VIRGINIA PRODUCTIVITY CENTER

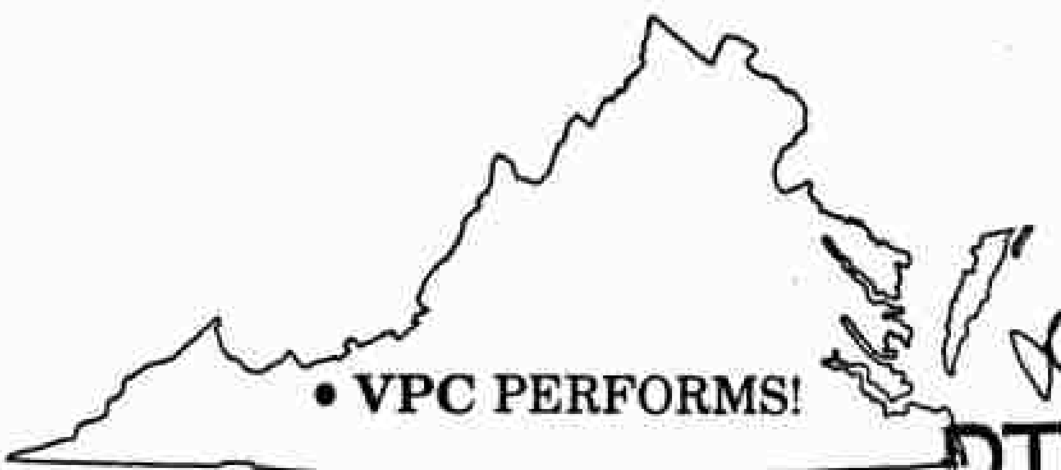
THE STUDY OF

PRODUCTIVITY MEASUREMENT

AND INCENTIVE METHODOLOGY

PHASE IV - FIELD TEST
FINAL REPORT

13 March 1987



Virginia Polytechnic Institute
and State University

Blacksburg, Virginia 24061

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PRODUCTIVITY MEASUREMENT

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Defense Supply Service - Washington

Contract MDA 903-85-C-0237

Virginia Productivity Center

Virginia Polytechnic Institute & State University

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Phase IV is part of a five-phase study to identify and develop productivity measurement models and methodologies. Phase I research identified and described current productivity measurement practices in the defense contractor community. The Phase II research developed a taxonomy of productivity measurement theories and techniques. Phase III, "The Study of Productivity Measurement and Incentive Methodology" involved a "paper test" of

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three measurement models identified in Phase II: the Multi-Factor Productivity Measurement Model (MFPMM), the Discounted Cash Flow/Shared Savings Approach (DCF/SSA), and Price Waterhouse's Cost Definition/Automated Cost Baseline Generator CDEF/ACBG.

The Phase IV research involved several deliverables. We were to: further evaluate and resolve specific developmental needs of the three models at LTV/Vought Aero Products Division (LTV/VAPD); complete the development of the integrated productivity management methodology designed in Phase III; design and draft a guide to communicate the principles and philosophies of performance management to defense contractors; and develop detailed plans for a series of evaluation workshops to be executed in Phase V that will expose both government and contractor personnel to the guide. This report documents field test effort.

THE STUDY OF PRODUCTIVITY MEASUREMENT AND INCENTIVE METHODOLOGY

PHASE IV FIELD TEST FINAL REPORT

13 March 1987

Defense Supply Service - Washington
Contract MDA 903-85-C-0237

Virginia Polytechnic Institute and State University
Contract No. N00039-84-C-0346

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I. Executive Summary

Phase IV is part of a five-phase study to identify and develop productivity measurement models and methodologies. Phase I research identified and described current productivity measurement practices in the defense contractor community. The Phase II research developed a taxonomy of productivity measurement theories and techniques. Phase III, "The Study of Productivity Measurement and Incentive Methodology" involved a "paper test" of three measurement models identified in Phase II: the Multi-Factor Productivity Measurement Model (MFPMM), the Discounted Cash Flow/Shared Savings Approach (DCF/SSA), and Price Waterhouse's Cost Definition/Automated Cost Baseline Generator CDEF/ACBG.

The Phase III paper test evaluated the models against several factors:

- Ease of use
- Data availability
- Measurement ability
- Focus/purpose
- Implementation cost
- Applicability
- User interfaces
- Flexibility

The Phase III study concluded that each of the three models can and will work in the defense contractor environment. Collectively, the models constitute a potentially satisfactory methodology for accomplishing what government and contractors want to do (i.e., the government wants to lower acquisition costs and improve product quality; contractors want to improve their competitiveness and profits). However, the models are relatively new developments and, as such, have "soft spots" or developmental problems that need to be, and are being worked on. Perhaps more importantly, a generic methodology for productivity management efforts within the industry needs to be further developed and communicated. The role that these three models and others, play in that methodology needs to be understood by a broader audience within the industry if any real impact is to be made. To accomplish this, the project team recommended that continuation of the research in Phase IV and V should develop and test a comprehensive "guide" to communicate the principles and philosophies, tactics and techniques, of performance management.

The Phase IV research involved several deliverables. We were to: further evaluate and resolve specific developmental needs of the three models at LTV/Vought Aero Products Division (LTV/VAPD); complete the development of the integrated productivity management methodology designed in Phase III; design and draft a guide to communicate the principles and philosophies of performance management to defense contractors; and develop detailed plans for a series of evaluation workshops to be executed in Phase V that will expose both government and contractor personnel to the guide. This report documents field test effort. The major findings of the field test build upon and add to those of the Phase III paper test:

1. CDEF/ACBG is capable of identifying and evaluating cost inputs to determine opportunities for plant improvement and appears to be applicable across a broad spectrum of defense contractors. The most significant task associated with using CDEF/ACBG is translating the company's cost profile into an activity of functionally based cost structure.

   ACBG is essential to the use of the CDEF methodology. ACBG is complete as it stands but would benefit from the ability to make year-to-year projections of cost and the ability to analyze business base changes. ACBG documentation could be enhanced through the development of detailed instructions for data collection prior to input.

2. The DCF/SSA model is primarily applicable at the project level to evaluate economic feasibility/profitability, negotiate the amount of government-to-contractor financial incentives and audit actual return on investment after project implementation.

   In these three modes of application, the DCF/SSA model will effectively integrate with IMIP and TECHMOD-type government to incentive methodologies. Under IMIP, the use of the model is required for Manufacturing Improvement Projects and is useful for Manufacturing Efficiency Projects.

   The model is appropriate for improved productivity and/or improved product quality incentives only to the extent that such improvements can be reflected in quantitative cost savings and tied directly to a particular investment project (and possibly, to a major program). The DCF/SSA model is judged not appropriate for a macro, company-level incentive.

The cost/savings components which make up the annual cash flows of the DCF/SSA model are quite detailed and reasonably complex. Because of this and the fact that the model is used as a negotiating tool, a computerized version of the model is necessary. If the LMI version of the model is to serve as the "example model" for the general defense contractor, then the software and User's Manual need further development. This issue was addressed in the Phase III Final Report in detail. The field test supports the earlier paper test findings in this regard and offers further suggestions for improving the comprehensiveness and clarity of the User's Manual.

3. The MFPMM is the only model of the three tested that measures total factor productivity at the division or firm level. The model uses standard accounting data from actual operations to provide management with information on productivity improvement, major cost drivers, should-be-budgets for performance improvement, rate of change in costs and sales, and the dollar impact change in productivity, price recovery, and profitability. A major outcome of the field test effort is the design of a defense contractor version of the model (DCMFPMM). The current version of the model did not accomodate the long cycle times, changing product mix, and constant design changes experienced in the defense environment; the model also was designed for a management team in the private sector and assumed there was control over variables such as the price of outputs, how much output is sold; product mix and engineering changes, planning horizons, and profits. The DCMFPMM does not make these assumptions. As such, the DCMFPMM meets the information needs of the management team of a defense contractor. While the MFPMM had limitations in this environment, the DCMFPMM version of model will be widely applicable across a broad spectrum of defense contractors.

4. The three models can and will work in the defense contractor environment. However, to achieve the desired outcomes of both the government (reduced acquisition costs and improved quality) and contractors (profitability, competitiveness, survival, growth, etc.) these models and others will have to be applied in a comprehensive and integrated fashion. The methodology described in Section VII is an excellent example of such an approach.

In summary, the Phase IV field test has allowed us to take the research to the next stage of evolution. We've moved beyond Phase III in both our understanding of the models, the defense contractor environment, and most importantly, the tools, tactics, and techniques needed to bring about improved performance in this environment. LTV/VAPD, which already practices an aggressive performance management effort using elements of these three models, believes they have gained valuable knowledge and experience from the Phase IV research to enhance their effort. We believe this research can also provide similar benefits to other defense contractors. The draft guide being prepared as part of the Phase IV is a first cut at communicating the knowledge, wisdom, and experience gained from this research. We believe taking the project to the next phase, Phase V, will result in a critical intervention that shows the path to create win-win situations: improved competitiveness and profitability on the part of contractors, reduced acquisition costs, and improved product quality experienced by the government.

II. Introduction

This report documents the Phase IV field test effort. Specifically, we were to prepare and submit a report on the results of the field test that addressed:

(a) Ease of measuring productivity and tracking costs in the field test for each model.

(b) Description of the inputs and outputs for field application of the models.

(c) Compare and contrast, where appropriate, the field test results of the three models.

(d) Identify and describe data required for field applications of the models. Compare and contrast data requirements for the three models.

(e) Identify and describe the level (unit of analysis) for which productivity was measured and evaluated in the field application tests. Describe the most appropriate unit of analysis(es) for each model.

(f) Evaluate the abilities of each model, in field applications, to satisfy the overall project goal.

(g) Describe the field site incentive/reward systems. Evaluate the effectiveness of the site's incentive/reward systems. (Note: the field test did not address the field site's reward systems. The reason for this is LTV/VAPD has not yet incentivized the system (i.e., contractor-to-employee gainsharing) though plans are being made to do so in the future.

First, the field test approach is presented and discussed. Next, field test results for the ACBG, DCF/SSA, and MFPMM are presented. Of particular interest is the development of an aerospace and defense version of the MFPMM. The generic productivity management methodology developed in Phase III is then discussed in light of the field test results. Summary comments and conclusions follow.

III. Approach to the Field Test

Each subcontractor was responsible for coordinating and executing the field test for a specific model: Price Waterhouse for ACBG; the Virginia Productivity Center for the MFPMM and DCF/SSA; LTV/VAPD, the field test site, facilitated, participated in, and provided overall support for the field test.

During the course of the Phase III research, the project team struggled with the distinction between a measurement and evaluation model and a productivity management methodology. We concluded that measurement and evaluation models are integral components of a productivity management methodology. We knew that the models we were testing were designed to accomplish certain elements of an overall methodology and our findings suggest that each performs its function(s) effectively. Our conclusion was that each of the three models (MFPMM, CDEF, DCF/SSA) can and have been used successfully in the defense contractor environment. However, the fact that the models have been applied successfully does not ensure that they will be implemented with widespread success throughout the defense contractor community. Models such as these are best viewed as decision support tools. Their successful application cannot be ensured unless the systems designer successfully builds an infrastructure for their use in the organizational system. Figure III-1 depicts critical elements of the management system that these tools are a part of. This figure depicts several things. First, it depicts the measurement, evaluation, control and improvement process. Data is collected from the system(s) being managed (the M for measurement). Data is input into specific measurement and evaluation systems, models, tools. These models, such as the MFPMM, CDEF/ACBG, and DCF/SSA approaches, use specific data from the system, analyze/manipulate the data and present modified data to the manager and/or management team for the system. The modified data may also be used to satisfy the needs of other audiences. The designed intent of these models is to support decision making and to support control and improvement of performance of the system(s).

Notice that two measurement and evaluation "loops" are identified. The first loop (Loop 1) focusses upon the measurement and evaluation and control and improvements needs/demands of the manager, management team and employees. The focus of this loop is on providing the information necessary to control and improve, in a timely and effective fashion, the performance of the system(s) being managed. The focus of Loop 2 is on providing information to satisfy the wide variety of needs and requests of other audiences. Examples of other audiences are the government, the IRS, the comptroller, the manager's boss, the president, etc. The reason for making a distinction between these two loops of information is that different measurement systems are often required to satisfy the differing needs. System designers that fail to recognize design requirement differences for the two loops frequently fail to design successful decision support systems.

We believed this management systems approach should be used as the field test "Grand Strategy." The steps for Management Systems Analysis (MSA) are (Sink, 1986):

Step 1. Complete an Input/Output Analysis for the System.

Step 2. Improvement interventions: identify the basic strategies and tactics that are, can be, or should be taken to improve the performance of the system.

Step 3. Information needs: identify the information needed to support and/or justify performance improvement interventions (i.e., what measures of performance should we be evaluating to tell us how well the system is performing?)

Step 4. Data requirements: identify the data needed from the system to create the information/measures identified in Step 3.

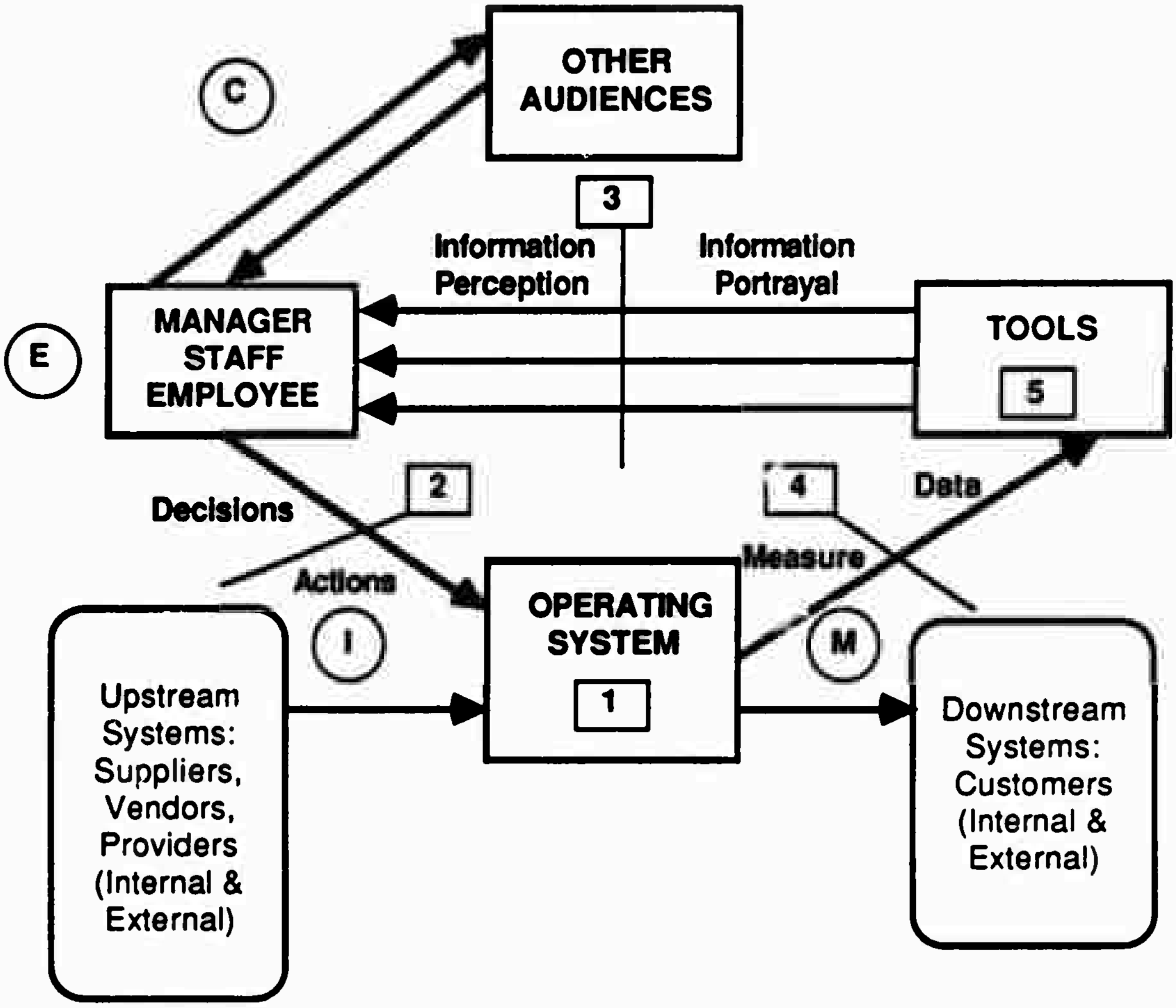


Figure III-1. Management System Model

Step 5. What "tools" are available or need to be developed to capture and process the data and present the right information to the right people?

Parts of each step were addressed in the Phase IV field test. We focussed on specific questions and development needs relative to the application of each model in the field. Those specific questions are:

1. Describe the unit of analysis.

   Research Questions:

   What is the appropriate/best unit of analysis for the model?

   What is the appropriate/best scope (frequency) of measurement for the model?

   Is the model applicable across the defense contractor community?

   How does the mix of type of contractor affect the use and interpretation of the model?

2. Identify the major audiences for the model and their information needs.

   Research Questions:

   Who are the most appropriate audiences for the model?

   How can we improve the output design relative to various audiences?

3. Identify what can/should be done by the management team of the system to improve system performance.

   Research Questions:

   What development work needs to be completed on MFPMM?

4. Identify the data and information the management team needs to support performance improvement interventions.

   Research Questions:

   What is a typical operating scenario for use of each model in the aerospace and defense (A&O) setting?

   Can the operating scenario be described in a detailed manner so that it is understood by all contractors?

5. Identify the data the model presents. Discuss its criticality, use, uniqueness, and benefits.

Research Questions:

Does the model measure productivity? What other elements of performance does it measure?

Does the model present unique information? What information does it provide that is redundant?

Does the model satisfy project goals and objectives?

Is the model useful as a measurement system for an incentive system?

6. Identify where the model fits in with the total set of tools available to management.

Research Questions:

What is the interrelationship between the three models?

How does or can each model interrelate with other measurement and evaluation systems in A&D?

7. Identify the specific data needed from the ssytem to support the model.

Research Questions:

What software support needs exist for the model?

What types of costs does the model evaluate?

IV. CDEF/ACBG Field Test

A. Introduction

Phase III of the "Study of Productivity Measurement and Incentive Methodology" included a paper test of Price Waterhouse's Cost Definition (CDEF) methodology and its associated Automated Cost Baseline Generator (ACBG) software tool. The paper test evaluated CDEF/ACBG on the following factors:

- Ease of use
- Data availability
- Measurement ability
- Focus/purpose
- Implementation cost
- Appropriateness for defense environment
- User interfaces
- Flexibility.

Upon completion of the paper test it was concluded that a field test should be conducted to identify opportunities for enhancements to CDEF/ACBG for applicability across the aerospace and defense (A&D) community.

This field test was conducted by Price Waterhouse at LTV/VAPD with VPC in attendance. In summary, the findings of the CDEF/ACBG field test, relative to its applicability across the A&D contractor community, are as follows:

CDEF Methodology

The CDEF methodology is capable of measuring productivity on a partial factor basis. Cost inputs are evaluated to determine opportunities for improvement in the unit of analysis (plant). It was also determined from the field test that the CDEF/ACBG, DCF/SSA and MFPMM methodologies/models could be integrated into a total factor productivity measurement system.

The CDEF methodology appears to be applicable across nearly all A&D contractor sites. The most significant task associated with using CDEF/ACBG is translating the company's cost profile into an activity or functionally based structure.

ACBG Model

ACBG is essential to the efficient utilization of the CDEF methodology. ACBG is complete as it stands, but would benefit from the ability to make year-to-year projections of cost and the ability to analyze business base changes. Finally, ACBG documentation could be enhanced through the development of detailed instructions for data collection prior to input.

This report summarizes the approach and results of the CDEF/ACBG field test.

B. Overview of CDEF/ACBG

Price Waterhouse has developed its CDEF methodology as an approach for preparing cost baseline data in support of factory modernization efforts for both commercial factories and for factories participating in the Department of Defense Industrial Modernization Incentives Program (IMIP). CDEF utilizes a top-down analysis technique which facilitates the identification of appropriate performance and cost measurement criteria, selection of improvement opportunities (through capital investment and/or efficiency improvements), and economic justification of identified investments. The CDEF methodology has been applied at over 30 defense contractor sites; therefore, it has been field tested and found workable.

The CDEF methodology has been tailored to accomodate several objectives:

- Provide an auditable, consistent approach for performance and cost benefit analysis and tracking.
- Identify the true costs of a manufacturing process to clearly establish savings criteria.
- Provide outputs that remain reliable when product mix and volume changes over time.
- Provide a mechanism for evaluating projects and compensate for project risk.

To aid in the development of a comprehensive cost baseline, Price Waterhouse has developed a proprietary software tool, ACBG. This microcomputer management tool is licensed only as part of a CDEF project. It should be stressed that ACBG is only used to augment the principles of CDEF and is not a stand-alone software package.

A detailed description of CDEF/ACBG was provided in the Phase III paper test.

C. General Approach

The approach taken by the Price Waterhouse project team was designed to make maximum use of the paper test results and lessons learned while addressing specific research questions developed by the Virginia Productivity Center. Based upon the management systems analysis guidelines developed by Dr. Sink (which assume that a management system is represented by the field test site), the Price Waterhouse team (Mr. Muir and Ms. Thayer) conducted a field test of CDEF/ACBG at LTV Vought Aero Products Division. The questions proposed for management systems analysis by Dr. Sink are as follows:

1) Describe the unit of analysis for the field test.

2) Identify the major audiences for the model and their information requirements.

3) Identify what can/should be done by the management team or the system to improve the performance of that system.

4) Identify what data and information the management team needs to support performance improvement changes.

5) Identify the data that CDEF/ACBG presents. Discuss its criticality, use, uniqueness, and benefits.

6) Identify where the model fits in with the total set of tools available to management.

7) Identify specific data needed from the system to support CDEF/ACBG.

The field test of CDEF/ACBG, therefore, is structured to reflect the above steps. Each area of discussion is preceeded by the relevant research questions used to bound the test.

D. Field Test Results

D.1. Unit of Analysis

Research Questions:
1) What is the appropriate/best unit of analysis for CDEF/ACBG?
2) What is the appropriate frequency of measurement for CDEF/ACBG?
3) Is CDEF/ACBG applicable across the defense contractor community?
4) How does the mix of type of contractor affect the use of and interpretation of CDEF/ACBG?

CDEF/ACBG utilizes a top-down analysis technique. Figure IV-D-1-1 illustrates the concept of a top-down approach. CDEF/ACBG attempts to isolate costs associated with a manufacturing process; therefore the best unit of analysis would be the plant level. Figure IV-D-1-2 demonstrates the top-down unit of analysis concept. If, however, the work center or work cell is an independent unit of production (or cost center), CDEF/ACBG can also be applied effectively.

The advantages of applying CDEF/ACBG at the highest level of operation include the following:

- Provision for an auditable, consistent approach of performance

FIGURE IV-D-1-1

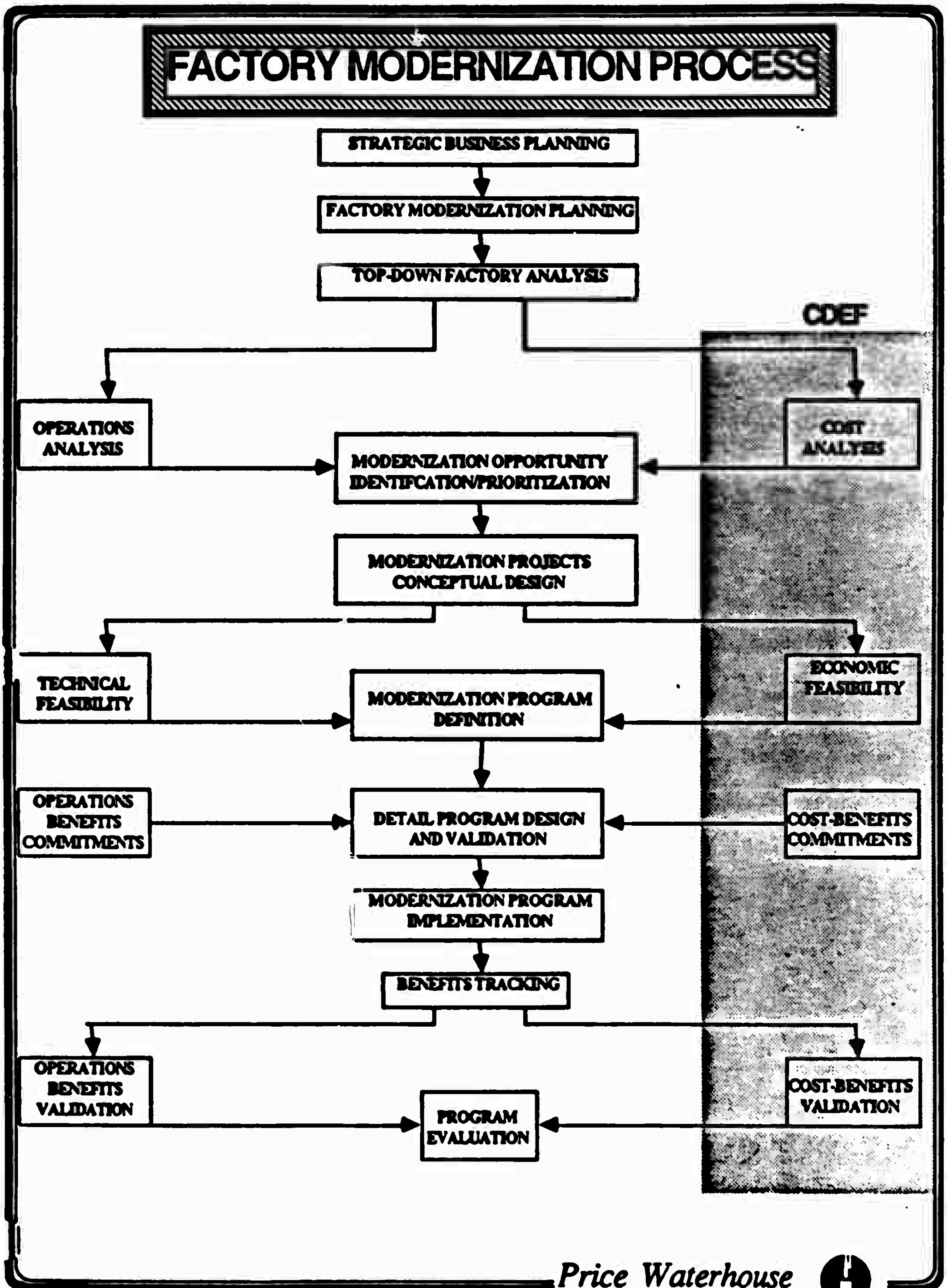
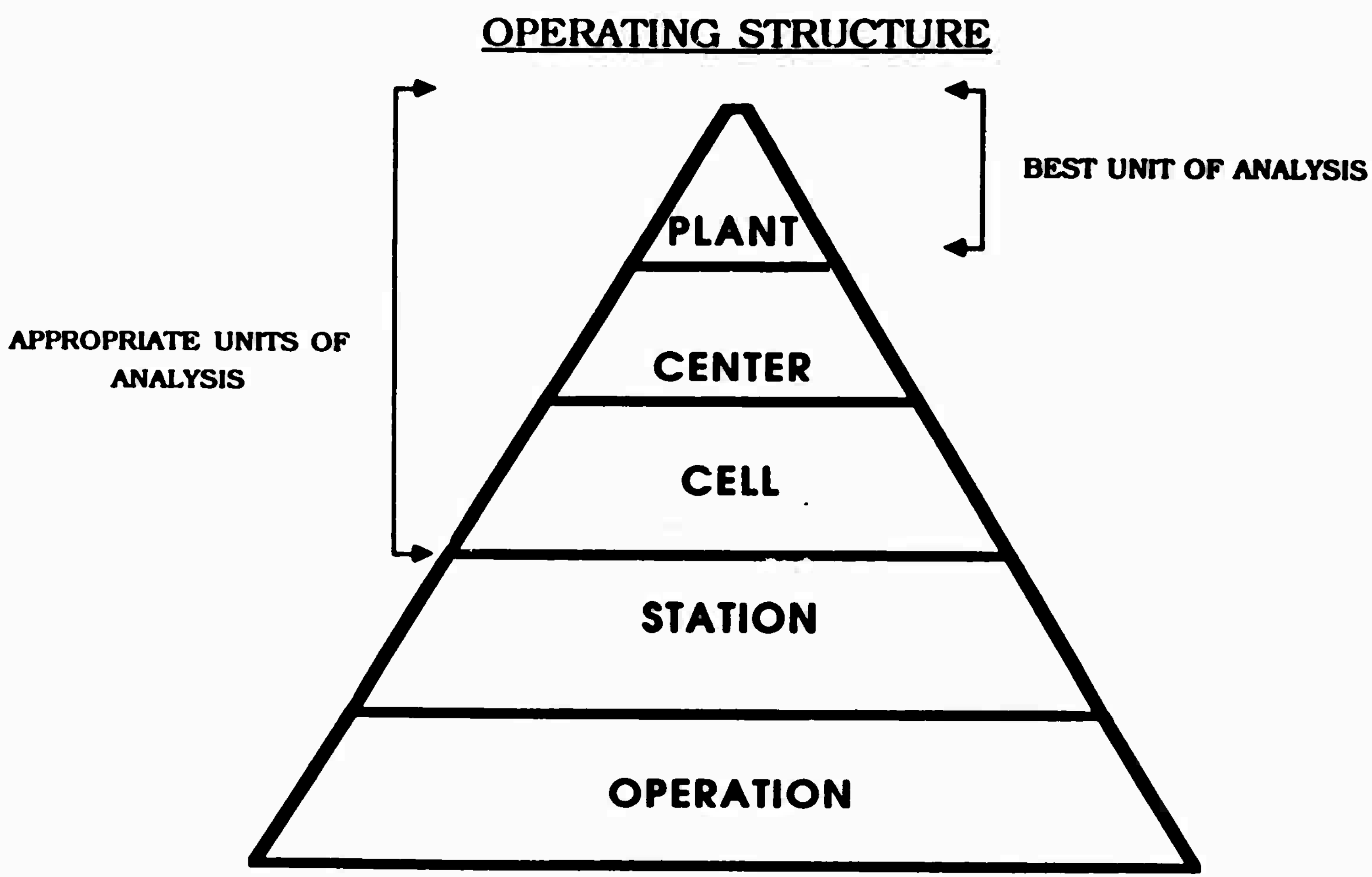


Figure IV-D-1-2

UNIT OF ANALYSIS



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and cost benefit analysis and tracking.

- Elimination of the potential for cost shifting between functions. CDEF/ACBG takes a total cost "bottom-line" perspective.

- Provision for ACBG outputs that remain consistent and reliable even when product mix and volumes change over time.

The most appropriate time period for data analysis is on an annual basis. This is especially important for cross-reference with the company's financial statements or annual budget.

The applicability of CDEF/ACBG across contractor sites was implied to refer to the ability to implement CDEF/ACBG on a site-by-site basis. The data required to drive the model is available at all contractor sites where financial statements are compiled (or where the data is collected which can be used to compile financial statements). In this respect, CDEF/ACBG appears to be universally applicable.

The suitability of CDEF/ACBG for a particular contractor is primarily dependent upon the complexity of operations performed in the unit of analysis. Practical application of CDEF/ACBG indicates that it is suitable to the widest variety of industries and operations.

As long as the unit of analysis can be bounded in financial terms, there is practically no limit to the diversity of contractors that can be evaluated using CDEF/ACBG.

D.2. Audiences for CDEF/ACBG

Research Questions:
1) Who are the most appropriate audiences for CDEF/ACBG output?
2) How can we improve the output design relative to various audiences?

Based upon the field test discussions with VPC/LTV team members, it was determined that the following are the most appropriate audiences for CDEF/ACBG outputs (ranked in order of importance):

- System Program Office (SPO)/Program Managers

- Internal Functional (Production) Managers

- Internal Program Management
  Internal Productivity Council/Division Management

- On-site Government Representatives (NAVPRO, AFPRO,etc.)

Table IV-D-2-1 cross-references the data outputs of ACBG with perceived requirements of each of the above audiences. From this

Table IV-D-2-1
Information Needs of CDEF/ACBG Audiences

Information	Audience: SPO/ Program Managers	Internal Functional Managers	Internal Program Managers	On-Site Government Representatives
Cost Elements	X	X	X	
Cost Type (Fixed, Variable)		X	X	
Cost Source		X	X	
Performance Allocation Bases		X	X	
Function Groups	X	X	X	
Cost Centers		X	X	
Functional Architecture	X	X	X	
As Is Cost Baseline	X	X	X	X
-Summary	X	X	X	X
-Detail		X	X	
Cost Savings Report	X	X	X	X
Inflation Summary Report	X	X	X	

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table it appears that the outputs provided by ACBG satisfy the needs of all four major audiences. The only exception may be in the case of program management. Generally, programs are not isolated in the cost baseline unless there is a reporting mechanism in place to directly assign costs incurred by a specific program. ACBG does have the capability to assign a program to a cost center on a one-to-one basis.

D.3. Improving System Performance

Research Questions:
1) What development work needs to be completed on CDEF/ACBG?

Currently CDEF/ACBG does not have the capability to project cost baselines beyond one To Be scenario. This is a limitation which is somewhat alleviated by ACBG's ability to interface with the Logistic Management Institute's Discounted Cash Flow model (forerunner of the DCF/SSA model). ACBG, by itself, would benefit from the addition of projection capability and the addition of a business base analysis feature. All performance models which rely on base-year data run the risk of projecting improvements on today's product and volume mixes. If this mix changes in the To Be environment, it will influence the correctness of the projections. Price Waterhouse estimates it will require 1000+ person-hours to add these enhancements to ACBG.

D.4. Data and Information Requirements

Research Questions:
1) What is a typical operating scenario for use of CDEF/ACBG in the A&D setting?
2) Can the operating scenario be described in a detailed manner so that it is understood by all contractors?

The typical operating scenario for the use of CDEF/ACBG is as follows:

An A&D contractor uses CDEF to understand in which activity areas costs are truly being incurred and their opportunity for reduction or improvement (reduced cost per unit). The CDEF methodology is applied at the facility level to analyze and document all "value-added" costs (with value-added referring to all costs added to raw material inputs). Operational and cost performance is captured for each major activity area (Function Group). Operational performance improvement opportunities are mapped against their respective costs to identify those Function Groups with the greatest apparent need for improvement.

Once targeted areas are selected, conceptual designs for improvement programs are developed. Associated costs, benefits and risks are estimated and overall life-cycle program benefits are generated.

Detail design and implementation follow with ACBG used for tracking expected versus actual results.

Baseline updates are generally prepared annually. The contractor decides the most appropriate project team organization; usually an advisory committee is established.

CDEF/ACBG is ideally used to monitor both short and long-term cost and operational performance and is not restricted to monitoring one improvement program at a time.

D.5. Data Results

Research Questions:
1) Does the model measure productivity? What other elements of performance does it measure?
2) Does the model present unique information? What information does it provide that is redundant?
3) Does the model satisfy project goals and objectives?
4) Is CDEF/ACBG useful as a measurement system for an incentive system?

CDEF/ACBG does not measure total input/output productivity. It does, however, provide partial measures of productivity as internal operating efficiency and effectiveness relative to cost and performance inputs. A ratio analysis method is used to evaluate measures of performance.

The top-down methodology is unique to CDEF/ACBG among the models studied. Other unique features include the segregation of cost by source, analysis of cost by activity or function, and the linkage to total entity operating cost. Because ACBG provides an interface to the DCF/SSA model, this data is redundant.

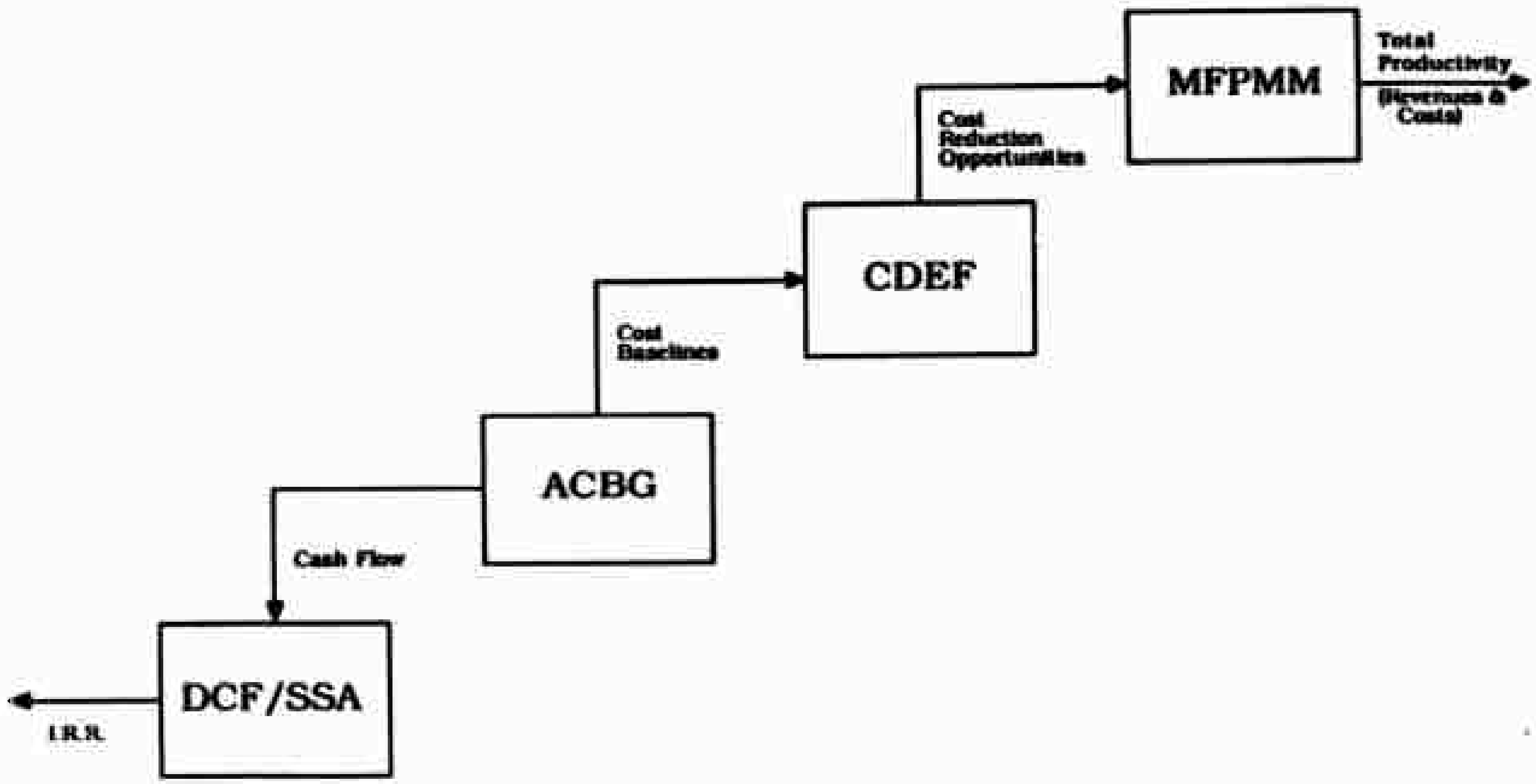
The project goals and objectives are to identify linkages between various productivity models and incentive methodologies. CDEF/ACBG has been found to be an effective method for evaluating IMIP and TechMod programs as evidenced by the numerous programs underway. CDEF/ACBG could be sufficient for company level macro incentives if examining only inputs is deemed to be appropriate.

D.6. Management Tools

Research Questions:
1) What is the interrelationship between CDEF/ACBG, MFPMM and DCF/SSA?
2) How does or can CDEF/ACBG interrelate with other measurement and evaluation systems in A&D?

Figure IV-D-6-1

Interrelationship between Productivity Models



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The interrelationship between the three models appears to be hierarchical (Figure IV-D-6-1). The outputs from the DCF/SSA model are an input into ACBG. CDEF is then an input into MFPMM. Linked together into one program the three models could evaluate total factor productivity.

Companies who utilize measurement systems according to Mil.Std. 1567 will be in a better position to provide inputs into the CDEF/ACBG model, due to the structured establishment of production standards required. CDEF/ACBG has been employed successfully to augment productivity measurement systems currently in place at A&D contractors.

D.7. CDEF/ACBG Data Inputs

Research Questions:
1) What software support needs exist for CDEF/ACBG?
2) What types of costs does CDEF/ACBG evaluate?

ACBG is a Revelation-based microcomputer tool which is available for the IBM-PC. Specific operating requirements are listed in Figure IV-D-7-1.

Based on the field test conducted at LTV/VAPD, Price Waterhouse estimates that it would require 800 to 1200 person hours to implement CDEF/ACBG for a unit of analysis such as the Flexible Machining Cell. The actual number of hours required from LTV/VAPD personnel will depend upon the level of involvement that Price Waterhouse undertakes. No major modifications in the software would be required to implement the model at LTV/VAPD.

Training on the CDEF/ACBG methodology would be required to implement the model successfully. Follow-up training may be required to guide the development of an entire modernization program.

FIGURE IV-D-7-1

ACBG Hardware and Software

Required:

- IBM PC or compatible
- 10 mb hard disk
- 320 K memory
- DOS 2.0
- Revelation database
- Security key

Recommended:

- 512 K memory
- 8087 (or 80287) math co-processor

Price Waterhouse

V. DCF/SSA Model Field Test

A. Introduction

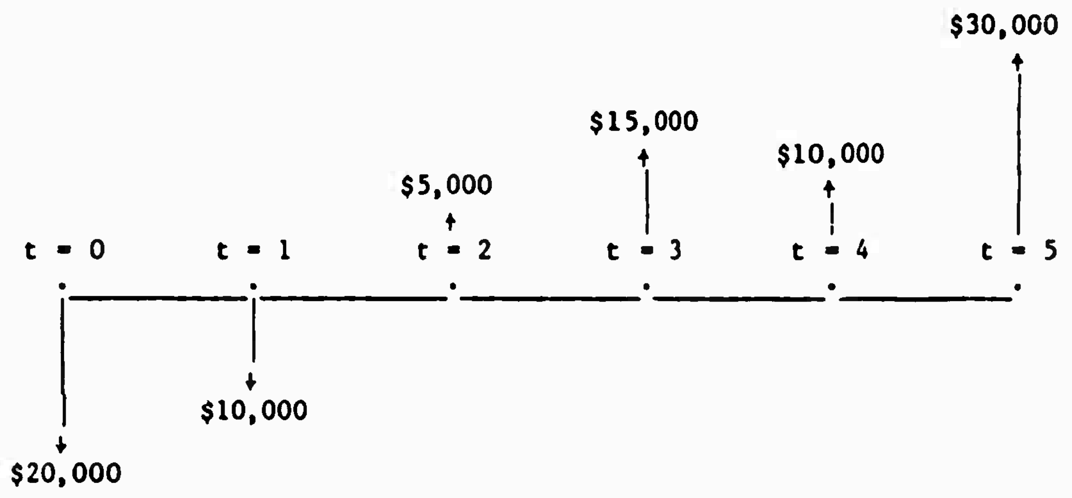
The discounted cash flow model (DCF) is a time-phased model of cash receipts (or savings) and cash disbursements over a particular planning horizon. There are different versions of the model depending upon whether the planning horizon established is finite or infinite, and whether the cash flows occur at discrete points in time or are assumed to occur continuously over the planning horizon. Most applications of the model in the business/industrial world are based on a finite planning horizon and assume cash flows occur at discrete points in tir .

In the commercial environment, the DCF model is typically used to evaluate the economic feasibility and/or profitability of a proposed project involving capital expenditures. The project is then treated as an equivalent investment which has resultant, estimated cash receipts/disbursements over time. The receipts/disbursements have a time value, as reflected in an assumed (or calculated) compound interest rate, which is also termed a discount rate or the desired minimum attractive rate of return. Using the discount rate, cash flows can be converted to a single-valued equivalent "measure of economic effectiveness" in order to judge feasibility/profitability, or to rank alternative investment projects. A variety of "measures" may be used, such as present worth, future worth, annual worth, cost-benefit ratio, and internal rate of return (also termed the return on investment, or the discount rate when a present worth value of zero results). For the purposes of the DCF/SSA model, the two measures of concern are present worth and internal rate of return.

The shared savings aspect of the DCF/SSA model occurs in the Department of Defense and Prime Contractor environment when the contractor proposes a modernization project which will reduce product cost to DoD but, the project will not be economically feasible unless DoD provides some type of monetary incentive, such as shared savings. This aspect of the DCF/SSA model will be discussed more fully subsequently. However, it is first necessary to briefly explain the basic DCF model, provide a general discussion of its application in the commercial vs. the defense industry environment, and review the major findings of the Phase III "paper-test" of the DCF/SSA model.

A.1. Basic Cash Flow Model (DCF)

The DCF model is most easily explained by an example cash flow diagram as shown below:



In this diagram, assume the time periods are years, the vectors at end of time periods t = 0 and t = 1 are cash disbursements, and the vectors at other time periods are cash receipts (or savings). If an annual compound interest rate (minimum attractive rate of return) of 10% is applicable, the equivalent present worth single value at t = 0 can be calculated as:

$$PW\ (10\%) = -\ \$20,000 - \$10,000\ (1 + 0.10)^{-1} + \$\ 5.000\ (1 + 0.10)^{-2} + \$15,000\ (1 + 0.10)^{-3} + \$10,000\ (1 + 0.10)^{-4} + \$30,000\ (1 + 0.10)^{-5} = \$11,767.50$$

The fact that the present worth is positive-valued indicates the example investment project earns greater than 10% compounded annually. Thus, the project is economically feasible based on a desired 10% rate of return. The equivalent actual rate of return (internal rate of return) which the project earns can also be calculated.

The internal rate of return (IRR) for an investment having both cash disbursements and cash receipts is the compound interest rate, say i*, which results in a value of zero for the present worth equivalent at $t = 0$. That is,

$$PW\ (i^*) = \sum_{j=0}^{j=n} A_j\ (1 + i^*)^{-j} = 0,$$

where A_j = the amount of the cash flow for year j.

The value of i* can be found by using root-seeking algorithms or by a trial-and-error method. In the example project, the internal rate of return is 20.819%. The IRR depends on the magnitude of the cash flows, the number of cash flows, and the timing of these cash flows. This fact has relevancy to the application of the DCF/SSA model in the DoD/Contractor environment and will be discussed further in a later section. In this introductory section, the reader is reminded that the cash flow pattern can be such that multiple rates of return can occur. Further, the rates can be both positive-valued and negative-valued. This point will not be elaborated on in this research report, and the reader is referred to virtually any standard text on Engineering Economy for further discussion. For the usual investment project in the business world, the issue of multiple rates (multiple roots for the present worth equation) does not arise. That is, when the sum of the positive-valued cash flows exceed the sum of the negative-valued cash flows and a single series of cash disbursements is followed by a single series of cash receipts (savings), there will be a single, positive-valued rate of return.

A.2. Applications of the DCF Model in Commercial vs. Defense Industry Environments

The basic DCF model as presented in the previous section consists of two components: (a) the schematic time diagram of discrete cash flows occurring at discrete periods of time over a planning horizon, and (b) a calculated measure of economic effectiveness. The model is typically used to evaluate proposed capital expenditures. By implication then, virtually all cash flows are based on estimates of disbursements and receipts (or savings). The cash flows reflect the difference in cash flows for a present, or "as-is," situation and a proposed, or "to-be," situation. In this sense, the DCF model is used as an evaluative tool in both the commercial and defense industry environments. It is noted, however, that the model can be applied only after considerable research, analysis, and calculations on cost/revenue estimates have been performed outside the model.

The components of costs/revenues that make up the net cash flow for a particular year are quite different when the DCF model is applied in the commercial vs. defense industry environment. This is especially true when the cash flows are after-income taxes (ATCF) rather than before-income taxes (BTCF). In the defense industry, for example, the prime contractor must use labor and overhead rates that have been negotiated with, and approved by, DoD in estimating costs/revenues. In the commercial environment, labor rates may be negotiated with a labor union, but the various business cost factors and rates are not regulated by the U.S. Government as in the defense industry. Further, the method of handling depreciation expenses is significantly different in the defense industry than in the commercial environment. In the commercial environonment, depreciation expenses are reflected in overhead rates and thereby allocated to the cost of production. Similarly, in the defense industry, depreciation expenses are also added to the cost base. However, in applying the DCF model in the defense industry, depreciation expenses are treated as positive cash flows. This is not the case when the DCF model is applied in the commercial environment.

Another general use for the DCF is to audit the economic effectiveness of an investment project after the project has been implemented and operational for several years (or perhaps terminated). A comparison can then be made between the estimated economic effectiveness when the project was initially proposed and the actual economic effectiveness after project implementation. In the commercial environment, such auditing is typically not done, and therefore, accounting records are not necessarily kept in a fashion that would permit such an audit. In the defense industry, records must be kept that would permit an audit. Further, if the DCF model is used for a project whereby DoD provides financial incentives to the contractor through shared savings, the actual savings to DoD must be verifiable from accounting records. For the situation where DoD shares savings with the contractor, the application of the DCF must provide considerably more output data to DoD than if a financial incentive to the contractor were not involved. Again, the details of this output data is presented later.

A summary of the major differences in applying the DCF model under three scenarios is shown in Figure V.1. The three scenarios are: commercial enviroment, defense industry (without government to contractor incentives), and defense industry (with government to contractor incentives, particularly shared savings).

Figure V.1. DCF Model Under Three Scenarios

(A) 100% Commercial	(B) Defense Industry - Without Contractor Incentives	(C) Defense Industry With Government to Contractor Incentives
1. Follow accepted cash flow techniques.	1. Must follow cash flow techniques associated with the defense industry, i.e., regulated cost accounting and pricing techniques.	1. Same as (1) under Column (B), except cash flow includes a "savings share" retained by the contractor, as negotiated. Also, government may provide initial funding.
2. Follow conventional CAS Guidelines relative to expense/ capital definitions, depreciation methodology, taxation laws, etc.	2. Follow CAS, DAR, FAR Guidelines.	2. Same as (2) under Column (B), plus all of the policy guides for the negotiation of incentives. If an IMIP project, then % savings retained, sharing period, total amount of savings, ROI.
3. Provides financial indicators (Present Worth, ROI, etc.) to evaluate estimated/ actual results of project implementation. Auditing is typically not done.	3. Same as (3) in Column (A).	3. Must show details of cash flows for both contractor and government, with and without incentives for each. Contractor Uses: evaluate project's economic feasibility, verify need for government incentives, test and track shared savings to negotiated ROI. If savings rate is faster than negotiated, must readjust savings such that maximum negotiated is not exceeded.

A.3. Review of Phase III Paper Test Results

The detailed paper-test analysis of the DCF/SSA model is contained in Volume III of the Final Report for the Phase III Research Project. Quotations, comments, and summary statements follow.

"The objective of the DCF/SSA (model) is to provide a basis for analyzing a proposed Industrial Modernization Incentives Program (IMIP) business arrangement for the contractor, the Department of Defense (DoD), and the government.

"The purpose of the DCF/SSA (model) is to provide an evaluation tool for capital investment decisions by measuring a projected rate of return for proposed investment projects." (page 439) The projected rate of return is then compared to the contractor's acceptable rate of return (or "hurdle rate") to ascertain financial feasibility. If the proposed project is not feasibile, then financial incentives from DoD may make the project feasible. The DCF/SSA model is then used to evaluate various percentages of savings and the number of years which DoD might share these savings with the contractor in order to make the project economically feasible.

In the paper test, two computerized versions of the DCF/SSA model were evaluated; namely, the Westinghouse Electric Company's version and the Logistics Management Institute's (LMI) version. Personnel from Westinghouse explained their model and evaluated the LMI version. Personnel from LTV/VAPD also evaluated both the Westinghouse and the LMI versions. Before proceeding with a summary of these evaluations, a distinction should be made between Industrial Modernization Incentives Program projects which are capital intensive, or manufacturing investment projects (MIP), and those which are not capital intensive, or Manufacturing Efficiency Projects (MEP), which are not capital intensive. The two software versions of the DCF/SSA model, which key on calculating a rate of return, were designed for projects which are capital intensive. The issue of using the LMI model to evaluate MEP was addressed in the Phase III paper test (see pages 481-482 of Volume II of the Final Report). It was concluded that, in its present form, the LMI model was not suitable for evaluating such projects. However, the DCF/SSA model could be structured to provide output information useful in the evaluation of Manufacturing Efficiency Projects. Several cash flow indicators for evaluation purposes were suggested; e.g., the Ratio of Cumulative Government Cash Flow to Cumulative Contractor Cash Flow.

A second note of information to the reader is that the Westinghouse DCF/SSA model was created utilizing EXECUCOM Systems Corporation's Interactive Financial Planning System software package for implementation on Hewlett-Packard's HP3000 hardware. The LMI version of the DCF/SSA model was created as a template for the commercial Lotus 1-2-3 software for implementation on an IBM PC. A computerized version of the DCF/SSA model is judged necessary because of the numerous calculations required. However, the general defense contractor must address the question of whether to develop such a model in-house, procure the LMI version, etc.

Since LTV/VAPD evaluated both the Westinghouse and LMI computerized versions of the DCF/SSA models, these summary comments will now be reviewed. In regard to the Westinghouse model, it was judged that this model's overall cash flow analysis realistically follows the accounting and pricing methodology employed by defense contractors. Specific evaluation comments follow (page 483 of Volume II -Phase III Final Report):

- The model's data requirements are not extensive and does not rely on side calculations to provide input data; many internal calculations simplify user effort. (It is noted, however, that this model requires external and apriori calculations to arrive at the estimated savings per year).

- Westinghouse's rates for income tax, investment tax credit, % government business, and % contractor savings share, etc. are programmed into the model for internal calculation purposes.

- The model has good flexibility in that it handles multiple-year expenditure entries, different asset classes (for depreciation purposes), and service lives. However, the model is currently loaded for either five-year or eight-year equipment service lives.

- The model factors straight-line depreciation's cash flow effect proportionately according to the ratio of government to total business base but does not treat ACRS depreciation in the same fashion. (Note: Westinghouse responded to this comment - Page 446 of Volume II - and observed that the ACRS depreciation ratio was accounted for in their model's ACRS Tax Adjustment calculation).

- For a particular project planning horizon, the model calculates a single-valued rate of return for the contractor, with government incentive savings included in the calculations. In order to determine the project's rate of return without incentives, a separate run of the program must be made with savings set to zero.

- Depreciation profit calculation includes project expenses as a part of the depreciation base. The profit realized from expense should be broken out separately. (NOTE: Westinghouse responded to this comment -page 446 of Volume II - and observed that this term "Depreciation-Profit" should be changed to "Profit on Recoverables"; expense is a recoverable cost that does receive profit).

- The model does not allow for any government funding which might be a part of project startup. Also, the model does not calculate a DoD/government rate of return.

As stated earlier, the LMI version of the DCF/SSA model was paper-tested independently by both Westinghouse and LTV personnel. Their findings were essentially the same. (See pages 442-445 and 480 of Volume II of the Final Report). The LMI model has deficiencies which limit its direct application to IMIP projects. Specific deficiencies discovered follow:

- The model does not provide for differing classes of capital investments nor their associated service lives. (This can cause erroneous cash flows due to inaccurate depreciation expenses).

- The model does not recognize benefits the contractor may realize from the application of an IMIP project to commercial programs. (This results in an understatement of the cash flows to the contractor and consequent understatement of the contractor's rate of return).

- The model does not recognize the added cost base created by additional depreciation and its associated profits. (Thus, the effect of project implementation on the total profit is understated).

- The model does not recognize that contractor's project expenses are unreimbursed costs which can be a separate cost item that is legitimately recoverable in the cash flow calculation. (Results in an incorrect cash flow).

- The model does not provide an indicator of the DoD/government rate of return. Rather, a payback period is calculated. (This understates the actual benefit DoD receives over subsequent years).

- Throughout the model there is a reliance upon side calculations to provide the data necessary to drive the model. Many of these calculations, such as "Profit Effect" and "Productivity Savings Reward" could be calculated within the model.

The paper test was quite detailed on the Westinghouse and LMI computerized versions of the DCF/SSA model For each model, each operational step was identified and displayed in a standard exhibit format which linked input data to output data. Evaluative comments were offered regarding data sources required in regard to Cost Benefit Analysis purposes and in regard to Cost Benefit Tracking purposes. Further, input requirements and output results were evaluated for the degree of relative ease or difficulty in use. These detailed results are reported in Volume II, Section VII. B, of the Phase III Final Report and will not be repeated in this field test report.

Also, a description of the Westinghouse and LMI versions of the DCF/SSA model is given in appendix A.2 of Volume I of the Phase III Final Report. The description for the LMI version is essentially a user's manual for the software which explains terminology and the nature of the calculations performed by the software.

A.4. Purpose of the Field Test

The field test of the DCF/SSA model was carried out by representatives from the Virginia Productivity Center, Dr. Marvin H. Agee and Mr. Paul Rossler, in cooperation with Mr. Ray Thornton and Mr. Len Calhoun at LTV/VAPD. The purpose of the field test was to address certain research questions related to the implementation of the DCF/SSA model in the defense industry for government incentive purposes. The research questions were motivated by the steps involved in performing a management systems analysis as proposed by the principal investigator, Dr. Scott Sink. Those specific questions are:

(1) Describe the unit of analysis for the field test.

(2) Identify the major audiences for the model and their information requirements.

(3) Identify what can/should be done by the management team or the system to improve the performance of that system.

(4) Identify what data and information the management team needs to support performance improvement changes.

(5) Identify the data that the model presents. Discuss its

criticality, use, uniqueness, and benefits.

(6) Identify where the model fits in with the total set of tools available to management.

(7) Identify specific data needed from the system to support the model.

The field test of the DCF/SSA model was therefore structured to reflect these questions. The results of the field test are reported in Section V.C. Each area of discussion is preceded by the relevant research questions used to bound the test.

B. LTV/VAPD's Application of the DCF/SSA Model

B.1. Use of the Model

The DCF model is an integral part of LTV/VAPD's overall productivity management process. The model is used in an evaluation mode for proposed projects and in an audit mode for projects that have been implemented. In the evaluation mode, it is used to assess the estimated economic benefits of modernization projects which may or may not be candidates for DoD/government incentive programs. If the projects are proposed under a DoD/government incentive program such as IMIP, then the shared savings feature is incorporated into the DCF model. The DCF/SSA model is then used in both an evaluation mode and an audit mode.

At LTV/VAPD, the DCF model is used primarily for capital intensive modernization projects but can also be used to evaluate non-capital intensive projects. For the latter type of project which might be proposed as a Manufacturing Efficiency Project under DoD/government incentives, the economic measure of effectiveness is the ratio of total DoD benefits over a planning horizon to the total

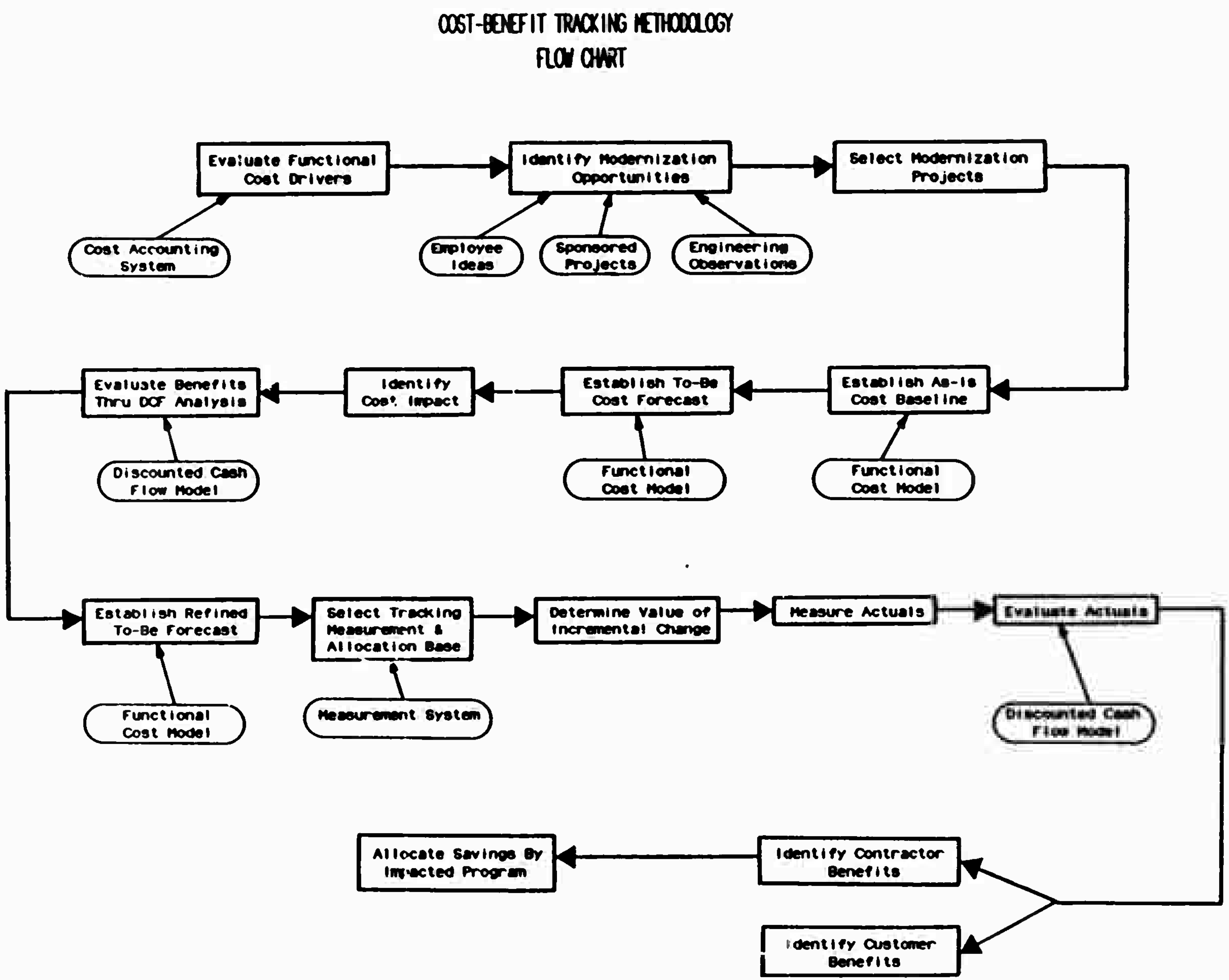


Figure V.2. Cost-Benefit Tracking Methodology Flow Chart contractor's after-tax cash flow, rather than a rate of return measure.

The fact that the DCF/SSA model is an integral part of LTV/VAPD's overall productivity management process can be seen in the Figure V.2 schematic supplied by LTV/VAPD, entitled "Cost-Benefit Tracking Methodology Flow Chart." From this figure, the DCF/SSA model is applied as an evaluative tool after modernization projects have been identified, prioritized, and selected as candidates; and also after the incremental benefits have been determined by an "as-is" vs. "to-be" cost analysis has been performed. In this figure, it is implied the DCF model is used to evaluate the actual costs/savings from project implementation for auditing purposes.

Although not shown in this figure, for DoD/government incentive projects, the DCF/SSA is also used in a negotiating mode to determine the rates of return to the contractor and to DoD when the % shared savings and the number of years to share savings are varied.

B.2. LTV/VAPD's Computerized Version of DCF/SSA Model

As noted in the Final Report for the Phase III Research Project, LTV/VAPD personnel were in the process of developing their own computerized version of the DCF/SSA model. This development is essentially now complete and was developed for use in analyzing the viability of projects for participation in the DoD Industrial Modernization Incentives Program. The evaluative output generated by the model will provide measures of acceptability for both the capital intensive and non-capital intensive modernization projects.

The model is implemented as a template for the commercial software LOTUS 1-2-3, version 2.0, and is run on an IBM PC. The model has addressed the deficiencies of the LMI version which were noted in the Phase III Final Report. The LTV/VAPD model has been designed to analyze investment opportunities over a planning horizon of 15 years and the spreadsheet output provides year-by-year results over this horizon. A listing of the inputs required and output results are given in Table V.1. and Table V.2. below:

Table V.1. Input, Listing for LTV/VAPD's Version of the DCF/SSA Model

DATA INPUTS (By Year)

DOD FUNDING

PROJECT EXPENDITURES

- Machinery Capital
- Material Handling Equipmenr
- Computer Systems
- Expenses

SALVAGE VALUES

- Machinery
- Material Handling

SAVINGS

- DoD Savings
- Major Program Savings
- Retained Program Savings
- Commercial Savings

INFLATION RATES

OTHER DATA INPUTS (Not By Year)

Table V.1. Cont.'d

CONTRACTOR ANALYSIS FACTORS

- % Shared Savings
- Number of Years Savings Shared
- % Profit
- % Government Business
- Tax Rate
- ITC Rate
- Discount Rate
- CAS 414 Rate

CONTRACTOR DEPRECIATION

- CAS 409 Depreciation
  - Depreciation Method (Choice of Straight Line, Sum-of-the-Years' Digits, Sum-of-the-Years' Digits with Half-Year Convention, 150% Declining Balance, 150% Declining Balance with Switching to Straight-Line)
  - Asset Service Life (Years)

    Machinery
    MH Equipment
    Computer Systems
  - Year Placed Into Service
- ACRS Depreciation
  - Depreciation Method (Choice of Standard ACRS Tables, Straight-Line)
  - Asset Class (3,5, or 10 Year Service Life)

    Machinery
    Material Handling
    Computer Systems
  - Year Placed Into Service

SENSITIVITY FACTORS

- Investment
- Expense
- DoD Funding
- DoD Savings
- Retained Savings
- Commercial Savings

Table V.1. Cont.'d

ESTIMATED RETURN ON INVESTMENT

- Estimated DoD Return on Investment (ROI)
- Estimated Contractor ROI Without Incentive
- Estimated Contractor ROI With Incentive

FIRST YEAR OF FULL SAVINGS

In the above table of input factors, the section labelled "Estimated Return on Investment" is simply an initializing value (or seed value) to calculate the various return on investment values indicated. The Sensitivity Factors are embellishments to the basic model to permit "what if" simulation runs of the model and are not requirements of the model for IMIP purposes. The output results from the model are next listed in Table V.2.

Table V.2. Output Listing for LTV/VAPD's Version of the DCF/SSA Model (Mostly by Year)

SECTION I - INVESTMENT DATA

- Machinery
- Material Handling Equipment
- Computer Systems
- Capital Investment Subtotal
- Expenses
- Total Investment

SECTION II - PROJECT CASH FLOW

- Productivity Savings Reward
- Retained Program Savings
- Commercial Program Savings
- Total Contractor Savings
- Cost of Money Recovery
- CAS 409 Depreciation
- Expense Recovery
- Lost Profit Effect
- Depreciation Profit
- Equipment Salvage Value
- Material Handling Salvage Value
- Before Tax Cash Flow

SECTION III - TAX CALCULATIONS

- ACRS Depreciation
- Taxable Income
- Investment Tax Credit
- Expense Tax Adjustment
- After Tax Cash Flow
  - Cumulative Total

SECTION IV - DOD BENEFIT SUMMARY

- Program Benefits (Without Incentive)
  - Cumulative Total
- Program Benefits (With Incentive)
  - Cumulative Total
- Funding (Government)
  - Cumulative Total
- Net Cash Flow
- Cumulative Cash Flow Net Present Value
- Years to Payback (Single Value)
- Rate of Return
- Cash Flow (DoD to Contractor Ratio - A Single Value)

From the above listings in Tables V.1. and V.2. the reader should not interpret that all data inputs and output values from the DCF/ SSA model are necessary for IMIP purposes or for internal use by a particular defense contractor. Nevertheless, the model does represent a rather comprehensive approach to the application of the DCF/SSA model for evaluation purposes in the defense industry environment.

C. Field Test Results

As mentioned earlier in Section V.A.4., the general approach of the field test was to follow a seven-step management systems analysis procedure. Several of these steps were actually accomplished in the Phase III paper-test study, but additional information was obtained during the field test of the DCF/SSA model. Both the field-test and the paper-test results were utilized to answer the following specific research questions.

C.1. Unit of Analysis

Research Questions:

1) What is the appropriate/best unit of analysis for the DCF/SSA model?

2) What is the appropriate frequency of measurement?

3) Is the DCF/SSA model applicable and valuable across the defense contractor environment?

The DCF/SSA model is primarily applicable at the project level, and possibly at the program level. Cash flows which are inputs for the model are typically estimated on an annual basis. If the model is used in an audit mode, the actual cash flows are typically aggregated on an annual basis. (It is noted, however, that any period of time could be used if matched with the appropriate interest rate per time period).

As stated in the Introductory Section V.A., the basic DCF model is universally used by business/industrial firms to evaluate proposed modernization projects. The "shared savings" aspect is added to the model when a defense contractor negotiates a financial incentive from the U.S. government. The fundamental structure of the cash flow model is not changed by the addition. Further, if the contractor is proposing a Manufacturing Improvement Project (MIP) under the Industrial Modernization Incentives Program, it is necessary that the DCF/SSA model be used to negotiate the shared savings. Thus, the DCF/SSA model is obviously applicable and valuable across the defense contractor environment. However, the computerized versions of the model (Westinghouse and LMI) which were paper-tested would not be universally applicable across the defense contractor environment.

Software modifications would be required.

C.2. Audiences for the DCF/SSA Model

Research Questions:

1) Who are the most appropriate audiences for the DCF/SSA model output?

2) How can we improve the output design relative to various audiences?

Based upon the field test discussions with VPC/LTV team members, it was determined that the following persons are the most appropriate audiences for the DCF/SSA model outputs (ranked in order of importance).

- Internal Division Management
  Top Management of the Firm

  (At LTV, division management includes the president of LTV/VAPD and members of the Productivity Council. This group makes decisions on productivity improvement interventions. Top management is corporate management and board members.)

- System Program Office (SPO) Program Managers

- On-Site Government Representatives (NAVPRO, AFPRO, etc.)

In regard to the informational needs (model outputs) for each of the above audiences, the spirit of the Industrial Modernization Incentives Program, as stated in DoD Guide 5000.XX-G., dated August, 1985, should first be recalled. Selected quotations from the Foreward of this document are:

"Specific 'how to' or 'cookbook' approaches are not covered in order that creativity in structuring specific IMIP applications is not inhibited.---------potential users are cautioned to approach any IMIP applications on a case-by-case basis. Existing examples should not be construed as good or bad ----or the way things have to be done. --

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Knowledge and good judgment are essential rather than rigid adherence to specific procedures."

This document further states there are multiple types of financial incentives which the contractor and the government may consider under the IMIP guidelines. However, from page 1 - 3 of the document, "the primary incentive under IMIP is Productivity Savings Reward" (or shared savings).

Thus, in the context of IMIP and assuming the primary government incentive to the contractor is shared savings, then the DCF/SSA model is the recommended evaluation tool for Manufacturing Improvement Projects (capital intensive). Given this scenario, the informational needs (model outputs) for the above audiences are essentially the same. F.exibility in application of the DCF/SSA model notwithstanding, there are certain required outputs from the model. In general, the year-by-year cash flows on a before-income tax and after-income tax basis should be displayed. The display should show both the individual year's cash flow and the cumulative cash flows at the end of each year in the planning horizon. The end result output requirements are:

- The internal rate of return (ROI) to the contractor both with DoD/government incentive and without incentive
- The internal rate of return (ROI) to the DoD/government both with incentive and without incentive.

Since the % of shared savings and the number of years that savings are shared are two manipulative variables used to negotiate a mutually acceptable rate of return, then the output rates of return should be displayed on a year-by-year basis.

Other specific output requirements are:

- Basic project investment data for different asset classes, and contractor expenses, year-by-year.

  Detailed components of the contractor's year-by-year cash flows particularly the productivity savings reward, retained program savings, and commercial program savings. Other components include cost of money recovery, CAS 409 depreciation, depreciation profit, income tax details, expense recovery, lost profit effect, and salvage values for project equipment (if applicable.)

- Amount of DoD/government funding, if applicable

- Savings to DoD/government, year-by-year

At this point, it should be mentioned that calculations to determine the amount of savings which are projected to result from project implementation are performed outside the DCF/SSA model. These calculations should consider inflation/deflation factors. The basis for this statement is the August 5, 1985 publication of the DoD Guide 5000.XX-G, pages 2-11; namely, "Methods for negotiating appropriate PSR (productivity savings reward) amounts depend on the category of contractor projects involved. To ensure consistency in any documentation of reporting, DoD personnel should express financial IMIP benefits in terms of gross and net DoD savings in then-year dollars for specified years." Thus, a computerized version of the DCF/SSA model should have the capability to perform inflation/deflation-adjustment calculations and display the factors used in the output.

Other output information which is contractor specific might be added at the discretion of the contractor. For example, the LTV/VAPD's version has the capability of handling sensitivity factors for certain input data to permit "what-if" gaming with the model. Their model also outputs a ratio of DoD to Contractor cash flows (present worth values) as a possible financial measure for negotiating incentives relative to Manufacturing Efficiency Projects (see Section V.C. previously).

In any case, all three spreadsheet-type computerized models (Westinghouse, LMI, LTV/VAPD) perform numerous internal calculations, the accuracy of which can not necessarily be ascertained from the model ouputs. The term, accuracy, as used here refers to the formulas used to calculate the various cost/revenue components of yearly cash flows. Also, accuracy refers to the algebraic aggregation of the various components to arrive at the net yearly cash flows. This "accuracy" issue is raised because the calculations for the DCF/SSA are numerous, and reasonably complex. This is particularly true when determining the after-tax cash flows. Such accuracy of the "formulas" can, of course, be checked by investigating the computer program source code. However, as a general statement, the greater the amount of detailed information provided in the output (including the echo of the input data), the more readily the accuracy of the internal cash flow calculations can be verified by manual calculations.

C.3. Improving System Performance; Data and Information Requirements

Research Questions:

What development work needs to be completed on the DCF/SSA model?

What is a typical operating scenario for use of the DCF/SSA model the Aerospace and Defense setting?

Can the operating scenario be described in a detailed manner so that it is understood by all contractors?

Developmental work needed on the DCF/SSA model pertains to the computerized version. This question was answered in the Phase III paper-test study for the Westinghouse and LMI versions. A summary of these findings was mentioned earlier in Section V.A.3.

Assuming that the LMI version will be the "example model" for the general defense contractor, this model should be revised to correct the deficiencies noted in the Phase III Study Results. (Although it was not an objective of this Phase IV study to field test LTV/VAPD's version, it is observed that their version does appear to have corrected for the deficiencies of the LMI and Westinghouse versions). Further, formulas used inside the model should be generalized to the extent feasible to allow contractor-specific inputs (% commercial business, etc.). A somewhat more complicated issue is the diversity of depreciation methods and the internal calculations for annual depreciation expenses. As CAS standards and income tax laws periodically change in this regard, then the model must, of course, be periodically revised to reflect such changes. If the model could be generalized to accept year-by-year percentage values as inputs, by asset class, the computer source code would be more understandable to the general user and also, repeated model updates could possibly be avoided.

It is the opinion of the research team that a typical operating scenario for use of the DCF/SSA model in the Aerospace and Defense setting has been adequately described in the DoD Guide 5000.XX-G publication, in the Phase III Final Report and, to a lesser extent, in this Section V of the Phase IV Final Report.

On the other hand, the ease of use and application of the DCF/SSA model could be improved, particularly in regard to the computerized LMI model. Continuing with the assumption that the LMI model will be the "example model" for the general defense contractor audience, any revised version which corrects the deficiencies noted earlier should also have a revised user's manual.

In addition to the usual definition of terms, explanations of formulas used, and instructions for using the software, the User's Manual should include a flow chart(s) which explain the linkage of input data to appropriate calculations to output data (see Section VII of Volume II of the Phase III Final Report). Further, the User's Manual should provide numerical examples for different operating scenarios. Scenarios which depict government funding vs. no government funding, commercial savings vs. no commercial savings, major program savings vs. no major program savings, inflation factors used vs. no inflation factors used, different patterns of shared savings, etc. would aid understandability of the model (and its application) by a larger cross-section of contractors.

Other simplified numerical examples which show the effect of different cash flow patterns on the internal rate of return should perhaps be included in the User's Manual to demonstrate the manipulative nature of the DCF model. Table V.3. below illustrates this nature.

Table V.3. Effect of Cash Flow Patterns on IRR

End-of-Year	Without Shared-Savings Incentive A_1	With Shared Savings Incentive = $30,000 Maximum				A_6–DoD Funding = $30,000; No Shared Savings
		A_2 – Increasing Amounts	A_3 – Decreasing Amounts	A_4 – Uniform Amounts	A_5 – Uniform, but 20% Shifted	
0	- $50,000	- $50,000	- $50,000	- $50,000	- $50,000	- $20,000
1	15,000	15,000	25,000	20,000	16,000	15,000
2	15,000	17,000	23,000	20,000	20,000	15,000
3	15,000	19,000	21,000	20,000	20,000	15,000
4	15,000	21,000	19,000	20,000	20,000	15,000
5	15,000	23,000	17,000	20,000	20,000	15,000
6	15,000	25,000	15,000	20,000	24,000	15,000
IRR	19.91 %	29.12 %	36.83 %	32.66 %	30.54 %	72.12 %

In Table V.3. above. improvement project A_1 has an internal rate of return of 19.91 % without DoD/government incentives. If the contractor's desired IRR (or hurdle rate) is 25%, then the project is not economically feasible. Projects A_2, A_3, A_4, and A_5 are the same project as A_1 but with DoD/government to contractor shared savings of $30,000 maximum. The resulting IRR's of 29.12%, 36.83%, 32.66% and 30.54% all exceed the hurdle rate of 25% but show that the pattern of savings receipts affect the contractor's IRR. Project A_5 shows the effect of a time lag in the contractor receiving a portion of the cash flows. This arises when certain savings to the contractor can be obtained only through future contracts. This delay lowers the contractor's actual ROI (A_4 vs. A_5). By the same token, the IRR for the DoD/government would also vary. Project A_6 is again the same as Project A_1; however, in lieu of the contractor receiving $30,000 in shared savings, DoD funding of $30,000 is provided up front to finance the project. It is noted, of course, that this has a significant effect on the IRR.

Such example scenarios should promote consistency and standardization in the submittal of proposals to DoD/government for shared savings purposes.

C.4. Data Results

Research Questions:

Does the model measure productivity? What other elements of performance does it measure?

Does the model present unique information? What information does it provide that is redundant?

Does the model satisfy project goals and objectives?

Is the DCF/SSA model useful as a measurement system for an incentive system?

The DCF/SSA model does not measure partial, or total, input/output productivity in the conventional sense. As is well known, it measures the profitability of a proposed and/or implemented improvement project, as reflected in an economic measure of effectiveness, such as internal rate of return on investment.

By virtue of its fundamental purpose, the DCF/SSA model does present unique and nonredundant information to a decision-maker; namely, a time-phased portrayal of the cash flows resulting from an improvement project and their economic impact. Whereas productivity measurement models provide information which may identify potential areas for productivity improvement interventions, the DCF/SSA model measures the profitability (estimated or actual) of an improvement project if it is implemented. In addition to the aggregate cash flows per time period, the detailed components of each cash flow as provided by the computerized versions of the DCF/SSA model is probably also information not contained in productivity measurement models. Accounting records for the firm should contain most, if not all, of the information (data) used in the DCF/SSA model, however. This is especially true for auditing purposes, if an improvement project involves DoD/government financial incentives. As stated previously, the accounting system to verify and track costs/savings is external to the DCF/SSA model. A potential difficulty in this regard is noted in that accounting systems are typically not established to record costs at the project level.

The overall goal of this research study (Phases I-V) is to identify and develop productivity measurement and evaluation methodologies/ models that will effectively integrate with government to contractor incentive methodologies. As an evaluation model, the DCF/SSA model will clearly "effectively integrate" with IMIP (both MIP and MEP) and TECHMOD-type incentives. In this sense, the model accomplishes the research project's goal. By the same token, the model is not only useful but necessary for these shared savings-type incentives.

The model is appropriate for improved productivity and/or improved product quality incentives only to the extent that such improvements can be reflected in quantitative cost savings and tied directly to a particular improvement project (and possibly, to a major program). The DCF/SSA model is judged not appropriate for a macro, company level incentive.

C.5. Management Tools

Research Questions:

What is the interrelationship between CDEF/ACBG, MFPMM, and DCF/SSA?

How does or can DCF/SSA interrelate with other measurement and evaluation systems in the Aerospace and Defense Industry?

The interrelationship between the three models investigated in the Phases III, IV of the research project is schematically depicted in Figure IV-D-6-1 previously. The output from the ACBG model is the incremental difference in costs between an "as-is" and "to-be" analysis. These cost savings are inputs to the DCF/SSA model. As stated repeatedly in this Phase IV Study Report, and in the Phase III Final Report, the DCF/SSA model is an "end-result" evaluation tool. Thus, the economic output results from any model which performs an "as-is" vs. "to-be" comparison serve as inputs to the DCF/SSA model.

C.6. DCF/SSA Data Inputs

Research Questions:

What software support needs exist for the DCF/SSA model?

What types of costs does the DCF/SSA model evaluate?

These questions have been addressed previously in this Section V.

VI. MFPMM Field Test

A. Introduction

Phase III of the "Study of Productivity Measurement and Incentive Methodology" involved a paper test of the Multi-Factor Productivity Measurement Model (MFPMM). That is, the research team evaluated on paper the MFPMM aginst several criteria: ease of use; applicability; data availability; measurement ability; flexibility; focus/purpose; user interfaces; and implementation costs. A conclusion of the Phase III study was that the MFPMM can and will work in the aerospace and defense (A&D) industry. However, modifications must be made to the model; LTV has made modifications to the model and is applying it succesfully.

The purpose of field testing the MFPMM in Phase IV was to resolve specific developmental problems of the model and identify opportunities for further improvement to make the model applicable across a broad spectrum of defense contractors. The major outcome of this field test effort is an A&D version of the MFPMM.

This section of the report documents the MFPMM field test effort. We first present a succinct overview of the current version of the model and LTV's application of a modified version of this model. Next, the general approach to the field test is discussed. The field test results are then presented. Last, the defense contractor version of the MFPMM is described.

B. Overview of MFPMM

B.1. Current Version (excerpt from Sink, D.S., Tuttle, T.C., and Devries, S., "Productivity Measurement and Evaluation: What's Available?" <u>National Productivity Review</u>, Summer, 1984)

Multi-Factor Productivity Measurement Model

The Multi-Factor Productivity Measurement Model (MFPMM) is a dynamic, aggregated, indexed, and computerized approach to measuring productivity. MFPMM can be utilized to measure productivity change in labor, materials, energy, and capital. It also measures the corresponding effect each one has on profitability. With essentially the same accounting data that are used to track revenues and costs, the MFPMM can provide additional insight into the individual factors that are most significantly affecting profits.

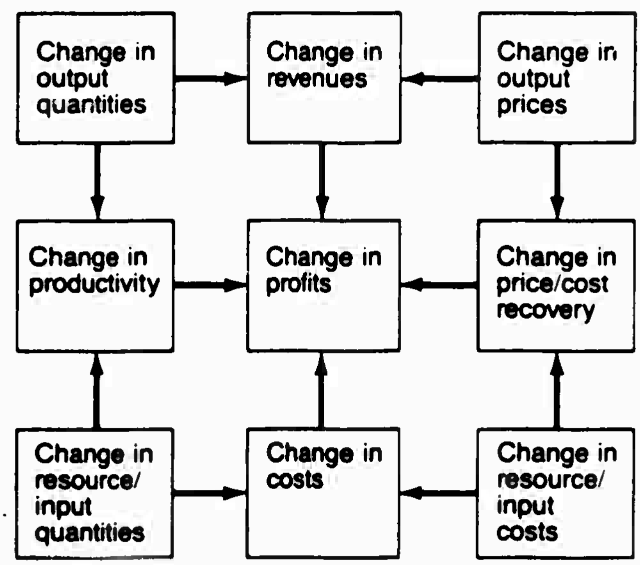
The MFPMM is based on the premise that profitability is a function of productivity and price recovery; that is, an organizational system can generate profit growth from productivity improvement and/or from price recovery. Productivity relates to quantities of output and quantities of inputs, while price recovery relates to prices of output and costs of inputs. Price recovery can be thought of as the degree to which input cost increases are passed on to the customers in the form of higher output prices. The relationship between productivity, profitability, and price recovery are depicted in Figure 4.

The data required for the MFPMM are periodic (i.e., monthly, quarterly, annually, etc.) data for quantity, price, and value of each output and input of the organizational system being analyzed. Since value equals quantity times price, having two of the quantity, price, and value variables obviously yields the third algebraically. Quantity, price, and/or value of the various outputs produced and most of the inputs consumed are straightforward and should be provided by most basic accounting systems.

The MFPMM compares data from one period (base period) with data from a second period (current period). This comparison forms the basis of the productivity/price recovery/profitability analysis. The choice of a base period is a critical decision, since it establishes the period against which the current period will be compared. Therefore, the base period should be as representative of normal business conditions as possible. If the data exists, the budget or "standards" could be used as the base period data. Depending on the needs of the user, the availability of data, product cycle time, etc., period length could be a week, a quarter, a year, or any other period for which input data can be matched to output data.

Figure 4

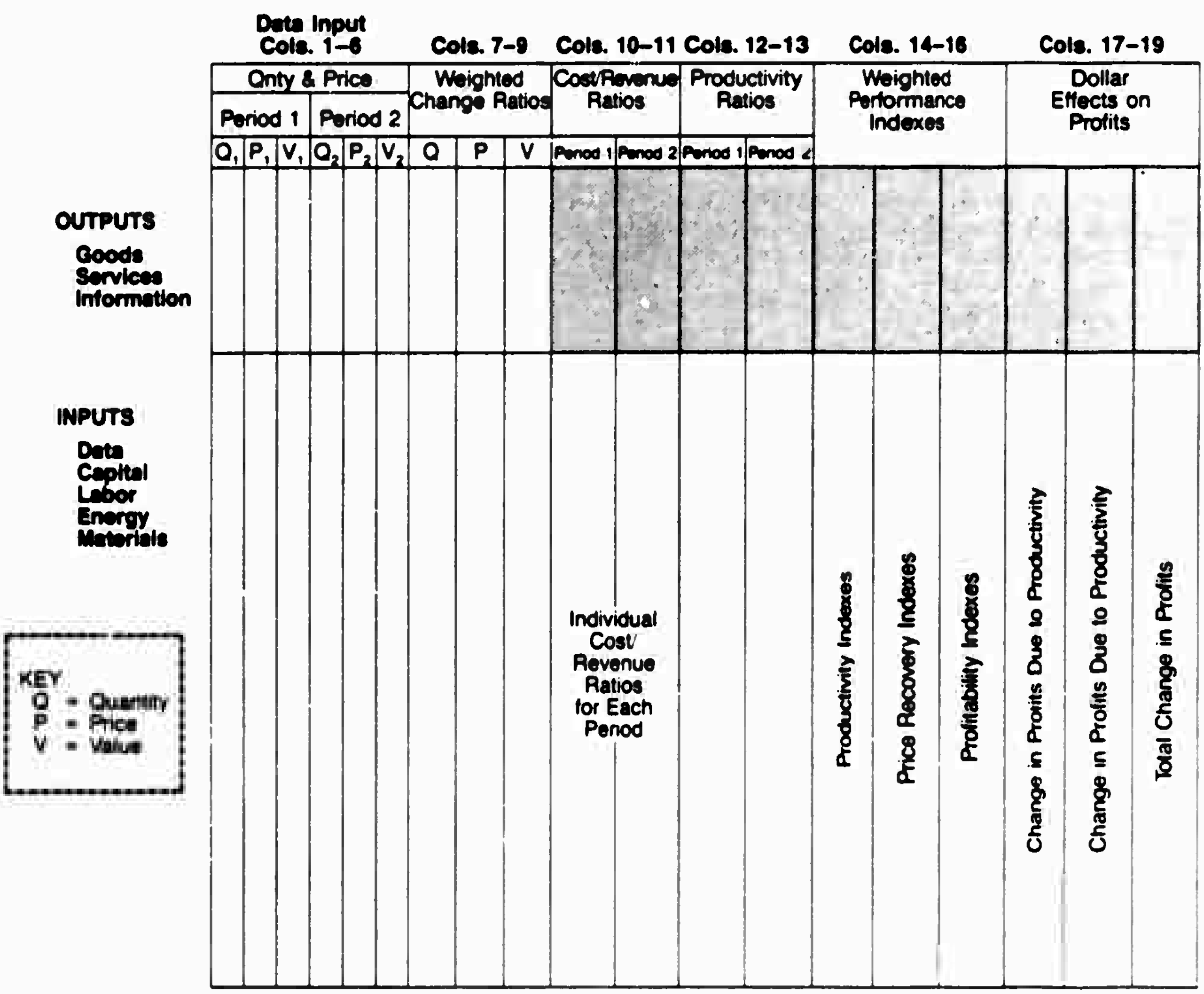
Relationships between Productivity, Price Recovery, and Profitability as Evaluated in the Multi-Factor Productivity Measurement Model



From the base and current period data, the MFPMM generates a series of ratios and indexes, each communicating different information about the system under study. Figure 5 depicts, from left to right, the data input, and then the ratios and indexes derived from them: weighted change ratios, cost/revenue ratios, productivity ratios, weighted performance indexes, and total dollar effects on profits. Weighted change ratios depict the percentage increase (or decrease) of an output or input item from the base to current period. Price, quantity, and value weighted change ratios are generated by the model to show the percentage changes from period to period. Cost/revenue ratios reflect the percentages of reported revenue consumed by a particular input in a given period. This information provides the user with insights as to where leverage exists. The most common method of productivity improvement is cost reduction, and these ratios show exactly where cost reductions will pay the biggest dividends. Productivity ratios—the ratios of total output value to the various input values—depict absolute productivity values in the base and current period. These ratios show the absolute

The MFPMM is most appropriate at the firm and plant levels and would be most useful to senior management.

Figure 5
Basic Structure of the Multi-Factor Productivity Measurement Model



increase or decrease of productivity for each of the inputs. The weighted performance indexes are actually output over input change ratios from period 1 to period 2. The final set of indexes are the dollar effects on profits. In other words, these indexes indicate what impact (in dollars) are caused by changes in productivity, price recovery, and profitability. The ratios and indexes identify areas that need improvement, and they also identify areas that are operating at an acceptable level. If the information is used correctly, productivity can improve, which in turn should increase profits.

The MFPMM is most appropriate at the firm and plant levels and would be most useful to senior management. It could be used at the cost center level as a separate accounting system for an assembly line, individual product line, etc.; however, at lower levels of organizations, managers do not normally need the kind of detail offered by the model. The MFPMM has been most often applied in manufacturing settings, but it can be used anywhere the necessary data exists.

It is estimated that somewhere between 50 and 100 organizations in the United States are utilizing this approach. Among these are: Phillips Petroleum Company, Anderson Clayton, General Foods, Hershey Foods, Sentry Insurance, John Deere, and Federal Express.

Case example

Figure 6 depicts an actual case example. The figure represents the computer output or tableau for the MFPMM. Only a portion of the output is presented here, but it will suffice to serve as an example by which to clarify the model. We will briefly describe what the output tells us regarding the performance of this fiberglass boat manufacturing firm in periods 1 and 2.

Columns 1–6 are data input to the model. Columns 1–3 present period 1 data regarding output and input quantity, price unit costs, and revenues/costs. Columns 4–6 represent equivalent period 2 data.

As can be seen, comparing period 2 to period 1 this company: sold more boats and raised prices; used less labor and had an increase in labor rates; used more fiberglass and paid more for it; and used more wood and electricity while unit cost for both remained the same. Also, the data columns show that the company did not choose to capture its capital consumption in the data for the model.

Columns 7–9 represent weighted change ratios. Column 7 tells us the period price and cost weighted change ratios for outputs and inputs. For example, the company (see circled highlights):

1. Produced 27.27 percent more boats in period 2 than period 1;
2. Consumed or paid for 5 percent less labor in period 2 than period 1; and
3. Consumed 36.36 percent more fiberglass in period 2 than period 1.

Column 8 tells us the period 2 quantity weighted change ratios for outputs and inputs. For example (see circled highlights):

1. Boat prices increased 15 percent from period 1 to period 2;
2. Labor unit costs or salaries and wages increased 13.11 percent from period 1 to period 2; and
3. Fiberglass unit costs increased 70 percent from period 1 to period 2.

Column 9 tells us the simultaneous effect of changes in prices/costs and quantities sold/used. Column 9 for output rows tells us the increase in revenues from period 1 to period 2 was 46.36 percent. Column 9 for input rows tells us the increase in costs from period 1 to period 2 (e.g., material costs up 129.84 percent; total costs up 110.75 percent).

Columns 10 and 11 depict cost/revenue ratios and assist in invoking Pareto's principle with respect to focusing in on where our big costs are. For example, material costs in period 1, column 10, were 20.41 percent of total revenues, while material costs in period 2, column 11, were 32.05 percent of total revenues.

Columns 12 and 13 are the absolute productivity ratios for periods 1 and 2 respectively. Labor productivity was 28.18 in period 1 and 37.5 in period 2. These numbers will have meaning only once they are tracked over time and interpreted in the context of what is or has happened to the company.

Columns 14–16 represent the weighted performance indexes. Column 14 tells us the rate of change of productivity from period 1 to period 2. Labor productivity is up 34 percent, material productivity is down 7 percent, and overall productivity is down 2 percent. Column 15 tells us the rate of change of price-recovery or prices over costs from period 1 to period 2. We can see that material price recovery is down 32 percent. That is, suppliers increased their costs to the company faster than it raised its prices to its customers. Column 16 depicts the simultaneous change in prices/costs and quantities sold/used. Profits increased 36 percent from period 1 to period 2 due to productivity and price recovery gains in the labor area. Overall, profits decreased by 31 percent due to a slight decline in overall productivity and a significant decline in overall price recovery.

Columns 17–19 depict the dollar effect on profit changes from period 1 to period 2 from productivity and price recovery. The bottom line is that this company became $85,594.81 less profitable from period 1 to period 2.

Certain software versions of the MFPMM incorporate simulation routines for playing "what if" games with the data.

Figure 6
Case Application of the Multi-Factor Productivity Measurement Model

Outputs/Inputs	Period 1			Period 2			Weighted Change Ratios		
	Quantity (1)	Price $ (2)	Value $ (3)	Quantity (4)	Price $ (5)	Value $ (6)	Quantity (7)	Price (8)	Value (9)
Boat A	50	5000.00	250000.00	70	5500.00	385000.00	1.4000	1.1000	1.5400
Boat B	30	10000.00	300000.00	35	12000.00	420000.00	1.1667	1.2000	1.4000
Total Outputs			550000.00			805000.00	1.2727	1.1500	1.4636
Labor-Management	320	20.00	6400.00	304	22.00	6688.00	.9500	1.1000	1.0450
Labor-Glass	800	8.00	6400.00	760	9.00	6840.00	.9500	1.1250	1.0687
Labor-Assembly	1120	6.00	6720.00	1064	7.00	7448.00	.9500	1.1667	1.1083
Total Labor			19520.00			20976.00	.9500	1.1311	1.0746
Fiberglass	2200	50.00	110000.00	3000	85.00	255000.00	1.3636	1.7000	2.3182
Wood	750	3.00	2250.00	1000	3.00	3000.00	1.3333	1.0000	1.3333
Total Materials			112250.00			258000.00	1.3630	1.6863	2.2984
Electricity	8000	10	800.00	8200	10	820.00	1.0250	1.0000	1.0250
Natural Gas	90	4.00	360.00	90	4.00	360.00	1.0000	1.0000	1.0000
Total Energy			1160.00			1180.00	1.0172	1.0000	1.0172
Multi Inputs			132930.00			280156.00	1.2994	1.6220	2.1075

Note. The circled numbers are those utilized in the text for illustration

This brief discussion of this case application of the MFPMM should suffice to at least clarify the basic characteristics of this technique for measuring productivity and other elements of performance. Certain software versions of this model also incorporate simulation routines so that management can play "what if" games with the data.

Cost/Revenue Ratios		Productivity Ratios		Weighted Performance Indexes Change in:			Dollar Effects on Profits		
Period 1 (10)	Period 2 (11)	Period 1 (12)	Period 2 (13)	Productivity (14)	Price Recvy. (15)	Profitability (16)	Change in Productivity (17)	Change in Price Recovery (18)	Change in Profitability (19)
.0116	.0083	85.94	115.13	1.34	1.05	1.40	2065.45	613.82	2679.27
.0116	.0085	85.94	115.13	1.34	1.02	1.37	2065.45	461.82	2527.27
.0122	.0093	81.85	109.65	1.34	.99	1.32	2168.73	218.91	2387.64
.0355	.0261	28.18	37.75	1.34	1.02	1.36	6299.64	1294.55	7594.18
.2000	.3168	5.00	4.67	.93	.68	.63	−10000.00	−84000.00	−94000.00
.0041	.0037	244.44	233.33	.95	1.15	1.10	−136.36	−429.55	−293.18
.2041	.3205	4.90	4.58	.93	.68	.64	−10136.38	−83570.44	−93706.81
.0015	.0010	687.50	853.66	1.24	1.15	1.43	198.18	152.73	350.91
.0007	.0004	1527.78	1944.44	1.27	1.15	1.46	98.18	68.73	166.91
.0021	.0015	474.14	593.22	1.25	1.15	1.44	296.36	221.45	517.82
.2417	.3480	4.14	4.05	.98	.71	.69	−3540.38	−82054.44	−85594.81

B.2. LTV's Application of the MFPMM (Taken from the Phase III Final Report, March 1986)

LTV utilizes the MFPMM (note: they incorporate all outputs and all inputs, and, therefore, the correct title, per their application, is the Total Factor Productivity Model) to establish competitive productivity targets. They utilize the model at the Division (Firm) level in a very macro fashion. It has been customized to incorporate long cycle times and a constantly changing product mix. The purpose of the M(T)FPMM in their application is to establish productivity improvement targets that are based upon a competitive pricing strategy analysis. Long range (2-5 years), desired profit margins are established, competitive pricing strategies are factored in, and the end results are challenge budgets that will make the equation balance out. Total budget projections are developed. The major controllables, therefore, assumed in the LTV application of the model are budgets (i.e. resources consumed and the cost of those resources) and product price. There exists an implicit assumption that quality is managed aggressively while the disciplined budget management process is being implemented. Figure VI-B-2-1 develops the equations from the MFPMM that indicate how LTV utilizes the model in their overall system.

(1) Basic MFPMM equation Profit = Productivity x Price Recovery

(2)
$$\frac{\text{Sales}}{\text{Costs}} = \frac{\text{Output}}{\text{Input}} \times \frac{\text{Output Price}}{\text{Input Price}}$$

(3)
$$\Delta \text{ Profit} = \Delta \text{ Productivity} \times \Delta \text{ Price Recovery}$$

(4)
$$\Delta \text{ Profit} = \Delta \text{ Productivity} \times \frac{\Delta \text{ Output Price}}{\Delta \text{ Input Price}}$$

Forecasted (i.e., we know these from published data or can constrain Δ Output Price to gain competitive edge).

(5)
$$\Delta \text{ Product Price or Output Price} = \Delta \text{ Productivity} \times \frac{\Delta \text{ Input Price}}{\Delta \text{ Profit}}$$

Forecasted

From equation (5), we can develop strategic objectives for product pricing and annual productivity improvement that are interrelated.

Figure VI-B-2-1: Basic MFPMM Equation and its Derivation to Show How the Model is Utilized by LTV

C. General Approach

The Virginia Productivity Center (VPC) project team (Sink, Agee, Roberts, and Rossler) conducted a field test of the MFPMM at LTV. The approach taken by the VPC was designed to build upon the paper test results while addressing the specific research questions developed by Dr. Sink. The research questions were motivated by the steps involved in performing a management systems analysis. Those specific questions are:

Describe the specific unit of analysis.

Identify the major audiences for the model and their information needs.

Identify what can/should be done by the management team of the system to improve system performance.

Identify the data and information the management team needs to support or justify performance improvement interventions.

Identify the data that the model presents. Discuss its criticality, use, uniqueness, and benefits.

Identify where the model fits in with the total set of tools available to management.

Identify specific data needed from the system to support each model.

The presentation of the field test results follows. The field test of the MFPMM is structured to reflect these questions. Each area of discussion is preceded by the relevant research questions used to bound the test.

D. Field Test Results

D.1 Unit of Analysis

Research Questions:

What is the appropriate/best unit of analysis for the MFPMM?

What is the appropriate/best scope (frequency) of measurement for the MFPMM?

Is the MFPMM applicable across the A&D community?

How does the mix of contractory types affect the use and interpretation of the MFPMM?

The MFPMM is most appropriate at the firm, division, and plant levels. It could be used at the cost center level as a separate accounting system for an assembly line, individual product line or program, flexible machining center, etc.; however, this is not recommended for two reasons. First, at lower levels of organizations, managers do not normally need the kind of detail offered by the model. Second, cost accounting structures typically do not capture all costs associated with the particular assembly line, program, flexible machining center, etc. Table VI-D-1 shows, for example, the percent of costs tracked by program in a typical A&D contractor. The implications of this are that the MFPMM could be used at the program level and capture roughly 45-50% of total costs.

Table VI-D-1

Percent of Costs Tracked by Program at a Typical Aerospace and Defense Contractor

Cost Category	% of Total Costs	% Tracked by Program
Labor	56	40-60
Materials	28	70
Energy	2	0
Capital	14	0

The appropriate scopes of measurement with the MFPMM are monthly, quarterly, semi-annually, and annually. However, the best scope in the A&D environment is annual with quarterly updates.

The MFPMM can be used anywhere the quantity, price, and/or value of the necessary data exists. LTV uses the model without quantity and price data at the output unit and input unit level. They operate their version of the model with value (revenues and costs) only. They index the data to constant value dollars so as to ensure they are evaluating only productivity improvement. Various outputs produced and most of the inputs consumed are straightforward and should be provided by most basic accounting systems. Therefore, the MFPMM appears to be widely applicable.

The applicability of MFPMM for a particular contractor depends on product cycle times, product mix, seasonality, and frequency of design changes. The current version of the software has been developed for application in an environment characterized by relatively short cycle times (i.e., < one month), few product mix changes, little seasonality, and few product design changes. The defense contractor environment, however, is characterized by long cycle times, a constantly changing product mix, and frequent design changes. A defense contractor version of the MFPMM has been developed for application in this environment (DCMFPMM).

D.2 Audiences for MFPMM

Research Questions:

Who are the most appropriate audiences for MFPMM output?

How can we improve the output design relative to various audiences?

The MFPMM was designed to operate on specific units of analysis and, therefore, satisfy the needs of specific audiences associated with these units of analysis. Several key audiences were identified in the A&D environment that require the output produced by the MFPMM for effective planning, evaluation, and decision support (listed in order of importance):

- Division Management (President, Vice-President)
- Operations Management (Directors - individuals between division and department-level management)
- Internal Program Management
- System Program Office/Program Management

The MFPMM provides, at a minimum, the following information:

- Percent Productivity Improvement
- Major Cost Drivers
- Guidance as to or Insight Useful for Corrective Action
- Dollar Impact Change in Productivity
- Should-Be Budget for Targeted Productivity Improvement
- Direct/Indirect Cost Ratios
- Departmental Cost Contributers
- Rate of Change in Costs
- Rate of Change in Sales by Program

Table VI-D-2-1 is a mapping of MFPMM outputs to the needs of the audiences. The outputs provided by MFPMM satisfy the information needs of all four key audiences. This is to be expected in the case of division and operations management; the MFPMM was designed for these specific audiences in mind. On the other hand, the system program office/program managers and internal program management are a very different audience with respect to the MFPMM because of their focus at the program level; however, the MFPMM still provides both managements with information needed to make control and improvement interventions.

Table VI-D-2-1

Information Needs of Top Audiences for MFPMM

Information \ Audience	Division Management	Operations Management	Internal Program Management	System Program Office/Program Managers
% Productivity Improvement	X	X	X	X
Major Cost Drivers	X	X		
Recommendation for Corrective Action	X	X	X	X
Dollars Impact Change in Productivity	X	X	X	X
Should-Be Budget for Targeted Productivity Improvement	X	X	X	
Direct/Indirect Cost Ratios	X	X		
Dept. Cost Contributers				
Rate of Change of Costs		X		
Rate of Change in Sales by Program		X	X	X

D.3. Improving System Performance

Research Questions:

What development work needs to be completed on the MFPMM?

Several moderator variables determine the applicability of a measurement technique for a particular operating scenario: technology, process cycle time, and controllability. Therefore, the current version of the model must be modified to operate in the A&D environment. The design criteria for this A&D version were identified:

1. Column 3 (Input Value) and Column 6 (Output Value) are required to capture the value of all inputs and outputs. Quantity and price data (Columns 1 and 2, 4 and 5) are not needed. The value of inputs and outputs must be converted to constant dollars using the DRI Inflation/Deflation and othre published indexes index before being inputted to the model.

2. Columns 6a-6d must be added to represent forecasted periods. This allows for long range (2-5 year) planning with the model.

3. The model should accomodate thirty outputs. Categories are needed for product, and/or program. This allows us to track rate of change in sales by product and program.

4. Thirty cost categories (inputs) are required by function. The model should show labor, material, capital, energy, data/information, cost allocations by function.

5. Columns 7,8,9 "Changes in Cost Ratios" are required for cost-driver analysis.

6. Columns 14-16 are required. Column 14 shows percent change in productivity. Column 15 is forecasted changes in price-recovery. Column 16 is the established level of profits. However, in the LTV application, the use of price recovery and level of profits as strategic variables is used to forecast in a backward driv'n fashion.

7. Column 17 is required to show the dollar impact change in productivity.

D.4. Data and Information Requirements

Research Questions:

What is the typical operating scenario for use of MFPMM in the A&D setting?

Can the operating scenario be described in a detailed manner so that it is understood by all contractors?

The MFPMM can be an integral component of an A&D contractor's productivity management process. The model is applied at the division (firm) level and can play a role in planning, measurement and evaluation, control and improvement. To support planning, the MFPMM is used to establish budgets which will result in a competitive pricing advantage. Longe range (2-5 years) total budgets are projected, strategy set, desired profit margins are established, and "challeng.." budgets are developed to balance the equation out (i.e. the needed productivity improvement is identified to achieve the desired strategic pricing advantage and profit margins).

Once the annual productivity target is set, the MFPMM is used for measurement and evaluation, control and improvement. Each quarter the model is rerun with data from actual operations to obtain the productivity improvement required for the remainder of the year to meet the target. A productivity council then meets quarterly to review both MFPMM output and ongoing productivity improvement projects in several functions (functions parallel the cost accounting structure). The productivity council consists of division management from Operations/Manufacturing; Manufacturing Support; Finance; Materials; Program Management; Marketing; Quality; Engineering; and Human Resources. The council improves the communication, coordination, and cooperation between and within the various functions. Council members brief their staffs on MFPMM output and the status of improvement interventions throughout the division. The sharing of this information creates the visibility necessary to motivate and drive constant improvement.

D.5. Data Results

Research Questions

Does the model measure productivity? What other elements of performance does it measure?

Does the model present unique information? What information does it provide that is redundant?

Does the model satisfy project goals and objectives?

Is MFPMM useful as a measurement system for an incentive system?

The MFPMM is the only model among those studied that measures the productivity change in labor, material, capital, energy, and data/information by function. For each factor, the model partials out the effects of productivity from the effects of price recovery to measure the corresponding effect on profitability. LTV does this in their version through indexing.

The goal of this project has been to identify productivity measurement models which link to and support incentive methodologies. With respect to government-to-contractor incentive methodologies the MFPMM could be used to accurately measure and base rewards on contractor productivity improvement at the division level. The MFPMM could easily be used to support contractor-to-employee gainsharing; the model accurately measures and tracks changes in productivity and their effect on profitability. This change in profitability due to productivity improvements could then be shared between the contractor and employees.

D.6. Management Tools

Research Questions:

What is the interrelationship between MFPMM, CDEF/ACBG, and DCF/SSA?

How does or can MFPMM interrelate with other measurement and evaluation systems in A&D?

The MFPMM allows a management team to evaluate period-to-period changes in a division's or plant's productivity, price-recovery, and profitability. In the LTV application, the focus on concentration is just on productivity. The model can be easily integrated with the planning process to establish annual productivity targets which will result in a competitive advantage. Functions, departments, and workgroups can use both the information provided by the MFPMM and CDEF/ACBG to target specific areas with the greatest need for improvement. The Nominal Group Technique can then be used to identify specific interventions within the targeted area. Using the DCF/SSA, projects can be evaluated, and those proving most favorable can be selected. Once the project is implemented, performance improvement can be measured and evaluated at the various units of analysis using the MFPMM, ACBG, and DCF/SSA (cost benefit tracking position), and the Multi-Criteria Performance Measurement Technique (MCPMT).

D.7. MFPMM Data Inputs

Research Questions:

What software support needs exist for the MFPMM?

What types of costs are evaluated by the model?

We estimate it would take 2000 person hours to design and develop an application of this model. There will, of course, be considerable variance in this forecast based upon numerous factors such as expertise of persons involved, data systems, accessibility, management support, continuity of effort, etc. We must also separate collection of data and analysis using the model from development and application of the model as a management support system. This distinction forces us to separate our estimates for resource requirements (person hours) into two pieces. We believe one could expect an elapsed time of two to three years for successful management systems development and perhaps 2000 person hours expended during that period. LTV has been developing their application since 1984 and has expended roughly 5000 person hours just on MFPMM application development. Collection of data and use of the model to analyze the data, however, could easily be done in 6 months with 500 person hours of effort.

Software is developed and has been developed for the MFPMM. The current version of the model is programmed in BASIC for the IBM-PC and requires 64K of memory, DOS 2.1 or higher, and a color graphic monitor and adaptor.

Some expertise is required to execute this model. As such, an educational intervention is required. LTV staff has been quite systematic and disciplined in their educational and development process. They have researched the literature and the field well. We believe a disciplined developmental program will be required to successfully apply this and other productivity measurement models.

E Defense Contractor Industry MFPMM

E.1. Introduction

This report section contains a description of an Defense Contractor Industry Multi-Factor Productivity Measurement Model design (DCMFPMM). The primary purpose of these pages is to describe the inputs necessary to drive the DCMFPMM and the outputs that can be obtained from the DCMFPMM. No attempt has been made to describe the details of the model in this portion of the phase IV field test report.

The model inputs and outputs for the DCMFPMM were derived from the paper test of the MFPMM in Phase III and the field test of the MFPMM in the current contract phase. Several detailed meetings with LTV personnel were held to develop this modification to the MFPMM.

The DCMFPMM should be viewed as a component of an overall organizational performance management effort. More specifically, the DCMFPMM is a management decision making tool most applicable to the macro organizational level, such as the division, plant or company level. The DCMFPMM facilitates the creation of a productivity improvement targets and assists in the development and tracking of budgets that will meet the productivity improvement targets. Further, the DCMFPMM acts as a diagnostics tool by revealing the areas of poor productivity and/or price recovery.

The development and utilization of a DCMFPMM application would require the following steps or activities.

1. Model Setup

    a. Development of functional cost centers.
    b. Development of functional cost categories.
    c. Base year data acquisition.

2. Budget Development

    a. Development of strategic two to five year forecast and plan.
    b. Development of performance improvement targets.
    c. Development of yearly cost center budgets.

3. Budget and Productivity Tracking

    a. Annualization of quarterly budgets and budget tracking.
    b. Productivity and price recovery tracking.

E.2 Model Setup

Functional Cost Centers

MFPMM field test results and LTV experience indicate that the initial model step involves defining or establishing cost centers for the organization. The cost centers can be existing cost centers or a set of newly defined cost centers. It appears that most Defense Contractors will use a functional breakdown to determine their cost centers. LTV experience indicates that it is advisable to separate overhead into separate individual cost centers where possible, rather than mixing the overhead items with other cost centers. An example of this is Facilities which might include maintenance on all areas.

Making cost centers out of overhead items will eliminate some accidental double counting in the DCMFPMM input section. An example set of functional cost centers is listed below.

* Manufacturing
* Materials
* Engineering
* Logistics
* Accounting
* Information Services
* Modernization Program
* Human Resources
* Facilities

Functional Cost Categories

All cost centers share common categories of costs. There may also be some costs common only to one or a few of the cost centers. Establishing these cost categories simply involves making a comprehensive cost category list. It should be remembered that the defined cost categories need to be trackable. A suggested set of cost categories is listed below. A full DCMFPMM matrix is demonstrated in Figure VI-E-2-1. As it can be seen in Figure VI-E-2-1, these cost categories can be further subdivided.

* LABOR
* MATERIALS
* ENERGY
* CAPITAL
* MISC.

These cost categories also represent the level at which productivity is tracked. Therefor the category detail level should be sufficient for productivity tracking. Likewise, cost data must be gathered for each defined level. A detailed cost categorization can cost extra time and money. It is prudent to take the time to develop a realistic and sufficient set of cost categories.

Base Year data

Using the DCMFPMM to track productivity requires the aquisition of a base year of data. The productivity of an organization is most meaningful when it is tracked over many periods as opposed to a few periods. Productivity measures that relate to only two periods will indicate the degree of improvement but indicate nothing about the desired productivity. For example, lets say that two periods of data reveal a 5 percent productivity increase. Is this good or bad? The answer depends on the potential productivity improvement. In other words, a productivity ratio (outputs/inputs) of 1.34 does not necessarily indicate a good productivity ratio if the contractor is capable of a 1.67 productivity ratio. Although it is difficult to establish the potential productivity improvement, tracking over time can be used to indicate the time trends and consistency of the productivity effort.

The base year of data consists of actual costs for each of the functional cost centers across all of the cost categories for a given year and the value of all outputs for that same year. The base year data could fill a matrix similar to Figure VI-E-2-1.

The base year is the point from which progress is measured. Budgets are constructed from the base year for the base year + 1, or the next year and for the remaining years in the forecast and plan. At the end of each year the 2-5 year budget and plan is recalculated and formulated. All future years data will be deflated to reflect base year dollars. This is important for a true productivity comparison. More on these deflators is found in the section on budget development.

E.3 Budget Development

Two to Five Year Forecast

Before actual budgets can be determined, there needs to be a good idea of what goods and services will be sold for any given year. Although there may be many fixed contracts, there will likely be some degree of uncertainty. This is especially true when budget planning is done for a multiple year horizon. The LTV experience indicates that a two to five year budget planning horizon is very appropriate for productivity planning and budgeting and therefore for the DCMFPMM.

A two to five year forecast is important for the success of budgets based on productivity improvement targets. The two to five year forecast should include a forecast of where the contractor will be at the present rate of productivity and forecasted price recovery. The forecast also needs to be flexible to accommodate change in productivity/price recovery improvement targets as addressed in the next section.

The two to five year forecast is done in conjunction with the productivity/price recovery targeting. One of the results of this combined activity is a forecast of sales for the two to five year horizon. Another result is a two to five year forecast of inventory change. Figure VI-E-3-1 depicts a hypothetical forecast of sales and inventory.

Due to the semi-competitive nature of the Defense Contractor Industry there are several difficulties in making a two to five year forecast. A possible Defense Contractor management goal is "Establish prices that will maintain or obtain given contracts while maximizing allowable profit." Idealistically the overall goal would be changed to "Establish prices that represent the lowest possible prices for the highest quality (conforming to specification) products." In order to solicit this goal from Defense Contractor Management, a reduction in profit must not be the implied result.

Success of the DCMFPMM depends on the Defense Contractor accepting and driving this idealistic goal. The goal then restated is that the Defense Contractor will will be anxiously engaged in reducing all possible costs while maintaining services and quality or, producing more products for the same cost.

	1986	1987	1988
OUTPUTS			
F16	345.8	361.7	360.8
B1B	650.2	690.8	721.4
F28	130.7	120.7	120.6
C5A	150.6	141.6	140.5
F15	372.6	360.1	380.3
747	275.6	270.6	366.3
OTHER	404.6	490.8	680.7
TOTAL OUTPUTS	2330.1	2436.3	2770.6

Figure VI-E-3-1
Sales and Inventory Forecast

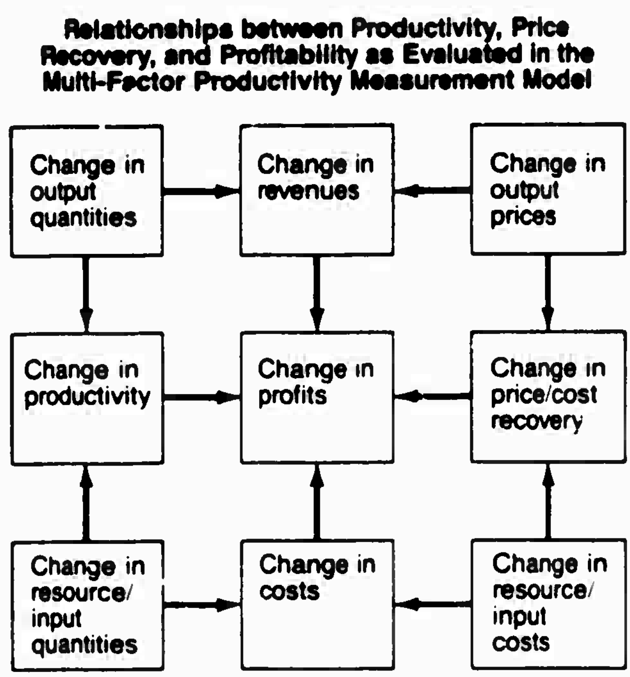


Figure VI-E-3-2
Productivity-Price Recovery
Relationship

Productivity/Price Recovery Improvement Target

The two to five year forecast establishes trends and relationships of expected profitability to productivity and price recovery. The productivity/price recovery improvement target answers the questions:

* "What price can be charged to obtain/maintain desired contracts?"

OR

* "What prices need to be charged to stay/become more competitive than other contractors?"

Both of these questions are dependent on productivity and price recovery.

Establishing a productivity/price recovery improvement target is done in conjunction with the two to five year forecast. Any change in the current prices charged for goods and services could change the projected output for the years that the change would occur. Price changes then are the tool used to acquire more contracts and are directly related to total profitability.

It is important to recognize that total profitability change is the sum of price recovery change and productivity change. This concept is illustrated in Figure VI-E-3-2 Due to this relationship, productivity gains and losses can be determined given both the change in total profitability and the change in price recovery. Likewise, given any two of the tree components, the other one can be determined.

The productivity/price recovery improvement target then becomes the change in productivity and price recovery needed to accomplish the DCMFPMM assumed goal which is, "charge the lowest prices for the highest quality goods" and which implies staying ahead of the competition and receive highest possible profit.

Figure VI-E-3-3 demonstrates a three year forecast that incorporates the three year sales and inventory forecast and the productivity /price recovery target. All forecasts are deflated to base year dollars. These deflators must be supplied to the model. The use of published industry deflators is a possible source. The DCMFPMM inputs are the sales forecast, the price deflators, and either the desired improvement percent (productivity / price recovery target) or the budget desired to assure necessary profits.

ITEM	1986	1987	1988	1989
OUTPUTS				
CURRENT YEAR VALUE	2329.6	2436.3	2770.6	3401.5
PRICE INFLATION %	BASE	5.0	8.0	7.0
BASE YEAR VALUE	2329.6	2320.3	2443.2	2803.4
IMPROVEMENT %	BASE	-0.4	5.3	14.7
INPUTS				
CURRENT YR. VALUE	2245.0	2343.0	2611.5	3169.1
COST INFLATION %	BASE	8.0	9.0	9.0
BASE YR. VALUE	2245.0	2169.4	2218.4	2469.8
COST/REVENUE	96.4	93.5	90.8	88.1
IMPROVEMENT %	BASE	3.0	3.0	3.0
PRODUCTIVITY INDEX	100.0	103.0	106.1	109.3

Figure VI-E-3-3

3-year Forecast with Target Budgets

The output of the DCMFPMM is the % improvement if the budget was supplied or it is the budget if the % improvement is supplied. The Productivity/Price Recovery goal then dictates the budget needed to drive the desired profitability (productivity and price recovery).

Yearly Cost Center Budgets

Once the future year forecasts have been made, budgets are requested for each of the cost centers. That is, information concerning the projected product output is relayed to the directors of the cost centers and from the directors to all functions that contribute to that cost center. This information is in part that found in the sales and inventory forecast. Also included are all other services to be rendered and information on all functional requirements.

Each cost center then submits a budget for the forecasted output. It should be clear that producing these budgets is facilitated when the cost centers are functions. These budgets can be solicited without sharing knowledge of the Productivity/Price recovery Improvement Target.

Ideally, the budgets would be broken down to the category costs already defined in the model setup section. Such a breakdown enables productivity tracking for each of the cost categories. A partial example of these budgets is shown in Figure VI-E-3-4. These budgets become and important input into the model.

Since upper management already knows how much money it wants to spend to achieve the goal, the proposed status can easily be checked. Inputting the functional budgets into the model will yield a comparison of the desired budget to the proposed budget. The DCMFPMM will indicate what percent improvement or negative improvement will occur under the proposed budget. Figure VI-E-3-5 shows the model output for the proposed or submitted budget vs. the desired budget.

If the proposed budget is not satisfactory budget reductions are in order. The method of obtaining those reductions is not a feature of the model but instead, a part of the management process and infrastructure for this process. Some possible suggestions are:

1. Reduce everyone's budget by the required percent.
2. Solicit further reductions voluntarily.

	MANUFACTURING	ACCOUNTING	ENGINEERING
LABOR			
DIRECT	212.6	10.9	165.6
INDIRECT	217.4	63.9	263.7
SALARIES	180.1	50.2	185.5
OVERTIME	23.7	7.6	52.6
ABSENCES	13.6	6.1	25.6
FRINGE BENEFITS	87.1	21.3	73.4
TOTAL LABOR	517.1	96.1	502.7
MATERIALS			
DIRECT MATERIALS	527.5	8.8	20.2
SUPPLIES & EXPS.	110.7	23.6	103.2
TRAVEL	82.6	8.0	56.7
COMMUNICATION	15.9	8.9	18.2
OFFICE SUPPLIES	12.2	6.7	28.3
TOTAL MATERIALS	638.2	32.4	123.4
ENERGY			
ELECTRICITY	80.4	4.0	6.2
OTHER	23.2	1.2	7.5
TOTAL ENERGY	103.6	5.2	13.7
CAPITAL			
TAXES	24.6	7.5	17.9
INSURANCE	21.2	6.4	13.0
DEPRECIATION	81.4	4.3	44.7
RENT	55.6	33.2	75.2
TOTAL CAPITAL	182.8	51.4	150.8
TOTAL FUNCTION INPUT	1441.7	185.1	790.6
TOTAL INPUTS	2417.4		

Figure VI-E-3-4
Non-deflated Budget Proposals

ITEM	BASE YR	DESIRED 1987	SUBMITTED 1987
OUTPUTS			
CURRENT YEAR VALUE	2329.6	2436.3	2436.3
PRICE INFLATION %	BASE	5.0	5.0
BASE YEAR VALUE	2329.6	2320.3	2320.3
IMPROVEMENT %	BASE	-0.4	-0.4
INPUTS			
CURRENT YR. VALUE	2245.0	2343.0	2417.0
COST INFLATION %	BASE	8.0	8.0
BASE YR. VALUE	2245.0	2169.4	2238.3
COST/REVENUE	96.4	93.5	96.5
IMPROVEMENT %	BASE	3.0	-0.1
PRODUCTIVITY INDEX	100.0	103.0	99.9

Figure VI-E-3-5
Proposed vs. Desired Budget

3. Compare past productivity rates to identify productivity increases or decreases for each cost category and/or cost center and allocate reductions accordingly.

The budget process continues back and forth, driving the model forward to find out what the profit and productivity gain will be, examining the model driven backward for comparison, revising and changing. The end result, no matter how obtained, should be a set of budgets. Each cost center will know what it must do during the coming year and how much money it can spend to accomplish that work. The sum of these budgets will sum to the desired budget obtained from the forecast. These budgets are termed "Challenge Budgets". They are the budgets that must be met reach to contractor goals.

E.4 Budget and Productivity Tracking

Budget Annualization and tracking

Periodically, the status of the organization must be evaluated. This is accomplished by gathering interim cost and inventory data. This data is then annualized by the finance department. The result of the annualization will appear in the same function matrix divided up by cost categories. The annualized data is an input into the DCMFPMM. An output resulting from this input is a matrix of differences in desired to actual costs. Figure VI-E-4-1 shows an example of one of these matrices.

Positive values represent a budget underspent, or one that is doing better than desired while a negative value represents an overspent budget. Another output is the same as in Figure VI-E-3-5. This output shows the %improvement given the current cost rate. Based on the annualized budget, changes can be made in the budget or in the functions to insure that the challenge budget is met.

Productivity and Price Recovery Tracking

The relationship between profitability, productivity and price recovery has already been explained. This relationship allows the DCMFPMM to provide management with some valuable information. To do this, however, price recovery and productivity must be separated. It is difficult to separate a quantity and a price out for all of the cost categories in the Defense Contractor industry. This is because it is difficult to measure the price and the quantity for each cost category. One solution is to ignore price and quantity and only deal with value. The problem with this approach is that changes in productivity and price recovery are not generated.

LTV experience indicates that it is possible to forecast the change in price recovery for each year. This makes it possible to evaluate the change in productivity for that same period since:

QUANTITY X PRICE = VALUE

where = change in

	MANUFACTURING	ACCOUNTING	ENGINEERING
LABOR			
DIRECT	12.3	0.2	8.1
INDIRECT	-11.3	-0.4	-4.6
SALARIES	-3.5	-0.3	-2.1
OVERTIME	-7.5	0.0	-1.3
ABSENCES	-0.3	-0.1	-1.2
FRINGE BENEFITS	0.1	0.0	0.0
TOTAL LABOR	1.1	-0.2	3.5
MATERIALS			
DIRECT MATERIALS	-11.2	-0.2	0.1
SUPPLIES & EXPS.	4.1	-1.3	-7.1
TRAVEL	-3.1	-0.7	-4.1
COMMUNICATION	4.2	0.1	0.0
OFFICE SUPPLIES	3.0	-0.7	-3.0
TOTAL MATERIALS	-7.1	-1.5	-7.0
ENERGY			
ELECTRICITY	-0.1	-0.1	-0.1
OTHER	-0.1	0.0	0.0
TOTAL ENERGY	-0.2	-0.1	-0.1
CAPITAL			
TAXES	0.0	0.0	0.0
INSURANCE	-0.2	-0.1	-0.1
DEPRECIATION	0.1	0.0	0.1
RENT	-0.1	-0.1	-0.1
TOTAL CAPITAL	-0.2	-0.2	-0.1
TOTAL FUNCTION INPUT	-6.4	-2.0	-3.7
TOTAL INPUTS	-12.1		

Figure VI-E-4-1
Annualized Absolute Differences
Desired to Actual Costs

This is the same as columns 14 to 16 of the original MFPMM.

The DCMFPMM functions as the original MFPMM by calculating columns 3,6,9,14,15,16 directly. These column become multiple columns however, with one column for each function or cost center. A matrix is calculated for each of the 6 columns above. The dollar effect of productivity is lost, however, when only these columns are used. Annualized can also be used to track productivity. An example of these 6 columns follows.

Figure VI-E-4-2 represents the base year, or period 1 input and output values. This Figure corresponds to column 3 of the original MFPMM. This data must be supplied to the model.

Figure VI-E-4-3 represents year 2 data or base year +1 data. The values are in constant dollars as supplied by the finance department. Again, these values are total input and output values for the year. This data must be supplied to the model.

Figure VI-E-4-4 represents the input and output change ratios. That is the percent increase or decrease in the inputs and the outputs. Because these values are already deflated, they represent actual changes. This data is calculated by the model.

Figure VI-E-4-5 represent a cost revenue ratio for the base year of data. That is, the ratio of a particular input value to the entire revenue value. These values can also be represented in the DCMFPMM by pie charts. This data is calculated by the model.

Figure VI-E-4-6 represents the cost revenue ratios for period two, or the base year +1 data. This figure and the previous year cost revenue ratio are good for comparison between each other. This data is calculated by the model.

Figure VI-E-4-7 is the profitability index. This data can be derived from the input data supplied in Figures VI-E-4-2 and Figure VI-E-4-3. This data is calculated by the model. This value is obtained by dividing the sum of the deflated output valuesfor period two by the sum of the output valuesfor period one which becomes a numerator. The denominator is the individual cell or input valuefor period 2 divided by the input value for period one.

Figure VI-E-4-8 represents the price recovery index. These values indicate the percent increase or decrease in price recovery. This data must be supplied to the model. In this figure the numbers are purely hypothetical numbers. As previously mentioned, the LTV experience indicates that these forecasts can be obtained.

Figure VI-E-4-9 represents the productivity index. These values indicate the percent productivity increase or decrease. The data is calculated from the model and is dependent on the price recovery forecasts supplied in Figure VI-E-4-8 and the profitability indes in figure VI-E-4-7. the value is obtained by dividing the profitability idex by the price recovery index.

	1986
OUTPUTS	
F16	345.8
B1B	650.2
F28	130.7
C5A	150.6
F15	372.6
747	275.6
OTHER	404.6
TOTAL OUTPUTS	2330.1

INPUTS	MANUFACTURING	ACCOUNTING	ENGINEERING
LABOR			
DIRECT	212.6	10.1	150.1
INDIRECT	209.0	53.7	250.9
SALARIES	177.2	41.1	180.4
OVERTIME	20.4	7.4	50.3
ABSENCES	11.4	5.2	20.2
FRINGE BENEFITS	80.1	19.0	70.2
TOTAL LABOR	501.7	82.8	471.2
MATERIALS			
DIRECT MATERIALS	500.3	7.6	21.6
SUPPLIES & EXPS.	92.7	15.9	91.9
TRAVEL	70.6	7.2	51.7
COMMUNICATION	12.8	5.3	14.0
OFFICE SUPPLIES	9.3	3.4	26.2
TOTAL MATERIALS	593.0	23.5	113.5
ENERGY			
ELECTRICITY	71.1	3.2	5.9
OTHER	22.2	1.3	7.4
TOTAL ENERGY	93.3	4.5	13.3
CAPITAL			
TAXES	22.6	6.3	16.7
INSURANCE	19.1	5.1	10.0
DEPRECIATION	75.0	4.1	33.6
RENT	51.9	29.7	74.1
TOTAL CAPITAL	168.6	45.2	134.4
TOTAL FUNCTION INPUT	1356.6	156.0	732.4
TOTAL INPUTS	2245.0		

Figure VI-E-4-2
Period 1 Input & Output Values

	1987
OUTPUTS	
F16	361.7
B1B	690.8
F28	120.7
C5A	141.6
F15	360.1
747	270.6
OTHER	490.8
TOTAL OUTPUTS	2436.3

INPUTS	MANUFACTURING	ACCOUNTING	ENGINEERING
LABOR			
DIRECT	211.5	10.0	152.2
INDIRECT	194.0	54.0	241.5
SALARIES	169.6	42.2	165.2
OVERTIME	11.9	6.4	54.2
ABSENCES	12.5	5.4	22.1
FRINGE BENEFITS	79.5	18.3	65.2
TOTAL LABOR	485.0	82.3	458.9
MATERIALS			
DIRECT MATERIALS	480.8	6.5	22.3
SUPPLIES & EXPS.	88.0	15.7	90.2
TRAVEL	61.8	5.4	47.2
COMMUNICATION	13.9	6.5	14.9
OFFICE SUPPLIES	12.3	3.8	28.1
TOTAL MATERIALS	568.8	22.2	112.5
ENERGY			
ELECTRICITY	62.5	3.1	5.5
OTHER	23.8	1.3	7.5
TOTAL ENERGY	86.3	4.4	13.0
CAPITAL			
TAXES	23.1	6.7	17.2
INSURANCE	20.3	6.0	11.1
DEPRECIATION	75.0	4.1	33.6
RENT	48.9	23.6	66.4
TOTAL CAPITAL	167.3	40.4	128.3
TOTAL FUNCTION INPUT	1307.4	149.3	712.7
TOTAL INPUTS	2169.4		

Figure VI-E-4-3
Period 2 Input & Output Values

	CHANGE RATIO
OUTPUTS	
F16	1.0460
B1B	1.0624
F28	0.9235
C5A	0.9402
F15	0.9665
747	0.9819
OTHER	1.2130
TOTAL OUTPUTS	1.0456

INPUTS	MANUFACTURING	ACCOUNTING	ENGINEERING
LABOR			
DIRECT	0.9948	0.9901	1.0140
INDIRECT	0.9282	1.0056	0.9625
SALARIES	0.9571	1.0268	0.9157
OVERTIME	0.5833	0.8649	1.0775
ABSENCES	1.0965	1.0385	1.0941
FRINGE BENEFITS	0.9925	0.9632	0.9288
TOTAL LABOR	0.9667	0.9940	0.9739
MATERIALS			
DIRECT MATERIALS	0.9610	0.8553	1.0324
SUPPLIES & EXPS.	0.9493	0.9874	0.9815
TRAVEL	0.8754	0.7500	0.9130
COMMUNICATION	1.0859	1.2264	1.0643
OFFICE SUPPLIES	1.3226	1.1176	1.0725
TOTAL MATERIALS	0.9592	0.9447	0.9912
ENERGY			
ELECTRICITY	0.8790	0.9688	0.9322
OTHER	1.0721	1.0000	1.0135
TOTAL ENERGY	0.9250	0.9778	0.9774
CAPITAL			
TAXES	1.0221	1.0635	1.0299
INSURANCE	1.0628	1.1765	1.1100
DEPRECIATION	1.0000	1.0000	1.0000
RENT	0.9422	0.7946	0.8961
TOTAL CAPITAL	0.9923	0.8938	0.9546
TOTAL FUNCTION INPUT	0.9637	0.9571	0.9731
TOTAL INPUTS	0.9663		

Figure VI-E-4-4
Input Output Change Ratios

INPUTS	MANUFACTURING	ACCOUNTING	ENGINEERING
LABOR			
DIRECT	0.0912	0.0043	0.0644
INDIRECT	0.0897	0.0230	0.1077
SALARIES	0.0760	0.0176	0.0774
OVERTIME	0.0088	0.0032	0.0216
ABSENCES	0.0049	0.0022	0.0087
FRINGE BENEFITS	0.0344	0.0082	0.0301
TOTAL LABOR	0.2153	0.0355	0.2022
MATERIALS			
DIRECT MATERIALS	0.2147	0.0033	0.0093
SUPPLIES & EXPS.	0.0398	0.0068	0.0394
TRAVEL	0.0303	0.0031	0.0222
COMMUNICATION	0.0055	0.0023	0.0060
OFFICE SUPPLIES	0.0040	0.0015	0.0112
TOTAL MATERIALS	0.2545	0.0101	0.0487
ENERGY			
ELECTRICITY	0.0305	0.0014	0.0025
OTHER	0.0095	0.0006	0.0032
TOTAL ENERGY	0.0400	0.0019	0.0057
CAPITAL			
TAXES	0.0097	0.0027	0.0072
INSURANCE	0.0082	0.0022	0.0043
DEPRECIATION	0.0322	0.0018	0.0144
RENT	0.0223	0.0127	0.0318
TOTAL CAPITAL	0.0724	0.0194	0.0577
TOTAL FUNCTION INPUT	0.5822	0.0669	0.3143
TOTAL INPUTS	0.9635		

Figure VI-E-4-5
Period 1 Cost Revenue Ratios

INPUTS	MANUFACTURING	ACCOUNTING	ENGINEERING
LABOR			
DIRECT	0.0868	0.0041	0.0625
INDIRECT	0.0796	0.0222	0.0991
SALARIES	0.0696	0.0173	0.0678
OVERTIME	0.0049	0.0026	0.0222
ABSENCES	0.0051	0.0022	0.0091
FRINGE BENEFITS	0.0326	0.0075	0.0268
TOTAL LABOR	0.1991	0.0338	0.1884
MATERIALS			
DIRECT MATERIALS	0.1973	0.0027	0.0092
SUPPLIES & EXPS.	0.0361	0.0064	0.0370
TRAVEL	0.0254	0.0022	0.0194
COMMUNICATION	0.0057	0.0027	0.0061
OFFICE SUPPLIES	0.0050	0.0016	0.0115
TOTAL MATERIALS	0.2335	0.0091	0.0462
ENERGY			
ELECTRICITY	0.0257	0.0013	0.0023
OTHER	0.0098	0.0005	0.0031
TOTAL ENERGY	0.0354	0.0018	0.0053
CAPITAL			
TAXES	0.0095	0.0028	0.0071
INSURANCE	0.0083	0.0025	0.0046
DEPRECIATION	0.0308	0.0017	0.0138
RENT	0.0201	0.0097	0.0273
TOTAL CAPITAL	0.0687	0.0166	0.0527
TOTAL FUNCTION INPUT	0.5366	0.0613	0.2925
TOTAL INPUTS	0.8904		

Figure VI-E-4-6
Period 2 Cost Revenue Ratios

INPUTS	MANUFACTURING	ACCOUNTING	ENGINEERING
LABOR			
DIRECT	1.051	1.056	1.031
INDIRECT	1.126	1.040	1.086
SALARIES	1.092	1.018	1.142
OVERTIME	1.792	1.209	0.970
ABSENCES	0.954	1.007	0.956
FRINGE BENEFITS	1.053	1.086	1.126
TOTAL LABOR	1.082	1.052	1.074
MATERIALS			
DIRECT MATERIALS	1.088	1.223	1.013
SUPPLIES & EXPS.	1.101	1.059	1.065
TRAVEL	1.194	1.394	1.145
COMMUNICATION	0.963	0.853	0.982
OFFICE SUPPLIES	0.791	0.936	0.975
TOTAL MATERIALS	1.090	1.107	1.055
ENERGY			
ELECTRICITY	1.189	1.079	1.122
OTHER	0.975	1.046	1.032
TOTAL ENERGY	1.130	1.069	1.070
CAPITAL			
TAXES	1.023	0.983	1.015
INSURANCE	0.984	0.889	0.942
DEPRECIATION	1.046	1.046	1.046
RENT	1.110	1.316	1.167
TOTAL CAPITAL	1.054	1.170	1.095
TOTAL FUNCTION INPUT	1.085	1.092	1.074
TOTAL INPUTS			

Figure VI-E-4-7
Profitability Index

INPUTS	MANUFACTURING	ACCOUNTING	ENGINEERING
LABOR			
DIRECT	1.043	1.067	1.010
INDIRECT	1.000	1.011	1.046
SALARIES	0.980	0.930	0.976
OVERTIME	1.450	0.987	0.957
ABSENCES	0.962	0.955	0.943
FRINGE BENEFITS	1.046	0.979	0.988
TOTAL LABOR	1.041	1.080	1.021
MATERIALS			
DIRECT MATERIALS	1.011	1.200	0.990
SUPPLIES & EXPS.	1.130	1.034	1.032
TRAVEL	1.150	1.240	1.130
COMMUNICATION	0.999	0.943	0.983
OFFICE SUPPLIES	0.850	0.890	0.960
TOTAL MATERIALS	1.020	1.020	1.020
ENERGY			
ELECTRICITY	1.130	1.050	1.050
OTHER	1.030	1.040	1.040
TOTAL ENERGY	1.040	1.020	1.120
CAPITAL			
TAXES	0.990	0.990	1.000
INSURANCE	0.978	0.988	0.988
DEPRECIATION	1.030	1.020	1.020
RENT	1.050	1.050	1.052
TOTAL CAPITAL	1.040	1.054	1.053
TOTAL FUNCTION INPUT	1.070	1.080	1.080
TOTAL INPUTS			

Figure VI-E-4-8
Price Recovery Index

INPUTS	MANUFACTURING	ACCOUNTING	ENGINEERING
LABOR			
DIRECT	1.008	0.990	1.021
INDIRECT	1.126	1.028	1.039
SALARIES	1.115	1.095	1.170
OVERTIME	1.236	1.225	1.014
ABSENCES	0.991	1.054	1.013
FRINGE BENEFITS	1.007	1.109	1.139
TOTAL LABOR	1.039	0.974	1.052
MATERIALS			
DIRECT MATERIALS	1.076	1.019	1.023
SUPPLIES & EXPS.	0.975	1.024	1.032
TRAVEL	1.039	1.124	1.014
COMMUNICATION	0.964	0.904	0.999
OFFICE SUPPLIES	0.930	1.051	1.016
TOTAL MATERIALS	1.069	1.085	1.034
ENERGY			
ELECTRICITY	1.053	1.028	1.068
OTHER	0.947	1.005	0.992
TOTAL ENERGY	1.087	1.048	0.955
CAPITAL			
TAXES	1.033	0.993	1.015
INSURANCE	1.006	0.900	0.953
DEPRECIATION	1.015	1.025	1.025
RENT	1.057	1.253	1.109
TOTAL CAPITAL	1.013	1.110	1.040
TOTAL FUNCTION INPUT	1.014	1.012	0.995
TOTAL INPUTS			

Figure VI-E-4-9
Productivity Index

VII. A Performance/Productivity Management Methodology for the Defense Contractor Industry

A major outcome of the Phase III research was the development of a generic performance/productivity management methodology for defense contractors. The Phase IV field test has helped us to take this methodology one step further and better communicate it to a broader audience in the defense contractor community.

The methodology, as depicted in Figure VII-1, has 10 stages. The methodology focusses upon decisions associated with modernization investment projects (projects requiring significant capital investment) and decisions associated with modernization efficiency projects (projects requiring little or no capital investment). Stage 1 indicates the importance of driving the productivity improvement process from the results of corporate strategic planning processes. This is an attempt to ensure that our capital investment decisions for modernization are compatible and congruent with the larger scoped strategic plans. The MFPMM is utilized at this stage to support strategic improvement decisions. Stage 2 represents the process of analyzing data for the factory, division, or project in an attempt to identify target areas for improvement. ("Cost driver analysis" is then used to target improvement areas.) The CDEF methodology utilizes the ACBG to assist in the development of "as-is" cost and performance baselines. Stage 3 represents the process by which specific improvement projects are identified. The Nominal Group Technique can be used to generate consensus regarding improvement projects. This facilitates ease of implementation at later stages. The contractor then evaluates the normatively generated projects against Stage 2 analysis to ensure quality and needed impact. Stage 4 is the point at which actual selection of projects takes place. A variety of decision analysis

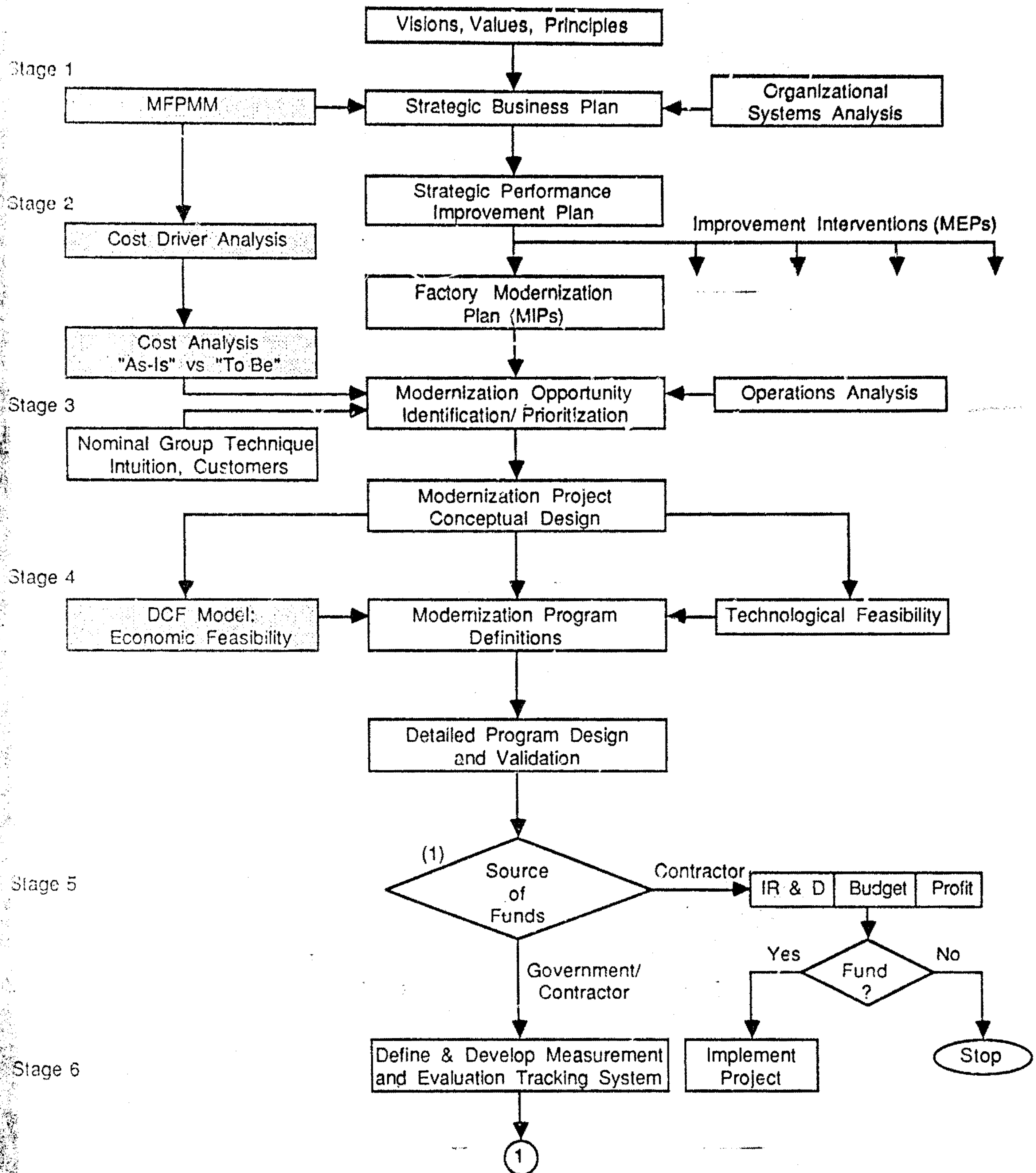
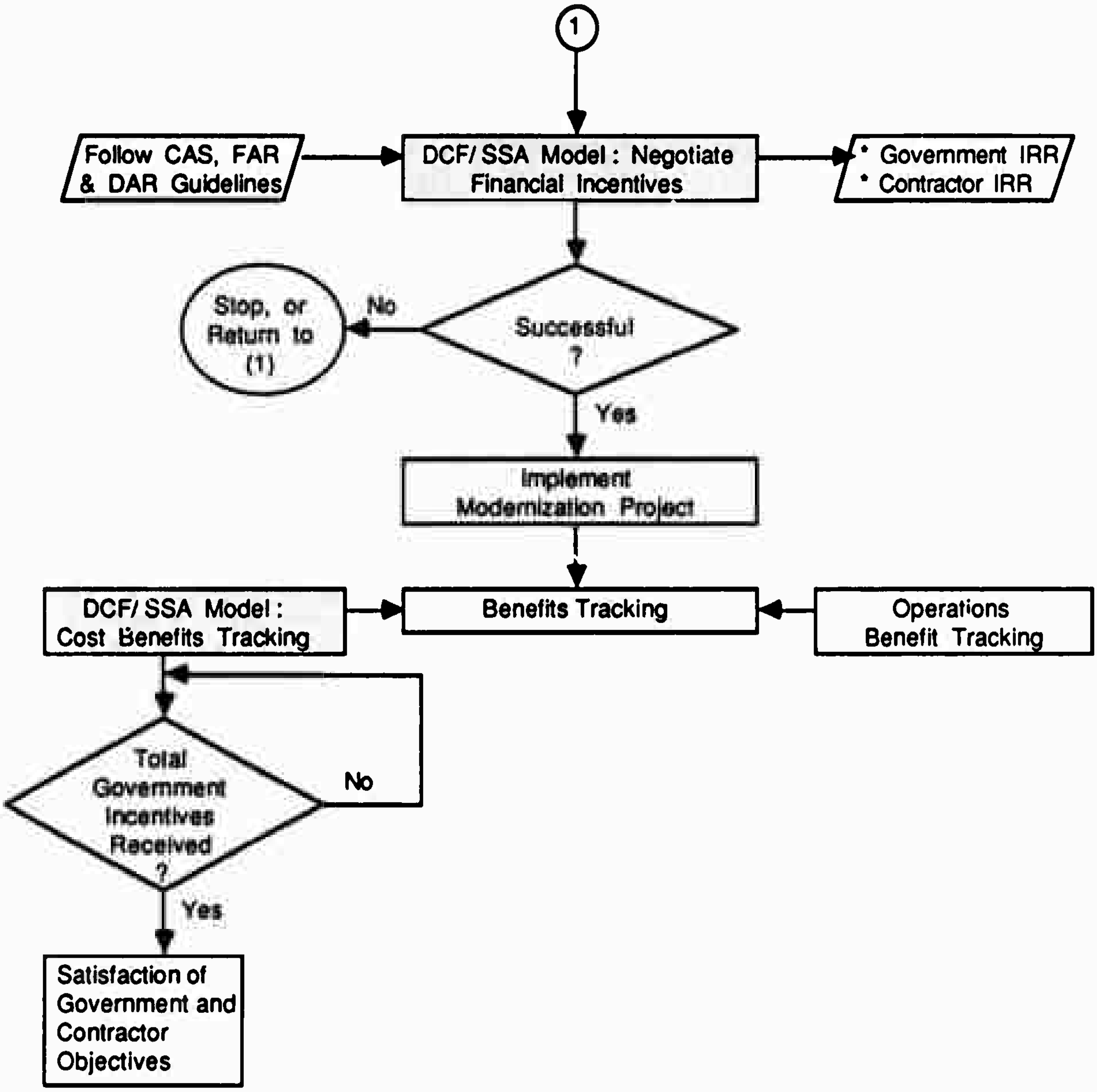


Figure VII-1. Generic Productivity Management Methodology As Related To Defense Industry.



Stage 7

Stage 8

Stage 9

Stage 10

techniques could be utilized to determine which projects are worthy of further development. The CDEF methodology develops and compares "as-is" costs and performance in relation to "to-be" costs and performance in order to select projects with the biggest potential for improvement. The DCF model is used to assess the economic feasibility of each project. Stage 5 is an obviously critical step and involves an analysis of sources of funds available to support the projects. Various decision analysis methods are required at this stage depending upon the audience/funding source. Stage 6 is a political reality involving the negotiation process associated with obtaining support for improvement projects. The DCF/SSA plays a critical role in the negotiation of financial incentives. Assuming the funding for the project is achieved, Stage 7 represents the implementation phase. Many, if not most, government supported investment programs, such as IMIP, require cost-benefit tracking Stage 8. The ultimate goal of this overall project is to develop improved models that will enable valid evaluation of improvement projects. Did the government, the taxpayer, obtain the desired/predicted performance improvement? Improved productivity measurement techniques will play a key role in being able to answer this question. Stage 9 is the desired outcome of the inprovement intervention. To promote and assure productivity improvement in the defense contractor community it has been convincingly argued that there must be incentives. Stage 9 represents the point at which these incentives become a reality. The question of whether shared savings are validated is, in fact, at the heart of this project. To date, shared savings are primarily based upon projected benefits rather than a systematic cost-benefit tracking process. Measurement and evaluation (validation) of improvements has been an illusive goal. Stage 10 is the bottom line, if you will, for the government and likely for the contractor also.

This productivity management methodology is actually just a subset of the one described by Sink, 1985. However, in the defense contractor environment this modernization investment oriented approach is certainly a key element to improved performance in the 80's and 90's.

VIII. Summary

The purpose of the field test effort was to move beyond the Phase III paper test and resolve specific developmental needs of the model and identify areas for future development. We believe the field test accomplished these objectives. Our understanding of the models, their role in the defense contractor community, and their interrelationship with other management tools and processes has become more crystallized. This has improved our ability to communicate, translate, and transfer these models and methodologies to a broad spectrum of defense contractors. The guide being developed in the Phase IV research has reflected this point; the guide is a first cut at communicating the principles and philosophies, strategies, tactics, and techniques of the performance management process. Overall, the project to date has allowed us to define the path to performance improvement; a path designed to achieve the desired outcomes of both the government and contractors.

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X. Appendix A. Distribution List

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