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A case study of the costs for two Army tanks, XM-1 and M60A3, demonstrated the importance of life-cycle cost comparisons. The XM-1 main battle tank was developed to succeed M60 series tanks which have been produced for 17 years. Findings/Conclusions: Comparing only acquisition costs, the XM-1 is twice as expensive as the M60A3. When life-cycle costs (totals for buying, operating, and maintaining tanks) during a 20-year period are considered, the XM-1 costs about 20% more because of large, nearly equal maintenance and operation costs for the two tanks. Thus, the XM-1 need be only 20% more cost effective, and the consensus of Army studies has been that its cost effectiveness compared to the M60A3 is considerably more than this percentage. Cost estimates made before starting production are subject to uncertainty such as inflation and other factors. Cost estimate assumptions were examined, and the sensitivity of XM-1 costs to these assumptions was reflected in life-cycle cost data. Weapon systems decisions are not made solely on cost or effectiveness data. For example, NATO weapons standardization programs offer possible economies in research and development and logistics, but other costs may be higher. Foreign military sales can help recoup development costs of weapons systems, but the market for these is not highly predictable. (Author/HTW)

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STUDY BY THE STAFF OF THE U.S.

General Accounting Office

Comparative Life Cycle Cost: A Case Study

UNITED STATES GENERAL ACCOUNTING OFFICE

PAD-78-21
AUGUST 16, 1978

PREFACE

In considering funding new programs, the Congress needs answers to several questions: How much will it cost? How reliable are the estimates? Would something else be better? This study deals with these questions.

Comparing unit cost is one means of determining the appropriate method of achieving an objective; an even better method is comparing life cycle cost. Using the case study method, we have portrayed the importance of life cycle cost and present a rough frame for its use, using as examples two Army tanks--XM-1 and M60A3. Our study relied on data provided by the Department of Defense and our previous reports.

We have not verified the information and analysis from non-GAO sources. Given the complexity of many of the issues and problems associated with estimating tank costs and effectiveness, other studies should be sought in fully assessing these tanks. We hope this study will be useful to the Congress in considering future procurement programs.

This study was prepared by our Economic Analysis staff. Any questions you may have regarding the analysis should be directed to Mr. Kenneth M. Brown, (202) 275-3588.

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STUDY BY THE STAFF OF THE U.S. GENERAL ACCOUNTING OFFICE

COMPARATIVE LIFE CYCLE COST: A CASE STUDY

D I G E S T

The XM-1 main battle tank was developed to succeed M60 series tanks, which have been produced for 17 years. The Army's purchase of 3,312 new tanks will cost about $4 billion in 1976 dollars. Operation and maintenance costs over 20 years will bring the costs to over $10 billion 1976 dollars. This study shows how the XM-1 costs compare with those of the M60 series.

We compiled cost estimates of XM-1 and M60A3. Comparing only acquisition costs, the XM-1 is twice as expensive as the M60A3. When life cycle costs (totals for buying, operating, and maintaining tanks) during a 20-year period are considered, the XM-1 costs about 20 percent more because of large, nearly equal maintenance and operation costs for the two tanks.

If these cost estimates are reliable, the XM-1 need be only 20 percent more cost effective. Although the definition of "effectiveness" is to some extent subjective, the consensus of Army studies has been that the XM-1 is considerably more effective than 20 percent over the M60A3.

Cost estimates made before starting production are subject to some uncertainty. Inflation and other factors can cause significant cost increases. We examine the underlying cost estimate assumptions for large weapon systems and show the sensitivity of XM-1 costs to the basic assumptions and reflect them in life cycle cost data.

We recognize that weapon systems decisions are not made solely on cost or effectiveness data. For example, NATO weapons standardization programs offer possible economies in research and development and logistics, but other costs may be higher. Foreign military sales can help recoup development costs of weapons systems, but the market for these sales is not highly predictable.

Contents

ABBREVIATIONS

DOD	Department of Defense
FMS	Foreign Military Sales
FRG	Federal Republic of Germany
GAO	General Accounting Office
MBT	main battle tank
NATO	North Atlantic Treaty Organization
R&D	research and development

CHAPTER 1

INTRODUCTION

In considering funding new programs, the Congress needs answers to several questions about costs:

--How much will it cost to acquire and use?

--How sound are cost estimates?

--Would some other system (perhaps less effective but less expensive) be better?

This study deals with these questions relative to XM-1, the Army's new main battle tank. The third question can only be answered with classified effectiveness information. We have, however, presented cost information to easily relate it to assessing XM-1's relative effectiveness.

COST ESTIMATES

We have excluded costs already incurred as irrelevant and have added operation and maintenance to compute life cycle costs.

CONFIDENCE IN THE ESTIMATES

Estimates necessarily involve numerous assumptions, some of which are crucial to the final total. Sensitivity analyses show how assumption changes affect cost estimates.

COMPARISON TO ALTERNATIVES

Continued production of M60A3, the most advanced U.S. tank, was a possible alternative to XM-1. It is less effective but also less costly. Acquisition costs of M60A3 are about half of those for XM-1, but since operation and maintenance costs are about equal for the two tanks, life cycle costs for the XM-1 are only about 20-percent higher than for M60A3. If XM-1 is considered significantly over 20-percent more effective than M60A3, it would be a better choice based on cost-effectiveness.

According to DOD, the German LEOPARD 2AV was less effective and more costly than XM-1. Therefore, if cost-effectiveness were the sole criterion for selection, the LEOPARD would be excluded. Only benefits of NATO standardization could tip the scales in favor of the LEOPARD. (These benefits, however, are difficult to quantify.)

OUTLINE OF STUDY

Chapter 2 presents costs for three main battle tanks--M60A3, XM-1, and the LEOPARD 2AV. Chapter 3 deals with the assumptions on which the cost estimates are based and shows the sensitivity of costs to changes in these assumptions. Chapter 4 discusses unclassified information on operational effectiveness and other considerations (standardization, procurement decisions by other NATO countries, foreign military sales, and coproduction) which are not a part of the basic cost-effectiveness analysis but which are relevant to procurement decisions.

SCOPE OF STUDY

We used information from the Office of the Secretary of Defense and the Department of the Army. We did not try to verify the data because they are estimates. We met with Army officials and reviewed documents at the following locations:

--Headquarters, U.S. Army, Washington, D.C.

--Headquarters, U.S. Army Materiel Development and Readiness Command, Alexandria, Virginia.

--U.S. Army Tank Automotive Materiel Readiness Command, Warren, Michigan.

CHAPTER 2

COMPARATIVE COST ANALYSIS

In making program and budget decisions, the Congress must consider both the cost and the effectiveness of the program. This chapter presents figures for comparing XM-1 and M60A3 costs. Because "sunk costs" (funds already spent) are not relevant, we have not included them.

INCREMENTAL COST COMPARISON

If we assumed that there was no tank system in the current inventory, fielding XM-1 would be based on expected performance versus expected costs. The decision to purchase 3,312 XM-1s means committing about $10.3 billion, over 20 years, in constant dollars. The costs in inflated dollars could be as much as twice the 1976 dollar estimate.

The decision does not have quite the magnitude that the $10.3 billion figure might imply. The decision was not whether to spend $10.3 billion for the XM-1. Instead, the decision was made on whether to spend the difference between XM-1 costs and the costs of M60; that is, the incremental cost. However, even this decision may not be straightforward because alternatives may exist which have not been considered.

Life cycle costs have three groupings: research and development, investment, and operating and support. Totaling these costs for a selected period provides the cost to acquire, operate, and maintain the weapon system. Proceeding with a weapon system's development has generally been based on its estimated acquisition cost. Less attention has focused on the system's total cost, although these could ultimately amount to several times the acquisition cost.

20-year life cycle cost

To determine the XM-1 incremental cost, we obtained the life cycle costs of 3,312 XM-1 and M60A3 tanks from their respective project offices. The M60A3 was chosen because the Army is expected to produce it as its firstline tank in 1980 when XM-1 production is to start. During our review, estimates were revised several times and they will continue to be refined. However, when comparing alternative weapon systems, the estimates give a relative measure of costs between the two tanks and can be of considerable interest and value.

A life cycle of 20 years is a fairly common assumption in cost studies of major weapons. It means that tanks are expected to last 20 years with specified maintenance and are to be unserviceable thereafter. By comparing 20-year life cycle costs, however, one assumes no tanks will be lost in battle. In fact, there is some (unknown) probability of using the tanks in combat and some additional probability of their being damaged or destroyed. The larger these probabilities, the shorter the probable life cycle and the higher the relative cost of XM-1 (due to its higher acquisition cost). A favorable factor to XM-1, however, is its superior survivability. In general, one would expect an XM-1 force to have lower casualty figures than those for an M60A3 force for any given battle. A complete consideration of costs would therefore have to ascribe some value to crew safety on which XM-1 would have the advantage.

Using a shorter life cycle would require an essentially subjective estimate of the probability of battle casualties and their costs. Such estimates are beyond the scope of this study.

The data we obtained were adjusted to reflect remaining funds only and were not verified. The estimated 20-year life cycle costs, as of December 1976, in 1976 dollars appear in table 1.

The incremental hardware cost of 3,312 XM-1s is about 34-percent more than the M60A3 ($2.259 billion compared to $1.689 billion). There are costs which must be incurred by XM-1 because it is a new program. The M60A3 program will not incur these costs. For example, XM-1 requires a new production plant, 1/ whereas M60A3 will be produced in an existing plant. Also, because M60A3 is only a modification of an existing tank, there will be considerably less cost in introducing the tank into the inventory in such areas as training service/equipment and initial spares and repair parts. These items and others, when added to the remaining research and development costs, make the incremental acquisition cost of XM-1 about $2.1 billion, or about 116 percent more costly to produce. More than twice as many M60A3s could be bought for the same investment in XM-1s (7,138 M60A3s compared to 3,312 XM-1s). These are only part of the costs involved. Actually using the tanks requires people, parts, supplies--all of which are costly.

1/See our report (PSAD-77-107, May 11, 1977), "Selecting Production Site for Army's New Main Battle Tank."

Table 1

Incremental Costs of the XM-1
(note a)

FY 76 $ Constant
(millions)

20-year period

	M60A3 (note b)	XM-1 (note c)	Difference
Research & development (note a)	$ 9.3	$ 309.6	$ +300.3
Non-recurring investment	6.6	691.2	+684.6
Production (hardware cost)	1,689.3	2,259.2	+569.9
Engineering changes	24.2	68.7	+44.5
System test	4.9	3.2	-1.7
Data	2.8	26.9	+24.1
System project management	19.1	177.6	+158.5
Operational site activation	-0-	-0-	-0-
Training services/equipment	2.1	72.2	+7[illegible]1
Initial spares/repair parts	20.3	253.5	+23[illegible]
Transportation	28.6	34.0	[illegible]
Support equipment	15.0	31.4	+1[illegible].4
Subtotal	$1,822.2	$3,927.5	+$2,105.3
Percent difference			116%
Crew (note d)	$1,638.9	$1,726.0	$ +87.1
Maintenance	1,521.0	878.0	-643.0
Vehicle overhaul	591.8	574.5	-17.3
Ammunition	1,666.0	1,702.5	+36.5
Fuel and lubricants	43.5	67.9	+24.4
Training	782.2	744.8	-37.4
Integrated logistics support	44.5	14.7	-29.8
Transportation	34.4	43.[illegible]	+9.3
Indirect	476.2	582.4	+106.2
Total operating and support (note e)	$6,798.5	$6,334.5	-$464.0
Percent difference			-7%
Total funds to be expended	$8,620.7	$10,262.0	+$1,641.3
Average cost per vehicle	$ 2.60	$ 3.10	$ +.50
Percent incremental cost difference			+19%

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a/ Excludes all sunk costs for both systems.

b/ Based on production of 3,312 M60A3s, 60-month rate, 1-8-5, one plant, 105 mm gun.

c/ Based on production of 3,312 XM-1's, 60-month rate, 1-8-5, two complementary plants, having 105 mm gun in hybrid turret, and a learning curve of 93 percent. (The 120 mm gun would increase costs by about $35,000 for each tank produced.)

d/ There is a difference in crew cost only because the estimates were prepared by separate Army offices.

e/ Total cost incurred to operate each vehicle in a 1940 vehicle fleet for 20 years. Battalion overhead costs of $3,917.9 million not included above. Based on 1,000 miles of operation a year.

The project managers' 20-year estimates show incremental costs to operate and support the XM-1 at $464 million, or 7 percent less than the M60A3. Some reasons for this are:

--The XM-1 was designed to be more reliable and more easily maintained than other tanks. The lower cost estimate for maintenance reflects this. However, its higher hardware cost, reflected in repair parts, and its complexity, adding labor hours, both increase costs.

--The difference in ammunition is not readily comparable since the tanks mount different weapons. Therefore, there will be a real increase in the costs of the ammunition used by XM-1. This cost estimate is based on both tanks mounting 105-mm guns. When the 120-mm gun is introduced, these costs could rise. 1/

--The fuel and lubricant costs are greater for XM-1 because of its larger engine.

The costs of acquisition and ownership, when added together, reveal the total incremental XM-1 cost--$1.641 billion, or 19 percent more than M60A3.

Present value analysis of the systems' costs could be misleading. For example, producing 3,312 XM-1s would require at least 5 years at normal capacity because the XM-1 plants will be phased in, beginning in 1981, and will not reach 60 tanks a month until 1983. Procurement of 3,312 M60A3s would require only 2-1/2 years because the M60A3 plant will be able to produce over 100 tanks a month at normal capacity. The M60A3's investment money discounted over a 2-1/2-year period, compared with the XM-1's investment money discounted over a 5-year period, present the M60A3 as artificially more expensive.

LEOPARD 2AV COSTS

Army studies have concluded the LEOPARD 2AV is more costly and less effective than the XM-1. Though exactly comparable cost figures are not available, the FMC Corporation

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1/The Federal Republic of Germany (FRG) and the U.S. Army have signed a memorandum of understanding for standardizing the main gun in their future main battle tanks. The project manager's office has stated that the 120-mm gun added about $35,000 to the cost of each XM-1.

has estimated the cost of producing the LEOPARD 2AV at $783,700 each in 1976 dollars. The XM-1 project manager's office comparable XM-1 cost estimate is $728,400. Both these estimates, which we did not verify, are based on the assumption discussed on page 8.

SUMMARY

Our analysis shows the XM-1 as 19-percent more expensive than the M60A3, considering acquisition costs plus operation and maintenance for 20 years. The projected XM-1 unit cost is 34-percent more than M60A3, considering only average unit cost, and 74-percent more, if nonrecurring investment is included. Acquisition cost alone, however, is about twice as much for XM-1 as for M60A3.

Our analysis did not consider war losses. During a war, tank life may be limited, so incremental costs would be closer to acquisition costs. This consideration does not necessarily favor the cheaper M60 tank, because the XM-1's superior armor would mean lower attrition.

CHAPTER 3

COST UNCERTAINTY IN LIFE CYCLE COST

Cost estimates in advance of production are subject to some degree of uncertainty. We varied some basic assumptions about cost estimates to show the sensitivity of cost estimates to these assumptions.

HARDWARE COST

In 1972 the Army established an average-unit-hardware-cost goal of $507,800 in 1972 dollars. The Army Materiel Development and Readiness Command Headquarters established a conversion factor based on a composite index using (1) Bureau of Labor Statistics inflation indices; (2) labor rate contracts between contractors and their union; (3) wholesale price index code 101, iron and steel; and (4) other applicable charges for converting to 1976 dollars. This conversion factor was established at 1.484, thus making the goal $754,000 1976 dollars.

Obviously, with production not scheduled until 1980, these cost figures will increase due to inflation in the U.S. economy. However, since inflation will also raise costs of other tanks, it should not greatly affect their relative magnitudes.

The basic assumptions on which the cost goal was based are (1) a production of 3,312 tanks, (2) a production rate of 30 a month, and (3) a learning curve of 93 percent. The Army, after selecting the prime contractor, estimated that the XM-1 would cost 3-percent less than the cost goal established in 1976 dollars. Based on the above assumptions, the Army currently estimates XM-1 hardware cost at $728,400, assuming the conversion factor properly escalates the 1972 cost to 1976 cost. (We did not verify this estimate.)

The project manager has changed one basic assumption on which the cost goal had been based. The current hardware cost estimate is $705,555-assumed production of 60 tanks a month, rather than the 30 tanks a month formerly planned. Also, this new production plan requires two complementary plants, one in Lima, Ohio, and one at the U.S. Army Tank Plant in Warren, Michigan. Initial production is to begin at the Lima Plant in 1980. The Plant in Warren, which currently produces M60 tanks, will be converted to producing XM-1 tanks after M60 production ends.

RANGE OF UNCERTAINTY

The XM-1 project manager estimates the 20-year life cycle cost of 3,312 XM-1s to be about $10.5 billion (includes all sunk cost), composed of: research and development--$539.3 million, investment--$3,617.9 million ($2,259.2 of this for hardware cost), and operating and support--$6,334.5 million.

No matter how good these estimates may be, they are based on judgment and specific assumptions. Either of these can change producing variances from the original estimate. Fluctuations in estimated cost could result from policy changes, such as those affecting the frequency of maintenance, miles driven, quantity produced, rate of production, learning curve experienced, arms to be mounted, inflation rates used, number of years the estimate is to cover, etc.

In the past, budgetary decisions by the Congress have largely been based on the unit cost estimated. If costs subsequently increase, much has been made of it. We believe that it is also necessary to examine those assumptions which may ultimately change and determine a range of possible costs. 1/

We have examined four assumptions upon which XM-1 costs have been based: the volume of monthly production, the learning curve, the quantity to be produced, and the distance that the tank will be driven each year. The first three directly affect the unit cost of the XM-1 tank and the last affects the operational and support cost of the tank. As we will show, each of these factors involves a degree of uncertainty about cost.

MONTHLY PRODUCTION VOLUME

Originally, the Army planned to produce 30 XM-1s a month. In 1976 the Army established a goal of eventually producing 60 XM-1 tanks a month on a one shift, 8 hours-a-day basis. This would provide 30 tanks a month in two complementary plants, each having a surge capacity to 75 a month. This planned change has reduced the tanks' cost by about 3 percent. The project manager gave us data which would indicate the effects of producing

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1/See our reports: "Ways To Make Greater Use of the Life Cycle Costing Acquisition Technique in DOD" (May 21, 1973), "Life Cycle Estimating--Its Status and Potential Use in Major Weapons System Acquisitions" (Dec. 30, 1974), and "Application of Design-to-Cost Concept to Major Weapons Systems" (June 23, 1975).

more or less than the planned 60 tanks a month. The following chart is an adaptation of the supplied data.

Monthly production	Hardware cost (1976 dollars)
30	$718,300
40	714,000
50	709,800
60	705,600
70	701,300
80	697,100
90	692,900

The data indicates that changing the monthly production volume by 10 units would change the average unit cost by about $4,000, or 0.6 percent, without other assumption changes.

LEARNING CURVE

The Government frequently uses the learning curve technique to estimate the costs of new weapons. Labor and manufacturing expenses are unusually high for the first units produced for practically any new item since there is a learning period involved before production flows smoothly. (It takes time to solve equipment problems and to teach workers to produce the new product.) Determining the leveling point for such costs is important in pricing the product.

The Army has assumed that the XM-1 unit production cost will follow a 93-percent learning curve. This means that once the cost of the first tank is established, 7-percent cost reduction will occur each time production doubles. The decision to assume a 93-percent learning curve was based on the Army's experience with M60 tanks. Studies by the competitive contractors, Chrysler and General Motors, reaffirmed that a 93-percent learning curve was reasonable. The Army estimates the average XM-1 cost at $705,600, based on the assumptions of two complementary plants producing 60 tanks a month, with total production of 3,312 and a 93-percent learning curve. Given these data, we produced the following chart using different learning curves.

Assumed learning curve percent	Average unit cost	Total hardware cost
	(1976 dollars)	
		(billions)
96	$973,100	$3.22
95	875,000	2.88
94	786,000	2.60
a/93	a/705,600	a/2.34
92	632,800	2.10
91	567,000	1.88
90	507,600	1.68

a/The Army has used a 93-percent learning curve in projecting the cost of 3,312 XM-1 tanks.

From the above chart, it is clear that the learning curve assumption is important in the hardware cost estimate. Each 1-percent change in the assumed learning curve can cause the cost estimate to fluctuate by about 10 percent, ranging from $0.2 billion to $0.34 billion, depending on the end of the scale examined.

In testimony before the House Armed Services Committee in March 1977, the XM-1 project manager stated that XM-1 production may reach 5,000 to 7,000 tanks, depending on the current attrition rate and force structure studies. Considering this possibility, we continued the above analysis and present in the following chart the learning curve results of producing 5,000 and 7,500 tanks.

Assumed learning curve	5,000 XM-1 Tanks		7,500 XM-1 Tanks	
	Average unit cost	Total hardware cost	Average unit cost	Total hardware cost
	1976 dollars			
(percent)		(billions)		(billions)
96	$920,300	$4.60	$907,700	$6.81
a/93	a/675,800	a/3.38	a/647,900	a/4.86
90	476,800	2.38	448,400	3.36

a/The Army has used a 93-percent learning curve in projecting the cost of 3,312 XM-1 tanks.

Comparing the average unit hardware cost of 3,312, 5,000, and 7,500 tanks at the assumed 93-percent learning curve indicates that as production increases, costs decrease. Savings associated with the learning curve obviously cannot be realized indefinitely. After doubling production 13 times, obtaining an additional 7-percent savings requires producing about 8,200 additional tanks--not very likely at this time considering that 8,200 tanks would already have been produced.

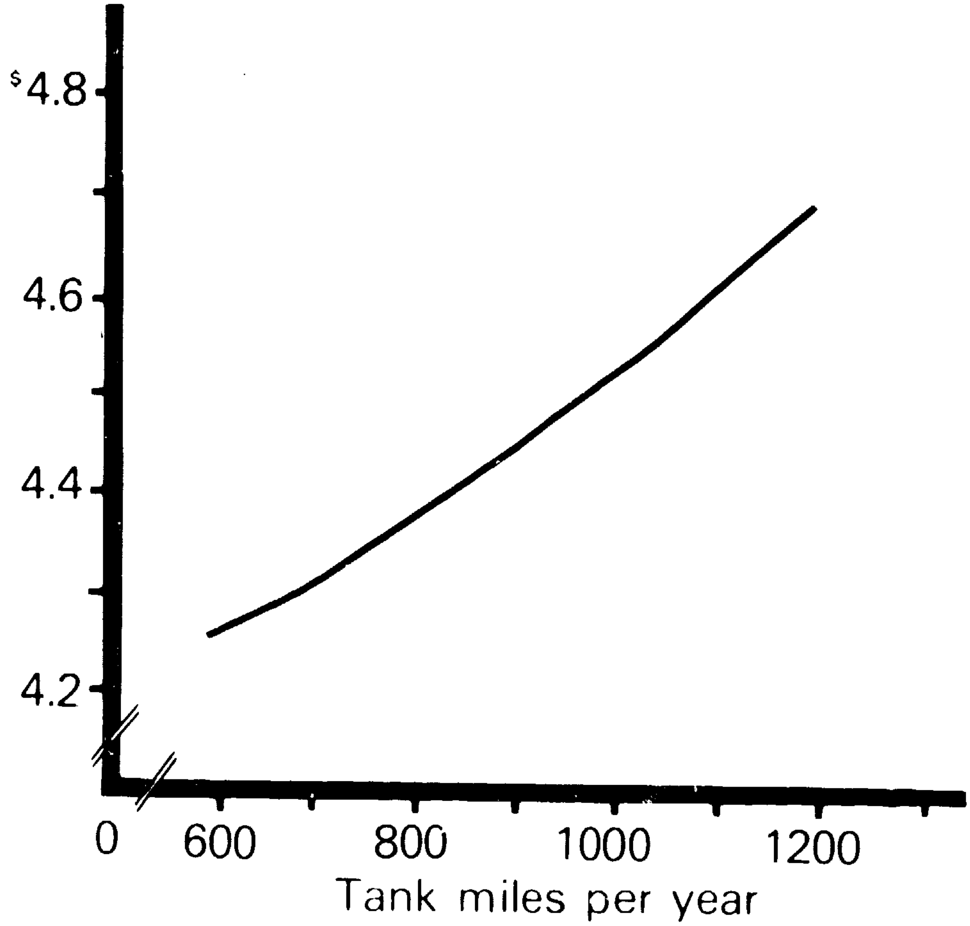
QUANTITY PRODUCED

The currently approved production goal is 3,312 tanks. (The Army is considering increasing total production to between 5,000 and 7,000 tanks.) The average unit hardware cost of the tank will not be materially affected by increased production quantity except as noted above. Some economies may be realized through changes in procurement practices, such as saving through quantity discounts. However, program cost would be affected because a much greater quantity would be supported by the original production base.

ANNUAL DISTANCE DRIVEN

The project manager reported an average life cycle cost of $3.17 million a tank operating a fleet of 1,940 tanks out of 3,312 produced. The remainder will be used as war reserves--in training, as maintenance floats, and prepositioned. Built into the estimate is an average 1,000 miles driven per year per tank. (The average tank in 1976 traveled about 650 miles.) We adjusted the average life cycle cost to reflect the costs of only those tanks actually used, resulting in the inuse vehicle life cycle cost. Cost categories mainly affected by changed mileage are "operating" and "support." These include initial spares and the transportation cost attributed to distributing them, maintenance costs, amortized overhaul costs, annual petroleum, oil and lubricants, and operational transportation costs. For example, operating the tank for 1,200 miles a year, rather than 800 miles, would add about $1 billion to the life cost of a 3,312 tank fleet. Total life cycle cost would increase by about 7 percent. On the other hand, operating the fleet for 600 instead of 1,000 miles would reduce the cost by about $1 billion. The graph below depicts the impact of annual mileage on life cycle cost per tank.

AVERAGE OPERATIONAL VEHICLE LIFE CYCLE COST (MILLIONS OF 1976 DOLLARS)



SUMMARY

Varying the assumptions on which the XM-1s' estimated costs have been based demonstrates that these assumptions have greatly affected its estimated cost. We found that a variation of 1 percent in the learning curve could change the hardware cost by about 10 percent, variation of 10 units in the monthly production quantity could change hardware cost by 0.6 percent, and variation of annual mileage of 100 miles per tank could change total life cycle cost by almost 2 percent. The revised production plan requiring two complementary plants will reduce the hardware cost by about 3 percent.

CHAPTER 4

OPERATIONAL EFFECTIVENESS AND OTHER ISSUES

Over the years, many tests have been conducted to determine the effectiveness of tanks but few have been based on concepts agreed to by all NATO tank users or even by the four major tank producers. Some of the reasons are obvious. The combat experience and professional background of the different countries' armor officers differ. Analysis and study of wars are and will be based on these individual differences and the countries' scientific evaluation capabilities. All countries regard the tank as a prestigious weapon. The larger NATO members, for reasons of national pride and economic interests, would prefer to field their own tanks, even though the advantages of a common tank and potential savings are acknowledged by all. We do not discuss effectiveness in detail since most of the results of DOD effectiveness studies are classified and this study deals mainly with life cycle cost. However, once comparative life cycle costs are established, effectiveness becomes a key consideration. The cost comparisons in chapter 2 indicate the increased effectiveness needed to justify selecting the more costly XM-1.

OPERATIONAL EFFECTIVENESS

Our analysis in chapter 2 indicates a 19-percent cost difference between XM-1 and M60A3 over a 20-year life cycle. The Army states that XM-1 is twice as effective overall as M60A3. If this is true, then XM-1 would be an outstanding purchase, assuming force effectiveness is somewhat proportional to cost (that is, no substantial effectiveness-advantage reduction occurs when expending equal amounts on XM-1 and M60A3). For example, suppose there are two types of tanks, A and B. In simulated battles in which five As fight five Bs, A might be found 40-percent more effective. Yet if five As fight six Bs, tank B might win. Therefore, using more Bs could produce more than a proportionate increase in force effectiveness.

Effectiveness depends on the uses of the system. Defense capability is different from offensive capability, so the assumption about the ratio of defensive to offensive use may influence the conclusion about which tank is more effective. Army studies have examined the relative likelihood of a tank's use in defense or offense. The ratios examined were 1 to 1, 7 to 3, and 9 to 1 for use in defense operations. That is, a 9 to 1 ratio represents the assumption that a tank is used in a defensive operation 90 percent of the time. The 7 to 3 ratio was the preferred rate.

The XM-1's overall effectiveness advantage was moderately sensitive to the offensive or defense ratio in the comparison but dominated in all comparisons. For example, in a defensive position where fire power is more important than protection and mobility/agility, the XM-1's advantage over M60A3 is decreased by only 10 percent. Not considered was that 20-percent more M60A3s could have been involved in a battle for the same money, thus reducing the XM-1's advantage to some additional degree.

Another consideration NATO defense primarily emphasized is that for about the same expenditure as is planned for the current 3,312 XM-1 program, it would be possible to purchase about 6,300 M60A3 tanks; store 3,000 in Europe; and meet training and operational needs in the United States, Europe, and elsewhere with the remaining 3,300. Should the need arise, the 6,300 tanks stored in Europe would need only be staffed and supplied to be used; thus, decreasing the mobility forces required and possibly increasing the speed of overseas deployment. However, problems could occur, such as supplying fuel for the increased number of tanks that would eventually be available. Obviously, there are other variations that need considering when making overall effectiveness-assessments based on comparable cost. The important premise is that given a dollar benchmark, several considerations must be considered, not just cost and effectiveness of one tank against another.

In offensive situations, the heavy XM-1 tanks are excellent alternatives to the M60 series tanks. However, the armor protection advantage which these tanks have will not continue indefinitely because enemy tanks are likely to be improved. Enemy tanks currently outnumber NATO tanks 2.5 to 1. Even if all the planned XM-1s were fielded now, the ratio would only drop to about 2 to 1.

OTHER ISSUES AFFECTING CHOICES

Some benefits cannot be quantified. For example, we are unable to quantify the benefits of NATO's deploying only one type of tank, instead of several types, although these benefits might be considerable.

International trade considerations are important for large weapon systems. With continued growth of world spending on arms, foreign markets for weapons are important because they not only increase domestic production and employment but also affect DOD acquisition costs through economies of large scale production. Foreign sales can also help recoup part of the development costs. Coproduction with our allies could bring larger sales to other countries. We discuss these issues below but we cannot fully analyze them.

Standardization

Some defense analysts believe that NATO will replace 10,000 tanks in the next 15 years. Standard tanks would offer possible economies in research and development, production, and logistics operations. Though there have been a number of partial standardization projects, we found little analysis of the resultant savings. In the January 1977 addition to a 1974 memorandum of understanding, the U.S. Army and the Federal Republic of Germany agreed to standardize on the U.S. turbine engine and to explore additional areas for standardization, including a 120-mm main gun.

In principle, standardization reduces costs of duplicative research and development among the Allied nations. With the new tanks, however, savings in research and development would be limited. Over half the XM-1's research and development funds already have been spent, and the LEOPARD 2 was already in full scale production in 1977.

Producing weapons for the total NATO market could result in longer production runs and larger scale factories, both of which would lower unit costs. However, this too requires international agreement in the early planning stages.

Standardization could eliminate redundant support facilities and overhead, reduce staffing needs for support forces, and lower overall stock levels by merging supplies. All of these actions would reduce NATO logistical costs. Also, through increased standardization, unit costs for spare parts and supplies may decrease due to quantity discounts. However, current tank inventories limit the near-term benefits achievable through standardization. Great savings are unlikely while large numbers of M60, M60A1, M60A2, LEOPARD, and XM-1 tanks continue in service because, even with standardization, existing tanks will remain in service for a long time. However, as long as no movement toward standardization occurs, these savings continue to be postponed.

An argument against standardization is the cost of failure. Vast sums have been spent on standardization projects which never materialized. The example of U.S.-German efforts to develop a common main battle tank, known as MBT-70, is often cited.

Decisions by other North Atlantic Treaty Organization (NATO) countries and foreign military sales

Current plans do not include foreign XM-1 sales. However, Army officials plan to study the possibility in the fall of 1978, and they believe demand for XM-1 could be great. Foreign sales might result in an extended U.S. procurement program, an increased production rate, or a combination of both.

If the United States decided to sell the XM-1 tank to foreign countries after domestic needs have been met, there would be no reason to assume that XM-1 program costs would change. However, jobs would be available at XM-1 facilities into the 1990s, and the United States would recoup some of its sunk costs. There is, however, no reason to think potential buyers would wait until 1986 for new tanks. If the United States decided to sell the XM-1 tank to foreign countries early in the production program, the program cost could be reasonably expected to drop.

Department of Defense (DOD) Directive 2140.2 states that a surcharge for nonrecurring research and development (R&D) will be included in the sale price to non-U.S. Government customers. The amount is determined within the Department based on a prorata share of all units made.

The United States plans to buy at least 3,312 XM-1s, with a chance of selling 7,000 more. Should this unlikely event happen, total R&D costs (over $.5 billion in 1976 dollars) would be prorated over 10,312 tanks. The United States would add about $51,400 to the price of each tank sold under Foreign Military Sales (FMS), and the United States would recover about $360 million or approximately 51 percent of its R&D costs. If FMS sales totaled 1,750 XM-1 tanks, the United States should add $104,700 to the price of each tank, recovering $183 million, or 35 percent, of its R&D costs.

Other savings

R&D is only one area for which this type of surcharge is assessed. Nonrecurring production costs are also prorated, and this surcharge would be somewhat less than the R&D surcharge. There is also a surcharge of 4 percent of the unit cost per unit for DOD sunk investment in facilities and equipment. However, DOD officials may grant deviations from the stated policy and may not charge any surcharge or may reduce the amount as they see fit. In addition to the recovery of some R&D and nonrecurring investment costs, other savings may be realized through learning curve effects.

Coproduction 1/

There are political and economic barriers to adopting standard weapons and equipment. Each nation needs to maintain high levels of employment, develop a modern industrial base, and preserve a reasonable balance of international trade. Therefore, it may not be feasible for many NATO Allies to purchase tanks from other countries or even to develop tanks of their own. Coproduction arrangements are a logical way of increasing cooperation and standardization in NATO. Because there are major political, economic, and technological advantages for participating countries, there will probably be increased pressure for coproduction programs.

There is the possibility that harmonization of XM-1 and LEOPARD 2 will involve some coproduction or licensing arrangements. (Officials at the XM-1 project manager's office told us that they expected royalty fees on the turbine engine.)

Coproduction agreements are difficult and present many management challenges. Total costs may be higher than if totally produced in the United States. On the other hand, coproduction agreements could save money if excess coproducer plant capacity could be used to meet surge requirements.

In economic terms, if the assumption were made that foreign countries would buy directly from the United States without coproduction incentives, coproduction arrangements could result in economic loss to the United States. Conversely, if sales of an item were dependent on coproduction, coproduction would be positive because part of the item would be produced in the United States. If these agreements are considered an extension of U.S. production capabilities, they could also be considered beneficial to the U.S. economy since U.S. firms could possibly realize royalty fees which contribute to the profit margin of firms, the U.S. tax base, and the balance of payments.

U.S. participation in a coproduction effort may significantly restrict prerogatives to change the program schedule or reduce funding levels. Such actions could cause political repercussions in the participating nations and could affect U.S. relations with the nations involved.

1/See "Sharing the Defense Burden: The Multinational F-16 Aircraft Program" (Aug. 15, 1977).

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