JPL PUBLICATION 80-79

FBI Fingerprint Identification Automation Study: AIDS III Evaluation Report

Volume IV: Economic Feasibility

November 15, 1980

Prepared for
U.S. Department of Justice
Federal Bureau of Investigation
Through an agreement with
National Aeronautics and Space Administration
by
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

JPL PUBLICATION 80-79

FBI Fingerprint Identification Automation Study: AIDS III Evaluation Report

Volume IV: Economic Feasibility

November 15, 1980

Prepared for
U.S. Department of Justice
Federal Bureau of Investigation
Through an agreement with
National Aeronautics and Space Administration
by
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

Prepared by the Jet Propulsion Laboratory, California Institute of Technology, and sponsored by the U.S. Department of Justice, Federal Bureau of Investigation, through an agreement with the National Aeronautics and Space Administration.

ACKNOWLEDGMENT

The following persons have contributed to the analysis described in this report and/or to the preparation of this report:

H. Alioth
E. Bahm
C. Beswick
G. Brunstein
P. Caples
R. Chafin
J. Chillemi
E. Cuddihy
R. Cunningham
J. Eskenazi
A. Feinberg
E. Gold
M. Goldberger
M. Gottdiener
D. Hopelain
J. Johnson
L. Keith
F. Kuhn
J. Lee
P. Lindley
W. MacFadden
R. Mancini
R. Miles
R. Miller
A. Mobilia
S. Mouneimne
J. Mustain
L. Perelman
C. Schober
D. Schwartz
C. Seafeldt
M. Slonski
E. Records
I. Reed
J. Urena
L. Webster
C. Weiner
R. Wells
J. Whitney

B. D. L. Mulhall
Task Manager

ABSTRACT

This volume, Economic Feasibility, presents the results of the economic analysis of the AIDS III system design. AIDS III evaluates a set of economic feasibility measures including life cycle cost, implementation cost, annual operating expenditures and annual capital expenditures. The economic feasibility of AIDS III is determined by comparing the evaluated measures with the same measures, where applicable, evaluated for the current system. A set of future work load scenarios was constructed using JPL's environmental evaluation study of the fingerprint identification system (Environmental Analysis, Volume VI of this report). AIDS III and the current system are evaluated for each of the economic feasibility measures for each of the work load scenarios. They are compared for a set of performance measures, including response time and accuracy, and for a set of cost/benefit ratios, including cost per transaction and cost per technical search. Benefit measures related to the economic feasibility of the system are also presented, including the required number of employees and the required employee skill mix. For a synopsis of the entire report, see the Executive Summary in the Compendium (Volume I).

CONTENTS

Figures

Tables

SECTION I

INTRODUCTION

The objective of this volume is to provide an economic evaluation of Rockwell's proposed AIDS III fingerprint identification system. This comprises one part of the overall evaluation that forms a basis upon which the FBI will make its decision on whether or not to proceed with the development and installation of AIDS III. In a later phase of the FBI Fingerprint Identification Automation Study, JPL will evaluate and rank additional alternative fingerprint identification systems.

The economic feasibility issues that are addressed in this volume include:

(1) Is the life cycle cost (1980-2004) of AIDS III less than the life cycle cost of the current FBI fingerprint identification system under a variety of future system work load requirements?

(2) Are the estimated annual personnel cost savings that would accrue with AIDS III implementation sufficient to justify AIDS III implementation costs? What is the payback period?

(3) Does the predicted improved performance of AIDS III over the current FBI fingerprint identification system justify the AIDS III implementation costs?

(4) What are the expected annual expenditures with the AIDS III implementation? How do these compare with the annual expenditures for the current system?

(5) Which of the many uncertainties in the future economic and operational environment of AIDS III have a significant effect on the AIDS III cost estimates and the cost comparisons between AIDS III and the current system? What are the effects?

The general approach to determining the economic feasibility of AIDS III was to compare AIDS III with the current FBI fingerprint identification system (Current System). AIDS III is Rockwell Corporation's AIDS III system design with the work cell concept, implemented according to Rockwell's implementation and transition plans (References 1,2,3). The Current System is the current FBI fingerprint identification system, including its automated name search and automated response generation capabilities (AIDS II). The comparisons are based on the required annual operating and capital expenditures for the two systems between 1980 and 2004. Pre-1980 expenditures were not included in the cost analysis of either system.

AIDS III and the Current System were treated as dynamic systems. Over the 25-year period (1980-2004), a growing portion of the work load in each system was assumed to be handled by an automated function. This dynamic quality was accounted for in the economic feasibility analysis using a set of automation indices which are estimates of the percentage of the fingerprint identification work load that is to be performed by an automated function. The automation indices are then used to estimate the number of employees needed to perform the automated name searches, technical searches and response generation. The number of employees needed to operate the AIDS II portion of the Current System is derived from Rockwell's AIDS III design. It is possible that if AIDS III is not adopted an entirely different approach to expanding the automated name search and response generation capabilities may be implemented.

SECTION II

SUMMARY

AIDS III and the Current System (current FBI fingerprint identification system, including AIDS II) have been evaluated for a set of economic feasibility measures under a range of work load scenarios derived from the forces of change described in the Environmental Analysis, Volume VI, of this report and from the Identification Division Guidelines for AIDS III.

This section summarizes the results obtained under the base case work load scenario which is described in Section III-B of this Volume. The results based on this and other work load scenarios are further documented in Sections IV and V of this Volume.

A. FINDINGS

Using the expected cost and system performance data supplied to JPL by Rockwell, AIDS III will achieve the cost savings necessary to offset the $50.591M implementation cost, with the payback year occuring in 1991, if the system is implemented on schedule. The life cycle cost of AIDS III is $553.6M compared to $573.5M for the Current System. This represents a discounted savings of $19.9M over the 25-year evaluation period. On a cumulative cost basis (no discounting) AIDS III will save $161M over the 25-year evaluation period. The cost savings are due mainly to a reduction in the number of employees needed to operate the system. It is estimated that 2,400 employees will be needed to operate AIDS III in 1993; this is 900-1,000 fewer employees than would be required to operate the Current System in 1993 (Table 2-1).

B. UNCERTAINTIES

The economic analysis of AIDS III is based on cost and system performance data supplied by Rockwell International, Inc. Since AIDS III is in the conceptual design stage of development, there is a fair amount of uncertainty in the data. In particular, only a portion of Rockwell's data was developed from firm sources such as pilot studies or manufacturer costs for system hardware.

The implementation cost estimates are Rockwell's estimates of the efforts required to design and develop new subsystems; these include automatic image retrieval, an allocator subsystem, the interface software for the proposed loosely coupled computer configuration and an automatic technical search subsystem applied to a very large (22×10^6 records) file. Cost estimates for the design and development of a system with the magnitude of AIDS III are uncertain and Rockwell does not address this issue, especially with respect to the possibility that significant problems may be encountered in the development of the various subsystems. Pilot studies have not been conducted for many of the new subsystems. Thus, the system performance

Table 2-1. Economic Feasibility Measures Evaluated for AIDS III, Current System and Current System with Full Authorized Complement under Base Case Scenario*

System	Life Cycle Cost 1980 - 2004 M	Total Implementation Cost 1980 - 1989	Total Additional Capital Cost 1993 - 2004	1993 Annual Cost M	1993 No. of Employees	Cumulative Costs 1993 M	Cumulative Costs Total M
AIDS III	$553.6	$50.591M	$3.5M	$46.9	2,398	$734.6	$1,295.9
Current System	$573.5	See Note	See Note	$58.8	3,389	$748.5	$1,456.1
Current System With Full Authorized Complement in 1986	$595.7	See Note	See Note	$60.7	3,528 (1993) 3,600 (1986)	$778.6	$1,506.6

Note: For the purposes of this analysis, a zero cost was assumed. It is possible that additional capital equipment will be needed to expand and maintain AIDS II capabilities through 2004.

*The Base Case Scenario has a 1.7% growth rate with a design work load to be achieved in 1986.

estimates, which are used to estimate the number of personnel needed to operate AIDS III, are uncertain. These personnel estimates, along with the implementation costs, constitute the most important cost elements in the life cycle cost analysis.

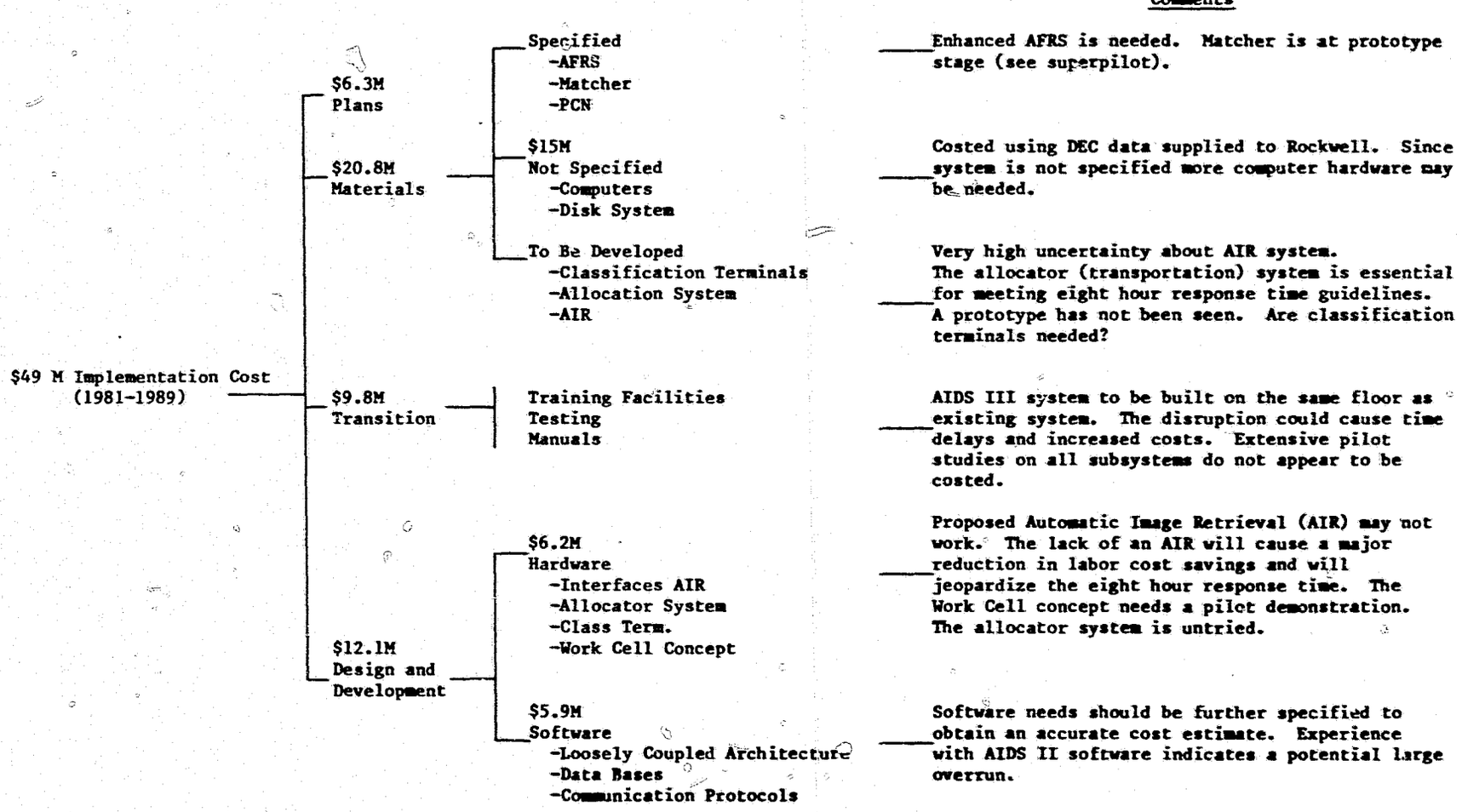
Based on the history of the AIDS project within the Identification Division, it is unlikely that AIDS III would be implemented without a series of pilot studies on the new subsystems, e.g., a pilot work cell, a pilot system supervisor, etc. These items do not appear in the implementation cost breakdown from Rockwell. It is also possible that AIDS III itself will become the pilot system, in which case the manual system could be expected to operate for many years. These possibilities and uncertainties would undoubtedly affect the life cycle cost of AIDS III unfavorably. Table 2-2 presents some of the uncertainties associated with the implementation cost estimates. Since it is impossible for the Economic Feasibility subtask to put a probability distribution on these uncertainties, the relationship of the life cycle cost to variations in the implementation cost and personnel reductions attributable to AIDS III are depicted parametrically in Figure 2-1. The rectangle represents a Rockwell estimate of $\pm$25% uncertainty in their implementation cost estimates and a JPL estimate of a $\pm$25% uncertainty factor in Rockwell's estimates for the number of personnel reductions due to AIDS III in 1993 at the design work load. Interpretation of this figure illustrates that a 25% increase in implementation cost coupled with a 25% decrease in the number of personnel reductions due to AIDS III jeopardizes the economic benefits of AIDS III. Thus, on a life cycle cost basis, AIDS III is of marginal economic benefit primarily because of the uncertainties described.

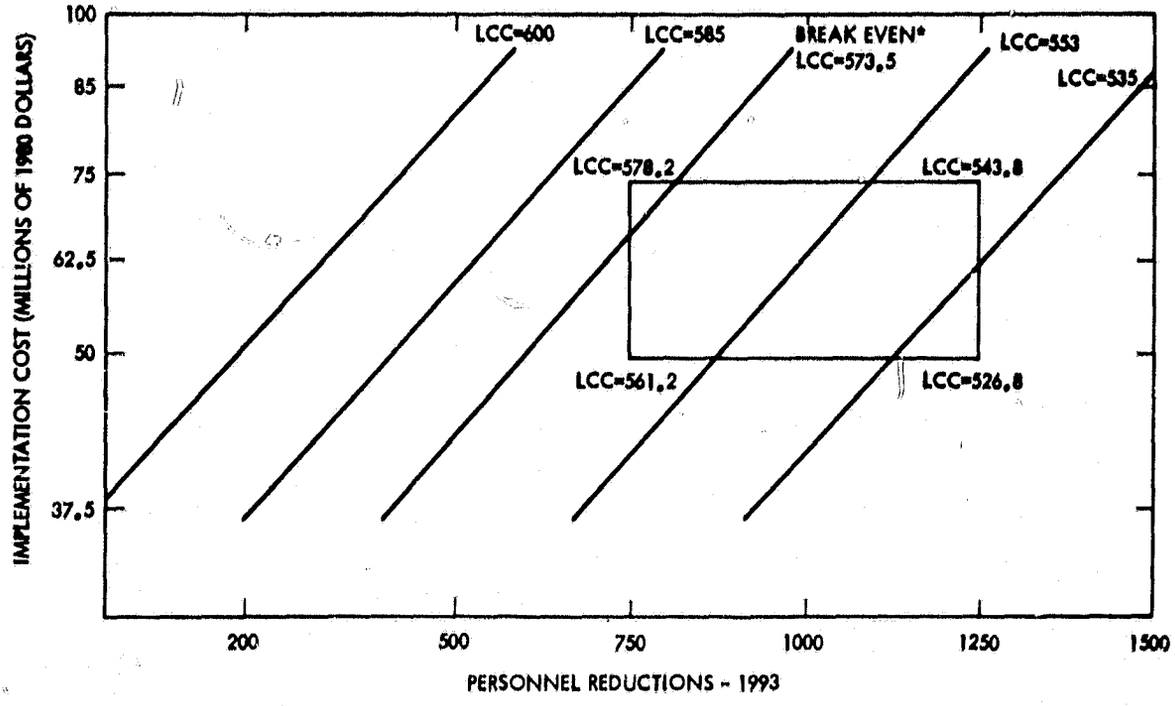
The Current System life cycle cost is based on 1986 staffing estimates of 3,400 people. Some interest has been expressed in the cost of the Current System if it were staffed at a complement of 3,600 people in 1986. This assumption increases the life cycle cost of the Current System to $595.7M and would allow a much larger uncertainty space for AIDS III in Figure 2-1 and thus improve the economic benefit of AIDS III on a life cycle cost basis. (It should be noted that this improvement is based on the increase in the Current System life cycle cost only and not on any improvements in the AIDS III life cycle cost.)

C. PERSONNEL REDUCTIONS

The number of employees needed to operate the FBI Identification Division with AIDS III implementation according to Rockwell estimates will drop from the 3,400 needed for the Current System to 2,800, when the automated technical search (AIDS III) system becomes available. Another drop to 2,500 will occur when the automated image retrieval becomes available in 1990. Throughout the period 1992-2004 the automated functions of AIDS III will process an increasing share of the Identification Division work load, thus reducing the number of employees further to 2,400 (Figure 2-2).

Table 2-2. Implementation Costs and Associated Uncertainties





*NOTE: THE LIFE CYCLE COST OF THE CURRENT SYSTEM IS ESTIMATED TO BE $573.5M

Figure 2-1. Variation of the AIDS III Life Cycle Cost (Millions of 1980 Dollars) with Implementation Cost and Personnel Reductions

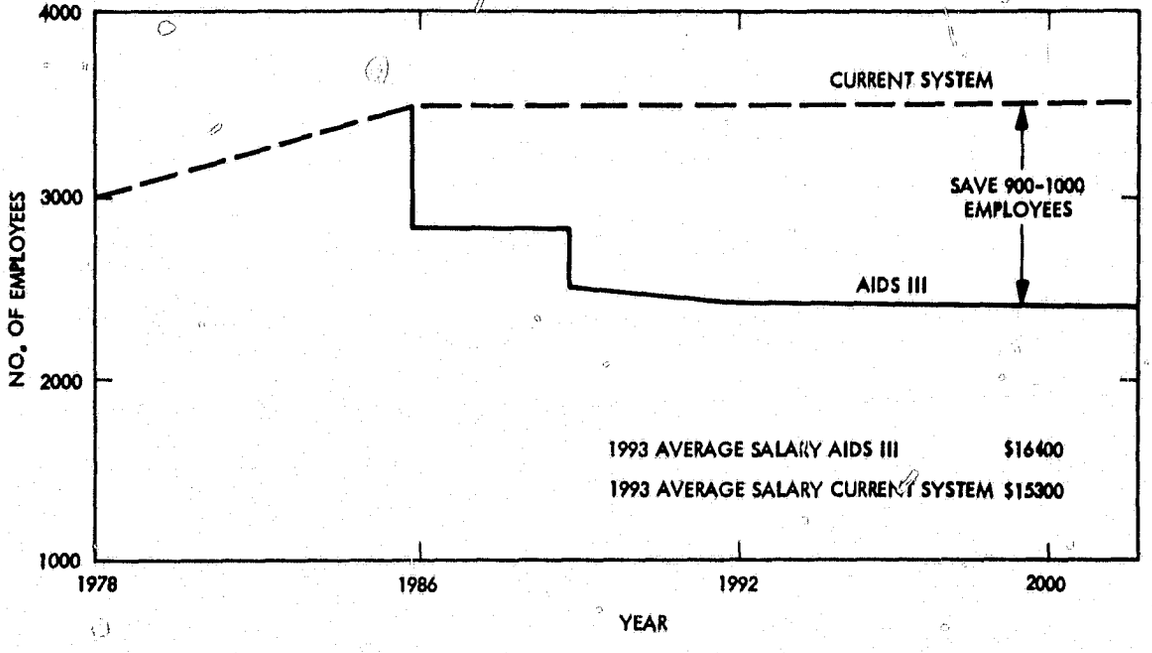


Figure 2-2. Number of Employees Over Time for AIDS III and Current System. Base Case Scenario

Thus, the personnel reductions attributable to AIDS III are estimated to be 900-1,000 people. Even with significantly incorrect estimations of expected personnel reductions as related to the system performance, it is unlikely that if AIDS III is technically and operationally feasible, reductions will be less than 400-500 people. However, a savings of 400-500 people is not enough to offset the implementation costs on a life cycle cost basis.

D. PAYBACK PERIOD

The payback period of AIDS III is estimated to be five years beyond the date of full implementation, including automated image retrieval. A set of contour lines depicting the payback periods associated with different implementation cost-personnel reduction combinations is shown in Figure 2-3. These lines were drawn based on the fact that an approximate estimate of the payback period for AIDS III can be given by:

$$\text{Payback period} = \frac{\text{Implementation Cost}}{\text{Annual Personnel Savings}}$$

$$= \frac{\text{Implementation Cost}}{13900n_1 - 15900n_2}$$

$$= \frac{\text{Implementation Cost}}{15900\ (n_1 - n_2) - 2000n_1}$$

where n_1 = number of employees in Current System, excluding Front Office, Latents, Automation and Research (A&R) (estimated as 3,100)

n_2 = number of employees in AIDS III, excluding Front Office, Latents, A&R

The set of contour lines in Figure 2-3 indicates the relationship between payback period and the point in the implementation cost - personnel reduction space where AIDS III may eventually lie. For example, a 25% implementation cost overrun coupled with a 10% increase in the number of people needed to operate AIDS III results in a payback period of 12 years. It is also evident from this figure that, since the AIDS III employees are paid, on the average, a slightly higher salary, the payback period will go to infinity if fewer than 400-500 jobs are saved by AIDS III.

E. COST SENSITIVITY ANALYSIS

The sensitivity of life cycle cost and annual labor cost to changes in Rockwell's implementation schedule is presented in Figure 2-4. A delayed implementation schedule results in a 2% higher life cycle cost ($564.9M vs $553.6M) while an early implementation schedule results in a 1.1% lower life cycle cost ($547.2M vs $553.6M). The payback year shifts ± 2 years depending on the implementation schedule. The pattern of annual labor cost changes considerably with a change in implementation schedule.

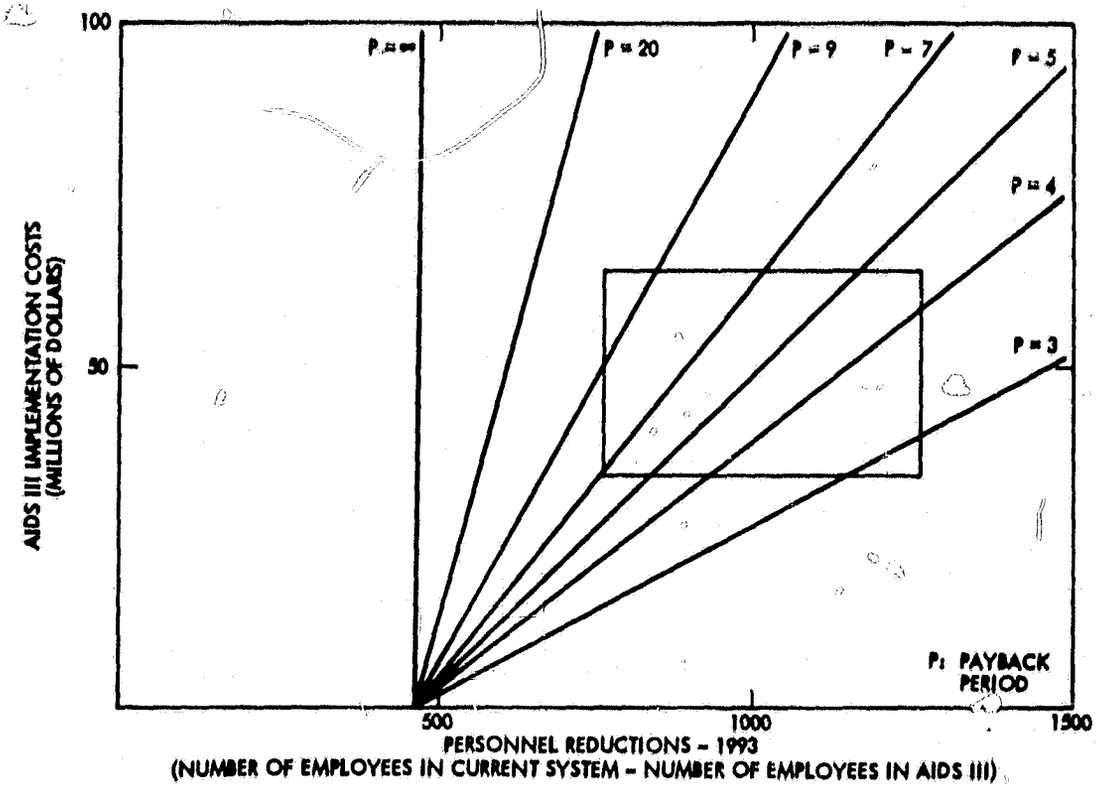
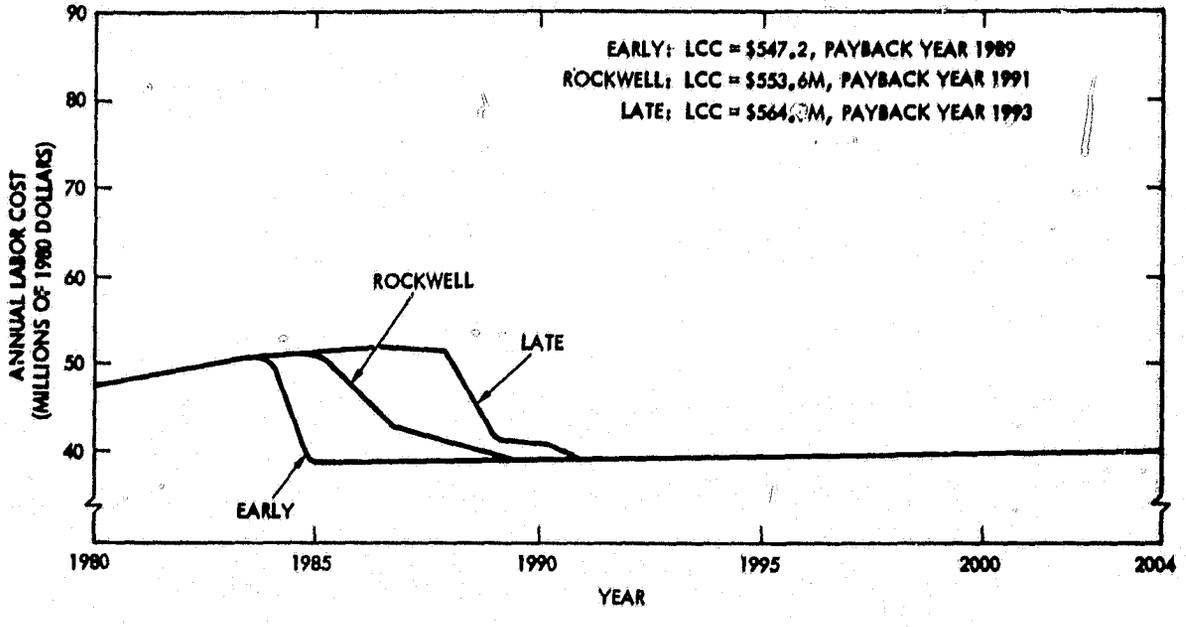


Figure 2-3. Variation of the AIDS III Payback Period with Implementation Cost and Personnel Reductions



NOTE:

SCHEDULE	AIDS III READY	AUTOMATED IMAGE RETRIEVAL
EARLY	1985	1985
ROCKWELL	1987	1989
LATE	1989	1992

Figure 2-4. Variation of Life Cycle Costs (LCC), Annual Labor Costs and Payback Year with Implementation Schedule

The economic feasibility measures were evaluated under a set of work load scenarios ranging from a 10% decrease in criminal fingerprint card submittals over a 13-year period to a 50% increase in work load volume over a 20-year period. The scenarios had several different applicant/criminal fingerprint card mixes. Under each scenario, the life cycle cost for the AIDS III system is less than for the Current System (Table 2-3). AIDS III produced a significant annual cost savings by 1993 under each scenario. The payback year is 1991 in all of the scenarios. The conclusion is that AIDS III is the more economic alternative, subject to the assumptions of the analysis and the uncertainties in the Rockwell cost and system performance data, and is insensitive to those potential changes in work load scenario identified in the Environmental Analysis, Volume VI of this report.

The economic viability of AIDS III also is sensitive to major permanent reductions in work load volume. Although no such major reductions have been identified in the Environmental Analysis, AIDS III was evaluated at reduced work load volumes. It was found that the life cycle cost of AIDS III is greater than the life cycle cost of the Current System when work load volume is gradually reduced to approximately 53% of the 1980 work load by the year 2004, or nearly a 3% annual decline in the work load volume.

F. BENEFITS

In addition to the labor cost savings, the major benefits accruing to the Identification Division with AIDS III implementation are a decrease in fingerprint card response time, decreases in costs per transaction and an increase in system accuracy.

Based on Rockwell design assumptions, a computer-based simulation of the AIDS III design has shown that the mail-room-to-mail-room response time for a fingerprint card processed in the AIDS III system

Table 2-3. Life Cycle Costs (Millions of 1980 Dollars)

Scenario / System	Base Case	1.7% Constant Growth	Mixed Growth Rates	III	Automation of FBI Identification
AIDS III	553.6	579.0	621.3	566.9	566.7
Current System	573.5	605.2	658.5	592.2	593.5

is less than four hours with probability 0.999, if the time spent in a manual name search is neglected. In 1993, 20% of the fingerprint cards are expected to need a manual name search. If this manual name search time is included, then a closer estimate of the 99.9th percentile of system response time is 8-16 hours. (The 8-16 hours is JPL's estimate of the time for a manual name search in 1993.) By 2004 only a very small percent of the cards will need a manual name search (Year of Birth < 1958); hence, the system will eventually achieve the design guideline eight hour response time for virtually all of the fingerprint cards submitted.

The Current System, scaled to handle the 1993 work load with 3,600 employees, is estimated to have a 24 hour response time (2-3 working days). The Current System (1980) with 3,100 employees has a response time of several weeks. The reduction from several weeks to 24 hours is due to the expansion of AIDS II and to a larger work force. Table 2-4 summarizes these results.

With AIDS III implementation the cost per transaction drops from $5.45 to $4.35, while the cost per technical serach drops from $7.76 to $3.67. Since it is estimated that there will be 2.9M technical searches in 1993, this results in an annual savings of $11.9M in automating the technical search and image retrieval function (Table 2-5).

The pilot studies for the AIDS III technical search process show that AIDS III will have an improved technical search accuracy. The miss rate in technical searches will drop from 20% in the Current System to 5% in AIDS III. This results in a 26% increase in the number of people identified who already have FBI records.

Table 2-6 summarizes the performance of AIDS III as measured against the FBI performance guidelines.

Table 2-4. Fingerprint Card Response Time (Mail Room to Mail Room) under 1993 Design Work Load

System	Response Time (operating hours) Average	95th Percentile	99.9th Percentile	Saturation Point[4]
AIDS III[1]	1.8	2.9	3.8	9% over Design Work Load
AIDS III[2] w/Manual	3.4-5	8-16	8-16	9% over Design Work Load
Current[3] System - 1993	24.2 (3,748 employees)	24.7	26.3	?

(1) Response time for AIDS III does not include time spent in manual name search. About 20% of the fingerprint cards will need a manual search in 1993.

(2) The time for manual name search (8-16 hours) has been included. The formula for the average response time is 1.8 + 0.2x (Time in Manual Name Search).

(3) The Current System with 3,600 employees will have a response time of 24 hours with high utilizations. A computer-based simulation of the Current System with 3,748 employees yielded a 24 hour response time with all utilizations ≤ 0.9.

(4) The saturation point for a system is reached at the work load volume that causes waiting times and waiting lines within the system to grow without bound. At the saturation point, the utilization of one or more of the subsystems = 1.0.

Table 2-5. Costs per Transaction for AIDS III and Current System

System	Cost Per Transaction 1993 (Docs and Cards)	Cost Per Subject Search 1993	Cost Per Tech Search 1993
AIDS III	$4.35	$1.13	$3.67
Current System	$5.45	$1.13	$7.76

Table 2-6. AIDS III Measured Against a Selected Set of Performance Guidelines

Guideline*	Does AIDS III Meet Guideline?	Comment
Achieve Operating Cost Savings	Yes	Saves 900-1,000 people per year when fully implemented. This is offset slightly by higher average wages paid to AIDS III employees. The labor cost savings in 1993 is $12.2M.
Response Time	Yes, if time spent in manual name search is not counted	20% of incoming fingerprint cards will need a manual name search in 1993.
Improved Level	Yes	Pilot studies indicate a 26% improvement in technical search accuracy. Also, there are many verification steps in AIDS III which will catch human errors.
Improve Quality of Service (Completeness, Legibility)	Yes	Computer generated responses.
Preserve or Improve Integrity and Security of Files	Unknown	Are computer files more secure than paper files? Is a computerized file update system more secure?
Preserve Legal and Accountability Features of File Information	Yes	No change from manual system.
Staffing - 2 to 1 Day Shift to Night Shift	Yes	50% spare hardware capacity at night.

*Performance Standard Guidelines

SECTION III

METHODOLOGY

The following steps were taken to evaluate the economic feasibility of the AIDS III Identification System.

(1) Select economic feasibility measures.

(2) Select future work load scenarios.

(3) Evaluate economic feasibility measures for the current FBI fingerprint identification system (Current System) and for the AIDS III System under each work load scenario.

(4) Compare the evaluated economic feasibility measures for the Current System and for AIDS III.

(5) Perform a sensitivity experiment: Cost versus design work load volume, design work load mix and the implementation and transition schedule.

The economic feasibility measures, the work load scenarios, the sensitivity experiment and the underlying assumptions used in the computations are discussed in this section. The results of the evaluations are in the following sections.

A. ECONOMIC FEASIBILITY MEASURES

There are a number of measures that contribute to the evaluation of the economic feasibility of a candidate system. The primary measures selected for the determination of economic feasibility for the FBI study are listed in Table 3-1. The measures were chosen for two reasons--their ability to describe the costs and performance of both the current and the AIDS III identification systems in terms pertinent to FBI management, and the reasonableness of obtaining data for these measures in a timely manner. In order to facilitate the comparison of the two systems, the economic feasibility measures are presented in a variety of ways, including variation over time, variation with work load, and cost/benefit ratios.

The two identification systems compared in this report are:

(1) The current system in the FBI Identification Division as configured in November 1979, with AIDS II (Current System). The AIDS II portion of the Current System is allowed to expand to its full potential over the 1980-2004 time period.

(2) The Rockwell Corporation AIDS III system with the work cell concept, as of its May 1980 description, implemented according to the Rockwell implementation and transition plans.

Table 3-1. Economic Feasibility Measures for AIDS III Evaluation

Life Cycle Cost

Annual Measures
- Annual Operating Cost (excluding labor costs)
- Annual Implementation Cost
- Annual Labor Cost
- Total Annual Cost
- Percent of Transactions Processed by the Automated System Each Year

Cumulative Measures
- Total Implementation Cost
- Cumulative Cost

Performance Measures
- Accuracy
- Response Time--for selected years
- Saturation Volume

Employment Measures
- Number of Employees
- Skill Mix

Cost/Benefit Ratios
- Annual Operating Cost/% Identified of Those That Should Have Been Identified
- Annual Operating Cost/Number of Transactions per Year
- Cost of Technical Search/Number of Technical Searches per Year
- Cost of Subject Search/Number of Subject Searches per Year
- Cumulative Cost/Cumulative Number of Transactions

Selected Other Ratios
- Total Transactions Per Year/Total Number of Employees
- Annual Labor Cost/Total Number of Employees
- Annual Operating Cost/Total Number of Employees

1. Life Cycle Cost Measure

Life cycle costing is an evaluation technique that takes into account all of the relevant costs over the useful lifetime of a system, including design, development, purchase, installation, training, operation, and maintenance. The life cycle cost approach incorporates all of the various costs for a system, adjusts them for differences in the time of occurrence by taking into account the time value of money, and expresses the net result as a single cost number.

The purpose of performing a life cycle cost analysis is to assess the economic feasibility of alternative systems. Since different alternatives have different cash flows over time it is often difficult to determine directly which alternative is the most economic. A life cycle cost analysis of each alternative collapses the cash flows into a single number that allows a direct comparison; the alternative with the lowest life cycle cost, if all are equally effective, is the most cost-effective.

The basic structure and flow of the life cycle cost model for the AIDS III evaluation is illustrated in Figure 3-1. The various cost elements are combined with the economic parameters to calculate the present value for each; these are then summed to obtain the life cycle cost. The methodology is described in Appendix A.

2. Annual Measures

The life cycle cost is determined by a methodology that combines the economic effects of the annual measures in Table 3-1, and, hence, could be used as the sole measure of the economic feasibility of one alternative compared with another. However, separate evaluation of the annual measures allow for the possibility that there are additional economic constraints, such as an annual expenditure ceiling, and facilitates a comparison of the benefits and cost of the alternative systems.

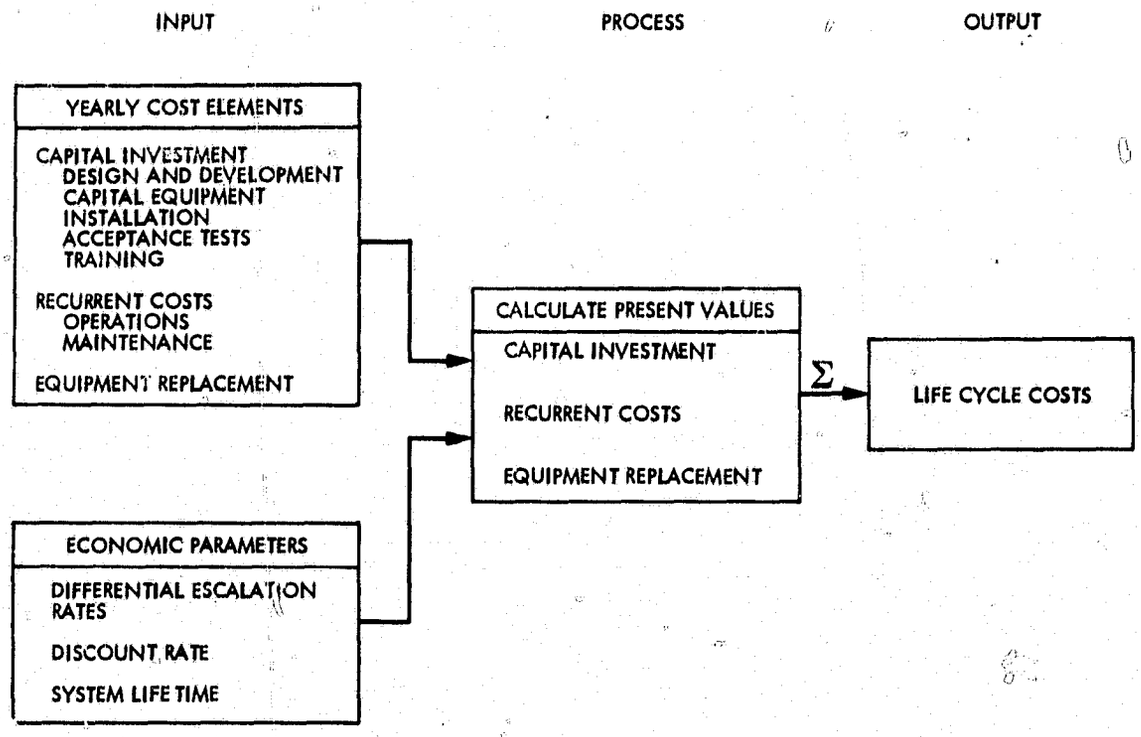


Figure 3-1. Basic Structure and Flow of Life Cycle Cost Model for AIDS III Evaluation

The non-cost annual measure--the percent of transactions processed by the automated system each year--is one way of indicating the transition schedule. Thus, changes in the transition schedule will affect this measure. A comparison of this measure for alternative systems will give an indication of how rapidly the new system is phased into full operation and at which point the benefits of the new system become fully effective.

3. Cumulative Measures

The measure of cumulative costs over time will be depicted in graphical form for the different alternatives and will facilitate the evaluation of the economic feasibility of the alternatives in terms of payback period.

4. Performance Measures

The accuracy measure is defined as the number of fingerprint cards that are identified in technical search divided by the number of fingerprint cards that have matching prints in the file, multiplied by 100 to convert to a percentage. Expanded discussion of accuracy and the other performance measures is given in Section V.

The response time or responsiveness measure is based on the turnaround time for a fingerprint card. Here, turnaround time for a fingerprint card is defined to be the elapsed time between its departure from the FBI mail room as an incoming transaction and its return to the FBI mail room as an outgoing transaction. The response time will be determined for those cards processed solely in the automated system and for those cards passed through the manual system. Statistics for response time including the mean, median, and 95th percentile are calculated.

The saturation volume is defined as the number of daily transactions at which the system would begin to have a continually growing backlog of unprocessed transactions.

5. Employment Measures

The number of employees required to operate the system is a key measure, especially over time, since it is the principal area in which cost reductions are expected to occur. The skill mix, however, is also important and is defined as the percentage of employees in each GS grade. Changes in skill mix can affect the amount of savings in labor costs.

6. Cost/Benefit Ratios and Selected Other Measures

These measures will help assess the trade-off of cost versus benefit and may illuminate some important considerations with respect

to system requirements. Since the benefits of the AIDS III system and the Current System are unequal, a set of cost/benefit ratios and other ratios will be computed.

B. BASE CASE AND ALTERNATIVE WORK LOAD SCENARIOS

Both the Current System and the AIDS III system concept were evaluated for a base case and four alternative work load scenarios.

1. Base Case Assumptions

The principal assumption for the base case is that there is a 1.7% annual work load increase from 1980 to 1986, followed by no additional increase throughout the remainder of the evaluation period. This is based on the Rockwell International document, Automated Identification Division System (AIDS III) System Concept (Reference 1) wherein it is reported that the growth rate in work load between 1973 and 1978 averaged about 1.7% per year; the design of the AIDS III system is based on the assumption that the rate is maintained through 1986.

The assumption with respect to the work load mix is that it will remain as planned in the future; that is, 50% of the transactions are applicant cards and 50% are criminal cards. For AIDS III, and for the AIDS II part of the current system, the number of employees required to process the work load will reflect the projections specified by Rockwell International in the AIDS III Technical Memo, AIDS III Operations and Maintenance Staffing Estimate (Reference 4).

The final assumptions for the base case are that the implementation schedule and transition schedule will be followed as planned in the Rockwell International documentation. These have been incorporated in the form of automation indices that are applied to three areas in which an automated system will operate. These areas are subject search, technical search, and report generation. For simplicity, several activities that will be automated in other functional areas are grouped with one of these three areas. In particular, for the purposes of this analysis, card index and posting have been included in the subject search area and fingerprint correspondence and assembly have been included in the report generation area. Both the subject search and report generation functions have been automated with the operation of AIDS II. The technical search function will be automated with the operation of AIDS III. Each of these functions will have some manual and some automated processing that depends on a demographic distribution and transition of processing that are incorporated in the automation indices. The indices are the estimated percent of the work load for the given function that will be performed by AIDS II and AIDS III in the given year.

The method of applying the indices is to estimate the labor force required to process the transactions in each area as if the processing were 100% manual and also as if it were 100% automated. By applying the automation index and its complement to each of these estimates, a revised labor count is derived that comprises both manual and automated processing. The indices for each functional area by year are listed in Table 3-2.

Table 3-2. Automation Indices for Technical Search, Subject Search and Report Generation

Year	Technical Search AIDS III	Subject Search Current System and AIDS III	Report Generation Current System and AIDS III
1980	0.0	0.42	0.46
1981	0.0	0.44	0.49
1982	0.0	0.46	0.52
1983	0.0	0.49	0.56
1984	0.0	0.50	0.58
1985	0.0	0.53	0.62
1986	0.0	0.55	0.65
1987	0.75	0.58	0.68
1988	0.75	0.60	0.72
1989	0.75	0.63	0.74
1990	0.96	0.66	0.78
1991	0.97	0.69	0.81
1992	0.97	0.72	0.84
1993	0.98	0.76	0.88
1994	0.98	0.80	0.90
1995	0.99	0.84	0.93
1996	0.99	0.86	0.96
1997	0.99	0.92	0.96
1998	1.0	0.96	0.96
1999	1.0	0.96	0.96
2000	1.0	0.96	0.96
2001	1.0	0.96	0.96
2002	1.0	0.96	0.96
2003	1.0	0.96	0.96
2004	1.0	0.96	0.96

2. Alternative Work Load Scenarios

Four alternative work load scenarios to the base case were also evaluated. The assumptions associated with each are discussed below. For a more complete discussion of these scenarios see Environmental Analysis, Volume VI of this report.

a. Scenario 1: 1.7% Constant Growth. This scenario is an extension of the base case with the additional assumption that the 1.7% growth in the work load volume continues throughout the evaluation period.

b. Scenario 2: Mixed Growth Rates. In this scenario the number of applicant cards submitted grows at a faster rate than the number of criminal cards submitted. Since the type of processing, and consequently the number of employees involved is different for each category, the different growth rates will affect the labor estimates and costs. Identification Division data show that the increase in applicant card submission has been greater than the increase in criminal card submission over the past six years. Extrapolating from this data the assumption used for this scenario is that applicant cards grow at a 6.5% rate until 1985 followed by a 2.0% rate for the remainder of the evaluation period and the criminal cards grow at a rate of 1.4% for the entire period. Because of a decision not to process state applicant cards without a state law requiring a clearance for the applicant, applicant submissions dropped dramatically during 1971-1972. The 6.5% growth rate until 1985 reflects the return of the applicant submissions to the pre-1970 levels.

c. Scenario 3: Interstate Identification Index (III). The assumption for this scenario is that the Interstate Identification Index system will become operational over the years 1980-1993 and that it will enable the states to handle more of the criminal fingerprint card processing, thus reducing the load on the FBI. The growth rates assumed are 6.5% through 1985 for applicant cards and a negative rate of -0.85% for criminal cards through 1992.

d. Scenario 4: Automation of Fingerprint Identification. This scenario is based on the assumption that an automated fingerprint identification system will make full searching of all types of cards presently submitted which are operationally and economically feasible, including military and alien submittals. This scenario assumes that the immigration quota is raised to 700,000 per year and that the military submittals grow to the level of the Vietnam era. Thus, the assumed yearly growth rates become 2.87% for applicant cards and 0.35% for criminal cards, both through 1992, followed by no growth for the rest of the evaluation period.

C. SENSITIVITY EXPERIMENT

Different sets of assumptions with respect to three parameters will be used in the sensitivity experiment. The three parameters are the work load volume or average daily input, the work load mix (percent criminal versus the percent applicant), and the implementation/transition schedule which covers both the timing of the installation of AIDS III and the time required to phase in the new system to the point where it is handling all planned inputs.

The sensitivity experiment is statistically designed to determine the sensitivity of the economic feasibility measures to changes in these parameters (Reference 5). Table 3-3 shows the sensitivity experiment used for the economic feasibility analysis. Table 3-4 shows the factor levels used in the experiment.

D. GENERAL ASSUMPTIONS

The basic assumptions with respect to the various factors used in the calculations and the assimilation of all relevant data, including estimates of future costs, and other factors to be evaluated, follow.

The values assumed for the various economic factors used in the present value calculations apply to all of the alternatives that are evaluated. For this study, the relevant economic factors are the discount rate, inflation rate, differential escalation rates, and the system lifetime. The assumptions with respect to these factors are discussed in the subsequent paragraphs.

Table 3-3. Sensitivity Experiment to Determine the Effects of Work Load Volume, Mix and Implementation Schedule on the Economic Feasibility Measures. The Economic Feasibility Measures Are Evaluated at the Conditions in Each Column

	BASE CASE	EXPERIMENTAL RUN							
		1	2	3	4	5	6	7	8
ANNUAL WORK LOAD VOLUME	DESIGN WORK LOAD	HIGH	HIGH	HIGH	HIGH	LOW	LOW	LOW	LOW
ANNUAL WORK LOAD MIX	DESIGN WORK LOAD	MOSTLY CRIMINAL	MOSTLY CRIMINAL	MOSTLY APPLI-CANT	MOSTLY APPLI-CANT	MOSTLY CRIMINAL	MOSTLY CRIMINAL	MOSTLY APPLI-CANT	MOSTLY APPLI-CANT
IMPLEMENTA-TION SCHEDULE	ROCKWELL	LATE	EARLY	LATE	EARLY	LATE	EARLY	LATE	EARLY

Table 3-4. Factor Levels Used In Sensitivity Experiment

Design Work Load Volume:	7.6 million fingerprint cards/year
High Work Load Volume:	9.5 million fingerprint cards/year (25% over Design)
Low Work Load Volume:	6.08 million fingerprint cards/year (25% under Design)
Design Work Load Mix:	50% applicant, 50% criminal
Mostly Criminal Mix:	100% criminal
Mostly Applicant Mix:	100% applicant
Rockwell Implementation Schedule:	AIDS III ready in 1987 Automatic Image Retrieval in 1989
Late Implementation Schedule:	AIDS III ready in 1989 Automatic Image Retrieval in 1992
Early Implementation Schedule:	AIDS III ready in 1985 Automatic Image Retrieval in 1985

1. Discount Rate

The Office of Management and Budget (OMB), in Circular A-94, has established that a discount rate of 10% should be used for "the evaluation of government decisions concerning the initiation, renewal, or expansion of all programs or projects ... for which the adoption is expected to commit the government to a series of measurable costs extending over three or more years..."

2. Inflation

The OMB requires that all costs be measured in constant dollars, excluding expected changes due to general inflation. For this analysis constant 1980 dollars were used. In general, the effect of including inflation is to bias the outcome in favor of those systems with higher capital costs and lower operating costs; excluding inflation will bias the outcome in the opposite direction. However, when there are no tax effects, as is the case for the FBI study, the life cycle cost equations for either the inclusion or exclusion of an inflation factor are mathematically equivalent. Thus, excluding inflation in the analyses for the FBI study will not affect the outcome of the comparisons.

3. Differential Escalation Rates

A differential escalation rate is normally the incremental difference in the expected rate of increase in the cost of a particular factor compared with the expected rate of inflation. For the FBI study it is assumed that all costs will escalate at the same rate as inflation. Thus, the differential escalation rate would normally be zero for all factors. However, in this special case where there are no tax effects, the differential escalation rate can be used to measure the expected increase in quantity, or volume, of various factors which translates into a real increase in the cost of that factor. For example, it is expected that the work load volume will increase at a certain annual rate; that increase will most likely affect various factors, such as the number of workers, resulting in an increase in labor costs.

4. System Lifetime

The system lifetime is usually the period of time over which the system is expected to be operational and a life cycle cost analysis usually covers that period of time. For this study, the concept of an evaluation period, rather than the operational period, wil be used. Whereas the operational period of a system starts after the complete installation has been made and extends to the end of its useful life, the evaluation period is a predetermined length of time during which all costs incurred will be discounted and summed. The use of an evaluation period for the analysis at hand is more appropriate. Since the complete phaseout of the manual system is not expected to occur until 2020, a reasonable evaluation period would be at least 25 years. Costs incurred after 25 years will most likely not have a significant effect on the life cycle cost of the system because the discounted value of expenditures that far in the future is less than 10% of the actual amount. In contrast, the discounted value of expenditures in the 10th year is 38.6% of the actual amount, which may have a significant impact on the life cycle cost of the system. Thus, a 25-year evaluation period starting with 1980 is assumed.

E. SOURCES OF DATA

All of the AIDS III cost data was directly or indirectly supplied to JPL by Rockwell. Implementation costs were directly supplied by Rockwell. Annual personnel costs were derived from Rockwell's estimates of the number of employees and the employee skill mix needed to operate the AIDS III system under design work load conditions (Reference 1) and from Rockwell's estimate of the transition period from the manual system to a fully automated (AIDS III) system. A JPL computer simulation model of the AIDS III system was used to project the number of personnel needed to operate AIDS III under a set of future work load scenarios (A complete description of the model can be found in Volume III of this report.) The AIDS III simulation model used Rockwell supplied values for service times at the various work stations and transportation times between work stations.

A parallel economic analysis was performed for the Current System using FBI Identification Division reports and JPL measurements of the Current System. The number of employees needed to operate the AIDS II portion of the Current System in future years was derived from Rockwell's AIDS III design.

SECTION IV

COST ANALYSIS

A. INITIAL COSTS

The evaluation period for the cost analysis portion of the economic feasibility study is the period from 1980 through 2004. The cost data and assumptions for both the Current System and AIDS III are described below.

1. Capital Investment

a. Current System. The Current System comprises both the manual system and AIDS II, and it is assumed that all capital investment for this system has already occurred. Those costs are therefore treated as sunk costs and as such are not relevant to the analysis. Any additional capital investment needed to expand the AIDS II function from its 1980 levels will increase only the Current System costs and accentuate the differences between AIDS III and the Current System.

b. AIDS III. The AIDS III capital investment schedule, provided by Rockwell International, is presented in Table 4-1.

These estimates are subject to significant uncertainties as discussed in Section II. A breakdown of the implementation cost estimates, using Rockwell's work breakdown structure, is presented in Appendix B.

2. Recurrent Costs

Recurrent costs for both the current system and AIDS III are the same at the start of the evaluation period, 1980, and remain the same until AIDS III becomes operational. The recurrent costs were estimated for 1980 and then extended to 2004 based on various assumptions. To obtain the 1980 estimate, the recurrent costs were divided into three groups, labor costs, variable operating costs and fixed operating costs. The 1980 base year costs used for the cost analysis are listed in Table 4-2 and explained in the following paragraphs.

Table 4-1. AIDS III Capital Investment (1980 Dollars)

Year	Dollars	Year	Dollars
1980	1,600,000	1985	13,532,000
1981	1,282,000	1986	7,069,000
1982	1,041,000	1987	1,898,000
1983	5,738,000	1988	3,425,000
1984	12,466,000	1989	2,567,000

Table 4-2. 1980 Base Year Operating Costs - Current System and AIDS III (1980 Dollars)

Element	Cost	Total
Labor	47,101,000	47,101,000
Variable Operating Costs		814,000
Printing, Reproduction	600,000	
Supplies, Materials	214,000	
Fixed Operating Costs		6,148,000
Travel	196,000	
Transportation	4,000	
Rent, Communications, Utilities	5,342,000	
Non-Capital Equipment	466,000	
Equipment Maintenance	140,000	

a. Labor Costs. Labor costs were estimated by computing average salaries for personnel in different categories as follows: front office, latent prints, automation and research, manual functions and automated functions. Data from the Current System Evaluation Interim Report, Table 6-1 (Reference 6), AIDS III Operation and Maintenance Staffing Estimate (Reference 4), and the GS level table of salaries for fiscal year 1980 were used to compute the average salaries. In addition, it was assumed that benefits were an additional 10.5%, overtime was an additional 2% and the night time premium was 8% of the salaries for 20% of the number of first shift personnel for the Current System and for 33.3% of the number of first shift personnel for AIDS III. The average salaries are listed in Table 4-3. The labor costs for 1980 and subsequent years were then computed based on estimates of the number of personnel from each group required. Additional personnel required to implement the system, i.e., convert files, were not included. For the Current System and for AIDS III during implementation the functions are mostly manual with the exception of those served by AIDS II. For AIDS III, as the transition occurs, the functions become more automated.

b. Variable Operating Costs. The variable operating costs are those costs that will grow along with the growth in work load and may also be affected by changes in the work load mix. Data obtained from the FY 1980 budget request for the Identification Division were used to estimate these costs.

Table 4-3. Average Salaries

Personnel Categories	Dollars
Front Office	14,934
Latent Prints	24,519
Automation and Research Section	19,746
Manual Functions	13,903
Automated Functions	15,969

c. Fixed Operating Costs. These costs are not generally related to the level of the work load or the work load mix and are expected to be fairly constant in real terms (inflation is not a factor in this analysis). The data for these costs were also obtained from the FY 1980 budget request for the Identification Division.

3. Equipment Replacements

a. Current System. A ground rule specified by the Identification Division of the FBI is that no major equipment replacement is anticipated for the Current System during the evaluation period. It is possible that the Current System with AIDS II will require additional disk storage in the future. However, these costs have not been addressed in the evaluation.

b. AIDS III. No major equipment replacement is anticipated for the AIDS III system during the evaluation period. However, it was estimated, as part of this study, that normal data record retention will require the addition of mass storage in the future. Costs assumed for these capital expenditures are listed in Table 4-4.

B. RESULTS

1. Life-Cycle Cost

The life cycle costs for both the Current System and AIDS III, for the five scenarios described earlier are presented in Table 4-5. In each scenario, the life cycle cost for the AIDS III system is less than for the Current System. Thus, under the assumptions utilized for these scenarios and using Rockwell's cost and system performance data, the AIDS III system is the more economic alternative on a cost basis alone.

Table 4-4. Capital Expenditures for Additional Disk Storage - AIDS III

Year	Item	Amount* (in 1980 Dollars)
1993	New SPM and 7 Disks	435,000
1994-1999	7 Disks	238,000 per year
2000	New SPM and 7 Disks	435,000
2001-2004	7 Disks	238,000 per year

*Each Search Processor Module (SPM) is estimated to cost $197,000, and each 300 Megabyte disk is estimated to cost $34,000.

Table 4-5. Life Cycle Costs (Millions of 1980 Dollars)

Scenario / System	Base Case	1.7% Constant Growth	Mixed Growth Rates	III	Automation of FBI Identification
AIDS III	553.6	579.0	621.3	566.9	566.7
Current System	573.5	605.2	658.5	592.2	593.5

The sensitivity of the life cycle cost to changes in Rockwell's implementation schedule was evaluated for the base case scenario. A delayed implementation schedule wherein AIDS III is not operational until 1989 results in a life cycle cost of $564.9M (a 2% increase). Early implementation with AIDS III operational in 1985 results in a life cycle cost of $547.2M (a 1.1% decrease).

Since AIDS III life cycle cost is less than the Current System life cycle cost in each alternative scenario, the question arose as to what scenario would cause the AIDS III life cycle cost to be greater than the Current System life cycle cost. It was found that the life cycle cost of AIDS III is greater than that of the Current System when the work load volume decreases at an annual rate close to 3%. This decrease results in approximately a 53% reduction of the 1980 work load volume by the year 2004. The sensitivity of the life cycle cost to reductions in work load volume is illustrated in Figure 4-1.

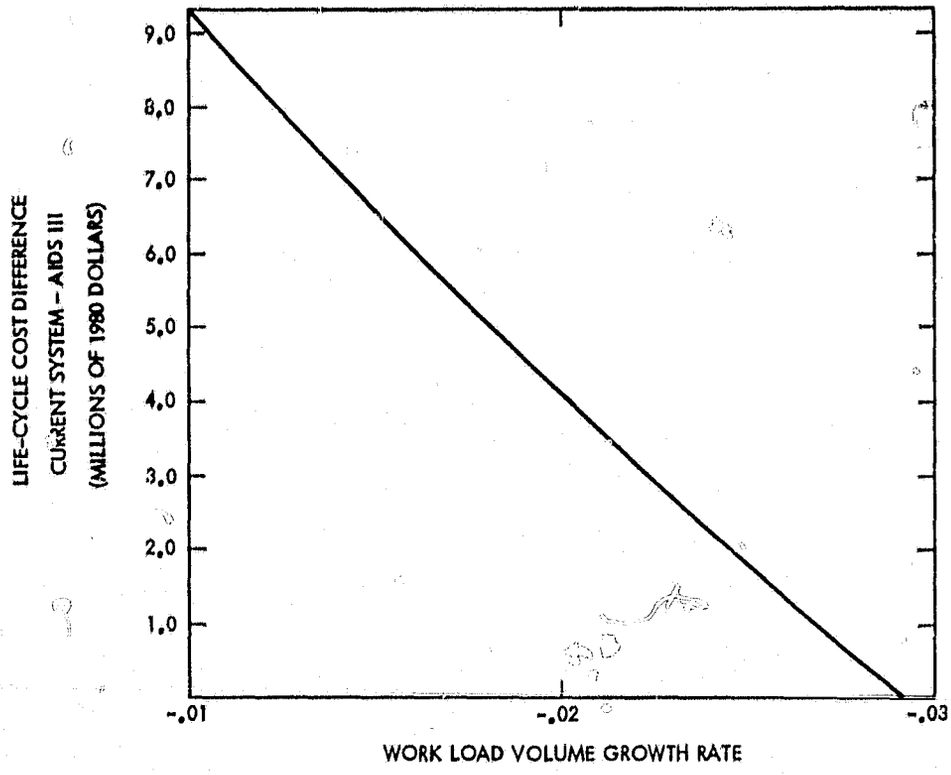


Figure 4-1. Sensitivity of Life Cycle Cost to Reductions in Work Load Volume

2. Annual Measures

a. Annual Operating Costs (Excluding Labor Costs). Figures 4-2 through 4-6 present the graphical comparisons of the annual operating costs for the current system and AIDS III under the alternative work load scenarios. In each instance the AIDS III operation is about $60,000 higher than the Current System, due primarily to additional maintenance of both hardware and software for AIDS III.

b. Annual Implementation Costs. The AIDS III annual implementation costs and capital costs for disk storage expansion are presented in Figures 4-7 through 4-9. The implementation costs are the same (Rockwell International estimates) for each scenario, but the disk storage requirements vary some, depending on the work load assumptions.

The effect of future hardware cost reductions for disk storage was assessed and found to have only a minor effect on the system life cycle cost. The crossover point for total cumulative costs (payback year) was not affected by a reduction in future hardware costs.

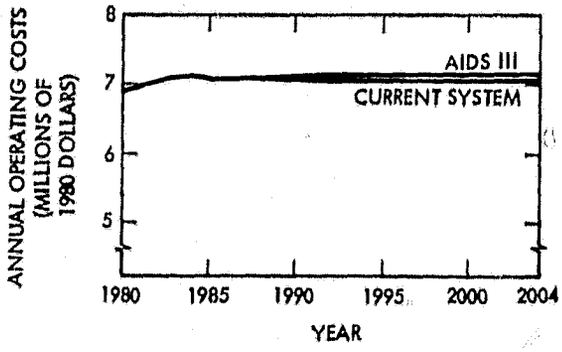


Figure 4-2. Annual Operating Costs Base Case

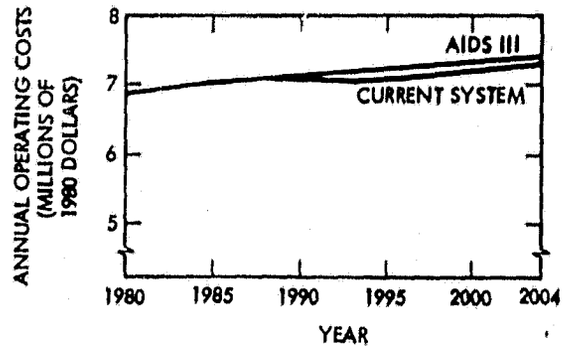


Figure 4-3. Annual Operating Costs Scenario 1: 1.7% Constant Growth Rates

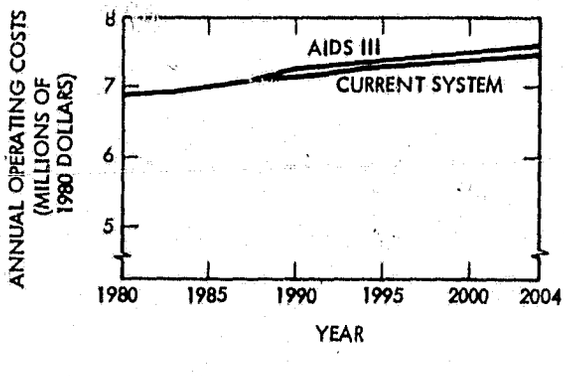


Figure 4-4. Annual Operating Costs Scenario 2: Mixed Growth Rates

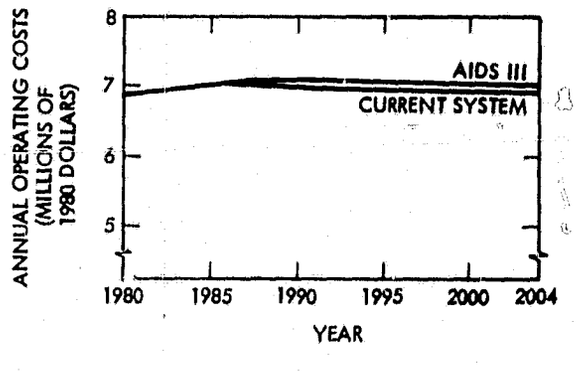


Figure 4-5. Annual Operating Costs Scenario 3: III

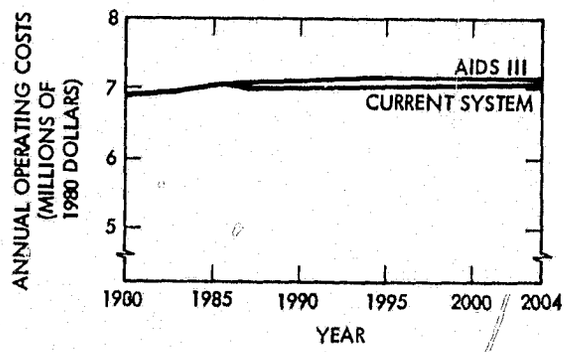


Figure 4-6. Annual Operating Costs Scenario 4: Automation of Fingerprint Identification

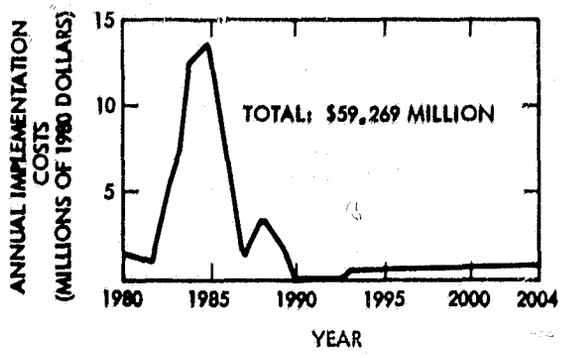


Figure 4-7. Annual Implementation and/or Capital Costs Scenario 1: 1.7% Constant Growth Rate and Scenario 2: Mixed Growth Rate

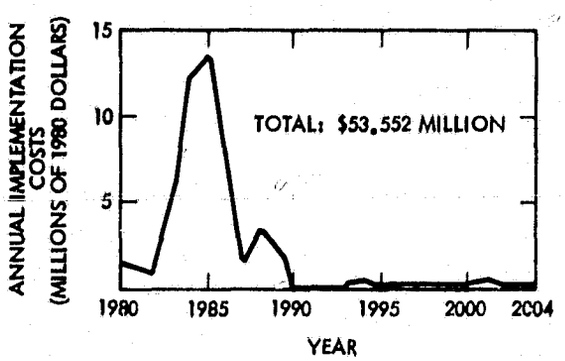


Figure 4-8. Annual Implementation and/or Capital Costs Scenario 3: III

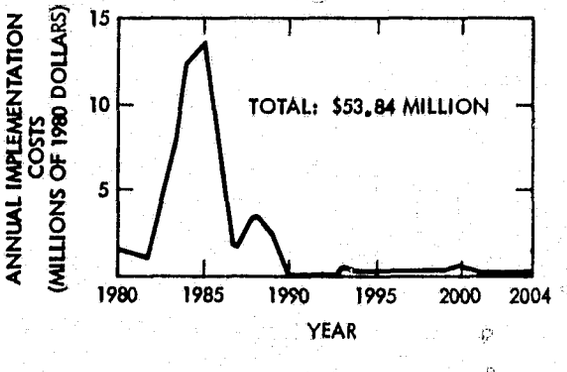


Figure 4-9. Annual Implementation and/or Capital Costs Base Case and Scenario 4: Automation of Fingerprint Identification

c. Annual Labor Cost. Graphical comparisons of the annual labor costs for the Current System and AIDS III are presented in Figures 4-10 through 4-14. AIDS III labor costs are lower than the current system under the assumptions used for each scenario. The labor cost savings attributable to AIDS III are presented, graphically on a finer scale, for each scenario in Figures 4-15 through 4-19.

d. Total Annual Cost. The total annual costs for each system under the various work load scenarios are presented graphically in Figures 4-20 through 4-24. In each instance, once AIDS III becomes operational, it is clear that AIDS III will produce an annual cost savings compared with the Current System under the work load assumptions specified. The slight increase in annual operating costs is more than offset by the labor cost savings. In addition, the life cycle cost analysis indicates that the early capital expenditures for AIDS III are favorably offset by the later reductions in cost.

e. Percent of Transactions Processed by the Automated System Each Year. The percent of the transactions processed by the automated system by function is presented graphically in Figure 4-25. The technical search function is automated in two pieces. In 1987 the technical search itself is automated. In 1989 the image retrieval function is automated. These assumptions account for the steps in the technical search graph. The subject search and report generation functions gradually rise from 40-50% automated to 96% automated in 1996. The gradual increase is due to the fact that an automated name search file is being built on a day forward basis. This means that all fingerprint cards submitted with a date of birth earlier than 1958 must be manually name searched. The automated response generation used the name search file to generate the responses.

3. Cumulative Measures

a. Total Implementation Costs. The total implementation cost including 1980 costs, for AIDS III has been estimated by Rockwell International at $50.591M. An additional $3.25M has been estimated for disk storage expansion.

b. Cumulative Costs. Total cumulative costs for the current system and AIDS III are presented graphically on a semilog scale, in Figures 4-26 through 4-30. On each graph, the crossover point can be interpreted to represent the breakeven, or payback, year for AIDS III compared to the current system under the assumptions for the various scenarios. It is interesting to note that the breakeven year is the same (1991) for all scenarios.

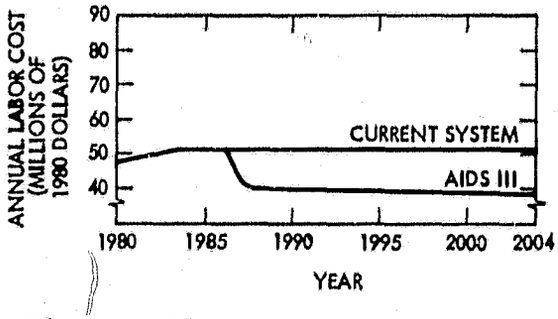


Figure 4-10. Annual Labor Costs Base Case

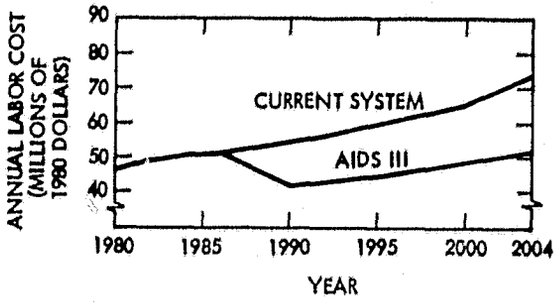


Figure 4-11. Annual Labor Costs Scenario 1: 1.7% Constant Growth Rate

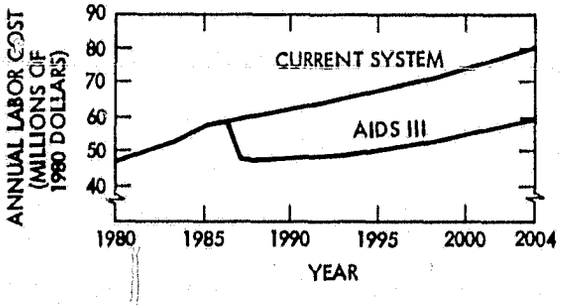


Figure 4-12. Annual Labor Costs Scenario 2: Mixed Growth Rate

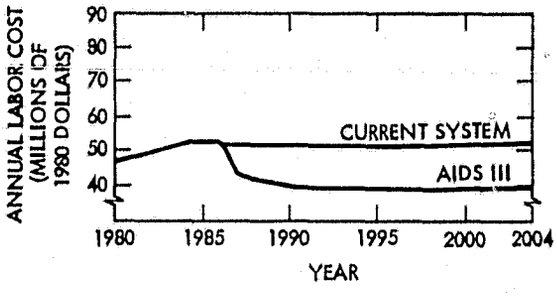


Figure 4-13. Annual Labor Costs Scenario 3: III

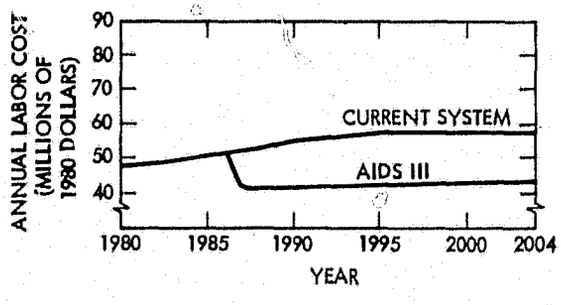


Figure 4-14. Annual Labor Costs Scenario 4: Automation of Fingerprint Identification

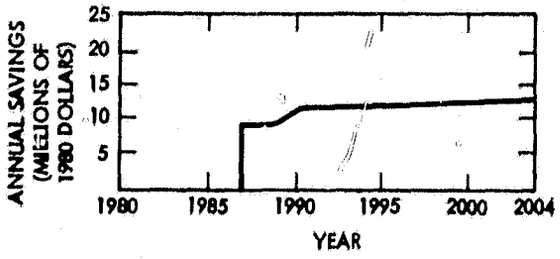


Figure 4-15. Annual Labor Cost Savings with AIDS III Implementation: Base Case

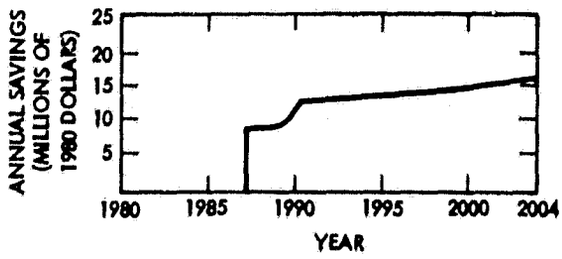


Figure 4-16. Annual Labor Cost Savings with AIDS III Implementation Scenario 1: 1.7% Constant Growth

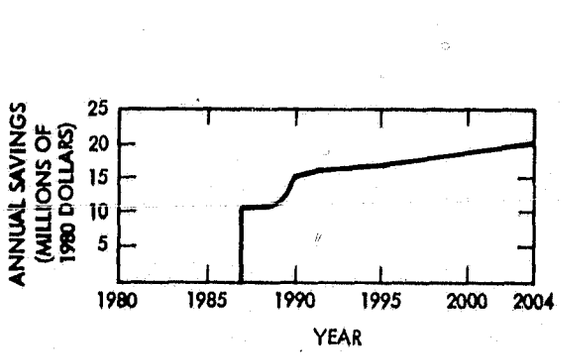


Figure 4-17. Annual Labor Cost Savings with AIDS III Implementation Scenario 2: Mixed Growth Rates

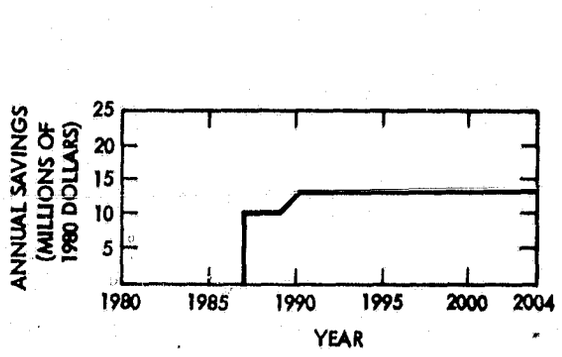


Figure 4-18. Annual Labor Cost Savings with AIDS III Implementation Scenario 3: III

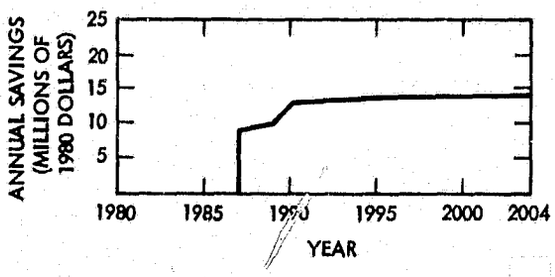


Figure 4-19. Annual Labor Cost Savings with AIDS III Implementation Scenario 4: Automation of Fingerprint Identification

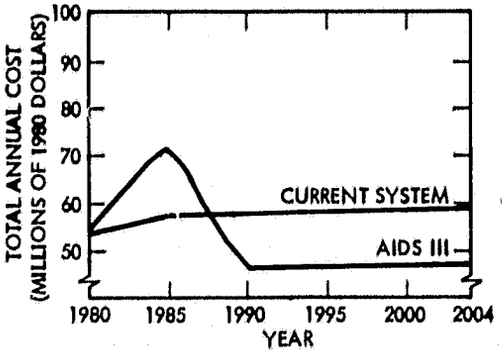


Figure 4-20. Total Annual Cost Comparison: Base Case

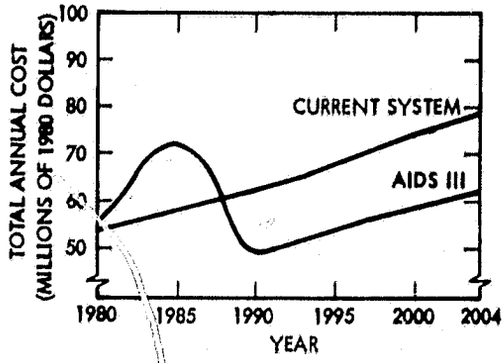


Figure 4-21. Total Annual Cost Comparison Scenario 1: 1.7% Constant Growth

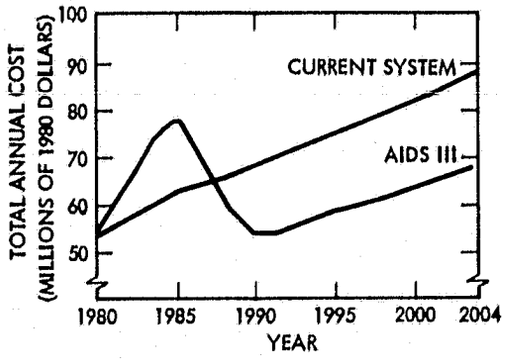


Figure 4-22. Total Annual Cost Comparison Scenario 2: Mixed Growth Rates

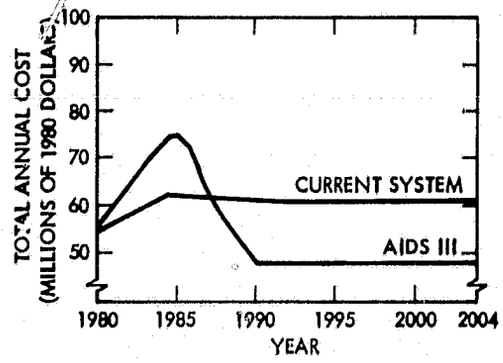


Figure 4-23. Total Annual Cost Comparison Scenario 3: III

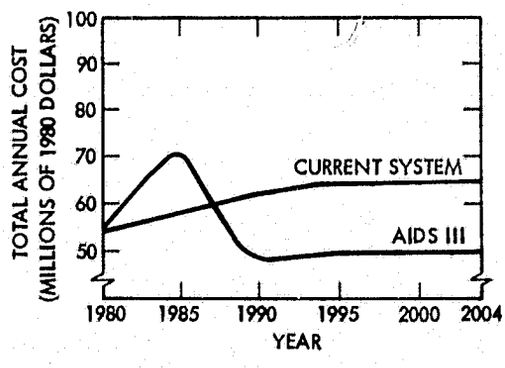


Figure 4-24. Total Annual Cost Comparison Scenario 4: Automation of Fingerprint Identification

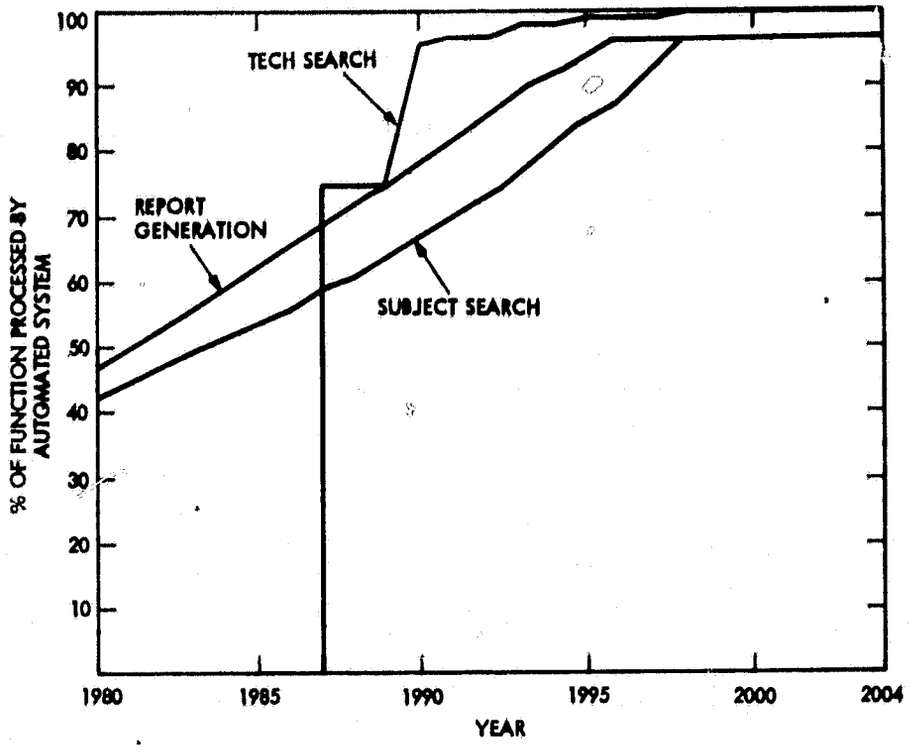


Figure 4-25. Percent of Transactions Processed by Automated System

4. Sensitivity Experiment

The sensitivity experiment described in Figure 3-2 was evaluated for the following dependent variables:

Life Cycle Cost	1980-2004	(LCC)
Cumulative Total Cost	1980-2004	(CUMTOT)
Annual Cost	1993	(TAC93)
Annual Cost	2004	(TAC04)
Number of Employees	1993	(EMP93)
Number of Employees	2004	(EMP04)

All costs are in millions of 1980 dollars. The numeric results are shown in Table 4-6. An analysis of variance (ANOVA) was performed on these data to determine the significant factors and factor interactions for each dependent variable. In all cases the work load volume had the largest effect on the dependent variables compared to the base case. A work load volume higher than the design work load volume results in higher costs and numbers of employees; a work load volume lower than the design work load volume results in lower costs and numbers of employees. The work load mix and the implementation schedule had secondary, but significant, effects. A shift to a mostly criminal work load had the effect of increasing

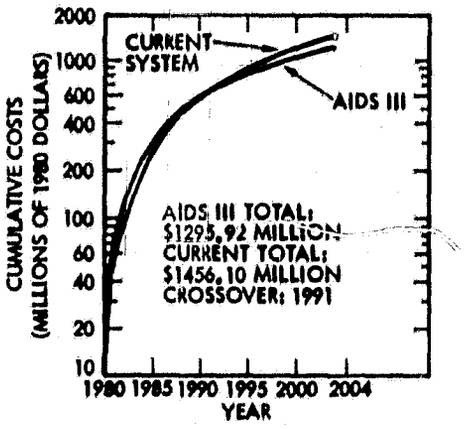


Figure 4-26. Total Cumulative Costs: Base Case

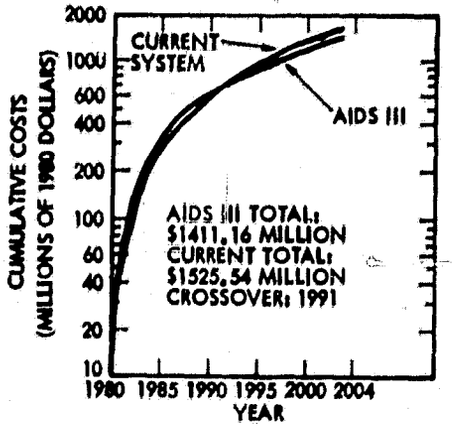


Figure 4-27. Total Cumulative Costs Scenario 1: 1.7% Constant Growth Rate

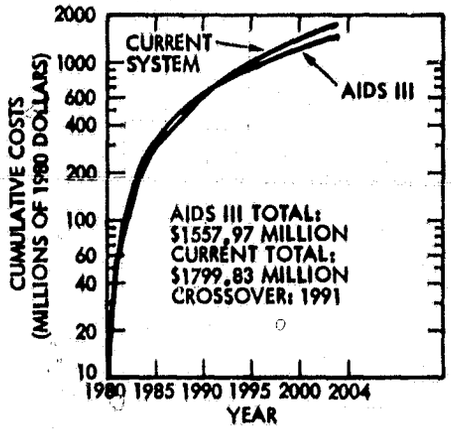


Figure 4-28. Total Cumulative Scenario 2: Mixed Growth Rates

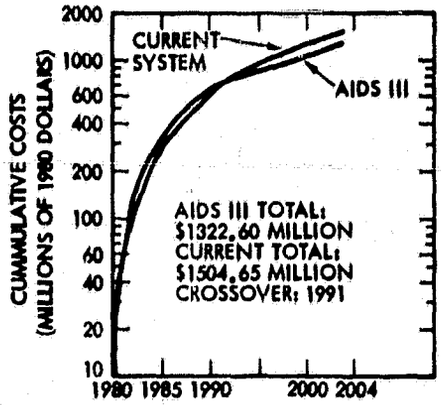


Figure 4-29. Cumulative Costs Scenario 3: III

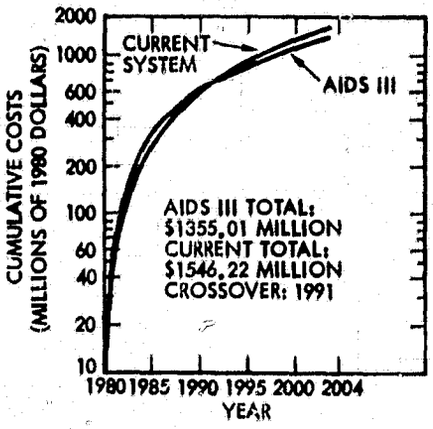


Figure 4-30. Total Cumulative Costs Scenario 4: Automation of Fingerprint Identification

costs and numbers of employees in all cases, whereas a shift to a mostly applicant work load has the effect of decreasing cost and numbers of employees. A delay of two years in the implementation schedule increased the life cycle cost (LCC) and the cumulative total by approximately the same amount as a shift to a mostly criminal work load. Similarly, an implementation schedule two years earlier than Rockwell's plan decreased LCC and cumulative total by approximately the same amount as shifting to a mostly applicant work load. A two year shift of the implementation schedule in either direction had no effect on 1993 or 2004 total annual costs (TAC) or numbers of employees.

The effects of the factor interactions were small. In general, the effects of the work load mix and the implementation schedule were lower at lower levels of work load volume.

The results of the ANOVA applied to LCC, cumulative total and number of employees in 1993 are summarized in Tables 4-7 through 4-9. The main effect column can be interpreted as the cost of moving from the design level of the given factor to the high level of that factor. The negative of the main effect is the cost of moving from the design level of the factor to the low level of that factor. For example, an increase of 25% in the design work load would add approximately $107.9M to the base case LCC of AIDS III whereas a 25% decrease would reduce the base case LCC by approximately the same amount. A change from the design work load mix to a mostly criminal work load would increase the base case LCC of AIDS III by about $13.2M, and a change to a mostly applicant mix would decrease it by approximately the same amount.

The sum of squares column gives values indicative of the variation in life cycle cost cumulative total cost, or number of employees for each factor. Finally, the F-ratio column relates this variation by factor to the variation due to randomness.

A complete analysis of the variance table for LCC is found in Table 4-10.

Table 4-6. Sensitivity Experiment Comparisons (Millions of 1980 Dollars)

	Base Case	Experimental Runs							
		1	2	3	4	5	6	7	8
LCC	553.598	693.833	655.682	654.649	629.352	463.636	441.475	439.744	425.139
Cum Tot	1295.92	1618.74	1538.90	1530.33	1471.95	1084.66	1036.86	1030.14	994.90
TAC 1993	46.995	57.388	57.388	54.504	54.504	38.605	38.605	36.787	36.787
TAC 2004	46.757	57.215	57.431	54.140	53.197	38.500	38.632	38.567	36.361
TLC 1993	39.410	48.950	48.950	47.155	47.155	31.082	31.082	29.918	29.918
TLC 2004	39.409	49.271	49.486	46.790	46.488	31.276	31.406	29.698	29.492
# Emp 1993	2398	3001	3001	2889	2889	1872	1872	1799	1799
# Emp 2004	2368	2999	2997	2844	2807	1871	1869	1772	1750

Table 4-7. Summary of ANOVA for Life Cycle Cost (1980-2004) in Millions of Dollars

Factor	Main Effect	Sum of Squares	F-ratio
Work Load Volume	107.9	93,208	20,000
Work Load Mix	13.2	1,398	398.35
Implementation Schedule	12.5	1,255	357.79

Table 4-8. Summary of ANOVA for Cumulative Total Costs (1980-2004) in Millions of Dollars

Factor	Main Effect	Sum of Squares	F-ratio
Work Load Volume	255.6	506,702	50,000
Work Load Mix	31.5	7,927	800.69
Implementation Schedule	27.7	6,119	618.05

Table 4-9. Summary of ANOVA for Number of Employees (1993)

Factor	Main Effect	Sum of Squares	F-ratio
Work Load Volume	555	2,461,980	10,000
Work Load Mix	47	17,112	90
Implementation Schedule	(no effect)	--	--

Table 4-10. ANOVA for LCC by VOL, MIX, IMPL

Source of Variation	Sum of Squares	DF	Mean Square	F	Significance of F
Main Effects	95,861.808	3	31,953.936	9,107.317	.008
VOL	93,208.781	1	93,208.781	20,000	.004
MIX	1,397.671	1	1,397.671	398.356	.032
IMPL	1,255.356	1	1,255.356	357.794	.034
2-Way Interactions	220.985	3	73.662	20.995	.159
VOL MIX	79.923	1	79.662	22.779	.131
VOL IMPL	88.991	1	88.991	25.364	.125
MIX IMPL	52.071	1	52.071	14.841	.162
Explained	96,082.792	6	16,013.799	4,564.156	.011
Residual	3.509	1	3.509		
Total	96,086.301	7	13,726.614		

SECTION V

COST AND BENEFIT ANALYSIS

A. BENEFIT MEASURES

Five benefit or performance measures to describe the operation of the two systems were selected for comparison. Three of the measures, accuracy, response time, and saturation volume, describe the performance of the systems. The other two measures, number of employees required and employee skill mix, describe labor input needed for operation of the systems. Each of the five benefit measures will be discussed in turn.

1. Accuracy

Accuracy is an important benefit of an identification system. Two types of error can occur during the searching of a file: 1) missing a matching record that is in the file; and 2) selecting an individual whose record does not match the one being searched. The second type, usually termed a "false drop", is caught in both AIDS III and the Current System during the manual verification step and does not result in an error leaving the system. False drops cause extra work and thus extend the average turnaround or response time for fingerprint cards. Since response time is another benefit measure, the effects of false drops are taken into account. Hence, the measure of accuracy to be used will be based on the first type of error, that of missing a matching record in the file.

An accuracy measure derived from the miss rate is its complement, the hit rate = 100 - miss rate. The hit rate is the number of transactions that are identified in subject search or in technical search divided by those that do have prints in the file, then multiplied by 100 to convert to a percentage. The reason for using hit rate rather than the miss rate is because larger values of hit rate are preferred to smaller ones, thus enabling its use in cost/benefit ratios.

The Automated Technical Search (ATS) Pilot System* has tracked the comparative miss rates between the manual technical search system and the AIDS III technical search system. The May 24, 1980, Evaluation Summary Report (FBI Identification Division) contains comparative results for 28,218 sets of prints searched by both systems during a nearly one-year period. The comparative miss rates reported for the manual and automated systems were 24.57% and 5.20%, respectively. Thus, the comparative hit rates were 75.43% for the

*For more detail on the Pilot System, see JPL Report 5030-457, FBI Fingerprint Identification Automation Study: AIDS III Evaluation Interim Report-Volume III: Operational Feasibility, March 1980, pp. 4-3 to 4-5.

manual system, and 94.8% for the automated system. The manual system identified 1,087 prints while the automated system identified 1,366 prints of those in the pilot file, an increase of nearly 26% in identification with the automated system.

The comparative technical search hit rate for the manual system differed considerably between applicant and criminal fingerprint cards, with hit rates of 60% for applicants and 81% for criminals. On the other hand, the comparative technical search hit rates for AIDS III were 96% for applicants and 94% for criminals.

The implications of these comparative technical search hit rates can be applied to the design work load volume of 29,200 fingerprint cards per day. This total includes approximately 1,600 resident alien cards and 2,200 military cards which are not to be technically searched. Of the remaining 25,400 cards received each day, 11,600 are assumed to be applicant cards; the balance of 13,800 are criminal cards. Since the design work load specifications assume that 72% of the incoming applicant cards and 27% of the incoming criminal cards result in technical searches, this leads to about 8,350 technical searches for applicants and 3,725 for criminals. Using the proportions of searches that should have fingerprint cards in the file as determined in the pilot study, about 200 applicant card matches per day and 500 criminal card matches per day should result. Applying the comparative hit rates for the Current System and AIDS III yields a total of 525 matches per day for the Current System and 662 matches per day for AIDS III. These results are summarized in Table 5-1.

Table 5-1. Fingerprint Search Accuracy Comparison Based on Pilot Study for Base Case Work Load

Search Characteristic	Current		AIDS III	
	Applicant	Criminal	Applicant	Criminal
FP Card Daily Volume	11,600	13,800	11,600	13,800
Number of Technical Searches	8,350	3,725	8,350	3,725
Number in File (Approx.)	200	500	200	500
Number Found	120	405	192	470
Comparative Hit Rates %	60	81	96	94
Total Found	525		662	

Since the data on comparative system accuracy came from a pilot test involving over 28,000 fingerprint cards, there is more certainty in the accuracy estimates than for other benefit data derived from sources other than pilot tests. One source of uncertainty is that the work of Unit 14 may not be representative of the fingerprint mix handled by the Identification Division. Expansion of the pilot test beyond Unit 14 would help reduce this source of uncertainty.

2. Response Time

Another key measure of benefit or performance of the identification system is response time. Response time is to be measured in terms of the turnaround time for a transaction, where turnaround time is the elapsed time between departure from the FBI mail room as an incoming transaction and return to the FBI mail room as an outgoing transaction.

In the AIDS III system, some cards will pass solely through the automated portion while others will pass through both the manual portion and the automated portion. Response times for both situations are included in the response time computations.

Response time data for the Current System under various scenarios were provided by a simulation model prepared for the Current System Evaluation Task. The model is described in the Current System Evaluation, Volume V of this report. The number of servers used in the model of the Current System was the number of servers needed to maintain system-wide utilizations less than or equal to 0.90 at the given work loads.

The simulation model for the Current System was run for a simulated period of 20 days for scenarios including: the base case, 1.7% constant growth case, implementation of AIDS III, a 20% increase and 20% decrease in work load from the base case system, and a similar increase and decrease in work load with a rescaled system. The results of these runs are shown in Table 5-2.

In those cases that did not saturate the system and cause it to be unstable, the mean, median and 95th percentile response times were between 24 and 25 hours. The 99th and 99.9th percentiles for the stable runs were between 25.23 and 26.28 hours. It should be noted that 3,748 employees were required to handle the design work load -- considerably more for higher work loads -- to achieve these response times with the Current System. If the subsystem utilization is allowed to rise above 0.90, 3,600 employees will be able to handle the design work load but the system will be very sensitive to fluctuations in work load.

The simulation model for the AIDS III system provided the response time data presented also in Table 5-2. The model was prepared for the Operational Feasibility Subtask and is described in Operational Feasibility, Volume III of this report. The model was run

Table 5-2. Response Times for the AIDS III System and the Current System under Several Scenarios

System	Scenario	System Size	Daily* Fingerprint Card Volume	Year	No. of Employees	Response Times in Hours				
						Mean	Median	95%	99%	99.9%
AIDS III	Base Case	Enhanced AIDS III	27,740	1993	2,388	1.50	.81	2.9	3.0	3.8
	Constant Growth of 1.7%	Designed for ≤8 hour	31,154	1993	2,650	1.65	2.70	2.8	3.2	3.7
		Turnaround for ≥95% of	37,500	2004	3,163	1.75	.80	2.9	3.1	3.7
	Mixed Growth of 1.7%	Transactions at the	34,913	1993	3,085	1.76	.85	3.0	3.1	3.4
		Indicated Work Load	42,188	2004	3,563	1.84	.85	3.2	3.4	3.7
	III Implemented		28,929	1993	2,584	1.68	.81	3.1	3.3	3.7
	Base Case at .8 Work Load	Same Size as for Base Case	22,253	1993	2,388	1.53	.79	2.8	2.9	3.0
	Base Case at 1.2 Work Load	Same Size as for Base Case	33,196	1993	2,388	**				
	Rescaled System at .8 Work Load	System Rescaled from Base Case to Provide	22,253	1993	2,051	1.68	2.72	2.9	3.1	3.7
	Rescaled System at 1.2 Work Load	≤8 hour Response for ≥95% of Transactions	33,196	1993	2,797	1.47	2.72	2.9	3.0	3.4
Current	Base Case	Current System Enhanced	27,600	1993	3,748	24.25	24.18	24.77	25.38	26.28
	Constant Growth of 1.7%	to Provide ≤25 hour	31,000	1993	4,174	24.33	24.27	24.77	25.47	25.83
		Turnaround for ≥95% of	37,300	2004	5,009	24.33	24.27	24.93	25.39	25.60
	Mixed Growth of 1.7%	Transactions at the	34,250	1993	***					
		Indicated Work Load	41,000	2004	***					
	III Implemented		27,200	1993	3,748	**				
	Base Case at .8 Work Load	Same Size as Base Case	22,100	1993	3,748	24.18	24.12	24.62	25.23	25.77
	Base Case at 1.2 Work Load	Same Size as Base Case	33,100	1993	3,748	**				
	Rescaled System at .8 Work Load	System Rescaled from Base Case to Provide	22,100	1993	3,180	24.42	24.42	24.85	25.53	25.9
	Rescaled System at 1.2 Work Load	≤25 hour Turnaround for ≥95% of Transactions	33,100	1993	4,464	24.33	24.27	24.93	25.32	25.77

* Daily Fingerprint Card Volume not Including Resident Alien Cards
** System Overloaded and Unstable
*** Results in Preparation

for a simulated period of four days for scenarios including: the base case, 1.7% constant growth case, the mixed growth case, AIDS III implementation, and 20% increase and 20% decrease in work load with and without rescaling the system size from the base case. In general, the number of servers used in the AIDS III model was the number of servers necessary to maintain stable queues. This usually corresponded to utilizations ≤ 0.96.

For the AIDS III system, when it was not saturated, mean response times ranged from 1.47 to 1.84 hours. Median response times were about three hours for fingerprint cards which went through the image comparison subsystem and about one hour for cards which did not. The 95th, 99th, 99.9th percentile response times were all between 2.8 and 3.8 hours.

There are several sources of uncertainty in the response time data just presented. In the case of the Current System, the uncertainty stems from the assumptions that adequate staffing could be provided to avert long queues and that transportation delays could be kept very small. These assumptions led to mean response times from the computer simulation on the order of 24 work hours while a recent Identification Division survey disclosed turnaround times averaging 25.5 work days.* It is much more likely that the response times for the Current System estimated by the computer-based simulation are higher than the average of 24 work hours rather than lower. In order to measure the fully staffed Current System response times with less uncertainty, a pilot study with full staffing could be conducted.

In the case of the response times estimated by the computer-based simulation of the AIDS III System, the chief uncertainty stems from the assumption that this system will perform as specified by Rockwell. In particular, the reliability levels specified for the subsystems seem rather high (many over 0.99). This point is discussed more elaborately in Volume III of this report. Also, in order for the AIDS III system to handle the design work load volume in the computer-based simulation, additional units, beyond those specified by Rockwell, had to be added to several of the subsystems. Hence, it is more likely that response times with the AIDS III system will be higher than the aforementioned simulation results rather than lower.

3. Saturation Volume

Saturation volume for a fingerprint identification system is that daily transaction volume that causes queues within the system to grow without limit. Growing queues within the system indicate instability in the system.

---

*Cited in letter to Brendan D. L. Mulhall from John M. Jones, Section Chief, Latent Fingerprint Section, Identification Division, August 20, 1980, p. 7.

In the simulation runs reported in Table 5-2, instability occurred for both AIDS III and the Current System when a 20% increase in work load was input without expanding the capacity of the system from the base case work load capacity. In other simulation runs instability occurred with increases in volume of less than 10%.

The saturation point of the systems depends upon the utilization of each of the subsystems. A subsystem with a utilization of 1 (or near 1) will cause unstable queues to form.

Table 5-3 presents the utilization and saturation work load volumes for various subsystems in AIDS III. In each case the capacity of the subsystem can be expanded to accommodate the work load volume with utilizations less than 1. The nature of the expansion is usually to add a few work stations (employee + terminal, if necessary). In

Table 5-3. Saturation Work Load Volume for AIDS III System Design (Fingerprint Card Processing)

Subsystem	No. of Servers	Utilization	Saturation Volume Point* (% over Design Work Load)
PCN	2	0.62	61
MFILM	5	0.82	22
QC	14	0.97	3
Work Cell	15	0.92	9
CSORT	12	0.96	4
AFRS**	5	0.87	15
SAR	7	0.88	14
ICI	19	1.00	0
ICV	13	0.99	1
SEAR	15	0.88	14
AUTOCOR***	24	0.91	10

Notes:
*Saturation Volume = $((\text{utilization})^{-1} - 1)$ 100% of Design Work Load.
**Rated at 250 cards per hour.
***Extra capacity may be needed to handle documents.

the case of the AFRS, an additional AFRS will be needed or additional shifts must be worked. Since the work cell may need to be redesigned or replicated, if permanent additional capacity is needed, the saturation point of AIDS III can, for the purpose of this study, be put at 9% over the design work load volume, which is the saturation point of the work cell subsystem.

A computer simulation of AIDS III showed that it could operate at work load volumes 20% higher than the design work load if approximately 20% more work stations are added to AIDS III. The limits of this expansion are estimated by Rockwell to be 50%.

AIDS III has been designed to have high utilization at many points in the system; at several points the utilization is in excess of 0.95 at the design work load. These high utilization levels lead to very unstable situations with small sustained increases in the work load volume. An analysis of the planned operation of the AIDS III work cell concept demonstrates that a 9% increase in the work load volume will result in increasingly long queues, i.e., the work is arriving faster than it can be processed (Figure 5-1). As can be seen in Figure 5-1 the delay time in the work cell rapidly increases as the work load volume increases from the design point of 158 cards per hour to the saturation point of 170 cards per hour.

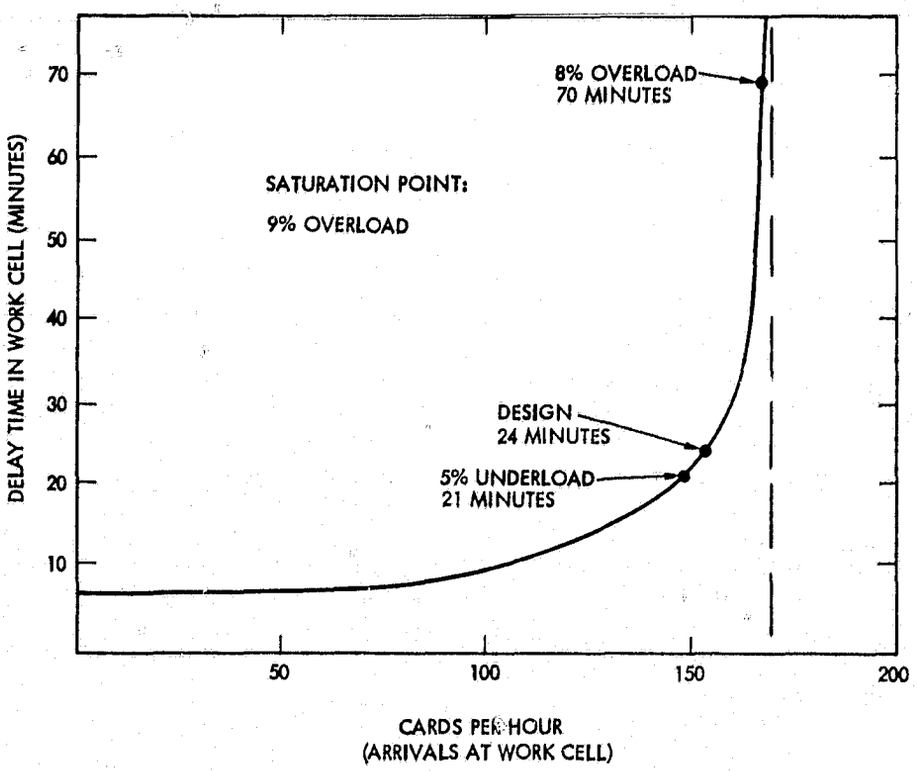


Figure 5-1. Delay Time in Work Cell vs Work Load Arrival Rate AIDS III System Design

4. Number of Employees and Employee Skill Mix

The number of employees required to provide various response times, although not an output performance measure, is a key measure of the benefits associated with an identification system. Employment ceilings have been enforced and may prevent actions of adding employees to deal with increased work loads.

Skill mix is one important factor to measure the tradeoff between automated versus manual systems. That is, does a small additional number of more skilled (more expensive) employees favorably offset the large number of replaced unskilled employees? To answer this question, both the number of employees required and the skill mix of those employees are needed to compare the automated AIDS III and current manual systems with regard to employment.

The number of employees required for each system under each scenario, presented in Table 5-2 and elsewhere, includes all Identification Division employees; that is, front office, latents, and automation and research as well as those more directly involved with fingerprint card identification. The skill mix of employees required reflects that of the entire Identification Division as just enumerated. The AIDS III employee count does not include any additional personnel needed to implement the AIDS III system. For example, it does not include the personnel needed to convert the fingerprint card file to a microfiche card image file. The file conversion cost is included in the implementation costs and thus is not included in the labor costs.

B. VARIATION OF BENEFITS OVER TIME

1. Accuracy

As previously mentioned, the only definitive data on accuracy for automated and manual fingerprint identification systems come from the ongoing pilot system at the FBI. The accuracy results to May 24, 1980, indicate a comparative hit rate of 75.43% for the manual system and 94.80% for the automated system. They also indicate that the manual system is not as adequate for applicant searches as it is for criminal searches, (about 60% hit rate for applicants, 80% for criminals), while the automated system is about the same for both (about 96% for applicants, 94.5% for criminals). Thus, if the mix of fingerprint cards has an increasing proportion of applicant cards over time, the hit rate for the manual system will decline, while if the proportion of criminal fingerprint cards increases, the hit rate for the manual system will rise.

2. Response Time

The simulation runs carried out to provide the response time data shown in Table 5-2 added employees as work load grew or reduced employees as work load decreased. These runs were not designed to

display changes in response time over time. However, if the work force is kept fixed, response time will change over time in direct relation to the work load, i.e., an increase in work load will cause an increase in response time. It should be noted that when a 20% increase in work load was simulated without additional work force, both the Current System and AIDS III became saturated. Thus, only a 20% increase in work load, without increased work force, caused both systems to become unstable.

3. Employment

The measure of system operation that does change over time is the number of employees required to maintain specified response time performance. The number of employees required for both the Current System and AIDS III from 1980 to 2004 is displayed in Figures 5-2 through 5-6 for the five scenarios of base case, 1.7% constant growth, mixed growth, III implementation and technological breakthrough. In all cases, the Current System requires at least 1000 additional employees compared to AIDS III by the early to middle 1990's. In the constant and mixed growth scenarios, the number of additional employees required by the Current System is even greater.

C. VARIATION OF COST WITH WORK LOAD

In order to explore the variation of total annual cost with work load, simulation runs for both the Current System and AIDS III were performed for 80%, 100%, and 120% of the 1993 base case work load with the system rescaled to provide approximately equivalent response times. The number of employees required in each case is reported in Table 5-2.

Table 5-4 that follows gives the total annual costs for both systems for the three work load levels along with the differences in total annual costs. These total annual costs are plotted in Figure 5-7. From these results, one can infer that the savings in total annual cost with AIDS III increase more with a 20% work load increase than they decline with a 20% work load decrease, assuming that the systems are rescaled to provide approximately equivalent response times.

D. VARIATION OF RESPONSE TIME WITH WORK LOAD

An investigation of the variation of response time with work load was attempted by varying work load $\pm$20% from the base case without rescaling the systems. With both the Current System and AIDS III, when 20% additional work load was put through, the systems saturated and became unstable. On the down side, when 20% less work load was fed in, only slight decreases in the median, 95th and 99th percentile response times occurred but a larger drop in the 99.9th percentile response time occurred. These results are included in Table 5-2.

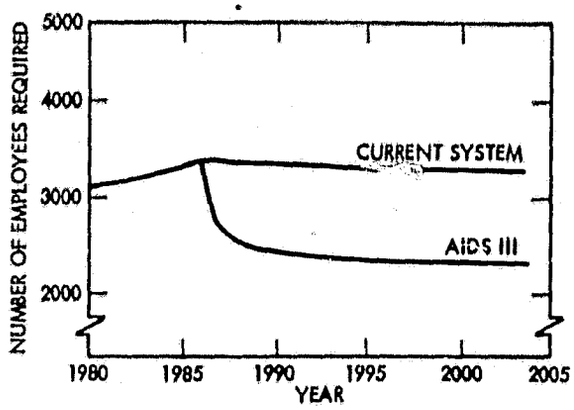


Figure 5-2. Number of Employees Required for AIDS III and Current Systems with Base Case Scenario

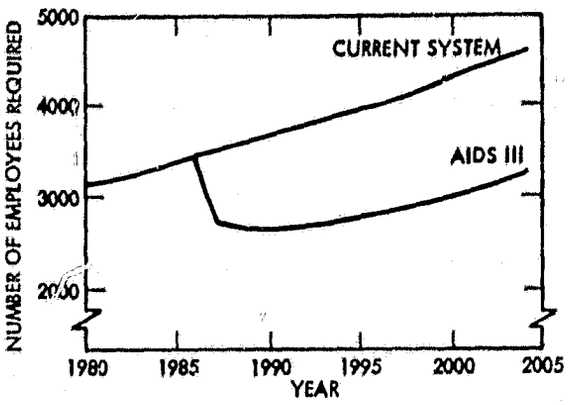


Figure 5-3. Number of Employees Required for AIDS III and Current Systems with 1.7% Constant Growth Scenario

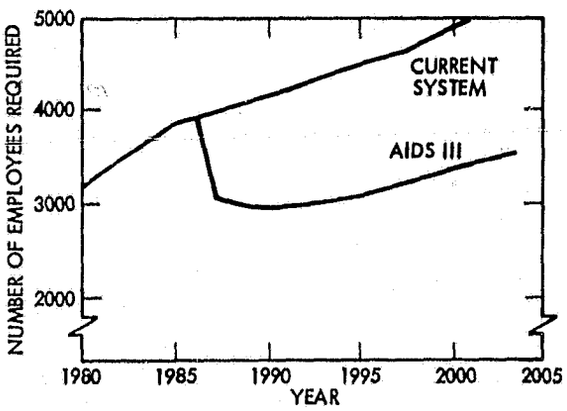


Figure 5-4. Number of Employees Required for AIDS III and Current Systems with Mixed Growth Rates Scenario

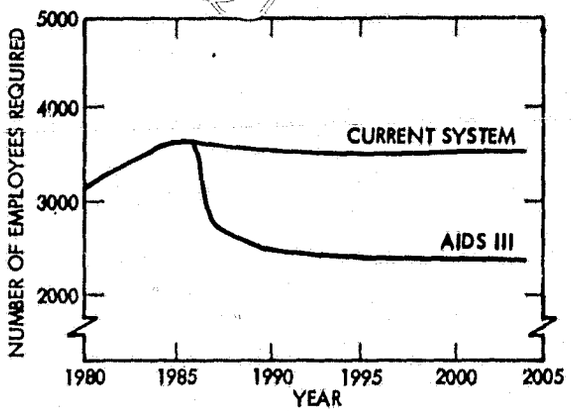


Figure 5-5. Number of Employees Required for AIDS III and Current Systems with AIDS III Scenario

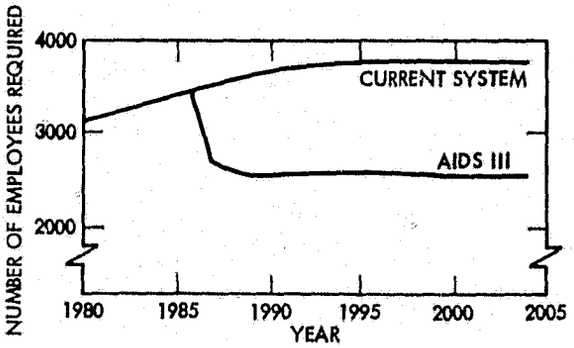


Figure 5-6. Number of Employees Required for AIDS III and Current Systems with Automation of Fingerprint Identification Scenario

Table 5-4. Variation of Total Annual Cost with Work Load

Work Load (% of Base Case)	Total Annual Cost (in millions of 1980 dollars)		
	Current	AIDS III	Difference
80%	55.2	39.6	15.6
100%	65.0	46.1	18.9
120%	77.5	54.0	23.5

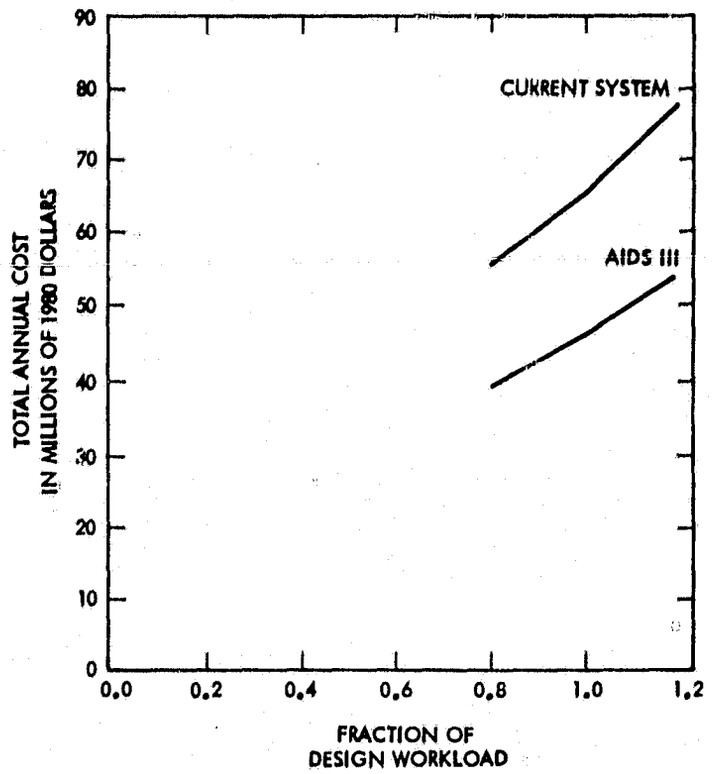


Figure 5-7. Variation of Total Annual Cost with Work Load for 1993

Both AIDS III and the Current System are carefully balanced for a given work load to afford high utilization at each work station, yet smooth flow through the system. Since the utilization is already high, a small increase in work load without additional stations saturates the system. Also, both system models have large fixed-time tasks to be carried out, so that decreased work loads cannot significantly decrease the response time.

E. SELECTED COST/BENEFIT AND OTHER RATIOS

Ic is important to recognize that for a cost/benefit ratio to be meaningful the benefit quantity must be defined so that larger values are preferred to smaller values. If the reverse is true, smaller benefit quantities are preferred to larger, and the cost/benefit ratio is not an indicator of the preferences of an individual.

Since benefit quantities require that larger values be preferred to smaller values, response time measures such as mean, median or 95th percentile cannot be combined into a cost benefit ratio because the result would be that smaller values would be preferred to larger ones. It has been hoped that a response time measure of the percentage of transactions completed within a specified number of hours could be used to compare AIDS III and the Current System. Table 5-2 indicates that virtually all of the AIDS III transactions are completed within four hours while the median response time for the Current System is over 24 hours. Hence, no appropriate number of hours can be specified to make the comparison.

In obtaining a cost/benefit ratio involving accuracy, a different problem arose. The hit rates for the Current System and AIDS III are 75.43% and 94.8%, respectively. To compute a cost/benefit ratio of total annual cost per hit rate, one divides the comparative total annual costs (see Figures 4-20 through 4-24) by one constant for the Current System and by another for AIDS III. The result of this would be a rescaling of Figures 4-20 through 4-24 that would enhance the advantage of AIDS III over the Current System following its planned 1987 implementation.

Several cost/benefit ratios were computed that related a cost measure to an output measure. These ratios are as follows:

(1) Total annual cost/number of transactions per year.

(2) Annual technical search cost/number of technical searches per year.

(3) Annual subject search cost/number of subject searches per year.

(4) Cumulative cost/cumulative number of transactions.

Each of these ratios was computed for 1980-2004 for both systems for each of the five scenarios described earlier.

The ratio of total annual cost/number of annual transactions per year is displayed in Figures 5-8 through 5-12 for the five scenarios. In all five scenarios, AIDS III resulted in a reduction of more than one dollar per transaction, when the scheduled implementation of automated microfilm retrieval was followed. In this computation, the number of transactions per year included documents handled as well as all fingerprint cards.

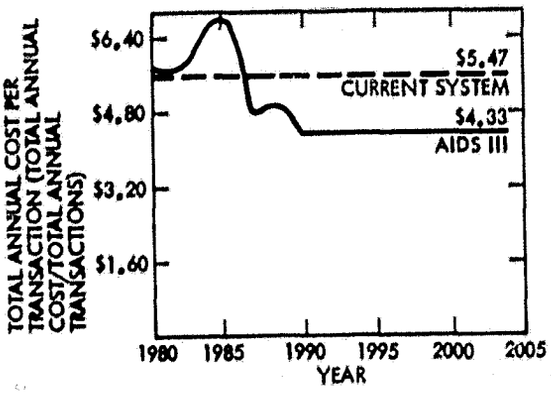


Figure 5-8. Total Annual Cost Per Transaction over Time with Base Case of 1.7% Growth to 1986, Zero Afterward

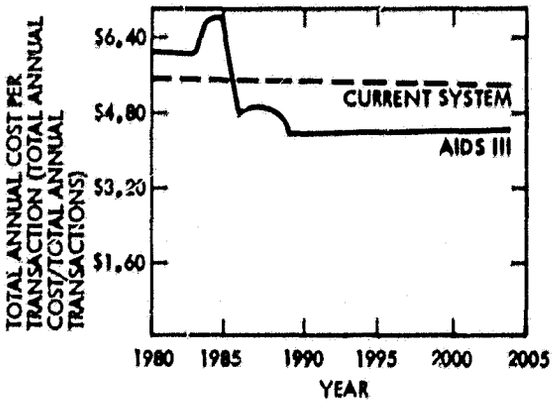


Figure 5-9. Total Annual Cost Per Transaction over Time with Continuous Growth of 1.7% from 1980-2004

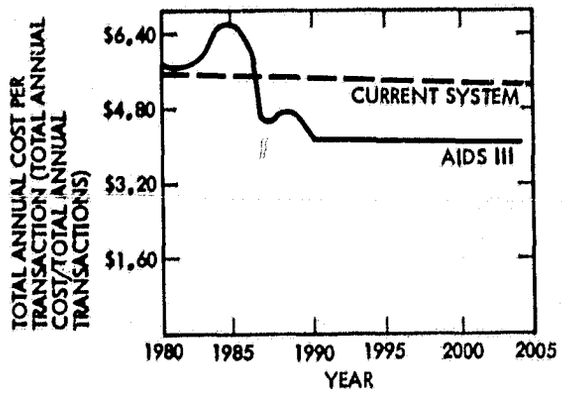


Figure 5-10. Total Annual Cost Per Transaction over Time with Mixed Growth

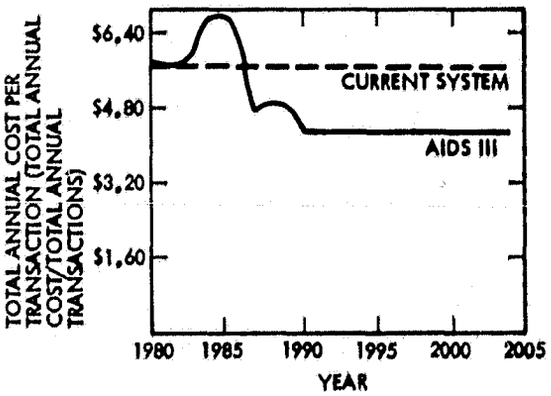


Figure 5-11. Total Annual Cost Per Transaction over Time with Declining Growth Due to AIDS III

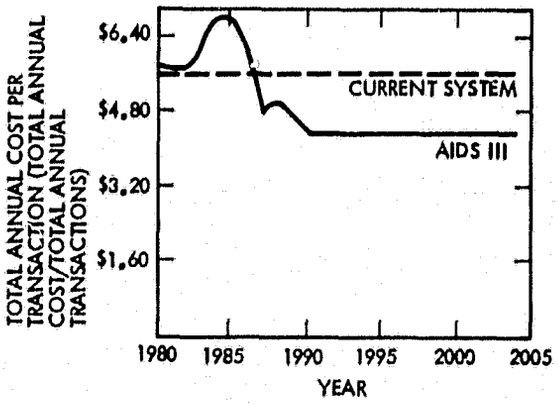


Figure 5-12. Total Annual Cost Per Transaction over Time with Automated Fingerprint Identification

The cost per technical search was computed for both systems for all five cases for the years 1980-2004. The results are displayed in Figures 5-13 to 5-17. In all cases, AIDS III reduced the cost per technical search by more than half following implementation of automated microfilm retrieval in 1989.

Cost per subject search, shown in Figure 5-18, was identical for both AIDS III and the Current System since both systems included the same subject search system. Cost per subject search ran a little over one dollar and was not greatly affected by the different scenarios.

Cumulative cost per cumulative transaction is displayed for the five scenarios in Figures 5-19 to 5-23, respectively. In all cases, AIDS III cumulative cost per transaction first became less than the corresponding value for the Current System in about 1991.

As a measure of productivity, the ratio of total annual transactions to total number of employees was computed for the five scenarios. Differences between scenarios were not significant so the approximate results for all five are displayed in Figure 5-24. Following scheduled implementation of automated microfilm retrieval in 1989, AIDS III yields about 900 more transactions per year per employee.

As a measure of labor cost reflecting skill mix, the ratio of annual labor cost to the number of employees was computed for the five cases. The results did not differ much for the cases and are shown in Figure 5-25. AIDS III costs nearly $1300 more per year per employee by the mid-1990s due to the use of some more skilled, and more highly paid employees.

Finally, the total annual cost per employee was computed. The results were similar for the five cases and are shown in Figure 5-26. The peaks in AIDS III costs per employee around 1986 and 1989 correspond to the implementaton of automated technical search and automated microfilm retrieval, respectively. The additional cost of over $2000 per year per employee for AIDS III by 2004 is due to several factors, including fewer, and on the average, more highly paid employees.

F. DIFFERENCES IN BENEFIT MEASURES

Another means of comparing AIDS III and the Current System was to compute differences in benefit and employment measures. The benefit differences were calculated for accuracy and response time while the employment differences were computed for employee skill mix and number of employees.

The previously mentioned pilot study has yielded accuracy data in the form of comparative overall hit rates for the Current System of 75.43% and the AIDS III of 94.80%: the difference is 19.37%. By extrapolating this difference to the 1993 fingerprint card daily volume of 27,600 cards (not including resident aliens) and assuming that the

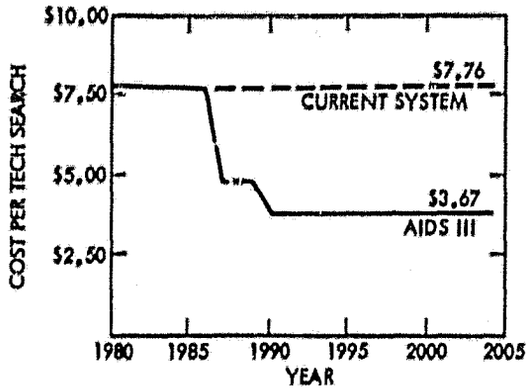


Figure 5-13. Cost Per Technical Search 1980-2004 with Base Case

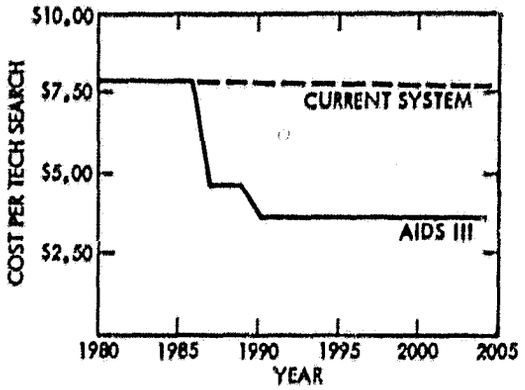


Figure 5-14. Cost Per Technical Search 1980-2004 with Constant Growth of 1.7%

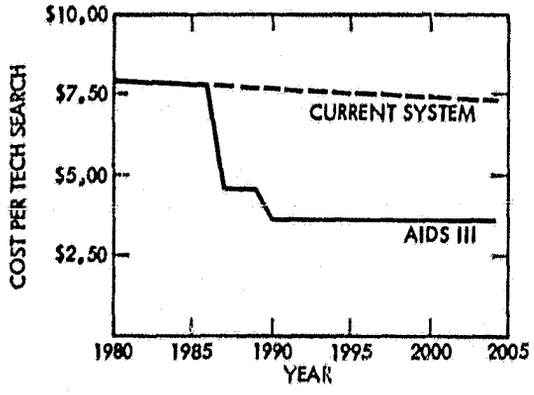


Figure 5-15. Cost Per Technical Search 1980-2004 with Mixed Growth Scenario

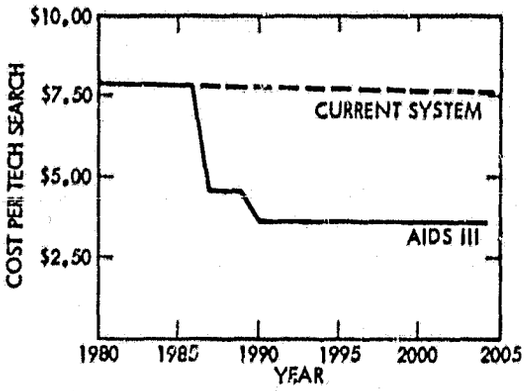


Figure 5-16. Cost Per Technical Search 1980-2004 with AIDS III Scenario

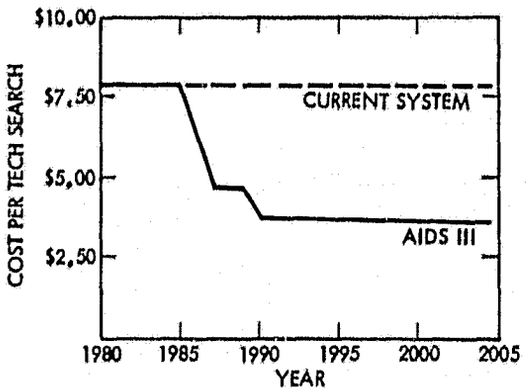


Figure 5-17. Cost Per Technical Search 1980-2004 with Automation of Fingerprint Identification

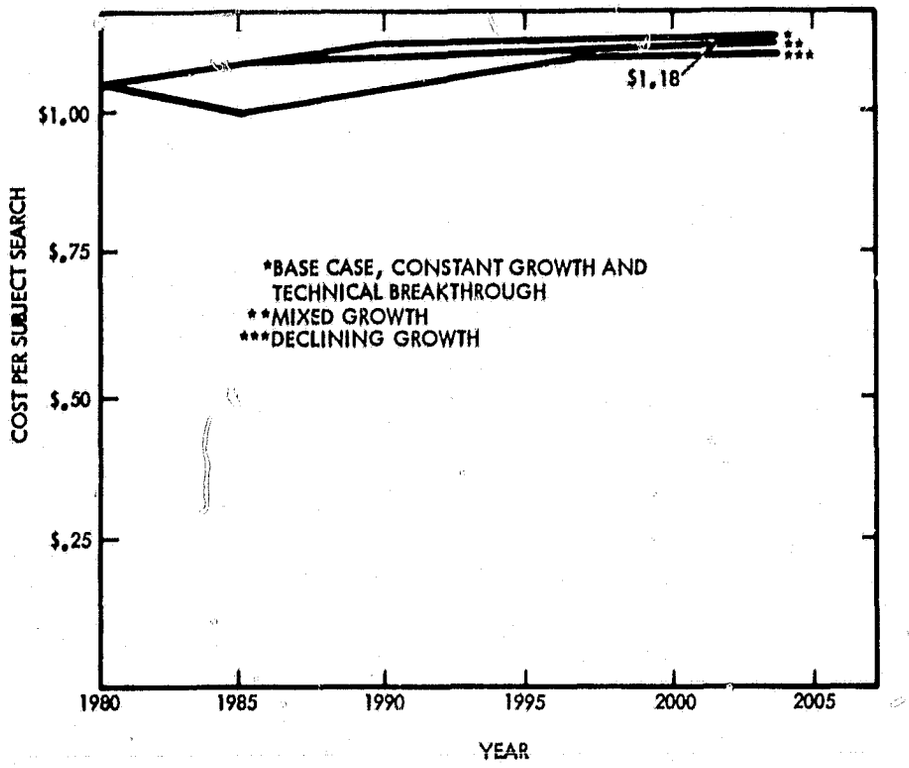


Figure 5-18. Cost Per Subject Search 1980-2004 for Both AIDS III and Current System (with AIDS II)

technical searches are performed for 72% of applicant cards, 27% of criminal cards, and none for military cards, about 137 additional identifications result per day with AIDS III, as shown in Table 5-1.

Response time differences can be computed from Table 5-2. For all cases, and for the response time measures of mean, median, 95th percentile, etc., AIDS III has a response time over 20 hours shorter than the Current System.

The employee skill mix for 1986 for both AIDS III and the Current System was calculated and the differences in number of employees by GS grade computed and displayed in Figure 5-27. The differences include over 1,100 fewer employees in GS grades 2-5 with AIDS III but includes approximately 200 additional employees in GS grades 6-15. Many of the additional employees in the grades 8-11 with AIDS III are involved with software or hardware maintenance.

Finally, the difference in the number of employees between AIDS III and the Current System was computed for the five scenarios for the years 1986-2004. In all five cases, AIDS III had at least 1,000 fewer employees by the early 1990s as shown in Figures 5-28 through 5-32. In the higher growth cases, constant growth and mixed growth, the number of employees fewer with AIDS III was well over 1,000.

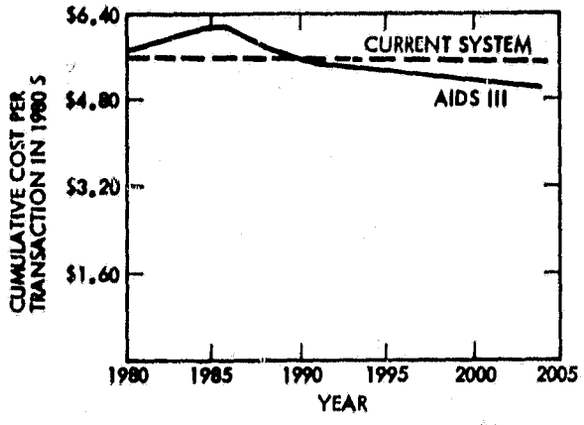


Figure 5-19. Cumulative Cost Per Transaction 1980-2004 for Base Case

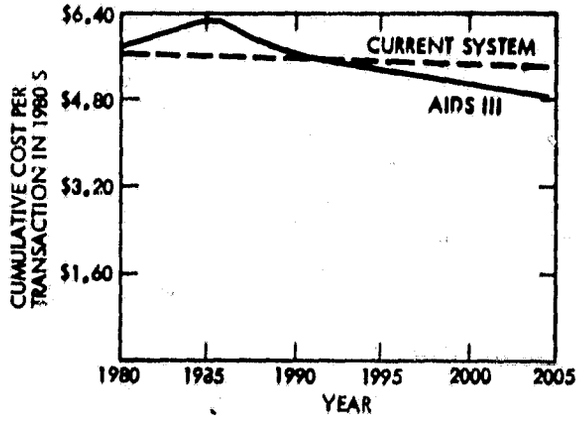


Figure 5-20. Cumulative Cost Per Transaction 1980-2004 for Continuous Growth 1980-2004

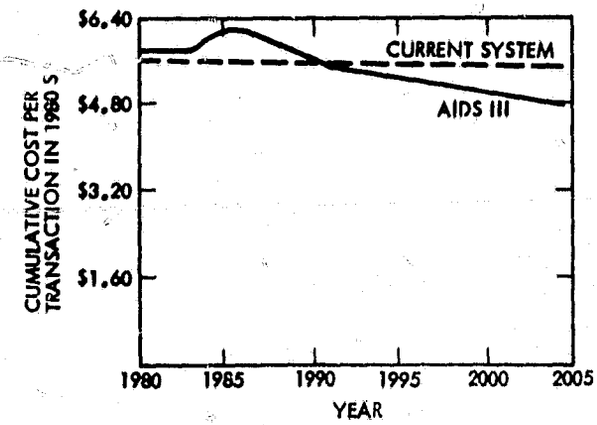


Figure 5-21. Cumulative Cost Per Transaction 1980-2004 for Mixed Growth

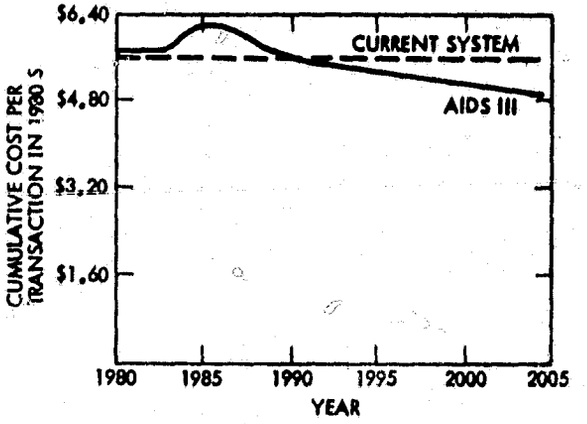


Figure 5-22. Cumulative Cost Per Transaction 1980-2004 with III Scenario

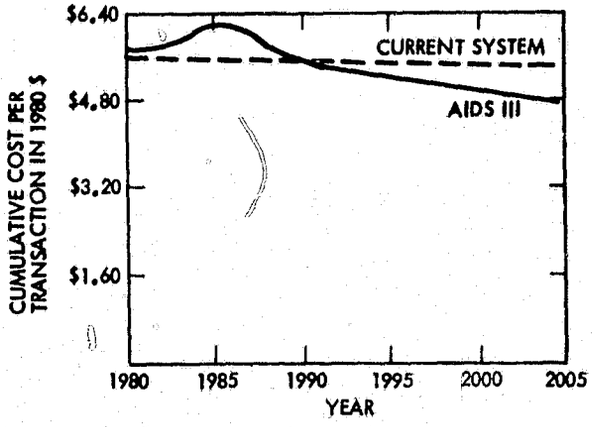


Figure 5-23. Cumulative Cost Per Transaction 1980-2004 with Automation of Fingerprint Identification

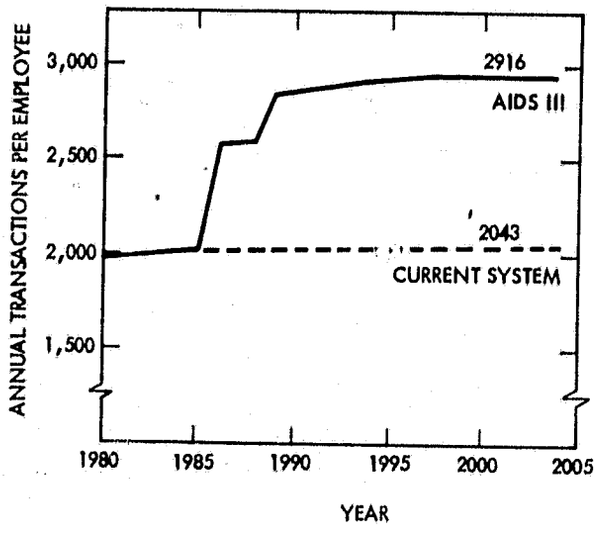


Figure 5-24. Approximate Annual Transactions Per Employee 1980-2004 for All Five Cases

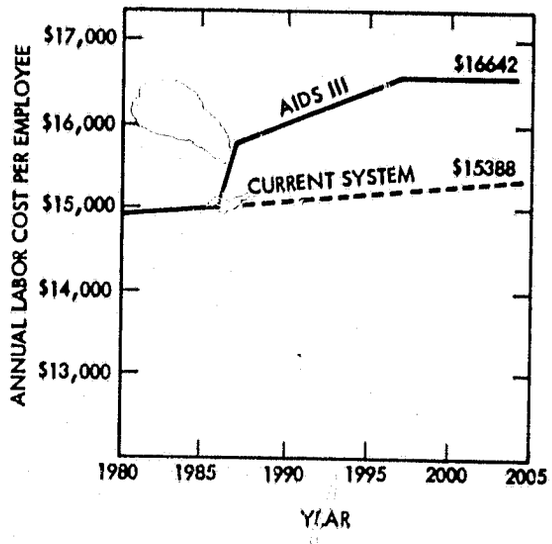


Figure 5-25. Approximate Annual Labor Cost Per Employee 1980-2004 for All Five Cases

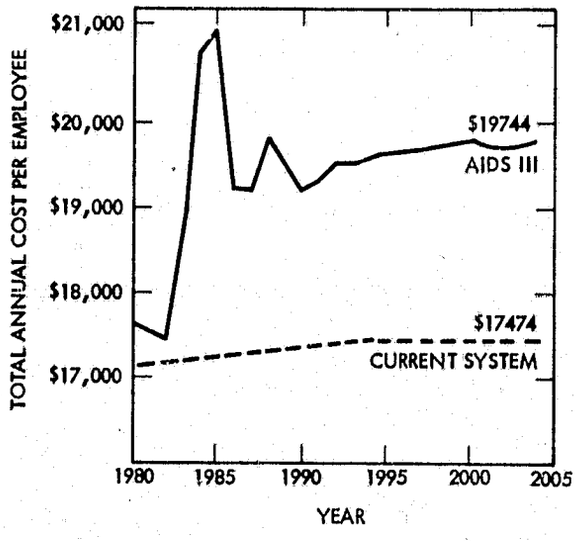


Figure 5-26. Total Annual Cost Per Employee 1980-2004 for Base Case (Other Scenarios Similar)

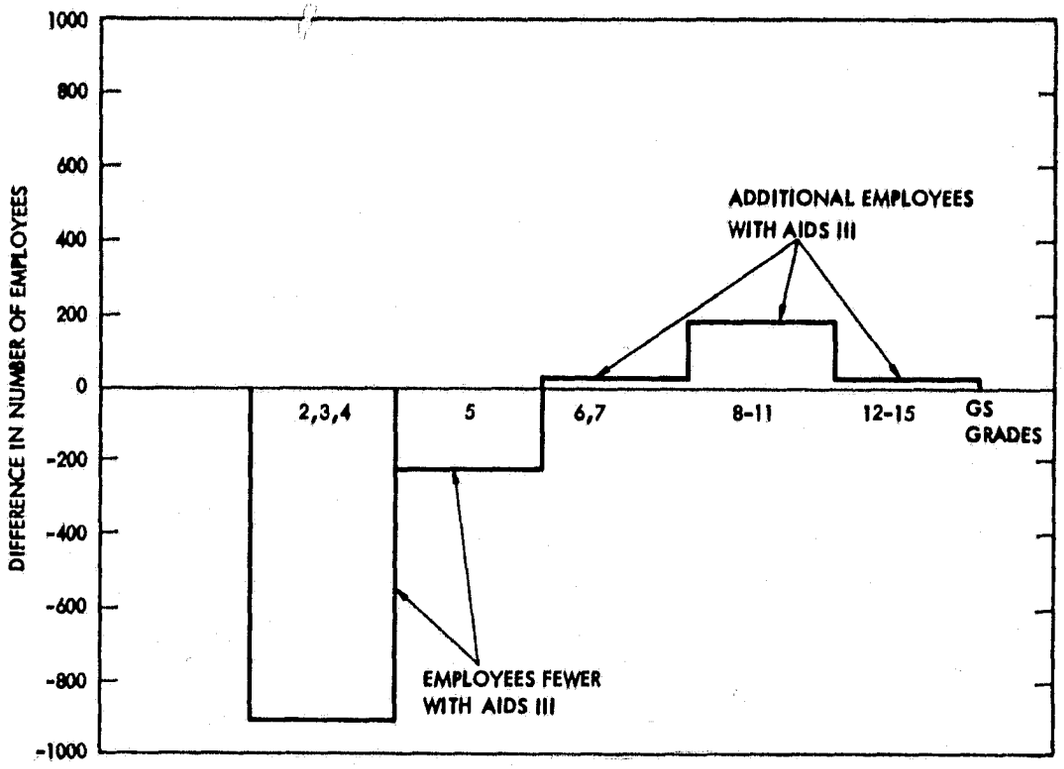


Figure 5-27. Difference in Skill Mix Between AIDS III and Current System for 1986 with Design Work Load

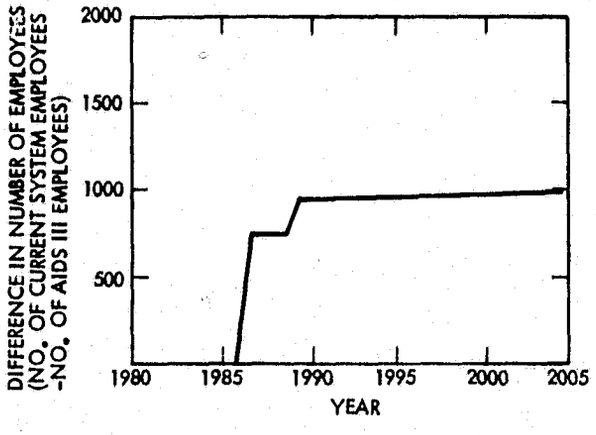


Figure 5-28. Employees Saved with AIDS III versus Current System with Base Case Scenario

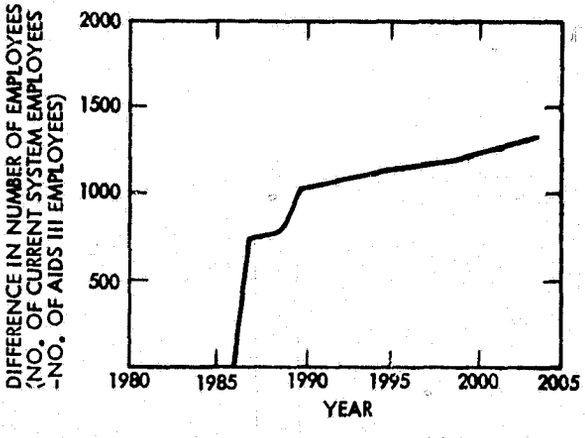


Figure 5-29. Employees Saved with AIDS III versus Current System with 1.7% Constant Growth Scenario

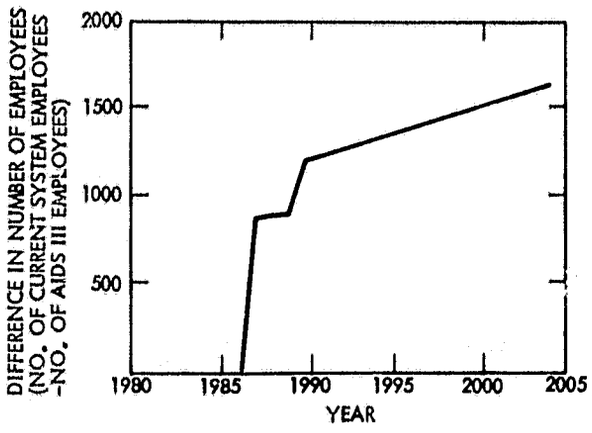


Figure 5-30. Employees Saved with AIDS III versus Current System with Mixed Growth Rates Scenario

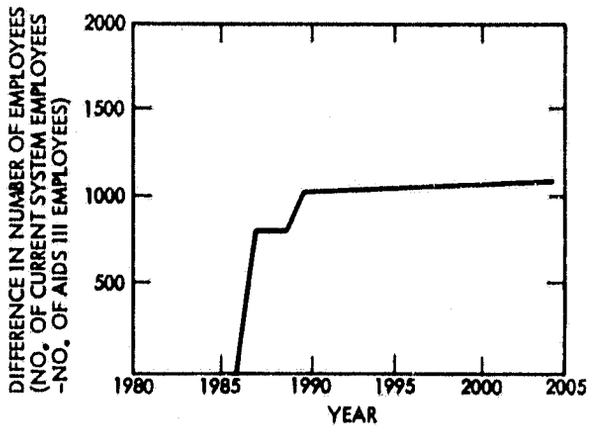


Figure 5-31. Employees Saved with AIDS III versus Current System with III Scenario

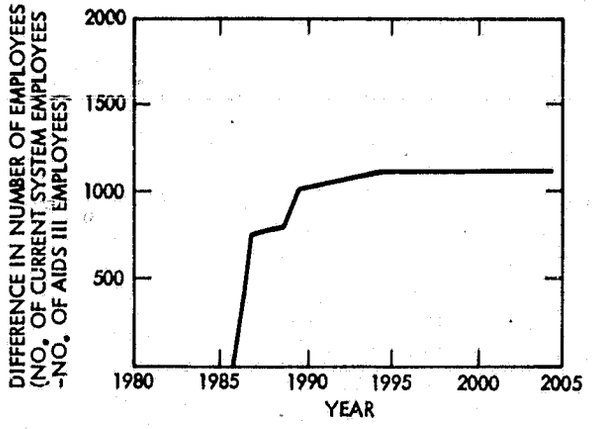


Figure 5-32. Employees Saved with AIDS III versus Current System with Automation of Fingerprint Identification

REFERENCES

1. Burgard, J. F., et al., Automated Identification Division System (AIDS III) System Concept; Task A: Initial Report, Rockwell International, Anaheim, California, January 1980.

2. Hamilton, D.O., et al., AIDS III Process Control - Queuing, AIDS III Technical Memo, No. 80-008J, Rockwell International, Anaheim, California, May 1, 1980.

3. Burgard, J.F., AIDS III WBS - General Structure - Revision 2, AIDS III Technical Memo, unnumbered document, Rockwell International, Anaheim, California, February 22, 1980.

4. Davis, R.E., et al., AIDS III Operations and Maintenance Staffing Estimate, AIDS III Technical Memo, unnumbered document, Rockwell International, Anaheim, California, February 8, 1980.

5. Schwartz, D. L., Feinberg, A., and Miles, R. F., Jr., "A Methodology for the Analysis and Ranking of Alternative Systems for the Automation of Federal Bureau of Investigation ID Division Functions," Jet Propulsion Laboratory, Pasadena, California, April 1980.

6. FBI Identification Automation Study: AIDS III Evaluation Report Vol. V, Current System Evaluation, JPL Pub. 80-79, Jet Propulsion Laboratory, Pasadena, California, August 1980.

APPENDIX A

COST ANALYSIS MODEL

A. PROCESS CHARTS

The Cost Analysis Model computes annual labor cost, annual operating cost, total annual cost and cumulative annual cost over the 25 year evaluation period from 1980-2004 for both the Current System and AIDS III. The model also calculates annual differences and a variety of annual ratios and the life cycle cost for each alternative.

The program description, in the form of input-process-output charts, is presented in the following pages. The first chart is the over-all program description followed by one chart for each process step. Following the program description charts is a discussion of the life cycle cost methodology.

Table A-1. Cost Analysis Program Description

AIDS III - CURRENT SYSTEM: COST ANALYSIS MODEL

INPUT	PROCESS	OUTPUT
Work load mix - fraction applicant cards by function	Read input	Annual labor counts
Work load volume escalation rates	Calculate annual labor counts	Annual labor cost
Number of years to apply escalation rates	Calculate annual labor cost	Annual operating cost
Number of years until AIDS III operational	Calculate annual operating costs	Total annual cost
Automation indices	Calculate total annual costs	Cumulative annual cost
Average salaries	Calculate cumulative annual cost	Life cycle cost
Initial labor counts	Calculate annual difference	Annual differences for each factor
Annual capital investment	Calculate life-cycle cost	Annual ratios
Fixed operating costs	Calculate various ratios	
Initial variable operating costs	Write out results	
Discount rate		
Initial transaction count		
Hit rate AIDS III Current System		

Calculations are performed for both the Current System and AIDS III.

Input data that differ for each system: automation indices, average salaries, initial labor counts, annual capital investment, and initial variable operating costs.

Input data that are the same for each system: work load mix, work load volume escalation rates, number of years to apply escalation rates, number of years until AIDS III operational, and fixed operating costs.

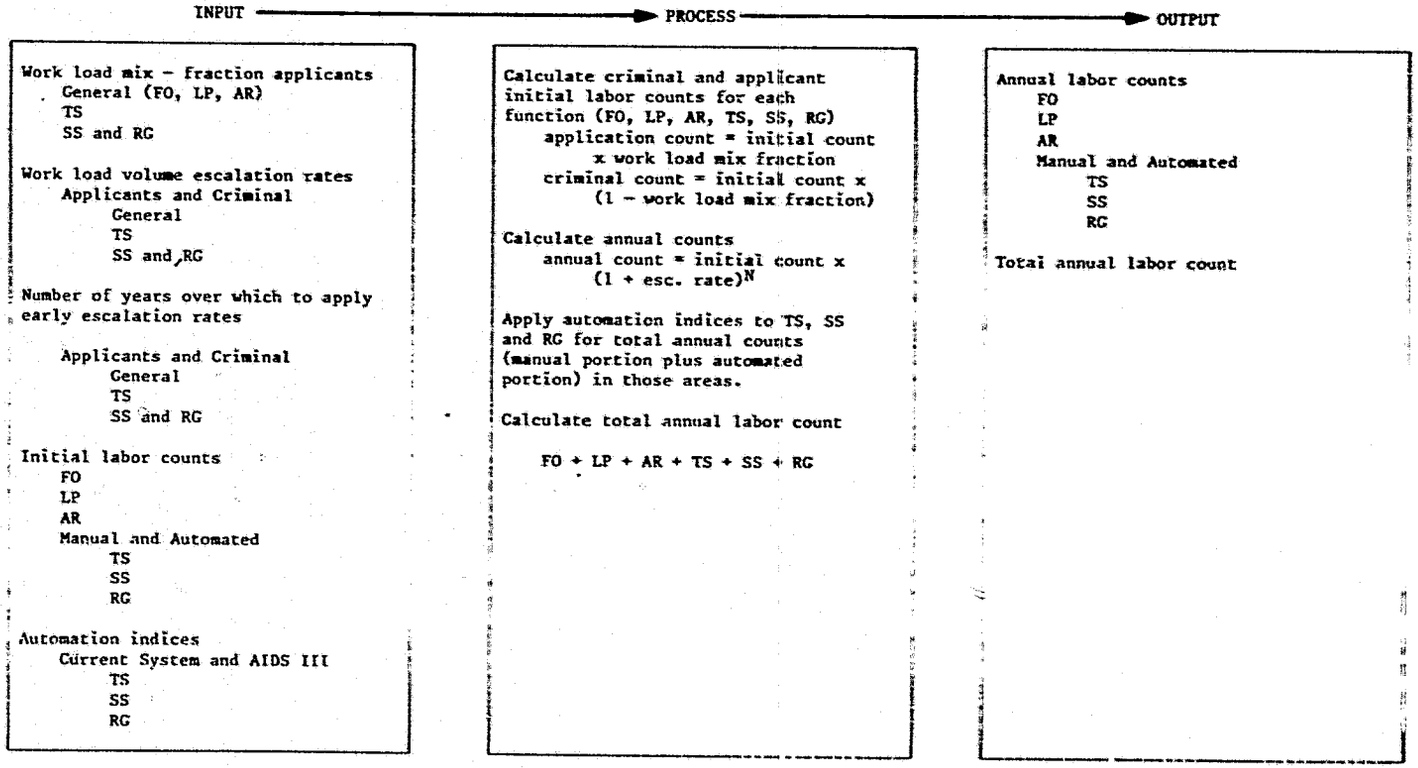
Table A-2. Process Steps

READ INPUT

INPUT	PROCESS	OUTPUT
Namelist variables: $TITL TITLE $FRAC APFRAC ADESC CRESC TA TC T HITRT $INDX TSINDX SSINDX RGINDX $AVGSAL FOSAL LPSAL ARSAL MTSSAL ATSSAL MSSSAL ASSSAL MRGSAL ARGSAL $COUNT FOCNT LPCNT ARCNT MTSCNT ATSCNT MSSCNT ASSCNT MRGCNT ARGCNT TRNCNT $COST CAPCST FOPCST VOPCST	Read namelist	Data in input variables

Table A-2 Process Steps (Continuation 1)

CALCULATE ANNUAL LABOR COUNTS



Work load mix - fraction of work load in each area that responds to applicant transactions. The fraction that responds to criminal transactions is assumed to be the complement.

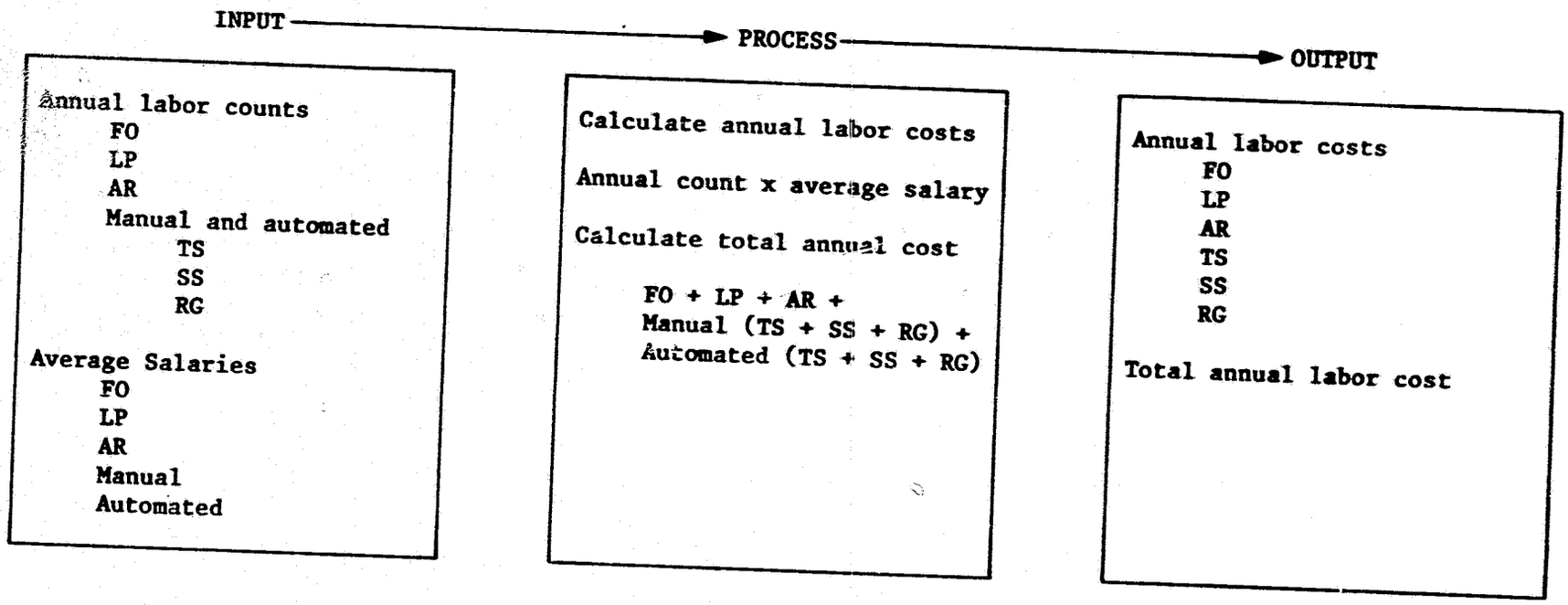
Work load volume escalation rates - two rates in each area for both applicant transactions and criminal transactions. The first rate applies to the early years of the evaluation period and the second rate applies to the remaining years of the evaluation period.

Initial labor counts - total number of personnel required for each function for 1980 work load if the function were 100% automated or 100% manual.

Automation indices - fraction of work in each area that is fully automated. These indices reflect both the implementation plan and the transition schedule.

Table A-2. Process Steps (Continuation 2)

CALCULATE ANNUAL LABOR COST



Average salaries computed based on personnel estimates, skill mix and GS level salary data.

Table A-2. Process Steps (Continuation 3)

CALCULATE ANNUAL OPERATING COST

INPUT	PROCESS	OUTPUT
Fixed operating cost Initial variable operating cost Work load mix fraction Work load volume escalation rates Number of years to apply early escalation rate Number of years until AIDS III operational	Calculate criminal and applicant related variable operating costs Calculate annual variable operating costs by escalating Calculate total annual operating cost Fixed operating cost + annual variable operating cost	Variable annual operating cost Total annual operating cost

Table A-2. Process Steps (Continuation 4)

CALCULATE TOTAL ANNUAL COST

INPUT	PROCESS	OUTPUT
Annual capital investment Annual labor cost Annual operating cost	Calculate total annual cost Total annual cost = annual capital investment + annual labor cost + annual operating cost	Total annual cost

Table A-2. Process Steps (Continuation 5)

CALCULATE CUMULATIVE ANNUAL COST

INPUT	PROCESS	OUTPUT
Total annual cost	Calculate annual cumulative cost $CUMCOST = \sum_{N}$ total annual cost	Cumulative annual cost

Table A-2. Process Steps (Continuation 6)

CALCULATE ANNUAL DIFFERENCES

INPUT	PROCESS	OUTPUT
Annual labor count Current System AIDS III Annual labor cost Current System AIDS III Annual operating cost Current System AIDS III Total annual cost Current System AIDS III Cumulative annual cost Current System AIDS III	Calculate differences DIFFERENCES = AIDS III cost - Current System cost	Annual labor count difference Annual labor cost difference Annual operating cost difference Total annual cost difference Cumulative annual cost difference

Table A-2. Process Steps (Continuation 7)

CALCULATE LIFE-CYCLE COST

INPUT	PROCESS	OUTPUT
Total annual cost Discount rate - 10%	Calculate life-cycle cost $LCC = \sum_{N} TAC\ (1.10)^{-N}$	Life-cycle cost

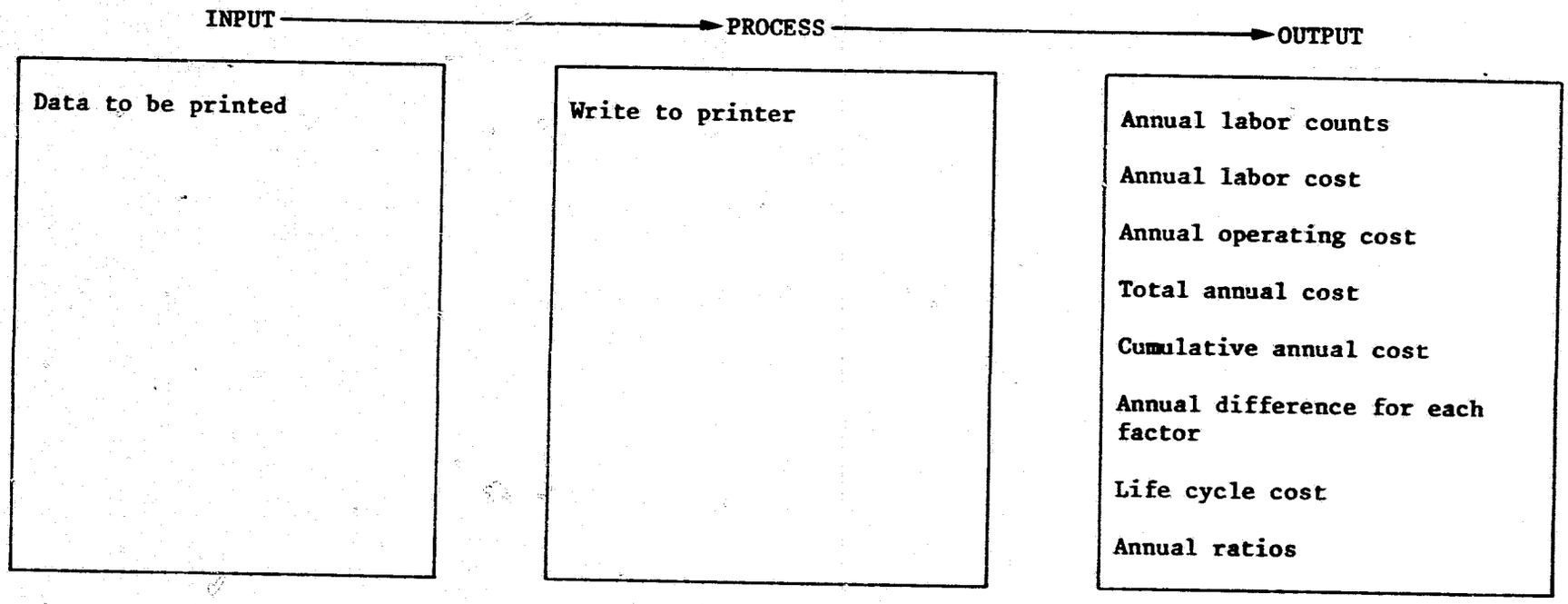
Table A-2 Process Steps (Continuation 8)

CALCULATE VARIOUS RATIOS

INPUT	PROCESS	OUTPUT
Initial transaction count	Calculate annual transaction count	Annual transaction count
Hit rate	Calculate cumulative annual transaction count	Cumulative Annual Transaction count
Annual labor count	Calculate annual number of transactions per employee	Annual number of transactions per employee
Annual SS labor cost	Calculate annual SS cost per transaction	Annual SS cost per transaction
Annual TS labor cost	Calculate annual TS cost per transaction	Annual TS cost per transaction
Total annual labor cost	Calculate average annual labor cost per employee	Annual labor cost per employee
Total annual cost	Calculate total annual cost per hit rate	Accuracy ratio
	Calculate total annual cost per transaction	Total annual cost per transaction
	Calculate total annual cost per employee	Total annual cost per employee
	Calcuate cumulative annual cost per cumulative transaction	Cumulative annual cost per cumulative transactions

Table A-2. Process Steps (Continuation 9)

WRITE OUT RESULTS



B. LIFE-CYCLE COST METHODOLOGY

The life-cycle cost is the sum of the present value of all costs associated with each system to be evaluated. The various cash flows are input in constant dollars for a particular base year, in this study 1980 dollars; the present value amounts are usually computed in year-of-operation dollars, necessitated by complicating factors such as interest during construction, depreciation, and tax rates. However, due to the situation that the systems are owned by a government agency, those complicating factors are eliminated from the calculations. Thus, the life-cycle cost is calculated by discounting all costs to the base year present value and summing as follows:

$$LCC = CIPV + \sum_{k} PVRC_k + ECPV$$

where

LCC = life-cycle cost

CIPV = capital investment present value

$PVRC_k$ = present value of the recurrent costs for a category, k

ECPV = equipment replacement cost present value

The basic equations are standard discounting formulas and are explained in the following paragraphs.

1. Capital Investment

The capital investment includes all the future costs associated with the design, purchase, and installation of the system being evaluated, expressed in base year dollars. If the system is an on-going system and the capital investment has already been made it is considered a sunk cost and is not included in the analysis.

The present value of the capital investment is computed by discounting the amounts using the following equation:

$$CIPV = \sum_{i} \sum_{j} \left[CI_{ji} \times \left(\frac{1 + GCI_j}{1 + R} \right)^i \right]$$

where

$CIPV$ = capital investment present value

CI_{ji} = capital investment amount for category, j, made in year, i, after the start of the evaluation period

GCI_j = real escalation rate for the capital investment category, j

i = number of years after the start of the evaluation period in which expenditure occurs

R = discount rate, 10% per year

The capital investment categories are subdivided only to the extent that the real rate of escalation is different.

2. Recurrent Costs

Recurrent costs are those costs associated with the system operation and manitenance that occur throughout the system lifetime. Estimates of the recurrent costs are provided as a stream of annual costs, expressed in base year dollars and escalated at a constant real rate.

The present value of the recurrent costs is computed using the following equation:

$$PVRC_k = \sum_{i=1}^{N} RC_k(i) \times \left(\frac{1 + G_k}{1 + R}\right)^i$$

where

$PVRC_k$ = present value of the recurrent costs

$RC_k(i)$ = recurrent costs for a category, k, i years after the start of the evaluation period

G_k = real escalation rate for the category of recurrent costs

R = discount rate

N = evaluation period

i = number of years after the start of the evaluation period

3. Equipment Replacement

Equipment replacement costs are those costs associated with capital equipment replacement that is often required during the operational lifetime of the system. The present value of the replacement costs is calculated as follows:

$$ECPV = \sum_{i} EC_i \times \left(\frac{1 + G}{1 + R}\right)^i$$

where

ECPV = equipment replacement cost present value

EC_i = equipment cost for a particular year, i

G = real escalation rate for the equipment

R = discount rate

i = number of years after the start of the evaluation period in which replacement occurs

C. ACRONYMS

The following is an acronym list applicable to Appendix A:

$AVGSAL	Required for Namelist; Identifies Section of Data Input that Constitutes Average Salaries
$COST	Required for Namelist; Identifies Section of Data Input that Constitutes Expenditures
$COUNT	Required for Namelist; Identifies Section of Data Input that Constitutes Initial Personnel Counts
$FRAC	Required for Namelist; Identifies Section of Data Input that Constitutes Fractions and Other General Input Data
$INDX	Required for Namelist; Identifies Section of Data Input that Constitutes the Automation Indices
$TITL	Required for Namelist; Identifies Section of Title Input that is Title Information
APSEC	Variable Name for Applicant Escalation Rate
APFRAC	Variable Name for Applicant Fraction
AR	Automation & Research
ARCNT	Variable Name for Automation and Research Section Initial Personnel Count
ARGCNT	Variable Name for Report Generation Section Initial Personnel Count if 100% Automated Operation
ARGSAL	Variable Name for Report Generation Section Average Salaries Under Automated Operation
ARSAL	Variable Name for Automation and Research Section Average Salary
ASSCNT	Variable Name for Subject Search Section Initial Personnel Count if 100% Automated Operation
ASSSAL	Variable Name for Subject Search Section Average Salaries Under Automated Operation
ATSCNT	Variable Name for Technical Search Section Initial Personnel Count if 100% Automated Operation
ATSSAL	Variable Name for Technical Search Section Average Salaries Under Automated Operation
CAPSCT	Variable Name for Capital Expenditures

CESC	Variable Name for Criminal Escalation Rate
FO	Front Office
FOCOUNT	Variable Name for Front Office Section Initial Personnel Count
FOPCST	Variable Name for Fixed Operating Costs
FOSAL	Variable Name for Front Office Section Average Salary
HITRT	Variable Name for Hit Rate
LP	Latent Prints
LPCNT	Variable Name for Latent Prints Section Initial Personnel Count
LPSAL	Variable Name for Latent Prints Section Average Salary
MRGCNT	Variable Name for Report Generation Section Initial Personnel Count if 100% Manual Operation
MRGSAL	Variable Name for Report Generation Section Average Salaries Under Manual Operation
MSSCNT	Variable Name for Subject Search Section Initial Personnel Count if 100% Manual Operation
MSSSAL	Variable Name for Subject Search Section Average Salaries Under Manual Operation
MTSCNT	Variable Name for Technical Search Section Personnel Count if 100% Manual Operation
MTSSAL	Variable Name for Technical Search Section Average Salaries Under Manual Operation
RGINDX	Variable Name for Report Generation Automation Index
SS	Subject Search
SSINDX	Variable Name for Subject Search Automation Index
T	Variable Name for Number of Years Until AIDS III Operational
TA	Variable Name for Number of Years Over Which Applicant Escalation Rate is to Apply
TC	Variable Name for Number of Years Over Which Criminal Excalation Rate is to Apply
TS	Technical Search

TITLE	Variable Name Used to Input Title
TSINDX	Variable Name for Technical Search Automation Index
VOPCST	Variable Name for Variable Operating Costs

APPENDIX B

IMPLEMENTATION COST ESTIMATES

The implementation cost estimates provided by Rockwell International, Inc. are broken down according to the work breakdown structure presented in Figure B-1. The work breakdown structure assumes:

(1) The entire system is implemented through a single procurement action.

(2) The system supplier performs or subcontracts the prescribed work, thus reflecting the overhead structure of the general contractor.

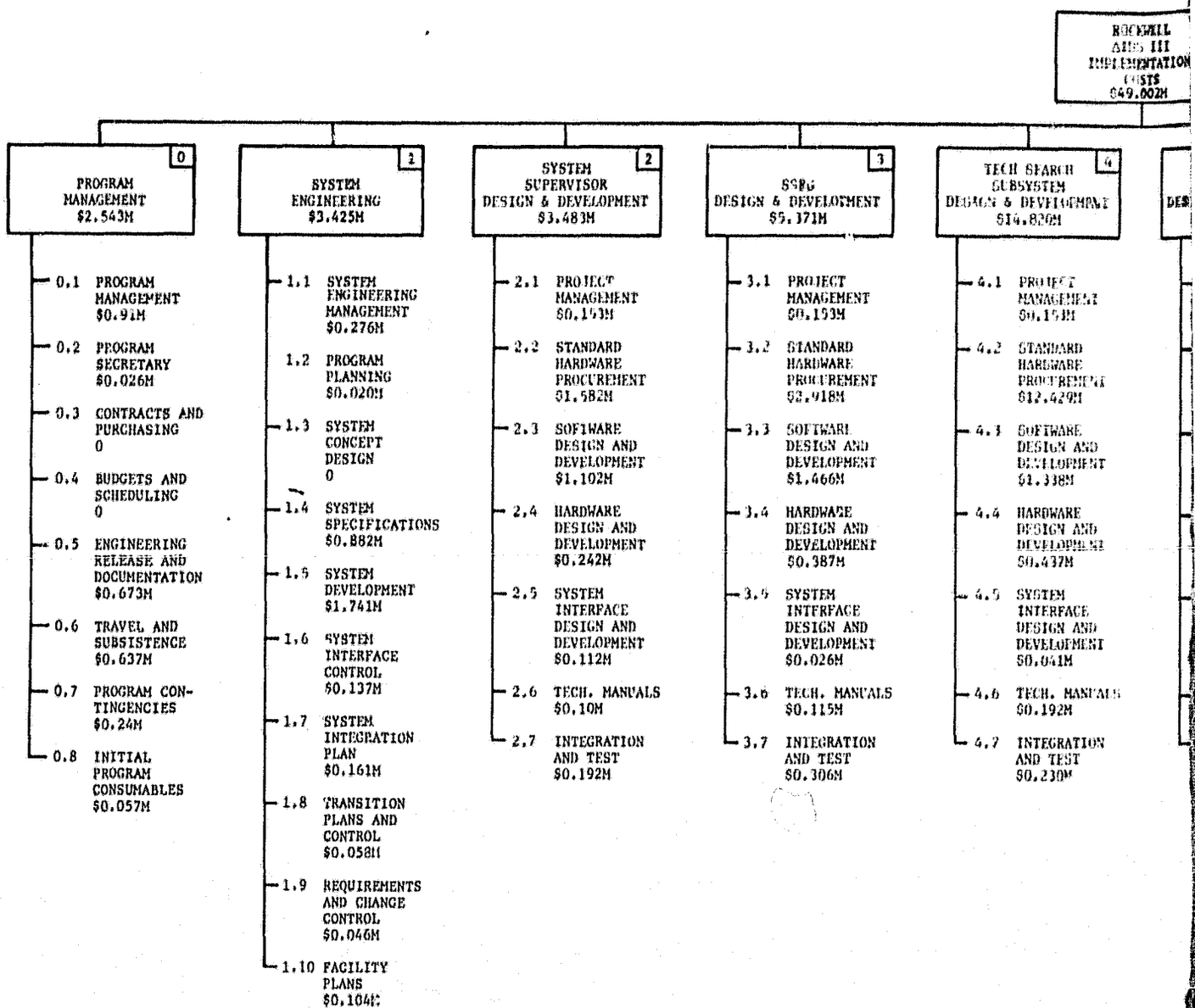
(3) FBI labor costs for monitoring the contracted effort are not included.

(4) FBI labor costs for attending training sessions are not included.

(5) FBI labor costs for the initial staffing of portions of the system during system-level testing or participation in special studies are included.

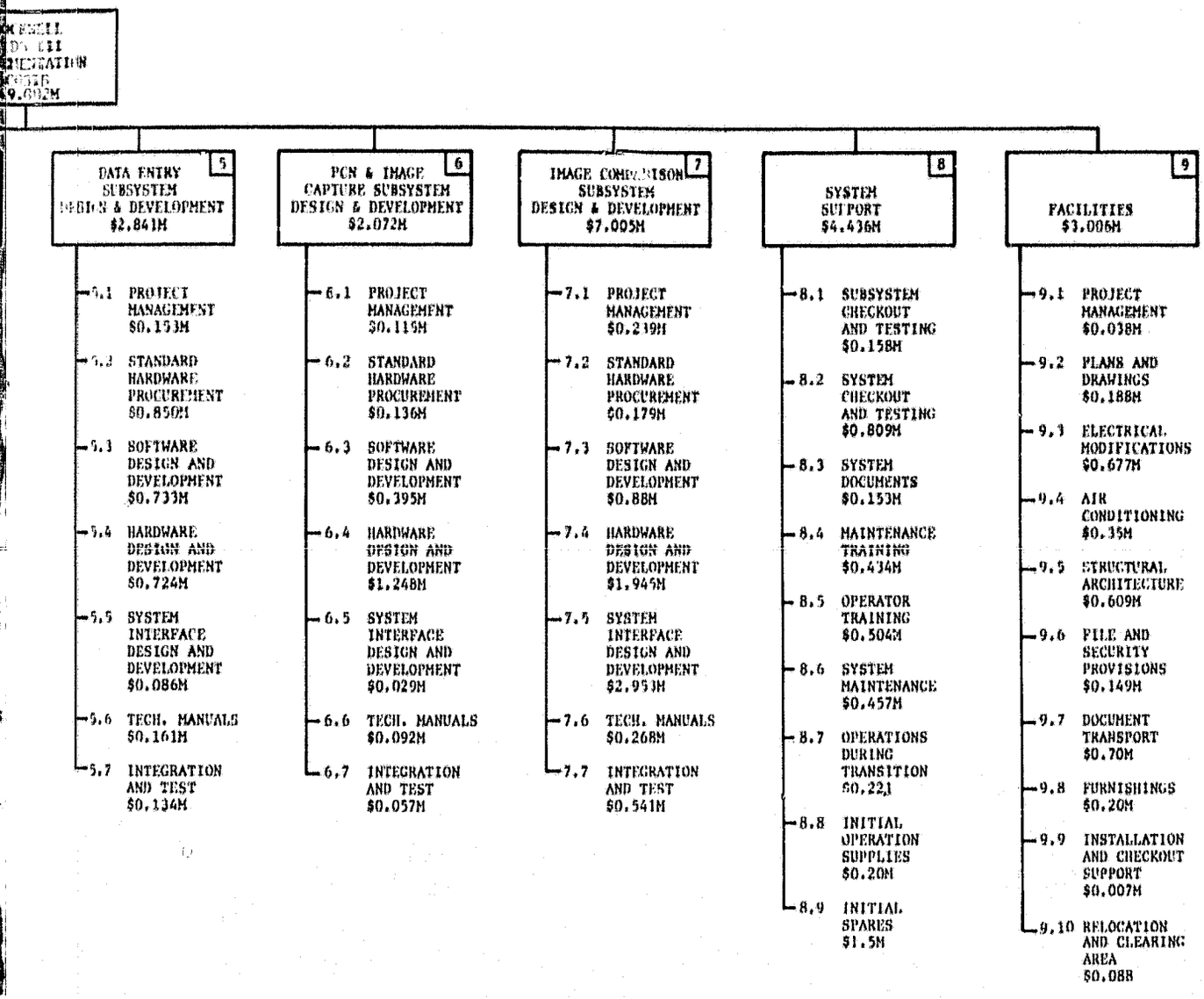
(6) The contractor's program/project organization is of the matrix management type to permit the economies that existing functional departments and resources can provide to the program.

(7) The project implementation schedule follows Rockwell's implementation plan.



FOLDOUT FRAME

FOLDOUT FRAME



FOLDOUT FRAME 2

FOLDOUT FRAME

Figure B-1.

Work Breakdown Structure-
Implementation Cost Estimate
for 1981-1989 (Millions of 1980 $)

PRECEDING PAGE BLANK NOT FILMED

APPENDIX

ACRONYMS

ACS	Automated Classification System
AFRS	Automated Fingerprint Reader System
AHU	Anti-Halation Underlayer
AIDS	Automated Identification Division System
ANS	Automated Name Search
ATS	Automated Technical Search
ATSPS	Automated Technical Search Pilot System
AUTOCOR	Automated Correspondence Station (part of AIDS)
AUTORESP	Automated Response Generation (part of AIDS)
A&R	Automation and Research Section of Identification Division
BER	Bit Error Rates
BLO	Blocking Out
CCA	Computerized Contributor Abbreviated Name
CCH	Computerized Criminal History (part of NCIC)
CCN	Computerized Criminal Name
CCNR	Computerized Criminal Name and Record (part of AIDS)
CCR	Computerized Criminal (Arrest) Record (part of AIDS)
CIR	Computerized Ident Response File (part of AIDS)
CLASS-A	Classification-A
CLASS-B	Classification-B
CLASS-C	Classification-C
CLCK	Classification Check
CNR	Computerized Non-Ident Response File
COA	Cut-off Age
CPU	Central Processing Unit

CRS	Computerized Record Sent File (part of AIDS)
CRT	Cathode Ray Tube
CSORT	Centerline Sort
DATE STP	Date Stamp, Count and Log
DBMS	Data Base Management System
DEDS	Data Entry and Display Subsystem (part of AIDS III)
DENT	Data Entry
DENT-A	Data Entry-Cards
DENT-B	Data Entry-Documents
DOA	Date of Arrest (on f/p card)
DOB	Date of Birth (on f/p card)
ECL	Emitter Coupled Logic
EMI	Electromagnetic Interference
ENC	Encode Input Data-Cards
ENCDOC	Encode Input Data-Documents
ENCK	Encode Check-Cards
ENDOCK	Encode Check-Documents
ERR	Update Error File
EYE	Color of Eyes (on f/p card)
FBI	Federal Bureau of Investigation
FEP	Front End Processor
FIFO	First-In-First-Out
FLAB	Film Lab Processing/Computer
FLOAD	Film Load
FPC	Fingerprint Classification
FPCS	Fingerprint Correspondence Section of the Identification Division
f/p	Fingerprint

GDBMS	General Purpose Data Base Management System
GEO	Geographic Location (on f/p card)
GPSS	General Purpose Simulation System
HAI	Color of Hair (on f/p card)
HGT	Height (on f/p card)
IBM	International Business Machines Corporation
ICI	Image Comparison Identification
ICRQ	Image Comparison Request
ICS	Image Comparison Subsystem (part of AIDS III, actually used for image retrieval for manual comparison)
ICV	Image Comparison Verification
ID, I.D.	Identification Division
IDENT	Identification
JPL	Jet Propulsion Laboratory
KIPS	Thousands of Instructions per Second (as executed by a computer)
LEAA	Law Enforcement Assistance Agency
MAIL	Open Mail and Sort
MFILM	Image Capture Microfilm
MIPS	Millions of Instructions per Second (as executed by a computer)
MMF	Minutiae Master File
MOE	Measures of Effectiveness
MTBF	Mean Time Between Failures
MTR	Master Transaction Record
MTTR	Mean Time to Repair
NAM	Name (on f/p card)
NASA	National Aeronautics and Space Administration
NCIC	National Crime Information Center

NCR	National Cash Register Company
OCA	Local Identification Number (on f/p card)
OCR	Optical Character Recognition
OMB	Office of Management and Budget
ORI	Originating Agency Identification Number (on f/p card)
PCN	Process Control Number
PICS	PCN and Image Capture Subsystem (part of AIDS III)
PMT	Photomultiplier Tubes
POB	Place of Birth (on f/p card)
QC	Quality Control
QUERY	On-Line Query
RAC	Race (on f/p card)
READ	Quality Control Check, Read, Annotate
RFI	Radio Frequency Interference
RH	Relative Humidity
RVF	Ridge Valley Filter
SACS	Semi-Automatic Classification System
SAR	Semi-Automatic Fingerprint Reader
SEAR	Search Review
SEX	Reported Sex of a Subject (on f/p card)
SID	State Identification Number
SKN	Skin Tone (on f/p card)
SOC	Social Security Number (on f/p card)
SPM	Search Processor Module
SS	System Supervisor Subsystem (part of AIDS III)
SSM	Subject Search Module
SSRG	Subject Search and Response Generation Subsystem (part of AIDS III)

TDFA	Top Down Functional Analysis
TFC	Technical File Conversion
TR	Transaction Record
TRC	Transaction Control File
TSS	Technical Search Subsystem (part of AIDS III)
TTL	Transistor - Transistor Logic
VDENT-A	Verify Data Entry-Cards
VDENT-B	Verify Data Entry-Documents
VLSI	Very Large Scale Integration
WAND	Wand Out of System