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Technical Report 767

Army Manpower Cost System (AMCOS): Concept and Design for a Life Cycle Cost Model for Active Army Manpower

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This report discusses the first year in the development of the Army Manpower Cost System (AMCOS). The project will design and build a family of budget, economic, and life cycle cost models over a 5-year period. The report sets forth a concept and design for a life cycle cost model for active Army manpower.

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20. Abstract (Continued)

The report describes how

1) Consistent methodology, a comprehensive data base, and a sound theoretical approach produce accurate estimates for problems with manpower costs that vary over time.

2) The materiel system cycle, acquisition cycle, and personnel career cycle all influence a manpower life cycle cost model.

3) The model takes into account relevant analytical and practical issues.

4) Modular design of the essential components of the completed operational model centers on a structured cost data base.

The report also describes how the original AMCOS development plan was adjusted to develop a life cycle cost model for active Army manpower by the end of the first year and to defer budget and economic models for later development. The report presents alternatives for second-year development that would enhance the now operational lead model for active Army manpower, extend development to build Reserve and civilian models, or do portions of both.

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Manpower and Personnel

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FOREWORD

This report discusses the first year in the development of the Army Manpower Cost System (AMCOS). The project will design and build a family of budget, economic, and life cycle cost models over a 5-year period. The report sets forth a concept and design for the first model, a life cycle cost model for active Army manpower.

The report describes how

1. Consistent methodology, a comprehensive data base, and a sound theoretical approach produce accurate estimates for problems with manpower costs that vary over time.

2. The material system cycle, acquisition cycle, and personnel career cycle all influence a manpower life cycle cost model.

3. The model takes into account relevant analytical and practical issues.

4. Modular design of the essential components of the completed operation model centers on a structured cost data base.

This work was executed under the sponsorship of Dr. Harry West, III, Deputy Comptroller of the Army, with the Letter of Agreement titled "Life Cycle Cost Models" dated March 1983. The research was conducted as part of Research Task 2.1.2. The Life Cycle Cost Model for Active Army Manpower was delivered to Dr. West and the United States Army Cost and Economic Analysis Center in March 1987. Dr. West was briefed on the Life Cycle Cost Model for Active Army Manpower in May, 1987. AMCOS has been used most recently to cost the manpower requirements for the Armored Family of Vehicles.

EDGAR M. JOHNSON
Technical Director

ARMY MANPOWER COST SYSTEM (AMCOS): CONCEPT AND DESIGN FOR A LIFE CYCLE COST MODEL FOR ACTIVE ARMY MANPOWER

EXECUTIVE SUMMARY

Requirement:

The Army Manpower Cost System (AMCOS) is a 5-year research and development project sponsored by the Deputy Comptroller of the Army to develop manpower costs and to improve the Army's ability to conduct cost analysis. The purpose is to build a series of budget, economic, and life cycle cost models for the active, Reserve, and civilian components of Army manpower. These models are intended to improve the accuracy and flexibility of the Army's cost estimates. Applications include budget decisions, economic trade-offs among active, Reserve, and civilian forms of manpower, cost-effectiveness, and life cycle cost estimates of manpower for weapon systems and the force structure.

Procedures:

The Deputy Comptroller of the Army has asked that we begin with active-duty life cycle models, followed by development of the budget and economic models. Our strategy is to begin with sound but relatively simple life cycle cost models and evolve to more sophisticated models as experience is gained. Following this strategy, we have built a life cycle cost model for active-duty officer and enlisted personnel. Each model is composed of several policy modules that emulate personnel policies, and a static cost-estimating routine that includes the amortization of selected costs.

The models will accept manpower requirements generated by the MANPRINT process and produce a time-phased profile of the cost of manpower over the life cycle of a weapon system. By developing a working model early in the process, we can use the results of actual cost estimation efforts to refine and improve the models to meet the Army's real needs, not just what the Army and its contractors might hypothesize in advance. As more research is conducted, we will develop selected modules in more detail and will modify the cost model to make it more dynamic, flexible, and useful. Our modular design makes this evolutionary strategy practical. This strategy has provided the Army with working life cycle cost models in the first year of the 5-year development process. Subsequent years will be used to develop life cycle cost models for the Reserve Components and Army civilian personnel, and build budget and economic models for all personnel communities.

Findings:

By the end of the 5-year contract period, the Army will have an effective family of manpower cost models proven in successive real-world applications. The Army staff will understand the models completely and will be using them as on-line management tools.

Utilization of Findings:

AMCOS interfaces the Army's manpower requirements and personnel policies to improve manpower cost estimating capabilities in the following areas:

New Weapon Systems. Accurate manpower cost estimates over the life of a weapon system will assist in choosing the most efficient system, and in developing the most cost-effective manpower/hardware configuration for that system.

Manpower Requirements. Cost estimation by grade and occupation for the active, Reserve, and civilian components will help in choosing the most efficient manpower mix.

Personnel Policies. Explicit cost modeling of personnel policies, such as tour lengths, reenlistment bonus policies, the proportion of high-quality recruits and PCS (permanent change of station) moves, will allow rapid estimation of how changes in these policies affect the costs of filling specific manpower positions.

ARMY MANPOWER COST SYSTEM (AMCOS): CONCEPT AND DESIGN FOR A LIFE CYCLE COST MODEL FOR ACTIVE ARMY MANPOWER

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ARMY MANPOWER COST SYSTEM: THE CONCEPTUAL DESIGN OF THE LIFE CYCLE ACTIVE ARMY MANPOWER COST ESTIMATION MODEL

PART 1 - BACKGROUND

FIRST YEAR DEVELOPMENT FOCUSES ON A LIFE CYCLE COST MODEL

The AMCOS Project Will Build a Series of Budget, Economic, and Life Cycle Cost Models

The Army Manpower Cost System (AMCOS) is a project sponsored by the Deputy Comptroller of the Army to improve the Army's ability to conduct manpower cost analysis. The Army Research Institute is the office responsible for the project and is the contracting agency and technical advisor. The Cost and Economic Analysis Center (CEAC), Office of the Comptroller of the Army, is the primary user of project products.

The purpose of this research and development project is to build a series of budget, economic, and life cycle cost models for the active, reserve, and civilian components of Army manpower. These models are intended to improve the accuracy and flexibility of the Army's cost estimates. Applications include budget decisions; economic trade offs between active, reserve, and civilian forms of manpower; cost effectiveness; and life cycle cost estimates of manpower for weapon systems and for the force structure.

The Report Describes a Life Cycle Cost Model for Active Army Manpower

This technical report is an exposition of a life cycle cost model for active Army manpower. The purpose, uses, environment, and design of the model are discussed. Though such a model has several potential applications, emphasis is placed throughout this exposition upon life cycle cost estimation over the materiel acquisition cycle. This application, we believe, places the most stringent demands on the model.

Debate continues concerning the "affordability" of force modernization and whether procurement practices are efficient in the Department of Defense. Operation and Support (O&S) costs, as measured by the "readiness" accounts[1], constitute about 55% of

[1]The Military Personnel (MPA) and the Operation and Maintenance (OMA) accounts are often called the "readiness" accounts.

the Army's budget. About 30% of the budget is allocated to procurement and research. The Military Personnel, Army portion of the "readiness" accounts is over 50%. Hence, if force modernization is to be cost effective and affordable, the same attention that procurement costs have drawn must be focused on manpower costs.

For example, the Army will have invested better than 85% of its MI/MIAI tank procurement dollars by FY92 (last year of the Army 5-year program). On the other hand, because of the time lapse between procurement and fielding, little better than 30% of the sustainment costs will have been paid over that same period. If the Army is to ensure that its $30 billion investment in the MI/MIAI procurement will be cost-effective, an accurate assessment of Operating and Support (O&S) requirements must be made up front, especially in the manpower area which comprises the bulk of these costs. A model that underestimates manpower costs may result in inadequate manpower resources to operate an expensive weapon system already purchased.

As mentioned, the report focuses on a conceptual life cycle cost model for active Army manpower, both its concept and design. Subsequent papers will focus on reserve and civilian manpower.

The Model Estimates the Manpower Cost of a System's Life Cycle

Life cycle costs are all the costs to the government associated with an Army materiel system over its life cycle.[2] Life cycle cost is defined in Army regulations (AR) as:

> Total cost of an item or system over its full life. It includes the cost of development, acquisition, ownership, operation, maintenance, support, etc. and where applicable, disposal. [AR 11-28, p. B-3.][3]

---

[2]"Materiel," "weapon," or more simply, "defense" system will be used interchangeably throughout this paper.

[3]The Office of the Secretary of Defense uses a similiar definition:

> Life cycle cost includes <u>all</u> WBS [work breakdown structure] elements; <u>all</u> related appropriations; and encompasses the costs, both contract and in-house, for <u>all</u> cost categories. It is the total cost to the government for a system over its full life, and includes the cost of development, procurement, operating, support and, where applicable, disposal. [DoDI 5000.33, p. 5.]

Life cycle cost estimation is defined as:

> **An approach to costing that considers all costs incurred during the projected life of the system. The life cycle cost includes all costs associated with three life cycle phases: research and development, investment, and operations.** [AR-18, p. D-1.]

A life cycle cost model estimates the cost of a system, or a component of the system, over the system's life cycle. Hence, a manpower life cycle cost model estimates the cost of the manpower component over the system's life cycle. A life cycle cost model does not estimate requirements but must take them as given.[4]

Life Cycle Cost Estimates Help Decisionmakers Allocate Resources

The primary purpose of cost analysis is to aid decisions. The cost of choosing a particular option is the value of the resources that will no longer be available for other uses.[5] Cost analysis provides decisionmakers with an estimate of those resources for each alternative. Better cost estimates result in more informed decisions and improved resource allocation.

---

[4]This is explicitly recognized in Army discussions of life cycle cost estimation procedures:

> **Cost estimating and cost analysis will receive emphasis equal to that given requirements estimating and analysis in the weapon system and force manning processes. Costs estimates and analysis are necessarily sequential activities.** [AR 11-18, p. 1-3.]

and,

> **. . . the cost analyst must know certain information about the system being costed. This information must be obtained from agencies which have the responsibility for setting the requirements for the system . . . .** [AR 11-18, p. 2-9]

[5]This is often called the "opportunity" cost. AR 11-28 defines "opportunity cost" as "The measurable advantage foregone as the result of the rejection of the next best alternative use of the resources. . . . A dollar spent here is a dollar not available to be spent elsewhere." The term "opportunity cost" carries with it the connotation that it is an esoteric notion, of interest only to economists. This is unfortunate and not the case. Opportunity cost should be considered during every decision by asking the question, "Is this the best use we can make of these dollars?"

The Estimates Help Determine Affordability, Select Alternatives, and Make System Trade Offs. Life cycle cost estimates aid in at least four key allocative decisions over the acquisition cycle. First, estimates of the life cycle cost of a proposed new weapon system provide the Army with an indication of the resources it, and perhaps the taxpayer, will be giving up if the Army chooses to build that system. These estimates help determine if the new system is affordable, that is, if it is likely to be worth the resources required to build and operate it. Second, life cycle cost estimates help the Army choose among competing systems so that the Army can obtain the most capable mix of weapon systems for the resources expended. Third, the life cycle cost estimates allow the Army to alter the design or configuration of a new system, trading hardware and manpower to obtain the most cost-effective weapon system. Fourth, a manpower life cycle model can help determine the best mix of manpower to operate and maintain a materiel system over its life cycle. This entails not only trading off among active, reserve, and civilian components of Army manpower but also balancing the skill and experience mix within a component.

In addition, life cycle cost estimates assist in preparing budgets. They help determine how many dollars should be added to the budget and into which accounts. Often, they highlight when constraints on the use of certain types of dollars are about to be violated and in this way affect resource allocation decisions.[6]

We draw a distinction, however, between the type of cost estimates used to make far-reaching resource allocation decisions and the type of estimates necessary to prepare next year's budget. The former focuses on issues that reflect the current and future cost implications of resource allocation decisions. They provide the level of detail necessary to make an informed investment decision but are not so detailed that they obfuscate the real allocation issues. Budget estimates, on the other hand, are concerned with issues such as the precise timing of obligations and outlays and require costs at a very refined level of detail.

The primary purpose of life cycle cost estimates, by their nature, is resource allocation, not budget preparation. Budget estimates and life cycle cost estimates must be consistent, of course. Eventually the life cycle cost estimates will be reflected in annual budgets for the options chosen. But, attempts to provide budget-level precision to costs that will be incurred 5, 10, or 30 years in the future are suspect and may

[6]However, too much focus on near-term budget constraints is misleading. For planning purposes, dollars tend to be fungible across accounts. Moreover, even the overall level of the Army's budget is negotiable, within limits, based upon the merits of the case.

divert attention away from the cost analysis issues that are important to the resource allocation decision.[7]

This view of life cycle cost estimates is consistent with Army policy. For example:

> **The objectives of the cost analysis program are:**
>
> **1. To improve the allocation and management of Army resources at all levels through rigorous cost analysis of Army programs, material systems, units and activities.** [AR 11-18, p.1-3.]

Also:

> **Need for Cost Estimates: [Life Cycle Costs]**
>
> **a. To permit labor savings.**
>
> **b. To permit trade offs between life cycle phases.**
>
> **c. To achieve better balance between equipment purchase and repair.**
>
> **d. To perform better comparisons between materiel systems.**
>
> **e. To provide management visibility of critical resource requirements.** [DA Pam 11-3, p. 1-2.]

The Estimates Try to Get the Big Ones Right, Focusing on Relevant Future Costs Not Past Expenditures. Our view of life cycle cost analysis means that a life cycle cost model for manpower must not be, simply, an exercise in historical cost accounting. The test of the model is not whether it can reproduce last year's budget but whether it can adequately

---

[7]An obvious analogy is the distinction in the type of cost estimates used in preparing and discussing of Program Objective Memorandum (POM) issues, the resulting Program Decision Memorandum (PDM), and the type of estimates used for preparing and discussing issues relevant to the President's budget and the Program Budget Decisions (PBD) that result. A typical POM issue in the manpower area might be whether the Army has programmed enough recruiting resources to meet its accession demand over the next 5 years, while a typical Budget issue might be whether Army's assumption concerning the seasonality of the entry of recruits into the Army is in error. The former is a resource allocation issue, the latter is a pricing issue, given that the resource allocation decision has been made.

estimate the resource implications of future manpower demands. The purpose is to predict future manpower costs that are relevant to a decision, not to account perfectly for past budget expenditures.

The model should be constructed in a way that enables it to respond to known or hypothesized future changes in manpower or personnel policies or to prices. It is, of course, impractical to build a model that can respond, without alteration, to any hypothesized policy change. This suggests a modular construction for each of the major components of cost. If a major policy change arises that could not be adequately accommodated within the formulation of the current cost element policy module, a revised module can be developed and easily inserted to accommodate the unforeseen change.

This contrasts sharply with an approach that uses historical data exclusively and does not attempt to model personnel policies, per se. The weaknesses of models irrevocably tied to historical or external cost estimates are apparent when the model is asked to estimate costs under policies that have yet to be implemented.[8]

Moreover, the historical cost-accounting approach to cost estimation often leads to a focus on average costs, rather than marginal costs. Marginal cost is the added cost that is incurred when a particular choice is made. Sometimes average and marginal cost are about the same, but when they differ substantially, marginal cost is the more appropriate measure of the cost of choosing a particular option. Average cost is an attractive measure for the historical cost-accounting approach because it is equal to the relevant portion of the budget divided by the relevant quantity.[9]

---

[8]We do not mean to suggest that historical budget data should not be used in constructing a manpower life cycle cost model. What we do mean is that a philosophical approach that is based solely on what happened in the past will suffer a methodological breakdown when policies change, with no obvious solution. For example, the future costs of the Army New GI Bill are unknown and there is little historical data. Yet, one can provide a reasonable estimate by modeling the policies and procedures and making informed assumptions on unknown parameters, such as usage rates. These assumptions can be refined as evidence accumulates.

[9]Note that if marginal cost differs from average cost, the average cost before the cost of the alternative chosen is added into the computation will differ from the average cost computed afterwards. If marginal cost exceeds average cost, the average cost computed ex ante, or before the decision is made, will be less than the average cost computed ex post, or after the decision is made. The cost of the alternative will

These observations appear to be consistent with Army policy:

> **It is the Department of the Army's policy that:**
>
> **1. Cost analysis will assist Army management in establishing and maintaining credibility with respect to materiel system cost estimates. A measure of credibility is the degree to which the cost estimates can stand the test of time.**
>
> **2. Cost analysis is an integral part of the PPBES.**
>
> **3. Cost analysis employs an approach and procedures oriented more to macro rather than micro aspects of cost estimating. Cost analysis must demand completeness over preciseness, and be more concerned with issue development than with detailed accounting procedures. Simplification in level of cost analysis detail is essential.** [AR 11-18, p. 1-3.]

For these reasons, we focus on the major cost elements of military manpower--the ones that are more likely to affect decisions. The appropriate theoretical approach is crucial and cannot be neglected in the analysis. One can have rigorous and detailed accounting of each manpower cost element. Yet, if they are combined inappropriately, they may generate misleading cost estimates.[10]

Our approach to life cycle cost analyses is evolutionary. We anticipate that the model will change over time in response to advances and insights gained from cost research and to the most pressing Army cost issues. We expect to have the first model

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have been understated. Note that this "ex ante/ex post" distinction conveniently does not arise when computing the average based on historical budgets because the books have long since been closed and all decisions made.

Marginal cost is likely to differ from average cost for some resources used by the Army because the Army is a particularly large purchaser of those resources. Active duty manpower is a good example. If the Army were to attempt to expand the size of its active force by 5%, average pay, including special incentives, and recruiting incentives would have to rise above the current average.

[10]For example, a difficult theoretical and practical problem is how to generate the personnel flow requirements that will fill the manpower requirements. How useful the manpower life cycle cost model will be depends much more on how this difficult problem is solved than on whether the model has included leprosarian pay.

working by January 31, 1987, and the second by February 28, 1987. This approach is entirely consistent with our 5-year research and development contract. We start with a good, simple model that gets the big costs right. Complexity is added as it is needed.

The Design Features Policy Modules Interacting with a Structured Cost Data base Coupled with a Cost Estimating Model

This paper begins to develop the concept of a manpower life cycle cost model by examining the institutional environment in which the model must operate. The typical life cycle of a weapon system and how it interacts with the DoD major system acquisition process have very clear implications for a life cycle manpower cost model. The model must be sufficiently flexible to accept requirements specified at widely different levels of detail and must be able to estimate time-phased costs of requirements that vary over the cycle.

A review of the Army personnel system and how it fills manpower requirements reveals a fundamental conceptual issue in manpower cost estimation. The personnel system produces a flow of people to fill manpower requirements, but manpower requirements or authorizations are more of the nature of a "stock." The appropriate conceptual cost model must capture the costs generated by the soldiers as they flow through the personnel system satisfying manpower requirements. But, a model that captures the dynamic nature of the cost process has some technical problems that must be resolved prior to development. In the interim, a less sophisticated, but fundamentally sound, static model will be developed.

Figure 1 shows the proposed design of the manpower life cycle cost model.

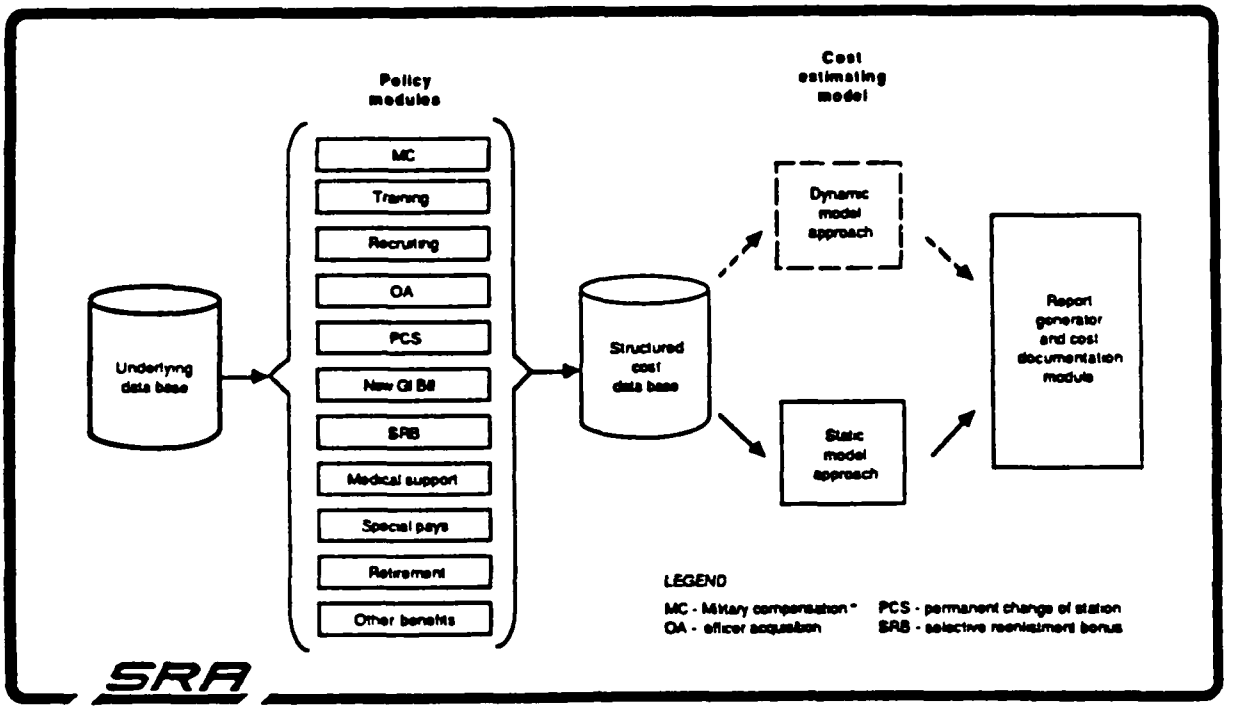

Figure 1. Schematic design of the manpower life cycle cost model.

The "policy modules" are equations that transform basic data into cost flows by grade and military occupational specialty. This is accomplished by modeling the personnel policies generating these costs. Both marginal and average costs are estimated by the modules.

The "structured cost" data base accepts costs generated by the policy modules and deposits them in their appropriate pay grade and MOS positions. The costs in the structured cost data base represent flows, or outlay costs. These are the costs that are incurred as a soldier moves through a particular pay grade.

User-specified requirements meet the cost flows in either the dynamic or static model. Time-phased manpower costs are estimated by fiscal year.

Using our evolutionary strategy for development we will begin with simple policy modules, coupled with a static cost estimating module. Then, the policy modules will be improved, and the static module will be made increasingly flexible, as it evolves into the dynamic version.

Modular design, coupled with the structured cost data base, makes this evolutionary strategy for model development practical. Each of the policy and the cost estimating modules can be modified independently. The structured cost data base serves as a "mail box" for each cost element. It is a unique pivot point around which the two major analytic components of the model revolve.

A LIFE CYCLE COST MODEL WILL MORE LIKELY PRODUCE SOUNDER ESTIMATES THAN AN AD HOC APPROACH

Life Cycle Models Improve Cost Estimates

The Army has found that sound life cycle cost estimates are an essential part of the weapon system acquisition process. They are used to determine the affordability of a new system and to compare the full costs of alternative types of weapon systems. They improve the cost effectiveness of a given system by focusing attention on designs that minimize total costs, not simply one or two high-visibility components of total cost. It is not necessarily self-evident, however, that a life cycle cost model is the best way to produce those estimates.

The Army is presented with the prospect of estimating the costs of many different systems with widely varying characteristics. One can question whether a single set of life cycle cost models can work well for all of these diverse systems. Put another way, is it feasible to develop models that are general enough to have wide applicability that can also be readily applied to a large number of specific systems? If feasible, is it desirable?

An alternative approach is to continue to provide ad hoc estimates, tailored to each particular system. This approach may offer the potential advantage of allowing the cost analyst to focus on system-specific characteristics by using cost methods most appropriate to the case at hand. The analysis, while subject to overall guidelines, would not be forced into a narrow compartment dictated by cost methods that are adequate for many systems but ideal for none.

Although the argument for an ad hoc approach has some merit, our experience indicates that the life cycle cost model offers better promise. For one reason, life cycle models generalized across systems readily do apply to particular systems. For another, life cycle cost models, well grounded in theory and rich in data, will free the cost analyst of many of the more mundane general problems and allow him or her to focus on problems peculiar to the particular system. Accordingly, and as amplified below, we believe that life cycle models will improve cost estimates and result in more cost-effective weapon systems.

Standardization Promotes Consistent Cost Estimates

The argument that every problem is different, that is, that the idiosyncratic features of each weapon system make a general model of life cycle costs impractical, is least applicable to Army manpower. The Army recruits untrained people from a common pool of applicants. The personnel and compensation system that drives the costs of Army manpower is common to all soldiers,

regardless of the weapon system associated with their assignment. Hence, much of manpower cost is readily generalized across weapon systems, especially if the grade and MOS of the manpower requirements are known.

The cost most likely to be defense-system unique is training cost. But even here, the bulk of the training costs may be easily generalized within career management fields (CMF). Basic courses in electronics, hydraulics, and the like will be roughly the same across systems demanding those general skills. System-unique training can then be estimated by analogy to similar systems or by parametric methods such as hedonic cost equations. Precisely because the cost model provides the analyst common information, access to the model will free time needed to assess system-unique costs.

Military manpower is one of the more difficult components of a weapon system cost to estimate. Unlike the cost of spare parts, contract services, and, to a large extent, in-house civilian manpower, the current "purchase price" (pay and allowance cost) is not all one needs to know to estimate the cost of military manpower. A standardized model will help to ensure that apparent cost differences are the result of real differences in alternatives and not simply the result of inconsistencies in methods and data. Moreover, the number of "reasonable" methods for resolving some of the complex cost estimation issues is large.

Numerous Cost Elements from Many Data Bases Support Comprehensive Estimates

Consistency of manpower life cycle costs cannot be an end in itself, of course. One can be consistent simply by agreeing to ignore manpower costs, as has been the case too often in the past. The manpower costs should attempt to capture as much of the life cycle costs of the materiel system as is economical.

Manpower costs are composed of numerous cost elements from a diverse set of data bases. The expense and difficulty of capturing all of them for any single ad hoc estimate is prohibitive. However, in a model that will be used repeatedly for life cycle cost analysis, an investment in a more comprehensive data base becomes practical. Even in a general model, however, effort should be focused on the elements that have the largest effect on cost differences among potential alternatives.

Distinguishing Marginal and Average Costs and Applying Only Relevant Investment Costs Promote Sound Estimates

Consistent methodology and a comprehensive data base must be combined with a sound theoretical approach if accurate estimates

are to result. Good data combined with a poor approach produce estimates that are "precisely wrong".

Military manpower has its own, relatively complex, "life cycle" in which people are recruited, trained, promoted into progressively greater areas of supervisory and technical responsibility, provided "sustaining" training and retention incentives, and so forth. There are many reasonable ways to account for these costs, some of which may be preferable to others. Moreover, the ranking of life cycle costs among competing weapon system designs may not be independent of alternative, reasonable ways to estimate the costs. It makes sense to invest time and resources to develop a sound theoretical approach to manpower cost estimation, to distinguish marginal from average costs where appropriate, and to appropriately account for common or investment costs only if the investment will be applicable in other analyses.

Consistent Methodology, a Comprehensive Data Base, and a Sound Theoretical Approach Produce Accurate Estimates

The accuracy of cost estimates is the ultimate criterion by which a cost model is judged. Accurate estimates, readily produced by the analyst, are the reason for building a life cycle cost model.

A manpower life cycle cost model using consistent methodology, a comprehensive data base, and a sound theoretical approach produces accurate estimates because:

- Standardized application of common costs promotes consistent cost estimates.
- Repeated use makes it worthwhile to invest time and resources to establish a comprehensive data base that captures numerous cost elements from a diverse set of data bases.
- Well grounded theory results in sound estimates.

A Manpower Life Cycle Cost Model Applies to Any Problem Requiring Manpower Costs That Vary Over Time

The focus of our effort has been upon the role of a manpower life cycle cost model in estimating manpower requirements over the life cycle of a materiel system. That use, we believe, is its most demanding application.

The salient feature of the model, however, is that it estimates the costs of manpower requirements as they vary over time. For this reason, the life cycle model finds use in any application where time phasing of manpower costs is important.

Other applications might include estimating manpower life cycle costs of a proposed new element of the force structure, such as adding a division or estimating the manpower costs or savings from moving to alternative authorized levels of organization (ALO). Often, one of the more difficult problems in cost estimation exercises during the POM process is obtaining a rapid estimate of the personnel cost implications of a change in manpower requirements or authorization. A manpower life cycle cost model would facilitate timely estimates of the cost of changes in manpower authorizations through the POM or Five Year Defense Program (FYDP).

The design of the life cycle model, and its planned evolutionary development, should permit it to serve as a flexible tool, adaptable to many cost estimation problems.

THE INSTITUTIONAL ENVIRONMENT HELPS DEFINE THE CONCEPT AND CHARACTERISTICS OF A MANPOWER LIFE CYCLE MODEL

The Materiel System Cycle, Acquisition Cycle, and Personnel Career Cycle All Influence a Manpower Life Cycle Model

The institutional environment in which a manpower life cycle model is expected to operate helps to define the concept and characteristics of the model. This section reviews that environment and its implications for a manpower life cycle cost model.

A manpower life cycle cost model must operate in the environment of three separate life cycles: the life cycle of the weapon or materiel system itself, the acquisition cycle, and the soldier career cycle. The requirements that a manpower life cycle cost model must satisfy, and the problems entailed in meeting those requirements, relate directly to these life cycles. Each cycle has implications for the concept and design of a manpower life cycle cost model.

The life cycle of the weapon system dictates the period, or time horizon, over which manpower costs are estimated. Also, it suggests how the type of costs may vary from phase to phase and the phases during which manpower costs become most important. Further, it suggests how the technical information inherently available during a particular phase may determine how little or how much is known about a system's manpower requirements at that stage of development or fielding.

The program acquisition cycle introduces decision milestones. The manpower life cycle model must be structured so that the information necessary to generate manpower costs at each milestone accords with the information likely to be available at that stage.

The third life cycle bearing on manpower cost analysis is the life cycle of the soldier himself. The Army's personnel system and the implied personnel career cycle drives the manpower cost estimation problem. Manpower requirements are filled by a flow from the personnel pipeline that give rise to complicated conceptual issues. These issues make manpower cost determinations some of the most challenging of all life cycle cost problems.

We will now examine each of these three life cycles.

The Six Phases of the Life Cycle of a Materiel System Variously Shape Manpower Requirements by Skill and Grade

The life cycle of a typical Army materiel system, depicted in Figure 2, may be viewed as occurring over the following six phases:[11]

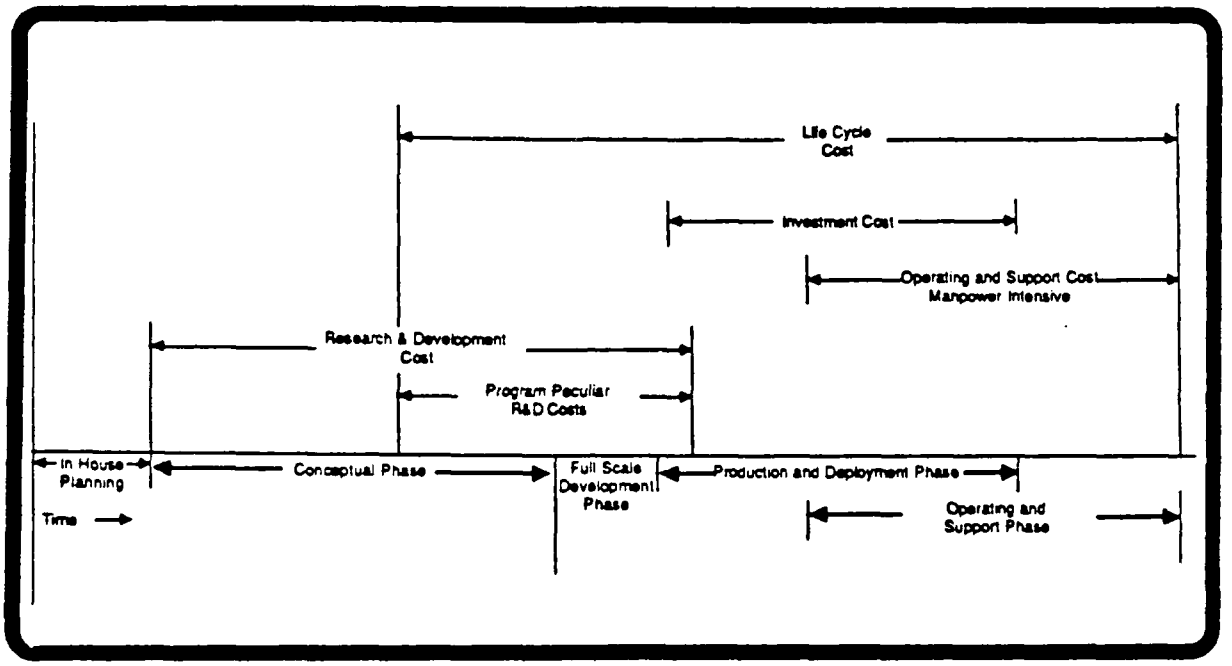

Figure 2. Life cycle of a materiel system showing portion of cycle having significant research, investment and operating costs.

(1) Planning phase. During the planning phase, the threat is identified, and alternatives that will be considered for meeting the threat are identified. At this point, the details of the weapon system itself and manpower requirements to operate and support it are quite vague. The planning phase typically lasts about 1 to 2 years.

(2) Conceptual phase. The conceptual phase consists of research and exploratory and advanced development. During this phase, most competing alternatives are eliminated. The materiel system becomes well defined but details about operating and

[11]The phases, with the exception of the "retirement" phase and the outline of the diagram, are from DA Pam 11-5. The description of each phase is original. They are stylized characterizations and are not meant to imply that they are the only events of importance that occur during the respective phases of the cycle.

support requirements generally lag. The conceptual phase lasts about 4 1/2 to 6 1/2 years.

(3) Full scale development phase. During full-scale development, the hardware is engineered and built. Operating requirements are quite clear, but information concerning support requirements is still subject to uncertainty. The full-scale development phase lasts about 4 to 5 years.

(4) Production and deployment phase. During production and deployment, the system is introduced into the operational Army. It is then that data on operating and support requirements based on experience first become available. The old system, if any, begins to be replaced. The production and deployment phase phase typically requires 3 to 4 years.

(5) Operating and support phase. During operation and support, the old system is phased out and the new system is put in place. The operating and support phase lasts typically 20 years.

(6) Retirement phase. During the retirement phase, the system is gradually phased out of the inventory.

The Army is currently attempting to revise and streamline the lengthy development phase of a new materiel system. After requirements are established, the system would enter a "proof of principle" phase that would compress the concept exploration and validation from 4 1/2 to 6 1/2 years to about 2 years. If approved, the system will go into a 4-year development phase. The streamlined process will attempt to compress the "conceptual and development phases" from their current duration of 8 1/2 to 11 1/2 years to 6 years. The Army expects the first fielding of the system to occur within 1 1/2 to 2 years after production starts.

Most manpower costs accrue over the lengthy "operating and support" phase of the weapon system life cycle. DA Pam 11-4 contains an excellent description of the cost implications of the phase:

> The term, "life cycle operating and support cost" is defined to be the sum of all costs resulting from the operation, maintenance, and support (including personnel support) of the weapon system after it is accepted into the Army inventory. O&S cost buildup begins when the first production equipment enters the active or reserve force structure either as operating equipment or combat crew training equipment. The total number of operating years may be calculated by a number of methods. One method uses a buildup period, a period of level operations, and a phasedown period. Another method uses one number, the Service Life, to express the number of operating years. Operating and Support costs will

normally be based upon assumed authorized strength with full authorized equipment in a peacetime environment. [DA Pam 11-4, "Operating and Support Cost Guide for Army Materiel Systems," April 1976.]

The Acquisition Cycle of a Major System Needs Cost Estimates for Key Decisions

As a result of the recent report of the Packard Commission,[12] the acquisition process is undergoing revision. Nevertheless, many of the conceptual issues for a manpower life cycle cost model arise regardless of the exact nature of the acquisition process. It is useful, therefore, to analyze the process and its implications for the concept of a life cycle cost model. This review will be followed by a brief description of the changes recommended by the Packard Commission that are relevant to manpower cost estimation.

Each Acquisition Milestone Has a Particular Cost Estimation Need. Figure 3 superimposes major system acquisition cycle

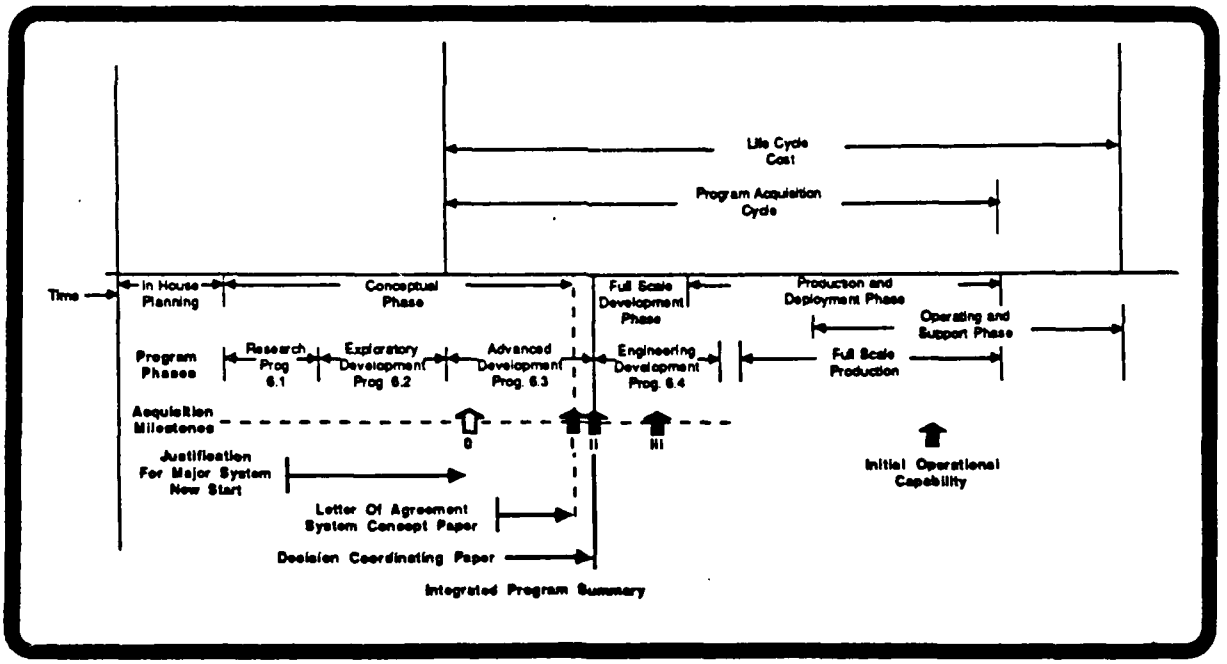

Figure 3. Acquisition milestones and R&D program phases superimposed on the life cycle of a materiel system.

[12] A Formula for Action: A Report to the President on Defense Acquisition, by the President's Blue Ribbon Commission on Defense Management, 1986.

milestones on the materiel system life cycle diagram. The milestones and the demands they place on life cycle cost estimation are as follows:

(1) Milestone Zero. Milestone Zero occurs at the beginning of the conceptual phase of the system life cycle. A paper entitled "Justification for Major System New Start" (JMSNS) is prepared. It contains a description of the threat and alternative concepts for meeting the threat. The overall affordability of the proposed system is discussed and when an alternative has initially been selected, a "gross" estimate of the life cycle cost is provided.

(2) Milestone I. Milestone I occurs towards the end of the conceptual phase of the system life cycle. A system concept paper (SCP) is provided, describing the alternatives examined in the concept exploration stage, explaining why some alternatives were rejected, and identifying the alternatives carried forward into the advanced concept development stage or demonstration stage. The paper provides the results of cost-effectiveness studies of each alternative considered and verifies the affordability of the proposed system.

(3) Milestone II. Milestone II occurs prior to the engineering development phase and requires two documents. The decision coordinating paper (DCP) is a top-level decision paper that addresses much the same issues as the SCP but focuses on a single concept. The integrated program summary (IPS) explores many of the same issues as the DCP but in greater detail. The IPS contains a detailed section on maintenance support and personnel. In this section manpower requirements and costs of the proposed system are compared to a comparable "reference" system, as are training requirements and costs. Projected manpower shortages by occupational specialty are discussed and alternatives for alleviating them are identified.

(4) Milestone III. Milestone III (if required) occurs after Full-Scale Engineering Development. The IPS is updated. A summary of detailed plans and cost estimates for training initial units of operating and support personnel for conversion to the new system is presented.

Managerial Improvements Emphasize Early Cost-Performance Tradeoffs and Prototype Development. The Packard Commission has recommended that the Joint Requirements and Management Board (JRMB) assume many of the functions once performed by the former Defense Systems Acquisition Review Council (DSARC). The commission made two recommendations that have implications for the manpower life cycle cost model concept.

First, the JRMB is encouraged to examine tradeoffs between performance and costs early and continuously in the process, up to Milestone II. The JRMB will decide, partially on the basis of

these tradeoffs, whether or not to proceed with full-scale development at that point.

Second, the development of prototypes early in the process and prior to full-scale development is strongly encouraged. Prototypes, it is argued, ". . . provide a basis for realistic cost estimates prior to a full-scale development decision."[13]

The Materiel Life Cycle Interacts with the Acquisition Cycle at Decision Milestones to Affect Model Concept and Design in Various Ways

The nature of the typical materiel life cycle and its interaction with key decision points of the acquisition cycle have important implications for the concept and design of a manpower life cycle cost model. Information available for analysis over the acquisition cycle is initially limited but grows continuously. At the beginning of the process, little is known about the types and skills of manpower required. Near the end of the cycle, manpower analysis is required at the occupational specialty level of aggregation. A life cycle cost model must be able to adapt to the information available.

Other implications include:

(1) Requirements information. Manpower requirements information is at a relatively general level through much of the conceptual stage and only crystalizes at the full-scale development stage. Actual support requirements will generally remain uncertain until maintenance experience data becomes available. The manpower life cycle cost model must be flexible enough to:

- o Accept both manpower requirements data specified at a very aggregate or general level; and
- o Progress to more detailed levels of aggregation as more information becomes available.

(2) Cost estimation uncertainty. The uncertainty surrounding manpower cost estimates throughout the acquisition process will be driven as much, if not more, by uncertainty in the requirements as it is by the cost (or price) of those requirements. However, some types of manpower requirements (such as operators) may be inherently subject to less uncertainty than others (such as maintenance). If tradeoffs are to be made between components of manpower life cycle costs and the cost of the hardware design, it may prove useful to decisionmakers to separate components of life cycle cost estimates into risk

[13]Op. cit. p. 18.

categories, based on subjective estimates of the uncertainty surrounding the underlying requirements in those components.

(3) Time-varying manpower requirements. It is clear from even a cursory review of the materiel system life cycle that manpower requirements will not be constant over that cycle, nor even over major portions of the cycle. A manpower model of life cycle costs must be able to estimate the costs of requirements that vary over time.[14]

(4) Transition costs. Transition costs are inevitable. They include nonrecurring costs needed to shift to the new system. Examples include: the development cost of new training courses and the retraining costs of soldiers operating and supporting the old system.

(5) Putty-clay dilemma. Early in the process, while the system design is quite amorphous, it costs relatively little to alter the design in a way that attempts to minimize the life cycle costs of the system, including operation and support costs, resulting in a more cost-effective system. However, the information on manpower requirements and operation and support costs in general is quite vague during these early stages. In later stages much more information on operation and support requirements is available, but by this point the hardware design has become relatively rigid and much more costly to change. Manpower life cycle cost models will become increasingly useful in the early stages of system acquisition, as requirement estimation procedures improve.

(6) Prototyping. The Packard Commission has strongly endorsed prototyping of the weapon system early in the research stage, well before full-scale development. One implication of prototyping is that better information on operation and support requirements will be available, presumably improving the accuracy of cost estimates and increasing the value of and demand for life cycle cost tradeoff analyses.

(7) Balancing cost and performance. One of the strongest themes of the Packard Commission report is that tradeoff analyses between cost and performance should be conducted early and often in the acquisition process. This acceleration increases the importance of sound cost estimation methods.

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[14]Although this point would appear to be self-evident, it rules out certain types of models that have been suggested in the past. For example, the "Minimum Flow Model" of Mannle and Risser (1982), which provides the "steady-state" personnel inventory required to fill a time-invariant manpower requirement, is clearly not applicable to a time-varying manpower requirement. Moreover, a time-varying manpower requirement greatly complicates the technical problems in developing a "dynamic" model of manpower life cycle costs.

The Personnel Career Cycle Relates Inventories of Officers and Enlisted Personnel to Manpower Requirements

The relationship between the Army personnel system and inventories of soldiers and manpower requirements is critical to the development of a sound manpower cost model. The materiel system life cycle and the acquisition process have important implications for the conceptual issues surrounding the development of a manpower life cycle cost model. However, they pale in comparison to those of the Army personnel career cycle system or the soldier career cycle represented in Figure 4.[15]

How the Army matches faces (personnel) with spaces (requirements) is a complicated and often misunderstood process. It presents both conceptual and technical problems for estimating the cost of military manpower. To better understand the nature of these problems it will be helpful to review, briefly, the Army personnel life cycle. The review that follows is a stylized exposition of the Army enlisted personnel so that the relevant details of the system for manpower cost analysis are highlighted.

The Army enlisted personnel system is frequently described as a pipeline. People enter the Army system at the bottom, usually at a pay grade of E-1, as untrained recruits. They will have signed enlistment contracts to stay for at least 2, 3, or 4 years. There are very few lateral entrants in the Army's "closed" personnel system. The Army invests resources in recruiting qualified people and providing them with basic and specialized training in skills useful to the Army.

The Army will discharge some entrants during initial training, but most will proceed to their first duty station. By this time, most will have been promoted to a rank of E-3 and will be filling a manpower requirement position for the first time. At the end of the first enlistment, about half of those left from the initial entry cohort will decide to leave. The rest will reenlist and move on to another duty station. The offer of a reenlistment bonus to those in military occupational specialties (MOS) in short supply may induce some to reenlist who otherwise would leave.

The Army's competitive promotion system is based on vacancies at the next higher grade, time in service, time in grade, and performance of the individual soldier. The Army

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[15]The exposition focuses on the enlisted personnel system. The officer system certainly differs, but characteristics relevant to the manpower cost issues raised here sufficiently parallel those of the enlisted system to make a conceptual discussion of the officer system superfluous.

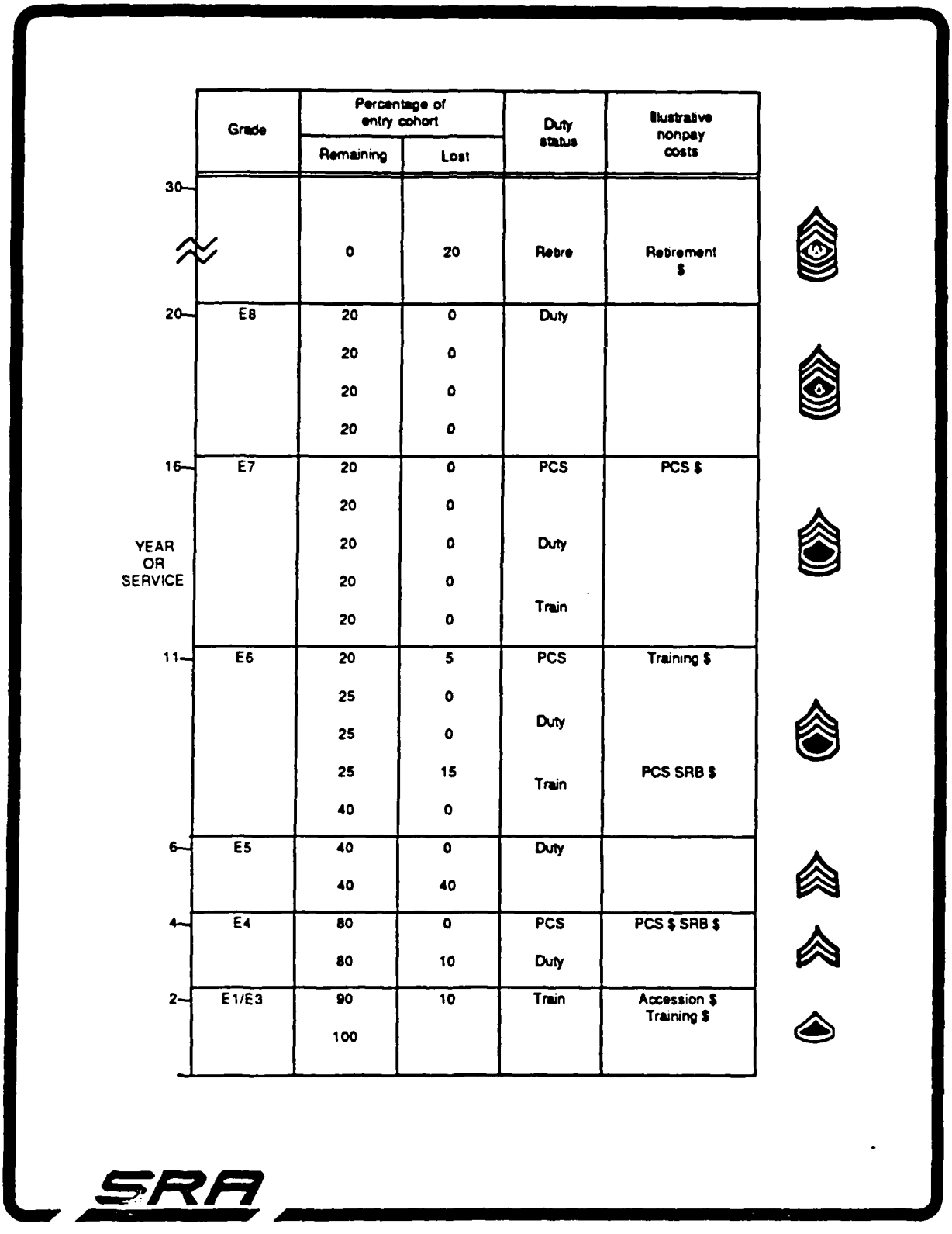

Figure 4. Notional career cycle of Army enlisted peronnel illustrating nonpay costs associated with current duty status.

promotes the best-qualified soldiers to fill vacancies created by those who leave, die, or retire. The Army then assigns soldiers to fill these vacancies. At the end of the second enlistment, more soldiers will leave but not nearly as large a proportion as at the first reenlistment decision. The higher reenlistment rate is due, in part, to the increasing draw of the military retirement system.[16]

Most of those who reenlist the second time will stay at least to the vesting point for retirement.[17] During this period, the Army may invest in additional formal training for some individuals so that they may successfully serve in positions of higher technical or supervisory responsibility. Most of those who stay for 20 or more years will retire at grade E-6, E-7, E-8, or E-9.

The important characteristics of this system for manpower cost analysis are: (1) all, or most, soldiers enter untrained at very junior pay grades; (2) the Army invests in recruiting and training these entrants, and the benefits of these investments accrue to the Army over the soldier's career; (3) individuals remain in service at different rates and are promoted to the next higher pay grade at different rates; (4) manpower requirements are specified by skill and pay grade; and (5) the rate of flow through the personnel system is controlled by the number of required positions at each MOS and pay grade and the number of soldiers in each MOS and grade who leave, die, retire, or are promoted or demoted.[18]

The Personnel Career Cycle Structures Manpower Skills by Pay Grade with Annotated Costs

What does the Army personnel system have to do with estimating the cost of filling an additional manpower position, an E-6, for example?

If the Army were able to rent the services of fully trained soldiers for a year from firms in competitive private-sector markets, the cost to the Army of filling an E-6 position for a year would be the rental payment made to the firm. The private-sector firm would invest resources in recruiting and training the

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[16]Retirement becomes vested after one completes 20 years of service.

[17]There are no manpower positions written for students or trainees.

[18]The Army can influence the effect of various characteristics by its personnel policy decisions. For example, an increase in reenlistment bonuses will increase the number who choose to reenlist.

soldier, as well as compensating him. These costs would all be reflected in the rental fee paid by the Army. The individual components of cost that would underlie the rental fee would present an interesting pricing and investment problem to the private-sector firm, but they would be irrelevant to the Army.

However, the Army recruits and trains its own soldiers. There is essentially no competitive rental market.[19] The cost of an E-6 position is not nearly as clear.[20] At each point along the life cycle of the soldier, the Army incurs costs. Most of these costs reflect payment for the services of the soldier at particular duty stations, or the cost of moving the soldier to particular duty stations. There is no conceptual difficulty in attributing these costs to the manpower position the soldier fills.

But, some costs, such as recruiting and training costs, are more of the nature of investments or common costs that will benefit the Army as the individual serves in several future positions. How much, if any, of these costs should be attributed to the E-6 position? The conceptual approach usually taken is to average or "amortize" the investments costs over all the future grades that will enjoy the benefits. Although this is a useful approximation in most instances, it unfortunately is not generally correct.

To understand why, consider the ways of filling an additional E-6 position, while at the same time keeping all other positions filled. First, one could "grow" an E-6 by recruiting and training additional people. This method is probably the most popular notion of how the Army fills a billet. Because of attrition, it may require five recruits to eventually fill the E-6 position. Under this view, most of the people in the inventory are there because the Army is waiting for them to "grow" into something else. The cost of the E-6 position would be breathtaking, under this view, and the Army would have to recruit for the position years in advance.

A second way of filling the position is to promote an E-5 to E-6 early and an E-4 to an E-5 early and so forth, while recruiting and training one additional soldier. The first year's cost of the new E-6 would be approximately equal to the pay and allowances of the new E-6, plus the costs of recruiting and training the new entrant. Finally, one could retain an E-6 who would have otherwise left the Army, perhaps by offering a slightly higher reenlistment bonus. The first year's costs would be the soldier's pay and allowances, plus the cost of the

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[19]A few stripes for skills and prior service accessions are exceptions.

[20]Nor is it clear that a single cost for an E-6 position is the correct way to conceptualize the problem.

reenlistment bonus. The Army would incur no additional training or recruiting costs.

These examples illustrate that there is more than one way to fill a manpower position and that the cost of that position depends, at least in part, on how it is filled. Presumably, there is a way to fill the position that minimizes cost, and this may vary with time and circumstance. The perspective also is important. The life cycle minimum cost may call for a very different solution than the lowest first-year cost.

Because the personnel system is a "flow" variable, while manpower requirements are equivalent to a "stock", it is inappropriate to think of the manpower costs as unique prices by pay grade and MOS. Rather, one should concentrate on the manpower cost outlays expected to be generated in the process of filling requirements.

The preceding discussion of the personnel life cycle suggests the following observations are relevant to a manpower life cycle cost model:

(1) Focus on Outlays. The averaging, or amortization, of investment or common costs, such as recruiting and training costs, into an overall cost of a manpower position is an approximation that may be useful in many instances. However, it is not generally correct. Instead, the focus should be on the manpower cost outlays that will occur as the manpower requirement is filled. In other words, recruiting and training costs should be attributed to the cost of filling the requirement only as individuals are recruited or trained.

(2) Dynamic Model. A manpower cost model that projects manpower costs by simulating the interaction between the personnel inventory flow and manpower positions is, in concept, the appropriate way to estimate life cycle manpower costs. We call this a "dynamic" model. However, there are significant technical difficulties in constructing such a model. Moreover, the model may also be somewhat difficult to operate.

(3) Static Model. A "static" model is the term we have given to a manpower cost model that computes the cost of a typical position by grade and skill, averaging training costs over all relevant grades according to some amortization mechanism. Using this as the price, or unit cost of that type of position, the cost of manpower requirements can be estimated by simply multiplying the "price" by the quantity of the manpower requirements. As discussed above, it is not without flaw. However, it involves much less technical risk and is likely to be easier to use than a dynamic model.

A MANPOWER LIFE CYCLE MODEL SHOULD TAKE INTO ACCOUNT RELEVANT ANALYTICAL AND PRACTICAL ISSUES

The Model Should Try to Distinguish between Costs Incurred by the Army and Other Government Costs

Costs estimated in the manpower life cycle cost model will attempt to include all the manpower-related costs incurred by the government.[21] The model will have the ability to suppress costs incurred by the DoD that are not part of the Army's budget, or costs incurred by the government that are not part of DoD's budget. However, no attempt will be made to distinguish a category of costs that are imposed upon society but that do not appear in the government's budget.[22]

Model Output Should Be Comparable with Other Cost Elements of the Materiel System and Share a Common Cost Analysis Framework

Manpower costs are only one element of the the total life cycle cost of an Army materiel system. To be useful, the model's output must be able to be compared to hardware costs and other major costs of the materiel system. It must be compatible with a common cost-analysis framework.[23]

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[21]DoD Instruction 5000.33 states that ". . . it [life cycle costs] is the total cost to the government for a system over its full life . . . ." DoDI 5000.33, p. 5. (Their underline, our boldface.)

[22]An example might be environmental damage caused bycertain training exercises or the inherent opportunity cost to society of a Selective Service draft.

[23]The Department of the Army cost guide for life cycle costs states:

> a. It must be compatible with both top-down and bottom-up cost estimating approaches. The framework must not, by its composition, preclude either approach. It must be compatible with cost analysis policy and convention.
>
> b. It must capture 100 percent of costs. It must be comprehensive, but not necessarily detailed.
>
> c. It must be manageable in size. Simplification in level of cost analysis detail is essential. [DA Pam 11-4, p. 2-1.]

Using Manpower Management Communities as Building Blocks in a Bottom-Up Approach to Aggregation Promotes Consistency in Cost Estimates. Aggregation by manpower management communities offers consistency with both the personnel and requirements systems. A "bottom-up" approach to aggregation ensures consistency across estimates at different levels of aggregation.

The level of aggregation of manpower costs in a life cycle model is important for at least two reasons. First, it should be compatible with the level of detail used in estimating other components of the life cycle cost of the weapon system. Second, as we argued in the previous section, the life cycle model must be able to accept manpower requirements specified at various levels of detail.

Manpower management communities offer a natural hierarchy of aggregation. Table 1 suggests possible aggregation tiers that could be used in the manpower life cycle cost model. The most disaggregated level (level 1) would use military occupational specialty (MOS) and pay grade. The most aggregated level (level 6) would use total active Army strength and average Army costs.

Table 1

Manpower Aggregation Levels
for Cost Analysis Hierarchy

Aggregation tier	Skill dimension	Grade dimension
1	MOS	Pay grade
2	CMF	Pay grade
3	CMF	Average
4	Officer/enlisted	Pay grade
5	Officer/enlisted	Average
6	Active Army	Average

The basic building block will be manpower costs at the grade and MOS level of detail. This overall "bottom-up" approach offers much flexibility. Higher levels of aggregation can be built simply by taking weighted averages, where the weights are determined by current inventories. Consistency of cost estimates across different levels of aggregation, a potential problem in life cycle cost estimation for materiel systems, is ensured by this construction.

Not all costs can be obtained from the "bottom-up." Unfortunately, some costs, especially those for which there is little variance across skills, can only be allocated in a "top-down" approach, starting from overall budget data. CHAMPUS costs are an example. They will vary by grade but not much by skill.[24]

Most of the important costs, such as basic pay, training costs, and enlistment and reenlistment bonus costs--the costs that differ among skills--will be constructed from the bottom up.[25]

The Model Incorporates Major Appropriation Categories as a Separate Dimension. Incorporating major appropriation categories as a dimension in the manpower cost model conforms with the budget process and complies with OSD and DA instructions.

Most manpower costs are in the accounts for Military Personnel and Operation and Maintenance, but all the following categories will be included: Military Personnel, Operation and Maintenance, Procurement, Family Housing, and Military Construction.

The Model Avoids Double Accounting by Omitting Costs of Manpower Support Positions Other Than for Trainers and Recruiters. To avoid double counting and incompatibility with other support models, the manpower life cycle cost model will not have the costs of manpower support positions embedded in the costs of operational or TO&E positions.

Only the cost of positions explicitly provided by the model's user will be estimated. There will not be a "piece" of a personnel specialist included in the cost of an E-5 infantryman, for example. The only exceptions to this are in training and recruiting costs, where the cost of trainers and recruiters are included, respectively.

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[24]The major variables in CHAMPUS cost estimation are the number of dependents.

[25]Cost estimating relationships (CERs), which attempt to infer costs from a statistical relationship estimated over historical data, are not necessary for manpower costs, per se. The "bottom-up" approach, in which the researcher may ask what pays, allowances, bonuses, and training the individual filling the requirement will receive, is straightforward and undoubtedly more accurate. CERs, or variations of them, such as hedonic cost functions, might be useful in estimating the costs of training for new systems.

The Model Should Provide Both Total Costs and Costs by Year, Adjusting Time-Phased Costs to Obtain Compatibility

Several important analytical issues arise because life cycle costs accrue over time. Estimates of costs over the life cycle as they are incurred by fiscal year, as well as total costs, must be provided.[26] But costs occurring in different periods are often not directly comparable.

The Model Distinguishes between Constant and Inflated Dollars. Prices change over time. Time-phased manpower costs should be displayed both at the prices of the year in which they are incurred and in constant dollars, using approved price indices from the Office of the Secretary of Defense.[27]

The Model Discounts Future Costs to Obtain Their Present Value. The manpower life cycle cost model should have the ability to discount costs incurred in future periods and calculate the present value of costs over the life cycle.

Costs incurred in different periods, even if they are in constant dollars, are not directly comparable. A dollar cost incurred next year is, in fact, less costly than a dollar incurred today. One can always invest a dollar today and, in a year, liquidate the investment, use the principal to pay off the dollar's worth of cost, and be ahead by the return on the investment.

If the manpower life cycle cost model were to be used only for budget decisions, that is, only for deciding precisely how

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[26]The DA pamphlets on the life cycle costs of materiel systems refer to the total cost, without a time dimension, as "static" costs. This is not the same notion as a static cost model developed in the previous section.

[27]Some confusion exists in applying these indices, however. Separate price indices are constructed for O&M costs, manpower costs, and so forth, which are projected to grow at different rates. Hence, the price indices project changes in the relative prices of these inputs. However, in estimating the costs in "constant" dollars of general purchasing power, which is the intent of "constant" dollar estimates, one should deflate the costs that have escalated in terms of the input-specific price index by an index of general purchasing power. This preserves any "real" increase or decrease in the price of the input implied by the input-specific price index. Instead, the usual practice is to estimate "constant purchasing power" costs at today's or a base year's prices, ignoring the previous prediction of relative price changes.

much money should be added to the budget to cover the costs of decisions already made, then discounting would make little sense. However, if the model is used in making allocation decisions, it should have the ability to discount future costs.

Consider the case of trading off an increase in initial hardware procurement costs to obtain a reduction in operation and support costs. Assume the procurement cost increase is $100, and it saves $125 in undiscounted operating and support costs over the system's life cycle. Should the trade be made? If the procurement cost is incurred immediately, but the O&S savings only begin to accrue in 5 years, and the relevant discount rate is 10%,[28] the $125 future savings is equivalent, at most, to $77 now.

Department of the Army guidance on this issue requires both nondiscounted and discounted costs.

> In formulating cost estimates for major weapon systems and in formulating unit cost estimates for input in Cost and Operational Effectiveness Analysis (COEA), priority will be given to developing the best estimate possible of absolute (i.e., non-discounted) cost, both total and unit. **These costs will be discounted unless specifically exempted by Headquarters, DA.** Office of Management and Budget Circular No. A-94, dated 27 March 1972, cites specific categories for exempting discounting. [AR 11-18, p 5-1.]

The Model Should Incorporate the Notion of Opportunity Costs and Distinguish Average and Marginal Costs

The notion of opportunity costs and the distinction between marginal and average costs are important for manpower cost estimation. Opportunity costs are relevant to the internal allocation of Army resources. The distinction between average and marginal cost is especially important when estimating the costs of relatively scarce resources such as manpower.

The Model Recognizes as Opportunity Costs Manpower and Ohter Resource Costs That Although Unchanged in the Aggregate Are Reallocated within the Army. The manpower life cycle cost model should include the cost of manpower and other resources even though they may not change in the aggregate as a result of a weapon system decision, but are simply reallocated within the Army.

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[28]OMB Circular A-94, currently under revision, specifies a 10% discount rate.

It is the Army's policy that active component strength will remain constant during peacetime at about 780,000. Any new materiel system, whether it replaces an old system or is a net addition to the force structure, presumably must be operated and maintained within that overall strength limitation. One might ask, why does it make sense to include pay costs in a manpower cost model if the strength is neither increasing nor decreasing?

Even though Army's total strength does not change, the manpower and dollars are drawn from or released to other uses within the Army. Even though the Army personnel budget may remain roughly the same, the change in resources would be drawn from or put to other uses, affecting Army's readiness in other areas. Comparing manpower costs among competing systems allows the Army to choose systems that economize on overall Army resources, releasing the savings so that they may improve Army readiness and capability in other areas.[29]

Guidance from the Cost Analysis Improvement Group on this issue states:

> Use of existing assets or assets being procured for another purpose must not be treated as a free good. The "opportunity cost" of these assets should be estimated,

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[29]There is a difficulty, however, in estimating the true price at which manpower should be valued in the Army. It is caused by the 780,000 strength constraint. The underlying reason that we can value Army resources at their cost is that, at least within the Army's budget constraint, it can trade off resources at their cost to obtain an optimal mix. That is, as long as the Army is able to buy whatever resources it wants while staying within its overall budget, the Army will achieve the most capability for those resources when it has adjusted its mix of resources such that an additional dollar's worth of any one resource buys the same amount of additional capability as an additional dollar's worth of any other. Hence, a "dollar's worth" of resources is comparable across resource types.

If this were not true, the Army could improve capability by reducing expenditures on resources that buy relatively little additional capability at the margin and increasing expenditures that buy relatively large amounts of additional capability at the margin. Hence, dollars represent an appropriate measure of the opportunity cost of resources within the Army. If, however, the cap on Army end strength is binding, a dollar's worth of manpower buys more capability than a dollar's worth of other resources. Using manpower costs to make tradeoffs between manpower and hardware costs, given this binding constraint, results in systems that demand too much manpower.

where appropriate, and considered as part of the program costs.[30]

The Model Provides Estimates for Both Average and Marginal Costs. Marginal costs are appropriate for decisions because they attempt to provide the increase in costs resulting from that decision. Although average cost estimates may be useful for some budget purposes, marginal costs are important because the change in manpower may change the average cost. Accordingly, the manpower life cycle cost model will include estimates of both average and marginal costs, when they differ.[31]

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[30]In Criteria and Procedures for the Preparation and Presentation of Cost Analyses to the OSD CAIG, Discussion of Operating and Support Costs, in Enclosure 1 to DoD Directive 5000.4, Subj: DoD Cost Analysis Improvement Group, October 1980.

[31]See Evaluation of the Prototype (Draft), SRA Corporation, July 1986, for reasons why both are important.

ARMY MANPOWER COST SYSTEM: THE CONCEPTUAL DESIGN OF THE LIFE CYCLE ACTIVE ARMY MANPOWER COST ESTIMATION MODEL

PART 2 - CONCEPT, DESIGN, AND PLAN OF DEVELOPMENT

THE MODEL CONCEPT AND DESIGN DRAW FROM REPORTS DISCUSSED IN PART 1

The preceding chapters provide background for our conceptual approach to cost estimation in general and to estimating Army active component manpower costs over the life cycle of materiel systems, in particular. We describe what we believe to be the most demanding environment in which a manpower life cycle cost model will be used, the major system acquisition process. We also discuss the nature of the demands placed on the model by that process.

Understanding the nature of the interaction between manpower demand (setting requirements) and personnel supply (filling requirements) is key to developing a sound conceptual approach and to developing an appreciation for some of the technical problems. In Part I, this interaction and its implications for manpower costs are reviewed in detail, and some specific analytical issues are addressed.

The next section of this chapter presents our conceptual approach to life cycle costing for manpower. It draws on the previous chapters. The remainder of this chapter discusses the basic design of the model and a discussion of selected technical issues.

The Completed Model Emulates the Personnel System and the Cost Outlays the System Generates to Fill Manpower Requirements

The active Army component of the life cycle cost model will project the manpower costs of filling exogenously specified manpower requirements over time. The costs will include the costs incurred by the government in filling those requirements and in keeping them filled. The requirements themselves and the manpower costs they generate will vary over time. It is not a "steady-state" approach.

The conceptual approach begins with the premise that a manpower cost model will estimate the costs of defined manpower requirements or required spaces. These required spaces will probably be changing over time, as the Army moves toward a new materiel system or a new force structure configuration. Manpower costs, however, are generated by people as they flow through the

personnel system in an attempt to fill the manpower requirements. Hence, our approach is based on the fundamental notion that, explicitly or implicitly, a manpower cost model must be a model of the personnel system and the cost outlays generated by the personnel system as it attempts to fill requirements.

An Ideal Conceptual Model Sets the Goal. Our conceptual life cycle cost model will attempt to model manpower costs as the outlays generated by the Army personnel system in attempting to meet manpower demands.

Ideally, it will:

- Model explicit costs as outlays over the personnel career cycle, generated as a function of personnel policies and prices.
- Project how those outlays will change as personnel policies change, giving the model flexibility to forecast changes from historical budget costs.
- Model the flow of soldiers through the personnel system.
- Model the process by which the flow of soldiers is adjusted to meet specified time paths of manpower requirements and the costs generated thereby.
- Accept externally computed "transition" costs, for "start-up" and "phase-down", as necessary.

In addition, the model will perform several important "book-keeping" tasks, including:

- Display manpower costs by fiscal year and appropriation category.
- Compute both the discounted and nondiscounted sum of the costs over the life cycle.
- Adjust components of cost for the effects of anticipated price changes.

It will include the ability to respond to user-provided information:

- Adjust components of manpower costs, such as training cost, at the user's request.
- The model will be relatively easy to maintain and update.

Our Evolutionary Approach First Builds an Initial Version of the Ideal Model. The model outlined in the previous section is an "ideal" cost model. Any attempt to build such a model in "one giant step" would be folly. Our approach, instead, is to begin more modestly and build upon our successes, keeping the "ideal" model as the target. We will build good working models in the first contract year and then improve on them, rather than attempting to build perfect models all at once.

Our design, presented in the next section, is especially well suited to this strategy. The initial version of the model for active manpower will contain all of the essential "building blocks" of the ideal model. The design is modular so that particular elements can be improved upon without redesigning the entire model. The first active force enlisted and officer models will be on line by April 30, 1987.

The Completed Model Features a Modular Design Centered on a Structured Cost Data Base

The design characteristics of the model are presented in this section. The design is discussed first as an integrated whole and then by component. Although the details of each component of the model are, in many instances, under development, the overall design concept is complete.

The overall model is designed to emphasize flexibility and to realize the advantages of evolutionary development. Two related design concepts are largely responsible for this flexibility. First, each major component of the model is modular in design. Most components can be modified without radically affecting other components. Second, the "structured cost" data base serves as a unique pivot point for the model and makes this modular design possible. The "policy modules", intended to produce estimates of cost flows, can be modified independently of the cost estimating model that transforms those flows into elements for cost estimation.

Policy Modules Interact With an Underlying Data Base to Produce Cost Flows Converted by the Cost Estimating Component into a Time-Phased Profile of Manpower Costs. A diagram of the proposed design of the model is presented below.

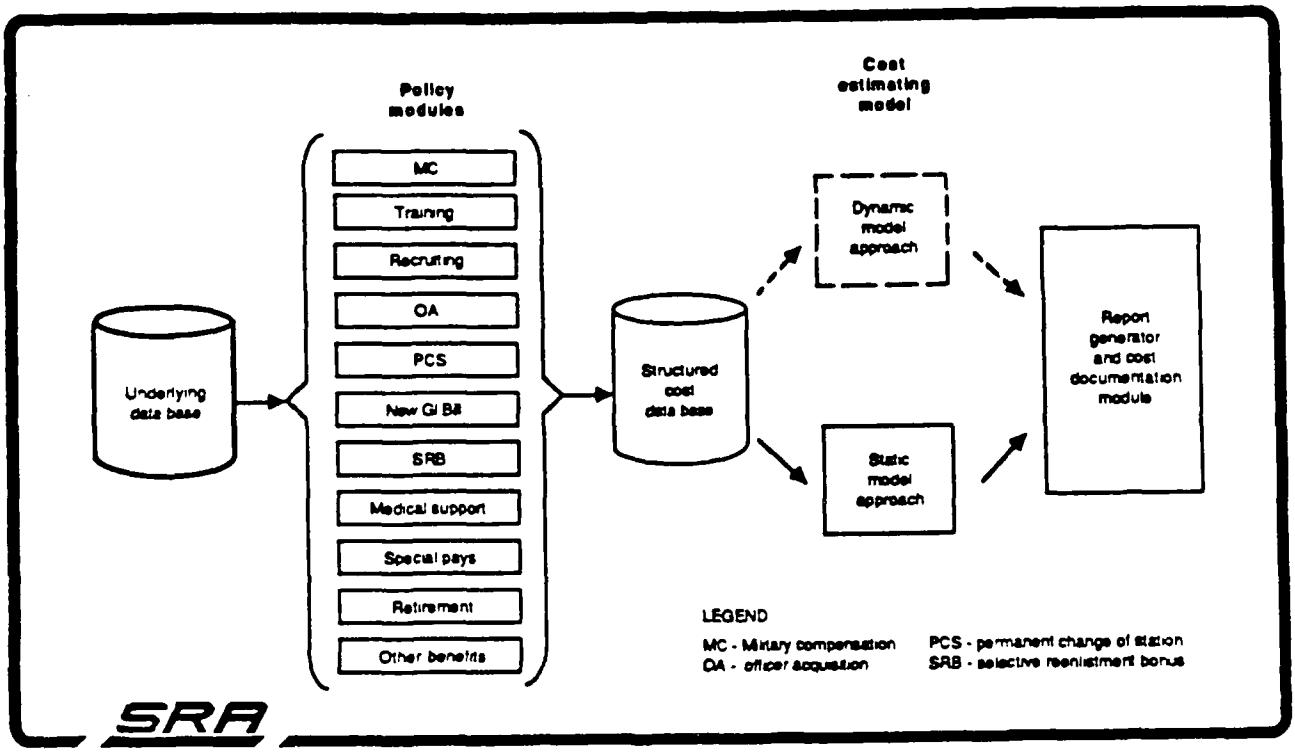

Figure 5. Schematic Design of the manpower life cycle cost model.

The logic of the model is quite simple. All of the data required for manpower cost estimates are stored in the underlying data base. Where relevant, these data are indexed by Military Occupational Specialty (MOS) and pay grade--the building blocks of the model.

The data are used largely, but not exclusively, by the policy modules. The policy modules are equations that attempt to capture the essential elements of personnel policies as they affect manpower costs. Using data from the data base, the policy modules convert that data into cost flows by MOS and pay grade. Both average and marginal costs are computed, where relevant. Under the current design, policy modules exist for 10 major manpower cost elements, but this is subject to change as the models evolve.

The manpower cost flows are then entered into the "structured cost" data base. The cost flows are structured by MOS and pay grade. Each of the major cost elements from the policy modules is also retained, and the dollar flows are stored by major appropriation. The structured cost data base defines the flow of costs an individual soldier will generate as he moves

through that pay grade. All transformations to the basic data in the policy analysis modules are attempts to estimate these cost flows.

Before either the static or dynamic model can compute manpower costs, the user must enter the time path of manpower requirements at the level of detail the requirements information permits. The cost estimating model will convert the cost outlays into a final form. The model then uses these data to estimate the time-phased cost of requirements.

The static and dynamic characterizations represent two alternative concepts for estimating the cost of manpower requirements. The static model attempts to convert the outlays into a matrix of manpower requirements costs, or prices, dimensioned by grade and MOS. It does this by averaging or amortizing certain of the investment or common costs, such as recruiting and training costs. Then, these prices are multiplied by the quantities of the manpower requirement and added to estimate the total. The dynamic model uses the cost flows from the structured cost data base in a model simulating the process by which the personnel inventory fills the manpower requirements. As personnel pass through different pay grades, costs are generated and collected.

The static and dynamic models are two extremes along a spectrum of cost models. They illustrate the evolutionary aspect of our model design and development plan. An operational static model will be produced first. This model will gradually be modified, subject to the Army's priorities, and will evolve into a model approximating the dynamic "ideal" model described previously.

The Underlying Data Base Contains Essentially all Data Used by the Model. The underlying data base (see Figure 5-2) will contain all the data used by the model, except for items supplied directly by the user that are peculiar to a particular application. One might categorize the data into four types: (1) pay data that are common across MOS, such as basic special and incentive pay tables and the average cost of operational and rotational moves; (2) policy data that vary by MOS, such as enlistment and reenlistment bonus awards and educational benefit "kickers"; (3) demographic and inventory statistics by MOS and CMF, such as the percentage of high-quality recruits or transition probabilities for the inventory; and (4) data on special pays and allowances that have been allocated to specific combinations of grade and MOS based on recent history and MOS specific training course cost data. Where relevant, the data will be indexed by MOS, CMF, and grade.

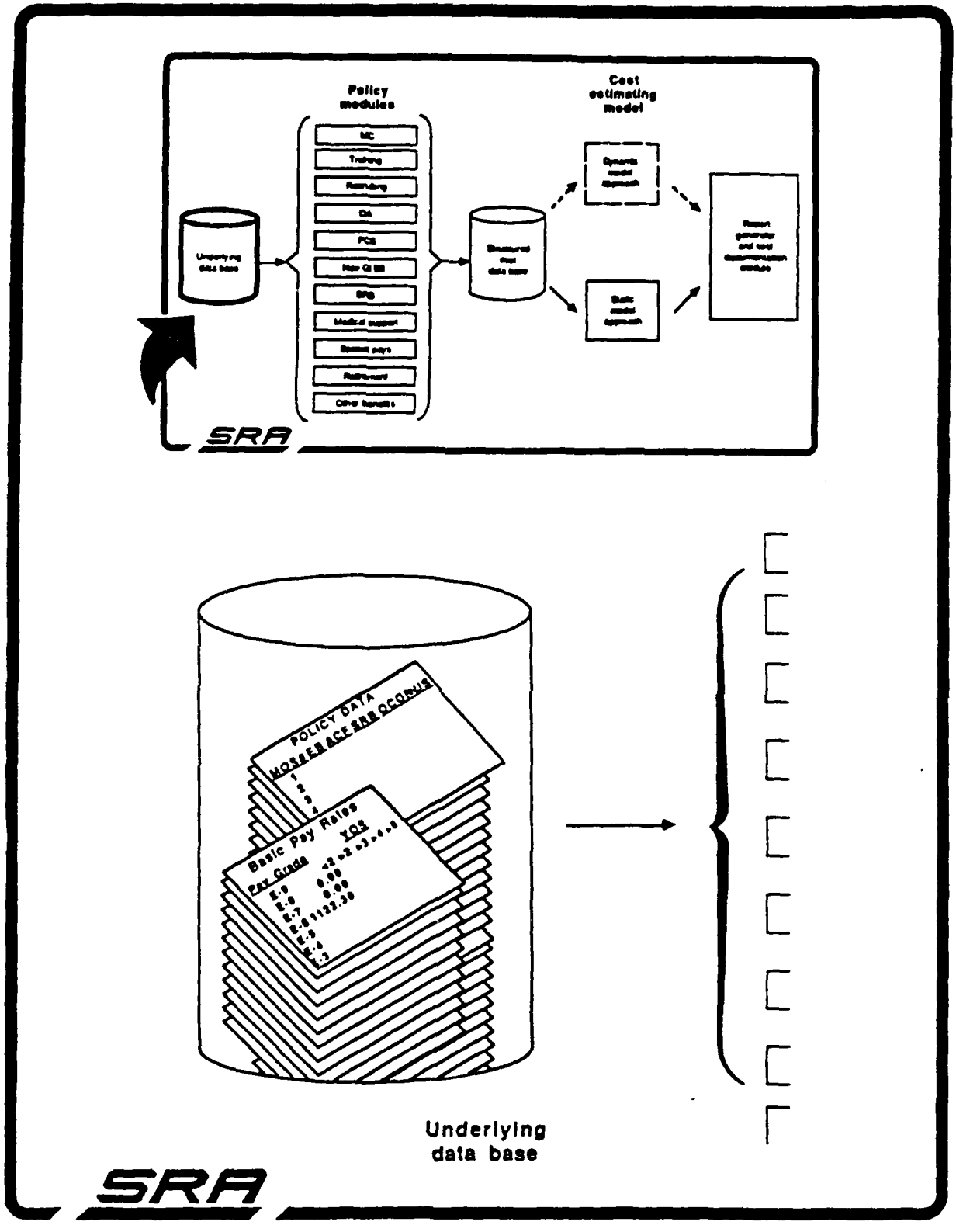

Figure 6. Underlying data base component of the manpower life cycle cost model.

A Data Information Resources Dictionary (DIRD), now being assembled, will describe each data element, along with its source and the period to which the data apply. Utility programs for modifying and updating the data base are being developed.

The Policy Modules Contain Sets of Equations that Generate Cost Flows. The policy modules (see Figure 5-3) are sets of equations that generate cost flows for 10 major cost elements.[32] Both average and marginal cost equations are included. They attempt, in a sense, to model Army personnel policies, producing the costs that result from the policies.

When policies change, the cost flows will change. The policy modules project the effects of these changes on costs. Where feasible, the policy modules build cost elements from the bottom up, rather than from the top down. The policy modules attempt to take prices as given and estimate quantities of relevant variables, such as PCS moves, based on personnel policies, rather than accepting historical budgets and allocating then according to "factors". A model based solely on historical data and fixed allocation factors will tend to unravel when policies change.[33] Modeling the personnel policies themselves is an attempt to prevent this unraveling.

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[32]See AMCOS Information Book, September 1986.

[33]See our discussion of this problem in Technical Report: Evaluation of the Prototype, July 1986.

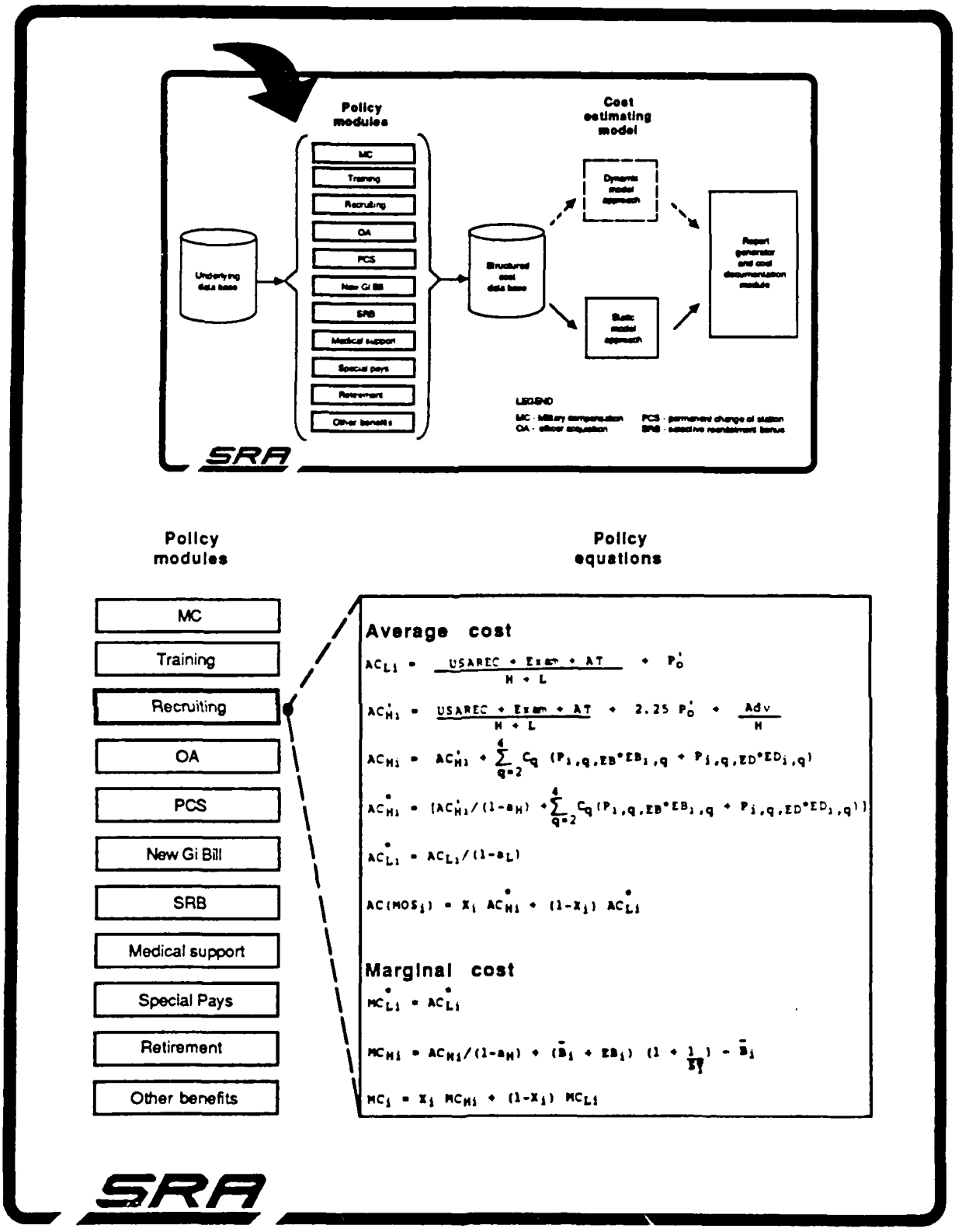

Figure 7. Representative equations from the policy modules component of the manpower life cycle cost model.

The current major cost elements included in the policy modules are:

- Basic Pay and Allowances;
- Training;
- Recruiting and Accession;
- Permanent Change of Station;
- Education Benefits (excluding "kickers");
- Selective Reenlistment Bonuses (SRBs);
- Medical Costs;
- Other Benefits;
- Retirement Costs; and
- Special Pay.

Underlying each of these major elements are additional components of costs. For example, the cost of enlistment bonuses, Army College Fund "kickers", recruiters, advertising, and accession travel are included in the recruiting and accession cost module.

Some of the policy equations are quite simple. For example, base pay costs for an MOS at a particular pay grade are computed as a weighted average, where the weights are the number in the inventory. However, the policy module will have the ability to increase pay at alternative rates over time. Moreover, the modules are interrelated. Because Selective Reenlistment Bonuses are a function of basic pay, if basic pay increases, projected SRB costs will increase also.

Other equations are somewhat more involved. For example, the current version of the recruiting cost policy module consists of over a dozen equations for average and marginal costs of high- and low-quality recruits.

At the current stage of the development process, most of the policy equations are quite simple. Our development strategy is to introduce simple equations to build a prototype working model. We will take advantage of the modular nature of the policy components to introduce more complexity later, if it is needed. Investing large amounts of time in refining the equations before

obtaining a working model is a riskier and less efficient strategy.[34]

The Structured Cost Data Base Receives the Cost Elements Produced by the Policy Module. The manpower cost elements produced by the policy modules will be entered into the "structured cost" data base (see Figure 5-4). Costs coming from the policy modules will be by pay grade and MOS. These costs represent an estimate of the costs that the Army would incur as a soldier moves into that pay grade or MOS. The investment or common costs will not be allocated or amortized across pay grades.

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[34]Technical Report: AMCOS Information Book, September 1986.

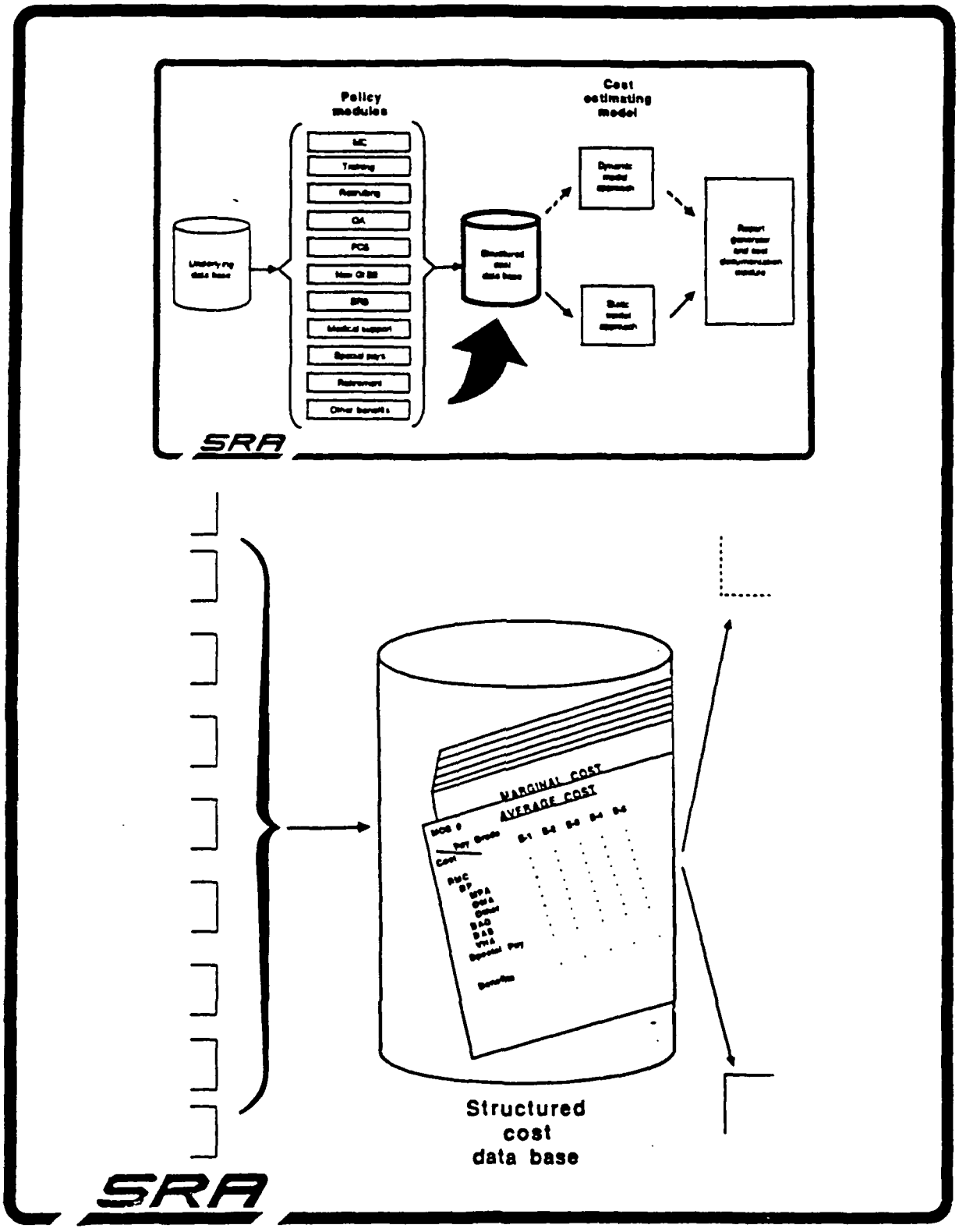

Figure 8. Structured cost data base component of the manpower life cycle cost model.

The structured cost data base stores the cost data by pay grade, MOS, major cost element, budget appropriation, and marginal or average cost. Those elements that are costs to the government, but do not appear in the Army's budget, are flagged. The structured cost data base is a cost model in its own right, for it defines the costs generated as a soldier progresses through the personnel system.

Unless personnel policies change, there is no reason to recreate the structured cost data base for every application of the model. Any particular cost analysis can begin with the structured cost data base. A copy of the data base will be created, and the user will be able to modify elements of that copy without affecting the actual data base.

The user may alter the data base in a number of ways. For example, certain elements may be modified or deleted. This would affect the cost flows that enter the cost estimating model and the results for that analysis but would not alter the original structured cost data base.

The structured cost data base, in which the flow costs of manpower reside, offers a number of design advantages. The cost flow data matrix is the kernel of the design structure, around which the two analytical components of the model (the policy analysis modules and the cost estimating model) revolve independently. The discipline supplied by the structured cost data base ensures that modifications to the policy analysis modules do not require changes to the estimating model, and vice versa.

The structured cost matrix provides the user with ready access to the basic building blocks of manpower cost estimates. The user could, literally, build his own cost scenario by deleting or modifying elements of the matrix and test the sensitivity of the estimates to changes in underlying data elements, such as recruiting costs.

The Cost Estimating Model Produces a Time-Phased Profile of Manpower Cost Over the System's Life Cycle. The cost estimating model will produce a time-phased profile of the cost of manpower over the life cycle of the materiel system (see Figure 5-5). Here, manpower requirements meet personnel cost flows. The model accepts the cost elements of the structured cost data base as input along with user-supplied manpower requirements. The cost elements may, in some cases, be transformed and are then used to compute the total manpower cost over the life cycle.

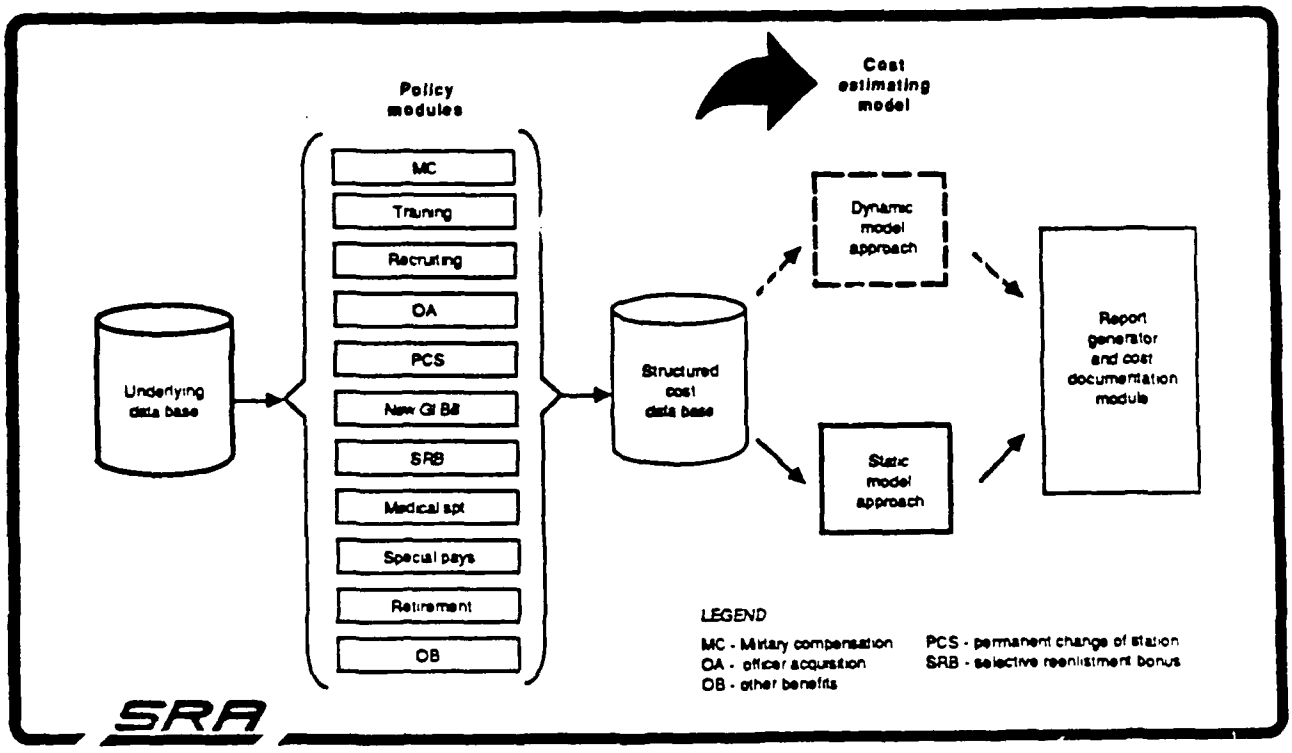

Figure 9. Cost Estimating Model Component of the manpower life cycle cost model.

Two alternative methodological approaches to estimating the cost of manpower requirements will now be discussed: a static model and a dynamic model.

The Static Model Approach Uses Structured Cost Data to Estimate Unit Cost of a Manpower Requirements. In the static model approach (Figure 5-6), the data from the structured cost data base is used to estimate the unit cost (or price) of a manpower requirement. These prices will have the same dimension as the requirements themselves. For example, the price of each pay grade for each MOS might be computed. This matrix of prices is then multiplied by a similarly dimensioned matrix of manpower requirements to compute the cost of manpower for that year of the life cycle. We have called this approach the static model approach. It is static in that it assumes that all personnel costs relevant to the manpower position can be represented by one static number or price.

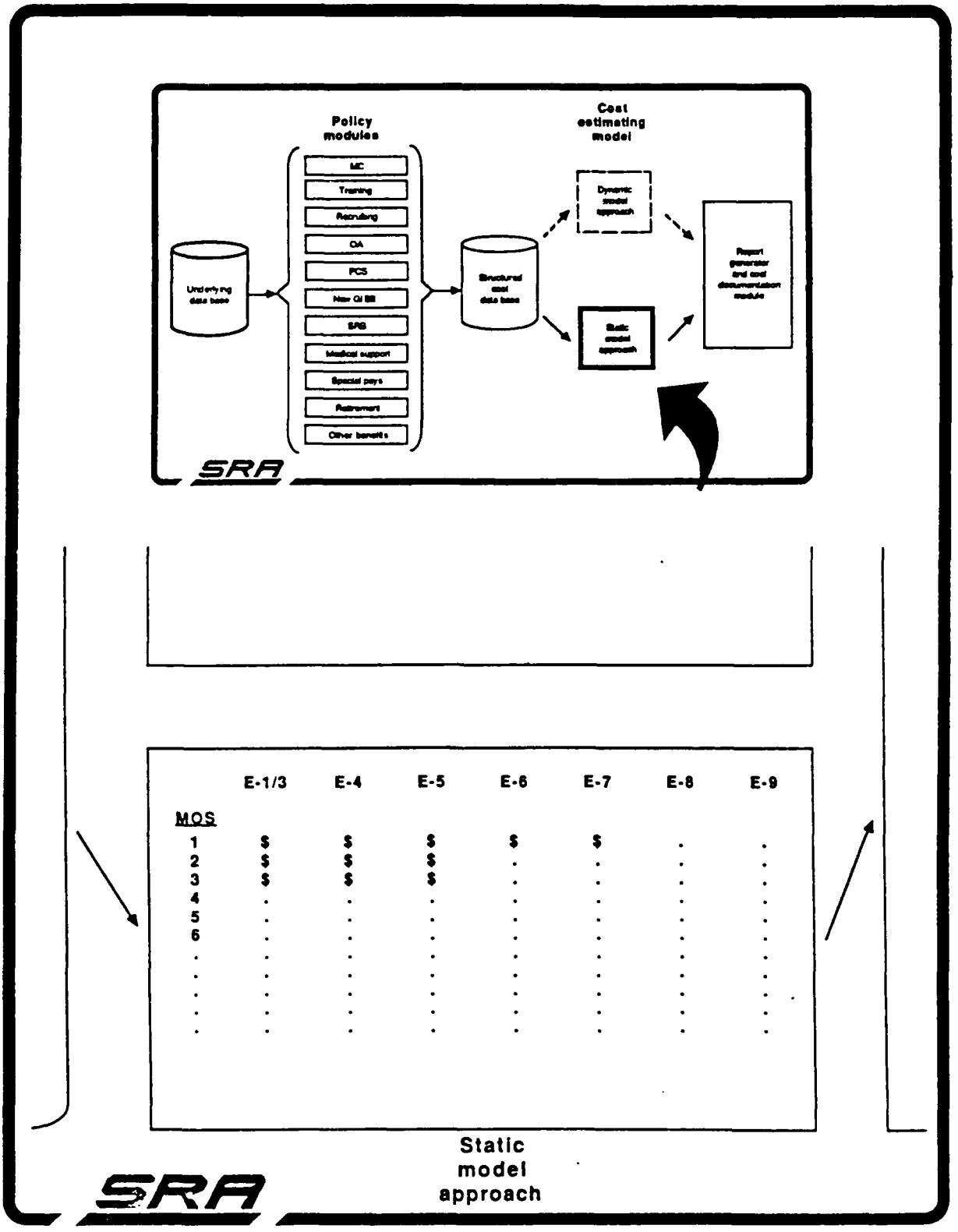

Figure 10. The static model of the cost estimating component of the manpower life cycle model.

The direct costs of a manpower requirement are the pay and allowance costs associated with the position. The attribution of these costs to the manpower position is straightforward. Much less clear is how the costs are attributed to specific manpower positions.

These costs, often displaced in time from the act of filling a manpower requirement, provide a flow of benefits to the Army over the soldier's career. Attributing them to any one position would generally overstate the relative cost of that manpower requirement. However, soldiers leave and must be replaced. A model that focuses on the costs of the manpower requirements must account for replacement recruiting and training costs somewhere. Hence, attributing all, or a portion, of these costs to the cost of a manpower space necessitates an allocation or amortization rule.

As mentioned in previous chapters, the potential problems with these rules can be seen by focusing on the actual recruiting and training cost outlays generated by the personnel system. Often, requirements can be staffed without generating any new recruiting or training costs, at least in the short run. A fixed allocation rule will attribute costs to the requirements, whether these costs are incurred or not.[35] Nevertheless, many allocation rules provide a close approximation to the actual costs generated.

In developing the static model, several options and combinations of options for allocating common costs will be offered to the user, in addition to a default. Examples include:

a. Allocation of investment costs in proportion to the historical loss rate from that MOS and pay grade. This replacement cost approach was used in aggregate form by Schank et al (1986). If T is training cost and r is the loss rate from the relevant grade, training cost allocation is r*T.

b. Allocation as a proportion of expected years of service. If the expected years of service for a trained soldier in a MOS is n, then (1/n)*T is allocated to a given position. This arbitrary rule has the advantage of minimizing distortion of the relative costs of different pay grades.

c. Allocation of all investment costs of "growing" a soldier for that position, in proportion to the loss rate for that position. This method recognizes that

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[35]Appendix B to our draft technical report, "Evaluation of the Prototype Model and Recommendations for AMCOS Development", SRA, 1986, contains a detailed discussion of the problems with cost amortization.

more than one person is required to be trained to eventually fill the position. If s is the survival rate from the time of training up to the time at which a soldier progresses to the required grade, the training cost allocation to that grade is (T/s)*r.

In addition to investment cost allocation methods, the user will be offered a menu of alternative assumptions concerning how a position is filled (promotion, retention, recruiting) and the different estimates of costs that are implied by them, both for transition periods and a notional steady-state. In addition, the user will have access to the structured cost data base, allowing him to adjust training cost and other data directly.

The development strategy is to reduce the potential shortcomings of a static model by providing flexibility in the choice of key cost assumptions. In all cases, a default option is offered that represents our estimation of what is likely to be the best alternative for most cases.

There are some distinct advantages to a static model despite the problem with cost allocation rules. The model will be straightforward and easy to understand and use. It will entail little or no development risk and can be constructed with fewer resources than the dynamic model. Finally, we believe we can provide the static model with sufficient flexibility to lessen the problems associated with fixed allocation rules.

An Alternative Dynamic Model Approach Would Model the Way the Personnel System Fills Manpower Requirements. A dynamic model approach, in the model's most rigorous form, attempts to model the way in which the personnel system fills manpower requirements (see Figure 5-7). Time-phased manpower costs are generated as soldiers progress through the personnel system to fill the requirements. One can picture a dynamic model by considering a model of the personnel system with costs attached to every state in that system. As a soldier moves through various states in the process of satisfying a time path of manpower requirements, he or she incurs costs that are accumulated by the model.

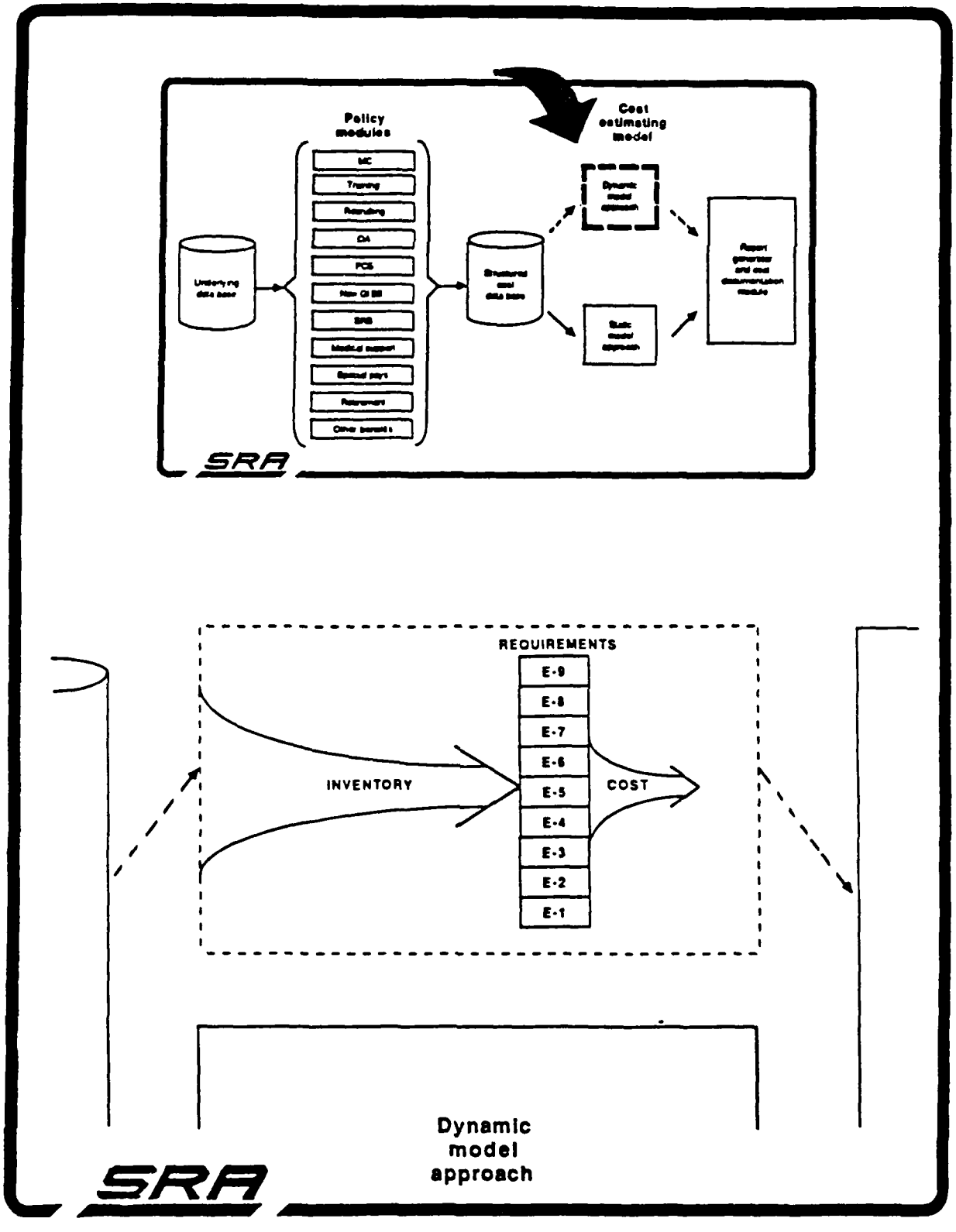

Figure 11. Alternative dynamic model of the cost estimating component of the manpower life cycle cost model.

There is no cost amortization in a dynamic model. Training costs are recorded only as the model simulates a soldier passing through a state in which training occurs. The time-phased estimates of manpower costs are the costs generated in each fiscal year as the model recruits, trains, and assigns soldiers to manpower positions.

At this point, we consider the dynamic model approach an area of research, rather than development. A number of significant technical and conceptual issues concerning a truly dynamic model must be resolved prior to full-scale development. Some of the more significant technical problems concern the way the model will attempt to match personnel flow with manpower requirements. Two issues are:

(1) **Choice of Personnel Policies.** There is more than one way to fill a manpower requirement. Should the model solve for an "optimal" strategy? If so, how should the objective function or criteria for choosing be specified?

(2) **Time-Varying Requirements.** The time pattern of requirements generated by a new weapon system probably will not match the time flows assumed by the personnel system. If the model were structured to exactly meet manpower requirements at every point in time, some unrealistic costs may result, especially as the requirements vary over time. On the other hand, if the model were permitted to deviate from meeting requirements exactly, what would be the penalty for being out of equilibrium?

Several existing models attempt to match personnel flows with inventory requirements. The Army Manpower Long Range Planning System (MLRPS) developed by Sigma Systems, Inc., solves for a path of flow rates (e.g., continuation rates, accession rates, promotion rates) that satisfies manpower requirements, but it does not include the cost of adjusting those rates in its objective function. Hence, the solution path is somewhat arbitrary. The Navy Bonus Optimization Model, developed by RGI, applies control theory to solve for an optimal time path of retention rates. It includes the cost of achieving those rates in its objective function, along with a quadratic loss function describing the cost of having too few or too many people to satisfy requirements. A similar approach was taken by Munch (1978) in constructing what she called a "Dynamic Optimization Model". These models offer good starting points, but some fundamental problems remain to be solved before dynamic models can be incorporated directly into AMCOS.

THE AMCOS DEVELOPMENT PLAN RESPONDS TO CHANGING ARMY PRIORITIES

The Original Development Plan as Revised Focuses on a Life Cycle Cost Model for the Active Army

One can never build a model that is incapable of being improved upon, though a notional "ideal" model is a useful goal toward which to start. As we emphasized in previous chapters, our research and development strategy is an evolutionary one, reflecting this belief. Starting within the framework of a conceptually solid design, we have built a simple, but sound, life cycle cost model. We have already begun to enhance the model and will improve upon it over time. A modular design and disciplined cost structure makes this evolutionary development strategy economical.

A "Flexible" Static Model Should be Constructed First. A life cycle cost model for active Army enlisted and officer components will be constructed first. The static model will be modified, increasing its flexibility and usefulness in cost estimation. The enhancements will move it closer to a dynamic version.

An Evolutionary Approach to Building the LCCM is Preferred. A dynamic model is the more theoretically sound of the two approaches. However, it would not be prudent to proceed directly to the task of building an "ideal" model. The development risks are great. Moreover, the "flexible" static model will be easier to use and interpret in the short term. An evolutionary approach to building an active component life cycle cost model provides the opportunity to weigh the benefits of a presumably more accurate and conceptually sound model with the risks at each stage of the research and development process, while at the same time reap the benefits of an operating life cycle cost model.

The Life Cycle Cost Model was Completed and Delivered in the Twelfth Month. The development schedule for AMCOS is shown in Table 2. A life cycle cost model for Army active enlisted manpower was operational and available for testing by January 31, 1987. An operational officer version was available for testing by February 28, 1987. Following four weeks of testing by both the research and development team, and the primary Department of the Army users, the models were modified to alleviate the shortcomings and "bugs" found in the initial testing. They were delivered to the Army as "enhanced" static models on 31 March 1987.

During this development, we provided the AMCOS team with several iterations of short working papers on different aspects of the model. As comments were incorporated and revisions issued,

this AMCOS Information Book became an excellent working document covering all aspects of the model. The AMCOS Information Book currently contains user's instructions, programming code and other model documentation as well as the original information papers. In addition this book has served as an excellent vehicle for communication between the AMCOS team members.

Table 2

Development Schedule for Active Army Components of AMCOS Life Cycle Models

Component	Completion Date
Draft Concept Paper (Active Component LCCM)	30 September 1986
Active Enlisted LCCM (Test Version)	31 January 1987
Active Officer LCCM (Test Version)	28 February 1987
Final Concept Paper Final Active Enlisted LCCM Final Active Officer LCCM	30 April 1987

The Evolutionary Approach Permits Alternatives for Second Year Development

In SRA's first progress report we laid out the following three alternative courses of action for the second year of the contract.

Alternative 1 - Enhance Active Component LCCM
Alternative 2 - Develop Civilian and RC LCCM
Alternative 3 - Do both 1 and 2

Alternative 1. Incorporate all enhancements required by the user to the Active Component LCCM. Under this alternative we continue to concentrate on the Active Component Model, making it more dynamic, developing the Policy Modules in more detail, and adding several enhancements to make it more user-friendly. The RC and Civilian models would be deferred until the third year. These enhancements will incur costs above those originally programmed for the Active Component LCCM and will delay the development of other models.

The Contract asks the contractor to develop proposals in response to changes in the system that require the undertaking of special tasks. Alternative 1 responds to that request and is within the scope of the current contract.

Alternative 2. Develop Reserve Components and Civilian LCCM. Under this Alternative the Active Component would be delivered with a minimum of enhancements and our emphasis would shift to developing the Reserve Component and Civilian Models. These models would be similar to the Active Component Model developed in the first year of the contract. This alternative maintains the schedule to develop all 15 models in accordance with the original cost and time profiles.

Alternative 3. Develop a combination of Alternative 1 and Alternative 2. Under this alternative we would begin development on the reserve and civilian LCCMs concurrent to enhancement of the Active Component Model. This alternative ultimately will require additional funds to ensure delivery of all of the models that are planned at the enhanced level of sophistication now prescribed for the Active Component LCCM.

All alternatives are viable. Alternative 1 will provide the Army with the enhanced capability to estimate active duty soldier replacement costs and will allow CEAC to quickly cost large volumes of requirements data. Alternative 2 will provide the Army with a complete set of models for all its manpower communities sooner than Alternative 1 would. Alternative 3 will deliver fully enhanced models for all components of manpower on an accelerated schedule, but at an increased overall cost.

In our first Semi-Annual Report, we recommended Alternative 2 to conform to the deliverable and cost profile of the original contract. However, if funds were to be available in year two, we then recommend the parallel development described in Alternative (3).

A Modified Parallel Development is the Preferred Development Option. The Deputy Comptroller selected a modified parallel development option, subject to the priorities and levels of effort described below. He emphasized that parallel development should not delay incorporation of the active component enhancements.

The Deputy Comptroller established the following priorities for the second year of the contract:

(1) Accelerate development of the enhancements.

(2) Develop a basic civilian model to include both General Schedule and Wage Board Personnel Systems.

(3) Develop Reserve Component models for National Guard and Army Reserve (Officer and Enlisted).

To accomplish the sponsor's direction, ARI's Chief of Manpower and Personnel Policies Research Group directed the contractor to sustain their current level of effort at least through the enhancement development period. Table 3 displays a timetable for work in the next six months.

Table 3

Table of Near Term Tasks for AMCOS

TASK	TIMELINE
1. Automated input of manning requirements - Program to read a track tape - Sort data by SRC	31 May 87
2. Create a more user friendly integrated model - Master Executive File; menu driven - Integrate Officer and Enlisted - Include SCDB default values/switches	30 June 87
3. Enhanced Training Cost Module - Collect cumulative training costs across grades - Apply career training costs to pay grade using CMF career paths - Develop automated interface with LOTUS database	30 June 87
4. Other Enhancements - Inflation rates by appropriation - Graphics capability	31 July 87
5. Update Active Component Database	31 August 87
6. Draft Concept Paper for Civilian LCCM	31 October 87

AMCOS Long Term Plans Must be Revised

Table 4 presents our proposed long-range plan. It includes the revisions necessary to comply with the Deputy Comptroller guidance. The first column shows the type of model, the second column shows applicable communities, and the third column shows the type of activity scheduled for each contract year.

Table 4

Revised Long-Range Plan

MODEL TYPE	ARMY COMMUNITY	ACTIVITY SCHEDULE CONTRACT YEARS (ENDING MARCH) 87	88	89	90	91
LCCM	ACTIVE	D	E	M	M	M
	CIVILIAN		D	E	M	M
	RESERVE		D	E	M	M
BUDGET	ACTIVE			D	E	M
	CIVILIAN			D	E	M
	RESERVE			D	E	M
ECONOMIC	ACTIVE				D	E
	CIVILIAN				D	E
	RESERVE				D	E

D = DEVELOP
E = ENHANCE
M = MAINTAIN

Given the decision discussed above, we will enhance the Active Force LCCM and develop the LCCMs for the Civilian and Reserve Components during the second contract year.

This means that work on the Economic and Budget Models is deferred until after the LCCMs are completed. We now plan to break them down into the same components as the LCCM. Much of the technology used for the LCCM will be applicable to the Budget and Economic Models. Within the revised level of effort we will be able to develop, enhance and maintain the increased number of models shown.

By the end of the five-year contract period, the Army will have an effective family of manpower cost models proven in successive real world applications. The Army staff will understand the models completely and will be using them as on-line management tools.

APPENDIX A
REVIEW OF RECENT ARMY MANPOWER COST STUDIES

A.1 Introduction

This appendix briefly reviews and analyzes five of the relevant, recent efforts to estimate Army manpower costs. The major points to be gleaned from the review are:

(1) None of the studies have made a major effort to estimate comprehensive manpower costs at the MOS level;

(2) Most studies estimate manpower costs as a per capita average cost based on recent budgets;

(3) No studies have attempted to distinguish average from marginal costs, but the Rand piece suggests that this is an area worthy of research; and

(4) None of the studies have a satisfactory solution to the problem of including investment (or common) costs in the cost estimates in a sound way. The Rand and the ARI/DRC studies grapple with the issue, and each suggests a partial solution.

The studies reviewed include:

(1) Unit Cost Analysis: Annual Recurring Operating and Support Cost Methodology;

(2) Estimating Manpower Personnel and Training Requirements Early in the Weapon System Acquisition Process: An Application of the HARDMAN Methodology to the Army's Division Support Weapon System;

(3) Man Integrated Systems Technology (MIST) User's Guide;

(4) U.S. Army OMA & MPA Cost Factors; and

(5) TRADOC-FORSCOM Resource Factor Handbook.

A.2 Review

This section discusses each of the five studies individually.

A.2.1 Unit Cost Analysis: Annual Recurring Operating and Support Cost Methodology. John F. Schank, Susan Bodily, and Richard Pei, The Rand Corporation, 1986.

This study describes a relatively simple methodological approach to estimating annual operation and support costs of active and reserve units. The primary data source is the Budget Justification Books, and costs are computed largely as average or per capita costs. Costs vary by officer and enlisted status but not by grade or MOS. Training cost estimates that vary by MOS were available from the MOS Cost Handbook (1982), but the authors chose to use average costs for officers and enlisted personnel derived from the handbooks. Per capita recruiting and training costs for replacement were estimated by computing the cost of recruiting and training to replace accrual losses and dividing these costs by unit strength. This amortization scheme is similar to amortization by conditional losses, described in the concept paper.[1]

The authors take some care to distinguish variable costs from fixed costs, but the major focus of the paper is on the identification of issues for further research. It concludes:

> "Future cost research should be devoted to understanding the non-recurring transition costs ["start-up" and "phase-down"] and to determining the difference between average and marginal costs. ["Start-up"] costs include such elements as ... the acquisition and initial training of personnel."

A.2.2 Estimating Manpower Personnel and Training Requirements Early in the Weapon System Acquisition Process: An Application of the HARDMAN Methodology to the Army's Division Support Weapon System, Thomas E. Mannle, Jr. (Dynamics Research Corporation) and Daniel T. Risser (ARI), Technical Report 616, Army Research Institute, February 1984.

This study is of interest primarily because of the way personnel flow requirements are estimated based upon stated manpower requirements. The "Minimum Flow Solution" model determines how many people are required to fill a given set of requirements, under the assumption that individuals enter at the bottom and flow through the personnel system under fixed continuation rates. The constraint that personnel must equal requirements is imposed at the pay grade that is most difficult to fill. It is this limit-setting pay grade that determines the size of the inventory. Excess people are available at all other pay grades.

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[1]Concept Paper: Life Cycle Cost Model - Army Active Manpower, Systems Research and Applications Corporation, September 1986.

This method is clearly one way to approach the difficult problem of estimating the flow of people (and the cost) of meeting a given set of manpower requirements. However, its rigid assumption that all new requirements are met by "planting" E-1 recruits and permitting them to grow under fixed continuation and promotion rates leads to unrealistically high personnel demands and creates unnecessary manpower costs. For example, this approach suggests that if the probability were 5% that an E-1 would become an E-9, adding one additional E-9 would require at least 20 additional recruits per year plus the "growth" positions for each of those E-1's as they flow through the system. Alternative ways to obtain the additional E-9 might include retaining or promoting an additional E-9.

The model permits the user to test the sensitivity of the results to changes in attrition or promotion rates, yet the model itself does not solve for an "optimal", or least cost, way of filling requirements. The model assumes no "transition" from existing systems. All personnel enter at the bottom for each system. Finally, the model's "solution" appears to apply only to a hypothetical "steady state" level of manpower requirements. It does not permit the requirements to vary over time.

A.2.3 Man Integrated Systems Technology (MIST) User's Guide, Dynamics Research Corporation, 1985.

In the MIST system, personnel flow demands are estimated by a variation of the "Minimum Flow Solution" model, discussed above. Training costs receive much attention in MIST and seem to be based upon methods used in TRADOC's ATRM-159 report. However, other manpower costs receive little attention. Because it uses training costs that vary by MOS, the MIST generates manpower costs that vary by MOS, as well as by grade.

A.2.4 U.S. Army OMA & MPA Cost Factors, Volume I & II, U.S. Army Cost and Economic Analysis Center, December 1984.

This comprehensive document estimates Army manpower costs by officer and enlisted status, by grade, and, with respect to some cost categories, by major command or geographic area. Also, an effort is made to include cost factors reflecting "start-up" or nonrecurring costs. Costs are computed as average costs and are based largely on the Budget Justification Books. Some of the allocation rules are unusual, however. For example, all selective, reenlistment bonus (SRB) costs are allocated to grades E-4, E-5, and E-6, and educational benefit "kickers" are omitted as a variable recruiting expense. Nevertheless, the cost factors are quite comprehensive. This source will be very useful during AMCOS development.

A.2.5 TRADOC-FORSCOM Resource Factor Handbook, Volume I: Cost Planning Factors, 1986, DCSRM TRADOC, DCSCOMPT FORSCOM.

This cost guide emphasizes allowances and PCS costs that vary by duty station. Average composite costs by grade are computed for TRADOC and FORSCOM installations. There is a Volume II for TRADOC and FORSCOM that uses Cost Estimating Relationships (CERs) to estimate the manpower demand and the costs of that manpower at the installation level. Costs are generally highly aggregated.