Instances where no parametric relationship resulted are due to either an inadequate data base or a statistically insignificant correlation between the production cost and the

TABLE I

AMMUNITION COST ESTIMATING METHODOLOGIES

	SMALL ARMS (Under 20mm)			MEDIUM BORE & TANK (20mm - 165mm)			HOWITZER (75mm - 8 in)				MORTAR (60mm - 4.2 in)			
	BALL	TRACER	BLANK	HE	AP	TP	HE	ILLUM	SMK	CHEM	HE	ILLUM	SMK	CHEM
Complete Round	X	X	X	-	-	-	-	-	-	-	-	-	-	-
LAP	-	-	-	X	X	X	X	X	N	N	N	X	N	N
Projectile	-	-	-	X	X	X	X	X	X	X	X	X	X	X
Case	-	-	-	X	X	X	X	X	X	-	-	-	-	-
Propellant	-	-	-	X	X	X	X	X	X	X	N	N	N	N
Primer	-	-	-	X	X	X	N	N	N	N	N	N	N	N
Explosive Fill	-	-	-	X	-	-	C	-	-	-	X	-	-	-
Fuze	-	-	-	C	-	-	C	-	C	C	C	N	C	N
Link	X	X	X	X	X	X	-	-	-	-	-	-	-	-

X: Cost estimating relationship (CER)/cost factor.

C Combination methodologies CER and conventional.

N: Conventional

-: Not applicable or data unavailable.

potential cost-driving variables. Conventional methods of cost estimating are recommended when no parametric relationship was developed. Statistically valid CER's were developed only for point detonating and proximity fuzes, and no CER's were developed for other fuze types but relevant production costs are provided in Section III.

3. Plant Analysis. Since the mid-1970's, production costs at the AAP's have been increasing at rates greater than can be explained by inflation. Hence, various plant factors were analyzed in an attempt to model these cost increases. Potential plant factors include measures of manufacturing technology and plant workload. Results achieved were limited and are useful only for internal ARRCOM purposes in conjunction with other information. Significant results for widespread usage were not achieved due to either limited available data or insignificant correlation.

B. USE OF AMMUNITION COST MODELS

The learning rates and CER's/cost factors are to be used to prepare and validate ammunition component and complete round cost estimates early in the item's life cycle. A complete round cost estimate is the sum of the component cost estimates. Later life cycle cost estimating and validation should make use of actual learning rates and production costs, as available, to minimize estimating uncertainty.

III. STUDY METHODOLOGY

A. AMMUNITION PROCUREMENT CONSIDERATIONS

The uniqueness of ammunition procurement practices is attributed in part to the number of manufacturers involved. It is not uncommon to find a wide mixture of contractor owned contractor operated (COCO) plants, Government owned contractor operated (GOCO) plants. and Government owned Government operated (GOGO) plants providing components that will become an integral part of an ammunition round. Figure I exemplifies the types of producers involved in manufacturing ammunition.

The bulk of production, which includes small arms ammunition items, artillery and mortar rounds, bombs, and fuzes, is done at AAP's. Basically, ammunition plants are classified into five categories:

1. Load. Assemble, and Pack (LAP)

2. Propellants and Explosives (P&E)

3. Small Arms Ammunition (SAA)

4. Metal Parts (MPTS)

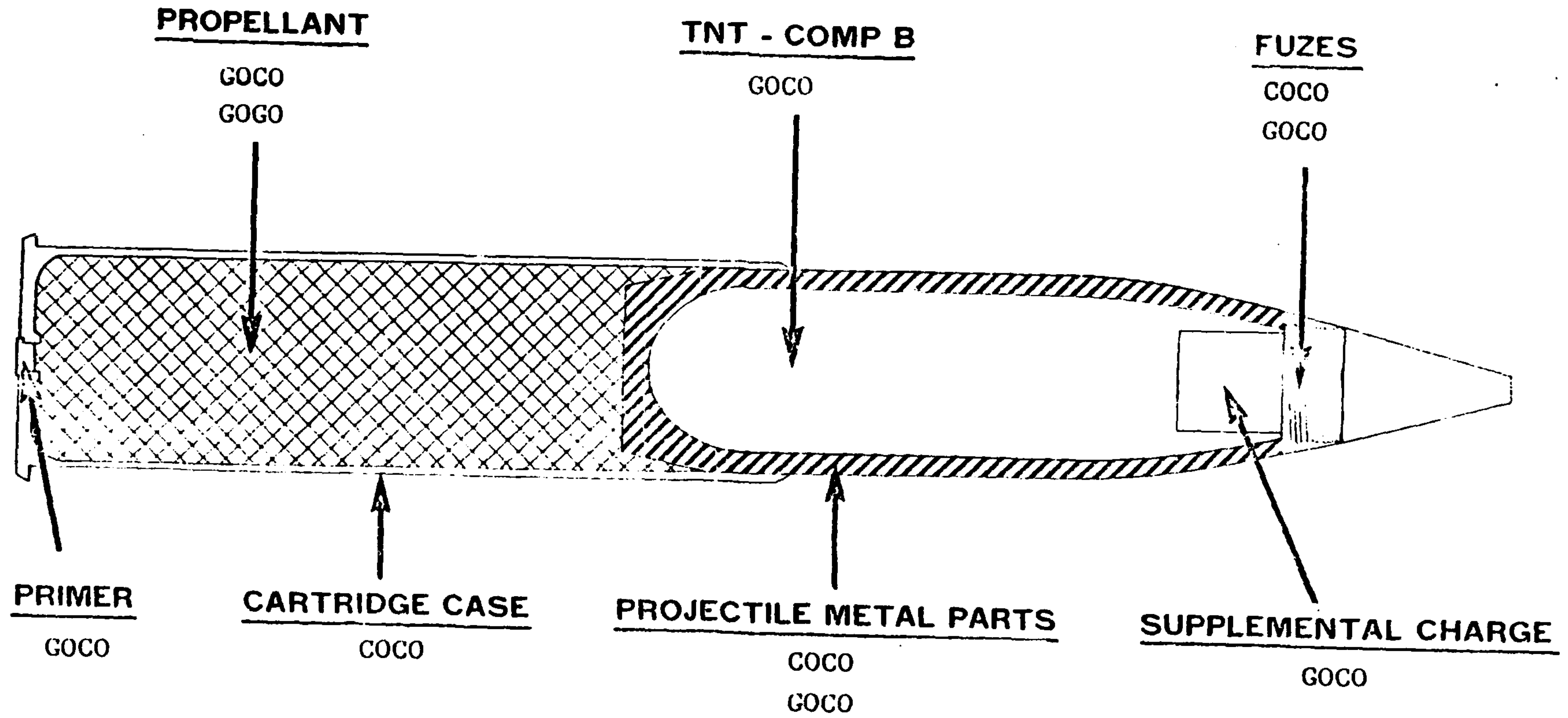
5. A plant with more than one of the above categories or multi-product use.

The types of contracts awarded for ammunition production vary. The LAP, P&E, SAA and multi-purpose plants normally operate under a cost-reimbursable contract with either fixed or incentive fee. The MPTS AAP's operate under a firm-fixed-price contract as do contractor owned plants.

Because there is no single producer of components that are used in the ammunition market, estimating the price is difficult. Consequently, the likelihood of incurring many different price combinations exists. Price combinations and the uncertainty of when inventory costs were incurred make it difficult to estimate the exact price of an ammunition round. For example, certain components may have been procured two years or more before becoming an integral part of a given round. The complete cost for the end item can be determined only when consideration is given to costs incurred by all producers involved in the manufacturing process. It is for this reason that individual components have been costed separately in this study.

FIGURE I

HIGH EXPLOSIVE COMPLETE AMMUNITION ROUND



In the production cost area these special considerations probably have the largest impact on the cost estimator. First. the data collection problems are greatly complicated because many manufacturers may have produced a component within a given round. Second. assuming that the first collective problem is solved and the data are cross-referenced and properly normalized for inflation. the estimator must determine the most likely learning rate from a myriad of manufacturers, producing over widely varying time periods and output rates. Third, external forces impacting on world-market economics are basically random and, hence, unpredictable. Finally, the estimating procurement method cannot possibly be duplicated in reality when the ammunition is finally procured because of the artificiality of the estimating assumptions.

B. DEVELOPMENT OF COST ESTIMATING RELATIONSHIPS AND FACTORS

1. Data Collection

ARRCOM ammunition procurement involves a mixture of ammunition obtained from COCO, GOCO, and GOGO plants. Most ammunition is procured from the GOCO's which support the Government's ammunition needs through the manufacture of propellants, explosives, metal parts, small arms, bag loading, and LAP. Each GOCO is operated by a major US corporation which was selected on the basis of proven success in management of large production operations. It is a common practice to find a variety of GOCO's, GOGO's and COCO's contributing components toward the final production of a round of ammunition. Thus, the collection of production data involves the accumulation of data generated by a variety of manufacturers.

Data collected for this portion of the study were taken from contract-price records and production-delivery schedules available in the ARRCOM Production and Product Assurance Directorates and represent procurements from 1951-1981.

a. Procurement Cost Data

The Summary of Orders and Cost of Deliveries (DRSAR Form 276) is a record of contract pricing which lists the production quantities and costs for the components ordered from GOCO plants. This record is created from a number of source documents furnished by producers and ordering officials. The summarization of data includes cost and delivery data incurred during the reporting period and cumulative cost and delivery data incurred from the inception of the procurement order.

The Component Cost Record (DRSAR Form 276-1) provides contract pricing information for metal parts manufactured by contractor owned plants. This record includes essentially the same production data as the Summary of Orders and Cost of Deliveries.

LAP, projectiles, explosive fill, primers, fuzes, cases, propellants, small arms ammunition and links are analyzed in this study. Tracking quantities and costs from the Summary of Orders and Cost of Deliveries and Component Cost Records required the analysis of approximately 11,500 line entries. Capturing quantities and costs for a specific round of ammunition required collecting data according to the components of the round and any related LAP operation. Data were collected from fiscal year 1951 through 1981 as available.

b. Production Quantity Data

The source documents used to capture delivery data were production-delivery schedules and ammunition data cards. The production-delivery schedule is a report that is prepared monthly by each active GOCO and GOGO. The report provides item production and final acceptance data. The ammunition data card is a delivery and acceptance report reflecting quantities shipped by a COCO. GOCO or GOGO.

Collecting production delivery data required an analysis of approximately 17,000 line entries. Analyzed production rates encompassed the review of data generated from fiscal years 1952 through 1980. The review disclosed instances in which production delivery data were available but corresponding costs could not be collected because of the unavailability of the applicable procurement cost record. Production quantities without corresponding costs were collected to determine potential breaks in production and insufficient initial production record.

c. Technical Data

Table II presents a listing of the physical and performance characteristics for which quantitative data have been gathered by complete round or ammunition component. These characteristics were chosen as potential independent variables for CER development because they are known in early development, and it was hypothesized that they could exhibit correlation with production cost. The technical data were collected from technical manuals, engineering drawings and similar sources in the armament technical community (Ref 3-9). Definitions of the technical characteristics are at Appendix A.

TABLE II

TECHNICAL DATA CATEGORIES

	Physical Characteristics	Performance Characteristics
Complete Round Level	Bore Size	Muzzle Velocity
	Cartridge Weight	Maximum Range
	Cartridge Length	Chamber Pressure
	Propellant Weight	Momentum
		Kinetic Energy
Component Level	Projectile Weight	
	Projectile Mass	
	Case Material	
	Case Length	
	Fuze Weight	
	Fuze Length	
	Fuze Number of Parts	
	Explosive Fill Weight	

2. Cost Data Normalization

All historical cost data were normalized to FY 80 constant dollars. FY 80 was chosen as the base year for inflation purposes because the final inflation rate for FY 81 was not available at the time the data were normalized. Historical inflation factors were developed for the following ammunition categories based on wholesale price indices (Ref 10-12).

Brass Cartridge Cases	Propellant Single Base
Steel Cartridge Cases	Propellant Double & Triple Base
Steel Cartridge Cases (Spiral)	Links
Combustible Cartridge Cases	Primers & Bursters
Aluminum Cartridge Cases	LAP Small Arms & TP
Forged Projectiles (20mm-30mm)	LAP Fuzes, CS & SMK
HE Forged Projectiles	LAP HE, HVAP & ILLUM
Cast Projectiles	BD (Non-Elec) & PD Fuzes
AP Projectiles	BD (Elec) Fuzes
APERS Projectiles	MT Fuzes
APFSDS Projectiles	PROX & VT Fuzes
HEAT Projectiles	Time Fuzes
ILLUM Projectiles	General Ammo
Explosive (Non-Oil Base)	

3. Analysis of Learning

Application of cost improvement curves adds great flexibility to the estimator's tools (Ref 13). It allows CER's to be applied easily to a wide range of procurement quantities with relatively simple calculations. Therefore. it became an objective of this study to develop CER's which could be coupled to learning rates wherever possible. To accomplish this objective, a critical question had to be answered:

> When the estimator must consider the use of learning, what are the proper learning rates to be used for each component assuming that there will probably be more than one producer?

Based upon linear regression theory,

$$B = \frac{\sum LnY}{\sum LnX}$$

where: B = Exponent corresponding to the composite learning rate

Y = Normalized lot average unit cost

X = Computed algebraic lot midpoint corresponding to Y

The composite learning rate was determined using the following equation:

$$\text{Learning Rate} = \text{Antilog}\ (0.30103\ B + 2)$$

b. Results

The composite learning rates and associated sampling data are displayed in Table III. Relative levels of confidence in the learning rates can be assessed based on the sampling data.

4. Component Cost Predictors

The cost estimating relationships (CER's) and cost factors presented in this study were developed using the UCLA BIOMEDICAL stepwise regression computer program (Ref 14). The computer program is a standard regression analysis package which sequentially adds an independent variable to the regression equation based on the variable exhibiting the greatest reduction in unexplained variation. Also, the computer program allows the analyst the flexibility of transforming and/or combining initial variables to test various equation forms against the desired dependent variable.

Regression analyses using appropriate physical and performance characteristics as independent variables and average unit costs as dependent variables were performed at the ammunition component level, except for small arms ammunition where the regression analyses were performed at the complete round level. Independent variables were allowed to stepwise enter and remain in the regression equation until a variable's coefficient was statistically not different from zero at the 0.10 level of significance based on Students t-distribution.

Table IV presents a directory of component production cost predictors by ammunition class. Definitions of the statistics that accompany the CER's are at Appendix B.

a. Methodology for Analysis of Learning.

(1) Selection of data for calculation of learning rates.

(a) The following criteria were established for selecting historical data for performing learning curve analyses.

1 The component must have two or more years of production cost history. A minimum of two data points are required to determine a relationship.

2 When a production break occurred and a reduced cost was experienced after the production break, the break was ignored.

3 When the constant-year cost data appeared inordinately high compared to prior years, only production cost history for the prior years were used since the increased costs are not associated with negative learning.

(b) Learning curves were developed for each producer by item within each component. The following criteria were then established for determining which learning curves would be used in developing a component composite learning rate.

1 Individual learning curves greater than 100 percent were excluded because cost increases are attributed to causes other than learning.

2 Extreme learning curves in the lower range were also eliminated since they are considered abnormal for highly automated production. This excluded any learning curves less than 80 percent.

(2) Calculations of the composite learning rate.

Once the learning results had been screened using the criteria outlined above, composite learning rates by component were determined. The regression form used in developing the composite learning rate is:

$$Y = AX^B$$

To normalize the cost data for each learning curve, the theoretical first-unit cost was set equal to 1.0. The ratio of 1.0 to the original theoretical first-unit cost was applied to the actual lot average unit costs resulting in normalized lot average unit costs. Since the theoretical first-unit costs were set equal to 1.0, the regression form above reduced to:

$$Y = X^B$$

TABLE III
COMPOSITE LEARNING RATES

Component	Composite Learning Rate	Sampling Data: $80 \le LR \le 100$	Sampling Data: $100 < LR < 80$	Sampling Data: Single Production Lot	Sampling Data: Total
LAP					
High Explosive	90.4	42	16	6	64
Armor Piercing	94.6	4	2	0	6
Target Practice	93.5	19	2	3	24
Illuminating	92.9	9	2	6	17
Smoke	93.1	7	6	5	18
Chemical	93.8	6	2	1	9
Projectile					
High Explosive	91.0	71	15	57	143
Armor Piercing	93.3	5	2	9	16
Target Practice	91.8	30	1	20	51
Illuminating	94.9	10	3	6	19
Smoke	92.6	9	2	6	17
Chemical	98.3	3	1	5	9
Case					
Brass	92.8	8	0	6	14
Steel	94.1	16	6	6	28
Aluminum	88.5	10	2	3	15
Combustible	84.8	2	0	1	3
Propellant	94.5	27	16	16	59
Prop Charge	89.7	16	8	1	25
Explosive Fill	94.9	9	5	1	15
Primer					
Percussion	91.0	30	1	1	32
Electric	91.7	5	1	3	9
Fuze					
Base Detonating	90.2	2	2	0	4
Point Detonating	93.7	8	3	8	19
Point Initiating, Base Detonating	87.1	4	0	0	4
Mechanical Time	92.0	6	0	7	13
Mechanical Time & Superquick	86.2	3	1	1	5
Time	86.9	2	0	2	4
Link	89.0	17	6	25	48
Small Arms	No composite learning rate due to lack of comprehensive historical production data.				

TABLE IV

AMMUNITION COMPONENT CER DIRECTORY

(Location by Page)

	SMALL ARMS (Under 20mm)			MEDIUM BORE & TANK (20mm - 165mm)			HOWITZER (75mm - 8 in)				MORTAR (60mm - 4.2 in)			
	BALL	TRACER	BLANK	HE	AP	TP	HE	ILLUM	SMK	CHEM	HE	ILLUM	SMK	CHEM
Complete Round	46	47	48	-	-	-	-	-	-	-	-	-	-	-
LAP	-	-	-	16	18	19	17	20	-	-	-	20	-	-
Projectile	-	-	-	21	27	28	23	31	30	32	25	31	30	32
Case	-	-	-	33 & 34			33 & 34				-	-	-	-
Propellant	-	-	-	36	36	36	39	39	39	39	-	-	-	-
Primer	-	-	-	40	40	40	-	-	-	-	-	-	-	-
Explosive Fill	-	-	-	41	-	-	41	-	-	-	42	-	-	-
Fuze	-	-	-	43 & 45			43 & 45				43 & 45			
Link	49	49	49	49	49	49	-	-	-	-	-	-	-	-

a. Load, Assemble and Pack

Loading, assembling and packing (LAP) costs cover the costs of component assembly into a complete round ready for shipping. These costs include the packing (including ready boxes) and other materials (handling, dunnage. pallets, etc.) normally purchased by the LAP plant.

Application: Medium-bore automatic cannon and tank main-armament high explosive ammunition.

$$\text{LnZ} = -3.3638 + 1.8822 \text{ LnX} - 0.1471 \text{ LnY}$$

$$\text{or} \quad Z = 0.03460 \, X^{1.8822} \, Y^{-0.1471}$$

where: Z = Estimated unit cost in FY 80 constant dollars
X = Bore size in millimeters
Y = Production quantity

Statistics:

Coefficient of determination	= 0.975
Standard error of estimate in Ln form	= 0.329
Coefficient of variation	= 0.117
Mean absolute percent deviation	= 26.7
Sample size	= 14

CER Data

Cartridge	Bore Size (mm)	Production Quantity	Actual Unit Cost	Estimated Unit Cost
M56A3 HEI	20	188,564,487	$ 0.76	$ 0.59
M210 HEI	20	724,400	0.91	1.34
M246 HEIT	20	14,452,800	1.01	0.86
M242 HEIT	20	320,800	1.22	1.51
M393 HEP-T	105	1,807,878	20.84	26.50
M456 HEAT-T	105	997,958	22.03	28.92
M496 HEAT	76	161,961	35.06	20.56
M71 HE	90	400	50.95	68.35
M431 HEAT	90	20,131	53.88	38.41
M356 HET	120	59,844	56.59	56.24
M123 HEP	165	83,461	70.07	97.51
M657 HET	152	87,628	72.24	82.96
M409 HEAT-T	152	386,138	90.19	66.71
M71 HE	90	50	123.09	92.81

a. LAP (continued)

Application: Howitzer high explosive ammunition

$$\ln Z = 0.5653 + 2.0120 \ln X - 0.3011 \ln Y$$

or $$Z = 1.7600\, X^{2.0120}\, Y^{-0.3011}$$

where Z = Estimated unit cost in FY 80 constant dollars
X = Cartridge length in inches
Y = Production quantity

Statistics·

Coefficient of determination	= 0.885
Standard error of estimate in Ln form	= 0.446
Coefficient of variation	= 0.126
Mean absolute percent deviation	= 35.7
Sample size	= 22

CER Data

Cartridge	Cartridge Length (in)	Production Quantity	Actual Unit Cost	Estimated Unit Cost
M1 HE	31.07	34,357,009	$ 6.57	$ 9.53
M107 HE	23.89	22,169,737	6.58	6.41
M1 HE	31.07	28,450,261	7.08	10.09
M1 HE	31.07	24,300.417	7.74	10.58
M107 HE	23.89	5,917,106	10.71	9.54
M107 HE	23.89	2,400.926	13.20	12.52
M329 HE	25.79	6,657,483	14.33	10.74
M329 HE	25.79	955,264	14.63	19.27
M106 HE	34.35	1,221,562	17.53	31.86
M106 HE	34.35	1,820,789	18.62	28.25
M106 HE	34.35	961,627	27.22	34.24
M449 HE	27.50	144,490	42.82	38.73
M449 HE	27.50	153,990	51.55	37.99
M483 HE	35.40	705.433	56.01	39.93
M437 HE	37.23	112,416	64.22	76.83
M483 HE	35.40	912,648	72.62	36.96
M404 HE	34.90	144,582	94.43	62.54
M549 HE	34.39	318,320	95.29	47.87
M795 HE	33.20	1,996	157.45	205.35
M549 HE	34.39	300	175.33	389.98
M483 HE	35.40	24,327	239.60	110.06
M509 HE	43.90	1,640	390.51	382.18

a. LAP (continued)

Application: Medium-bore automatic cannon and tank main-armament armor piercing ammunition.

$$\mathrm{Ln}Z = -1.0086 + 0.1152\ X$$

where Z = Estimated unit cost in FY 80 constant dollars
X = Cartridge length in inches

Statistics:

Coefficient of determination	= 0.993
Standard error of estimate in Ln form	= 0.131
Coefficient of variation	= 0.053
Mean absolute percent deviation	= 8.1
Sample size	= 6

CER Data

Cartridge	Cartridge Length (in)	Actual Unit Cost	Estimated Unit Cost
M53 API	6.58	$ 0.79	$ 0.78
M392A2 APDS-T	33.0	15.36	16.34
M339 APT	32.89	15.48	16.14
M728 APDS-T	33.0	16.78	16.34
M318 APT	37.43	23.64	27.23
M735 APFSDS-T	37.94	35.42	28.87

a. LAP (continued)

Application: Medium-bore automatic cannon, tank main-armament and mortar target practice ammunition.

$$\text{LnZ} = -4.0057 + 1.9083\ \text{LnX} - 0.1442\ \text{LnY}$$

or

$$Z = 0.01821\ X^{1.9083}\ Y^{-0.1442}$$

where Z = Estimted unit cost in FY 80 constant dollars
X = Bore size in millimeters
Y = Production quantity

Statistics:

Coefficient of determination	= 0.961
Standard error of estimate in Ln form	= 0.366
Coefficient of variation	= 0.159
Mean absolute percent deviation	= 28.8
Sample size	= 15

CER Data

Cartridge	Bore Size (mm)	Production Quantity	Actual Unit Cost	Estimated Unit Cost
M55A2 TP	20	203,466,782	$ 0.26	$ 0.35
M220 TPT	20	43,805,117	0.40	0.44
M206 TPT	20	1,303,177	1.23	0.73
M50A2 TP	60	451,603	4.31	6.89
M490 TPT	105	4,794,658	13.05	14.26
M467 TPT	105	388,335	13.74	20.49
M340A1 TPT	76	120,825	14.16	13.09
M456 TPT	105	307,722	14.76	21.19
M353 TPT	90	1,245,698	17.63	12.91
M393A1 TPT	105	274,083	20.20	21.55
M764 TPT	90	37,000	22.08	21.43
M764 TPT	90	83,396	28.47	19.06
M411 TPT	152	767,880	52.70	37.63
M411 TPT	152	638,249	60.59	38.64
M623 TP	165	3,590	65.80	95.38

a. LAP (continued)

Application: Mortar and howitzer illuminating ammunition.

$$LnZ = -7.1972 + 2.3118\ LnX$$

or $$Z = 0.0007487\ X^{2.3118}$$

where: Z = Estimated unit cost in FY 80 constant dollars
X = Bore size in millimeters

Statistics:

Coefficient of determination	= 0.990
Standard error of estimate in Ln form	= 0.096
Coefficient of variation	= 0.028
Mean absolute percent deviation	= 6.2
Sample size	= 5

CER Data

Cartridge	Bore Size (mm)	Actual Unit Cost	Estimated Unit Cost
M83A3 ILLUM	60	$ 9.58	$ 9.66
M301A3 ILLUM	81	17.90	19.34
M314A3 ILLUM	105	36.42	35.23
M335A2 ILLUM	107	41.65	36.80
M485 ILLUM	155	80.79	86.70

b. Projectiles

Projectile metal parts costs include procurement costs of all body parts excluding fuze parts. going into the LAP operations. The costs include profit and fees.

Application: Medium-bore automatic cannon and tank main-armament high explosive ammunition.

$$LnZ = -5.9722 + 2.4869\ LnX - 0.1040\ LnY$$

$$\text{or} \quad Z = 0.002549\ X^{2.4869}\ Y^{-0.1040}$$

where: Z = Estimated unit cost in FY 80 constant dollars
X = Bore size in millimeters
Y = Production quantity

Statistics:

Coefficient of determination	= 0.963
Standard error of estimate in Ln form	= 0.468
Coefficient of variation	= 0.193
Mean absolute percent deviation	= 34.6
Sample size	= 36

CER Data

Projectile	Bore Size (mm)	Production Quantity	Actual Unit Cost	Estimated Unit Cost
M56 HEI	20	9,000,000	$ 0.53	$ 0.83
M242 HEIT	20	1.077,276	0.57	1.03
M97 HEI	20	569,500	0.65	1.11
M246 HEIT	20	9,076,056	0.68	0.83
M56 HEI	20	120,379,370	0.71	0.63
M246 HEIT	20	4,233,520	0.71	0.90
M246 HEIT	20	2,406,080	0.73	0.95
M242 HEIT	20	766,836	0.76	1.07
M246 HEIT	20	1,436,900	0.80	1.00
M56 HEI	20	41,011,844	0.88	0.71
M56 HEI	20	52,589,192	1.06	0.69
M56 HEI	20	5,844,438	1.08	0.87
M246 HEIT	20	1,758,134	1.09	0.98
M246 HEIT	20	10,044,367	1.17	0.82
M56 HEI	20	42,000	1.17	1.45
M56 HEI	20	636,795	3.03	1.09
M495 HEAT	76	92,060	31.22	36.93
M393 HEP-T	105	1,488,088	34.69	61.78

b. Projectiles (continued)

Projectile	Bore Size (mm)	Production Quantity	Actual Unit Cost	Estimated Unit Cost
M393 HEP-T	105	2,079,496	$ 34.88	$ 59.67
M431 HEAT	90	934.309	45.78	44.07
M456 HEAT-T	105	210,330	46.85	75.72
M456 HEAT-T	105	159,696	57.21	77.92
M456 HEAT-T	105	299,400	57.55	72.99
M456 HEAT-T	105	1.178,988	63.68	63.30
M431 HEAT	90	212,400	77.76	51.56
M456 HEAT-T	105	568,328	82.76	68.29
M456 HEAT-T	105	2,000	92.44	122.88
M495 HEAT	76	92.060	106.58	40.07
M495 HEAT	76	30,750	111.09	41.40
M431 HEAT	90	934,309	124.33	44.19
M356 HET	120	18,000	145.93	136.28
M657 HET	152	69,050	153.45	213.32
M409 HEAT-T	152	41,200	182.00	225.09
M409 HEAT-T	152	41.200	186.42	225.09
M409 HEAT-T	152	401,650	194.42	177.63
M409 HEAT-T	152	34,000	258.22	229.64

b. Projectiles (continued)

Application Howitzer high explosive ammunition.

$$\mathrm{Ln}Z = 1.1366 + 0.6913\ \mathrm{Ln}X + 1.1868\ \mathrm{Ln}Y - 0.1172\ \mathrm{Ln}W$$

or $$Z = 3.1162\ X^{0.6913}\ Y^{1.1868}\ W^{-0.1172}$$

where Z = Estimated unit cost in FY 80 constant dollars
X = Projectile mass
Y = Cartridge length in inches
W = Production quantity

Statistics:

Coefficient of determination	= 0.872
Standard error of estimate in Ln form	= 0.281
Coefficient of variation	= 0.062
Mean absolute percent deviation	= 21.7
Sample size	= 40

CER Data

Projectile	Projectile Mass	Cartridge Length (in)	Production Quantity	Actual Unit Cost	Estimated Unit Cost
M1 HE	1.0257	31.07	100,963,472	$ 19.47	$ 21.59
M1 HE	1.0257	31.07	1,500,000	24.88	35.36
M1 HE	1.0257	31.07	23,848,148	24.99	25.57
M1 HE	1.0257	31.07	7,171,318	26.78	29.44
M449 HE	2.9527	27.5	1,276,636	44.62	64.75
M107 HE	2.9713	23.89	513,977	53.40	61.22
M107 HE	2.9713	23.89	3,235,162	56.13	49.35
M107 HE	2.9713	23.89	10,784,588	56.32	42.85
M107 HE	2.9713	23.89	217,500	57.47	67.71
M107 HE	2.9713	23.89	5,771,017	59.02	46.11
M107 HE	2.9713	23.89	2,283,032	61.92	51.41
M107 HE	2.9713	23.89	985,033	63.21	56.73
M449 HE	2.9527	27.5	83,807	64.00	89.10
M107 HE	2.9713	23.89	62,230	64.86	78.41
M107 HE	2.9713	23.89	4,447,637	65.02	47.54
M107 HE	2.9713	23.89	440,960	65.57	62.33
M449 HE	2.9527	27.5	290,444	72.91	77.02
M449 HE	2.9527	27.5	95,856	73.44	87.71
M449 HE	2.9527	27.5	120,000	77.10	85.43
M107 HE	2.9713	23.89	114,000	80.34	73.04
M106 HE	6.2473	34.35	2,215,435	91.36	132.69
M107 HE	2.9713	23.89	910,139	97.55	57.25
M106 HE	6.2473	34.35	410,385	104.88	161.68

b. Projectiles (continued)

Projectile	Projectile Mass	Cartridge Length (in)	Production Quantity	Actual Unit Cost	Estimated Unit Cost
M437 HE	4.5689	37.23	4,451,864	$105.33	$108.36
M106 HE	6 2473	34.35	1.967.765	108.29	134.55
M437 HE	4.5689	37.23	142,300	109.08	162.23
M106 HE	6.2473	34.35	1.717,309	116.01	136.70
M437 HE	4.5689	37.23	263,000	144.01	150.96
M692 HE	3.1858	35.4	294.610	150.52	109.36
M404 HE	6.2162	34.9	135,570	151.56	186.94
M106 HE	6.2473	34.35	65,117	154.18	200.62
M437 HE	4.5689	37.23	130,000	155.57	163.96
M483 HE	3.1889	35.4	471.500	161.76	103.57
M483 HE	3.1889	35.4	1,816,354	162.49	88.42
M404 HE	6.2162	34.9	31,220	213.36	222.05
M404 HE	6.2162	34.9	20,400	223.81	233.41
M404 HE	6.2162	34.9	21,720	251.04	231.69
M509 HE	6.4182	43.9	44,776	359.39	285.72
M650 HE	6.2162	43.9	13,200	405.25	322.50
M509 HE	6.4182	43.9	4,709	627.03	372.04

b. Projectiles (continued)

Application Mortar and grenade high explosive ammunition.

$$\text{Ln}Z = -1.9101 + 1.5434\ \text{Ln}X$$

or $$Z = 0.1481\ X^{1.5434}$$

where: Z = Estimated unit cost in FY 80 constant dollars
X = Cartridge length in inches

Statistics:

Coefficient of determination	= 0.983
Standard error of estimate in Ln form	= 0.182
Coefficient of variation	= 0.124
Mean absolute percent deviation	= 13.9
Sample size	= 8

CER Data

Projectile	Cartridge Length (in)	Actual Unit Cost	Estimated Unit Cost
M433 HEDP	4.05	$ 1.06	$ 1.28
M383 HE	4.42	1.43	1.47
M384 HE	4.42	1.51	1.47
M406 HE	3.89	1.54	1.21
M49 HE	11.59	5.73	6.50
M362 HE	20.84	13.03	16.07
M374 HE	20.84	18.10	16.07
M329 HE	25.77	26.09	22.31

b. Projectiles (continued)

Application: Recoilless rifle high explosive ammunition.

$$\mathrm{Ln}Z = -11.2272 + 3.2281\ \mathrm{Ln}X$$

or

$$Z = (0.1331 \times 10^{-4})\ X^{3.2281}$$

where: Z = Estimated unit cost in FY 80 constant dollars
X = Bore size in millimeters

Statistics:

Coefficient of determination	= 0.951
Standard error of estimate in Ln form	= 0.204
Coefficient of variation	= 0.063
Mean absolute percent deviation	= 14.8
Sample size	= 9

CER Data

Projectile	Bore Size (mm)	Actual Unit Cost	Estimated Unit Cost
M306 HE	57	$ 5.90	$ 6.20
M306 HE	57	6.31	6.20
M371 HEAT	90	27.60	27.07
M371 HEAT	90	29.87	27.07
M344 HEAT	106	35.33	45.91
M344 HEAT	106	36.11	45.91
M346 HEP-T	106	41.05	45.91
M344 HEAT	106	58.11	45.91
M344 HEAT	106	61.49	45.91

b. Projectiles (continued)

Application: Medium-bore automatic cannon and tank main-armament armor piercing ammunition with full-bore penetrator.

$$\text{LnZ} = -0.1434 + 0.03980\ X$$

where: Z = Estimated unit cost in FY 80 constant dollars
X = Bore size in millimeters

Statistics:

Coefficient of determination	= 0.990
Standard error of estimate in Ln form	= 0.202
Coefficient of variation	= 0.069
Mean absolute percent deviation	= 13.8
Sample size	= 4

CER Data

Projectile	Bore Size (mm)	Actual Unit Cost	Estimated Unit Cost
M53 API	20	$ 1.72	$ 1.92
M339 APT	76	21.37	17.83
M318 APT	90	34.22	31.13
M358 APT	120	86.90	102.73

b. Projectiles (continued)

Application: Medium-bore automatic cannon and tank main-armament target practice ammunition.

$$\mathrm{Ln}Z = -5.6566 + 2.2628\ \mathrm{Ln}X - 0.09840\ \mathrm{Ln}Y$$

or

$$Z = 0.003494\ X^{2.2628}\ Y^{-0.09840}$$

where: Z = Estimated unit cost in FY 80 constant dollars
X = Bore size in millimeters
Y = Production quantity

Statistics:

Coefficient of determination	= 0.981
Standard error of estimate in Ln form	= 0.306
Coefficient of variation	= 0.169
Mean absolute percent deviation	= 24.4
Sample size	= 37

CER Data

Projectile	Bore Size (mm)	Production Quantity	Actual Unit Cost	Estimated Unit Cost
M55A2 TPT	20	19,301,196	$ 0.41	$ 0.59
M55A2 TPT	20	32,357,167	0.46	0.56
M55A2 TPT	20	1,000,000	0.50	0.79
M55A2 TPT	20	16,380,749	0.52	0.60
M55A2 TPT	20	83,004,052	0.53	0.51
M221 TPT	20	18,356,990	0.58	0.59
M212A1 TPT	20	4,465,331	0.61	0.68
M55A2 TPT	20	5,148,814	0.63	0.67
M55A2 TPT	20	71,031,888	0.66	0.52
M221 TPT	20	11,450,062	0.67	0.62
M221 TPT	20	9,852,794	0.67	0.63
M221 TPT	20	4,249,221	0.74	0.68
M221 TPT	20	3,515,090	0.75	0.70
M55A2 TPT	20	17,062,338	0.81	0.60
M212A1 TPT	20	507,820	0.85	0.84
M212A1 TPT	20	200,000	1.26	0.92
M212A1 TPT	20	163,520	1.62	0.94
M340 TPT	76	106,000	11.97	20.17
M340 TPT	76	121,600	14.55	19.90
M353 TPT	90	1,514,480	15.30	22.76
M353 TPT	90	1,214,800	15.59	23.26
M353 TPT	90	226,100	18.10	27.45
M353 TPT	90	335,300	19.22	26.40
M489 TPT	105	130,885	35.43	41.05
M489 TPT	105	133,349	36.84	40.98
M489 TPT	105	79,600	36.94	43.11
M489 TPT	105	3,323,017	38.32	29.86
M468 TPT	105	401,287	40.11	36.77

b. Projectiles (continued)

Projectile	Bore Size (mm)	Production Quantity	Actual Unit Cost	Estimated Unit Cost
M489 TPT	105	216,360	$ 40.80	$ 39.07
M489 TPT	105	1,188,096	49.69	33.04
M489 TPT	105	1,646,731	56.21	32.00
M411 TPT	152	802,780	59.03	79.31
M489 TPT	105	251,000	69.20	38.50
M359 TPT	120	74,300	79.23	58.72
M411 TPT	152	73,775	108.90	100.31
M411 TPT	152	332,585	116.57	86.50
M623 TP	165	3,590	176.43	162.62

b. Projectiles (continued)

Application: Howitzer, mortar and recoilless rifle smoke ammunition.

$$\ln Z = 4.8490 + 0.7014 \ln X - 0.1001 \ln Y$$

or $$Z = 127.6127\, X^{0.7014}\, Y^{-0.1001}$$

where: Z = Estimated unit cost in FY 80 constant dollars
X = Projectile mass
Y = Production quantity

Statistics

Coefficient of determination	= 0.917
Standard error of estimate in Ln form	= 0.270
Coefficient of variation	= 0.090
Mean absolute percent deviation	= 17.8
Sample size	= 16

CER Data

Projectile	Projectile Mass	Production Quantity	Actual Unit Cost	Estimated Unit Cost
M375 WP	0.2831	1,440,200	$ 7.26	$12.74
M308A1 WP	0.0855	51,500	7.49	7.68
M302 WP	0.1224	183,800	7.49	8.69
M302 WP	0.1224	2,114,950	8.12	6.81
M308A1 WP	0.0855	10,486	8.34	9.00
M308A1 WP	0.0855	46,502	8.61	7.76
M375 WP	0.2831	2,324,868	12.23	12.14
M328 WP	0.8715	114,100	23.72	36.12
M370 WP	0.2838	160,200	26.24	15.90
M60 WP	1.0070	2,887,160	30.30	28.93
M84 SMK	1.0226	271,200	33.01	37.06
M416 WP	0.7708	455,893	36.05	28.85
M328 WP	0.8715	340,500	41.63	32.38
M84 SMK	1.0226	36,800	45.59	45.25
M116 SMK	2.6801	123,600	77.84	78.79
M110 WP	3.0612	428,250	79.73	76.38

b. Projectiles (continued)

Application: Howitzer and mortar illuminating ammunition.

$$\text{LnZ} = 2.8373 + 0.6454\ X$$

where: Z = Estimated unit cost in FY 80 constant dollars
X = Projectile mass

Statistics:

Coefficient of determination	= 0.872
Standard error of estimate in Ln form	= 0.364
Coefficient of variation	= 0.097
Mean absolute percent deviation	= 26.3
Sample size	= 6

CER Data

Projectile	Projectile Mass	Actual Unit Cost	Estimated Unit Cost
M83 ILLUM	0.1277	$ 15.69	$ 18.54
M335 ILLUM	0.7888	26.47	28.40
M314 ILLUM	1.1339	28.89	35.49
M301 ILLUM	0.3061	31.87	20.80
M485 ILLUM	2.8594	75.32	108.08
M118 ILLUM	3.2145	198.19	135.93

b. Projectiles (continued)

Application Howitzer and mortar chemical agent ammunition.

$$\mathrm{Ln}Z = 6.1832 + 0.8716\ \mathrm{Ln}X - 0.2440\ \mathrm{Ln}Y$$

or

$$Z = 484.5400\ X^{0.8716}\ Y^{-0.2440}$$

where: Z = Estimated unit cost in FY 80 constant dollars
X = Projectile mass
Y = Production quantity

Statistics:

Coefficient of determination	= 0.947
Standard error of estimate in Ln form	= 0.200
Coefficient of variation	= 0.048
Mean absolute percent deviation	= 12.3
Sample size	= 6

CER Data

Projectile	Projectile Mass	Production Quantity	Actual Unit Cost	Estimated Unit Cost
M633 CS	0.8221	159,000	$ 25.62	$ 21.97
M121 VX	3.0739	297,100	46.30	59.54
M629 CS	1.0257	11,000	46.77	51.13
M121 VX	3.0739	236,369	67.07	62.96
M121 VX	3.0739	64,260	84.78	86.51
M426 VX	6.3506	67,000	186.18	161.19

c. Cases

Application: Medium-bore automatic cannon, tank main-armament and howitzer brass cases.

$$LnZ = -0.4643 + 0.9538\ LnX - 0.1315\ LnY$$

or $$Z = 0.6286\ X^{0.9538}\ Y^{-0.1315}$$

where: Z = Estimated unit cost in FY 80 constant dollars
X = Proxy area variable in square inches
Y = Production quantity

Statistics:

Coefficient of determination	= 0.994
Standard error of estimate in Ln form	= 0.175
Coefficient of variation	= 0.092
Mean absolute percent deviation	= 11.7
Sample size	= 13

NOTE: The proxy area variable is defined as the bore area plus the area of the surface of the cylinder represented by the bore and the cartridge case length. The formula is:

$$\text{Proxy Area Variable} = \pi r^2 + 2\pi rL$$

where: r = Bore radius in inches
L = Cartridge case length in inches

The millimeter-to-inch conversion factor is 0.03937.

CER Data

Cartridge Case	Proxy Area Variable (in^2)	Production Quantity	Actual Unit Cost	Estimated Unit Cost
M103	10.41	10,170,000	$ 0.55	$ 0.70
M103	10.41	301,866,314	0.58	0.45
M103	10.41	113,027,876	0.58	0.51
M103	10.41	28,478,342	0.60	0.62
M21A1	11.22	3,914,000	0.82	0.86
M14	203.55	2,841,340	11.63	14.19
M14	203.55	423,000	19.16	18.23
M115	329.15	537,977	24.79	27.94
M150	329.15	547,000	25.33	27.87
T27	273.69	141,690	28.87	27.92
M150	329.15	283,800	29.95	30.38
M109	504.36	120,337	50.40	51.10
M109	504.36	23,000	86.24	63.52

c. Cases (continued)

Application: Medium-bore automatic cannon, tank main-armament, howitzer and recoilless rifle steel cases.

$$\text{Ln}Z = -0.8255 + 1.4890\ \text{Ln}X - 0.05948\ \text{Ln}Y$$

or $$Z = 0.4380\ X^{1.4890}\ Y^{-0.05948}$$

where: Z = Estimated unit cost in FY 80 constant dollars
X = Cartridge case length in inches
Y = Production quantity

Statistics·

Coefficient of determination	= 0.767
Standard error of estimate in Ln form	= 0.347
Coefficient of variation	= 0.125
Mean absolute percent deviation	= 26.4
Sample size	= 25

CER Data

Cartridge Case	Case Length (in)	Production Quantity	Actual Unit Cost	Estimated Unit Cost
M204	5.47	805,620	$ 2.85	$ 2.45
M14B3/B4	14.64	37.948.391	5.33	8.44
M14B3/B4	14.64	50,252,840	6.83	8.30
M30A1B3	12.00	347,842	6.95	8.29
M30A1B3	12.00	345,320	8.35	8.30
M14B1	14.64	32,211,138	8.39	8.52
M14B3/B4	14.64	94,000	10.30	12.05
M88B1	22.83	500,598	15.02	21.15
M104	27.62	29,500	15.90	33.24
M14B1	14.64	6.729,746	16.15	9.35
M171	22.83	151,854	16.21	22.70
M94B1	24.00	1.612,560	18.17	21.25
M93B1	24.00	1,316,029	18.42	21.51
M108B1	23.70	2.253,645	18.63	20.45
M200	23.55	132,300	19.25	23.97
M19B1	23.70	173.146	21.15	23.82
M148A1B1	23.98	373,791	21.44	23.15
M114	23.70	1.419,340	2[illegible].42	21.02
M150B1	24.31	3,244,304	25.66	20.78
M148A1B1	23.98	9,385,733	25.93	19.11
M115B1	24.31	2,417,766	26.23	21.15
M94B1	24.00	1.346.259	26.88	21.48
M104	27.62	24,240	42.04	33.62
M148A1B1	23.98	95,000	47.62	25.11
M114	23.70	50,000	49.29	25.64

c. Cases (continued)

Application: Recoilless rifle and grenade aluminum cases.

$$\ln Z = -0.1251 + 0.8866 \ln X$$

$$\text{or} \quad Z = 0.8824\ X^{0.8866}$$

where: Z = Estimated unit cost in FY 80 constant dollars
X = Cartridge case length in inches

Statistics:

Coefficient of determination	= 0.980
Standard error of estimate in Ln form	= 0.149
Coefficient of variation	= 0.199
Mean absolute percent deviation	= 9.1
Sample size	= 5

CER Data

Cartridge Case	Case Length (in)	Actual Unit Cost	Estimated Unit Cost
M195	1.19	$ 0.86	$ 1.03
M118	1.82	1.51	1.50
M169	2.09	1.78	1.70
M199	1.90	1.85	1.56
M112	16.29	10.04	10.48

d. Propellants

Application: Medium-bore automatic cannon and tank main-armament ammunition.

$$\ln Z = -12.6640 + 1.0436 \ln X$$

or

$$Z = (3.1629 \times 10^{-6})\, X^{1.0436}$$

where: Z = Estimated unit cost in FY 80 constant dollars
X = Kinetic energy

Statistics:

Coefficient of determination	= 0.963
Standard error of estimate in Ln form	= 0.357
Coefficient of variation	= 0.198
Mean absolute percent deviation	= 26.0
Sample size	= 52

CER Data

Cartridge	Kinetic Energy	Actual Unit Cost	Estimated Unit Cost
M53 API	38,900	$ 0.175	$ 0.195
M52 APIT	49,353	0.175	0.250
M55A2 TPT	38,729	0.178	0.194
M242 HEIT	39,071	0.178	0.196
M56A3 HEI	39,757	0.178	0.200
M246 HEIT	48,668	0.180	0.246
M220 TPT	40,842	0.182	0.205
M206A1 TPT	47,240	0.306	0.239
M54A1 HE	140,946	0.677	0.748
M55A1 TPT	140,946	0.677	0.748
M81 APT	250,814	1.158	1.364
MK2 HEIT	250,814	1.261	1.364
M91 TPT	250,814	1.282	1.364
M63 TP	169,000	2.097	0.903
M48 HE	356,953	3.437	1.972
M352A1 HE	1.341.792	6.814	7.852
M42A1 HE	1,449,981	7.020	8.514
M62A2 APT	1.617,668	7.020	9.544
M123A1 HEP	705,666	7.937	4.015
M623 TP	705,666	7.937	4.015
M338A1 APT	919,105	8.623	5.290
M348A1 HEAT	1.753.024	9.360	10.378
M71A1 HET	2,094,624	9.457	12.497
M496 HEAT	1.815.390	9.472	10.764
M416 WP	2,219,904	10.508	13.279
M467 TPT	2.219,904	10.864	13.279
M468 TPT	2,219,904	10.864	13.279

d. Propellants (continued)

Cartridge	Kinetic Energy	Actual Unit Cost	Estimated Unit Cost
M339 APT	2,306,048	$ 12.331	$13.817
M340A1 TPT	2,306,048	12.331	13.817
M77 APT	2,651,009	13.684	15.981
M657 HET	3,290,542	14.190	20.023
M409A1 HEAT-T	3,341,220	14.190	20.346
M411 TPT	3,341,220	14.190	20.346
M304 HVAPT	2,921,217	15.725	17.685
M580 APERS-T	2,937,150	16.474	17.786
M494 APERS	3,511,958	17.222	21.432
M431A2 HEAT	3,151,705	18.167	19.142
M353A1 TPT	3,370,500	18.937	20.532
M724 TPDS-T	3,384,182	19.818	20.619
M393A2 HEAT	2,219,904	21.728	13.279
M331A2 HVAPDS-T	2,173,746	23.610	12.990
M490 TPT	5,159,712	25.323	32.021
M456A2 HEAT-T	5,344,252	25.323	33.215
M728 APDS-T	4,860,142	26.424	30.081
M392A2 APDS	9,065,572	26.424	57.656
M735 APFSDS-T	4,817,167	27.525	29.806
M356 HET	4,894,375	30.591	30.305
M332A1 HVAP	2,912,280	32.437	17.628
M318A1 APT	3,370,500	35.312	20.532
M469 HET	6,796,406	41.184	42.687
M358 APT	9,687,912	119.074	61.794
M359 TPT	9,687,912	119.074	61.794

d. Propellants (continued)

Application Recoilless rifle ammunition.

$$\text{LnZ} = -2.9706 + 0.8949\ \text{LnX}$$

or $$Z = 0.05127\ X^{0.8949}$$

where: Z = Estimated unit cost in FY 80 constant dollars
X = Momentum

Statistics:

Coefficient of determination	= 0.972
Standard error of estimate in Ln form	= 0.152
Coefficient of variation	= 0.063
Mean absolute percent deviation	= 11.9
Sample size	= 20

CER Data

Cartridge	Momentum	Actual Unit Cost	Estimated Unit Cost
M306 TP	103	$ 3.475	$ 3.245
M306A1 HE	103	3.475	3.245
M307A1 HEAT	103	3.475	3.245
M308A1 SMK	103	3.475	3.245
M591 HE	161	3.755	4.832
M371 HEAT	146	3.935	4.427
M590 CSTR	150	4.506	4.556
M310A1 HEAT	407	11.085	11.104
M309A1 HEP-T	443	11.468	11.977
M349 HEP-T	374	11.676	10.296
M346A1 HEP-T	891	18.920	22.378
M344A1E1 HEAT	902	18.920	22.626
M581 APERS-T	962	18.920	23.968
M344A1 HEAT	902	19.157	22.626
M326 HEP	1,000	26.758	24.809
M323 HE	1,128	27.626	27.635
M341 HEAT	887	28.148	22.294
M344 HEAT	900	28.148	22.581
M324 HEAT-T	1,127	28.530	27.608
M345 HEP-T	924	28.669	23.129

d. Propellants (continued)

Application: Propelling charges in howitzer ammunition to achieve zone 7 or full charge.

$$\ln Z = -9.3401 - 0.2059\,X + 1.6066\,\ln Y$$

where: Z = Estimated unit cost in FY 80 constant dollars
X = Projectile mass
Y = Momentum

Statistics:

Coefficient of determination	= 0.895
Standard error of estimate in Ln form	= 0.447
Coefficient of variation	= 0.144
Mean absolute percent deviation	= 32.7
Sample size	= 30

CER Data

Cartridge	Projectile Mass	Momentum	Actual Unit Cost	Estimated Unit Cost
M66 HE	0.4155	416	$ 1.535	$ 1.299
M72 APT	0.4333	880	3.384	4.317
M48 HE	0.4569	571	3.437	2.146
M61A1 APC-T	0.4631	940	3.562	4.774
M1 HE	1.0257	1,590	5.101	9.890
M413 HE	1.0257	1,590	5.101	9.890
M60A2 WP	1.0070	1,632	5.101	10.354
M84B1 SMK	1.0226	1,658	5.101	10.587
M444 HE	1.0257	1,663	5.101	10.628
M334 HE	0.3975	1,063	6.365	5.891
M338A1 APT	0.4090	867	8.623	4.240
M546 APERS-T	0.8858	1,594	12.951	10.227
M548 HE	0.8858	1,594	32.406	10.227
M116B1 SMK	2.6801	4,819	52.878	41.783
M107 HE	2.8594	5,141	52.878	44.679
M485E2 ILLUM	2.8594	5,404	52.878	48.405
M718 AT	3.2013	5,756	52.878	49.929
M795 HE	3.2138	5,778	52.878	50.109
M110E2 WP	3.0612	5,679	52.878	50.290
M121A1 YX	3.0739	5,702	52.878	50.486
M692 HE	3.1858	5,856	52.878	51.496
M483A1 HE	3.1889	5,891	52.878	51.956
M708 HE	2.9838	4,506	56.959	35.237
M396 APERS	2.9527	5,462	56.959	48.308
M404 HE	6.2162	12,122	86.908	88.810
M106 HE	6.2473	12,182	86.908	88.943
M509A1 HE	6.4182	12,515	86.908	89.667
M650 HERA	6.2162	15,491	86.908	131.696
M549A1 HERA	2.9962	6,667	92.427	65.950
M101 HE	2.9527	8,268	92.427	94.029

e. Primers

Primer physical and performance characteristics useful in the development of CER's are generally unavailable during the early life cycle. Also, primer production costs do not correlate significantly with complete round physical and performance characteristics, conceivably since a primer may be used in a number of different ammunition rounds. For these reasons, cost factors are proposed as tools to estimate primer production costs. The cost factors represent average percentages that the primer cost is of the total round production cost.

Application: Medium-bore automatic cannon and tank main-armament ammunition.

Primer Type	Percent of Ammunition Hardware Cost: Mean	Percent of Ammunition Hardware Cost: Standard Deviation
Percussion	2.36	1.21
Electric	3.04	0.74

Cost Factor Data

Primer	Percent of Ammo Hardware Cost
Percussion	
M28	1.47
M57	1.65
M58	2.10
M60	3.11
M62	2.98
M79	2.70
M81	1.28
M90	0.75
M92	5.00
M104	2.52
Electric	
M73	3.47
M80A1	3.61
M83	3.00
M86	3.34
M120	1.78

f. Explosive Fill

Explosive fill is placed within the projectile to achieve a desired target effect. The explosive fill cost predictors cover the use of composition A, composition B and TNT.

Application: Tank main-armament, howitzer and recoilless rifle high explosive antitank ammunition.

$$\text{LnZ} = -12.9088 + 2.8526\ \text{LnX}$$

or $$Z = 0.000002476\ X^{2.8526}$$

where: Z = Estimated unit cost in FY 80 constant dollars
X = Bore size in millimeters

Statistics:

Coefficient of determination	= 0.960
Standard error of estimate in Ln form	= 0.144
Coefficient of variation	= 20.511
Mean absolute percent deviation	= 11.3
Sample size	= 15

CER Data

Cartridge	Bore Size (mm)	Actual Unit Cost	Estimated Unit Cost
M307 HEAT	57	$0.23	$0.25
M309A1 HEAT	75	0.54	0.55
M66 HEAT-T	75	0.59	0.55
M310A1 HEAT	75	0.59	0.55
M496 HEAT	76	0.64	0.57
M431A2 HEAT-T	90	0.70	0.93
M348A1 HEAT	90	0.91	0.93
M371 HEAT	90	1.01	0.93
M456A2 HEAT-T	105	1.25	1.44
M622 HEAT-T	105	1.25	1.44
M341 HEAT	105	1.39	1.44
M344 HEAT	106	1.63	1.48
M324 HEAT-T	105	1.79	1.44
M469 HEAT-T	120	2.63	2.11
M409A2 HEAT-T	152	3.69	4.15

f. Explosive Fill (continued)

Application: Mortar high explosive ammunition

$$\mathrm{Ln}Z = -19.2717 + 4.3873\ \mathrm{Ln}X$$

$$\text{or} \quad Z = (4.3 \times 10^{-9})\ X^{4.3873}$$

where: Z = Estimated unit cost in FY 80 constant dollars
X = Bore size in millimeters

Statistics:

Coefficient of determination	= 0.980
Standard error of estimate in Ln form	= 0.182
Coefficient of variation	= -7.686
Mean absolute percent deviation	= 13.0
Sample size	= 6

CER Data

Cartridge	Bore Size (mm)	Actual Unit Cost	Estimated Unit Cost
M49A4 HE	60	$0.25	$0.27
M720 HE	60	0.25	0.27
M362 HE	81	1.23	1.01
M374 HE	81	1.23	1.01
M3A1 HE	107	2.83	3.42
M329A2 HE	107	3.36	3.42

g. Fuzes

Fuze costs include the cost of procurement of metal parts in addition to the fuze LAP. In some instances, fuze metal parts are procured from a vendor and assembled at an Army ammunition plant.

Analyses of base detonating (BD), point initiating-base detonating (PIBD), time, mechanical time (MT), and mechanical time-super-quick (MTSQ) fuze costs proved fruitless. Relevant production cost information are provided for these fuzes.

Application: Point detonating fuzes.

$$\text{LnZ} = 2.7061 + 0.6143\ \text{LnX} - (0.7167 \times 10^{-7})\ \text{Y}$$

where: Z = Estimated unit cost in FY 80 constant dollars
X = Fuze weight in pounds
Y = Production quantity

Statistics:

Coefficient of determination	= 0.909
Standard error of estimate in Ln form	= 0.346
Coefficient of variation	= 0.157
Mean absolute percent deviation	= 29.9
Sample size	= 36

CER Data

Fuze	Fuze Weight (lb)	Production Quantity	Actual Unit Cost	Estimated Unit Cost
M505A3 PD	0.048	23,189,000	$ 0.24	$ 0.44
M505A3 PD	0.048	12,575,355	0.60	0.94
M505A3 PD	0.048	14,000,000	1.09	0.85
M505A3 PD	0.048	12,000,000	1.25	0.98
M505A3 PD	0.048	4,250,000	1.63	1.71
M505A3 PD	0.048	4,000,000	1.72	1.74
M717 PD	0.25	571,490	8.22	6.13
M567 PD	1.30	300,000	10.43	17.22
M503A2 PD	0.34	814,701	10.64	7.28
M739 PD	1.43	915,837	10.65	17.47

g. Fuzes (continued)

Fuze	Fuze Weight (lb)	Production Quantity	Actual Unit Cost	Estimated Unit Cost
M48A3 PD	1.41	1,802,448	10.72	16.25
M503A2 PD	0.34	252,336	10.73	7.58
M567 PD	1.30	1,071,100	11.23	16.29
M739 PD	1.43	915,837	11.30	17.47
M720 PD	2.10	90,000	11.41	23.46
M567 PD	1.30	1,625,899	12.06	15.66
M524A6 PD	1.27	14,104,883	12.93	6.31
M716 PD	1 25	5,785,580	13.25	11.34
M524A6 PD	1.27	2,514,828	13.51	14.48
M524A6 PD	1.27	176,002	13.85	17.12
M524A6 PD	1.27	600,000	13.97	16.61
M524A6 PD	1.27	666,666	14.04	16.53
M524A6 PD	1.27	4,769,359	14.68	12.32
M524A6 PD	1.27	4,120,179	14.86	12.91
M524A6 PD	1.27	3,982,150	15.11	13.04
M524A6 PD	1.27	3,181,102	15.44	13.81
M739 PD	1.43	3,168,072	15.47	14.86
M524A6 PD	1.27	3,045,000	17.37	13.94
M524A6 PD	1.27	1,257,000	19.24	15.85
M519 PD	1.25	966,100	19.40	16.02
M524A6 PD	1.27	2,160,000	19.61	14.85
M524A6 PD	1.27	500,000	19.99	16.73
M524A6 PD	1.27	2,177,420	20.20	14.83
M508A1 PD	2.15	77,300	21.03	23.83
M519 PD	1.25	377,100	21.96	16.71
M593 PD	1.27	10,529	26.25	17.33

g. Fuzes (continued)

Application: Proximity fuzes

$$Z = 536.81 + 15.4793\,X - 42.6263\,\mathrm{Ln}Y$$

where: Z = Estimated unit cost in FY 80 constant dollars
X = Fuze length in inches
Y = Production quantity

Statistics:

Coefficient of determination	= 0.935
Standard error of estimate	= 9.830
Coefficient of variation	= 0.174
Mean absolute percent deviation	= 14.6
Sample size	= 5

CER Data

Fuze	Fuze Length (in)	Production Quantity	Actual Unit Cost	Estimated Unit Cost
M732 Prox	5.97	1,346,106	$19.96	$27.65
M596 Prox	1.54	230,000	39.62	34.39
M532 Prox	5.97	579,232	60.96	63.59
M514 Prox	8.60	1,522,424	72.25	63.11
M517 Prox	6.19	314,089	89.04	93.09

Analyses of base detonating (BD), point initiating-base detonating (PIBD), mechanical time (MT), and mechanical time-superquick (MTSQ) fuze costs proved fruitless. Relevant production cost information for these fuzes follow. The average cost and quantity parameters are weighted averages across all producers of the fuze.

Fuze	Weighted Average Cost	Weighted Average Quantity
M62A2 PD	$ 13.763	75,758
M91A2 BD	14.891	222,550
M534A1 BD	21.239	476,480
M578 BD	20.324	1,950,556
M438 PIBD	47.726	217,450
M509A1 PIBD	9.564	2,036,452
M530A1 PIBD	11.607	678,221
M539 PIBD	29.627	558,753
M562 MT	43.524	158,000
M563 MT	100.853	80,000
M565 MT	46.450	2,315,046
M571 MT	163.345	120,831
M592 MT	232.827	73,817
M711 MT	200.492	103,500
M548 MTSQ	73.303	688,577
M564 MTSQ	51.349	3,108,247
M577 MTSQ	76.841	1,358,497

h. Small Arms

Small arms ammunition includes rounds with a bore size less than 20mm. The production cost for these ammunnition include the cost of the complete round, i.e., projectile, case, propellant, primer, and LAP.

Application: Ball ammunition.

$$Z = -0.002026 + 0.0004012\ X$$

where: Z = Estimated unit cost in FY 80 constant dollars
X = Cartridge weight in grains
(1 pound = 7,000 grains)

Statistics:

Coefficient of determination	= 0.993
Standard error of estimate	= 0.021
Coefficient of variation	= 0.109
Mean absolute percent deviation	= 16.1
Sample size	= 7

CER Data

Cartridge	Cartridge Weight (grains)	Actual Unit Cost	Estimated Unit Cost
Cal .22	52	$0.013	$0.019
5.56mm M193	182	0.075	0.071
Cal .38 Special	220	0.117	0.086
Cal .30 M2	416	0.134	0.165
Cal .45 M1911	331	0.139	0.131
7.62mm M80	392	0.145	0.155
Cal .50 M33	1,763	0.709	0.705

h. Small Arms (continued)

Application: Tracer ammunition

$$\ln Z = -2.3013 + 0.001070\ X$$

where: Z = Estimated unit cost in FY 80 constant dollars
X = Cartridge weight in grains
(1 pound = 7,000 grains)

Statistics:

Coefficient of determination	=	0.999
Standard error of estimate in Ln form	=	0.025
Coefficient of variation	=	-0.017
Mean absolute percent deviation	=	1.3
Sample size	=	3

CER Data

Cartridge	Cartridge Weight (grains)	Actual Unit Cost	Estimated Unit Cost
5.56mm M196	177	$0.123	$0.121
7.62mm M62	383	0.148	0.151
Cal .50 M17	1,732	0.640	0.638

h. Small Arms (continued)

Application: Blank ammunition

$$LnZ = -9.2819 + 3.4896\ LnX$$

or $$Z = 0.00009309\ X^{3.4896}$$

where: Z = Estimated unit cost in FY 80 constant dollars
X = Bore size in millimeters

Statistics:

Coefficient of determination	= 0.928
Standard error of estimate in Ln form	= 0.379
Coefficient of variation	= -0.166
Mean absolute percent deviation	= 20.7
Sample size	= 5

CER Data

Cartridge	Bore Size (mm)	Actual Unit Cost	Estimated Unit Cost
Cal .22	5.56	$0.023	$0.037
M200	5.56	0.058	0.037
M1909	7.62	0.112	0.111
M82	7.62	0.116	0.111
M1A1	12.7	0.650	0.662

i. Links

Application: Small arms and medium-bore automatic cannon ammunition.

$$\mathrm{Ln}Z = -1.9424 + 1.6223\ \mathrm{Ln}X - 0.2614\ \mathrm{Ln}Y$$

or

$$Z = 0.1434\ X^{1.6223}\ Y^{-0.2614}$$

where: Z = Estimated unit cost in FY 80 constant dollars
X = Bore size in millimeters
Y = Production quantity

Statistics:

Coefficient of determination	= 0.854
Standard error of estimate in Ln form	= 0.571
Coefficient of variation	= -0.269
Mean absolute percent deviation	= 53.0
Sample size	= 47

i. Links (continued)

CER Data

Link	Bore Size (mm)	Production Quantity	Actual Unit Cost	Estimated Unit Cost
M13	7.62	424,504,056	$0.005	$0.021
M13	7.62	161,000,000	0.019	0.028
M1	7.62	116,943,720	0.019	0.030
M1	7.62	95,000,000	0.019	0.032
M1	7.62	182,626,296	0.021	0.027
M13	7.62	2,104.199.716	0.022	0.014
M13	7.62	755,204,992	0.024	0.018
M13	7.62	362,942,112	0.024	0.022
M13	7.62	570,000,000	0.026	0.020
M13	7.62	388,552,352	0.026	0.022
M1	7.62	52,846,832	0.026	0.037
M13	7.62	672,325,364	0.028	0.019
M13	7.62	135,000,000	0.029	0.029
M13	7.62	130,000,000	0.030	0.029
M1	7.62	36,914,880	0.031	0.041
M1	7.62	113,948,800	0.032	0.030
M1	7.62	23,235,508	0.033	0.046
M9	12.7	41.285,544	0.046	0.091
M9	12.7	32,874,000	0.046	0.096
M9	12.7	94.915,000	0.057	0.073
M15	12.7	5,617,000	0.108	0.152
M15	12.7	17,301,872	0.109	0.114
MET B	12.7	36,362,142	0.122	0.094
M15	12.7	45,082,407	0.138	0.088
M14A2	20	41,695,232	0.226	0.189
M14	20	99,493,220	0.251	0.150
M14	20	21,957,444	0.266	0.223
M14	20	11,450,000	0.300	0.264
M16A2	40	5,861,200	0.307	0.970
M14	20	44.450,000	0.328	0.185
M14	20	41,176,836	0.337	0.189
M12	20	43,502,240	0.348	0.187
M22	20	1,500,000	0.384	0.450
M12	20	11,087,000	0.410	0.267
M12	20	4,497,000	0.441	0.338
M16A1	40	6,458,550	0.446	0.945
M16	40	1,475,350	0.450	1.390
M14	20	20,170,208	0.486	0.228
M14	20	6,986,839	0.490	0.301
M12	20	21,543,508	0.549	0.224
M16	40	23,007,370	0.558	0.678
M17	20	1,324,000	0.632	0.465
M16	40	4,178,000	0.677	1.059
M16	40	2,422,250	0.683	1.221
M17	20	1,300,000	0.873	0.467
M12	20	4,700,000	0.957	0.334
M24	20	355,520	1.156	0.655

C. ANALYSIS OF OTHER FACTORS

1. Introduction

It is recognized that many factors bear upon the cost of ammunition produced in AAP's. This study addressed two general factors in order to assess whether feasible methodology could be developed to allow rapid and generic consideration of them in the cost estimating process.

a. Manufacturing Technology

Based on the hypothesis that costs are impacted by improvements in manufacturing technology, an attempt was made to measure this impact in terms of a productivity index or in terms of the funds provided to AAP's for *improvement of the production base.*

b. Plant Workload

Workload flunctuations at the AAP's are known to cause cost changes. This study made an attempt to broadly measure this type of impact and to develop means to forecast it in general terms. In this area, particular attention was given to individual plant overhead at the total plant level.

2. Approach

a. Manufacturing Technology

To analyze the possible impact of changes in manufacturing technology, an attempt was first made to obtain productivity data on the various AAP's in the ARRCOM community. The measure of productivity selected was manufacturing direct labor expressed in unit man-hours per component item. It was found that these data are either completely unavailable for an item or not of sufficient duration to allow statistical analysis.

Hypothesizing that a measure of improving technology might be the funds furnished AAP's for maintenance and improvement of the production base, both budgeted and expended cost data were collected for replacement of production support equipment, modification or expansion of production facilities, and layaway of facilities. These production base support (PBS) data were collected from a work summary report published monthly by the HQ. ARRCOM Industrial Readiness Directorate (Ref 15). Regression analysis was used to analyze potential relationships between PBS costs and ammunition production costs at AAP's.

b. Plant Workload

To analyze the possible impact of variations in plant workload, the following data were collected:

(1) Plant operating costs collected from the Contractor's Plant Cost Statement by Appropriation (DA Form 4812-R).

(2) Plant man-year information collected from the Personnel Utilization Report (DA Form 4813-R),

(3) Plant summary production cost-quantity data which was a fiscal year roll-up of all component production cost-quantity data collected from the Summary of Orders and Cost of Deliveries (DRSAR Form 276) for the plant.

The former two records are maintained in the Data Analysis and Validation Branch of the Cost Analysis Division, HQ. ARRCOM. The formats of these two records have undergone several changes during the period under review, but only compatible data were collected. Table V presents a description of the production data collected.

TABLE V

PLANT PRODUCTION DATA

Record	Data Description
DA Form 4812-R	Direct manufacturing cost, or sum of: Direct material cost Direct labor cost Fringe benefits cost
	Total production cost including both direct and indirect cost but excluding GFM costs.
DA Form 4813-R	Direct production labor plus overtime man-years. Total contractor strength man-years including direct, indirect and overtime.
DRSAR Form 276	Component production quantities and costs.

As for manufacturing technology, regression analysis was the analytical tool used to develop potential relationships.

3. Results

a. Manufacturing Technology

Based on the available data and the analytical approach taken, it was found that no significant relationship exists between the level of funds provided to an AAP for production base maintenance/improvement and the cost of product output at the plant. It is believed that this is due, at least in part, to more significant impacts to production cost generated by variations in plant operating levels since the mid-1970's. Therefore, it was not possible to develop methodology for considering technology improvements in cost estimates using this approach.

b. Plant Workload

Analysis in this area showed that regressions performed on various forms of overhead, measured in terms of both costs and man-years resulted in insignificant relationships. However, regressions performed wherein each plant's overall annual production unit costs were compared to the corresponding production quantities yielded statistically valid relationships. However, these workload relationships can be used only in conjunction with other information available within ARRCOM and are suited only for internal ARRCOM usage. Therefore, the relationships are not presented for wide dissemination.

APPENDIX A

DEFINITIONS OF TECHNICAL CHARACTERISTICS

Bore Size is the diameter, expressed in millimeters or inches, of the bore across the rifling lands or flats of the weapon firing the ammunition.

Cartridge Weight includes the nominal weight in pounds of the complete round with all components for fixed, semi-fixed and separated ammunition. For separate-loading ammunition, weight includes the nominal weight of the projectile only.

Cartridge Length includes the total length in inches of the complete round for fixed, semi-fixed and separated ammunition; and of the projectile only for separate-loading ammunition.

Propellant Weight is the amount of propellant in pounds in the complete round for fixed and separated ammunition. For semi-fixed and separate-loading ammunition, propellant weight includes the amount of propellant to achieve the zone 7 or full charge.

Muzzle Velocity is the speed in feet per second of the projectile departing the muzzle of the weapon.

Maximum Range is the maximum distance in yards, or the effective distance which the round can perform its designed function when range is not a criterion. It is the approximate range expected when firing a stationary weapon at the most favorable elevation, under normal atmosphere conditions, with both weapon and projectile impact at sea-level altitude.

Chamber Pressure is the upper pressure limit developed by the propelling charge within the chamber of the weapon to produce a specified muzzle velocity.

Momentum is the product of projectile mass and muzzle velocity.

Kinetic Energy is the product of muzzle velocity squared and one-half the projectile mass.

Projectile Mass is the quotient of projectile weight in pounds divided by the acceleration of gravity which is 32.2 feet per second per second.

APPENDIX B

DEFINITIONS OF REGRESSION STATISTICS

Coefficient of Determination is the proportion of the variation in the dependent variable explained by the independent variables. The coefficient of determination ranges from zero (no variation explained) to one (all variation explained).

Standard Error of Estimate is a measure of the dispersion of the actual dependent-variable values about the regression equation. The standard error of estimate is of positive value and is used in determining confidence intervals. For a given set of dependent-variable data. the minimum standard error of estimate is associated with the best regression equation.

Coefficient of Variation is the ratio of the standard error of estimate to the mean of the actual dependent-variable values used in the regression. The coefficient of variation is used in comparing two or more CER's possessing the same dependent variable but with a different number of observations. The CER with the minimum absolute-valued coefficient of variation is the best regression equation. It is emphasized that the dependent variable used in the coefficient of variation needs to be of exactly the same form when comparing CER's.

Mean Absolute Percent Deviation is the average percent that the CER estimated values deviate from the actual values.

Sample Size is the number of data points used to develop the CER.

CER Data is a table which presents the actual independent and dependent variable values as well as the CER estimated dependent variable value for each item used in the CER development. Instances where an item is listed more than once are due to multiple producers of the item.

APPENDIX C

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This report presents statistically developed tools to estimate ammunition production costs at the component level-of-detail. These tools include learning rates and cost estimating relationships/cost factors applicable during early life cycle cost estimating.

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