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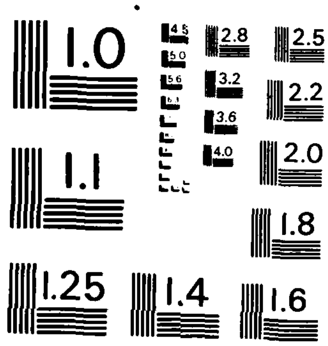

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APPLICATION OF THE DATA ENVELOPMENT ANALYSIS (DEA) AND CONSTRAINED FACET ANALYSIS (CFA) MODELS TO MEASURE TECHNICAL PRODUCTIVITY IMPROVEMENTS AT NEWARK AIR FORCE STATION, OHIO

THESIS

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THESIS

Presented to the Faculty of the School of Systems and Logistics

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the

Requirements for the Degree of

Master of Science in Logistics Management

Robert J. Donovan II, M.S.

Captain, USAF

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Preface

The feasibility of using Data Envelopment Analysis and Constrained Facet Analysis techniques for Air Force depot-level maintenance productivity analysis applications was successfully demonstrated in the research by Capt Richard Hitt and Maj Robert Horace. HQ Air Force Logistics Command was sufficiently interested in the application of the DEA/CFA models capability of measuring technical productivity improvements at Newark Air Force Station (AFS), Ohio to sponsor this research.

The author wishes to thank the following people for their assistance in this research effort. A special thanks to Mr. Dennis Campbell and Maj Dennis Dragich, the thesis advisor and reader respectively. Also, to Ms. Barbara Pruett of HQ AFLC/MAJE for suggesting Newark AFS to conduct this research effort. Next, a special thank you to Mr. Lucin Ball of AGMC/MAWB and his staff at Newark AFS, Ohio for their immense efforts in gathering the output data necessary for this research. And finally, to Capt Jose Montemayor for his assistance in interpreting the DEA/CFA computer program results and to Maj Robert Childress for his assistance in the computer generated graphing of the results.

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Abstract

This research advances the application of the Data Envelopment Analysis (DEA) and Constrained Facet Analysis (CFA) models to measure total factor technical productivity on maintenance levels above the Cost Center at Headquarters Aerospace Guidance And Metrology Center (HQ AGMC/MA). Input resources consumed and output quantities produced for eighteen Cost Centers, five Branches, four Divisions and the Directorate within AGMC/MA were collected, evaluated aggregated and applied to the DEA/CFA models for Fiscal Year 1983 through the second quarter of Fiscal Year 1985. Eleven Cost Centers, four Branches, two Divisions and the Directorate were then compared against themselves over those ten observation quarters and the analyses were discussed and validated by different HQ AGMC/MA management levels. The results of this research were deemed acceptable by these using managers as a useful aid to their decision making and demonstrates the capability of the DEA/CFA models to measure total factor technical productivity on maintenance levels above the Cost Center.

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I. Introduction

As a result of constantly rising costs and scarce resources, improving productivity has become one of the most important priorities of the Air Force Logistics Command (AFLC). In mid 1983, senior maintenance managers at the command Headquarters (HQ AFLC) formed the Productivity Measurement Working Group to develop a total factor productivity measure for depot-level maintenance (25). HQ AFLC sought to identify the most efficient organizations and discover new techniques to increase productivity, reduce costs and increase production (24:1).

In pursuit of this total factor productivity measure, the Directorate of Maintenance, Financial Management and Productivity Analysis Division proposed the following Air Force Institute of Technology (AFIT) thesis research topic:

> All efforts to date, to measure materials, energy, and capital productivity in AFLC have been less than successful. A system of standards, data collection and a measurement formula must be designed to provide a total factor (labor, material, energy, capital) productivity index. Additionally, a separate measurement of productivity should be developed for each input, i.e. material, energy, capital, and labor (23).

The thesis by Capt Richard E. Hitt Jr., USAF and Maj Robert F. Horace, USAF, (AFIT School of Systems and Logistics Class 84S), addressed this problem (24). Their research analyzed one Sacramento Air Logistic Center (ALC) hydraulic maintenance shop against itself over a three year period. The thesis validated the feasibility of measuring technical productivity improvements in AFLC depot-level maintenance by using the linear fractional programming techniques of Data Envelopment Analysis (DEA) and Constrained Facet Analysis (CFA). The DEA/CFA models were shown to simultaneously measure multiple inputs and outputs in the complex depot-level maintenance environment and display the results in an easily comprehensible format.

Statement of the Problem

HQ AFLC's desire for a command-wide technical productivity improvement measurement tool for maintenance operations was only partially fulfilled by validating DEA/CFA at the depot-level of maintenance. Hitt and Horace recommended further application, research and testing of DEA/CFA at the Aerospace Guidance and Metrology Center (AGMC), Newark Air Force Station (AFS), Ohio (24:74). AGMC was recommended because of its relatively small production output, stability, and highly automated actual basis accounting system.

On October 1, 1984, Mr. Robert E. Darling, Assistant Deputy Chief of Staff for Maintenance, HQ AFLC/MA, recommended that the research started by Hitt and Horace be continued at AGMC because of the promise of providing a command wide measure of total factor productivity (19). He stressed that, to be of value to HQ AFLC, it is essential to use actual operational data extracted from existing management information systems.

On October 12, 1984 Mr. William E. Daley, Deputy Director of Maintenance at HQ AGMC/MA agreed to let AGMC be used as a testing center for further research on the DEA/CFA models (18). Mr. Lucin E. Ball, Productivity Principal for the Directorate of Maintenance at HQ AGMC/MAWB was designated as the point of contact between HQ AGMC/MA and the continuing AFIT research.

With the approval of HQ AFLC/MA to sponsor the research at AGMC, and the agreement by HQ AGMC/MA Directorate of Maintenance to act as the testing center, further DEA/CFA application research could commence. It is the hypothesis of this research that the DEA/CFA models can be used to enhance the existing Management Information System (MIS) at HQ AGMC/MA to provide total factor measures of technical productivity improvements for maintenance Cost Centers, Branches, Divisions and the Directorate-level. The present MIS does not support decisions on total factor productivity improvement.

Objectives

The objectives of this thesis are as follows:

1. Establish input and output measures at AGMC to be used by the DEA/CFA model.
2. Evaluate the DEA/CFA models and discuss their advantages over other measurement techniques using data provided by AGMC.
3. Discuss the feasibility of using the DEA/CFA models as a total factor productivity measurement tool on maintenance levels above the Cost Center within AGMC.
4. Suggest specific recommendations on the use of the DEA/CFA models to measure technical productivity improvements at AGMC.

Scope

The continuing interest by HQ AFLC in increased productivity was thoroughly covered in the literature review done by Hitt and Horace. This thesis will review the background, current information on and applications of the DEA/CFA models. Also, information on productivity measurement techniques other than DEA/CFA published since the Hitt and Horace thesis will be reviewed for their applicability to this research.

This thesis examines the application of the DEA/CFA models to measuring technical productivity improvements for the entire Directorate of Maintenance at AGMC. The results of the DEA/CFA model simulations will be analyzed by the author and reviewed with AGMC Cost Center, Branch, Division and Directorate-level managers.

The following assumptions are made:

1. The reader is familiar with the information presented in the thesis by Hitt and Horace (24). However, Chapter III does contain a review of how DEA/CFA models work. Also, Appendix A contains a reference glossary of key definitions applicable to this research.

2. The input and output data supplied by the Directorate of Maintenance at AGMC is valid and accurate (4).

II. Literature Review

Background

The great emphasis HQ AFLC places on productivity improvements was underscored recently in a proclamation issued by Secretary of Defense Weinberger. His remarks made during DOD Productivity Week, January 7 - 13, 1985, stressed his personal commitment to achieving the highest level of productivity across all Defense operations:

> I encourage every individual in the Defense community, both military and civilian, to look for opportunities to improve the processes, products, and effectiveness of his or her organization. By being innovative and creative, and by aggressively pursuing goals of excellence and productivity, we can make significant gains in Defense readiness. Equally important, those efforts will ensure full value from the funds entrusted to us by the American taxpayer. (27:3)

HQ AFLC needs a total factor, command-wide technical productivity improvement measurement tool to address the issue raised above by Secretary Weinberger. This chapter will review current literature for information and applications of the DEA/CFA models published since the Hitt and Horace thesis. It will also discuss recent publications on productivity measurement techniques other than DEA/CFA to ascertain if they are more appropriate for this research.

Hitt and Horace presented the first application of the DEA/CFA models to an actual USAF activity. Their literature review presented a brief history of the productivity discipline, developed and defined key concepts, and gave a description of the current Department of Defense and United States Air Force productivity programs (24:5-20).

The methodology chapter of the Hitt and Horace thesis gave a brief insight into how DEA and CFA work (24:21-29). A more rigorous treatment of the past history, theory and applications of DEA models is contained in the report by Bessent, Bessent and Clark (9). Chapter III of this thesis contains a brief explanation of how DEA/CFA analysis works.

The above report traces the evolution and application of DEA from the 1957 work by Farrell (21) on measuring productive efficiency to the period just prior to the Hitt and Horace thesis. This work accomplished the following (9):

1. Related the theory of DEA to its predecessors in the literature.
2. Presented DEA mathematical models and their linear programming equivalents.
3. Contrasted DEA with other methodologies currently employed in measuring efficiency.
4. Reviewed the various applications that had been reported up to May 1983.
5. Suggested ways in which DEA could be used for management purposes other than efficiency assessment through extensions of the theory and improvement of existing software.

The inability of DEA to provide planning information led Bessent, Bessent, Clark and Elam in May 1983 to formulate a new method of computing efficiency called Constrained Facet Analysis (CFA) (8). A review of how DEA and CFA work is given in Chapter III of this thesis.

Current DEA/CFA Information and Applications

DEA was first reported in the literature in 1980 and CFA in 1983. Both analysis techniques are still quite new and the volume of literature published on them is relatively small, but growing. Since the beginning of 1984 four papers have been published on the DEA/CFA model. The subjects of the four papers are: determining the direction of returns to scale; an application of DEA and discussion of "window analysis"; investigating production relationships using CFA; and an application of measuring productive efficiency.

In the first paper, Banker, Charnes, and Cooper present models for estimating technical and scale inefficiency by using DEA (6). They introduce a new variable to the DEA mathematical formulation which makes it possible to determine whether operations under consideration were conducted in regions of increasing, constant or decreasing returns to scale (in multiple input and multiple output situations). An operation will exhibit increasing, constant or decreasing returns to scale depending on whether the marginal product is greater than, equal to, or less than the average product (3). Banker, Charnes and Cooper provide models for estimating technical and scale efficiencies of decision making units with reference to the efficient production frontier (6:1088). Their interpretations suggest that a scale efficiency measure can be defined as the ratio of the aggregate efficiency measure to the technical efficiency measure (6:1089).

The second paper presents a developmental application of using DEA to measure the efficiency of maintenance units in the USAF by Charnes, Clark, Cooper and Golany (13). The paper evaluates the efficiency of 14 Decision Making Units (DMUs) which were Air Force flying wings. These wings were elements of two USAF Numbered Air Forces (the next higher echelon of command than a wing) (13:1). The efficiency of the evaluated wings was referenced to output and input variables commonly used in evaluating the performance of aircraft maintenance units. The emphasis of the article was on the individual efficiency score of each wing (13:3). DEA was selected for this developmental application for the following reasons (13:3):

1. DEA is non-parametric (requires less stringent assumptions about the variables) and hence proceeds in a manner that does not require explicit specifications of the assumed functional forms.
2. DEA optimizes on each observation instead of averaging across all observations as is usually done in statistical regression (and related) approaches.

This paper also expanded on the concept of "window analysis" first employed by Divine, Klopp and Stutz (20) for DEA evaluation. "Window analysis" is the rearrangement of the data observation periods to overcome the limits of the degrees-of-freedom requirements that effect efficiency evaluations when using DEA (13:15-22). The authors concluded that the use of ratio analysis, regression analysis and simulation does not preclude the use of DEA or vice versa (13:30).

The third paper by Bessent, Bessent, Clark and Elam (10) deals with using CFA to investigate production relationships in local frontiers of efficiency. It was presented in November 1984 in Dallas, Texas to the Joint National Meeting of the Operations Research Society of America and the Institute of Management Science. The paper demonstrated that the properties of CFA broaden the applicability of the DEA model by creating enveloping conditions for nonenveloped units. Specifically, CFA was shown to (10:2-23):

1. Produce upper & lower efficiency bounds.
2. Determine marginal productivity and marginal rates of substitution.
3. Provide alternative efficient input and output mixes.

The paper concluded with a discussion of the cases that do not satisfy the conditions sought by CFA. The test data used in the article indicated that CFA results could be affected both by inadequacies of data and by distribution of units defining the frontier (10:23). The problem conditions discussed were (10:24-25)

1. Insufficient observations to fully define the measurement space.

2. Poorly defined frontier.

3. Inefficient outlier units with a dissimilar resource mix resulting in an intractable non-envelopment.

4. An input not trading off with at least one other input and/or being negatively correlated with at least one output. Inputs are suppose to trade off with at least one other input and be positively correlated with at least one output.

5. Univariate distribution of inputs and outputs are not required to assume any parametric form but low bimodal distributions are to be avoided.

The final paper by Byrnes, Fare and Grosskopf applied a generalized version of the Farrell measure of technical efficiency to a sample of Illinois strip mines (12). The authors developed a more general measure of technical efficiency than that derived by Farrell (21) by relaxing the following two assumptions (12:671):

1. That production exhibits constant returns to scales.

2. That there is a strong disposability of inputs.

Relaxing the above two assumptions permitted the authors to decompose the technical efficiency measure derived by Farrell into the following three components (12:671):

1. A measure of input congestion. Production technology exhibits congestion if one input is increased, and output falls. Stated differently, congestion occurs when reducing usage of a proper subset of inputs, holding constant the usage of all remaining inputs, generates a increase in output.

2. A measure of scale efficiency.

3. A measure of pure technical efficiency.

These components identify the sources and magnitude of inefficiency in production and can easily be calculated as the solutions to relatively simple linear programming problems (12:680).

The four papers discussed above which were published during 1984 indicate that the body of research into and applications of the DEA/CFA models is relatively small, but growing. The work by Bessent, Bessent, Clark and Elam (10) on broadening the applicability of the DEA model through the use of CFA will be extremely beneficial to this research.

Other Productivity Measurement Techniques

Bowlin, Charnes, Cooper and Sherman (11) made a detailed comparison of DEA with ratio and regression analyses approaches to efficiency estimation and evaluation. The presentation is the second revision of a paper first presented in November 1982 to the Fourth Annual Conference on Current Issues in Productivity at Cornell University. The authors conclude that ratio analysis is the most commonly used approach to efficiency evaluation, and the worst indicator available (11:35). Also, that regression approaches receive preferred status because of the standard types of statistical inferences available with these approaches. However, in their comparisons of DEA with ratio and regression analyses the authors stress that the different techniques could be used successfully in various combinations (11:37). They also emphasized that DEA was an alternative and that still other alternatives could be obtained by combining DEA with other approaches such as ratio and regression analyses.

The next publication by Sink, Devries, and Swaim (26) represents the development of a taxonomy of productivity measurement theories and techniques currently in use. An abstract of the February 29, 1984 report states

> This research effort is a component of project 83-01 contractor productivity measurement which is being executed by the Army Procurement Research Office for the DOD. Through the use of extensive literature searches and targeted site visits, the study identified three generic productivity measurement techniques. These techniques are:
>
> 1. Multi-factor productivity measurement model (also called the total factor productivity model, hybrid versions that operate the model at the product level of analysis also exist).
>
> 2. The multi-criteria performance/productivity measurement technique (also called the objectives matrix).
>
> 3. The normative productivity measurement methodology (a structured participative approach to developing productivity and performance measurement, evaluation, control and improvement systems).

> The study is highly correlated to productivity but is not a direct ratio of output to input. The final project report contains: a section on productivity basics, productivity measurement and evaluation tecnniques described in detail with site summary examples for each technique, productivity measurement theories and techniques taxonomy and, summary and conclusions. The study and report represent the most comprehensive compilation and description of state-of-the-art and practice productivity measurement techniques in existence at this time.

The final paper is a graduate thesis from the Naval Post Graduate School by Galdrun (22) published in March 1984. The thesis contains suggestions for development of computerized productivity measurement in military outpatient clinics. An abstract of this thesis states that it is:

> A method to measure productivity in military outpatient clinics does not exist. Present methodologies are too broad in scope to assess these clinics successfully. A methodology is proposed to measure output by using an indicator based on six weighted components of output measure. These components were derived from the literature concerning productivity measurement, from existing methodologies, and from the author's personal experience.

Galdrun's thesis relies exclusively on regression analysis techniques to measure productivity. The first presentation in this section by Bowlin, Charnes, Cooper and Sherman (11) amply pointed out the shortcomings of using regression analysis alone to measure multiple input/output productivity.

The most important of these three presentations to this research is the work by Bowlin, Charnes, Cooper and Sherman (11). Their work comparing DEA with ratio and regression analyses, forms the basis of the current research which prefers the DEA/CFA models over ratio and regression analyses.

Summary

This chapter has been a literature review of current information and applications of DEA/CFA reported in the literature since the Hitt and Horace thesis. It also discussed recent publications on productivity measurement techniques other than DEA/CFA to ascertain if they were the more appropriate to use in this research.

Current research demonstrates that the DEA/CFA models can measure total factor technical productivity improvements and are the best techniques presently available to use in this research effort.

The next chapter explains the methodology used in this research, as well a brief explanation of how the DEA/CFA models work.

III. Methodology

Introduction

This chapter fulfills the first objective of the thesis which is to establish criteria to select input and output measures to be used by the DEA/CFA model simulation. The methodology development starts with a review of how the DEA/CFA models work. Then the selection of AGMC as a testing center and its organizational layout is explained. Next, the data input and output variables are identified and selected for use in the DEA/CFA models. Finally, applying the models to the data for the 17 production Cost Centers, 5 Branches, 4 Divisions and the Directorate of Maintenance for the Aerospace Guidance and Metrology Center is discussed.

How DEA and CFA Analyses Work

Data Envelopment Analysis. DEA was developed by Charnes, Cooper and Rhodes (15) and is based on a concept of efficiency originally proposed by Farrell (21). The DEA procedure was designed to evaluate the relative efficiency of public sector organizations performing similar type functions for which actual measure of inputs and outputs can be obtained (14). DEA is an application of fractional linear programming techniques especially valuable for measuring the relative efficiency of public sector organizations because of the lack of a profit measurement. With the aid of computer resources, DEA can easily evaluate multiple inputs and outputs and their interrelationships simultaneously.

An example of DEA using a simple two input and one output situation is explained on the following pages. In this simplistic example the results of using DEA can be shown on a Cartesian Coordinate graph (see Figure 1). However, when more than one output or more than two inputs are evaluated, the results cannot be graphically displayed.

Clark expresses the mathematical form (shown in Appendix B) of DEA as a ratio cf outputs to inputs (16). He defines a decision making unit (DMU) as the organizational entity being evaluated. In the case of this research, each of the 18 Cost Centers will be a separate DMU, and will have similar measures of input and output. Another comparison method would be to analyze each individual Cost Center against itself over quarterly periods and treat each quarter as a DMU. The latter method is the one used in this research and will be explained further in the section on testing the DEA/CFA models near the end of this Chapter.

In order to understand of how DEA works, it is critical to differentiate between efficient and inefficient DMUs. Charnes, Cooper and Rhodes (15:669) define DMU efficiency as a combination of the following two factors:

1. Output Orientation. A DMU is not efficient if it is possible to increase output without increasing any input and without decreasing any other output.

2. Input Orientation. A DMU is not efficient if it is possible to decrease any input without augmenting any other input and without decreasing any output.

The following is a graphical example of a two input, single output comparison using DEA for nine organizations (DMUs). After all the organizations in the set are compared, the best ones will be located & used by DEA as a reference to measure the efficiency of the others. DEA using computer resources would accomplish the same thing using linear programming techniques. This example was developed in the AFIT Logistics Management course 6.35, Evaluation of Air Force Organizations, in February 1985 (16) and is based upon the work of Clark (17).

Suppose organizations A,B,...,I shown in Table I below, each produce the same type of output Z using the same two types of inputs X and Y during some specified time period. Table I shows the amounts of outputs produced and inputs consumed during the production process.

TABLE I

Input and Output Values for Organizations A through I

Organization	Inputs		Output
	X	Y	Z
A	3	12	3
B	6	6	3
C	8	2	2
D	5	1	1
E	2	3	1
F	3	3	1
G	3	2	1
H	16	24	4
I	4	16	2

Initially DEA reduces the inputs for the nine organizations by the amount of output produced. For organization A, inputs X of 3 & Y of 12 and output Z of 3 would be divided by the output Z, which in this case is 3. This division would result in X of 1, Y of 4 and Z of 1. The above procedure is repeated for all organizations and the results shown in Table II, along with the efficiency rating given each organization by DEA. Note that organization D in Table II, does not have an efficiency rating assigned to it at present because it is not enveloped by an actual organization (also see Figure 1), and cannot be handled by using DEA alone. The next section on Constrained Facet Analysis (CFA) will discuss organization D in detail.

TABLE II

DEA Efficiency and Scaled Input & Output Values for Organization A through I.

Organization	Input/Output X/Z	Input/Output Y/Z	Output/Output Z/Z	Efficiency Rating
A	1	4	1	1.00
B	2	2	1	1.00
C	4	1	1	1.00
D	5	1	1	??
E	2	3	1	0.86
F	3	3	1	0.67
G	3	2	1	0.86
H	4	6	1	0.43
I	2	8	1	0.50

Figure 1, on page 22, represents the above nine DMUs, each with different inputs (X and Y) and the same output quantity Z. The output quantities are all one because of the previous scaling illustrated in Table II. By connecting the DMUs closest to the origin value of 0 (in this case DMUs A, B, & C), a piece-wise linear frontier is established. This frontier represents the most efficient DMUs and is established as the relative efficiency frontier. Each DMU on the relative efficiency frontier (DMUs A, B, & C) produce the same output with less input quantities (mixes of X and Y) than DMUs not on this frontier (DMUs E through I). DMUs A, B, and C are considered by DEA to be 100% efficient (see Table II). This is not an absolute rating of these DMUS, but rating given by DEA to the best of the observed DMUs with no reference to an actual or ideal production function.

The next thing the DEA model does is to compare the inefficient DMUs (in this case E through I) to the segment of the frontier they are closest to. For example, DMU E, point (2,3) would be compared to the (A to B) segment and DMU G, point (3,2) would be compared to the (B to C) segment of the relative efficiency frontier. This comparison is done by extending a ray from the origin, point (0,0), to each of the DMUs as illustrated in Figure 1. The efficiency of DMU E would be the ratio of the length of the line segment from the origin to the intersection of the frontier segment (A to B), divided by the entire length of the ray from the origin to point E. In this case the efficiency is 0.86. The relative efficiency rating of DMUs F, G, H, and I would be computed in a similar manner.

Since the ray from the origin to DMU D does not cross any relative efficiency frontier, DEA is unable to evaluate the relative efficiency of D. The evaluation of organization D is the subject of the section on CFA.

The above example illustrates three important concepts of DEA:

1. ENVELOPMENT. Points beyond the frontier (such as point E) are compared to the empirically derived relative efficiency frontier segment (such as from points A to B), because the ray from the origin to point E passes through the frontier.
2. UNBIASNESS. The relative efficiency rating of points beyond the frontier (for example point E) is derived without comparison to any artificial weights or standards, but only to the relative efficiency frontier segment (from points A to B). Inefficient DMUs are directly compared only to DMUs on the relative efficiency frontier which have similar mixes of inputs and outputs. This is a fundamental advantage when using DEA because it overcomes the tendency to compare dissimilar activities.
3. NEIGHBORHOOD. The clustering of several DMUs together in an area of a graph (such as points B, C and G in Figure 1) is considered a neighborhood. For example, point G would be in the neighborhood of line segment (B to C).

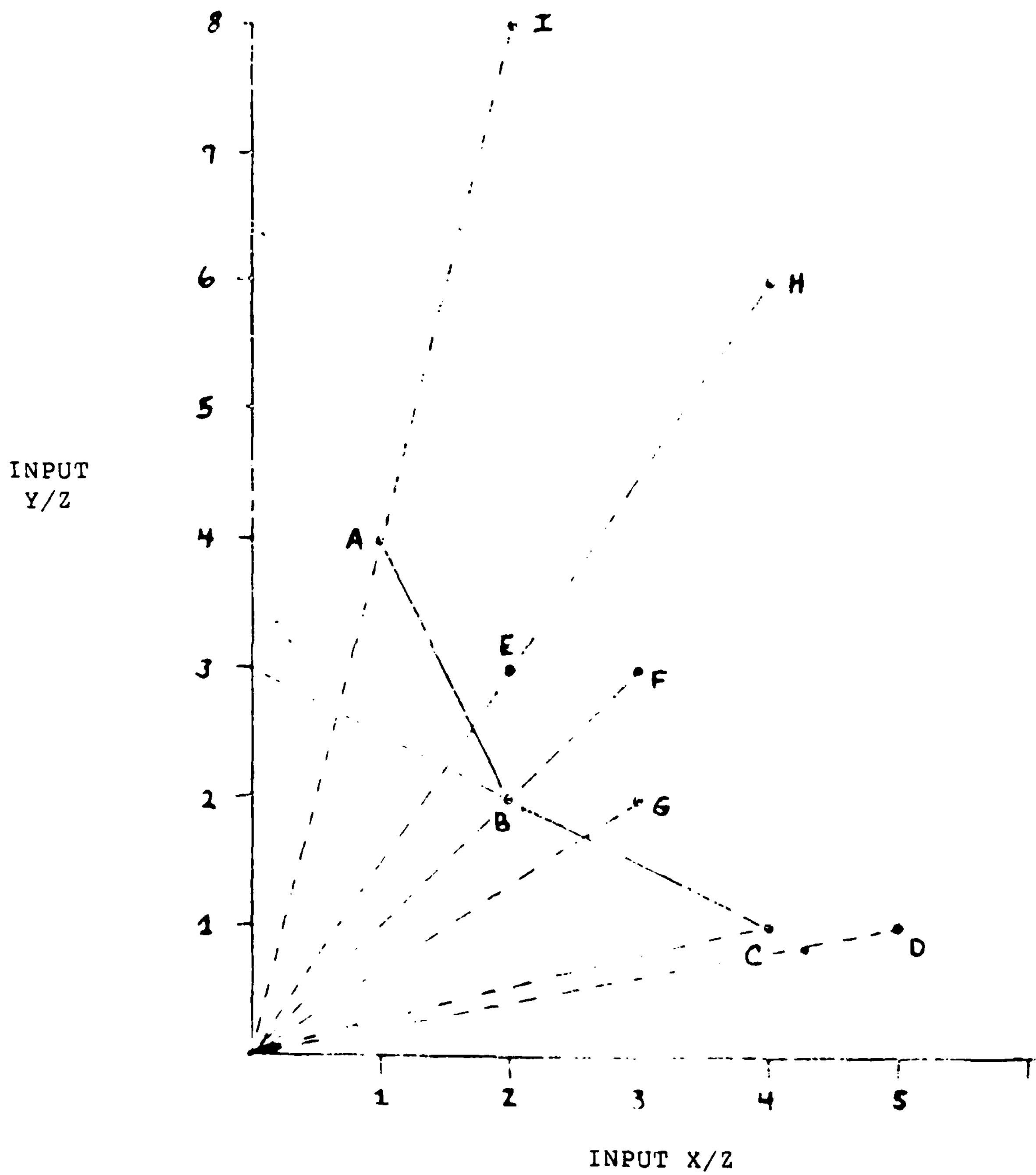


Figure 1. Graphical Presentation of How DEA & CFA Works

Constrained Facet Analysis. A limitation of the DEA model is that DMUs beyond the frontier and on the same ray as other DMUs on the frontier are not rated (7). To adjust for this limitation, Bessent, Bessent Clark and Elam (8) extended the use of DEA to cover situations like DMU D (see Figure 1), that are not enveloped by the relative efficiency frontier. Referring to Figure 1, CFA computes an artificial lower bound of efficiency by creating a downward sloping extension of the segment (B to C) to the X/Z axis and an upper bound of efficiency by creating a horizontal frontier extension parallel to the X/Z axis from DMU C. The relative efficiency rating of point D is now computed except that the two artificial frontiers are used. Using the DEA/CFA models on the Burroughs B-20 computer, and the data from Table I resulted in a range of efficiency for organization D. The range has an upper bound of 100% and a lower bound of 75%. Because of CFA, all DMUs can now be evaluated, although for points like D only a range can be given.

The second important utility of CFA is the in-depth analysis of neighborhood portions of the frontier. Several DMUs clustered together in an area of a graph (such as points B, C and G in Figure 1) are considered a neighborhood according to Clark (16). Specific actions that would move inefficient DMU G to the relative efficiency frontier segment (B to C) can now be explored by examining the general characteristics of the DMUs in that neighborhood.

Since points B and C are considered efficient and in point G's neighborhood, point G should be able to improve to an efficiency level comparable to B and C.

Summary of DEA and CFA Characteristics. Clark summarized these important DEA and CFA characteristics as useful to organization managers (16):

1. Frontiers of efficiency are based on empirical data instead of assuming an ideal production function.
2. All aspects of an organization including trade-offs and interactions between inputs and outputs are simultaneously measured.
3. Efficient or inefficient ratings of all DMUs are provided. If a DMU has a unique input/output mix and is unbounded by the relative efficiency frontier, it is still rated with estimates of efficiency boundaries.
4. Individual DMU inputs and outputs are rated for their contribution to a DMUs efficiency rating, thus helping to pinpoint and prioritize corrective actions for inefficient DMUs to management.
5. Value judgments or *a priori* weights are not used on inputs or outputs for DEA or CFA calculations, thus making DEA and CFA unbiased.

6. DEA/CFA assigns the highest possible efficiency rating to inefficient DMUs, thus giving them the benefit of doubt concerning measurement error and encourages participation in measurements reducing the reluctance to participate in the measurement.
7. Inefficient DMUs are compared only to similar, efficient DMUs in their neighborhood. This reduces the possibility of trying to compare "apples and oranges" in terms of scales of operation.

Data Collection

AGMC Selection. AGMC was selected by HQ AFLC as a testing center because of its relatively small production output, stability, and highly automated actual basis accounting system. AFLC Pamphlet 190-4 describes AGMC as:

> the single center within the Air Force for repairing inertial guidance and navigation systems for missiles and aircraft, and for certain aircraft displacement gyroscopes. It also provides a full range of engineering and consultation services on inertial systems to the Air Force and other DOD agencies. AGMC establishes, maintains and performs overall technical direction and management of the Air Force Metrology and Calibration Program and operates the Air Force Measurement Standards Laboratories. It provides technical and procedural direction for operation of a single, integrated measurement system, as well as the design and periodic calibration and certification of measurement standards used in all Precision Measurement Equipment Laboratories. (1)

Organizational Layout. This thesis will measure technical productivity improvements for the entire AGMC Maintenance Directorate. The Directorate consists of 35 Maintenance Shops, 17 production Cost Centers (plus one non-production cost center used to collect costs of certain employees who are on temporary duty), five Branches and four Divisions. The research will analyze the last ten quarters of maintenance productivity information, which includes all information for Fiscal Year (FY) 1983, FY 1984, plus the first two quarters of FY 1985. The information from FY 1983 will serve as the base year. Input dollar values for FY 1984 and FY 1985 data will be adjusted for inflation to the FY 83 base year before being used in the DEA/CFA models.

The 35 maintenance shops at AGMC will not be analyzed individually because the automated accounting system at AGMC records information by Cost Centers only. Therefore, the lowest organizational level evaluated by this research is the 17 production Cost Centers. Each is individually analyzed and compared against itself over the ten quarter period. The data from the 17 Cost Centers are summed to form the totals for the five Branches which will be analyzed individually and compared over the ten quarter period. Then the data from the five Branches are summed to form the totals for the four Divisions, which will be analyzed individually and compared over the ten quarter period also. Finally, the data from the four Divisions (and the one non-production cost center) are summed to form the totals for the entire Maintenance Directorate at AGMC which will be analyzed over the ten quarter period. Figure 2 shows the interrelationships of the codes used by AGMC for each Cost Center, Branch, Division, and the Maintenance Directorate.

As Figure 2 indicates, Cost Centers 1-4 form Branch MABP and Division MAB. Cost Center 5 is also Branch MAQC and Division MAQ. Cost Center 6-9 form Branch MAKP which is duplicated as Division MAK. Cost Centers 10-14 are contained in Branch MANL and Cost Centers 15-17 are contained in Branch MANT. Branches MANL and MANT together comprise division MAN. Division 1-4 (plus non-production cost center 18, MTTTA) comprise the entire Directorate MA.

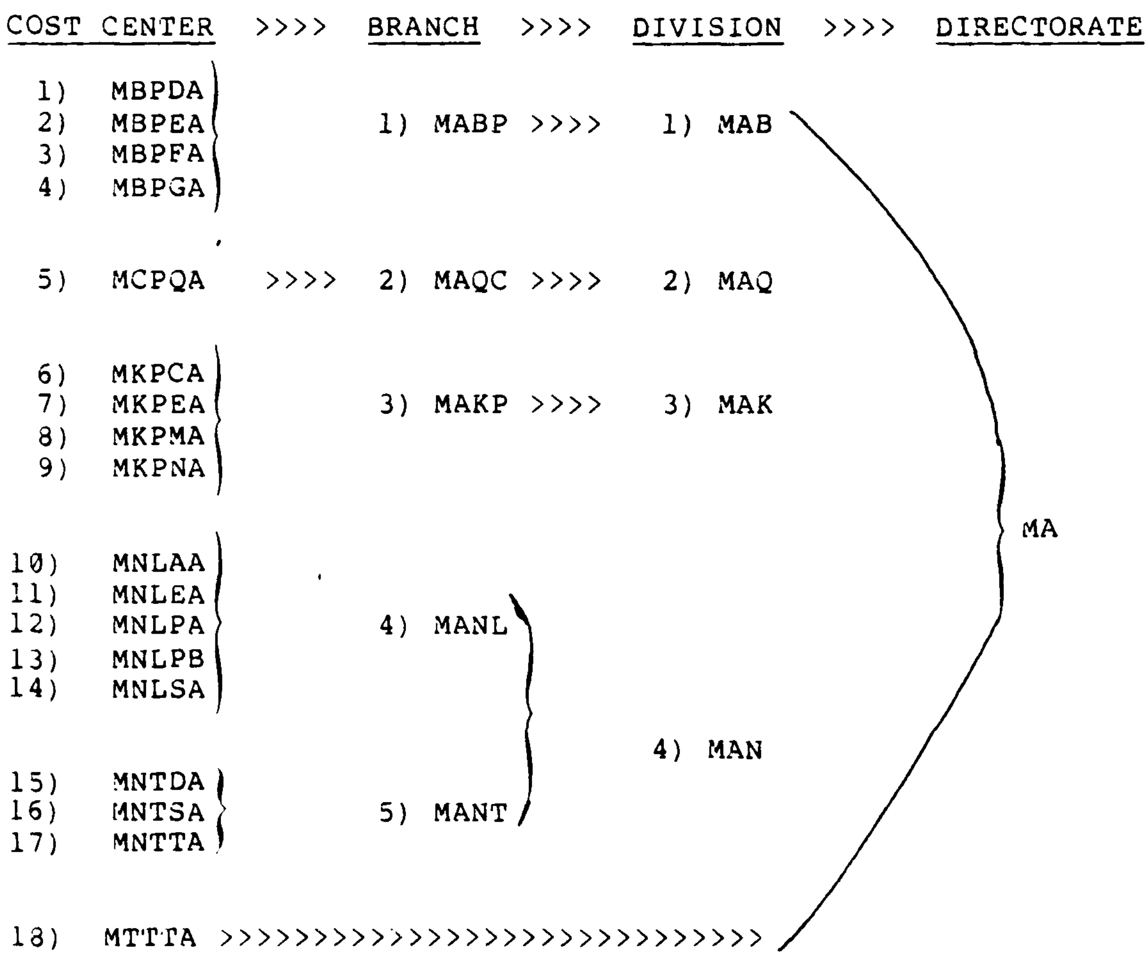


Figure 2. AGMC Cost Center, Branch, Division and Directorate Codes

Input and Output Measures Selected. According to Clark (16), input and output measures used in DEA/CFA analyses should have the following attributes:

1. The measure should have logical appeal to both the researcher and management so that they will be acceptable to both.
2. The advice and operational objectives from all levels of management should be considered in selecting the input and output mix to be used. Involving all levels of management in the selection process improves the future acceptance of the results by these managers.
3. To maximize the level of accuracy of the DEA/CFA model, the sum of the number of input and output variables used should be approximately one half of the number of observation periods. The reason for this is the degrees-of-freedom limitation imposed by statistical analysis.

A sample page of the raw input data from the Quarterly End Item Product Cost Report provided by AGMC's MIS is shown in Appendix C. This report is a computer printout product (FXAT59) which lists the inputs and end item outputs by Cost Center by FY quarter. It is necessary to combine selected values from the FXAT59 printout to derive the inputs for each Cost Center, Branch, Division and the Maintenance Directorate. Appendices D1 -D10 show the adjusted for inflation input and output values used in the DEA/CFA model for each Cost Center, Branch, Division and the Maintenance Directorate for all ten FY quarters.

FY 1983 was established as a base year because of the Industrial Maintenance Productivity Improvement Program (PACER IMPACT). According to AFLC Regulation 66-14 (2):

> PACER IMPACT is a total factor productivity improvement effort that includes labor, capital investments in equipment and facilities, energy, materials, methods design, and employee development and involvement. It includes all activities related to the improvement of Industrial Maintenance Productivity in AFLC's depot maintenance organizations at HQ AFLC, the Air Logistics Center (ALC) Maintenance activities, AGMC, and the Material Air Storage Disposal Center (MASDC). It shall include all productivity related programs funded by the Depot Maintenance Service (DMS), Air Force Industrial Fund (AFIF) as well as those related programs not funded by DMS or AFIF. PACER IMPACT is designed to balance resources and advance productivity while significantly increasing the AFLC Maintenance contribution to the war readiness of the Air Force.

The second quarter of FY 1985 (January - March 1985) was established as the cutoff date for data collection. Therefore, only ten observed quarters of data are available for analysis. The ten FY observed quarters of data limit the DEA model to ten DMUs. Ten observed quarters is not an ideal base to work with since only five or six variables can be measured simultaneously. However, the ten FY quarters of data are enough to effectively use the DEA/CFA modeling techniques. Follow on research to this thesis can add additional observations periods to expand the capability to measure more inputs and outputs simultaneously.

AGMC Financial Management and Productivity Branch personnel, Directorate level management and the author identified eight input and one output candidates for use in the DEA/CFA models. Since the DEA/CFA model can effectively use five or six total variables, combinations of some of the input variables was required to meet the imposed limitations of ten FY quarters observations. The next section on input measures will explain the four input combinations that were selected for use with the DEA/CFA models, and the section after that will explain the single output measure developed.

Input Measures. Satisfying the input selection attributes suggested by Clark and the restriction imposed by the limited number of FY quarters of data led to the four input combinations of Direct Product Actual Hours (DPAH), Direct Labor Cost (DLC), Direct Material Cost (DMC), and Overhead & Miscellaneous Cost (OMC). These input values can be obtained from the FXAT59 computer printout provided by AGMC for each Cost Center by FY quarter. As discussed earlier, Appendices D1-D10 list the actual values (adjusted for inflation), used as the inputs and output by FY quarter for each Cost Center, Branch, Division and the Maintenance Directorate. Appendices E1-E24 list the actual input and output measures (adjusted for inflation), used for each particular organizational entity over the ten observation quarters. The combinations of data from the FXAT59 computer printout contained in Appendices D1-D10 represent the following four inputs defined below (4):

1. Direct Product Actual Hours (DPAH) are the number of hours used by the Cost Center to produce the End Items (E/I) accomplished during the specified time period. The DPAH for an individual control number are the hours required to produce the specified quantity of End Items. The total DPAH for the Cost Center are the hours required to produce all of the E/I worked by the Cost Center.

2. Direct Labor Cost (DLC) identifies the cost of direct labor, in dollars, used to accomplish the specified production for the period.

3. Direct Material Cost (DMC) is composed of the dollar totals for DMC-Expense & DMC-Exchange defined as:

    DMC-Expense is the cost of material used by the cost center, which is installed directly on the product being worked by the Cost Center.

    DMC-Exchange is the cost of components exchanged (replaced) on End Items in order to make them serviceable. The exchangeable component is removed in an unservicealbe condition and replaced with a serviceable one. The exchange material cost is not included in the Grand Total row / Total column labeled C in Appendix C.

4. Overhead & Miscellaneous Cost (OMC) is composed of the sum of Shop, Support, General Administrative and Other Direct Miscellaneous Costs defined as:

    Shop Overhead Cost is labor charges for supervision, training, standby, and miscellaneous within the Cost Center.

    Support Overhead Cost is the cost of labor for the product support staff other than the Cost Center.

    General Administrative Overhead Cost is the cost of General and Administrative support including the Directorate office, and staff offices, Civilian Personnel. Civil Engineering, Dispensary, energy, etc.

    Other Direct Miscellaneous Cost are charges for temporary duty (TDY) that is made in direct support of a production output. (While it is not a true overhead or miscellaneous cost, this other direct miscellaneous cost category only accounts for $3,291.00 over the ten FY quarters and is therefore included to keep the figures in agreement. The Grand Total dollars spent by AGMC for the ten quarters is over $185 million. In comparison, this $3,291.00 is somewhat insignificant).

A sample calculation of input data extracted from Appendix C (unadjusted for inflation) is shown in Figure 3. Appendix C shows the final totals for the 1st quarter of FY 1985 for Cost Center MNTTA on the line labeled A. The values on the line labeled ACT, standing for actual amounts, are the ones used by this research effort. The Grand Total line labeled B represents the final totals for that quarter for the entire Maintenance Directorate. The values on the line labeled ACT, representing actual amounts, is the one used by this research effort. The inputs for the Maintenance Directorate (unadjusted for inflation) extracted from Appendix C are discussed in Figure 3. Note that the Grand Total row / Total column intersection labeled C in Appendix C is $19,055,488 and does not agree with the $20,000,288 Total shown in Figure 3. This is because the figure labeled C in the End Item Quarterly Product Cost Report shown in Appendix C does not contain the dollar value for the DMC-Exchange of $944,800, whereas this cost is a component of the DMC input used in this research effort.

INPUT NAME	VALUE	HOW DETERMINED
DPAH	435,523.17	Read directly from the printout. DPAH is in hours and not dollars.
DLC	$ 6,753,068.00	Read directly from the printout.
DMC	$ 5,151,277.00	Add dollar totals for DMC-Expense of $4,206,477 & DMC-Exchange of $944,800.
OMC	$ 8,095,943.00	Add Overhead for Shop of $2,699,341, for Support of $2,755,116 for General Administrative of $2,641,486 and for Other (located to the right of DLC) which is $0.00.
TOTAL	$20,000,288.00	This is a total of dollars only and does not include DPAH.

Figure 3. Sample Quarterly Input Calculation for the Directorate

Output Measure. A single output measure will be used by the DEA/CFA model because of the restriction on total input/output measures previously discussed. Because only a single output measure was possible, a scaling method was devised to quantify & equalize the End/Item output production at AGMC.

As previously discussed in the section on input and output selection, five is the optimal number of total variables when only 10 observations of data are available. Since four of these variable inputs have already been dedicated by the input selection, only one variable remains uncommitted.

A scaling method was developed to quantify and equalize the End/Item production within each organizational level. Scaling of the End/Items to a common "universal widget" within each organizational level is necessary because AGMC produces over 250 different End/Item products. Within any given Cost Center, dozens of these different End/Item products may be produced during any given quarter. For example, Cost Center MKPEA alone has over 600 different job control numbers during any given quarter, representing dozens of different End/Item products. There are over 2,000 job control numbers for all 17 production Cost Centers. Scaling the End/Item products by Cost Center is necessary to compute a "universal widget" which can be used to measure production. By scaling all the End/Item products the problem of adding different production output types within a Cost Center is overcome, because now everything has been converted to "universal widgets". The present MIS does not provide a universal output measure.

The scaling process identifies the End/Item product with the largest DPAH per unit in each Cost Center over the ten observation quarters. Mr. Lucin Ball, AGMC Financial Management & Productivity Branch (MAWB), used a Zenith 100 microcomputer to scale all 10 FY quarters of data for each organizational entity in the following manner. Using the

Zenith 100, Mr. Ball scaled the End/Item output units completed over all 10 observation quarters to the unit with the largest DPAH per unit in each Cost Center. The same type scaling was done for the Branch, Division, and Directorate levels. Each organizational level was scaled to its respective unit with the largest DPAH per unit over the 10 observation quarters. Figure 4 shows an actual scaling printout from the Zenith 100 of the relatively small Cost Center MBPGA. The scaling was accomplished for each job control number with End/Items completed (Column A) in a FY quarter by dividing DPAH (Column C) by the number of units completed (Column B) which yields hours per unit (Column D). The hours per unit for each control number (Column D) were then divided by the desired largest DPAH per unit for the entire 10 observation quarters, which yields the scale factor for that control number (Column E). The scale factor (Column E) was then multiplied by the number of units (Column B) to obtain the scaled number of equalized units or "universal widgets" (Column F). The same process was repeated for the Branch (Columns G & H) and the Directorate (Columns I & J). The scaled units were then totaled for the respective organizations shown in Columns F, H, and J.

Scaling was necessary because all End/Item units of output are not equal, in terms of labor standards or the DPAH actually required to produce one item. This scaling process equalizes all production output to the one unit with the largest DPAH in the respective organization, thereby producing the desired "universal widget". This "universal widget" can now be added as necessary to form the Branch, Division and Directorate totals. This scaling process ignores Work-In-Progress (WIP) at the end of a given FY quarter. However, it was assumed that the WIP will remain relatively constant from one FY quarter to the next. The output quantities produced by this scaling method is summarized by organization level and FY quarters in Appendices D1-D1Ø. Appendices E1-E24 contain individual data for each entity over the ten FY quarters.

[illegible]LE NAME: MBPGA852

[illegible]ARGEST DPAH/UNIT(CC): 84.68 BR: 969D/M: 3088

[illegible]NT	QTY	DPAH	HR/ UNIT	SCALE FACT.	UNITS SCLD	SCALE BR	UNITS SCLD	SCALE D/M	UNITS SCLD
A	B	C	D	E	F	G	H	I	J
[illegible]748	1	9	9	.1063	.1063	.0093	.0093	.0029	.0029
[illegible]478	1	15.81	15.81	.1867	.1867	.0163	.0163	.0051	.0051
[illegible]440	1	37.76	37.76	.4459	.4459	.0390	.0390	.0122	.0122
[illegible]462	1	17.49	17.49	.2065	.2065	.0180	.0180	.0057	.0057
[illegible]466	1	18.29	18.29	.2160	.2160	.0189	.0189	.0059	.0059
[illegible]000	450	13350.56	29.67	.3504	157.7	.0306	13.78	.0096	4.32[illegible]
[illegible]5050	86	2069.16	24.06	.2841	24.44	.0248	2.135	.0078	.67[illegible]
75200	288	9949.7	34.55	.4080	117.5	.0357	10.27	.0112	3.222
75250	60	1642.23	27.37	.3232	19.39	.0282	1.695	.0089	.5318
75300	67	3355.89	50.09	.5915	39.63	.0517	3.463	.0162	1.087
75500	53	3113.39	58.74	.6937	36.77	.0606	3.213	.0190	1.008
75600	144	5344.97	37.12	.4383	63.12	.0383	5.516	.0120	1.731
75[illegible]	89	4573.11	51.38	.6068	54.00	.0530	4.717	.0166	1.48[illegible]
75750	116	6430.15	55.47	.6546	75.93	.0572	6.636	.0180	2.092
[illegible]	40	1674.97	41.87	.4945	19.78	.0432	1.728	.0136	.5424
[illegible]					[illegible]		[illegible]		[illegible]

Figure 4. Output Scaling for Cost Center MBPGA
FY 1983, 1st Quarter

Applying the DEA/CFA Models

As previously discussed, a single scaled output measure was devised and four input measures were selected to analyze each Cost Center, Branch, Division and the Directorate. PACER IMPACT established FY 1983 as the base year and inflation factors from Air Force Regulation (AFR) 173-13 (condensed from the US Government Office of Management and Budget) will be used to discount the dollar values for all FY 1984 and two quarters of FY 1985 data.

The next chapter will analyze the results of applying the DEA/CFA models using four input variables (dollar amounts adjusted for inflation) and one output variable for each Cost Center, Branch, Division and the Directorate. It will compare the individual organizational entity against itself over the ten observation quarter periods. Since there are 17 production Cost Centers, 5 Branches (one is a repeat of a Cost Center), 4 Divisions (three are repeats of Branches) and the one Directorate, this will result in 23 possible separate comparisons of these entities against themselves over the ten FY observation quarters.

Summary

This chapter fulfilled the first objective of this thesis which was to select input and output measures to be used by the DEA/CFA models at AGMC. The chapter discussed the selection of AGMC as a testing center for further DEA/CFA application research and its organizational layout was explained. Then, the data input and output variables were identified and reduced to four inputs and one "universal widget" output. Finally, the application of the data to the DEA/CFA models for each of the 17 production Cost Centers, five Branches, four Divisions and the Directorate was explained.

The next chapter will analyze the results of applying the DEA/CFA models to the data for each organizational entity. Chapter V will discuss the validation of the analysis with AGMC managers. Chapter VI will present conclusions and recommendations based on the analysis and validation from Chapters IV and V.

IV. Analysis

Introduction

This chapter partially fulfills the second objective of this thesis which is to analyze the results of applying the DEA/CFA models using four input variables (dollar amounts adjusted for inflation) and one output variable for each Cost Center, Branch, Division and the Directorate. It will compare the individual organizational entity against itself over the ten observation quarters. As previously mentioned, there are 23 possible comparisons that could be made, of which only 18 are practical due to data limitations. Of the eighteen organizational entities evaluated in this chapter, twelve are Cost Centers and will be analyzed first. Next, two Branch/Division combinations and then two separate Branches will be analyzed. Finally, the Division for the former two Branches will be analyzed, followed by the entire AGMC maintenance Directorate. However, before providing the comparisons, a discussion of the computer resources utilized, the data base used, and how the analyses will be presented, is offered.

Computer Software & Hardware

The DEA/CFA computer program used in the Hitt & Horace research was adapted to run on the AFIT Burroughs B-20 microcomputer and verified by comparisons with the AFIT Harris 800.

The Data Base

Input Values. Appendices E1-E24 show the input quantities used to evaluate each organizational entity over the 10 observation periods. The inflation factors used to discount the dollar amounts for FY 84 & FY 85 were obtained from AFR 173-13 (condensed from the US Government Office of Management & Budget) and are shown in Table III.

TABLE III

Inflation Factor Adjustments to Input Dollar Amounts

YEAR	DIRECT LABOR $	DIRECT MATERIAL $	OVERHEAD $
FY85	5.8%, starting in 3rd QTR	9.4% each QTR	5.8% each QTR
FY84	2.8%, starting in 3rd QTR	4.3% each QTR	2.8% each QTR
FY83	BASE YEAR	BASE YEAR	BASE YEAR

The example below shows the procedure used to discount any given observation quarter's data (in this example, the first quarter FY85) to the base year for DMC.

EXAMPLE OF INFLATION DISCOUNTING TO BASE YEAR

Given actual 1st Quarter FY85 DMC of	$2,000,000.00
Apply FY85 inflation adjustment from Table III:	
($2,000,000.00 / 109.4%) =	$1,828,153.50
Now apply FY84 inflation adjustment to above:	
($1,828,153.50 / 104.3%) =	
INPUT DISCOUNTED BY INFLATION TO BASE YEAR =	$1,752,783.70

PROOF

Given Input Discounted by inflation above	$1,752,783.70
Multiply amount by FY84 inflation adjustment (from Table III) and add:	
($1,752,783.70 X 4.3%) =	+ $ 75,369.70
Input readjusted for FY84 inflation rate	$1,828,153.40
Multiply FY84 amount by FY85 inflation factor	
($1,828,153.40 X 9.4%) =	+ $ 171,846.41
Input readjusted for FY84 & FY85 inflation	$1,999,999.81
	(1)

Overhead dollar costs for a given observation quarter would be discounted the same way as in the example. The only difference for direct labor cost is that the discounting inflation factor is not applicable until the third quarter for any given FY because that is when employee cost of living raises take affect.

The inputs used in the DEA/CFA models by individual FY quarters for all organizational entities is shown in Appendices D1-D10. The inputs used for each particular organizational entity over the ten observation quarters is shown in Appendices E1-E24.

Output Values. The output quantities produced by the scaling process described in the previous chapter is summarized by organizational level and FY quarters in Appendices D1-D10. Appendices E1-E24 contain individual output quantities for each organizational entity over the ten FY quarters.

Analysis Description for each Organizational Entity

Of the 24 available input and output data sets contained in Appendices E1-E24, eighteen were used as inputs to the DEA/CFA simulation model. An analysis of the results of applying the eighteen data sets to the DEA/CFA models will be individually analyzed in the following sections.

First, an individual analysis will be made for each of the eighteen organizational entities followed immediately by their respective graphical representation. The next chapter will validate the results of some of these organizational entities with AGMC managers.

Second, for each application of a different data set, a graphical display of the results will be given which will show the upper and lower bounds of efficiency (the top most two curves) for each observed FY quarter (DMU). The lower curve on the same graph will show the total output quantity for each of the observed FY quarters. The reader should note the decimal value scale on the left axis is associated with the efficiency rating and it is associated with output quantities on the right axis.

Third, as part of the graphical display for each application of the DEA/CFA model, a table will be given to list the values for the lower bound, upper bound and output quantity that were used in plotting the two graphs.

Data sets for six different organizational entities (Appendices E5, E10, E11, E12, E13 and E18) were not applied to the DEA/CFA models for one of two reasons. Data sets in Appendices E5, E10, E11, E12, and E13 were not applied to the DEA/CFA model because of either insufficient history of the data over the ten quarters or extremely small fractional/zero output measure quantities. The data set for the organizational entity shown in Appendix E18 is AGMC's non-production Cost Center and will always have zero output production and therefore will not be used in this investigation. The notes at the bottom of the appropriate Appendix page explain why the data set were not applied to the DEA/CFA models.

MBPDA Cost Center Analysis

The data set for Cost Center MBPDA is shown in Appendix E1. Figure 5 shows the graphical application of the data set by the DEA/CFA models and the efficiency ratings generated.

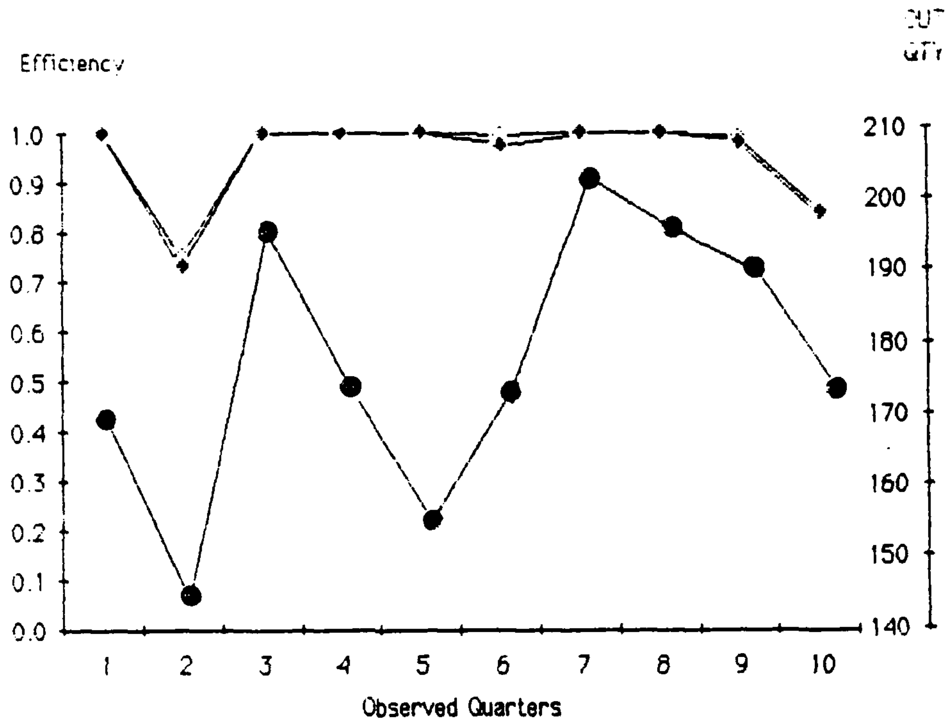
The upper bound efficiency rating for this Cost Center is above .987 for eight of the ten observation quarters with five rated at 1.0. The two quarters that were below the efficiency ratings of the other eight were 2 and 10.

Quarter 2, with a .75 efficiency rating, produced the smallest output quantity of the 10 quarters and subsequently had the highest ratio of all four inputs divided by outputs produced. The ratio of inputs to outputs is arrived at by dividing each of the four inputs by the number of outputs produced in that quarter. Computing this input/output ratio for all ten observation quarters now allows a comparison of inputs consumed per output produced. For instance, quarter 2 consumed an average of 83 more Direct Product Actual Hours (DPAH), $1,088 more in Direct Labor Cost (DLC) and $3,347 more in Direct Material Cost (DMC) than the eight quarters rated highly efficient. Either quarter 2 did not produce in an efficient manner, or consumed excessive resources for the output it produced.

Quarter 10 had a reduced efficiency rating of .844 after seven quarters of higher efficiency ratings because an excessive amount of overhead was applied. In fact, the overhead applied was $930 more per unit produced then the average for the eight efficient quarters.

The production quantity was quite variable in all observation quarters and yet the Cost Center had a average 95.74% efficiency rating. Since the Cost Center had previously adjusted to wide swings in production, possible reasons for this Cost Center's inefficiency in the second and tenth quarters would be input or output data collection errors, changes in work loading or procedures, or the Cost Center actually operated at 75.1% and 84.4% efficiency in the respective quarters. The MBPDA Cost Center manager will verify the input and output data used for this analysis and this verification will be discussed in the next chapter.

The upper bound average efficiency rating for all ten quarters is 95.74% and the lower bound efficiency rating is almost identical to the upper bound.



Observed Quarter	Lower Bound ◆	Upper Bound ◇	Output Quantity ●
1 FY83-1	1.00	1.00	169
2 FY83-2	.73	.751	144
3 FY83-3	1.00	1.00	195
4 FY83-4	.998	.998	173
5 FY84-1	1.00	1.00	154
6 FY84-2	.975	.994	172
7 FY84-3	1.00	1.00	202
8 FY84-4	1.00	1.00	195
9 FY85-1	.98	.987	189
10 FY85-2	.834	.844	172

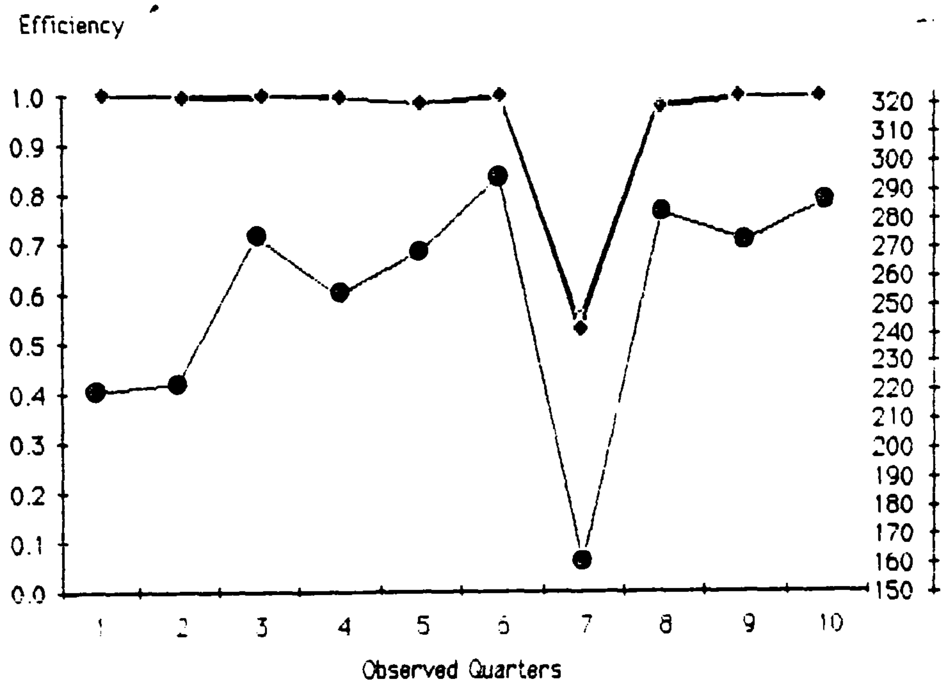
Figure 5. MBPDA Cost Center Analysis

MBPEA Cost Center Analysis

The data set for Cost Center MBPEA is shown in Appendix E2. Figure 6 shows the graphical application of the data set by the DEA/CFA models and the efficiency ratings generated.

The upper bound efficiency rating for this Cost Center is above 98% for every observation quarter except number seven. Observation quarter seven showed a significant decrease in efficiency rating to 55% from 100% in the previous quarter. Also, the production output quantity for the seventh quarter declined by 45% from 295 to 161 units.

The production quantity was quite variable in all observation quarters and yet the Cost Center was rated virtually 100% efficient for nine quarters. Since the Cost Center efficiency had previously adjusted to wide swings in production output, possible reasons for this Cost Center's inefficiency would be input or output data collection errors, a change in work loading or procedures, or the Cost Center actually operated at 55% efficiency for the seventh quarter. The Cost Center manager for MBPEA will verify the output production quantity data and this verification will be discussed in the next chapter. It can be seen that with the exception of the seventh quarter, Cost Center MBPEA normally operated at a very high efficiency rating. The average upper bound efficiency rating for all ten quarters is 95.18% and the lower bound is virtually identical.



Observed Quarter	◆ Lower Bound	◇ Upper Bound	● Output Quantity
1 FY83-1	1.00	1.00	219
2 FY83-2	.996	1.00	222
3 FY83-3	1.00	1.00	274
4 FY83-4	.994	.997	253
5 FY84-1	.983	.986	268
6 FY84-2	1.00	1.00	295
7 FY84-3	.532	.551	161
8 FY84-4	.981	.984	282
9 FY85-1	1.00	1.00	272
10 FY85-2	1.00	1.00	286

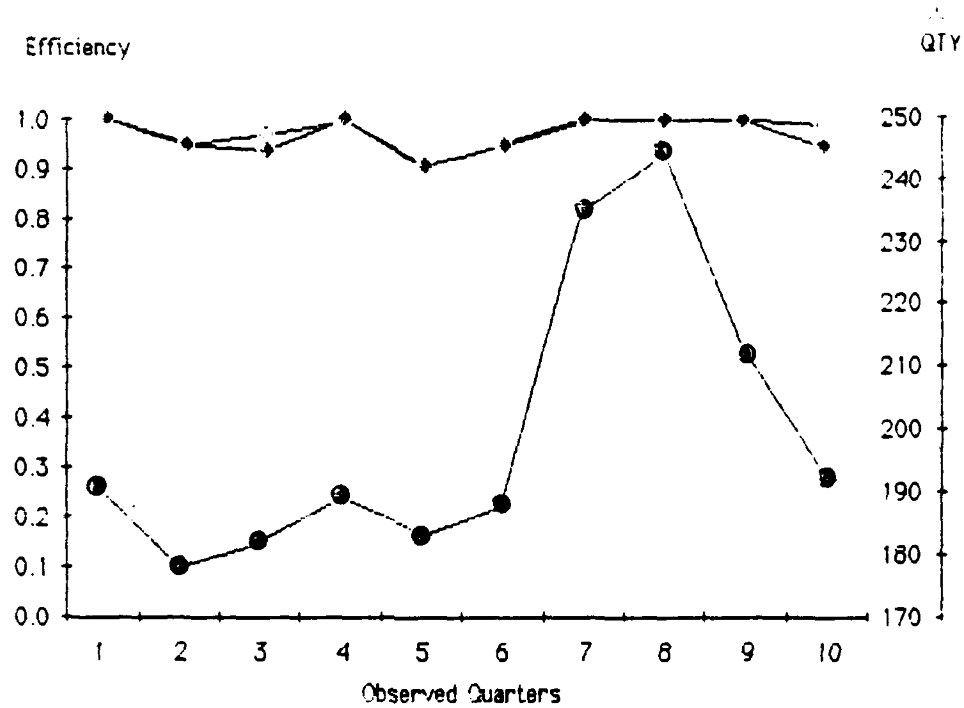
Figure 6. MBPEA Cost Center Analysis

MBPFA Cost Center Analysis

The data set for Cost Center MBPFA is shown in Appendix E3. Figure 7 shows the graphical application of the data set by the DEA/CFA models and the efficiency ratings generated.

Unlike the previous Cost Center, the upper bound efficiency rating for MBPFA was above 90% for all ten observation quarters despite a wide variance in production output. In fact, the efficiency rating was 100% for five of the ten quarters, and 95% or higher for four of the remaining ten observation quarters. The 10% drop in efficiency rating from the fourth to the fifth quarter is an area for managerial concern. The DEA/CFA models identified the fifth among all ten observation quarters as consuming the highest input amounts of both DPAH and DLC per output produced. The fifth quarter consumed an average of 28 more DPAH and $503 more in DLC.

Cost Center MBPFA appears to have operated efficiently despite wide variances in the quarterly production outputs. The DEA/CFA models point out that based on the production demands placed on this Cost Center, an efficient use of resources occurred. The average upper bound efficiency rating for all ten quarters is 97.63% and the lower bound efficiency rating is almost identical.



Observed Quarter	Lower Bound ♦	Upper Bound ◇	Output Quantity ●
1 FY83-1	1.00	1.00	191
2 FY83-2	.946	.949	178
3 FY83-3	.934	.970	182
4 FY83-4	1.00	1.00	189
5 FY84-1	.904	.906	183
6 FY84-2	.949	.950	188
7 FY84-3	1.00	1.00	235
8 FY84-4	1.00	1.00	244
9 FY85-1	1.00	1.00	212
10 FY85-2	.946	.988	192

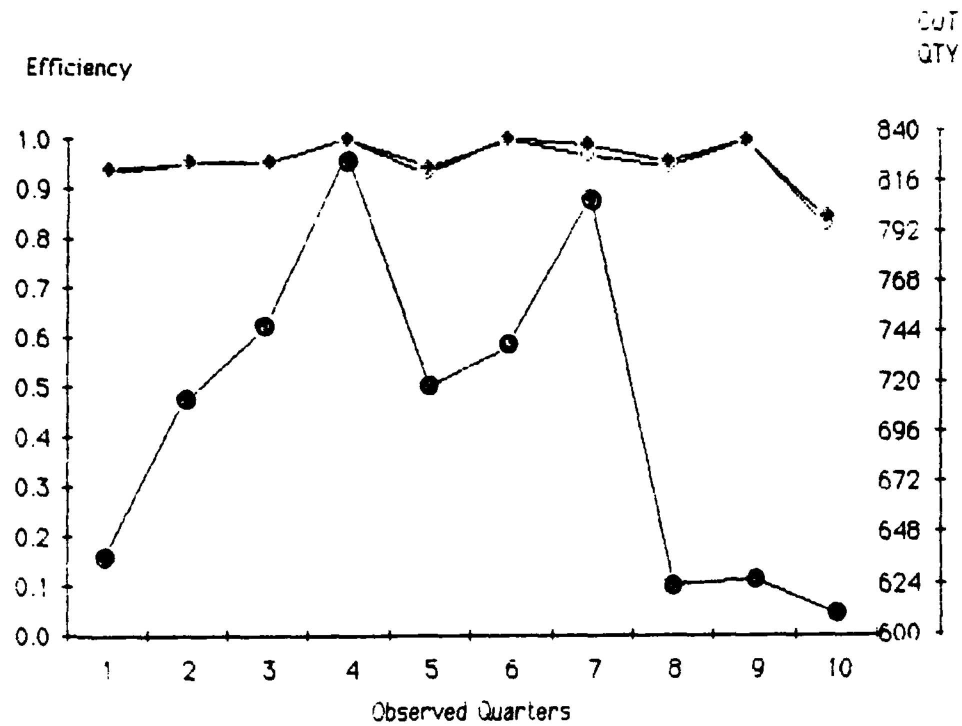
Figure 7. MBPFA Cost Center Analysis

MBPGA Cost Center Analysis

The data set for Cost Center MBPGA is shown in Appendix E4. Figure 8 shows the graphical application of the data set by the DEA/CFA models and the efficiency ratings generated.

The upper bound efficiency rating for this Cost Center is above 94% for every observation quarter except number ten. Observation quarter ten showed a 15% decrease in efficiency rating to 85% from the ninth quarter's 100% efficiency rating. Comparing the tenth quarter input/output ratios for input to the ninth quarter ratios reveals that they are almost identical except for direct material cost (DMC). The tenth quarter DMC is double the DMC of the ninth quarter and 2.4 times greater than the DMC of the fourth quarter, which was also rated 100% efficient. The DEA/CFA models indicate that the 15% drop in efficiency rating for the tenth quarter was caused by the over consumption of DMC for the output produced, resulting in an inefficient mix of resources. The drop in the tenth quarter efficiency rating followed two quarters of low production output.

The production quantity was quite variable throughout the ten observation quarters and the Cost Center still had a efficiency rating above 94% for all but the last quarter. Since the Cost Center efficiency had previously adjusted to wide swings in production outputs, possible reasons for the drop in efficiency include an accounting error in the input or output data collection, or the Cost Center may have operated at 85% efficiency in the tenth quarter. The production quantity output for the tenth quarter will be verified by AGMC managers and this verification will be discussed in the next chapter. It can be seen that with the exception of the tenth quarter, Cost Center MBPGA normally operated at a very high efficiency rating. In fact, the average quarterly upper bound efficiency rating for this Cost Center was 95.76% and the lower bound is almost identical.



Observed Quarter	◇ Lower Bound	◆ Upper Bound	● Output Quantity
1 FY83-1	.932	.938	637
2 FY83-2	.950	.95	712.7
3 FY83-3	.952	.952	748
4 FY83-4	1.00	1.00	829
5 FY84-1	.930	.944	719
6 FY84-2	1.00	1.00	739
7 FY84-3	.967	.989	808
8 FY84-4	.945	.956	623
9 FY85-1	1.00	1.00	626
10 FY85-2	.831	.847	609

Figure 8. MBPGA Cost Center Analysis

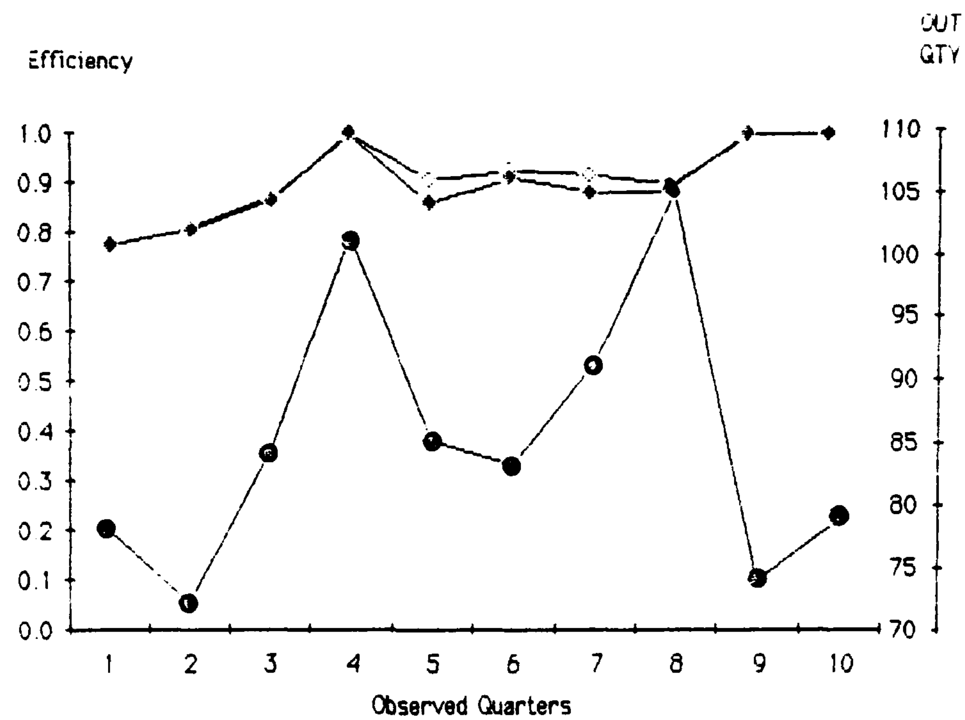
MKPCA Cost Center Analysis

The data set for Cost Center MKPCA is shown in Appendix E6. Figure 9 shows the graphical application of the data set by the DEA/CFA models and the efficiency ratings generated.

The upper bound efficiency rating for this Cost Center started low in the first quarter of FY83 and improved through all of FY83. The efficiency ratings for FY84 and part of FY85 have all been 90% or greater despite very wide fluctuations in the production outputs for each quarter.

Cost Center MKPCA appears to have operated efficiently since the fourth quarter of FY83. In fact, the average efficiency rating for the fourth though tenth observation quarters was 94.89%, and for all ten quarters was 90.96%. The lower bound efficiency rating is almost identical to the upper bounds.

The input/output ratios for the the first three quarters, in comparison to the other seven quarters, indicate possible excessive Overhead & Miscellaneous Cost (OMC) consumed by the Cost Center per unit produced. The first and second quarters also had the highest ratios of DPAH, DLC and DMC of all ten observation quarters. Therefore, the DEA/CFA models indicate a improving trend for Cost Center MKPCA in the efficient use of resource mixes over the ten observation quarters.



Observed Quarter	◆ Lower Bound	◇ Upper Bound	● Output Quantity
1 FY83-1	.772	.775	78
2 FY83-2	.805	.809	72
3 FY83-3	.863	.870	84
4 FY83-4	1.00	1.00	101
5 FY84-1	.860	.906	85
6 FY84-2	.910	.925	83
7 FY84-3	.880	.914	91
8 FY84-4	.889	.897	105
9 FY85-1	1.00	1.00	74
10 FY85-2	1.00	1.00	79

Figure 9. MKPCA Cost Center Analysis

MKPEA Cost Center Analysis

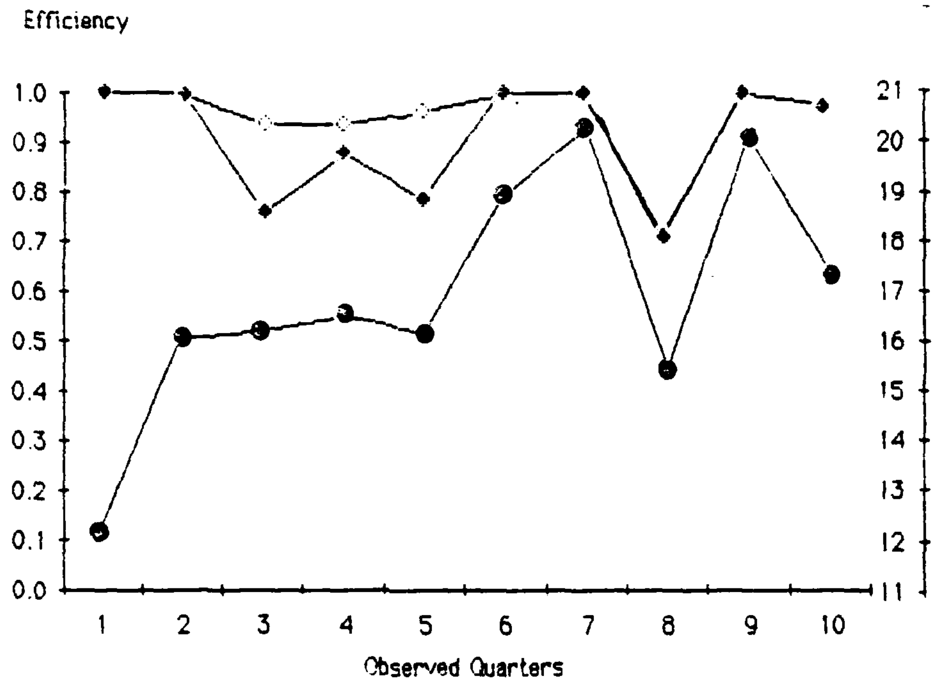
The data set for Cost Center MKPEA is shown in appendix E7. Figure 10 shows the graphical application of the data set by the DEA/CFA models and the efficiency ratings generated.

The upper bound efficiency rating for this Cost Center is above 93% for every observation quarter except number eight. Observation quarter eight showed a significant decrease in efficiency rating to 71.7% from 100% in the previous two quarters.

The production quantity was quite variable in all observation quarters and the Cost Center still had a upper bound efficiency rating above 93% for all but the eighth quarter.

Cost Center MKPEA appears to have consumed excessive input resources or not accounted for all production outputs in the eighth quarter. In fact, input quantities consumed per output produced, as well as in absolute aggregate terms, was the highest in the eighth quarter. Since the Cost Center efficiency had previously adjusted to wide swings in production outputs, possible reasons for the decline in efficiency ratings may include accounting errors in the input or output data collection, a change in the work force or work procedures, or the Cost Center operated at 71.7% efficiency in the eighth quarter. The production quantity output for the eighth q arter will be verified by the MKPEA

Cost Center manager and discussed in the next chapter. Also, it can be seen that the Cost Center normally operates above 93% efficiency. The average upper bound efficiency rating for all ten quarters is 95.27%, and the average lower bound efficiency ratings is 90.93%. The lower bound efficiency ratings show a significant decrease in the third and fifth quarters indicating the DEA/CFA models more pessimistic appraisal of those quarters.



Observed Quarter	Lower Bound	Upper Bound	Output Quantity
1 FY83-1	1.00	1.00	12.14
2 FY83-2	.996	.996	16.04
3 FY83-3	.755	.934	16.19
4 FY83-4	.876	.939	16.52
5 FY84-1	.782	.965	16.06
6 FY84-2	1.00	1.00	18.89
7 FY84-3	1.00	1.00	20.22
8 FY84-4	.710	.717	15.35
9 FY85-1	1.00	1.00	19.93
10 FY85-2	.974	.976	17.27

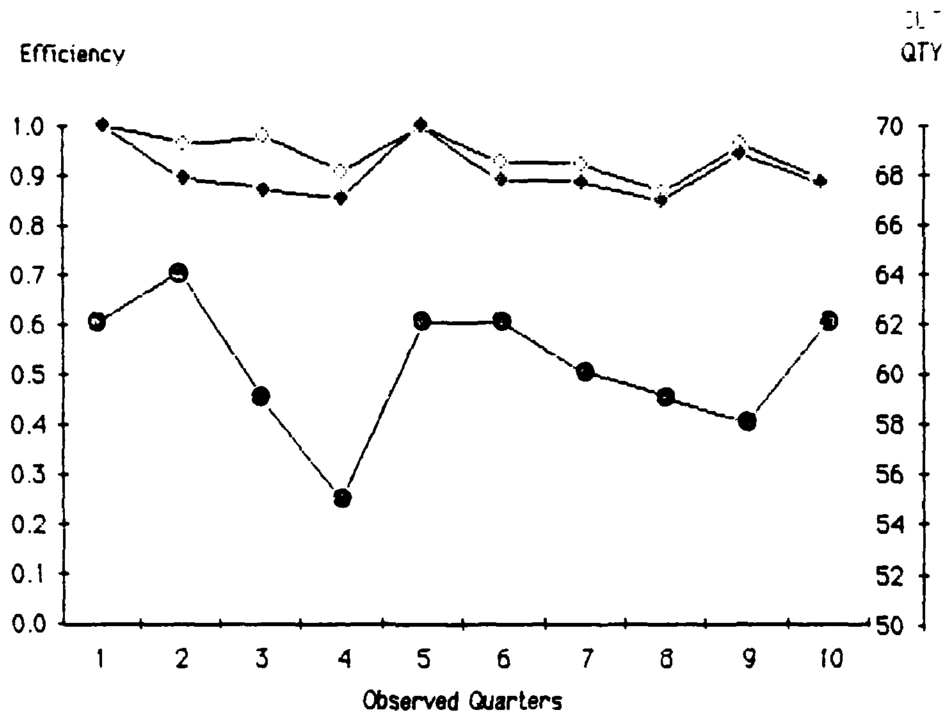
Figure 10. MKPEA Cost Center Analysis

MKPMA Cost Center Analysis

The data set for Cost Center MKPMA is shown in Appendix E8. Figure 11 shows the graphical application of the data set by the DEA/CFA models and the efficiency ratings generated.

The upper bound efficiency rating for this Cost Center is above 86% for all ten observation quarters and the average efficiency rating is 94.09%. The lower bound efficiency ratings are slightly lower than the corresponding upper bounds in almost all quarters.

The input/output ratio measures per output produced for DPAH, DLC and OMC are the highest for the eighth quarter. The DEA/CFA models indicates that the eighth quarter has the lowest efficiency rating because of the inefficient use of resources. The production quantity was quite variable in all observation quarters and the Cost Center had a efficiency rating above 86% for ten quarters. Compared to previous Cost Centers, MKPMA appears to have operated with moderate efficiency despite wide variances in the quarterly production outputs. The efficiency ratings for this Cost Center indicate a trend of decreasing efficiency which should be of managerial concern.



Observed Quarter	Lower Bound	Upper Bound	Output Quantity
1 FY83-1	1.00	1.00	62
2 FY83-2	.893	.965	64
3 FY83-3	.869	.979	59
4 FY83-4	.851	.906	55
5 FY84-1	1.00	1.00	62
6 FY84-2	.887	.924	62
7 FY84-3	.882	.920	60
8 FY84-4	.845	.863	59
9 FY85-1	.944	.961	58
10 FY85-2	.883	.891	62

Figure 11. MKPMA Cost Center Analysis

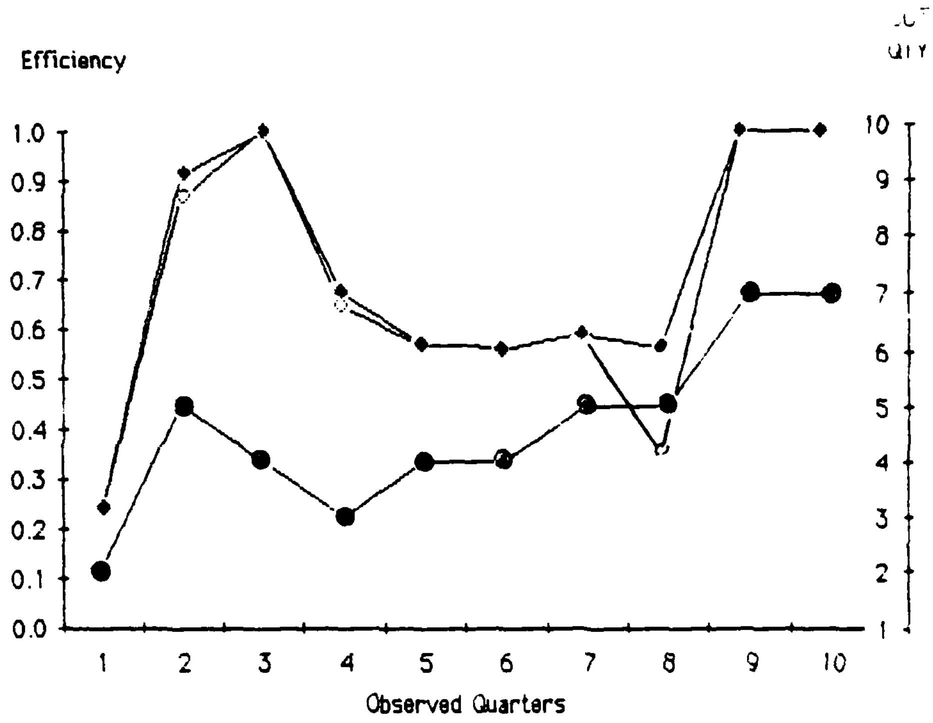
MKPNA Cost Center Analysis

The data set for Cost Center MKPNA is shown in Appendix E9. Figure 12 shows the graphical application of the data set by the DEA/CFA models and the efficiency ratings generated.

The upper bound efficiency ratings for this Cost Center are extremely erratic, varying from a low of 23.9% to a high of 100%. The lower bound efficiency ratings are almost identical to the corresponding upper bounds, except for a very steep decrease in the eighth quarter. The average upper bound efficiency rating for all ten quarters is 71.01%. Also, the production outputs for each quarter vary from a low of two to a high of seven.

The input/output ratios of the inefficient quarters of this Cost Center for DPAH, DLC and DMC are twice to three and one half times more than for the quarters rated 100% efficient. For observation quarters 5 through 8, the input/output ratios of DMC are excessive in comparison to the quarters rated 100% efficient, indicating a possible trend in inefficient use or resources.

It can be seen that Cost Center MKPNA operated efficiently for quarters 2, 3, 9 and 10. Also, MKPNA operated for sustained periods at below 67% efficiency, as in observations quarters 1 and 4 through 8. Because the efficiency ratings for MKPNA are radically different from the other eleven Cost Centers evaluated, the author will validate all input data and the DEA/CFA results in detail with the Cost Center manager. A discussion of this validation will be presented in the next chapter.



Observed Quarter	◇ Lower Bound	◆ Upper Bound	● Output Quantity
1 FY83-1	.239	.239	2
2 FY83-2	.868	.916	5
3 FY83-3	1.00	1.00	4
4 FY83-4	.647	.671	3
5 FY84-1	.566	.566	4
6 FY84-2	.558	.558	4
7 FY84-3	.591	.591	5
8 FY84-4	.354	.560	5
9 FY85-1	1.00	1.00	7
10 FY85-2	1.00	1.00	7

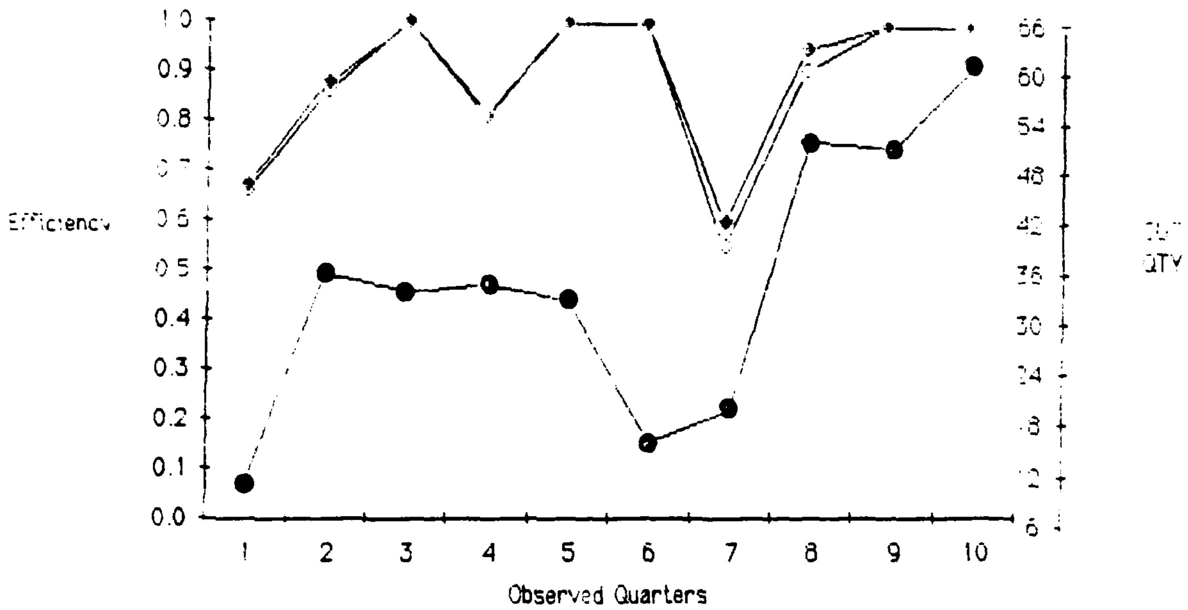
Figure 12. MKPNA Cost Center Analysis

MNLSA Cost Center Analysis

The data set for Cost Center MNLSA is shown in Appendix E14. Figure 13 shows the graphical application of the data set by the DEA/CFA models and the efficiency ratings generated.

The upper bound efficiency rating for this Cost Center is above 80% for each observation quarter except the first and seventh where it is 66.6% and 60.5% respectfully. The average efficiency rating for all ten quarters is 89.06% and the Cost Center operated above 80% efficiency for eight of ten quarters. The lower bound efficiency ratings are almost identical to the upper bound efficiency ratings for all ten quarters. The production quantity was extremely variable in all observation quarters ranging from a low of 10 to a high of 60 output units.

Cost Center MNLSA appears to have consumed excessive input resources or not accounted for all production outputs in the first and seventh quarters. In fact, the four input/output ratios were the highest in the seventh quarter. Also, the input/output ratios for DPAH, DLC and OMC for the first quarter were very close to the excessive amounts mentioned for the seventh quarter, indicating possible inefficient use of resources. Since the Cost Center efficiency had previously adjusted to wide swings in production outputs, possible reasons for the inefficiency of the first and seventh quarters are that an accounting error was made in the input or output data collection, a change in work loading or procedures, or the Cost Center actually operated inefficiently for those two quarters. The production quantity output for the first and seventh quarters will be verified by the MNLSA manager and discussed in the next chapter.



Observed Quarter	◇ Lower Bound	◆ Upper Bound	● Output Quantity
1 FY83-1	.656	.666	10
2 FY83-2	.855	.874	35
3 FY83-3	1.00	1.00	33
4 FY83-4	.805	.811	34
5 FY84-1	1.00	1.00	32
6 FY84-2	1.00	1.00	15
7 FY84-3	.555	.605	19
8 FY84-4	.908	.950	51
9 FY85-1	1.00	1.00	50
10 FY85-2	1.00	1.00	60

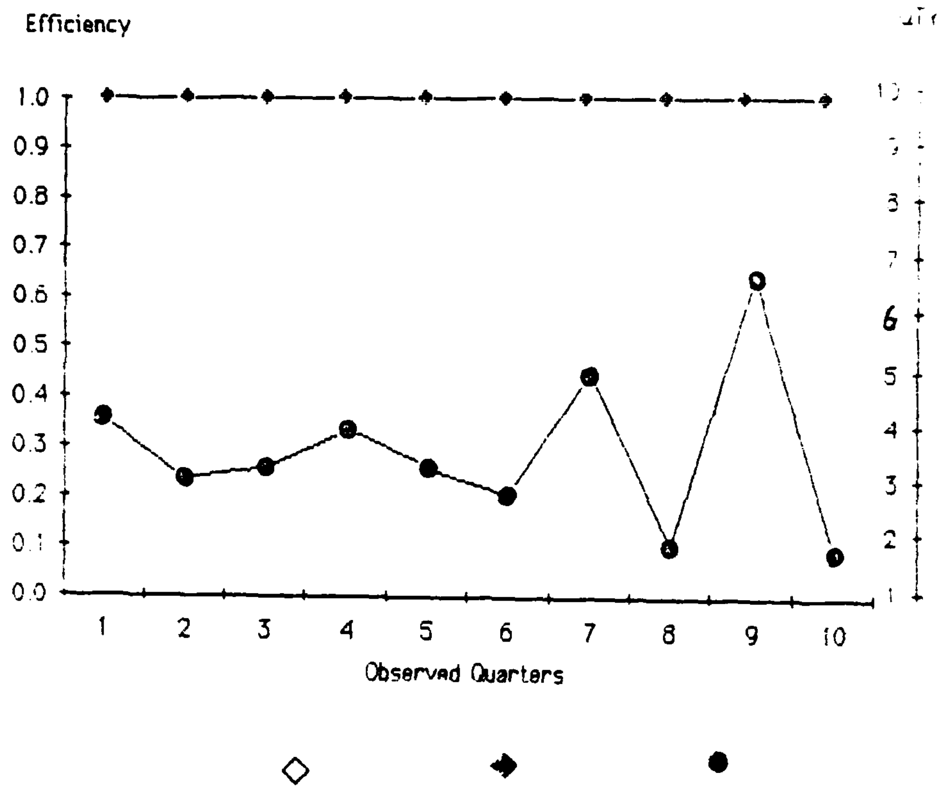
Figure 13. MNLSA Cost Center Analysis

MNTDA Cost Center Analysis

The data set for Cost Center MNTDA is shown in Appendix E15. Figure 14 shows the graphical application of the data set by the DEA/CFA models and the efficiency ratings generated.

The upper and lower bound efficiency rating for this Cost Center is 100% for each observation quarter. Cost Center MNTDA appears to have operated at 100% efficiency despite wide variances in the quarterly production outputs and indicates efficient use of resources. Just as ratings of low efficiency are of interest to management, sustained maximum efficiency ratings should be investigated thoroughly for their validity. Since the DEA/CFA models are known to be optimistic in assigning upper bound efficiency ratings, the validity of these sustained maximum ratings will be validated with the manager of the MNTDA Cost Center and discussed in the next chapter.

The production output quantity for this Cost Center was very variable from one observation quarter to the next. The low production output quantity was 1.8 in the tenth quarter and the high was 6.7 in the ninth quarter.



Observed Quarter	Lower Bound	Upper Bound	Output Quantity
1 FY83-1	1.00	1.00	4.2
2 FY83-2	1.00	1.00	3.1
3 FY83-3	1.00	1.00	3.3
4 FY83-4	1.00	1.00	4.0
5 FY84-1	1.00	1.00	3.3
6 FY84-2	1.00	1.00	2.8
7 FY84-3	1.00	1.00	5.0
8 FY84-4	1.00	1.00	1.9
9 FY85-1	1.00	1.00	6.7
10 FY85-2	1.00	1.00	1.8

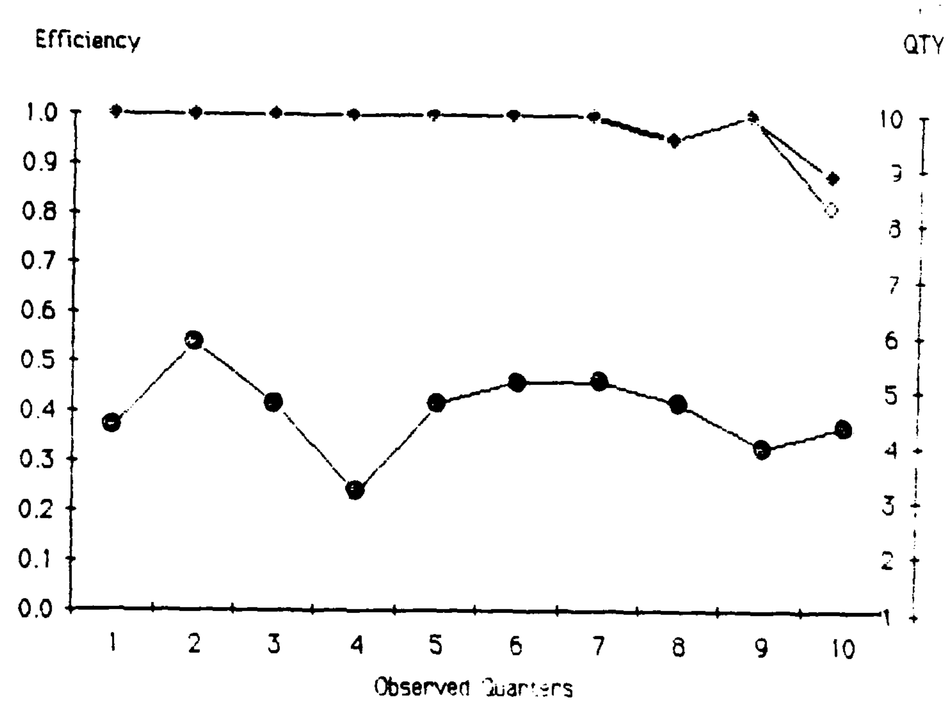
Figure 14. MNTDA Cost Center Analysis

MNTSA Cost Center Analysis

The data set for Cost Center MNTSA is shown in Appendix E16. Figure 15 shows the graphical application of the data set by the DEA/CFA models and the efficiency ratings generated.

The upper bound efficiency rating for this Cost Center is above 95% for every observation quarter except number ten where it was 88%. The lower bound efficiency ratings are also identical to the corresponding upper bounds for all quarters except number ten, where a decrease is observed from 88% to 81.5%.

The production output quantity for this Cost Center was fairly stable except for observation quarters four and nine. The low production output quantity was 3.1 in the fourth quarter and the high was 5.8 in the second quarter. Cost Center MNTSA appears to have adjusted to these production demands by operating very efficiently with an average quarterly upper bound efficiency rating of 98.3%, indicating very efficient use of resources.



Observed Quarter	◇ Lower Bound	◆ Upper Bound	● Output Quantity
1 FY83-1	1.00	1.00	4.3
2 FY83-2	1.00	1.00	5.8
3 FY83-3	1.00	1.00	4.7
4 FY83-4	1.00	1.00	3.1
5 FY84-1	1.00	1.00	4.7
6 FY84-2	1.00	1.00	5.1
7 FY84-3	.997	.998	5.1
8 FY84-4	.952	.952	4.7
9 FY85-1	1.00	1.00	3.9
10 FY85-2	.815	.880	4.3

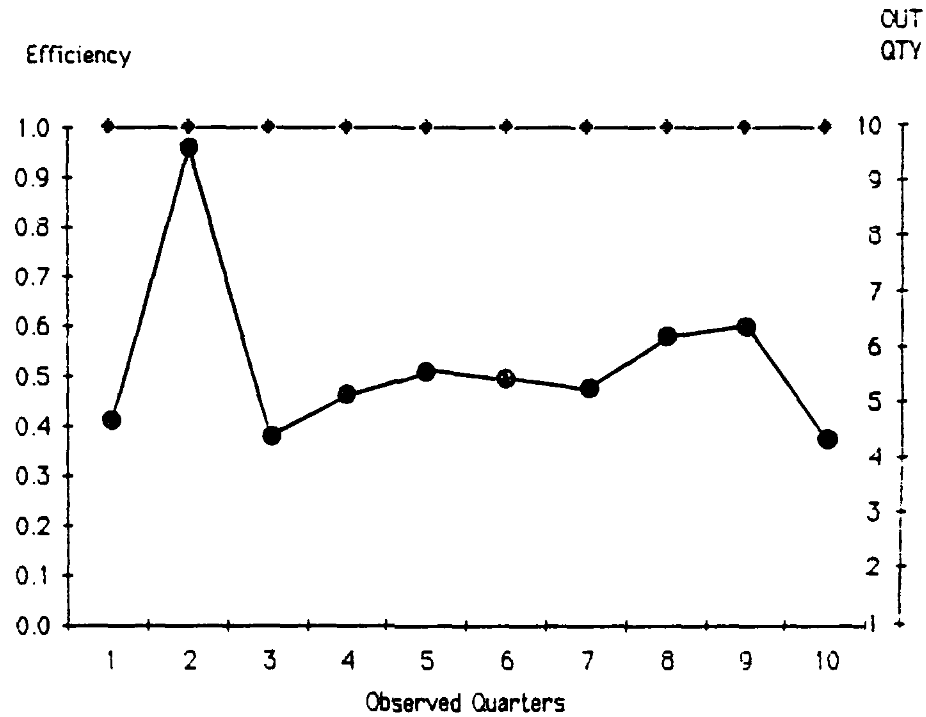
Figure 15. MNTSA Cost Center Analysis

MNTTA Cost Center Analysis

The data set for Cost Center MNTTA is shown in Appendix E17. Figure 16 shows the graphical application of the data set by the DEA/CFA models and the efficiency ratings generated.

The upper and lower bound efficiency rating for this Cost Center is 100% for each observation quarter. Cost Center MNTTA appears to have operated at 100% upper and lower bound efficiency despite very wide fluctuations in the quarterly production outputs and indicates efficient use of resources. As with Cost Center MNTDA which also obtained efficiency ratings of 100% for all ten quarters, the validity of these sustained maximum ratings will be validated with the manager of the Cost Center and discussed in the next chapter.

The production output quantity for this Cost Center was very variable from one observation quarter to the next. The low production output quantity was 3.7 in the tenth quarter and the high was 9.6 in the second quarter.



Observed Quarter		Lower Bound ◇	Upper Bound ◆	Output Quantity ●
1	FY83-1	1.00	1.00	4.1
2	FY83-2	1.00	1.00	9.6
3	FY83-3	1.00	1.00	3.8
4	FY83-4	1.00	1.00	4.3
5	FY84-1	1.00	1.00	5.2
6	FY84-2	1.00	1.00	5.0
7	FY84-3	1.00	1.00	4.8
8	FY84-4	1.00	1.00	5.8
9	FY85-1	1.00	1.00	6.0
10	FY85-2	1.00	1.00	3.7

Figure 16. MNTTA Cost Center Analysis

Interim Cost Center Summary

The purpose of the preceding twelve sections was to discuss the results of applying appropriate Cost Center data sets to the DEA/CFA models. This discussion of individual Cost Centers is necessary to gain an understanding of influential data sets to achieve the prime objective of analyzing total productivity of higher organizational levels.

Three potential problems identified at the Cost Center level need to be scrutinized as this analysis proceeds in the following sections to organizational levels above the Cost Center. First, erratic swings in quarterly output production quantities coupled with decreases in efficiency ratings may indicate possible input or output accounting errors. An example of this potential situation is illustrated in Figure 10 for Cost Center MBPEA in the seventh quarter. Second, highly erratic efficiency ratings within a Cost Center indicate areas where verification of the entire input data set needs to be accomplished or managerial explanations sought. Cost Center MKPNA in Figure 12 shows an example of erratic efficiency rating over sustained observation periods. The third problem is several Cost Centers show maximum or near maximum efficiency ratings over all ten observation quarters, which highlights the DEA/CFA models optimism in assigning efficiency ratings. Cost Centers MNTDA, MNTSA and MNTTA illustrate this situation in Figures 14 through 16.

These three potential problems identified at the Cost Center level are carried forward to the Branch and higher levels discussed in the following sections. For instance, if an accounting error was made in a quarterly output production quantity for a particular Cost Center, then the same error would be incorporated into the Branch quarterly outputs.

Although the DEA/CFA analysis was not conducted for Cost Centers MNLAA, MNLEA, MNLPA and MNLPB, their contributions to their respective Branch's data set were included in the following four sections. The fifth section is an analysis of the MAN Division which is composed of the MANL and MANT Branches. An analysis of the MA Directorate follows the interim Branch/Division summary.

MABP Branch & MAB Division Analysis

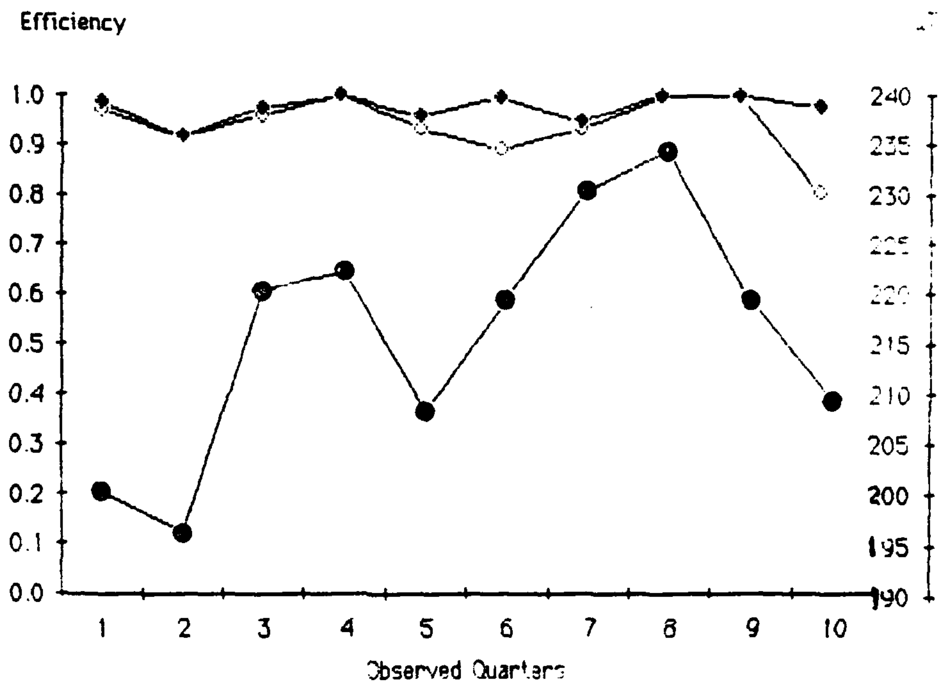
The data set for the combination MABP Branch and MAB Division is shown in Appendix E19. Figure 17 shows the graphical application of the data set by the DEA/CFA models and the efficiency ratings generated. The MABP Branch and MAB Division are composed of Cost Centers MBPDA, MBPEA, MBPFA and MBPGA (see Figure 2 on page 27). The efficiency ratings assigned to each of the four Cost Centers comprising this Branch/Division are shown in Figures 5 through 8.

The upper bound efficiency rating for this Branch/Division is above 91.4% for all ten observation quarters and the average efficiency rating is 97.5%. The lower bound efficiency rating is almost identical to the corresponding upper bounds, except for the sixth and tenth quarters.

The production quantity was quite variable in all observation quarters ranging from a low of 196 to a high of 234, and yet the Branch/Division had a upper bound efficiency rating above 91.4% for all ten quarters. Analyzing its four Cost Centers together reveals that, although some variance existed in various quarters, the Cost Centers were not inefficient all in the same quarter. Several possible explanations for the efficiency ratings for this Branch/Division are that the quarterly efficiency of one or several Cost Centers compensated for the quarterly inefficiency of one or more Cost Centers. The potential exists that errors made within the four Cost Centers were not repeated when the Branch/Division input/output totals were computed. Other explanations might include superior management, optimum demand rates, or highly efficient use of resources.

The combination MABP Branch / MAB Division appears to have operated efficiently despite wide variances in the quarterly production outputs of its four Cost Centers and the fluctuations caused by individual Cost Center inefficiencies.

While the quarterly upper bound efficiency ratings for this Branch/Division seem within reason, management must decide if the peaks and valleys they represent are reasonable. For instance, the DEA/CFA models indicates a 7% drop in efficiency and a 2% drop in production from the first to the second quarter. A 6% increase in efficiency and a 12.5% increase in production from the second to the third quarter. A 5.3% increase in efficiency and a 1% increase in production from the seventh to the eighth quarter. The DEA/CFA models also indicates that from the sixth to the seventh quarter, efficiency went down 5%, but production rose by 5%. This situation indicates the possible inefficient use of resources or at least a situation were increased management interest should be directed. The trend for this Branch/Division indicates a reactive relationship between efficiency and production, whereby if efficiency decreases production declines and if efficiency increases production increases.



Observed Quarter	◇ Lower Bound	◆ Upper Bound	● Output Quantity
1 FY83-1	.969	.984	200
2 FY83-2	.914	.914	196
3 FY83-3	.958	.974	220
4 FY83-4	1.00	1.00	222
5 FY84-1	.933	.957	208
6 FY84-2	.889	.997	219
7 FY84-3	.933	.947	230
8 FY84-4	1.00	1.00	234
9 FY85-1	1.00	1.00	219
10 FY85-2	.804	.978	209

Figure 17. MABP Branch & MAB Division Analysis

MAKP Branch & MAK Division Analysis

The data set for MAKP Branch and MAK Division is shown in Appendix E20. Figure 18 shows the graphical application of the data set by the DEA/CFA models and the efficiency ratings generated. The MAKP Branch and MAK Division are composed of Cost Centers MKPCA, MKPEA, MKPMA and MKPNA (see Figure 2 on page 27). The efficiency ratings assigned to the four Cost Centers are shown in Figures 9 through 12.

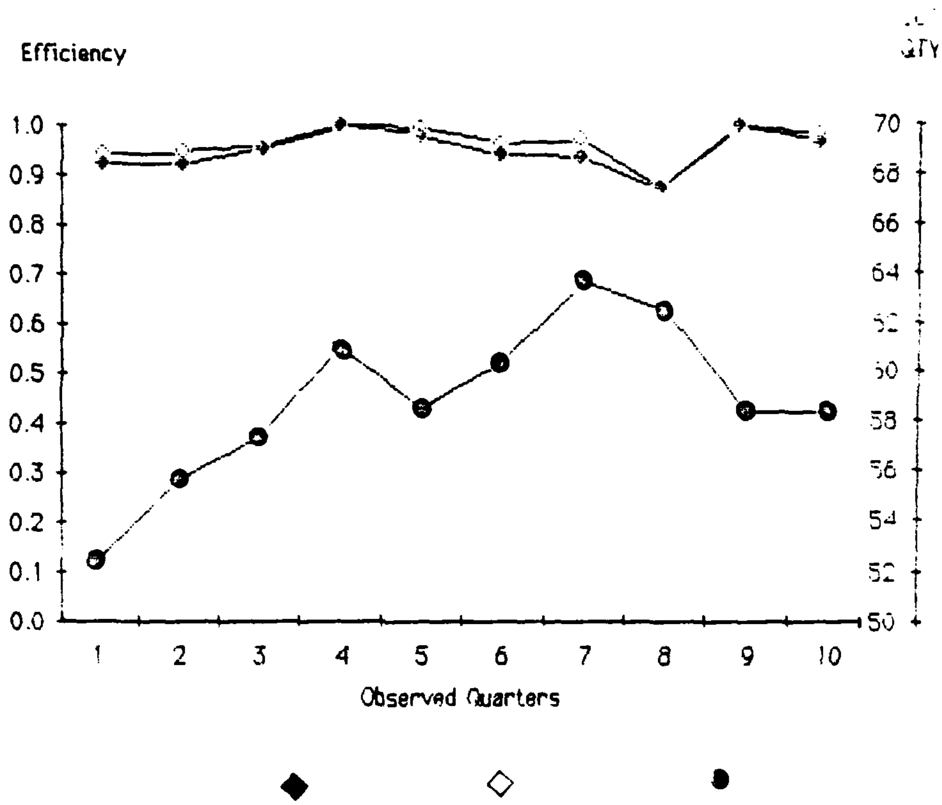
The upper bound efficiency rating for this Branch/Division is above 87.5% for all ten observation quarters and the average efficiency rating is 96.36%. The lower bound efficiency ratings are almost identical to the upper bounds for all ten quarters.

The production quantity was quite variable in all observation quarters, ranging from a low of 52.39 to a high of 63.56, and yet the Branch/Division had a upper bound efficiency rating above 87.5% for all ten quarters. Analyzing its four Cost Centers together reveals that the eighth quarter caused efficiency problems for each center, which is reflected in the eighth quarter Branch/Division's efficiency rating. The eighth quarter Branch/Division's efficiency rating was the lowest of the ten observation periods. MKPNA was the only Cost Center within this Branch/Division where the average efficiency rating was below 86% over the ten observation periods (see Figure 12). But, Cost Center MKPNA, with an average upper bound efficiency rating of 71%, was also the smallest contributor to the Branch/Division efficiency ratings in terms of input resources consumed and output quantity produced of the four Cost Centers.

The potential exists that errors made within the four Cost Centers were not repeated when the Branch/Division input/output totals were computed. Other explanations might include superior management, optimum demand rates, or highly efficient use of resources.

The combination MAKP Branch and MAK Division appears to have operated efficiently despite wide variances in the quarterly production outputs of its four Cost Centers and the fluctuations caused by individual Cost Center quarterly inefficiencies, especially Cost Center MKPNA.

While the quarterly upper bound efficiency ratings for this Branch/Division seem within reason, management must decide if the peaks and valleys they represent are reasonable. For instance, the DEA/CFA models indicate a 2.9% decrease in efficiency and a 3% increase in production from the fifth to the sixth quarters. This situation indicates inefficient use of resources or at least a contradiction worthy of managerial investigation. Also, a 12.5% increase in efficiency and a 6.5% decrease in production from the eighth to the ninth quarters should be noted by management. The trend for this Branch/Division indicates a reactive relationship between efficiency and production whereby if efficiency decreases production declines and if efficiency increases production increases. Manageriıl concern should be directed to these areas.



Observed Quarter	Lower Bound	Upper Bound	Output Quantity
1 FY83-1	.920	.942	52.39
2 FY83-2	.923	.947	55.55
3 FY83-3	.955	.958	57.24
4 FY83-4	1.00	1.00	60.90
5 FY84-1	.981	.995	58.46
6 FY84-2	.944	.964	60.39
7 FY84-3	.938	.973	63.56
8 FY84-4	.873	.875	62.40
9 FY85-1	1.00	1.00	58.43
10 FY85-2	.970	.982	58.36

Figure 18. MAKP Branch & MAK Division Analysis

MANL Branch Analysis

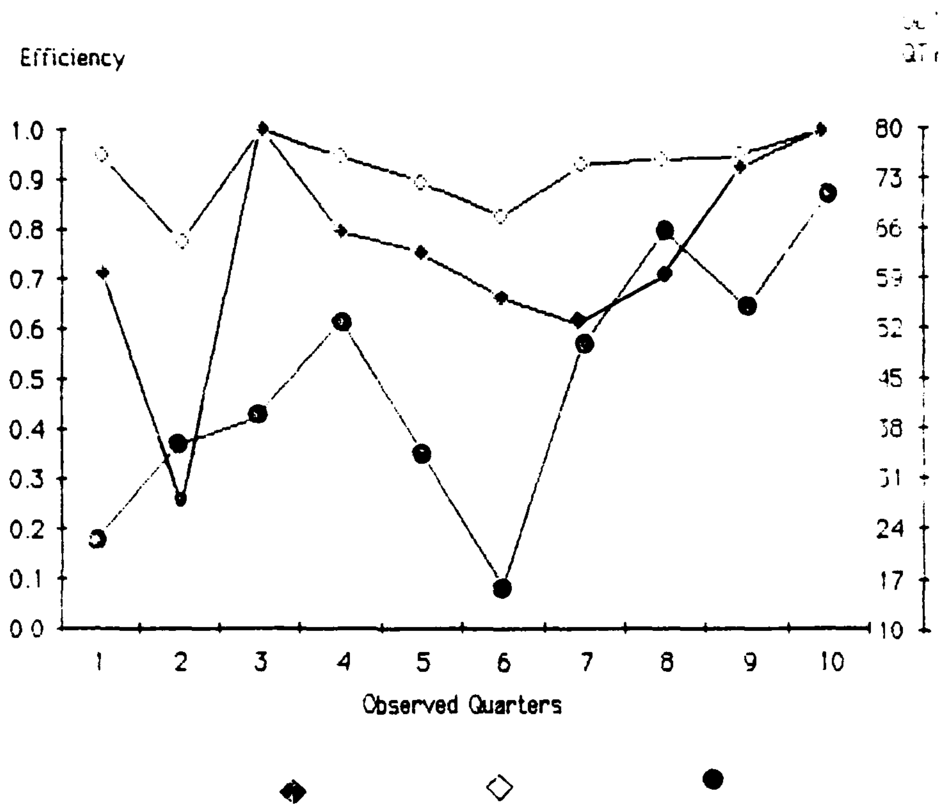
The data set for MANL Branch is shown in Appendix E21. Figure 19 shows the graphical application of the data set by the DEA/CFA models and the efficiency ratings generated. The MANL Branch is composed of Cost Centers MNLAA, MNLEA, MNLPA, MNLPB and MNLSA (see Figure 2 on page 27). Only the data set for Cost Center MNLSA was evaluated by the DEA/CFA models (see Figure 13) as the others had insufficient data histories or extremely small fractional output production quantities. However, all values from the five data sets were combined to determine the MANL Branch input values to the DEA/CFA models.

The upper bound efficiency rating for this Branch is above 89.5% for each observation quarter except the second and sixth where it was 77.4% and 82.7% respectfully. The lowest efficiency rating for this Branch is 77.4% and the average upper bound efficiency rating over all ten quarters is 92.09%. The lower bound efficiency rating was extremely erratic and showed large differences from the upper bound in all but the third quarter indicating the DEA/CFA models more pessimistic evaluation.

The production quantity was quite variable in all observation quarters, ranging from a low of 15.5 to a high of 65.3 output units. MNLSA is the largest contributor of the five Cost Centers to the Branch in terms of input resources consumed and output quantity produced. Therefore, it is no surprise that the inefficiencies within MNLSA for the second and sixth quarters should also be reflected in the MANL Branch.

The potential exists that errors made within the five Cost Centers were not repeated when the Branch input/output totals were computed. Other explanations might include superior management, optimum demand rates, or highly efficient use of resources. Branch MANL appears to have operated fairly efficiently despite wide variances in the production outputs of MNLSA and the other four Cost Centers. The inefficiencies noted in the second and sixth quarter for Cost Center MNLSA are reflected in the same quarters for the Branch because the other four Cost Centers were too small to compensate for it.

The quarterly upper bound efficiency ratings for this Branch seem erratic and management must decide if the peaks and valleys they represent are reasonable. For instance, the DEA/CFA models indicate a 17.1% decrease in efficiency and a 58% increase in production from the first to the second quarter. Also, a 4.5% decrease in efficiency and a 33% increase in production from the third to the fourth quarter. These situations indicate the inefficient use of resources or at least a contradiction worthy of managerial investigation. The trend for this Branch indicates a reactive relationship between efficiency and production whereby if efficiency decreases production declines and if efficiency increases production increases. Managerial concern should be directed to these areas.



Observed Quarter	Lower Bound	Upper Bound	Output Quantity
1 FY83-1	.710	.945	22.4
2 FY83-2	.260	.774	35.5
3 FY83-3	1.00	1.00	39.5
4 FY83-4	.792	.945	52.4
5 FY84-1	.752	.895	34.1
6 FY84-2	.665	.827	15.5
7 FY84-3	.609	.930	49.6
8 FY84-4	.704	.943	65.3
9 FY85-1	.926	.95	54.6
10 FY85-2	1.00	1.00	70.1

Figure 19. MANL Branch Analysis

MANT Branch Analysis

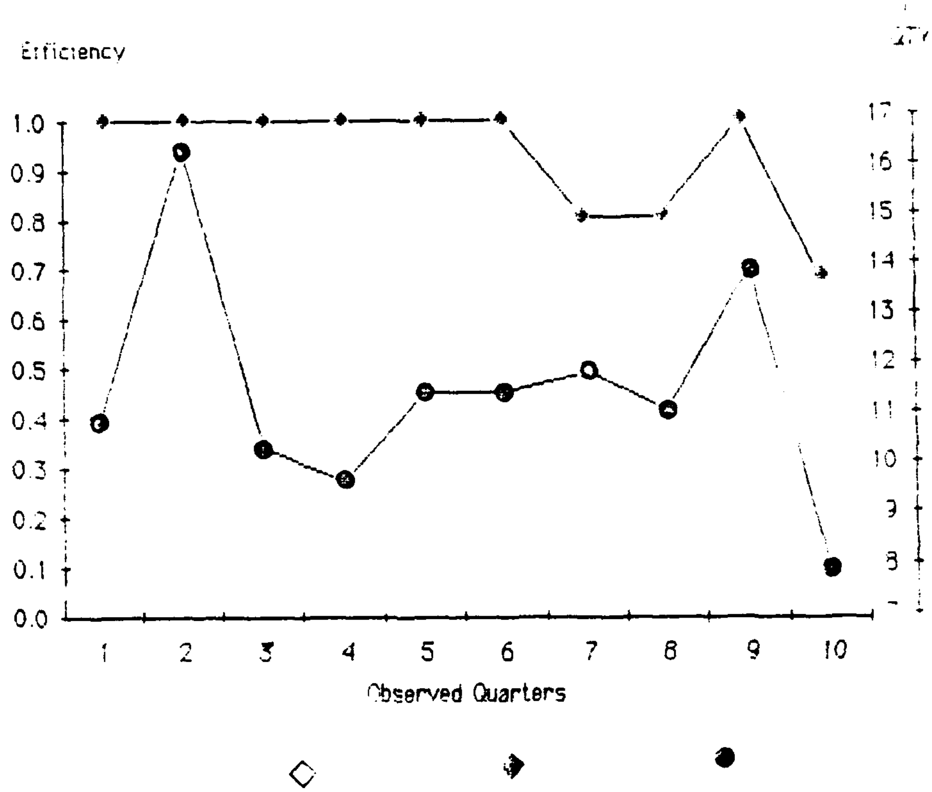
The data set for MANT Branch is shown in Appendix E22. Figure 20 shows the graphical application of the data set by the DEA/CFA models and the efficiency ratings assigned. The MANT Branch is composed of Cost Centers MNTDA, MNTSA and MNTTA (see Figure 2 on page 27). The efficiency ratings assigned to each of these Cost Centers are shown in Figures 14 through 16.

The upper and lower bound efficiency rating for this Branch is above 80% for each observation quarter except the tenth when it was 68%. The Branch average upper and lower bound efficiency rating for ten quarters was 92.95%.

The production quantity was quite variable in all observation quarters, ranging from a low of 7.9 to a high of 16.3 output units. Analyzing its three Cost Centers together reveals that all are extremely and consistently efficient over all ten observation periods.

Based on the fact that its three Cost Centers are all rated efficiently in nearly all quarters (only MNTSA experienced less than 100% efficiency in quarters 1, 8 and 10), Branch MANT would be expected to rate with equal efficiency. In fact, seven quarters for MANT had upper and lower bound efficiency rating of 100% and had adjusted to wide swings in production outputs. Possible explanations for the MANT drop in efficiency for the seventh, eighth and tenth quarters include an input or output data collection error or some unknown factor.

The three Cost Centers that comprise this Branch are all highly efficient, so the expectation would be that the Branch would also be highly efficient. Since the Branch shows unexplained inefficiencies in three quarters, management needs to verify the input data given for the three Cost Centers and for the Branch. The input data validation and DEA/CFA results for this Branch will be discussed in the next chapter.



Observed Quarter		Lower Bound	Upper Bound	Output Quantity
1	FY83-1	1.00	1.00	10.9
2	FY83-2	1.00	1.00	16.3
3	FY83-3	1.00	1.00	10.4
4	FY83-4	1.00	1.00	9.7
5	FY84-1	1.00	1.00	11.5
6	FY84-2	1.00	1.00	11.5
7	FY84-3	.807	.807	11.9
8	FY84-4	.808	.808	11.1
9	FY85-1	1.00	1.00	13.9
10	FY85-2	.680	.680	7.9

Figure 20. MANT Branch Analysis

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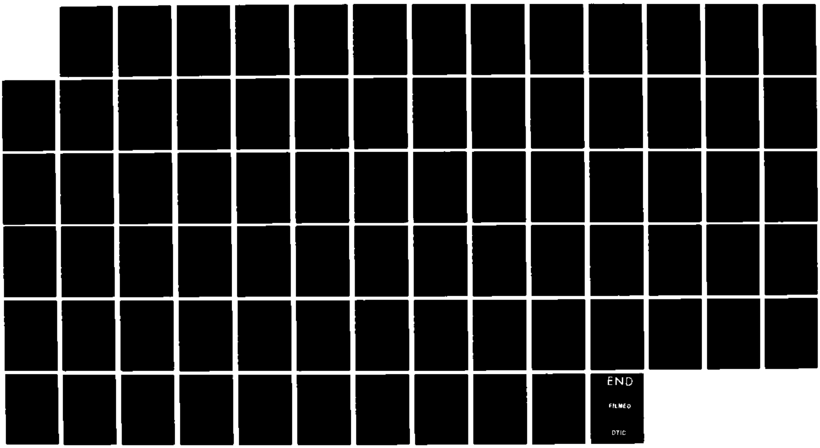

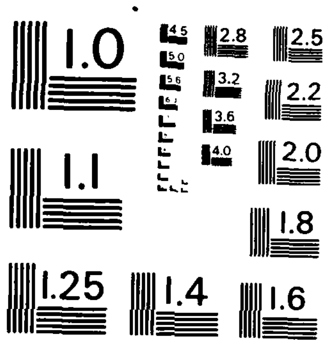

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MAN Division Analysis

The data set for MAN Division is shown in Appendix E23. Figure 21 shows the graphical application of the data set by the DEA/CFA models and the efficiency ratings generated. The MAN Division is composed of Branches MANL and MANT (see Figure 2 on page 27). The efficiency ratings for each of these Branches is shown in Figures 18 and 19).

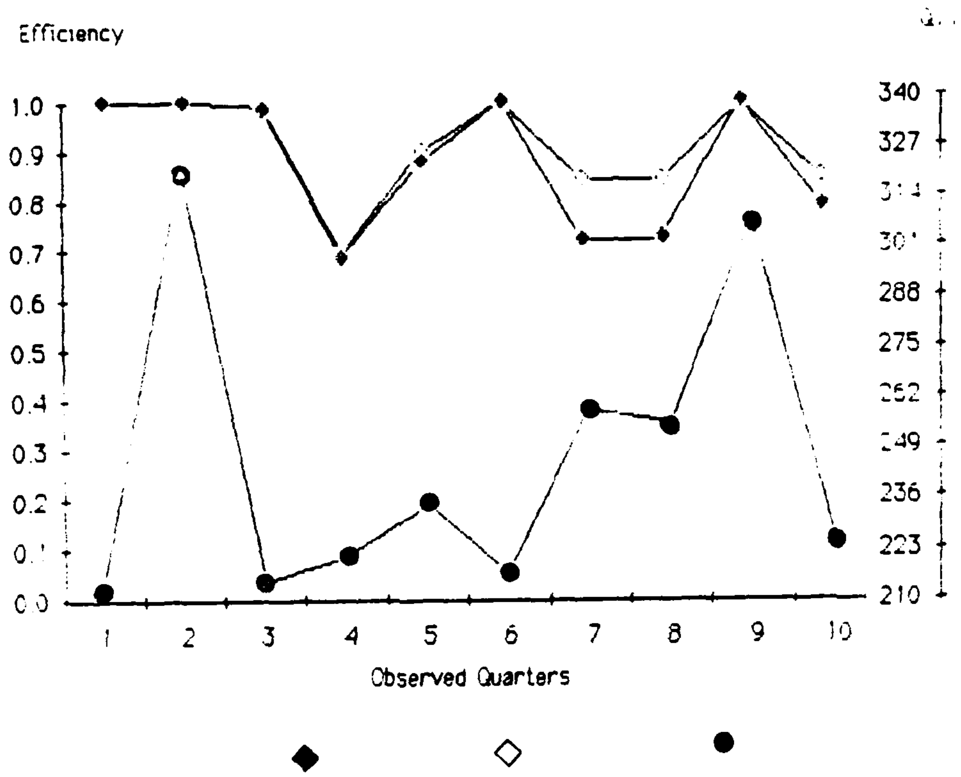
The upper bound efficiency rating for this Division is above 84% for every observation quarter except the fourth when it was only 69.1%. The average upper bound efficiency rating for all ten quarters is 91.12%. The lower bound efficiency rating is almost identical to the upper bound except in the seventh and eighth quarters.

The production quantity was quite variable in all observation quarters ranging from a low of 214.8 to a high of 320.4 units. Analyzing its two Branches together reveals that Branch MANT is much larger in terms of input resources consumed and output quantities produced than Branch MANL. Since MANT is the largest contributor of the two Branches comprising the Division, it is no surprise that the inefficiencies of MANL in the second and sixth quarters are compensated for by the efficiency of MANT in those quarters, and that the inefficiencies of MANT in the seventh, eighth and tenth quarters are reflected in the MAN Division.

All production output quantities do not seem to have been accounted for in the fourth observation quarter.

Since the two Branches operated efficiently during that observation quarter the expectation would be that the Division would have also. The amount of the four input resources consumed during the fourth quarter seem quite large, yet the production output does not justify this input consumption rate. Because of low production output, the fourth quarter had the highest input/output ratios of all four inputs consumed for all ten quarters. The manager of the MAN Division will verify the output production quantity for the fourth quarter and it will be discussed in the next chapter. The inefficiencies in the MAN Division for the seventh, eighth and tenth quarters are the result of the much larger MANT Branch inefficiencies.

The quarterly upper bound efficiency ratings for this Division seem erratic and management must decide if the peaks and valleys they represent are reasonable. In particular, the DEA/CFA models indicate a 27.7% decrease in efficiency and a 3.5% increase in production from the third to the fourth quarter. This situation indicates the inefficient use of resources or at least a contradiction worthy of managerial investigation. The trend for this Division indicates a reactive relationship between efficiency and production whereby if efficiency decreases production declines and if efficiency increases production increases. The above situation is an area where managerial concern should be directed.



Observed Quarter	Lower Bound	Upper Bound	Output Quantity
1 FY83-1	1.00	1.00	212.5
2 FY83-2	1.00	1.00	320.4
3 FY83-3	.986	.988	214.8
4 FY83-4	.684	.691	221.5
5 FY84-1	.879	.898	235.1
6 FY84-2	1.00	1.00	216.4
7 FY84-3	.721	.844	258.6
8 FY84-4	.726	.842	254.7
9 FY85-1	1.00	1.00	307.1
10 FY85-2	.790	.849	224.8

Figure 21. MAN Division Analysis

Interim Branch/Division Summary

The purpose of the preceding five sections was to discuss the results of applying the DEA/CFA models to the two combination Branch/Divisions, two Branches and the one Division data sets.

The three problems discussed on pages 71 and 72 in the interim Cost Center summary are also applicable at the Branch/Division level. Additionally, several of the Branches and or Divisions indicate inefficient use of resources because of decreasing efficiency and increasing production conditions, or increasing efficiency and decreasing production conditions. Both of these conditions are areas where management should focus its attention. The trend for all Branch and or Division organizations indicates a reactive relationship between efficiency and production whereby if efficiency decreases production declines and if efficiency increases production increases.

The next section is the culmination of the analyses whereby all organizational entities comprising the MA Directorate at AGMC are evaluated for total factor productivity.

MA Directorate Analysis

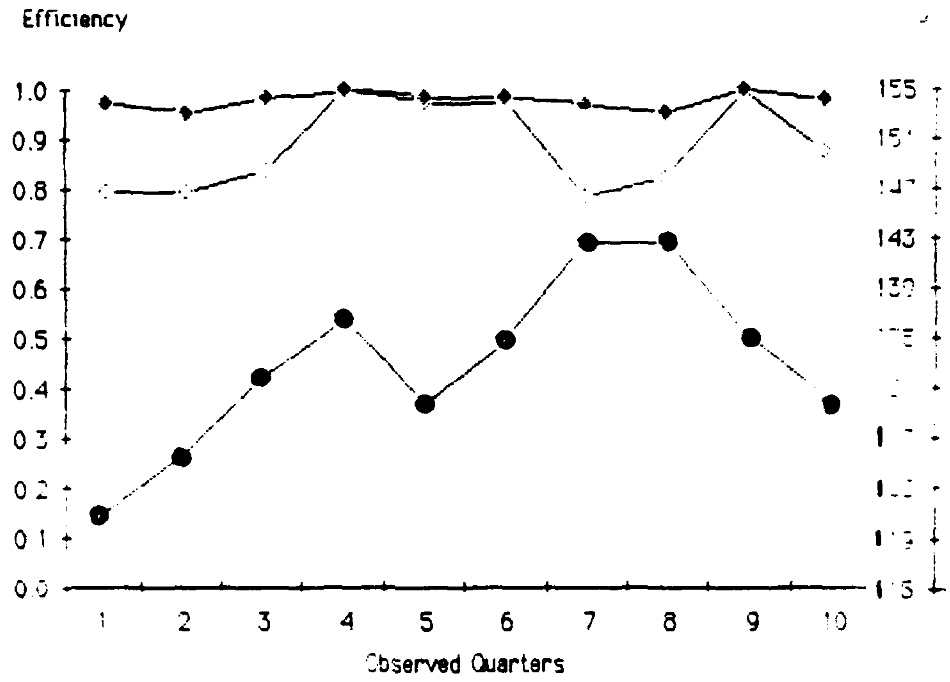
The data set for the MA Directorate is shown in Appendix E24. Figure 22 shows the graphical application of the data set by the DEA/CFA models and the efficiency ratings generated. The MA Directorate is composed of Divisions MAB, MAQ, MAK, MAN and Cost Center MTTTA (see Figure 2 on page 27). The efficiency ratings assigned to Divisions MAB, MAK and MAN are shown in Figures 17, 18 and 21 respectively. Division MAQ was not evaluated separately because of its extremely small fractional data set. However, data values from all 18 Cost Centers comprising the MA Directorate were combined to develop the data set for MA.

The upper bound efficiency rating for the Directorate is above 95% for all ten observation quarters reflecting the most optimistic DEA/CFA efficiency ratings. The average upper bound efficiency rating was 97.78%. The lower bound efficiency rating shows significant decreases from the upper bound in six of the ten quarters reflecting the more pessimistic DEA/CFA efficiency rating. The average lower bound efficiency rating was 88.57%. Thus, the MA Directorate would be expected to use its resources to operate between 88.57% and 97.78% efficiency.

The production quantity was variable in all observation quarters ranging from a low of 120.5 to a high of 142.5. Analyzing Divisions MAB, MAQ, MAK, MAN and Cost Center MTTTA together reveals that Divisions MAB and MAK accounted for the overwhelming majority of input resources consumed and production output quantities produced for the entire MA Directorate. Since Divisions MAB and MAK are the largest contributors to the MA Directorate it is no surprise that the inefficiencies within the much smaller MAQ and MAN Divisions and Cost Center MTTTA are compensated for.

On the aggregate, the MA Directorate appears to have effectively used its resources (average lower bound efficiency of 88.57% to average upper bound efficiency of 97.78%), despite wide variances in the quarterly production output as well as the fluctuations caused by the individual Division, Branch and Cost Center inefficiencies. However, as discussed in previous analyses of the Cost Centers, Branches, and Divisions, several problematic conditions of resource consumption require managerial attention. When multiple performance records are aggregated for analysis, the performance records of one organizational entity may be washed by another. Thus, tne DEA/CFA models and this research stress that attention toward maximizing efficiency and achieving optimum productivity must be clearly focused.

The quarterly upper bound efficiency ratings for the MA Directorate appear reasonable. However, management must decide if the peaks and valleys in efficiency are acceptable and investigate those that are not. The DEA/CFA models do show that the MA Directorate is highly efficient with upper bound average efficiency at 97.78%.



Observed Quarter		Lower Bound	Upper Bound	Output Quantity
1	FY83-1	.793	.972	120.5
2	FY83-2	.792	.951	125.4
3	FY83-3	.836	.985	131.7
4	FY83-4	1.00	1.00	136.3
5	FY84-1	.976	.986	129.7
6	FY84-2	.977	.984	134.7
7	FY84-3	.786	.969	142.4
8	FY84-4	.823	.952	142.5
9	FY85-1	1.00	1.00	134.9
10	FY85-2	.874	.979	129.7

Figure 22. MA Directorate Analysis

Summary

This chapter partially fulfilled the second objective of this thesis which was to analyze the results of applying the DEA/CFA models using four input variables (dollar amounts adjusted for inflation) and one output variable for selected organizational entities. It compared eighteen of the organizational entities against themselves over the ten observation quarters, see Figures 5 through 22.

The DEA/CFA models revealed several possible problems with the organizational entities evaluated. First, indications of possible accounting data errors concerning input resources consumed and or production output quantities produced within several organizational entities were discovered. Second, all of the input values for the MKPNA data set seem questionable since the results are extremely erratic in comparison to the other Cost Centers. Third, two instances of organizational entities receiving 100% efficiency ratings for all ten observation quarters seem suspect. Fourth, the conditions discussed in several of the Branches and or Divisions where possible inefficient use of resources is indicated by decreasing efficiency and increasing production conditions, or increasing efficiency and decreasing production conditions. Both of these conditions are areas where management should focus its attention. The trend for all Branch and Division organizations indicates a reactive relationship between efficiency and production whereby if efficiency decreases production declines and if efficiency increases production increases. These possible problems will be presented to managers of the respective organizational entities and discussed in the next chapter.

The DEA/CFA models also revealed three positive things about the organizational entities being evaluated. First, the average upper bound efficiency for many of the organizational entities is very high indicating a consistent performance pattern in the efficient use of resources. Second, the average trend in efficiency for all organizational entities except (Cost Centers MKPMA & MKPNA, Branch MANT and Division MAN) is increasing or constant at extremely high levels. Cost Center MKPMA shown in Figure 11 has a slightly decreasing trend in efficiency, and Cost Center MKPNA shown in Figure 12 has a very erratic trend in efficiency ratings. Branch MANT is highly efficient except for the unexplained inefficiencies in the seventh, eighth and tenth quarters. Division MAN is also highly efficient except for the unexplained inefficiencies in the fourth, seventh, eighth and tenth quarters. Third, the aggregation of all organizational entities into the data set for the MA Directorate was successful. The DEA/CFA analysis of the MA Directorate showed the upper bound efficiency ratings to be extremely high and stable with efficiency varying only slightly from one observation quarter to the next.

The next chapter will report on the validation of the analyses discussed in this chapter with AGMC managers and the potential usefulness of the DEA/CFA models to these managers. In Chapter VI, conclusions of this research effort will be presented as well as this authors recommendations.

V. Validation

The next step in the research effort is to validate the results of the analyses from the previous chapter and its potential usefulness with the managers of the respective organizational entities. This chapter completes the second objective of the thesis which is to evaluate the DEA/CFA models and discuss its advantages over other measurement techniques using data provided by AGMC.

Aerospace Guidance & Metrology Center (AGMC)

The importance of including management as well as modeling expertise in model design cannot be overstated (24:67). The close cooperation between the users and model designers is essential for meaningful and valid results. The information in the following sections reflects the findings from a review conducted by Mr. Lucin E. Ball (5) of each organizational entities performance, input and output data sets and discussion with the respective managers. Also, the author's personal observations from a tour of AGMC/MA and discussions with Mr. Ball and others of the HQ AGMC/MAWB staff are presented.

MBPEA Cost Center Validation. Mr. Ball rechecked the performance of MBPEA for the seventh quarter (see Figure 6) with the Cost Center manager and was unable to identify a cause for the drop in efficiency or production output. The Cost Center manager showed Mr. Ball his own Cost Center effectiveness figures, which though lower than those of the model, did parallel except for the seventh quarter. Production output data also paralleled the outputs used in the model, except for the seventh quarter. These two discrepancies indicated an accounting error was made in the output data collection. Mr. Ball rechecked his output calculations for the seventh quarter and found a production job which consumed 19,000 DPAH and produced 136 output units was inadvertently omitted.

Since this was the first instance of an accounting error in the output data, a revised data set was processed through the DEA/CFA models for this Cost Center. The addition of the missing 136 output units in the seventh quarter brought the production output up to 297 which resulted in that quarter now being rated at 100% efficiency. There were no changes in the other quarter's efficiency ratings. Due to the time limitations imposed upon this thesis, this error was not corrected in organizational levels above this Cost Center.

Processing the first data set for MBPEA through the DEA/CFA models indicates an inefficient quarter where in fact none existed. This situation was subsequently identified as an production output accounting data collection error. The higher efficiency ratings assigned to this Cost Center by the DEA/CFA models compared to the Cost Center manager's own effectiveness estimates are due to the models' greater generosity in establishing the best observed quarter as being 100% efficient.

No explanations for variations in efficiency ratings for Cost Centers MBPDA, MBPFA, MBPGA and MKPCA (see Figures 5, 7, 8 and 9 respectively) were offered by Mr. Ball or the Cost Center managers.

MKPEA Cost Center Validation. Mr. Ball rechecked both the inputs and outputs for this Cost Center and found no problems (see Figure 10). Upon discussing the performance of the Cost Center with the manager, Mr. Ball discovered that MKPEA had hired additional personnel and laid in additional supplies and equipment during the eighth quarter for a work load which began production in the ninth quarter. Although the output quantity was lower in the eighth quarter in comparison to the sixth, seventh and ninth, the manager felt that the necessary increases in inputs partially explained the variance in efficiency for the eighth quarter.

No explanation for variations in efficiency ratings for Cost Center MKPMA shown in Figure 11 were offered by Mr. Ball or the Cost Center manager.

MKPNA Cost Center Validation. Mr. Ball explained that this Cost Center shown in Figure 12 is AGMC's machine shop. The shop is manned to rework parts that fail in other Cost Centers and to fabricate tools and fixtures which may be required. The manager for Cost Center MKPNA explained that the machine shop needs to be manned as it is, in the event parts require rework or fabrication work is required. The workload for MKPNA is therefore dependent upon whether or not failures occur or fabrication is needed for other Cost Centers. If the workload is slack, the efficiency of MKPNA will be adversely affected as the manning must be retained in order to maintain the necessary response time and machinist skills required. The situation in the first quarter, where the input/output ratios for DPAH and DLC are the highest for all ten quarters, indicates an excessive work force is present causing that quarter to be inefficient.

However, another possible reason for the low efficiency ratings in this Cost Center for the fifth through eighth quarters is the much higher accumulation of DMC in comparison to the production output. For instance, the third quarter is rated 100% efficient and produced the same output quantity as the fifth quarter. The DPAH, DLC and OMC are almost identical for the third and fifth quarters. However, the DMC is $813.67 for the third quarter, $40,348.75 in the fifth, $36,367.50 in the sixth, $13,675.20 in the seventh and $5,651.20 in the eighth.

While the Cost Center manager's explanation accounts for the fairly stable consumption of DPAH and DLC in all quarters, the DEA/CFA models indicate that the source of inefficiency in the fifth through eighth quarters is in the possible excessive accumulation of DMC per output produced. The accumulation of DMC by this Cost Center should be an area of concern for management as it appears to be a driving factor in the efficiency ratings assigned to this Cost Center by the DEA/CFA models.

MNLSA Cost Center Validation. Mr. Ball explained that the Cost Center shown in Figure 13 is AGMC's test repair shop and is workloaded in a manner similar to the machine shop. MNLSA repairs test equipment which fails in other Cost Centers and must maintain manning even though there are periods when no repairs are required.

Mr Ball rechecked the input data shown in Appendix E14 and found no errors. However, he discovered an entire page of output data had been inadvertently omitted for the seventh quarter, which increased that quarter's output figure to 31 from 19.

The Cost Center manager's explanation accounts for the low output quantity in the first and fourth quarter which resulted in the subsequently lower efficiency ratings in those quarters.

A revised MNLSA data set with 31 as the output production quantity for the seventh quarter was not rerun through the DEA/CFA models due to time limitations on this research effort. Also, this error was not corrected in organizational levels above Cost Center MNLSA for the same reason. However, it should be noted that the revised input/output ratios and output quantity for the seventh quarter are very similar to the fifth quarter which had a upper and lower bound efficiency rating of 100%.

MNTDA, MNTSA, & MNTTA Cost Center Validations. Mr. Ball explained that the output quantities for these three Cost Centers listed in Figures 14 through 16 are measured in hours consumed rather than production units produced. Using hours consumed as a output measure does not cause difficulties for these three Cost Centers or the MANT Branch. However, the use of man hours consumed as an output measure for these three Cost Centers and the MANT Branch came as a surprise to this author. The output measure selected and agreed upon by AGMC/MAWB and this author for use in this thesis research is a scaled representation of End/Item output production within each organizational entity (see pages 33-36). By changing the output measure, AGMC/MAWB has created the situation of aggregating unlike output measures from the MANT Branch and the MANL Branch to form the MAN Division. This situation of comparing apples and oranges also occurs when the MAN Division is aggregated with the other Divisions and Cost Center MTTTA to form the MA Directorate output measure. The implications of this situation will be discussed in the upcoming section on the MA Directorate validation.

The three Cost Centers are workloaded for the number of man hours available and the efficiency is expected to be at or near 100% since one hour of output is equated to one hour of work. The Cost Center managers were therefore supportive of the DEA/CFA models' assignment of maximum or near maximum efficiency ratings to all three Cost Centers. The Cost Center manager for MNTSA offered no explanation for the decrease in efficiency ratings in the seventh, eighth and tenth quarter (see Figure 15).

Examining the data set for MNTSA in Appendix E16 reveals that the ratios of DPAH, DLC and OMC are almost identical for all ten observation quarters. However, the DMC consumed was zero in all but the seventh, eighth and tenth quarters. In order to run this data set through the DEA/CFA models all zeroes were replaced with .01. The DEA/CFA models interpreted the $16 DMC input for the seventh quarter as being 1,600 times greater (16 / .01 = 1,600) than that required for the seven quarters which in fact had zero DMC. The DEA/CFA models also interpreted the eighth quarter as using 700 times more and the tenth quarter as using 200 times more than the quarters where no DMC were used.

While the decrease in efficiency ratings for Cost Center MNTSA in the seventh, eighth and tenth quarters due to DMC is not severe at the Cost Center level, it becomes more pronounced when the MANT Branch and MAN Division data sets are processed through the DEA/CFA models. Therefore, care must be observed in future instances where a organizational entity has real input consumption in some quarters and imaginary (using .01 instead of zero) consumption in others.

No explanations for variations in efficiency ratings for MABP Branch / MAB Division shown in Figure 17 or MAKP Branch / MAK Division shown in Figure 18 were offered by Mr. Ball or the respective managers.

MANL Branch Validation. Mr. Ball explained that the MANL Branch shown in Figure 19 generally tracks the output of its largest Cost Center which is MNLSA. Since MNLSA has the greatest workload of the five Cost Centers assigned to MANL, it has the greatest effect on the Branch output. As indicated in the section for MNLSA, an output production accounting error was made at the Cost Center level which was repeated when the aggregate Cost Center totals were computed for the Branch level. Due to the lack of time imposed on this research effort, the revised data sets for Cost Center MNLSA and the MANL Branch were not processed through the DEA/CFA models.

No other explanations were offered by Mr. Ball or the Cost Center manager to explain the other variations in efficiency within the MANL Branch.

MANT Branch Validation. The MANT Branch is composed of Cost Centers MNTDA, MNTSA & MNTTA (see Figure 2 on page 27). The efficiency ratings assigned to each of these Cost Centers are shown in Figures 14 through 16. As discussed earlier in this chapter, the quarterly fluctuations in efficiency for Cost Centers MNTSA were apparently caused by the $25 spent in DMC in the seventh, eighth and tenth quarters. When the three Cost Center totals were aggregated to the Branch level the $25 spent on DMC causes similar but slightly more pronounced quarterly efficiency fluctuations resulting in lower Branch efficiency ratings for the seventh eighth and tenth quarters (see Figure 20).

The Branch manager was expecting to see ten quarters of 100% efficiency ratings because the Branch is composed of three highly efficient Cost Centers. However, since the $25 spent on DMC caused quarterly efficiency fluctuations within Cost Center MNTSA it also had a similar but slightly more pronounced effect upon the MANT Branch.

MAN Division Validation. Mr. Ball felt the efficiency variations within the MAN Division shown in Figure 21 were the results of trying to equalize man hours consumed in the MANT Branch and actual production output produced in the MANL Branch. Branch MANL has actual production quantity outputs, whereas Branch MANT has output expressed as man hours consumed. In aggregating the output data from the two Branches to form the MAN Division data set, Mr. Ball scaled the outputs of both Branches to the output quantity used in the MANL Branch.

Apparently trying to scale man hours consumed for Branch MANT by units of output production from Branch MANL and then adding it to output production from Branch MANL, created unrepresentative output data for the MAN Division. The output quantity figures generated by this aggregation of apples and oranges from the two Branches to form the MAN Division output quantities shown in Figure 21 are probably substantially in error. The efficiency ratings for the MAN Division are probably also substantially in error. The impact of using the MAN Division data set to partial form the data set for the MA Directorate will be discussed in the next section.

MA Directorate Validation. No explanations for variations in efficiency ratings for the MA Directorate shown in Figure 22 were offered by Mr. Ball or the Director of MA. However, it is known that the efficiency ratings for the MA Directorate reflect the two accounting errors resulting from the understatement of output quantities for Cost Centers MBPEA and MNLSA. Correcting these two accounting errors for the MA Directorate data sets would have slightly improved the MA Directorate efficiency rating for the seventh quarter.

Also, the efficiency ratings for the MA Directorate reflect the effect of the small but unreliable data set used for the MAN Division. The resources consumed by the MAN Division are extremely small in comparison to those used by the entire MA Directorate (see Appendices E23 and E24 respectively). Therefore, it can be assumed that the MAN Division data set had only a small impact on the actual efficiency ratings for the MA Directorate.

Due to time limitations on this research effort, the two accounting errors discovered within Cost Centers MBPEA and MNLSA and the possible unrepresentative data set for the MAN Division were not corrected in the MA Directorate data sets and the DEA/CFA models rerun.

Summary

The results of measuring the technical efficiency of the eighteen organizational entities is Chapter IV were accepted with some reservations by most managers at AGMC/MA. In general, the following four situations developed in the analysis and validation process which influenced how the managers reacted to the DEA/CFA results.

First, if the managers got what they were expecting, their validation of the results was almost assured. Examples of this would include the anticipated 100% efficiency ratings for all quarters in Cost Centers MNTDA and MNTTA shown in Figures 14 and 16. Another example would be the manager of Cost Center MKPEA expecting a drop in efficiency in the eighth quarter due to the hiring of additional employees and purchase of supplies for future consumption.

Second, if the managers got the efficiency trends they expected but the efficiency ratings produced by the DEA/CFA models were higher, they were somewhat reluctant to accept them. It was necessary to explain to these managers that the DEA/CFA models efficiency ratings were not absolute measures of efficiency and that the upper bounds were the most optimistic measure of efficiency. The validation comments offered by the MBPEA Cost Center manager are an example of this situation.

Third, if the managers didn't get what they expected, they rejected the model as flawed or containing errors. This situation arose in the following three cases. The first case was when the results were initially rejected because the original data set contained an error. However, when the error was corrected, the manager was able to accept the efficiency ratings. Examples of this situation were the output quantity error in the seventh quarter for Cost Center MBPEA and the output quantity error in the seventh quarter for Cost Center MNLSA. The second case where the efficiency results were initially rejected was the reduced efficiency ratings caused by the inclusion of DMC in the data set for Cost Centers MKPNA and MNTSA and also in Branch MANT. When actual DMC was used with imaginary DMC (using .01 instead of zero), the resulting efficiency ratings for the Cost Centers or Branch were rejected. The last case where the model was rejected was in the validation of the MAN Division. In this case, the problem with the output quantity in the MAN Division data set appears to be an inappropriate scaling of man hours consumed from Branch MANT and production output from Branch MANL.

Fourth, some managers initially rejected the results of the DEA/CFA models because they had never heard of it before and did not understand the process. However, after Mr. Ball thoroughly explained the models and how they work, the results were deemed acceptable.

The validation process has been extremely valuable in finding and correcting errors in the different data sets used by the DEA/CFA models, in securing support among AGMC/MA management for the DEA/CFA models, and in identifying the inconsistent output measurement situation for Cost Centers MNTDA, MNTSA, MNTTA, Branch MANT and the MAN Division.

In retrospect, many of the observations made in Chapter IV could have been avoided if the data sets used had been correct initially and the inconsistent output measurement situation within the MAN Division had been identified and resolved. However, one of the purposes of the research, to evaluate the feasibility of using DEA/CFA models in organizational levels above the Cost Centers level, was successfully accomplished.

VI. Conclusions and Recommendations

This chapter presents the conclusions and recommendations of this tnesis. First, the research problem is restated. Second a summary of how the research objectives from Chapter I were answered is presented. Third, the findings of this research effort are presented. Finally, recommendations are presented on how to implement the DEA/CFA models into the AGMC Management Information System.

Chapter I presented the thesis problem and scated four research objectives. The hypothesis of this research effort was that the DEA/CFA models could be used to enhance the existing Management Information System (MIS) at AGMC/MA to provide total factor measures of technical productivity improvements for maintenance levels above the Cost Center. This was stated in a HQ AFLC/MA thesis proposal (19) and confirmed by HQ AGMC/MA upper management (18) and HQ AGMC/MAWB (4).

The thesis answered the four research objectives shown on page 4 in the following manner.

Objective One. The first objective, to establish input and output measures at AGMC/MA for use by the DEA/CFA models, was met with the methodology in Chapter III. The data input and output variables at AGMC/MA were identified and reduced to four inputs and one "universal widget" output. The four input measures selected were Direct Product Actual Hours (DPAH), Direct Labor Cost (DLC), Direct Material Cost (DMC) and Overhead & Miscellaneous Cost (OMC). The "universal widget" output measure is a hypothetical product or service which standardized uncommon outputs within an organizational entity into single recognizable units.

Objective Two. The first half of objective two, to evaluate the DEA/CFA models using data provided by HQ AGMC/MAWB, begins in Chapter IV and is validated in Chapter V. Eighteen of the organizational entities at AGMC/MA were compared against themselves over the ten observation quarters using four input variables (dollar amounts adjusted for inflation) and one output variable. The eighteen data sets for these organizational entities were evaluated by the DEA/CFA models, then analyzed in Chapter IV and validated in Chapter V.

The second half of objective two, to discuss the advantages of using the DEA/CFA models over other measurement techniques began in the literature review of Chapter II and was completed in the validation of the thesis results in Chapter V.

Objective Three. Chapters III, IV and V combined successfully to accomplish objective three which was to discuss the feasibility of using the DEA/CFA models as a total factor productivity measurement tool on maintenance levels above the Cost Center within AGMC/MA. Chapter III identified the input and output variables that were required for use by the DEA/CFA models. Chapter IV analyzed the results of applying the data sets developed in Chapter III to the DEA/CFA models. Chapter V validated the results of the analyses from Chapter IV with the respective maintenance managers involved.

Objective four is met in the recommendation section of this thesis. The next section presents the major findings of this research effort.

Conclusions. There were several major findings from this thesis research effort. The following list indicates the author's ranking of the importance of these findings.

1. With the exception of the MAN Division at AGMC/MA, Chapters III through V clearly demonstrate that it is feasible to evaluate Branches by properly aggregating subcomponent Cost Centers, Divisions by properly aggregating subcomponent Branches, and the Directorate by properly aggregating all lower level organizational levels. However, the situation of aggregating unlike output measures within the MAN Division has not been resolved. The significance of this finding is that it

is feasible to measure productivity improvements on organizational levels above the Cost Center at AGMC/MA. The practically of using the DEA/CFA models to measure technical productivity improvements at AGMC/MA depends upon the adoption of the recommendations that follow.

2. The literature review in Chapter II indicates that the DEA/CFA models can measure total factor tecnnical productivity improvements and are the best techniques presently available.

3. The author is convinced that productivity measurement above the Cost Center level of maintenance is a valid problem because past total factor measurement techniques were inadequate, piecemeal or non-existent. The DEA/CFA models are improvements over other measurement techniques and should meet the decision making informational needs of AGMC/MA managers at any organizational level.

4. Interviews with AGMC/MA managers indicate that the DEA/CFA techniques are improvements over the current lack of total factor productivity measurement techniques. After thoroughly explaining the DEA/CFA techniques to AGMC/MA managers and correcting the initial data value errors, the managers (with the exception of the MAN Division) believed that the results were valid. The MAN Division still has the unresolved issue of combining total man hours consumed from one

Branch with actual production output from another Branch. These managers at AGMC/MA appear ready to receive efficiency rating productivity reports using the DEA/CFA techniques to aid in their management decision making.

5. The output measures selected for use as inputs to the DEA/CFA models must be the same from one organizational entity to the next. This would avoid the situation within the MAN Division of trying to aggregate apples and oranges to form an output measure.
6. The manual creation and manipulation of the data sets for each organizational entity is far too time consuming and error prone to be of practical use. The manual production of the output values in the data bases shown in Appendices E1 - E24 took HQ AGMC/MAWB over 300 man hours to produce using a Zenith 100 microcomputer. The manual production of the input values in the data bases shown in Appendices E1 - E24 took the author over 100 man hours. This included combining the input data from the quarterly FXAT59 printouts and discounting the dollar values for inflation. The author also spent another 50 hours of microcomputer processing time to input all of the data bases, process the data sets through the DEA/CFA models and print out the results.
7. Caution must be observed in selecting input values so that imaginary data is not evaluated along with real

input data by the DEA/CFA models. This was the case in the MNTSA Cost Center, the MANT Branch and the MAN Division. In these situations, real DMC was evaluated along with imaginary DMC (.01 data input values). The significance of this finding is that imaginary data can distort the efficiency ratings of an organizational entity because the DEA/CFA models are highly sensitive to the input/output ratios generated and the comparison of these ratios from one time period to the next.

8. Undetected errors in input or output measures are automatically aggregated into higher organizational levels, which distorts their efficiency ratings. Therefore, extreme care must be exercised to keep the data bases error free. When an error is detected, correction of the input or output values for all organizational levels involved must be performed.

9. The DEA/CFA models indicated several possible instances of inefficient use of resources where management attention should be directed. The analysis of several Branches and or Divisions indicated possible inefficient use of resources when efficiency decreased and production increased, or efficiency increased and production decreased. The overall trend for organizational entities within AGMC/MA indicates a reactive relationship between efficiency and production, whereby if efficiency decreases production declines and

if efficiency increases production increases. When this general tread in violated, the inefficient use of resources probably occurred.

10. The average upper bound efficiency for many of the organizational entities is very high indicating a consistent performance pattern in the efficient use of resources. Also, the average trend in efficiency for all organizational entities except (Cost Centers MKPMA and MKPNA, Branch MANT and Division MAN) is increasing or constant at extremely high levels.

Recommendations

Objective four, which is to suggest specific recommendations on the use of the DEA/CFA models to measure total factor technical productivity improvements at AGMC/MA, is met in this section with the following five recommendations:

1. HQ AGMC/MAWB needs to redefine the output measure used in the data bases for each organizational entity by establishing a AGMC/MA "standard output unit" and relating all outputs to it. By establishing a standard output unit, the data base for each organizational entity will not have to be rescaled when each new observation period is added. The output for each organizational entity would be described in terms of this standard output unit. The standard output unit would allow the efficiency comparisons of all

organizational levels and facilitate the aggregation of the output measures for organizational entities above the Cost Center. It would also overcome the situation within the MAN Division of combining an output in man hours from one Branch with an output in production units from the other Branch.

2. The time period for a DMU observation in the new data base should be shortened to a monthly basis to expedite the flow of efficiency information to the AGMC/MA managers. This would triple the number of DMU observation periods within a 90 day period from one to three. AGMC currently collects the input data necessary for a monthly data base at the end of each calendar month and then aggregates it to a quarterly value.

3. After expanding the number of DMU observation periods based on the above recommendation, the number of input or output variables used by the DEA/CFA models could be increased. Since this research was limited to ten observation quarters, only five input or output variables were evaluated. If the FY 83 monthly data sets had been available, 30 monthly observation periods would have been possible and up to fifteen input or output variables could have been evaluated. In the new monthly data base, all eight input variables identified on pages 31 and 32 plus the new standard output unit could be evaluated simultaneously. Evaluating the nine

variables simultaneously would be possible by adopting recommendation number two above. Using all eight input variables individually rather than in combinations should improve the sensitivity and accuracy of the DEA/CFA models in evaluating the technical efficiency ratings of each organizational entity.

4. HQ AGMC/MA should incorporate the Productivity Analysis Support System (PASS) DEA/CFA models into the AGMC main frame computer based Management Information System. PASS is the commercial version of the DEA/CFA models used in this research effort. This recommendation would overcome the biggest objection of the HQ AGMC/MAWB Division (5) which is that the manual manipulation of the data bases are too time consuming and introduces errors. Once the new data bases are properly established on the main frame computer at AGMC, the PASS DEA/CFA models would be able to process and print the results in a few hours instead of the hundreds of hours as is now required using small microcomputer and manual manipulations.

Appendix A: Glossary of Terms

Constrained Facet Analysis (CFA) - extension of Data Envelopment Analysis which analyzes efficiencies for DMUs that are not fully enveloped and provides upper and lower bound measures of efficiency. The actual efficiency measure is somewhere between the upper and lower bound.

Congestion - Production technology exhibits congestion if one input is increased and output falls. Congestion occurs when reducing usage of a proper subset of inputs generates a increase in output, while holding constant the usage of all remaining inputs.

Constraint - an equality or inequality that restricts or limits the linear fractional programming objective function to certain feasible solutions.

Data Envelopment Analysis (DEA) - a linear fractional program that evaluates multiple inputs and outputs simultaneously through multi-dimensional mathematics forming a frontier of efficiency and providing a relative efficiency rating for each decision making unit.

Decision Making Unit (DMU) - represents an organizational element that is analyzed by DEA/CFA models such as a Cost Center, Branch, Division or the Directorate.

Direct Labor Cost (DLC) - identifies the cost of direct labor used to accomplish the specified production for the period.

Direct Material Cost (DMC) - composed of the dollar totals for DMC-Expense and DMC-Exchange.

DMC-Exchange - the cost of components exchanged or replaced on End Items in order to make them serviceable. The exchangeable component is removed in an unservicealbe condition and replaced with a serviceable one.

DMC-Expense - the cost of material installed directly on the product being worked by the Cost Center.

Direct Product Actual Hours (DPAH) - the number of hours used by the Cost Center to produce the End Items (E/I) (during the specified time period). The DPAH for an individual control number are the hours required to produce the specified quantity of E/I. The total DPAH for the Cost Center are the hours required to produce all of the E/I worked by the Cost Center.

Effective - producing outputs quantities with input resources that are of sufficient quality and consistent with the quantity and timeliness goals of a person/organization.

Efficient - producing more outputs with the same input resources or the same outputs with less input resources.

Efficiency - the ratio of outputs produced or work completed divided by input resources consumed.

Envelopment - a characteristic of DEA analysis where the efficiency measure of an inefficient decision making unit is determined by comparison with a complete frontier facet which is defined entirely by empirical observations so the upper and lower bounds of efficiency are equal.

Floppy Disk - a removable magnetic disk used to store programs, data, etc. for use with small computer systems.

FY Quarter - Three consecutive months of a fiscal year.

General Administrative Overhead Cost - the cost of General and Administrative support including staff offices, personnel, civil engineering, dispensary, energy, etc.

Inflation Factors - inflation percentages from AFR 173-13 compiled from the U. S. Government Office Of Management and Budget, used to adjust FY 1984 and FY 1985 input dollars to the FY 1983 base year.

Input Measures - the four inputs DPAH, DLC, DMC and OMC.

Input Orientation - a DMU is not efficient if it is possible to decrease any input without augmenting any other input and without decreasing any output.

Linear Program - a mathematical problem which has an objective function and constraints where all mathematical expressions are linear.

Lower Bound Efficiency - the lowest possible efficiency rating for a given decision making unit.

Model - a mathematical representation of a real situation.

Neighborhood - the clustering of several DMUs together in an area of a graph, such as points B, C and G in Figure 1. For example, point G would be in the neighborhood of line segment (B to C).

Not-For-Profit Organization - an organization whose goal is not to make a profit but to provide a service.

Objective Function - a maximized or minimized mathematical expression limited by its set of constraints.

Other Direct Miscellaneous Cost - are charges for temporary duty that is made in direct support of a production output. (While it is not a true overhead or miscellaneous cost, this other direct miscellaneous cost category only accounts for $3,291.00 over the ten FY quarters and is therefore included to keep the figures in agreement. The Grand Total spent by AGMC for the ten quarters is over $185 million. In comparison, this $3,291.00 is somewhat insignificant).

Output Measure -the result of a scaling process that equalizes all production output to the unit with the largest DPAH in the respective organization.

Output Orientation - a DMU is not efficient if it is possible to increase output without increasing any input and without decreasing any other output.

Overhead & Miscellaneous Cost (OMC) - composed of the sum of Shop, Support, General Administrative and Other Direct Miscellaneous Costs.

Partial Ratio - one output divided by one input when multiple inputs and multiple outputs are available.

Piece-Wise-Linear Frontier - a frontier formed by the most efficient decision making units where each facet of the frontier is a linear combination of efficient observations.

Production Function - the theoretical maximum amount of output obtained from a given level of inputs of a process.

Productivity - a function of effectiveness and efficiency, the ratio of outputs produced divided by the inputs consumed where outputs are useful and consistent with the goals of a person or organization.

Quality - a standard by which an item or value is judged.

Ratio - the quotient of one number divided by another.

Scale Efficiency - the ratio of the aggregate efficiency measure to the technical efficiency measure.

Shop Overhead Cost - labor charges for supervision, training, standby, and miscellaneous within the Cost Center.

Software - programs used to simplify the use of a computer operating system.

Support Overhead Cost - labor charges for the product support staff other that at the Cost Center level.

Technical Efficiency - a measure of success in achieving the maximum output from inputs expended expressed as a ratio of an observed level of outputs over inputs divided by a maximum value of outputs over inputs on the piece-wise-linear frontier.

Timeliness - a state of being early, on time or late.

Total Factor Ratio - ratio of all outputs over all inputs.

Unbiasness - the relative efficiency rating of a point derived without comparison to any artificial weights or standards, but only to the relative efficiency frontier segment. Inefficient DMUs are directly compared only to DMUs on the relative efficiency frontier which have similar mixes of inputs and outputs. This is a fundamental advantage when using DEA because it overcomes the tendency to compare dissimilar activities.

Universal Widget - a term designating a hypothetical product/service output which standardizes uncommon outputs within an organizational entity into a single recognizable unit.

Window Analysis - rearrangement of data observation periods to overcome the degrees-of-freedom requirements that effect efficiency evaluations when using DEA.

Appendix B: Mathematical Expression of DEA

$$\text{MAXIMIZE} \quad H_j = \frac{\sum_{r=1}^{s} U_r Y_{rj}}{\sum_{i=1}^{m} V_i X_{ij}} \qquad j = 1,2,3\ldots M$$

$$\text{SUBJECT TO:} \quad \frac{\sum_{r=1}^{s} U_r Y_{rj}}{\sum_{i=1}^{m} V_i X_{ij}} \leq 1 \qquad j = 1,2,3\ldots M$$

$$U_r , V_i > 0 \quad \text{FOR EVERY } i, r$$

where:

i	=	counter for summation of 1 to s.
j	=	each organization for up to M.
m	=	the total number of inputs.
r	=	counter for summation of 1 to m.
s	=	the total number of outputs.
H_j	=	the efficiency rating for each.
M	=	total number being evaluated.
U_r	=	weight for output r to be calculated from the analysis (unbiased).
V_i	=	weight for input i to be calculated from the analysis (unbiased).
X_{ij}	=	measurement of ith input for DMU j.
Y_{rj}	=	measurement of rth output for DMU j.

(2)

Appendix C: Sample End Item Cost Report Page

[illegible] 83 JAN 15   END ITEM [illegible] COST REPORT QTR AS OF [illegible]

[illegible]OST [illegible]ENTER   MNTTA

CONTROL NUMBER	J O	STOCK NUMBER OR E/I COMPLETED	COST CENTER		DPAH	DIRECT LABOR	COST OTHER	DIR MATERIAL EXPENSE	COST EXCHANGE	OVERHEAD COST SHOP	OVERHEAD COST SUPPORT	G A	TOTAL
T[illegible]513	R	6605P[illegible]00513	MNTTA*	ACT PRE	705 47	11850	00	00	00	[illegible] 2265	2159 2315	4136 6091	[illegible]
T[illegible]513	R	1	CONTROL	TOTAL									
T0551	R	6605P[illegible]00551	MNTTA*	ACT PRE	208 96	5265	00	00	00	8[illegible]3 683	763 717	1211 1736	[illegible]
T[illegible]551	R	1	CONTROL	TOTAL									
T[illegible]556	R	6605P[illegible]00556	MNTTA*	ACT PRE	524 73	10230	00	00	00	1713 16[illegible]	1828 1736	3030? 1501	[illegible]
T[illegible]556	R	1	CONTROL	TOTAL									
T[illegible]557	R	6605P[illegible]00557	MNTTA*	ACT PRE	295 75	4082	00	00	00	[illegible]27 342	[illegible]	1725? [illegible]	[illegible]
T[illegible]557	R	0	CONTROL	TOTAL									
T[illegible]562	R	6605P[illegible]00562	MNTTA*	ACT PRE	120 75	2172	00	00	00	433? 396	117 416	719? [illegible]	[illegible]
T[illegible]562	R	1	CONTROL	TOTAL									
T[illegible]575	R	6605P[illegible]575	MNTTA*	ACT PRE	495 49	9999	00	00	00	2282? 1631	1810? 1728	[illegible]	[illegible]
T0575	R	1	CONTROL	TOTAL									
T0592	R	1095P[illegible]00592	MNTTA*	ACT PRE	208 00	3434	00	00	00	[illegible] [illegible]29	74[illegible] 71[illegible]	[illegible]	[illegible]
T[illegible]592	R	1	CONTROL	TOTAL									
T[illegible]593	R	6605P[illegible]593	MNTTA*	ACT PRE	690 76	11345	00	00	00	[illegible]	[illegible]	[illegible]	[illegible]
T[illegible]593	R	1	CONTROL	TOTAL									
T[illegible]417	G	66[illegible]354208	MNTTA	ACT PRE	6 53	125	00	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
T[illegible]417	G	0	CONTROL	TOTAL									
T[illegible]418	G	6605[illegible]354208	MNTTA	ACT PRE	6 00	115	00	00	00	13 18	[illegible] 17	3[illegible] 5[illegible]	[illegible]
T[illegible]418	G	0	CONTROL	TOTAL									
T7418	G	0	[illegible]C TOTAL	ACT PRE	7346 48	151866	00	00	00	26472 [illegible]	28195 26165	[illegible]	[illegible]
GRAND TOTAL				ACT PRE	435523 17	6753068	00	1206477	914800	26[illegible]341 24[illegible]	[illegible]116 2971350	2641336 1873[illegible]	[illegible]

A   B   C

[illegible]   END PAGE 0119

APPENDIX D1: FY 83 QTR 1, INPUT & OUTPUT DATA

		INPUTS				OUT
		DPAH	DLC $	DMC $	OMC $	QTY
COST CENTERS						
1)	MBPDA	38591.15	566846	401141	777328	169
2)	MBPEA	32313.05	484306	138705	515575	219
3)	MBPFA	78967.24	1063012	369853	1499400	191
4)	MBPGA	53947.29	776248	328413	1208565	637
5)	MCPQA	2025.58	34991	.01*	23551	.7
6)	MKPCA	77896.45	1060329	1808764	1669243	78
7)	MKPEA	38397.78	575058	556602	857515	12.2
8)	MKPMA	58777.30	902700	392801	1055309	62
9)	MKPNA	12541.95	172359	2166	209706	2
10)	MNLAA	.01	.01	.01	.01	.01
11)	MNLEA	.01	.01	.01	.01	.01
12)	MNLPA	564.56	9454	2303	6544	.47
13)	MNLPB	751.60	10480	06	8574	1
14)	MNLSA	1305.74	17673	26441	17608	10
15)	MNTDA	4162.41	64957	.01	56169	4.2
16)	MNTSA	6090.27	110088	.01	96751	4.3
17)	MNTTA	5016.56	73089	.01	86937	4.1
18)	MTTTA	8.00	106	.01	58	.01
BRANCHES						
1)	MABP	203818.73	2890412	1238112	4000868	200
2)	MAQC	2025.58	34991	.01	23551	.7
3)	MAKP	187613.48	2710446	2760333	3791773	52.4
4)	MANL	2621.90	37607	28750	32726	22.4
5)	MANT	15269.24	248134	.01	239857	10.9
DIVISIONS						
1)	MAB	203818.73	2890412	1238112	4000868	200
2)	MAQ	2025.58	34991	.01	23551	.7
3)	MAK	187613.48	2710446	2760333	3791773	52.4
4)	MAN	17891.14	285741	28750	272583	212.5
DIRECTORATE						
	MA	411356.93	5921696	4027195	8088833	120.5

* NOTE - DEA/CFA does not allow a 0 as a input or output value. As shown for Cost Center # 5 MCPQA, all 0 values have been converted to a .01 value.

APPENDIX D2: FY 83 QTR 2, INPUT & OUTPUT DATA

	INPUTS				OUT
	DPAH	DLC $	DMC $	OMC $	QTY
COST CENTERS					
1) MBPDA	43803.73	629597	857214	906808	144
2) MBPEA	33055.02	489868	305580	546057	222
3) MBPFA	72482.43	971364	569101	1497583	178
4) MBPGA	64146.60	945514	645421	1241305	713
5) MCPQA	1992.77	35301	2735	27125	.2
6) MKPCA	66758.88	898702	1757440	1446756	72
7) MKPEA	50623.00	764736	936330	1136087	16.1
8) MKPMA	61025.50	952451	734980	1138205	64
9) MKPNA	12244.97	172077	4538	206430	5
10) MNLAA	.01*	.01	.01	.01	.01
11) MNLEA	.01	.01	.01	.01	.01
12) MNLPA	895.22	13832	41683	11010	.07
13) MNLPB	450.46	6581	180	5493	.05
14) MNLSA	3465.29	47204	82832	46812	35
15) MNTDA	3109.14	49277	.01	49373	3.1
16) MNTSA	8347.89	149721	.01	128115	5.8
17) MNTTA	7333.42	120774	.01	108186	9.6
18) MTTTA	.01	.01	.01	.01	.01
BRANCHES					
1) MABP	213487.78	3036343	2377316	4191750	196
2) MAQC	1992.77	35301	2735	27125	.2
3) MAKP	190652.35	2787966	3433288	3927478	55.6
4) MANL	4810.97	67617	124695	63315	35.5
5) MANT	18790.45	319772	.01	285674	16.3
DIVISIONS					
1) MAB	213487.78	3036343	2377316	4191750	196
2) MAQ	1992.77	35301	2735	27125	.2
3) MAK	190652.35	2787966	3433288	3927478	55.6
4) MAN	23601.42	387389	124695	348989	320.4
DIRECTORATE					
MA	429734.32	6246999	5938034	8495342	125.4

* NOTE - DEA/CFA does not allow a 0 as a input or output value. As shown for Cost Center # 10 MNLAA, all 0 values have been converted to a .01 value.

APPENDIX D3: FY 83 QTR 3, INPUT & OUTPUT DATA

	INPUTS				OUT
	DPAH	DLC $	DMC $	OMC $	QTY
COST CENTERS					
1) MBPDA	43174.58	633349	678147	940299	195
2) MBPEA	40413.00	603843	457331	664843	274
3) MBPFA	72639.93	994044	463005	1501926	182
4) MBPGA	63430.00	926638	372678	1192349	748
5) MCPQA	2415.38	42350	.01*	35814	.3
6) MKPCA	72508.83	980779	1944030	1644238	84
7) MKPEA	51890.28	789204	1036969	1189208	16.2
8) MKPMA	55584.50	868637	845529	1033822	59
9) MKPNA	12388.59	175858	1556	214002	4
10) MNLAA	.01	.01	.01	.01	.01
11) MNLEA	.01	.01	.01	.01	.01
12) MNLPA	680.55	10365	5337	8712	.08
13) MNLPB	267.00	3826	.01	3164	.01
14) MNLSA	2948.31	39346	30703	42669	33
15) MNTDA	3297.49	52036	.01	52239	3.3
16) MNTSA	7428.53	137065	.01	95608	4.7
17) MNTTA	3716.35	66933	.01	50785	3.8
18) MTTTA	.01	.01	.01	.01	.01
BRANCHES					
1) MABP	219657.51	3157874	1971161	4299417	220
2) MAQC	2415.38	42350	.01	35814	.3
3) MAKP	192372.20	2814478	3828084	4081270	57.3
4) MANL	3895.86	53537	36040	54545	39.5
5) MANT	14442.37	256034	.01	198632	10.4
DIVISIONS					
1) MAB	219657.51	3157874	1971161	4299417	220
2) MAQ	2415.38	42350	.01	35814	.3
3) MAK	192372.20	2814478	3828084	4081270	57.3
4) MAN	18338.23	309571	36040	253177	214.8
DIRECTORATE					
MA	432783.32	6324273	5835285	8669678	131.7

* NOTE - DEA/CFA does not allow a 0 as a input or output value. As shown for Cost Center # 5 MCPQA, all 0 values have been converted to a .01 value.

APPENDIX D4: FY 83 QTR 4, INPUT & OUTPUT DATA

	INPUTS				OUT
	DPAH	DLC $	DMC $	OMC $	QTY
COST CENTERS					
1) MBPDA	38146.24	565035	462550	849406	173
2) MBPEA	37009.27	564774	144645	645919	253
3) MBPFA	75206.70	1037827	360057	1607195	189
4) MBPGA	67199.18	972964	373148	1302652	829
5) MCPQA	1606.67	26779	.01*	24359	2.3
6) MKPCA	74211.95	1012859	1751312	1735210	101
7) MKPEA	51830.51	795424	789456	1273703	16.5
8) MKPMA	52806.27	843826	564371	1058151	55
9) MKPNA	12331.13	177081	2441	219972	3
10) MNLAA	.19	1	.01	3	.01
11) MNLEA	.01	.01	.01	.01	.01
12) MNLPA	1512.70	23836	1665	20260	2.31
13) MNLPB	432.83	6556	.01	5538	.01
14) MNLSA	3465.83	48917	104416	51717	34
15) MNTDA	4865.88	74273	.01	69039	4
16) MNTSA	5979.27	109266	.01	80540	3.1
17) MNTTA	8227.33	152117	.01	126761	4.3
18) MTTTA	48.00	607	.01	390	.01
BRANCHES					
1) MABP	217561.39	3140600	1340400	4405172	222
2) MAQC	1606.67	26779	.01	24359	2.3
3) MAKP	191179.86	2829190	3107580	4287036	60.9
4) MANL	5411.55	79310	106081	77518	52.4
5) MANT	19072.48	335656	.01	276340	9.7
DIVISIONS					
1) MAB	217561.39	3140600	1340400	4405172	222
2) MAQ	1606.67	26779	.01	24359	2.3
3) MAK	191179.86	2829190	3107580	4287036	60.9
4) MAN	24484.03	414966	106081	353858	224.8
DIRECTORATE					
MA	434879.95	6412142	4554061	9070815	136.3

* NOTE - DEA/CFA does not allow a 0 as a input or output value. As shown for Cost Center # 5 MCPQA, all 0 values have been converted to a .01 value.

APPENDIX D5: FY 84 QTR 1, INPUT & OUTPUT DATA

	INPUTS				OUT
	DPAH	DLC $	DMC $	OMC $	QTY
COST CENTERS					
1) MBPDA	33950.64	511514	254627	866692	154
2) MBPEA	39182.55	620273	144849	619777	268
3) MBPFA	76912.50	1062131	565344	1390117	183
4) MBPGA	60848.04	917283	624234	952177	719
5) MCPQA	1462.40	22652	17974	24946	.01
6) MKPCA	71607.67	998395	1984444	1556125	85
7) MKPEA	50455.08	766191	924747	1099303	16.1
8) MKPMA	51998.03	849378	279820	1088396	62
9) MKPNA	12005.48	175711	161395	205710	4
10) MNLAA	7.43	108	82	294	.01
11) MNLEA	48.87	862	4265	627	.004
12) MNLPA	891.01	14647	2047	12365	.29
13) MNLPB	96.03	1612	529	1235	.01
14) MNLSA	2654.24	37212	66092	39056	32
15) MNTDA	3311.01	53796	.01*	44494	3.3
16) MNTSA	6920.95	131931	.01	91780	4.7
17) MNTTA	6721.28	120225	.01	103411	5.2
18) MTTTA	30.98	410	.01	234	.01
BRANCHES					
1) MABP	210893.73	3111201	1589104	3828763	208
2) MAQC	1462.40	22652	17974	24946	.01
3) MAKP	186066.26	2789675	3350406	3949534	58.5
4) MANL	3697.58	54441	73015	53577	34.1
5) MANT	16953.24	305952	.01	239685	11.5
DIVISIONS					
1) MAB	210893.73	3111201	1589104	3828763	208
2) MAQ	1462.40	22652	17974	24946	.01
3) MAK	186066.26	2789675	3350406	3949534	58.5
4) MAN	20650.82	360393	73015	293262	235.1
DIRECTORATE					
MA	419104.19	6284331	5030499	8096739	129.7

* NOTE - DEA/CFA does not allow a 0 as a input or output value. As shown for Cost Center # 15 MNTDA, all 0 values have been converted to a .01 value.

APPENDIX D6: FY 84 QTR 2, INPUT & OUTPUT DATA

	INPUTS				OUT
	DPAH	DLC $	DMC $	OMC $	QTY
COST CENTERS					
1) MBPDA	37958.57	564308	440681	901829	172
2) MBPEA	43250.94	683069	173232	631887	295
3) MBPFA	74640.83	1039296	592990	1260538	188
4) MBPGA	59765.95	910040	709036	904003	739
5) MCPQA	1677.6	28762	23149	27722	.01
6) MKPCA	71371.33	996032	1766338	1428715	83
7) MKPEA	59594.59	885867	1026673	1227459	18.9
8) MKPMA	58664.97	972806	526259	1165551	62
9) MKPNA	12108.11	178407	145470	189118	4
10) MNLAA	17.56	280	295	1264	.01
11) MNLEA	18.00	340	333	281	.01
12) MNLPA	138.69	2283	57	1912	.03
13) MNLPB	658.57	10378	1382	10722	.03
14) MNLSA	1261.35	18283	15029	17401	15
15) MNTDA	3120.97	47921	.01*	37335	2.8
16) MNTSA	7373.07	136542	.01	130126	5.1
17) MNTTA	6627.58	123660	.01	80028	5
18) MTTTA	.01	.01	.01	.01	.01
BRANCHES					
1) MABP	215616.29	3196713	1915939	3698257	219
2) MAQC	1677.60	28762	23149	27722	.01
3) MAKP	201739.00	3033112	3464740	4010843	60.4
4) MANL	2094.17	31564	17096	31580	15.5
5) MANT	17121.62	308123	.01	247489	11.5
DIVISIONS					
1) MAB	215616.29	3196713	1915939	3698257	219
2) MAQ	1677.60	28762	23149	27722	.01
3) MAK	201739.00	3033112	3464740	4010843	60.4
4) MAN	19215.79	339687	17096	279069	216.4
DIRECTORATE					
MA	438248.68	6598274	5420924	8015891	134.7

* NOTE - DEA/CFA does not allow a 0 as a input or output value. As shown for Cost Center # 15 MNTDA, all 0 values have been converted to a .01 value.

APPENDIX D7: FY 84 QTR 3, INPUT & OUTPUT DATA

	INPUTS				OUT
	DPAH	DLC $	DMC $	OMC $	QTY
COST CENTERS					
1) MBPDA	44452.40	641877	633254	996987	202
2) MBPEA	43480.19	662145	317408	655954	161
3) MBPFA	88385.94	1196406	826412	1422217	235
4) MBPGA	68509.96	992341	902686	1003094	808
5) MCPQA	1663.15	27612	14989	27937	.01
6) MKPCA	79851.81	1064634	2051250	1632269	91
7) MKPEA	65846.19	944435	1383249	1263199	20.2
8) MKPMA	57465.82	925079	530398	1131815	60
9) MKPNA	14589.70	210314	68376	221231	5
10) MNLAA	(4.88)*	(83)	(214)	(1857)	.01
11) MNLEA	5.00	101	12	96	.01
12) MNLPA	2012.33	31411	6656	33987	1.1
13) MNLPB	564.30	8433	29214	7725	.68
14) MNLSA	2587.56	37574	155814	35181	19
15) MNTDA	4913.17	75580	.01*	55924	5
16) MNTSA	7229.35	136423	16	123256	5.1
17) MNTTA	6471.18	116310	.01	79315	4.8
18) MTTTA	117.34	1490	.01	660	.01
BRANCHES					
1) MABP	244828.49	3492769	2679760	4078252	230
2) MAQC	1663.15	27612	14989	27937	.01
3) MAKP	217753.52	3144462	4033273	4248514	63.6
4) MANL	5164.31	77436	191482	75132	49.6
5) MANT	18613.70	328313	16	258495	11.9
DIVISIONS					
1) MAB	244828.49	3492769	2679760	4078252	230
2) MAQ	1663.15	27612	14989	27937	.01
3) MAK	217753.52	3144462	4033273	4248514	63.6
4) MAN	23778.01	405749	191498	333627	258.6
DIRECTORATE					
MA	488140.51	7072082	6919520	8688990	142.4

* NOTE - DEA/CFA does not allow a 0 or a negative number as a input or output value. All 0 values have been converted to a .01 value, and negative numbers enclosed in brackets.

APPENDIX D8: FY 84 QTR 4, INPUT & OUTPUT DATA

	INPUTS				OUT
	DPAH	DLC $	DMC $	OMC $	QTY
COST CENTERS					
1) MBPDA	42760.37	641070	433260	963229	195
2) MBPEA	41215.69	641085	148354	684963	282
3) MBPFA	93533.21	1275570	669379	1507793	244
4) MBPGA	52802.02	793084	565636	808983	623
5) MCPQA	1895.14	28896	14785	32830	.01
6) MKPCA	91668.69	1238513	2557380	1931438	105
7) MKPEA	67752.10	999839	1307440	1336093	15.4
8) MKPMA	58112.82	951358	414197	1197115	59
9) MKPNA	15258.67	222265	28256	240402	5
10) MNLAA	4.61	56	43	186	.01
11) MNLEA	359.83	5806	424	9182	.082
12) MNLPA	1643.62	26547	790	28812	.73
13) MNLPB	73.05	1047	867	1654	.05
14) MNLSA	4369.40	64330	192587	61869	51
15) MNTDA	1919.45	29300	.01*	21982	1.9
16) MNTSA	6648.92	126789	7	129485	4.7
17) MNTTA	7260.12	125478	.01	100154	5.8
18) MTTTA	16.00	207	.01	91	.01
BRANCHES					
1) MABP	230311.29	3350809	1816629	3964968	234
2) MAQC	1895.14	28896	14785	32830	.01
3) MAKP	232792.28	3411975	4307273	4705048	62.4
4) MANL	6450.51	97786	194711	101703	65.3
5) MANT	15828.49	281567	7	251621	11.1
DIVISIONS					
1) MAB	230311.29	3350809	1816629	3964968	234
2) MAQ	1895.14	28896	14785	32830	.01
3) MAK	232792.28	3411975	4307273	4705048	62.4
4) MAN	22279.00	379353	194718	353324	254.7
DIRECTORATE					
MA	487293.71	7171240	6333405	9056261	142.5

* NOTE - DEA/CFA does not allow a 0 as a input or output value. As shown for Cost Center # 15 MNTDA, all 0 values have been converted to a .01 value.

APPENDIX D9: FY 85 QTR 1, INPUT & OUTPUT DATA

	INPUTS				OUT
	DPAH	DLC $	DMC $	OMC $	QTY
COST CENTERS					
1) MBPDA	41993.69	632731	520244	951430	189
2) MBPEA	40535.45	644638	92046	613451	272
3) MBPFA	79698.92	1096452	657481	1189712	212
4) MBPGA	53074.39	802771	322348	849121	626
5) MCPQA	2111.12	33505	9993	36823	.01
6) MKPCA	62463.84	882663	1462551	1102069	74
7) MKPEA	63213.34	957113	1066304	1127107	19.9
8) MKPMA	54541.75	895477	322144	1045030	58
9) MKPNA	12166.20	184883	7095	180541	7
10) MNLAA	71.99	1184	507	3811	.01
11) MNLEA	1.22	18	462	23	.01
12) MNLPA	978.21	14922	716	16238	.31
13) MNLPB	201.17	3227	.01*	3022	.21
14) MNLSA	4256.14	59775	52647	55889	50
15) MNTDA	6745.34	107113	.01	75264	6.7
16) MNTSA	5523.92	104931	.01	100675	3.9
17) MNTTA	7946.48	147730	.01	93489	6
18) MTTTA	.01	.01	.01	.01	.01
BRANCHES					
1) MABP	215302.45	3176592	1592119	3603714	219
2) MAQC	2111.12	33505	9993	36823	.01
3) MAKP	192385.13	2920136	2858094	3454747	58.4
4) MANL	5508.73	79126	54332	78983	54.6
5) MANT	20215.74	359774	.01	269428	13.9
DIVISIONS					
1) MAB	215302.45	3176592	1592119	3603714	219
2) MAQ	2111.12	33505	9993	36823	.01
3) MAK	192385.13	2920136	2858094	3454747	58.4
4) MAN	25724.47	438900	54332	348411	307.1
DIRECTORATE					
MA	435523.17	6569133	4514538	7443695	134.9

* NOTE - DEA/CFA does not allow a 0 as a input or output value. As shown for Cost Center # 13 MNLPB, all 0 values have been converted to a .01 value.

APPENDIX D10: FY 85 QTR 2, INPUT & OUTPUT DATA

	INPUTS				OUT
	DPAH	DLC $	DMC $	OMC $	QTY
COST CENTERS					
1) MBPDA	44559.07	676469	658540	1022231	172
2) MBPEA	40766.00	641499	140016	678639	286
3) MBPFA	73023.04	1016178	627537	1138440	192
4) MBPGA	51596.79	781777	657786	904927	609
5) MCPQA	2703.08	44688	20457	57174	1.8
6) MKPCA	66757.93	947396	1545475	1181809	79
7) MKPEA	55513.09	823069	1208672	1122568	17.3
8) MKPMA	59542.25	990092	338697	1215050	62
9) MKPNA	11487.36	174104	8104	175739	7
10) MNLAA	94.19	1563	3	2181	1
11) MNLEA	439.69	7027	.01*	19476	1
12) MNLPA	678.55	10070	938	12331	.02
13) MNLPB	320.09	5159	180	6226	.38
14) MNLSA	4839.50	72577	85028	65320	60
15) MNTDA	1800.09	28363	.01	21400	1.8
16) MNTSA	6836.54	136987	2	114316	4.3
17) MNTTA	5185.16	95089	.01	67773	3.7
18) MTTTA	.01	.01	.01	.01	.01
BRANCHES					
1) MABP	209944.90	3115923	2083879	3744237	209
2) MAQC	2703.08	44688	20457	57174	1.8
3) MAKP	193300.63	2934661	3100948	3695166	58.4
4) MANL	6372.02	96396	86149	105534	70.1
5) MANT	13821.79	260439	2	203489	7.9
DIVISIONS					
1) MAB	209944.90	3115923	2083879	3744237	209
2) MAQ	2703.08	44688	20457	57174	1.8
3) MAK	193300.63	2934661	3100948	3695166	58.4
4) MAN	20193.81	356835	86151	309023	224.8
DIRECTORATE					
MA	426142.42	6452107	5291435	7805600	129.7

* NOTE - DEA/CFA does not allow a 0 as a input or output value. As shown for Cost Center # 11 MNLEA, all 0 values have been converted to a .01 value.

APPENDIX E1: MBPDA COST CENTER INPUT & OUTPUT DATA

FY - QTR	INPUTS: DPAH	INPUTS: DLC $	INPUTS: DMC $	INPUTS: OMC $	OUT QTY
1) FY 83-1	38591.15	566846	401141	777328	169
2) FY 83-2	43803.73	629597	857214	906808	144
3) FY 83-3	43174.58	633349	678147	940299	195
4) FY 83-4	38146.24	565035	462550	849406	173
5) FY 84-1	33950.64	511514	254627	866692	154
6) FY 84-2	37958.57	564308	440681	901829	172
7) FY 84-3	44452.40	641877	633254	996987	202
8) FY 84-4	42760.37	641070	433260	963229	195
9) FY 85-1	41993.69	632731	520244	951430	189
10) FY 85-2	44559.07	676469	658540	1022231	172

APPENDIX E2: MBPEA COST CENTER INPUT & OUTPUT DATA

FY - QTR		INPUTS				OUT
		DPAH	DLC $	DMC $	OMC $	QTY
1)	FY 83-1	32313.05	484306	138705	515575	219
2)	FY 83-2	33055.02	489868	305580	546057	222
3)	FY 83-3	40413.00	603843	457331	664843	274
4)	FY 83-4	37009.27	564774	144645	645919	253
5)	FY 84-1	39182.55	620273	144849	619777	268
6)	FY 84-2	43250.94	683069	173232	631887	295
7)	FY 84-3	43480.19	662145	317408	655954	161
8)	FY 84-4	41215.69	641085	148354	684963	282
9)	FY 85-1	40535.45	644638	92046	613451	272
10)	FY 85-2	40766.00	641499	140016	678639	286

APPENDIX E3: MBPFA COST CENTER INPUT & OUTPUT DATA

FY - QTR		INPUTS				OUT
		DPAH	DLC $	DMC $	OMC $	QTY
1)	FY 83-1	78967.24	1063012	369853	1499400	191
2)	FY 83-2	72482.43	971364	569101	1497583	178
3)	FY 83-3	72639.93	994044	463005	1501926	182
4)	FY 83-4	75206.70	1037827	360057	1607195	189
5)	FY 84-1	76912.50	1062131	565344	1390117	183
6)	FY 84-2	74640.83	1039296	592990	1260538	188
7)	FY 84-3	88385.94	1196406	826412	1422217	235
8)	FY 84-4	93533.21	1275570	669379	1507793	244
9)	FY 85-1	79698.92	1096452	657481	1189712	212
10)	FY 85-2	73023.04	1016178	627537	1138440	192

APPENDIX E4: MBPGA COST CENTER INPUT & OUTPUT DATA

FY - QTR		INPUTS				OUT
		DPAH	DLC $	DMC $	OMC $	QTY
1)	FY 83-1	53947.29	776248	328413	1208565	637
2)	FY 83-2	64146.60	945514	645421	1241305	713
3)	FY 83-3	63430.00	926638	372678	1192349	748
4)	FY 83-4	67199.18	972964	373148	1302652	829
5)	FY 84-1	60848.04	917283	624284	952177	719
6)	FY 84-2	59765.95	910040	709036	904003	739
7)	FY 84-3	68509.96	992341	902686	1003094	808
8)	FY 84-4	52802.02	793084	565636	808983	623
9)	FY 85-1	53074.39	802771	322348	849121	626
10)	FY 85-2	51596.79	781777	657786	904927	609

APPENDIX E5: MCPQA COST CENTER, MAQC BRANCH & MAQ DIVISION INPUT & OUTPUT DATA

		INPUTS				OUT
	FY - QTR	DPAH	DLC $	DMC $	OMC $	QTY
1)	FY 83-1	2025.58	34991	.01*	23551	.7
2)	FY 83-2	1992.77	35301	2735	27125	.2
3)	FY 83-3	2415.38	42350	.01	35814	.3
4)	FY 83-4	1606.67	26779	.01	24359	2.3
5)	FY 84-1	1462.40	22652	17974	24946	0
6)	FY 84-2	1677.6	28762	23149	27722	0
7)	FY 84-3	1663.15	27612	14989	27937	0
8)	FY 84-4	1895.14	28896	14785	32830	0
9)	FY 85-1	2111.12	33505	9993	36823	0
10)	FY 85-2	2703.08	44688	20457	57174	1.8

* NOTE - DEA/CFA does not allow a 0 as a input or output value. As shown for FY-QTR 83-1 all 0 values have been converted to a .01 value. This data set contains five zero output quantities out of ten and five extremely small output quantities. Subsequently it did not produce meaningful efficiency measures when applied to the DEA/CFA models.

APPENDIX E6: MKPCA COST CENTER INPUT & OUTPUT DATA

	FY - QTR	INPUTS				OUT
		DPAH	DLC $	DMC $	OMC $	QTY
1)	FY 83-1	77896.45	1060329	1808764	1669243	78
2)	FY 83-2	66758.88	898702	1757440	1446756	72
3)	FY 83-3	72508.83	980779	1944030	1644238	84
4)	FY 83-4	74211.95	1012859	1751312	1735210	101
5)	FY 84-1	71607.67	998395	1984444	1556125	85
6)	FY 84-2	71371.33	996032	1766338	1428715	83
7)	FY 84-3	79851.81	1064634	2051250	1632269	91
8)	FY 84-4	91668.69	1238513	2557380	1931438	105
9)	FY 85-1	62463.84	882663	1462551	1102069	74
10)	FY 85-2	66757.93	947396	1545475	1181809	79

APPENDIX E7: MKPEA COST CENTER INPUT & OUTPUT DATA

FY - QTR		INPUTS				OUT
		DPAH	DLC $	DMC $	OMC $	QTY
1)	FY 83-1	38397.78	575058	556602	857515	12.2
2)	FY 83-2	50623.00	764736	936330	1136087	16.1
3)	FY 83-3	51890.28	789204	1036969	1189208	16.2
4)	FY 83-4	51830.51	795424	789456	1273703	16.5
5)	FY 84-1	50455.08	766191	924747	1099303	16.1
6)	FY 84-2	59594.59	885867	1026673	1227459	18.9
7)	FY 84-3	65846.19	944435	1383249	1263199	20.2
8)	FY 84-4	67752.10	999839	1307440	1336093	15.4
9)	FY 85-1	63213.34	957113	1066304	1127107	19.9
10)	FY 85-2	55513.09	823069	1208672	1122568	17.3

APPENDIX E8: MKPMA COST CENTER INPUT & OUTPUT DATA

FY - QTR		INPUTS				OUT
		DPAH	DLC $	DMC $	OMC $	QTY
1)	FY 83-1	58777.30	902700	392801	1055309	62
2)	FY 83-2	61025.50	952451	734980	1138205	64
3)	FY 83-3	55584.50	868637	845529	1033822	59
4)	FY 83-4	52806.27	843826	564371	1058151	55
5)	FY 84-1	51998.03	849378	279820	1088396	62
6)	FY 84-2	58664.97	972806	526259	1165551	62
7)	FY 84-3	57465.82	925079	530398	1131815	60
8)	FY 84-4	58112.82	951358	414197	1197115	59
9)	FY 85-1	54541.75	895477	322144	1045030	58
10)	FY 85-2	59542.25	990092	338697	1215050	62

APPENDIX E9: MKPNA COST CENTER INPUT & OUTPUT DATA

FY - QTR		INPUTS				OUT
		DPAH	DLC $	DMC $	OMC $	QTY
1)	FY 83-1	12541.95	172359	2166	209706	2
2)	FY 83-2	12244.97	172077	4538	206430	5
3)	FY 83-3	12388.59	175858	1556	214002	4
4)	FY 83-4	12331.13	177081	2441	219972	3
5)	FY 84-1	12005.48	175711	161395	205710	4
6)	FY 84-2	12108.11	178407	145470	189118	4
7)	FY 84-3	14589.70	210314	68376	221231	5
8)	FY 84-4	15258.67	222265	28256	240402	5
9)	FY 85-1	12166.20	184883	7095	180541	7
10)	FY 85-2	11487.36	174104	8104	175739	7

APPENDIX E10: MNLAA COST CENTER INPUT & OUTPUT DATA

FY - QTR	INPUTS DPAH	DLC $	DMC $	OMC $	OUT QTY
1) FY 83-1	.01*	.01	.01	.01	0
2) FY 83-2	.01	.01	.01	.01	0
3) FY 83-3	.01	.01	.01	.01	0
4) FY 83-4	.19	1	.01	3	0
5) FY 84-1	7.43	108	82	294	0
6) FY 84-2	17.56	280	295	1264	0
7) FY 84-3	(4.88)*	(83)	(214)	(1857)	0
8) FY 84-4	4.61	56	43	186	0
9) FY 85-1	71.99	1184	507	3811	0
10) FY 85-2	94.19	1563	3	2181	1

* NOTE - DEA/CFA does not allow a 0 or a negative number as a input or output value. As shown for FY-QTR 83-1 all 0 values have been converted to a .01. As shown for FY-QTR 84-3 all negative values are enclosed in brackets and will not be used. Cost Center MNLAA is a relatively new Cost Center (started in FY-QTR 83-4) and therefore its valid observation history is insufficient to run the DEA/CFA model against. Also, nine of the ten output quantities are zero making these output measures unusable.

APPENDIX E11: MNLEA COST CENTER INPUT & OUTPUT DATA

FY - QTR	INPUTS				OUT
	DPAH	DLC $	DMC $	OMC $	QTY
1) FY 83-1	.01*	.01	.01	.01	0
2) FY 83-2	.01	.01	.01	.01	0
3) FY 83-3	.01	.01	.01	.01	0
4) FY 83-4	.01	.01	.01	.01	0
5) FY 84-1	48.87	862	4265	627	.004
6) FY 84-2	18.00	340	333	281	0
7) FY 84-3	5.00	101	12	96	0
8) FY 84-4	359.83	5806	424	9182	.082
9) FY 85-1	1.22	18	462	23	0
10) FY 85-2	439.69	7027	.01*	19476	1

* NOTE - DEA/CFA does not allow a 0 as a input or output value. As shown for FY-QTR 83-1 all 0 values have been converted to a .01 value. Cost Center MNLEA is a relatively new Cost Center (started in FY-QTR 84-1) and therefore its valid observation history is insufficient to run the DEA/CFA model against. Also, seven of the ten output quantities are zero, and two others are extremely small fractional amounts, making these output measures unusable.

APPENDIX E12: MNLPA COST CENTER INPUT & OUTPUT DATA

FY - QTR		INPUTS				OUT
		DPAH	DLC $	DMC $	OMC $	QTY
1)	FY 83-1	564.56	9454	2303	6544	.47
2)	FY 83-2	895.22	13832	41683	11010	.07
3)	FY 83-3	680.55	10365	5337	8712	.08
4)	FY 83-4	1512.70	23836	1665	20260	2.31
5)	FY 84-1	891.01	14647	2047	12365	.29
6)	FY 84-2	138.69	2283	57	1912	.03
7)	FY 84-3	2012.33	31411	6656	33987	1.10
8)	FY 84-4	1643.62	26547	790	28812	.73
9)	FY 85-1	978.21	14922	716	16238	.31
10)	FY 85-2	678.55	10070	938	12331	.02

* NOTE - The output quantities for this Cost Center are extremely small fractions and were therefore suspect. When applying this data set to the DEA/CFA model, extremely erratic efficiency measures were generated which were discarded by this author and AGMC management.

APPENDIX E13: MNLPB COST CENTER INPUT & OUTPUT DATA

FY - QTR	INPUTS: DPAH	INPUTS: DLC $	INPUTS: DMC $	INPUTS: OMC $	OUT: QTY
1) FY 83-1	751.60	10480	06	8574	1
2) FY 83-2	450.46	6581	180	5493	.05
3) FY 83-3	267.00	3826	.01*	3164	0
4) FY 83-4	432.83	6556	.01	5538	0
5) FY 84-1	96.03	1612	529	1235	0
6) FY 84-2	658.57	10378	1382	10722	.03
7) FY 84-3	564.30	8433	29214	7725	.68
8) FY 84-4	73.05	1047	867	1654	.05
9) FY 85-1	201.17	3227	.01	3022	.21
10) FY 85-2	320.09	5159	180	6226	.38

* NOTE - DEA/CFA does not allow a 0 as a input or output value. As shown for FY-QTR 83-3 all 0 values have been converted to a .01 value. The data set for MNLPB contained three zero and seven extremely small fractional output quantities. Therefore, based on the experience gained from applying the data set from Appendix E12, this data set was not applied to the DEA/CFA models.

APPENDIX E14: MNLSA COST CENTER INPUT & OUTPUT DATA

FY - QTR		INPUTS				OUT
		DPAH	DLC $	DMC $	OMC $	QTY
1)	FY 83-1	1305.74	17673	26441	17608	10
2)	FY 83-2	3465.29	47204	82832	46812	35
3)	FY 83-3	2948.31	39346	30703	42669	33
4)	FY 83-4	3465.83	48917	104416	51717	34
5)	FY 84-1	2654.24	37212	66092	39056	32
6)	FY 84-2	1261.35	18283	15029	17401	15
7)	FY 84-3	2587.56	37574	155814	35181	19
8)	FY 84-4	4369.40	64330	192587	61869	51
9)	FY 85-1	4256.14	59775	52647	55889	50
10)	FY 85-2	4839.50	72577	85028	65320	60

APPENDIX E15: MNTDA COST CENTER INPUT & OUTPUT DATA

	INPUTS				OUT
FY - QTR	DPAH	DLC $	DMC $	OMC $	QTY
1) FY 83-1	4162.41	64957	.01*	56169	4.2
2) FY 83-2	3109.14	49277	.01	49373	3.1
3) FY 83-3	3297.49	52036	.01	52239	3.3
4) FY 83-4	4865.88	74273	.01	69039	4.0
5) FY 84-1	3311.01	53796	.01	44494	3.3
6) FY 84-2	3120.97	47921	.01	37335	2.8
7) FY 84-3	4913.17	75580	.01	55924	5.0
8) FY 84-4	1919.45	29300	.01	21982	1.9
9) FY 85-1	6745.34	107113	.01	75264	6.7
10) FY 85-2	1800.09	28363	.01	21400	1.8

* NOTE - DEA/CFA does not allow a 0 as a input or output value. As shown for FY-QTR 83-1 all 0 values have been converted to a .01 value.

APPENDIX E16: MNTSA COST CENTER INPUT & OUTPUT DATA

	INPUTS				OUT
FY - QTR	DPAH	DLC $	DMC $	OMC $	QTY
1) FY 83-1	6090.27	110088	.01*	96751	4.3
2) FY 83-2	8347.89	149721	.01	128115	5.8
3) FY 83-3	7428.53	137065	.01	95608	4.7
4) FY 83-4	5979.27	109266	.01	80540	3.1
5) FY 84-1	6920.95	131931	.01	91780	4.7
6) FY 84-2	7373.07	136542	.01	130126	5.1
7) FY 84-3	7229.35	136423	16	123256	5.1
8) FY 84-4	6648.92	126789	7	129485	4.7
9) FY 85-1	5523.92	104931	.01	100675	3.9
10) FY 85-2	6836.54	136987	2	114316	4.3

* NOTE - DEA/CFA does not allow a 0 as a input or output value. As shown for FY-QTR 83-1 all 0 values have been converted to a .01 value.

APPENDIX E17: MNTTA COST CENTER INPUT & OUTPUT DATA

FY - QTR		INPUTS DPAH	DLC $	DMC $	OMC $	OUT QTY
1)	FY 83-1	5016.56	73089	.01*	86937	4.1
2)	FY 83-2	7333.42	120774	.01	108186	9.6
3)	FY 83-3	3716.35	66933	.01	50785	3.8
4)	FY 83-4	8227.33	152117	.01	126761	4.3
5)	FY 84-1	6721.28	120225	.01	103411	5.2
6)	FY 84-2	6627.58	123660	.01	80028	5.0
7)	FY 84-3	6471.18	116310	.01	79315	4.8
8)	FY 84-4	7260.12	125478	.01	100154	5.8
9)	FY 85-1	7946.48	147730	.01	93489	6.0
10)	FY 85-2	5185.16	95089	.01	67773	3.7

* NOTE - DEA/CFA does not allow a 0 as a input or output value. As shown for FY-QTR 83-1 all 0 values have been converted to a .01 value.

APPENDIX E18: MTTTA COST CENTER INPUT & OUTPUT DATA

	INPUTS				OUT
FY - QTR	DPAH	DLC $	DMC $	OMC $	QTY
1) FY 83-1	8.00	106	.01*	58	0
2) FY 83-2	.01	.01	.01	.01	0
3) FY 83-3	.01	.01	.01	.01	0
4) FY 83-4	48.00	607	.01	390	0
5) FY 84-1	30.98	410	.01	234	0
6) FY 84-2	.01	.01	.01	.01	0
7) FY 84-3	117.34	1490	.01	660	0
8) FY 84-4	16.00	207	.01	91	0
9) FY 85-1	.01	.01	.01	.01	0
10) FY 85-2	.01	.01	.01	.01	0

* NOTE - DEA/CFA does not allow a 0 as a input value. As shown for FY-QTR 83-1 all 0 values have been converted to a .01 value. Since this is a non-production Cost Center, it will always have 0 output production quantities and is therefore pointless to be evaluated by the DEA/CFA models.

APPENDIX E19: MABP BRANCH & MAB DIVISION INPUT & OUTPUT DATA

	INPUTS				OUT
FY - QTR	DPAH	DLC $	DMC $	OMC $	QTY
1) FY 83-1	203818.73	2890412	1238112	4000868	200
2) FY 83-2	213487.78	3036343	2377316	4191750	196
3) FY 83-3	219657.51	3157874	1971161	4299417	220
4) FY 83-4	217561.39	3140600	1340400	4405172	222
5) FY 84-1	210893.73	3111201	1589104	3828763	208
6) FY 84-2	215616.29	3196713	1915939	3698257	219
7) FY 84-3	244828.49	3492769	2679760	4078252	230
8) FY 84-4	230311.29	3350809	1816629	3964968	234
9) FY 85-1	215302.45	3176592	1592119	3603714	219
10) FY 85-2	209944.90	3115923	2083879	3744237	209

APPENDIX E20: MAKP BRANCH & MAK DIVISION INPUT & OUTPUT DATA

	INPUTS				OUT
FY - QTR	DPAH	DLC $	DMC $	OMC $	QTY
1) FY 83-1	187613.48	2710446	2760333	3791773	52.4
2) FY 83-2	190652.35	2787966	3433288	3927478	55.6
3) FY 83-3	192372.20	2814478	3828084	4081270	57.3
4) FY 83-4	191179.86	2829190	3107580	4287036	60.9
5) FY 84-1	186066.26	2789675	3350406	3949534	58.5
6) FY 84-2	201739.00	3033112	3464740	4010843	60.4
7) FY 84-3	217753.52	3144462	4033273	4248514	63.6
8) FY 84-4	232792.28	3411975	4307273	4705048	62.4
9) FY 85-1	192385.13	2920136	2858094	3454747	58.4
10) FY 85-2	193300.63	2934661	3100948	3695166	58.4

APPENDIX E21: MANL BRANCH INPUT & OUTPUT DATA

	INPUTS				OUT
FY - QTR	DPAH	DLC $	DMC $	OMC $	QTY
1) FY 83-1	2621.90	37607	28750	32726	22.4
2) FY 83-2	4810.97	67617	124695	63315	35.5
3) FY 83-3	3895.86	53537	36040	54545	39.5
4) FY 83-4	5411.55	79310	106081	77518	52.4
5) FY 84-1	3697.58	54441	73015	53577	34.1
6) FY 84-2	2094.17	31564	17096	31580	15.5
7) FY 84-3	5164.31	77436	191482	75132	49.6
8) FY 84-4	6450.51	97786	194711	101703	65.3
9) FY 85-1	5508.73	79126	54332	78983	54.6
10) FY 85-2	6372.02	96396	86149	105534	70.1

APPENDIX E22: MANT BRANCH
INPUT & OUTPUT DATA

FY - QTR	INPUTS DPAH	DLC $	DMC $	OMC $	OUT QTY
1) FY 83-1	15269.24	248134	.01*	239857	10.9
2) FY 83-2	18790.45	319772	.01	285674	16.3
3) FY 83-3	14442.37	256034	.01	198632	10.4
4) FY 83-4	19072.48	335656	.01	276340	09.7
5) FY 84-1	16953.24	305952	.01	239685	11.5
6) FY 84-2	17121.62	308123	.01	247489	11.5
7) FY 84-3	18613.70	328313	16	258495	11.9
8) FY 84-4	15828.49	281567	7	251621	11.1
9) FY 85-1	20215.74	359774	.01	269428	13.9
10) FY 85-2	13821.79	260439	2	203489	07.9

* NOTE - DEA/CFA does not allow a 0 as a input or output value. As shown for FY-QTR 83-1 all 0 values have been converted to a .01 value.

APPENDIX E23: MAN DIVISION INPUT & OUTPUT DATA

	INPUTS				OUT
FY - QTR	DPAH	DLC $	DMC $	OMC $	QTY
1) FY 83-1	17891.14	285741	28750	272583	212.5
2) FY 83-2	23601.42	387389	124695	348989	320.4
3) FY 83-3	18338.23	309571	36040	253177	214.8
4) FY 83-4	24484.03	414966	106081	353858	222.8
5) FY 84-1	20650.82	360393	73015	293262	235.1
6) FY 84-2	19215.79	339687	17096	279069	216.4
7) FY 84-3	23778.01	405749	191498	333627	258.6
8) FY 84-4	22279.00	379353	194718	353324	254.7
9) FY 85-1	25724.47	438900	54332	348411	307.1
10) FY 85-2	20193.81	356835	86151	309023	224.8

APPENDIX E24: MA DIRECTORATE INPUT & OUTPUT DATA

FY - QTR	INPUTS DPAH	DLC $	DMC $	OMC $	OUT QTY
1) FY 83-1	411356.93	5921696	4027195	8088833	120.5
2) FY 83-2	429734.32	6246999	5938034	8495342	125.4
3) FY 83-3	432783.32	6324273	5835285	8669678	131.7
4) FY 83-4	434879.95	6412142	4554061	9070815	136.3
5) FY 84-1	419104.19	6284331	5030499	8096739	129.7
6) FY 84-2	438248.68	6598274	5420924	8015891	134.7
7) FY 84-3	488140.51	7072082	6919520	8688990	142.4
8) FY 84-4	487293.71	7171240	6333405	9056261	142.5
9) FY 85-1	435523.17	6569133	4514538	7443695	134.9
10) FY 85-2	426142.42	6452107	5291435	7805600	129.7

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This research advances the application of the Data Envelopment Analysis (DEA) and Constrained Facet Analysis (CFA) models to measure total factor technical productivity on maintenance levels above the Cost Center at Headquarters Aerospace Guidance and Metrology Center (HQ AGMC/MA). Input resources consumed and output quantities produced for eighteen Cost Centers, five Branches, four Divisions and the Directorate within AGMC/MA were collected, evaluated aggregated and applied to the DEA/CFA models for Fiscal Year 1983 through the second quarter of Fiscal Year 1985. Eleven Cost Centers, four Branches, two Divisions and the Directorate were then compared against themselves over those ten observation quarters and the analyses were discussed and validated by different HQ AGMC/MA management levels. The results of this research were deemed acceptable by these using managers as a useful aid to their decision making and demonstrates the capability of the DEA/CFA models to measure total factor technical productivity on maintenance levels above the Cost Center.

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