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POWER UTILITY SYSTEMS MODELLING AND PERFORMANCE ANALYSIS

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MODELLING AND PERFORMANCE ANALYSIS

by

E U Percale

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MODELLING AND PERFORMANCE ANALYSIS

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ABSTRACT

Any business striving to improve its productivity, must first establish and practise at all levels a universal method for measurement and analysis of its performance.

A prerequisite for any analysis, is an appropriate definition of the system which is to be analysed. The rationale and derivation process for such system definition, is termed "modelling", and its product a "model".

Deterministic Productivity Accounting (DPA), is a comparative analysis method for business performance. It is based on the premise that business performance is primarily determined by resource management, and measured in terms of productivity.

By judicious partitioning and modelling of the business systems, and careful counting and accounting for every variance component, one traces the driving causes behind the apparent performance.

This work combines modelling of power utility systems with the application of DPA, into an integrated method for performance measurement and analysis within a power utility, especially in a power station.

KRAGNUTSMAATSKAPPYSTELSELS

MODELLERING en PRESTASIEONTLEDING

deur

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Graad waaroor verhandeling ingedien is: M Ing (Bedryfs)

OPSOMMING

Elke onderneming wat streef daarna om sy produktiwiteit te verbeter, moet eerste 'n universele metode vir die meting en ontleding van sy besigheidsprestasie daarstel, en beoefen op alle vlakke.

'n Voorvereiste vir enige ontleding is 'n gepaste definisie van die stelsel wat ontleed moet word. Die rasionaal en afleidings-proses vir so 'n stelseldefinisie word "modellering" genoem, en die produk daarvan 'n "model".

Deterministiese Produktiwiteits Rekeningkunde (DPR) is 'n vergelykende ontleedmetode vir besigheidsprestasie. Dit is gebaseer op die veronderstelling dat besigheidsprestasie hoofsaaklik deur bronnebestuur bepaal word en in terme van produktiwiteit gemeet word.

Met die oordeelkundige ontleding en modellering van die besigheidstelsels, en sorgvuldige telling en verantwoording vir elke variansiekomponent, word die dryfkragte agter die skynbare prestasie opgespoor.

Hierdie werk kombineer modellering van kragnutsmaatskappy stelsels met die toepassing van DPR in 'n geïntegreerde metode vir die prestasiemeting en ontleding van 'n kragnutsmaatskappy, meer spesifiek, 'n kragstasie.

In memory of my father
who was the first to ask me the questions
this work attempts to answer.

ACKNOWLEDGEMENTS

Deterministic Productivity Accounting (DPA), is the brain-child of Bazil J van Loggerenberg, who selflessly developed and promoted it for the last twenty years, and inspired me to undertake this work.

Eskom, the national power utility of South Africa, has presented me with the opportunity to carry out this work and provided all the necessary information.

I am especially grateful to my colleagues at Lethabo Power Station as well as Engineering Group, for their attentiveness, advice and support.

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SOME ABBREVIATIONS AND SYMBOLS

The following is a list of some abbreviations and symbols which are used frequently throughout this work, especially before the section entitled Notation and Key Definitions:

DPA = Deterministic Productivity Accounting

PSED = Power Station Engineering Department (in Eskom)

SBU = Strategic Business Unit (in Eskom)

ICS = Inter-Connected System (in Eskom)

ROI = Return On Investment

O&M = Operation and Maintenance (costs)

Q = Quantity

P = Price

V = Value

(subscript) u = product entity

(subscript) n = operating cost entity

(subscript) a = operating profit entity

(subscript) t = target profit or capital cost entity

(subscript) b = off-target profit entity

(subscript) k = asset, liability or capital resource entity

(subscript) $_o$ = old, reference or earlier (system or period)

(subscript) $_n$ = new, under review or later (system or period)

For example:

Qu_o = reference product quantity (for a specific product item)
Pt_n = new capital cost price (for a specific capital cost item)

A capital letter subscript denotes: "the total of that entity", eg: V_{Ao} = old value of total operating profit.

1.0 INTRODUCTION

Eskom is the fifth largest power utility in the world and it performs the whole range of power utility functions. Thus, it is considered to be a representative entity in the category of power utilities.

As such, it is a capital intensive business, and the bulk of its capital is invested in power station plant. Significant changes in Eskom's business performance, entail gains or losses which are large enough to affect the national economy.

Power Station Engineering Department (PSED) is involved in power plant design and technical investigations. It provides support to operating power stations in their performance enhancement programmes. It also provides technical and management services to new power station projects. The functions performed by this department, determine the potential productivity of:

(a) activities involving major capital expenditure;

(b) power plant usage;

(c) energy conversion processes;

(d) power station operation and maintenance.

This department therefore, must make the greatest contribution to the improvement of Eskom's total productivity, being equivalent to the greatest contribution to long term business performance.

This is because in real terms, productivity is the main factor affecting the product cost, which underpins the product price and required revenue. Thereby, the total productivity of a business, determines the product saleability and overall profitability.

The productivity issue is of special importance in the case of Eskom, because of the accepted restriction on its tariff increases, which should be smaller than the increases of the Producer Price Index. This means that the annual changes in Eskom's price recovery should be negative or nil, and it implies that Eskom, in order to survive, has to constantly improve its productivity.

Any improvement process must start with measurement and analysis of the apparent effects of business performance; for the purpose of tracing the causes which drive these effects.

1.1 Problem Statement

So far, conventional accounting methods have been of limited dependability, because they tend to be:

(a) based on a logic which is sometimes divorced from that of the real operation of the business, thus being flawed and leading to wrong conclusions and action plans;

(b) applicable only to part or parts of the business;

(c) restricted to a certain level of detail;

(d) non differentiating between physical, monetary,financial and fiscal effects.

Specific methods for analysing and optimising components of the power utility business, have been developed and used. Literature search failed to uncover a universal methodology for performance measurement and analysis at all levels of that business (Chapters 2 & 7).

Therefore, Eskom which must systematically improve its productivity, is in need of a universal method for measurement, analysis and diagnosis of its business performance.

The required method had to be identified, acquired and adapted for application throughout the organisation.

The practice of the method should be:

(a) promoting understanding and appreciation of the factors which determine the business performance of a power utility;

(b) facilitating costing, pricing, planning and budgeting at all levels;

(c) facilitating reporting on business performance;

(d) facilitating planning of performance enhancement activities and the measurement of their effect.

Power Station Engineering Department, which provides a large contribution towards the improvement of Eskom's productivity, needs to develop and practice such a method to enhance its understanding of the business, and to ascertain that its contribution is actually made. It also needs this as a facility for overall performance assessment of alternative configurations and designs of plant systems.

1.2 Proposed Solution

The solution consists of two phases:

(a) A substantial gain of insight and role clarity within the business, which is attained through developing the rationale for partitioning and modelling of the business systems, and by the participative implementation thereof.

(b) Thereafter, based on the models resulting from (a), sharper resolution is achieved by regular application and discussion of qualitative and quantitative performance analysis.

A whole partitioning and modelling approach with an appropriate rationale, has to be developed participatively; in a process involving the management team of the business as well as various other contributors. Then, it is to be applied to formulate and establish models which simulate the systems to be analysed:

(a) the power stations;

(b) Eskom as a whole;

(c) operations which are sub-systems of any of the above.

Deterministic Productivity Accounting (DPA), a representative method for comparative analysis of business performance, is used to analyse the systems under consideration. It uses asset, cost, revenue and profit variances for comparing two or more business systems.

The data input it requires, is mostly quantities and prices of the business products and resources. It breaks down the cost and profit variances into components which are expressed in plain money terms for each resource.

The cost or profit variance for any resource, can be further broken down into components of three categories;

(a) cost or profit variance due to change in productivity;

(b) cost or profit variance due respectively to change in resource price or to change in price recovery;

(c) cost or profit variance due respectively to change in product volume or to change in revenue.

1.2 Proposed Solution (continued)

Each of the variance components, represents an apparent effect caused by action taken within the business, or by the business interaction with its environment. The more specific the variance component, the more distinct is its link to the specific action which caused it, and the greater the facility to trace and affect that action.

The combination of the partitioning and modelling approach, with the application of DPA, results in an integrated method for high resolution measurement and analysis of business performance.

The combined method enables judicious partitioning and modelling of business systems, as well as careful counting and accounting for each and every variance component; to gain insight into the causes which drive the apparent performance effects.

1.3 Work Scope and Purpose

The activities and objectives, to be accomplished by the author in this work, are:

(a) to develop, formulate and generalise the modelling method;

(b) to define business system models, for any power station and a whole power utility;

(c) to formulate the necessary portions of DPA theory in a way which would facilitate its understanding by Eskom people;

(d) to formulate step by step derivation of cost and profit variance reports for any business operation;

(e) to formulate the method for interpreting these reports;

(f) to begin the implementation of the integrated method, primarily at Lethabo Power Station, and to impart the methodology to users within Eskom;

(g) to evaluate and demonstrate the validity and utility of this method.

2.0 LITERATURE SEARCH

This literature search had a specific objective; to substantiate assumptions implied in the problem statement, which are:

(a) that no rigorous and universal method has until now been available, other than conventional accounting methods, for measurement and analysis of power utility business performance;

(b) that prior to this work no attempt has been made, to adapt and apply DPA to power utility systems.

Two categories of literature have been explored:

(a) Publications dealing with performance measurement and analysis, particularly within the power utility business.

(b) Publications referred to in a book by the author of the DPA method; B J van Loggerenberg, 1988, "Productivity Decoding of Financial Signals", published by Productivity Measurement Associates, Pretoria. This book includes all references to DPA known to the method's author at that stage. An update released in 1990, has not been surveyed within this work.

With the help of the Eskom library network, which includes national and international links, a large number of publications were reviewed.

The search concentrated however, on publications and references made by authoritative practitioners, such as the De Villiers Commission, Rosenkranz, Kendrick et al. They have been active in this field for decades, and thus can be relied upon to have covered all noteworthy methods for measurement and analysis of business performance.

A representative sample of publications of both categories, as listed in Chapter 7, is discussed in the following sections.

This search failed to uncover a universal method, comparable with the method developed in this work, for performance measurement and analysis at all levels of the power utility business:

It has been found that numerous specific methods, for analysing and optimising particular operations and functions within that business, have been developed and used.

No reference was found to the application of DPA, for performance measurement and analysis of any power utility systems.

2.1 Search for Universal Method

Publications dealing with performance measurement and analysis, particularly within the power utility business:

The De Villiers Commission of Inquiry was instituted in 1983, as a result of the Government's concern about electricity tariffs and the then increasing amounts of capital required, for the provision of electricity. Its brief was to investigate and report on all aspects of electricity supply in South Africa with special reference, amongst others, to the applicable principles and policies, and cost effectiveness thereof.

The method employed in this Inquiry, was considered to be the state of the art of strategic planning for a business enterprise. It established a strategy for the future, based on an assessment of past performance and the current situation, and an exhaustive examination of various key issues, eg product, marketing, price, funding and investment. It emphasised identification, analysis and evaluation of resource allocation and action taken to exploit competitive advantages.

The Commission has processed an inordinate mass of evidence, both in terms of diversity and quantity, worked out every single step in terms of its inquiry method, and presented a profound report; of findings, conclusions and practical recommendations. However, no system model simulating the power utility business, was used in this process; to facilitate and clarify the inferences drawn, and to demonstrate their rigour and completeness.

Tuttle (1986) reports on an investigation which tested the actual applicability of a specific productivity measurement method, at a small "combination" utility; distributing water, gas, electricity and cable TV. This method is based on a comparison of actual performance measures, with standards which have been brainstormed by the management team. It makes no provision to ensure that the standards, and thereby the entire method, are rigorous, complete or valid.

Christ et al (1963), in a book which is a collection of papers, address basic economic issues in various mathematical approaches. One of these papers by M Nerlove, Returns to Scale in Electricity Supply, deals with the particular question of whether there are increasing or decreasing returns to scale in the power utility industry, and how that depends on the level of operation and output.

2.1 Search for Universal Method (continued)

Beltrami (1977), reviews several classes of mathematical models, with particular attention centered on how to improve the delivery of urban services. Power utility systems are briefly touched upon in the section Energy Models. That section only treats the issue of optimal energy distribution, by applying a simplified version of linear programming models.

Moder and Elmaghraby (1978) attempt to answer the question of where has the theory of Operations Research been applied? The second section of their book, concentrates on OR applications to some societal and industrial systems, including a chapter entitled Electric Utilities. It covers different mathematical models used to approach prominent planning issues, which are traditionally separated within the power utility business; load forecasting, production planning, generation and transmission expansion planning.

Kendrick (1973) updated estimates and analyses in this field, stressing his concept and estimation of total factor productivity, at the level of a national economy and major industry groupings. Under the heading Electric and Gas Utilities, he reaches the lowest level within a power utility: "Electricity output is measured in terms of kilowatt-hours sold, by class of service; residential, commercial and industrial, and other consumers..." (p 194)

Adam and Dogramacy (1981) provide a sample of papers related to measuring, analysing and improving productivity, at the level of business firms and municipal organisations. One chapter is entitled Productivity Measurement at the Firm Level; A Brief Survey. It concludes that there is little hope that a universal productivity measurement would be devised, and that efforts should be rather directed at better utilisation of the existing imperfect methods; "even crude productivity indicators".

Van Frederikslust (1978) expounds on his semi-empiric method for the prediction of business failure. That method is based on stochastic analysis of cash flow and profit indicators, derived from data found in statutory financial statements.
The implication of this approach, is that its user is unable to gain sufficient insight into the business workings, in order to make a deterministic assessment.

2.1 Search for Universal Method (continued)

Rosenkranz (1979) deals with the development of a conceptual framework for the construction, verification and implementation of corporate simulation and planning models. His concept of business systems modelling, is very similar to that developed in this dissertation: "A corporate simulation and planning model... (is) a description and explanation of a complete firm, and its development or activity in time and at different locations." (p 4) He expounds on a great variety of sophisticated modelling methods and applications, which appear to be too complex for the common practitioner. Although he is a prominent authority in this field, he has not developed or used any "global model". He rather developed specific approaches for different applications, with a degree of ad hoc integration.

Sullivan (1979) compares two economic evaluation procedures that are commonly used to evaluate engineering alternatives for industrial power plant; discounted cash flow analysis (eg present worth and internal rate of return), and the revenue requirement method. He demonstrates that the two procedures, when based on the same assumptions, produce the same preference ranking among alternatives being considered. It is therefore concluded, that the assumptions, rather than the mathematical equations, determine the answer; the assumptions being equivalent to the concept of the system under examination, or even to its modelling.

2.2 Search for DPA Application to Power Utility

Papers referred to in B J van Loggerenberg's book, published in September 1988:

Sink, Tuttle and De Vries (1984) survey different productivity measurement techniques which are available for different purposes. "Some are effective at the group (of companies) level and are primarily improvement oriented, while other techniques are effective at the plant or firm level". They explain and provide case examples for three basic techniques.

Sink, (1983) examines the relationship between seven components of performance for organisational systems, and presents some management basics; the general menagement process, the measurement of organisational systems performance, and productivity in general. He discusses specific productivity measurement approaches that can assist in developing productivity measurement systems; the Normative Productivity Measurement Methodology (NPMM), a participative approach, and the Multi Factor Productivity Measurement Model (MFPMM).

Gordon and Parsons (1985) describe the application of Deterministic Productivity Accounting, to a "one block" business operation.

Van Loggerenberg (1987) uses deterministic cost variance analysis, of changes in per unit labour cost from 1974 to 1984, to compare several national economies.

Guy, Brown and O'Hara (1983) use deterministic profit variance analysis, to identify the sources of net income changes from 1975 to 1981, of the US Postal Service.

Du Plooy (1988) emphasizes the importance of productivity improvement in achieving economic objectives. He uses Deterministic Productivity Accounting to analyse the performance of the South African manufacturing sector.

3.0 BUSINESS SYSTEM MODELLING

3.1 The Basic Rationale

When considering a system, a rigorous concept of it is required for any examination or improvement activity. The rationale and derivation process for a system definition, is termed modelling, and its product, especially in graphic representation, a model.

Such a model, when established in a participative process, often provides sufficient indications relating to the system's performance, and thus obviates the need for any further analysis.

Nevertheless, the same model greatly enhances the applicability and usefulness, of any method used for measurement and analysis of different performance aspects, eg quality, plant availability, critical success factors, productivity and cost management.

Once modelling becomes a common practice, it facilitates product costing and pricing, planning, budgeting and labour negotiations.

Any plant, management or ancillary system within Eskom, should be considered primarily as a business system which is to be examined and optimised as such, as well as in terms of Eskom's Mission.

Any business system must be defined in terms of:

(a) Its boundaries, where it starts and where it ends, what is included and what is excluded.

(b) Its final products, which cross its boundary into other systems, and the appropriate qualities and quantities by which they are measured.

(c) The resources it requires from its environment, as well as their appropriate quantities and prices.

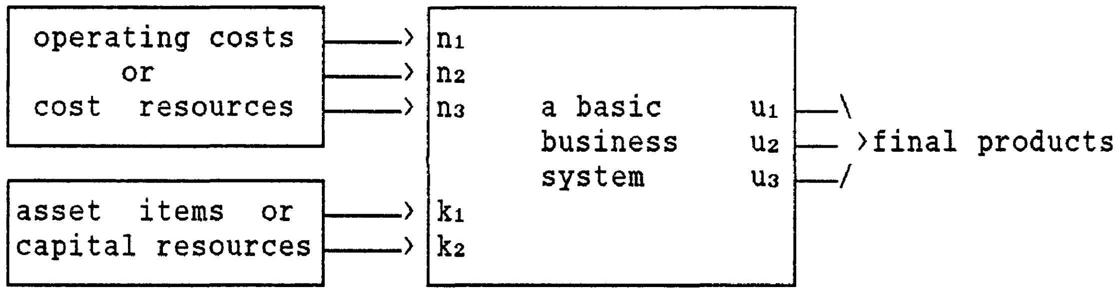
(d) Its partition into sub-system operations and the functions thereof. These operations may produce final products, or intermediate products which become resources in other operations within the system. Products can be tangible or intangible.

(e) The flow of resources and intermediate products within it. The functional partition and flow, when correlating to the organisational structure, facilitate managers' role clarity, especially in terms of accountability for performance.

(f) The period or periods of its life cycle, which are to be analysed.

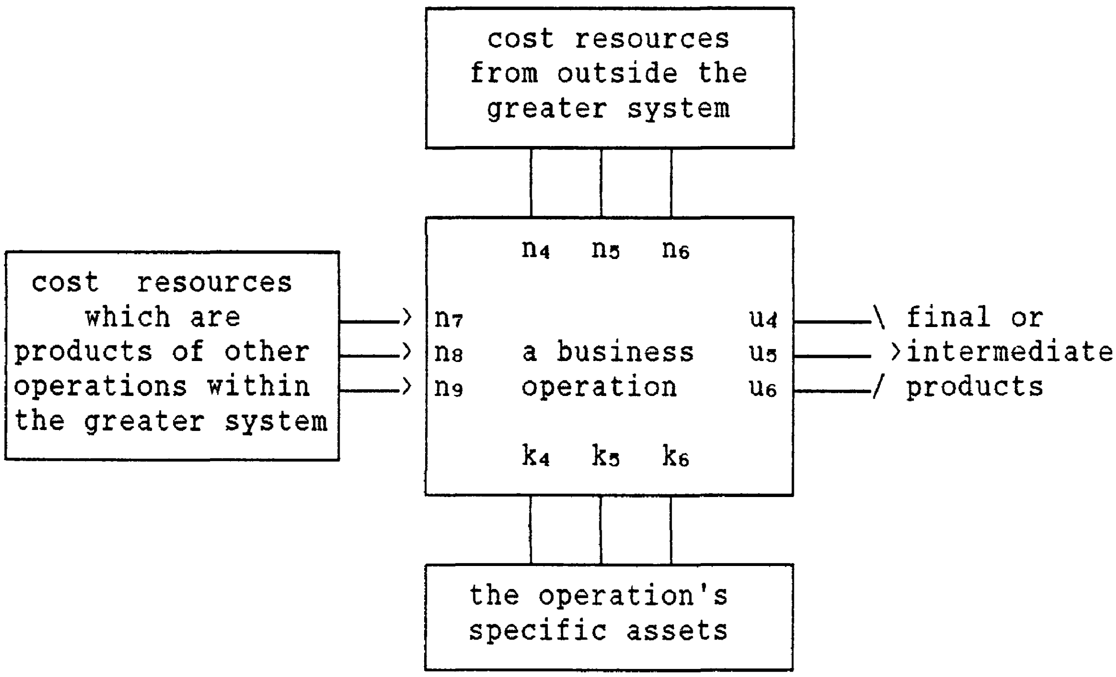
3.2 Graphic Representation

The following is a graphic representation of a basic business system which requires three cost resources and two capital resources for producing three final products:



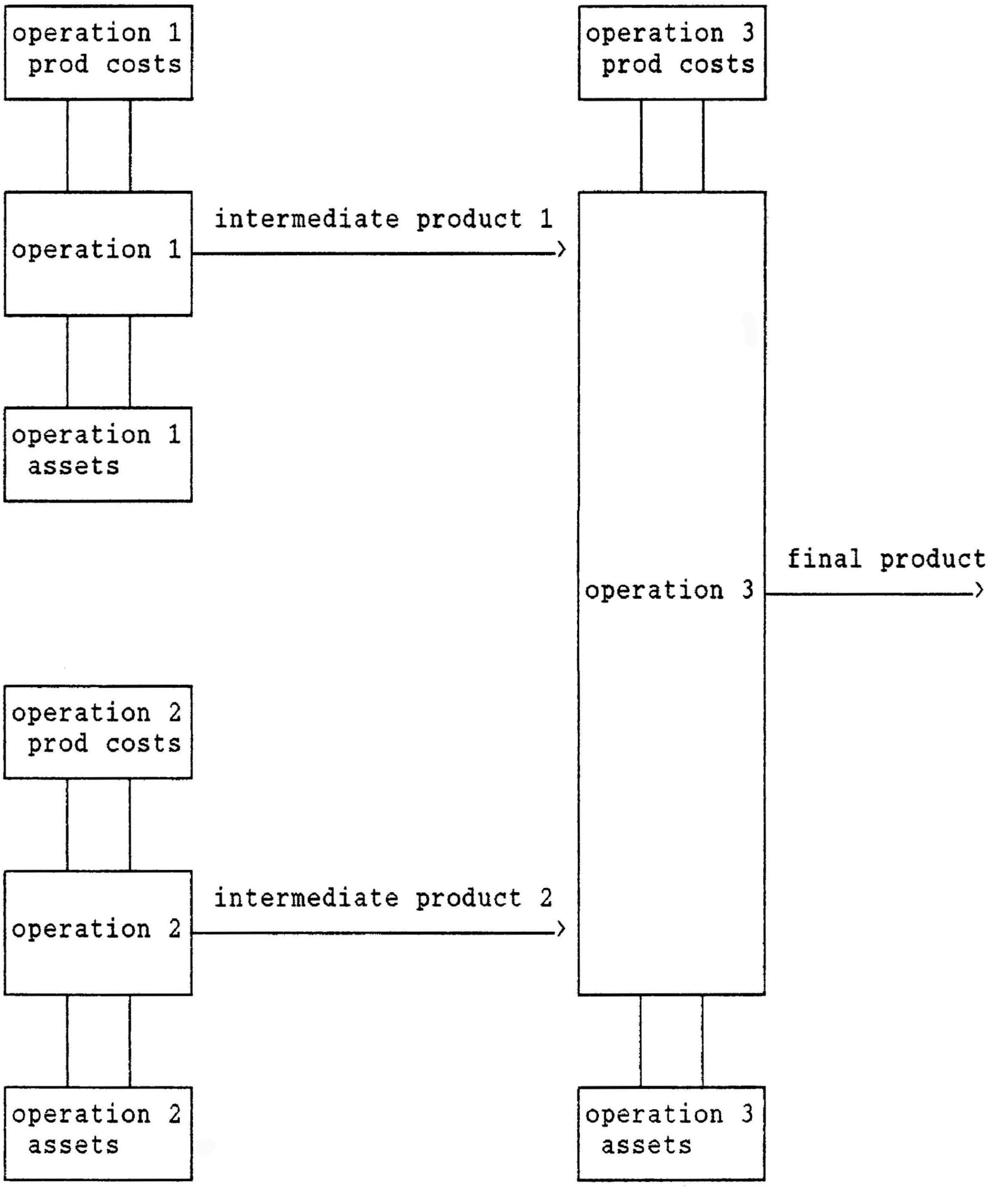
This representation implies that the total product cost is the sum of the operating costs plus the capital costs (as distinct from asset values). It therefore facilitates the derivation of tangible and intangible product costs. The system profit is the difference between the product revenue and the product cost.

A whole business system consists of a hierarchy of functional operations. It can be modelled by building it up from its sub-system operations, or by partitioning into such operations. The following is a graphic representation of a business operation which is a sub-system of a greater system:



3.2 Graphic Representation (continued)

The following is a graphic representation of a business system which consists of three sub-system operations. Each operation uses assets and production costs to produce an intermediate or a final product. Any product can be tangible or intangible, and its cost is the sum of the resource costs used in its production.



3.3 Modelling Approach and Criteria

A whole business system, which consists of a hierarchy of functional operations, processes resources into intermediate or final products. Each product or resource entity, is unique in terms of its physical characteristics and quality specification.

The purpose of deriving a model, is to gain insight into the business process and the factors which determine its performance.

The model can be derived by partitioning the system into its sub-system operations, or by building it up from them. It must depict the business process flow and its accountability structure.

Better resolution is attained where each sub-system operation produces a minimal number of products; preferably one product only. For each product, there is a complete set of relationships, with the various resources used in its production.

Therefore, the fewer the products the fewer and the more distinct the relationships between specific resources and specific products.

Furthermore, each operation should include a minimal number of process stages. The fewer the process stages, the simpler and more understandable the resource flow within the operation.

Therefore, it is advisable to partition a business system into operations which each produces one or few products, in one or few process stages. Moreover, it may be sometimes advantageous to separate operations which produce the same product or products, but for different purposes; eg coal handling for stockpile as distinct from coal handling for energy conversion.

This approach, if applied in an unchecked manner, may lead to great proliferation of elementary operations, which entails a multiplicity of intermediate products, and probably a complex flow within the business system.

In every case, a specific method must be found, to partition the business into a minimal number of high level operations. Each of these operations should produce one or few products, in one or few process stages. Also, this method should include a systematic approach to further partitioning, at the lower levels within the business.

3.4 Business System Modelling and Performance Analysis

Using modelling, one can represent a complete definition of a business system, in one diagram or model. Such a model, depicts the partitioning of a greater system into sub-system operations, and the flow of resources and intermediate products within it.

It provides a complete definition of the final and intermediate outputs which can be tangible or intangible. It also depicts the allocation of the costs, to specific input and output entities.

One can use the system model to precisely "map" the cost values, and the cost variances, throughout the system. In other words, one can graphically establish a specific cost value, or variance, as well as the relationships thereof, for each input or output of every operation within the system. This can be used to simulate the system cost flow, and together with the accounting system, to calculate product costs and marginal costs.

In this context, performance means the economic provision of tangible or intangible outputs, in terms of Eskom's Mission:

> Provide the means by which customers' electricity needs are satisfied in the most cost effective way subject to resource constraints and the national interest.

An appropriate model therefore, provides indications relating to performance examination and improvement, and complete information necessary for analysis of specific performance aspets, eg plant availability, critical success factors, quality and productivity.

Furthermore, it could and should be used for planning, budgeting and pricing, ie to represent and compare business scenarios, mutually and with a base case. Such scenarios can be:

(a) different states of the same business system;
(b) different periods in a business system life cycle;
(c) systems under review compared to a reference system;
(d) different configurations of a business system;
(e) altogether different business systems, which preferably have a comparable product range.

This modelling approach has been used to compare period on period performance of Eskom business systems, especially an operating power station and Eskom as a whole. It is further illustrated in the following sections, by outlining its application to those systems.

3.5 The Main Business Operation within a Power Utility

Generating plant, accounts for more than 80% of Eskom's total assets and more than 65% of its annual costs are incurred in the power stations. Therefore, the power station business system should be considered as the main operation of any generating power utility (as distinct from a non generating power utility).

It may not be realised from the beginning of the modelling process, that the power station performs another prime function, before the obvious; energy conversion. This is the conversion of its assets and fixed cost resources into AVAILABLE capacity.

Further, power stations differ in their operation modes. The main effect of such differences, are very different load factors. Yet all stations are required to maximise their available capacity.

One must also distinguish between functions which are within the brief of the power station manager and staff, and other functions which are determined outside the station.

Three models of the power station business system, marked as rev 2a, 2b & 2c, correspond to different operation modes.

The rev 2b version, has been developed to the point where it can be considered as a universal model of the power station system.

This model was originally designed for a power station which is required to maximise its available capacity, spin a proportion of that capacity and generate fluctuating amounts of energy.

Where a power station is required to maximise its total available capacity, minimise its spinning capacity and generate a minimal amount of energy, the 2b model for that station approximates the rev 2a version.

Where a power station is required to maximise its total available capacity as well as its spinning capacity, the 2b model for the station becomes congruent with the rev 2c version.

As the 2a and 2c versions, are therefore special cases of the 2b model, the 2b model is used as the model for any power station business system.

3.6 The Universal Power Station System

This business system is partitioned into three sub-system operations:

Capacity Made Available, uses all fixed resources to produce the intermediate product, Total Available Capacity (TAC). The resources are assets, manpower and other fixed costs. The total of such operations, twenty odd in number, accounts for one half of Eskom's total cost.

Allocation of Available Capacity, uses the total available capacity as a resource and splits it into a final product, reserve capacity, and an intermediate product which is the available capacity used for energy conversion. This operation is governed by a central Eskom body.

Energy Conversion, uses the Spinning Capacity and variable resources, mainly primary energy resources, to produce the energy sent out. The primary fuel and water account for some 20% of Eskom's total cost.

The system's final products are:

(a) Available Capacity NOT used for energy production;

(b) Energy Sent Out, using the remainder of the total available capacity.

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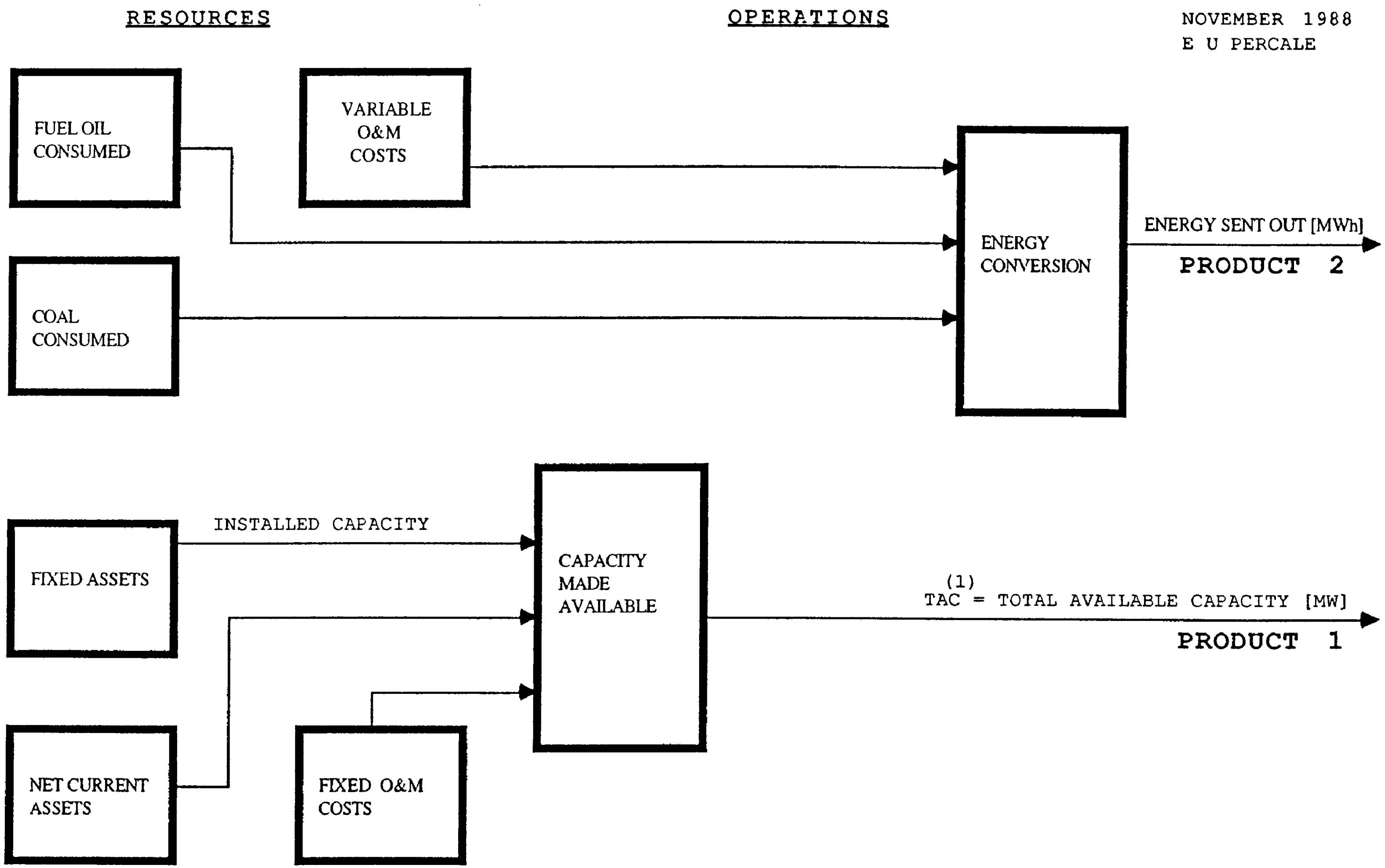
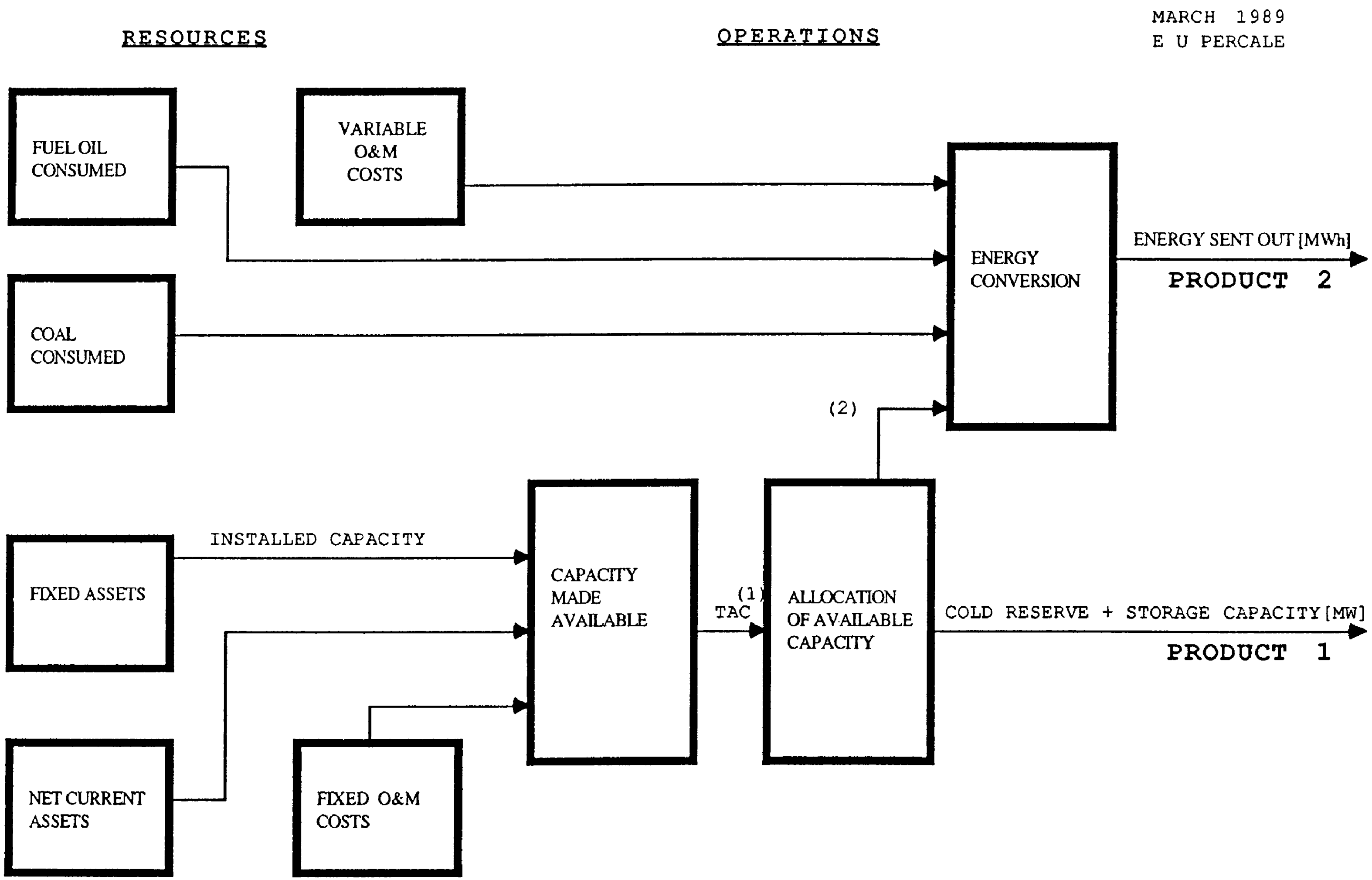


(1) TAC=STAND BY + COLD + SPINNING RESERVE = NOMINAL SENT OUT CAPACITY * AVAILABILITY RATIO

POWER STATION BUSINESS SYSTEM - rev 2a



(1) TAC=TOTAL AVAILABLE CAPACITY [MW]=NOMINAL SENT OUT CAPACITY*AVAILABLITY RATIO
(2) SPINNING CAPACITY [MW] = TOTAL AVAILABLE CAPACITY - (COLD RESERVE + STORAGE CAPACITY)

POWER STATION BUSINESS SYSTEM - rev 2b

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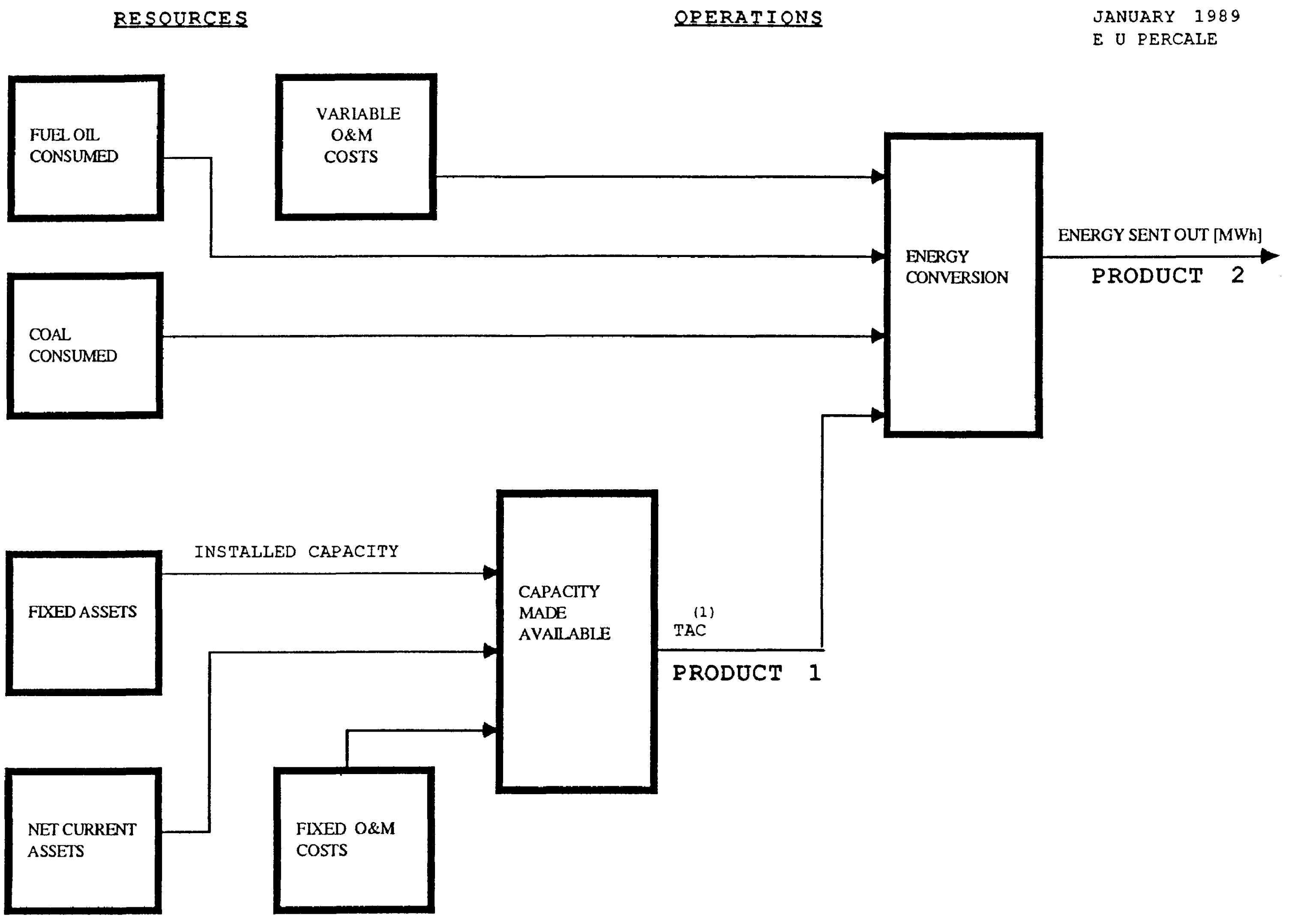


(1) TAC=TOTAL AVAILABLE CAPACITY [MW] = NOMINAL SENT OUT CAPACITY * AVAILABILITY RATIO

POWER STATION BUSINESS SYSTEM - rev 2c

3.7 Power Station System, Breakdown into Plant Systems

Based on the universal model (rev 2b), a further breakdown into plant systems has been developed and it is presented as rev 3. This development introduces two new concepts:

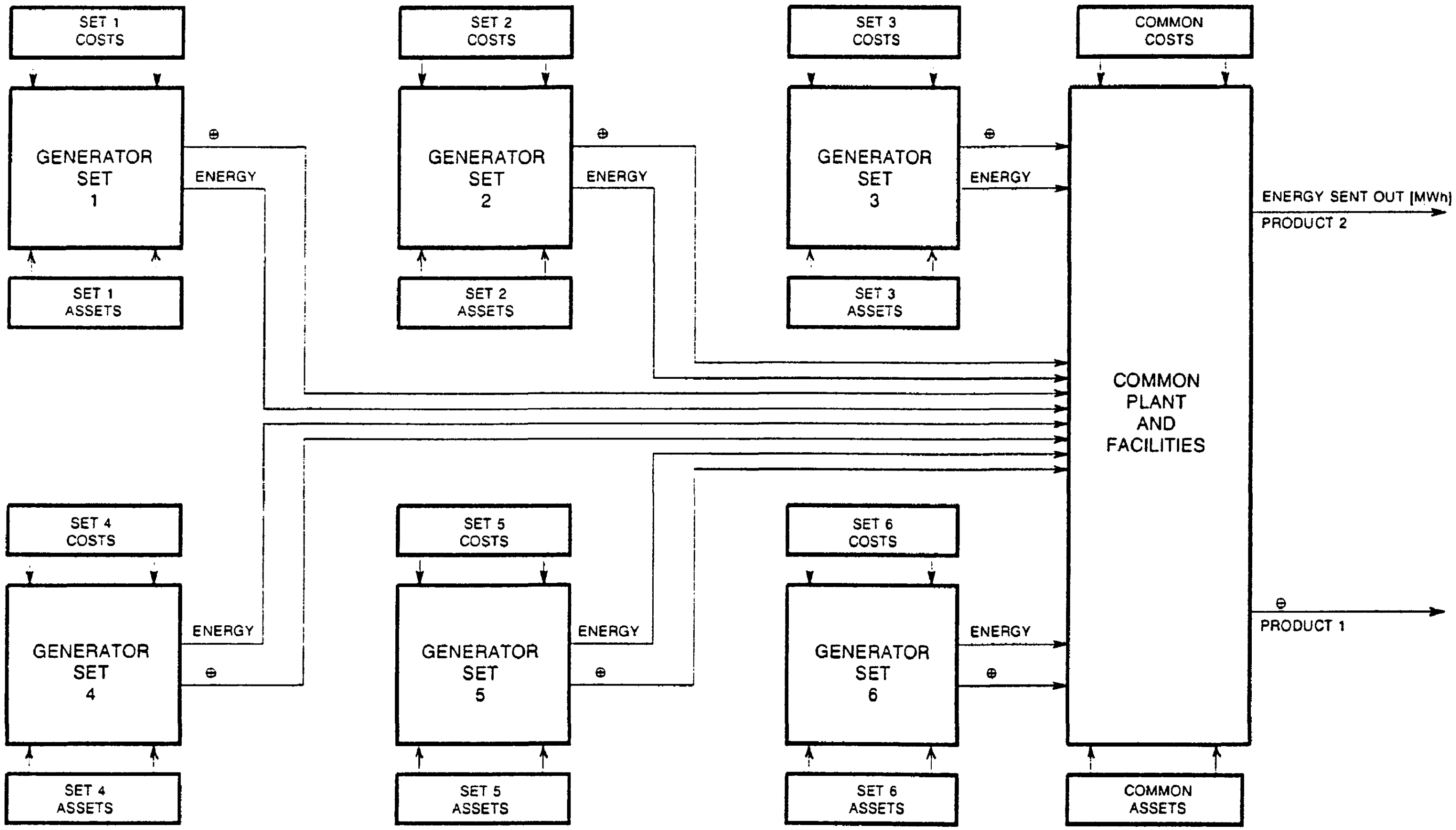
The main plant system, the generating set, is a small replica of the whole station system, with similar inputs and outputs. The costs and assets allocated to each set, are those which clearly and distinctly belong to it.

In addition to the generating sets, there is one "common plant and facilities" sub-system which complements the sum of these sets to become the complete station system. All costs and assets which could not be allocated to the generating sets, are allocated directly to the common plant and facilities sub-system.

This approach enables one to build a consistent hierarchy of systems and sub-systems. Thereby, each generating set, and the common plant sub-system, can be further partitioned. A further breakdown of the generating set, has been developed and it is presented as rev 4.

The common plant and facilities sub-system can be partitioned into its constituent operations, by separating definable sub-systems, eg Common Ash System, from the greater common plant and facilities system. Each of these sub-systems, allocated with its own costs and assets, is linked to the others through the flow of resources and intermediate products. This breakdown need not be total. Any number of operations can be separated from the greater common plant and facilities system. A list of the main operations which constitute the common plant and facilities sub-system, has been compiled. It also identifies appropriate outputs of these operations, and the quantities by which they can be measured.

It must be understood and accepted however, that there will always remain an inseparable residual of the common plant and facilities sub-system. Its function is to accept all the outputs of the other operations, add its own costs and overheads, and to transfer the whole station's final products across its boundary.



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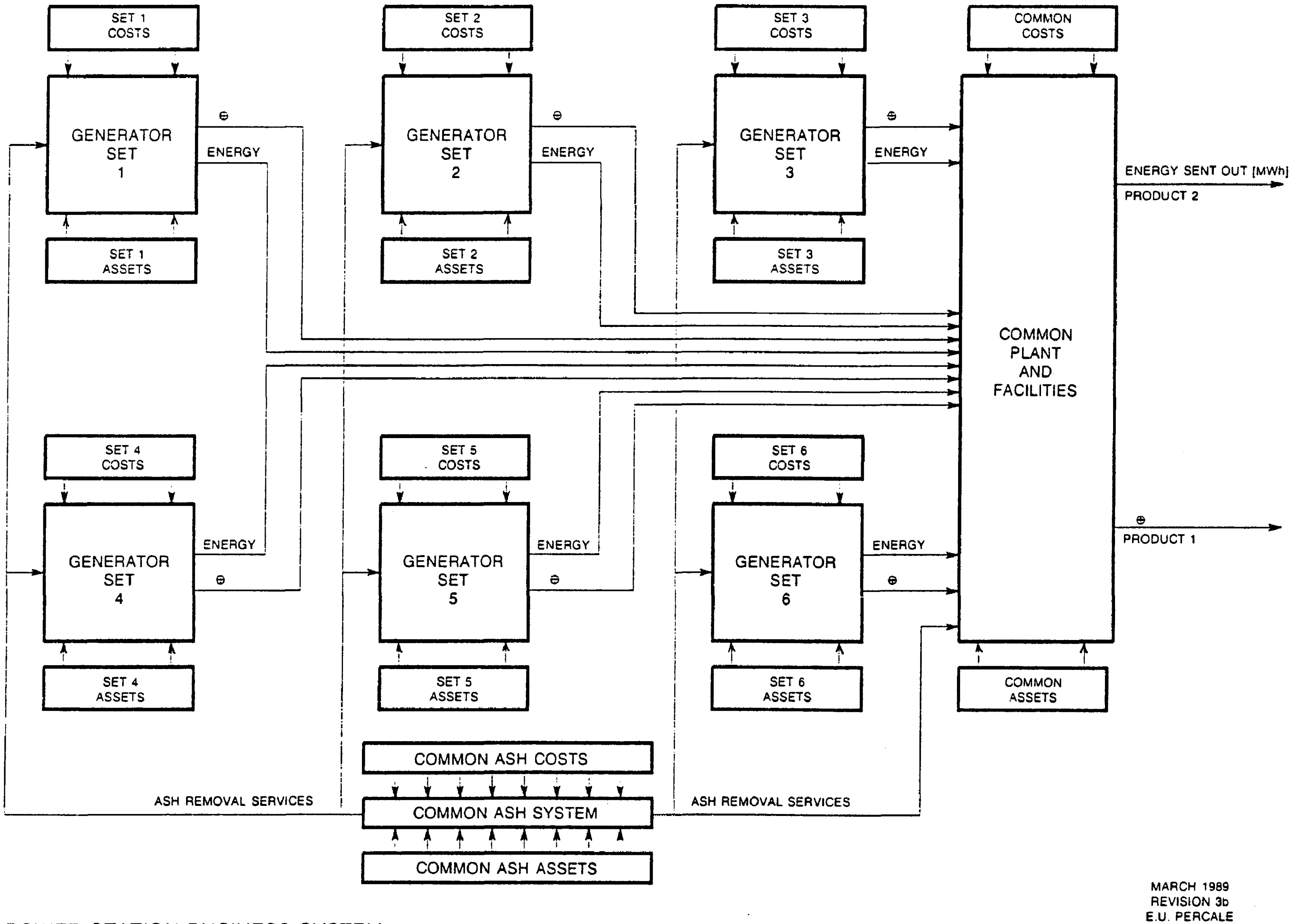
POWER STATION BUSINESS SYSTEM

⊕ = COLD RESERVE PLUS STORAGE CAPACITY [MW]



POWER STATION BUSINESS SYSTEM

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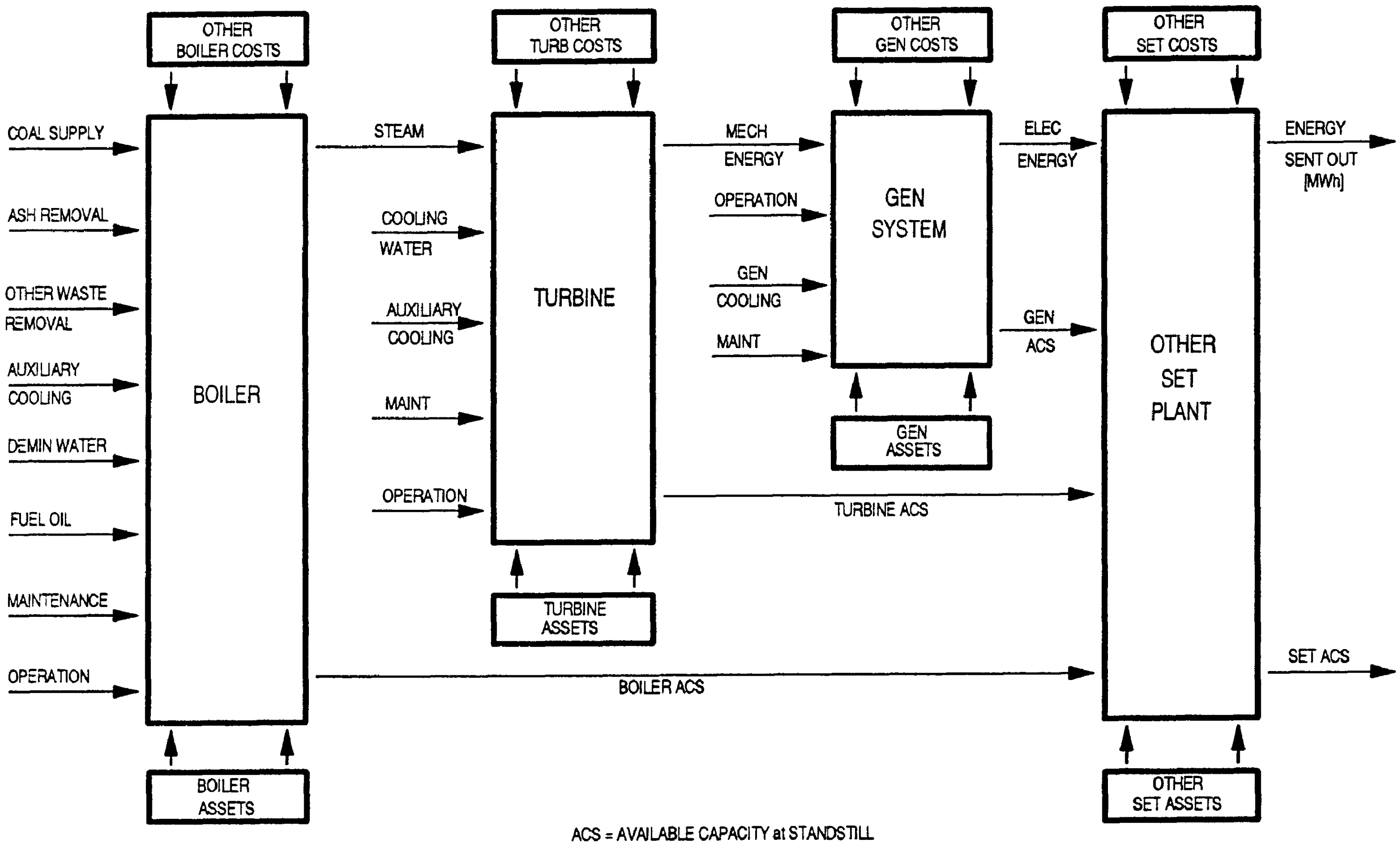


GENERATING SET BUSINESS SYSTEM -rev 4

MAY 1990
REVISION 4
E U PERCALE

List of Common Plant and Facilities Sub-Systems

Common Operation	Output or Function	Output Quantity or Measure
Coal Handling	Coal Supply	Mj coal supplied
Fuel Oil Plant	Fuel Oil Supp	Mj oil supplied
Ash Handling	Ash Disposal	Mj coal burnt
Flue Gas Handl	Flue Gas Disp	Mj coal+oil burnt
Water Supply and Treatment	Cooling Water	Ml supplied
	Demin Water	Ml supplied
	Other Water	Ml supplied
Auxiliary Cool	Aux Cool Water	Ml supplied
Compressed Air	Compressed Air	normal flow rate
Effluent Plant	Sewrage Disp	Avail sets MW*months
	Drain Recover	Avail sets MW*months
Eletric Power Dist	Eletric Power Dist	Avail sets MW*months
Other Comm Plant		Avail sets MW*months
Operation Dept	Operate Sets	Spin sets MW*months
	Op Comm Plant	Spin sets MW*months
Maintenance Dept	Maintain Sets	Avail sets MW*months
	Overhaul Sets	Avail sets MW*months
	Maint Comm Plant	Avail sets MW*months
	Maint Facilities	Avail sets MW*months
Security Dept	Guard Site	Avail sets MW*months
	Process Workers	Avail sets MW*months
	Process Visitors	Avail sets MW*months
	Fire Protection	Avail sets MW*months
	Respond to Incid	Avail sets MW*months
General and Administration	Manpower Admin	Avail sets MW*months
	Manage Finance	Avail sets MW*months
	Procure & Store	Avail sets MW*months
	Safety & Medical	Avail sets MW*months
	General Admin	Avail sets MW*months
Comm Facilities		

3.8 Definition of a Whole Power Utility Business System

A model for the entire Eskom system, has been built up from its sub-systems. It follows the same hierarchical logic which is used in the rev 3 version of the power station business system.

The main product, electrical energy, is generated and processed in three physical stages before it reaches an Eskom customer;

(a) the generating set;
(b) the inter-connected system (ICS);
(c) the distribution region.

In business terms, however, there is an additional operation, Eskom Corporate. It is the counterpart of the "common plant and facilities" in the power station system.

In a similar manner, the Eskom Corporate operation can be partitioned into its constituent SBU's, eg Engineering Group. There is always a residual of Eskom Corporate which neither has specific assets nor does it incur any specific costs. This operation fulfils inalienable functions which are:

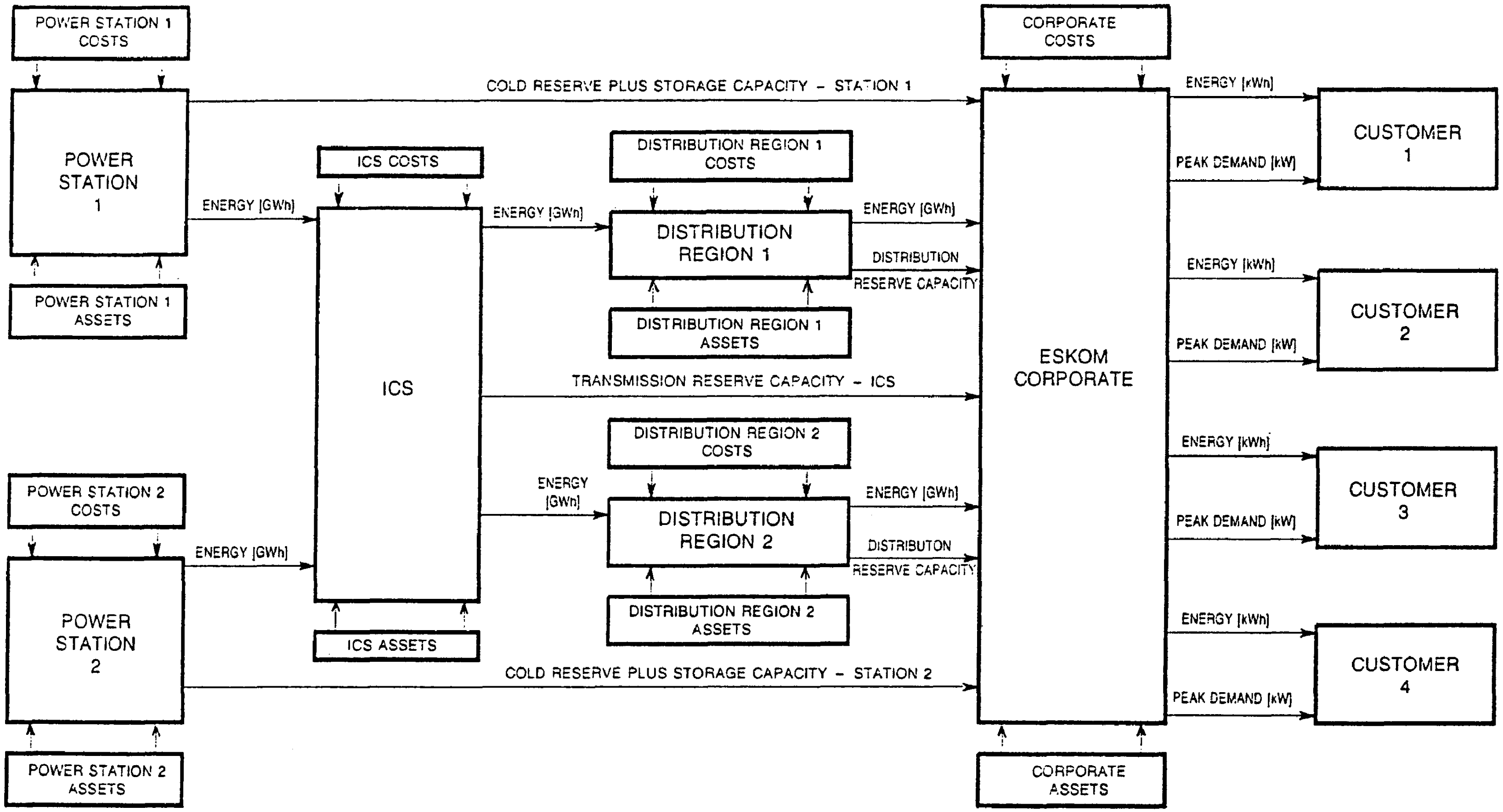
(a) it accepts the costs of the other operations (plus its own if any); as long as this operation determines the size and operating mode of the production and distribution sub-systems, it must accept the costs associated with reserve capacity;

(b) it exchanges the whole business final products for the revenue it receives from the business' customers thus creating the profit;

(c) it makes the key business decisions for the entire organisation.

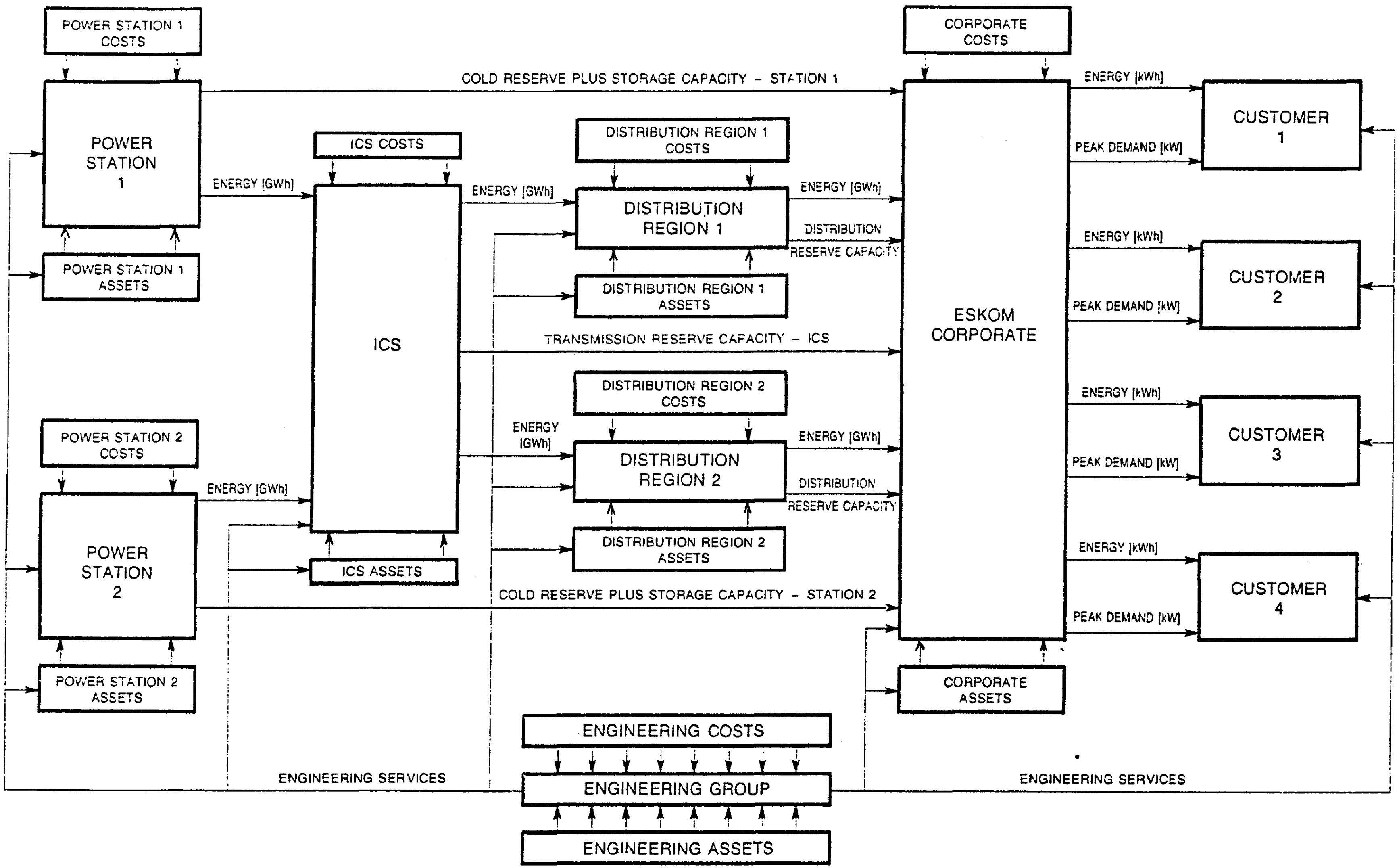
This means that Eskom Corporate is a true profit centre while the other operations are subsidiary cost centres. Hence the preference for cost rather than profit analysis at the SBU level.

In accountability terms, every manager is accountable for the aggregate output and cost performance of the operations reporting to him. The chief executive is accountable for the above functions of the residual corporate operation.



ESKOM BUSINESS SYSTEM – rev 0a

FEBRUARY 1990
REVISION 0a
E.U. PERCALE



ESKOM BUSINESS SYSTEM – rev 0b

FEBRUARY 1990
REVISION 0b
E.U. PERCALE

27

4.0 BUSINESS PERFORMANCE ANALYSIS

4.1 Business Performance

To appreciate business performance at the operational level, with a view to improve it, one seeks answers to four questions:

(a) To what extent the output required from an operation, is being provided, in terms of quality and quantity. This question tests the operation's effectiveness related to all output aspects both tangible and intangible, eg customer satisfaction, scope cover, product quantity and quality. Its answer can be derived in the modelling process, from the resultant models, the output targets and the actual output statistics.

(b) What is the cost of generating the output; currently, and over the operation's life cycle.

(c) Where and when cost increases and decreases occur within the operation.

(d) What are the prime needs, and opportunities, for cost saving.

The last three questions test the cost and resource management within the operation, and their answers should be derived from an appropriate cost analysis. Further, there are more practical reasons for developing cost analysis methodology within Eskom:

(a) There is a need to establish the cost structure of energy conversion, and the cost increments resulting from changes occurring or being effected, inside and outside the power stations. This is required to formulate cost based tariff policies, and to support capital expenditure decisions.

(b) Cost data is more tangible and readily available.

(c) Cost analysis being more readily understood, facilitates its application by the users.

Furthermore, product cost is the main consideration in setting product prices, and it thereby influences the product saleability and revenue. Thus profit, being the difference between revenue and cost, is doubly sensitive to cost changes.

Therefore, business performance is basically output and cost effectiveness, and thorough modelling, followed by rigorous cost analysis, is essential for managing it.

4.1 Business Performance (continued)

Profit, being the difference between revenue and cost, exists where a business is not bound to transfer its output at cost.

Such a business, retains the option to decide on at least two of three output parameters; quality, quantity or price. To establish these parameters, the business normally uses marketing, planning and engineering functions, to discover and assess market needs, and devise means to match them with the business capabilities. In other words, this business determines the requirements on its own output as well as the manner in which it fulfills them.

Thus business performance in a business for profit, is its output and cost effectiveness as at the operational level, PLUS its effectiveness in performing the above functions, and in making and implementing decisions. Hence life cycle profitability, the maximising of which is the prime objective of this business, is also a total factor measure of its performance.

Two levels of cost, and appropriate levels of profit, can be considered:

(a) Operating costs, which are for resources consumed within a period and exclude any cost of capital, correspond to operating profit;

operating profit = revenue - operating cost.

The operating profit is the return on the business total assets, and it is a measure of the profitability of the business as a whole.

(b) Total costs, which are for all resources used in a period and include cost of capital, correspond to net or off-target profit;

net or off-target profit = revenue - total cost.

The off-target profit is the net return on the shareholders investment, over and above THEIR cost of capital, and it is a measure of the profitability of the business equity.

Therefore, profit analysis is necessary, in addition to modelling and cost analysis, for comprehensive assessment and diagnosis of business performance.

In the following sections, portions of DPA theory are formulated and prepared, as a practical method for cost and profit analysis.

4.2 Cost and Income Statement

The following is an example of a basic cost and income statement, which has one product item, one operating cost item, one capital cost item and one asset item. Any number of items can be entered for each of these entities. At least two of the three variables, Quantity, Price and Value, must be specified for each item entered.

This example may illustrate the application of definitions and notations used in this work.

		FIRST PERIOD	SECOND PERIOD
PRODUCT REVENUE	(u)	$Qu_o * Pu_o = Vu_o$	$Qu_n * Pu_n = Vu_n$
LESS OPERATING COST	(n)	$Qn_o * Pn_o = Vn_o$	$Qn_n * Pn_n = Vn_n$
OPERATING PROFIT	(a)	V_{Ao}	V_{An}
LESS CAPITAL COST	(t)	$Qt_o * Pt_o = Vt_o$	$Qt_n * Pt_n = Vt_n$
OFF-TARGET PROFIT	(b)	V_{Bo}	V_{Bn}
ASSET ITEM	(k)	$Qk_o * Pk_o = Vk_o$	$Qk_n * Pk_n = Vk_n$

Such a statement is a source for the quantites, prices and values which are required for DPA analysis.

This statement implies that a capital cost item is derived for each asset item.

It also implies that for a period: $V_A = \Sigma all\ Vu - \Sigma all\ Vn$
and that: $V_B = \Sigma all\ Vu - \Sigma all\ Vn - \Sigma all\ Vt$

Basic assumptions which are maintained throughout this work:

(a) There are no gaps between any consecutive periods.

(b) All periods are of the same width.

4.3 Notation and Key Definitions

V≡ Value, Q≡ Quantity, P≡ Price

FOR ANY PRODUCT OR RESOURCE ENTITY : $V \equiv Q * P$

u ≡ product entity

n ≡ operating cost entity

a ≡ operating profit entity

t ≡ target profit or capital cost entity

b ≡ off-target profit entity

k ≡ asset, liability or capital resource entity

Σall ≡ the sum for all product or resource entities

DPA compares two or more different business systems which can be:

(a) different periods in a business system life cycle;
(b) systems under review compared to a reference system;
(c) different configurations of a business system;
(d) altogether different business systems which preferably have a similar product range.

This work concentrates on comparing different periods in the life cycles of Eskom business systems.

$_o$ ≡ old, reference or earlier

$_n$ ≡ new, under review or later

For any period:

$\Sigma all\ Vu \equiv \Sigma all\ Qu*Pu \equiv V_U,\ \Sigma all\ Vn \equiv \Sigma all\ Qn*Pn \equiv V_N$
$\Sigma all\ Vk \equiv \Sigma all\ Qk*Pk \equiv V_K,\ \Sigma all\ Vt \equiv \Sigma all\ Qt*Pt \equiv V_T$
$\Sigma all\ Va \equiv \Sigma all\ c*Vk \equiv V_A,\ \Sigma all\ Vb \equiv \Sigma all\ t*Vk \equiv V_B$

and $Qt \equiv Qk$ for each asset item.

4.3 Notation and Key Definitions (continued)

ROI ≡ return on investment

V_{Ao} / V_{Ko} ≡ Old Actual ROI for total assets
V_{An} / V_{Kn} ≡ New Actual ROI for total assets

Vt_o / Vk_o ≡ Old Target ROI for a specific asset item
Vt_n / Vk_n ≡ New Target ROI for a specific asset item

$$e \equiv \text{old price weighted product quantity relative} = \frac{\Sigma\text{all } Qu_n * Pu_o}{\Sigma\text{all } Qu_o * Pu_o}$$

$$f \equiv \text{new quantity weighted product price relative} = \frac{\Sigma\text{all } Qu_n * Pu_n}{\Sigma\text{all } Qu_n * Pu_o}$$

$$g \equiv \text{total product value relative} = \frac{\Sigma\text{all } Vu_n}{\Sigma\text{all } Vu_o} = \frac{\Sigma\text{all } Qu_n * Pu_n}{\Sigma\text{all } Qu_o * Pu_o} = e * f$$

Each of the ratios e, f and g, is an AVERAGE CHANGE, in product quantities, prices and values respectively, FOR ALL THE PRODUCTS of a business system. Any of these is the weighted average of the appropriate ratios for the individual products; which can be very diverse. Therefore, the average ratios pertain to the entire product range, which is seen as one total product.

To avoid averaging out of diverse changes in the quantities and prices of the individual products, one should endeavour to partition the business into operations, each producing one product.

$$\text{Productivity} \equiv \frac{\text{Product Quantity}}{\text{Resource Quantity}}$$

For each system or period, there is a productivity quotient for every product and resource pair. Where there is one product, or all products are considered as one total product, there is still a productivity quotient for each resource item.

4.3 Notation and Key Definitions (continued)

$$\text{Price Recovery} \equiv \frac{\text{Product Price}}{\text{Resource Price}}$$

For each system or period, there is a price recovery quotient for every product and resource pair. Where there is one product, or all products are considered as one total product, there is a price recovery quotient for each resource item.

Q_{np} ≡ NOTIONAL new resource quantity which would have maintained constant productivity = e * old resource quantity.

P_{nr} ≡ NOTIONAL new resource price which would have maintained constant price recovery = f * old resource price.

Defining and deriving Q_{np} and P_{nr} in this way, cannot imply that Q_{np} or P_{nr} are necessarily attainable for any resource, or whether any resource is variable or fixed.

In fact, it cannot imply any relationships between the product and resource quantities, or between the product and resource prices.

Such relationships are determined by the specific plant and process within the business under analysis. The analysis seeks to uncover these relationships in order to improve them.

Defining and deriving Q_{np} and P_{nr} in this way, only implies that:

(a) if for a resource, $Q_n = Q_{np} = e*Q_o$, then constant productivity has been maintained for that resource, and if $Q_n \neq Q_{np} = e*Q_o$, then a change in productivity has occurred whose consequential cost change is directly related to the difference $(Q_{np} - Q_n)$.

(b) if for a resource, $P_n = P_{nr} = f*P_o$, then constant price recovery has been maintained for that resource, and if $P_n \neq P_{nr} = f*P_o$, then a change in price recovery has occurred whose consequential profit change is directly related to the difference $(P_{nr} - P_n)$.

4.4 Breakdown of Total Cost Variance

The total cost variance, $\Sigma all\ (Vn_o - Vn_n) + \Sigma all\ (Vt_o - Vt_n)$, breaks down for each resource into components of three main categories :

cost variance due to change in productivity $\equiv Y_{new}$
cost variance due to change in resource price $\equiv Z_{long}$
cost variance due to change in product volume $\equiv COST_{volume}$

The "change in productivity" is represented for each resource item, by the difference between Q_{np} and Q_n. As $Q_{np} = e*Q_o$ and as e is independent of any change in resource price, this difference is free of any influence other than its direct relation to a favourable change in productivity.

The "change in resource price" is represented for each resource item, by the difference between the old and new resource price.

The "change in product volume" is represented for each resource item, by the relative difference, between the old and the new product quantity, weighted by the old product price:

$$\frac{\Sigma all\ (Qu_o - Qu_n)*Pu_o}{\Sigma all\ Qu_o*Pu_o} = 1 - \frac{\Sigma all\ Qu_n*Pu_o}{\Sigma all\ Qu_o*Pu_o} = 1 - e$$

For any resource item:

$$Y_{new} = (Q_{np} - Q_n)*P_n$$
$$Z_{long} = Q_{np}*(P_o - P_n)$$
$$COST_{volume} = Q_o*P_o*(1 - e)$$

$$\Sigma all\ Y_{new} + \Sigma all\ Z_{long} + \Sigma all\ COST_{volume} =$$

$$\Sigma all\ (Qn_{np} - Qn_n)*Pn_n + Qn_{np}*(Pn_o - Pn_n) + Qn_o*Pn_o*(1 - e) +$$
$$\Sigma all\ (Qt_{np} - Qt_n)*Pt_n + Qt_{np}*(Pt_o - Pt_n) + Qt_o*Pt_o*(1 - e)$$

As $Qn_{np} = e*Qn_o$ and $Qt_{np} = e*Qt_o$ for each resource,it can be readily shown that the above sum of the main cost variances, can be reduced to:

$$\Sigma all\ (-Qn_n*Pn_n + Qn_o*Pn_o) + \Sigma all\ (-Qt_n*Pt_n + Qt_o*Pt_o) =$$
$\Sigma all\ (Vn_o - Vn_n) + \Sigma all\ (Vt_o - Vt_n)$ which is the total cost variance.

4.5 Cost Variance Report

The cost variance report provides detailed and complete information pertaining to the business cost performance.

The following is a step by step derivation of a cost variance report. The format below illustrates the structure of this report for an operation which has one product item, one operating cost item and one capital cost item. This procedure is valid for any numbers of these items.

TCV ≡ Total Cost Variance (for one resource or for all resources)

Step 1 the product quantity relative e, is derived from the product quantities and prices.

Step 2 the new resource quantity which would have maintained constant productivity $Q_{np}=e*Q_o$, is derived for each resource.

Step 3 Y_{new}, Z_{long}, $COST_{volume}$ and TCV are derived for each resource.

Step 4 the total cost for each period, as well as the total of Y_{new}, Z_{long}, $COST_{volume}$ and TCV for all resources, are summated and cross checked.

1st PERIOD			2nd PERIOD							
Qu_o	Pu_o	Vu_o	Qu_n	Pu_n	Vu_n	e=?	COST VARIANCE BREAKDOWN			
						Q_{np}	Y_{new}	Z_{long}	$COST_v$	TCV
Qn_o	Pn_o	Vn_o	Qn_n	Pn_n	Vn_n					
Qt_o	Pt_o	Vt_o	Qt_n	Pt_n	Vt_n					
TOTALS										

4.6 Cost Variance Analysis

The cost variance breakdown, by resource and by category, is necessary and in most cases sufficient for:

(a) pinpointing the cost saving and cost wasting areas;
(b) tracing the causes for saving or waste;
(c) discerning trends and diagnosing problems;
(d) drawing conclusions.

These objectives can be achieved through:

(a) Comparing the overall TCV with the total cost variance due to the change in the product quantity $COST_{volume}$, which is the only cost variance when both productivity and resource price stay constant. This comparison gauges the deviation of the business as a whole from constant performance.

(b) Comparing the total cost variances which are due respectively to change in productivity and resource prices (Y_{new} and Z_{long}). This is to weigh the effect on the business performance, in terms of productivity change and change in resource prices.

(c) Identifying the resource or resources which have the worst TCV, as prime candidates for in depth investigation.

(d) For each of the resources, comparing the TCV with the cost variance due only to change in the product quantity, $COST_{volume}$. As this is the expected cost variance when the resource price and productivity stay constant, this comparison gauges the deviation from standard performance, in the use of each specific resource.

(e) For each of the resources, comparing the cost variance due to change in the resource price (Z_{long}), and the cost variance due to change in productivity (Y_{new}). This is to weigh the effect of productivity change and change in resource prices, in the use of each resource.

(f) Identifying the resources which have the worst Y_{new}/TCV and Z_{long}/TCV, also as candidates for in depth investigation.

(g) Identifying the resources which, for better resolution, need to be broken down into sub-groups or by source operation.

(h) Identifying and evaluating trade-offs which have occurred.

(i) Identifying areas in which there is need and opportunity for performance improvement and beneficial trade-offs.

4.7 Breakdown of Total Off-Target Profit Variance

The total off-target profit variance, which is
$\Sigma all(Vu_n - Vu_o) - \Sigma all(Vn_n - Vn_o) - \Sigma all(Vt_n - Vt_o)$,
breaks down into components of three main categories:

profit variance due to change in productivity $\equiv Y_{new}$
profit variance due to change in price recovery $\equiv R_{long}$
profit variance due to change in revenue $\equiv PROFIT_{revenue}$

The "change in price recovery" is represented for each resource item, by the difference between P_{nr} and P_n. As $P_{nr} = f*P_o$ and as f is independent of any change in productivity, this difference is free of any influence other than its direct relation to a favourable change in price recovery.

The "change in revenue" is represented by the relative change in the total revenue, which is:

$$\frac{\Sigma all\ (Vu_n - Vu_o)}{\Sigma all\ Vu_o} = \frac{\Sigma all\ Vu_n}{\Sigma all\ Vu_o} - 1 = g - 1 = e * f - 1$$

For any resource item:

$$Y_{new} = (Q_{np} - Q_n)*P_n$$
$$R_{long} = Q_{np}*(P_{nr} - P_n)$$

For each asset item:

$$PROFIT_{revenue} = (g-1)*Vk_o*(V_{Ao}/V_{Ko} - Qt_o*Pt_o/Vk_o)$$

As $g = e * f$, then $\Sigma all\ Y_{new} + \Sigma all\ R_{long} + \Sigma all\ PROFIT_{revenue}$ =

$$\Sigma all\ (Qn_{np} - Qn_n)*Pn_n + Qn_{np}*(Pn_{nr} - Pn_n) - Qn_o*Pn_o*(e*f - 1) +$$
$$\Sigma all\ (Qt_{np} - Qt_n)*Pt_n + Qt_{np}*(Pt_{nr} - Pt_n) - Qt_o*Pt_o*(e*f - 1) +$$
$$\Sigma all\ Qu_o*Pu_o*(e*f-1)$$

As $Qn_{np} = e*Qn_o$, $Qt_{np} = e*Qt_o$, $Pn_{nr} = f*Pn_o$ and $Pt_{nr} = f*Pt_o$ for each of the appropriate resources, it can be readily shown that the above sum of the main profit variances, can be reduced to:

$$\Sigma all(Qu_n*Pu_n - Qu_o*Pu_o) - \Sigma all(Qn_n*Pn_n - Qn_o*Pn_o) - \Sigma all(Qt_n*Pt_n - Qt_o*Pt_o)$$
which is the total off-target profit variance.

4.8 Off-Target Profit Variance Report

The off-target profit variance report, provides detailed and complete information pertaining to the profitability of the owners' investment.

The following is a step by step derivation of an off-target profit variance report.The format below illustrates the structure of this report for an operation which has one product item, one operating cost item and one capital cost item. This procedure is valid for any numbers of these items.

TPV≡Total Profit Variance (for one resource or for all resources)

Step 1 the product quantity relative e, is derived from the product quantities and prices.

Step 2 the product price relative f, is derived from the product quantities and prices.

Step 3 the total revenue relative g, is derived from e and f.

Step 4 the new resource quantity which would have maintained constant productivity $Q_{np}=e*Q_o$, is derived for each resource.

Step 5 the new resource price which would have maintained constant price recovery $P_{nr}=f*P_o$, is derived for each resource.

Step 6 Y_{new}, R_{long}, $PROFIT_{revenue}$ and TPV are derived for each resource.

Step 7 the total off-target profit for each period, as well as the total of Y_{new}, R_{long}, $PROFIT_{revenue}$ and TPV for all resources, are summated and cross checked.

1st PERIOD			2nd PERIOD							$g=e*f$	
Qu_o	Pu_o	Vu_o	Qu_n	Pu_n	Vu_n	e=?	f=?	PROFIT VARIANCE BREAKDOWN			
						Q_{np}	P_{nr}	Y_{new}	R_{long}	$PROFIT_r$	TPV
Qn_o	Pn_o	Vn_o	Qn_n	Pn_n	Vn_n					N/A	
Qt_o	Pt_o	Vt_o	Qt_n	Pt_n	Vt_n						
		V_{Bo}			V_{Bn}						

4.9 Off-Target Profit Variance Analysis

The profit variance breakdown, by resource and by category, is necessary and in most cases sufficient for:

(a) pinpointing profitable and lossy areas;
(b) tracing the causes for profit or loss;
(c) discerning trends and diagnosing problems;
(d) drawing conclusions.

These objectives can be achieved through:

(a) Comparing the overall TPV with the total profit variance due to the change in revenue, $PROFIT_{revenue}$, which is the only profit variance when both productivity and price recovery stay constant. This comparison gauges the deviation of the business as a whole from constant performance.

(b) Comparing the total profit variances which are due respectively to change in productivity and price recovery (Y_{new} and R_{long}). This is to weigh the effect on the business performance, in terms of productivity change and change in price recovery.

(c) Identifying the resource or resources which have the worst TPV, as prime candidates for in depth investigation;

(d) For each of the resources, comparing the TPV with the profit variance due only to the change in revenue, $PROFIT_{revenue}$. As this is the expected profit variance when price recovery and productivity stay constant, this comparison measures the deviation from standard performance, in the use of each specific resource.

(e) For each of the resources, comparing the profit variance due to change in price recovery (R_{long}), and the profit variance due to change in productivity (Y_{new}). This is to weigh the effect of productivity change and change in price recovery, in the use of each resource.

(f) Identifying the resources which have the worst Y_{new}/TPV and R_{long}/TPV, also as candidates for in depth investigation.

(g) Identifying the resources which, for better resolution, need to be broken down into sub-groups or by source operation.

(h) Identifying and evaluating trade-offs which have occurred.

(i) Identifying areas in which there is need and opportunity for performance improvement and beneficial trade-offs.

4.10 Breakdown of Total Operating Profit Variance

The total operating profit variance, which is
$\Sigma all(Vu_n - Vu_o) - \Sigma all(Vn_n - Vn_o)$,
breaks down into components of three main categories:

profit variance due to change in productivity $\equiv Y_{new}$
profit variance due to change in price recovery $\equiv R_{long}$
profit variance due to change in revenue $\equiv PROFIT_{revenue}$

For each operating cost item:

$$Y_{new} = (Q_{np} - Q_n) * P_n$$
$$R_{long} = Q_{np} * (P_{nr} - P_n)$$

For each asset item:

$$PROFIT_{revenue} = (g-1) * Vk_o * V_{Ao} / V_{Ko}$$

As $g = e * f$, then $\Sigma all\ Y_{new} + \Sigma all\ R_{long} + \Sigma all\ PROFIT_{revenue}$ =

$$\Sigma all\ (Qn_{np} - Qn_n) * Pn_n + Qn_{np} * (Pn_{nr} - Pn_n) - Qn_o * Pn_o * (e*f - 1) + \Sigma all\ Qu_o * Pu_o * (e*f - 1)$$

As $Qn_{np} = e*Qn_o$, and $Pn_{nr} = f*Pn_o$ for each cost resource, it can be readily shown that the above sum of the main profit variances, can be reduced to:

$\Sigma all(Qu_n*Pu_n - Qu_o*Pu_o) - \Sigma all(Qn_n*Pn_n - Qn_o*Pn_o)$ which is the total operating profit variance.

4.11 Operating Profit Variance Report

This report provides detailed and complete information pertaining to the profitability of the business operation, regardless of the capital structure.

The following is a step by step derivation of an operating profit variance report. The format below illustrates the structure of this report for an operation which has one product item, one operating cost item and one capital resource item. This procedure is valid for any numbers of these items.

TPV≡Total Profit Variance (for one resource or for all resources)

Step 1 the product quantity relative e, is derived from the product quantities and prices.

Step 2 the product price relative f, is derived from the product quantities and prices.

Step 3 the total revenue relative g, is derived from e and f.

Step 4 the new resource quantity which would have maintained constant productivity $Q_{np}=e*Q_o$, is derived for each cost resource.

Step 5 the new resource price which would have maintained constant price recovery $P_{nr}=f*P_o$, is derived for each cost resource.

Step 6 Y_{new}, R_{long}, $PROFIT_{revenue}$ and TPV are derived for each resource.

Step 7 the total operating profit for each period, as well as the total of Y_{new}, R_{long}, $PROFIT_{revenue}$ and TPV for all resources, are summated and cross checked.

1st PERIOD			2nd PERIOD							$g=e*f$	
Qu_o	Pu_o	Vu_o	Qu_n	Pu_n	Vu_n	e=?	f=?	PROFIT VARIANCE BREAKDOWN			
						Q_{np}	P_{nr}	Y_{new}	R_{long}	$PROFIT_r$	TPV
Qn_o	Pn_o	Vn_o	Qn_n	Pn_n	Vnn					N/A	
Qk_o	Pk_o	Vk_o	Qk_n	Pk_n	Vk_n	N/A	N/A	N/A	N/A		

4.12 Operating Profit Variance Analysis

The profit variance breakdown, by resource and by category, is necessary and in most cases sufficient for:

(a) pinpointing profitable and lossy areas;
(b) tracing the causes for profit or loss;
(c) discerning trends and diagnosing problems;
(d) drawing conclusions.

These objectives can be achieved through:

(a) Comparing the overall TPV with the total profit variance due to the change in revenue, $PROFIT_{revenue}$, which is the only profit variance when both productivity and price recovery stay constant. This comparison gauges the deviation of the business as a whole from constant performance.

(b) Comparing the total profit variances which are due respectively to change in productivity and price recovery (Y_{new} and R_{long}). This is to weigh the effect on the business performance, in terms of productivity change and change in price recovery.

(c) Identifying the resource or resources which have the worst TPV, as prime candidates for in depth investigation;

(d) For each of the resources, comparing the TPV with the profit variance due only to the change in revenue, $PROFIT_{revenue}$. As this is the expected profit variance when price recovery and productivity stay constant, this comparison measures the deviation from standard performance, in the use of each specific resource.

(e) For each of the resources, comparing the profit variance due to change in price recovery (R_{long}), and the profit variance due to change in productivity (Y_{new}). This is to weigh the effect of productivity change and change in price recovery, in the use of each resource.

(f) Identifying the resources which have the worst Y_{new}/TPV and R_{long}/TPV, also as candidates for in depth investigation.

(g) Identifying the resources which, for better resolution, need to be broken down into sub-groups or by source operation.

(h) Identifying and evaluating trade-offs which have occurred.

(i) Identifying areas in which there is need and opportunity for performance improvement and beneficial trade-offs.

5.0 IMPLEMENTATION

The learning required for this work, was mostly gained through extensive interaction with people of diverse roles, and by experimenting with real and imaginary data. The following sections are to:

(a) report on the initial implementation at Lethabo Power Station;
(b) discuss issues which cropped up from these activities, and need to be clarified to facilitate further implementation.

A practical example, which serves to illustrate the performance analysis method of this work, is discussed in Appendix B.

5.1 Lethabo Power Station

The modelling and analysis method of this work, has been developed in close co-operation with Lethabo Power Station. Consequently, the management team of that business, have adopted the method as their own, and they implement it as a matter of course for various applications.

Attached are formats, for cost and income statement as well as for cost variance report, which were developed in addition to the modelling activities.

For brevity and facility of presentation, these formats were simplified on one point; all asset and current liability items were lumped into one net assets item for the purpose of deriving only one capital resource item.

These formats were used at Lethabo Power Station for manual analysis of the universal power station model (rev 2b) and an experiment of comparing 1989 budget to 1988 actual performance. This experiment indicated:

What is the data required for analysis of power station performance, where and how it should be compiled and who is accountable for collecting it.

That further partition is required, for performance analysis of plant systems and other sub-system operations.

That the analysis work, could and should be carried out by the users, ie the power station people.

That the analysis work at the appropriate level of detail, should be aided by means of a software package.

			1st PERIOD			2nd PERIOD					
SENT OUT ENERGY		GWh									
COLD RESERVE + STORAGE CAPACITY		MW									
TOTAL REVENUE											
TOTAL OFF TARGET PROFIT											
TOTAL COST											
COST ITEM	REVA	UNIT	Vo IN R'000	Qo	Po IN R'000 PER UNIT	Vn IN R'000	Qne	Qnp	Qn	Pnr IN R'000 PER UNIT	Pn IN R'000 PER UNIT
TOTAL ENERGY COST		GWh									
COAL HANDLING	1	GWh									
COAL BURNT	1	GWh									
WATER CONSUMED	1	Ml									
FUEL OIL BURNT	0	TONS									
VARIABLE DEPRECIATION	1	Load Factor									
WATER TREATMENT	1	Ml									
SPINNING CAPACITY	0	MW									
TOTAL AVAILABLE CAPACITY COST		MW									
REMUNERATION PAID	0	BODIES									
FIXED DEPRECIATION	0	GEN SETS									
OTHER FIXED COSTS	0	GEN SETS									
TARGET PROFIT = CAPITAL COST	0	GEN SETS									
NET TOTAL ASSETS	0	GEN SETS									
TARGET RETURN ON NET TOTAL ASSETS											

COST & INCOME STATEMENT

OCTOBER 1990
E U PERCALE

ALL AMOUNTS IN R'000'					
	TOTAL AVAILABLE CAPACITY COSTS 2nd PERIOD				
	TOTAL AVAILABLE CAPACITY COSTS 1st PERIOD				
	AVAILABLE CAPACITY COST VARIANCE				
	EMPLOYEES	FIXED DEPR	FIXED COSTS	CAPITAL COST	TOTAL
AVAILABLE CAPACITY COST VARIANCE DUE TO PRODUCTIVITY CHANGE					
AVAILABLE CAPACITY COST VARIANCE DUE TO CHANGE IN RESOURCE PRICE					
AVAILABLE CAPACITY COST VARIANCE DUE TO PRODUCT VOLUME CHANGE					

COST VARIANCE REPORT - TOTAL AVAILABLE CAPACITY

ALL AMOUNTS IN R '000'

TOTAL ENERGY COST 2nd PERIOD	
TOTAL ENERGY COST 1st PERIOD	
TOTAL ENERGY COST VARIANCE	

	COAL BURNT	COAL HANDLING	WATER USED	WATER TREATMENT	FUEL OIL	VARIABLE DEPRECIATION	SPINNING CAPACITY	
COST VARIANCE DUE TO PRODUCTIVITY CHANGE								
COST VARIANCE DUE TO CHANGE IN RESOURCE PRICE								
COST VARIANCE DUE TO PRODUCT VOLUME CHANGE								

COST VARIANCE REPORT - ENERGY CONVERSION

ALL AMOUNTS IN R '000'

TOTAL COST 2nd PERIOD	
TOTAL COST 1st PERIOD	
TOTAL COST VARIANCE	

	COAL BURNT	COAL HANDL	WATER	FUEL OIL	EMPLOYEES	DEPRECIATION	OTHER COSTS	CAPITAL COST	
COST VARIANCE DUE TO PRODUCTIVITY CHANGE									
COST VARIANCE DUE TO CHANGE IN RESOURCE PRICE									
COST VARIANCE DUE TO PRODUCT VOLUME CHANGE									

COST VARIANCE REPORT - ALL RESOURCES

5.2 Power Utility Efficiency and Capacity Utilization

DPA uses asset, cost, revenue and profit variances for comparing two or more business systems. It breaks down the total cost and profit variances into increments; a cost or profit variance for each resource.

The cost or profit variance for any resource, can be broken down into its increments of three categories the first of which is cost or profit variance due to change in productivity, Ynew.

Normally, the causes for productivity changes should be known in a well defined business system, in terms of sub-system operations and major resources.

However, when in doubt as to what could cause cost or profit variance due to productivity change, one may attempt to clarify the issue by partitioning Y_{new} into further components:

(a) cost or profit variance due to change in "efficiency", $E_{new} = (Q_{ne} - Q_n)*P_n$;

(b) cost or profit variance due to change in "capacity utilization", $L_{new} = (Q_{np} - Q_{ne})*P_n$.

$$E_{new}+L_{new} = (Q_{ne} - Q_n)*P_n + (Q_{np} - Q_{ne})*P_n = (Q_{np} - Q_n)*P_n = Y_{new}$$

$Q_{ne} \equiv$ NOTIONAL new resource quantity which would have maintained constant "efficiency" $= Q_o + REVA*(Q_{np} - Q_o)$.

REVA is defined as Resource Variability, or the target ratio between the change in resource quantity and the change in product quantity. Being a "target ratio", implies that it can change when the production level changes, and that it is not determined by a universal rationale. Typically in the power utility business, there is either REVA = 1 or REVA = 0.

Where REVA = 1; for a totally variable resource:

$Q_{ne} = Q_{np}$, $E_{new} = (Q_{np} - Q_n)*P_n$ and $L_{new} = 0$

This case relates well to the common concept of efficiency in the use of variable resources; eg fuel efficiency which is a major issue in the power utility business.

This is so because in this case efficiency and productivity are synonymous as $E_{new} = (Q_{np} - Q_n)*P_n = Y_{new}$.

5.2 Power Utility Efficiency and Capacity Utilization (continued)

Where REVA = 0; for a totally fixed resource:

$Q_{ne} = Q_o$, as no change in resource quantity should be required;

$E_{new} = (Q_o - Q_n)*P_n$ and $L_{new} = (Q_{np} - Q_o)*P_n$

E_{new}, which is directly related to the "unnecessary" difference $(Q_o - Q_n)$, is a measure of saving or loss due to the change in resource quantity only. A concept exists by which this is the area of opportunity for short term improvement.

L_{new}, which is directly related to the difference $(Q_{np} - Q_o) = Q_o*(e - 1)$, is a measure of saving or loss due to the change in product quantity only. There is a concept by which this component of productivity change, is outside the scope of production management.

These notions and concepts are incongruent with similar notions which prevail throughout the power utility industry, and its related engineering disciplines. Therefore reference to these, without adaptation and within this context, may be of dubious significance or even misleading.

However, the notion of productivity is congruent with power engineering notions, which are the most important performance criteria in the power utility business. These are:

(a) Plant or System Availability Ratio = $\dfrac{\text{Available Capacity}}{\text{Installed Capacity}}$

(b) Plant or System Load Factor = $\dfrac{\text{Actual Energy Output}}{\text{Full Load Energy Output}}$

(c) Energy Conversion Efficiency = $\dfrac{\text{Energy Output}}{\text{Energy Input}}$

(d) Energy Productivity of Fuel = $\dfrac{\text{Energy Output}}{\text{Mass Input}}$

Manpower productivity is generally of secondary importance in the power utility business.

5.2 Power Utility Efficiency and Capacity Utilization (continued)

Of the above, the first two are related to totally fixed resources (REVA=0), and the second two to totally variable ones (REVA=1).

As productivity in the use of variable resources, is congruent with "efficiency", there is no point in splitting cost or profit variances due to productivity change, in such cases.

The following concentrates on partitioning of cost or profit variances, related to the first two of the above quotients.

In both these cases, the resource is installed capacity which is a totally fixed resource. In most Eskom SBUs, especially in power stations, this resource quantity is predetermined outside the scope of production management. Nevertheless, the cost or profit variance due to change in this resource quantity, is often of great interest. It is therefore useful to derive Enew = $(Q_o - Q_n)*P_n$, but it is advisable to identify it by specific terms prevalent throughout the power utility industry: Cost or profit variance due to change in Plant or System Availability, and in Plant or System Load Factor, rather than due to change in "short term efficiency".

Available capacity is the most costly product in the power utility and it is entirely within the scope of short term and long term production management. Therefore L_{new} in this case, referred to as "capacity utilization", is a most significant measure for that management performance.

The product output, of most operations in the power utility, is determined by the customer operation. Therefore L_{new} is useful where it is related to a fixed resource and identified by a specifically appropriate term. It measures the effect of load change, on productivity in the use of a fixed resource.

This is also a valid approach to the issue of manpower productivity. It is so because in the power utility business, manpower is mostly a fixed resource whose loading is determined by customer operations.

5.3 Cost Analysis, Profit Analysis and Transfer Prices

The management objective in a cost centre, is to produce the required output quantities, at minimum life cycle cost. The management functions in a cost centre, are production and cost management.

There are management functions which are normally outside the scope of cost centre management:

(a) strategic planning, interaction and monitoring;
(b) funding;
(c) major capital engineering;
(d) product development;
(e) product marketing;
(f) product pricing

Thus, most Eskom SBUs are cost centres; even those which perform one or two of the above functions, on behalf of Eskom Corporate. Therefore, cost variance analysis is primarily appropriate for analysing the performance of individual SBUs.

Profit variance analysis is also appropriate and useful, where a cost centre transfers a product or a service, to another operation within a greater business system. This is the case in virtually all of Eskom SBUs.

The objective for a profit centre, is to generate maximum life cycle profit, at maximum profitability. The management of a business for profit, must perform all of the above functions. Therefore, Eskom as a whole, Eskom Corporate and especially the residual Eskom Corporate, are profit centres for which profit variance analysis is appropriate.

Where a business operation, receives a resource from another operation at cost, that resource price is its cost value, divided by its quantity. The resource quantity is determined by the receiving operation's requirements, but the cost value depends on the performance of the preceding operation. Thus, the resource price to the receiving operation, depends on the performance of the preceding operation.

The receiving operation's cost variance due to change in resource price, reflects the effect of change in productivity or change in resource price, in the preceding operation.

5.3 Cost Analysis, Profit Analysis and Transfer Prices (continued

The following is a discussion of a method, for analysing the effect on the receiving operation, of productivity change in a preceding operation which transfers its products at cost.

Where a business operation, transfers its total product to another operation at cost, the product revenue is equal to the product cost. Both that operation's off-target profit, and its total profit variance (TPV), are always zero; VBo = VBn = 0.

Y_{new} = profit variance due to change in productivity
R_{long} = profit variance due to change in price recovery
$PROFIT_{revenue}$ = profit variance due to change in revenue

For an operation which transfers its total product at cost:

$TPV = \Sigma all\ Y_{new} + \Sigma all\ R_{long} + \Sigma all\ PROFITrevenue = 0$,

as $TPV = VBn - VBo = 0$.

$\Sigma all\ PROFIT_{revenue} = V_{Bo} * (V_{Un} - V_{Uo})/V_{Uo} = 0$, as $VBo = 0$.

Therefore, $TPV = \Sigma all\ Y_{new} + \Sigma all\ Rlong = 0$.

The last equation proves that in such an operation, there is a trade-off between productivity and price recovery. When the productivity increases the price recovery must decrease, and vise versa.

Further, as price recovery is the quotient of product price to resource price, there is also a trade-off between productivity and price "roll over". As productivity increases and price recovery decreases, the more this operation "absorbs" the increases in its resource prices, and the less it rolls those over to its customer operations.

This equation also provides a method for quantifying the money amounts involved.

A similar rationale applies as well in cases where intermediate products are transferred at any prices. Close examination of Σall Ynew, Σall Rlong and their total sum, yields a measure for the trade-off between productivity and price roll over. This is of special significance at the level of Eskom's outside customer.

5.4 Conventional Accounting Methods

It has been stated in this work that methods, such as standard cost accounting and inflation accounting, have been of limited dependability.

The broad reasons given for this statement were that these methods tend to be:

(a) based on a logic which is sometimes divorced from that of the real operation of the business, thus being flawed and leading to wrong conclusions and action plans;

(b) applicable only to part or parts of the business;

(c) restricted to a certain level of detail;

(d) non differentiating between physical, monetary,financial and fiscal effects.

Some conventional accounting methods use asset, cost, revenue and profit variances for comparing business systems. However, their analysis approaches are based on their own paradigmatic models of these systems, which are not always congruent with reality.

Other methods use quotients as measures of business performance. A quotient highlights one aspect of the business and ignores others. Comparison between batches of quotients is inconclusive.

Distortions may also arise from the way in which standard cost accounting partitions cost variances into further components. Not one of these components is exclusively related to a difference in resource price or price recovery.

This is the flawed logic referred to above, which sometimes leads to wrong conclusions and action plans. It is also the reason for applying conventional accounting methods to a part or parts of the business, where their presupposed models happen to be valid.

Standard cost accounting breaks down profit variances into components which are expressed in money terms, but it cannot do this for every resource. If a profit variance cannot be broken down for each resource, neither can it be attributed to various operations. Hence the above reference that conventional methods "tend to be restricted to a certain level of detail".

All these shortcomings decrease the ability of conventional accounting methods to differentiate between physical, monetary, financial and fiscal effects. If cost and profit variances, cannot be broken down into distinct components for each operation and resource, then there is no facility for separating the different effects. Furthermore, there is neither a facility for identifying these effects nor for tracing their causes.

5.5 Standard Cost Accounting (SCA) vs DPA

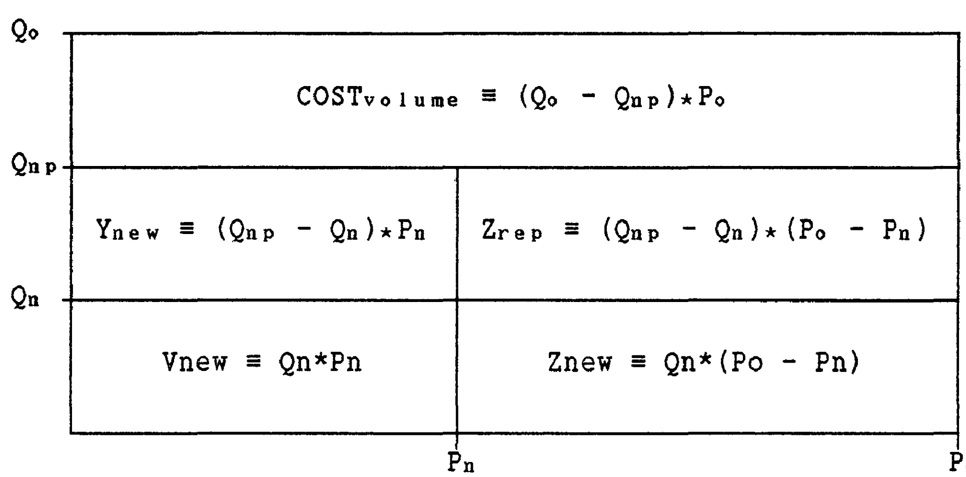
The total cost variance for a resource, $Q_o*P_o - Q_n*P_n$, can always be partitioned into four components:

$COST_v$ ≡ cost variance due to change in product volume = $(Q_o-Q_{np})*P_o$

Y_{new} ≡ cost variance due to change in productivity = $(Q_{np}-Q_n)*P_n$

Z_{new} ≡ cost variance due to change in resource price = $Q_n*(P_o-P_n)$

Z_{rep} ≡ cost variance due to change in productivity AND to change in resource price = $(Q_{np}-Q_n)*(P_o-P_n)$



The differences between SCA and DPA at the cost analysis level, arise from the different ways in which they split $COST_{long} \equiv Y_{new} + Z_{rep} + Z_{new}$, into TWO components:

In the case of DPA, $Z_{rep} = (Q_{np} - Q_n)*(P_o - P_n)$, is attached to the cost variance due to change in resource price;

$$Z_{long} = Z_{new} + Z_{rep} = Q_n*(P_o-P_n) + (Q_{np}-Q_n)*(P_o-P_n) = Q_{np}*(P_o-P_n)$$

In the case of SCA, $Z_{rep} = (Q_{np} - Q_n)*(P_o - P_n)$, is attached to the cost variance due to change in productivity;

$$Y_{old} \equiv Y_{new} + Z_{rep} = (Q_{np}-Q_n)*P_n + (Q_{np}-Q_n)*(P_o-P_n) = (Q_{np}-Q_n)*P_o$$

5.5 Standard Cost Accounting (SCA) vs DPA (continued)

Split of $COST_{long}$ for any resource:

	cost variance due to change in: PRODUCTIVITY		cost variance due to change in: RESOURCE PRICE		$COST_{long}$
DPA	$(Q_{np}-Q_n)*P_n$	+	$(P_o-P_n)*Q_{np}$	=	$Q_{np}*P_o-Q_n*P_n$
SCA	$(Q_{np}-Q_n)*P_o$	+	$(P_o-P_n)*Q_n$	=	$Q_{np}*P_o-Q_n*P_n$
	different	+	different	=	same

By both methods, the appropriate cost variances are based on the same difference expressions; $(Q_{np} - Q_n)$ represents a favourable change in productivity and $(P_o - P_n)$ represents a favourable change in resource price.

Those variances are different because the same difference expressions are multiplied in either case by different multipliers.

Arguments can be made in favour of the multipliers chosen in the case of DPA:

(a) Q_{np} represents the "standard" resource quantity which should have been used to maintain constant productivity.
Q_n represents the resource quantity which was actually used and it must have been affected by change in productivity.
Therefore, $(P_o - P_n)*Q_{np}$, rather than $(P_o - P_n)*Q_n$, is free of any influence of change in productivity which makes it a "cleaner" cost variance due to change in resource price.

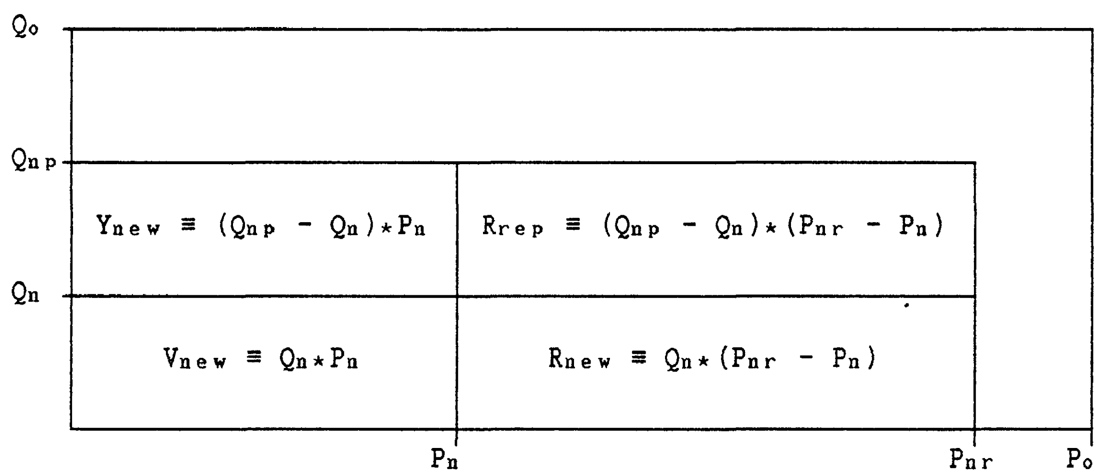
(b) P_n represents a "new" resource price or a resource price which is current in the period under review.
Therefore, $(Q_{np} - Q_n)*P_n$, rather than $(Q_{np} - Q_n)*P_o$, is the cost variance due to change in productivity, expressed in current money terms.

5.5 Standard Cost Accounting (SCA) vs DPA (continued)

The total cost variance for a resource, $Q_o*P_o - Q_n*P_n$, can also be split into two major components:

$PROFIT_{long}$ ≡ cost variance due to change in "relative resource performance" = $Q_{np}*P_{nr} - Q_n*P_n = Y_{new} + R_{rep} + R_{new}$.

$COST_{revenu}$ ≡ cost variance due to change in revenue, at constant performance which is constant productivity and constant price recovery = $Q_o*P_o - Q_{np}*P_{nr}$.



In the case of DPA, $R_{rep} = (Q_{np} - Q_n)*(P_{nr} - P_n)$, is attached to the cost variance due to change in price recovery;

$$R_{long} = R_{new}+R_{rep} = Q_n*(P_{nr}-P_n)+(Q_{np}-Q_n)*(P_{nr}-P_n) = Q_{np}*(P_{nr}-P_n)$$

DPA also partitions the total off-target profit variance into three major components:

(a) the total profit variance due to change in revenue, at constant productivity and constant price recovery = $\Sigma all\ (g-1)*VK_o*(V_{Ao}/V_{Ko} - Qt_o*Pt_o/VK_o)$ for each asset item;

(b) the total profit variance due to change in productivity, at new resource prices = $\Sigma all\ Y_{new} = \Sigma all\ (Q_{np} - Q_n)*P_n$ for any resource;

(c) the total profit variance due to change in price recovery = $\Sigma all\ (P_{nr} - P_n)*Q_{np}$ for any resource.

5.5 Standard Cost Accounting (SCA) vs DPA (continued)

The DPA approach appears to be based on the premise that:

(a) business performance is primarily resource management, in terms of productivity and price recovery;

(b) resource management is primarily productivity management which is the only way to maximum life cycle profitability;

(c) product prices (which also depend on productivity), are the standard for assessing resource prices.

SCA partitions the total off-target profit variance, into different components:

(a) the total profit variance due to change in product volume, at old prices and constant productivity = Σall $(Q_o - Q_{np})*P_o$ for each resource, plus Σall $(Q_n - Q_o)*P_o$ for each product;

(b) the total profit variance due to change in productivity at old resource prices = Σall Y_{old} = Σall $(Q_{np} - Q_n)*P_o$ for each resource;

(c) the total profit variance due to resource and product price changes, termed "cost passthrough" = Σall $(P_o - P_n)*Q_n$ for each resource, plus Σall $(P_n - P_o)*Q_n$ for each product.

The SCA approach appears to be based on the premise that:

(a) business performance is maximum short term profit rather than life cycle profitability;

(b) revenue analysis and cost analysis are separate; perhaps as revenue management and cost management are;

(c) old product and resource prices are standard prices.

6.0 CONCLUSION

6.1 Work Development Summary

This work began with an endeavour to absorb and prepare portions of the DPA theory, for cost and profit analysis of power utility systems, primarily a power station (Chapter 4 and Section 5.1).

Procedures were formulated for deriving and interpreting cost and profit variance reports, of any basic business operation depicted by a "one block" model (Sections 3.1 & 3.2).

Serious difficulties arose at that stage:

There was no clear concept of the power station's final products.

The one step analysis approach, to the power station business as one operation, was of limited significance as it produced obvious inferences. It examined the apparent performance of the business overall, rather than the performance of the sub-system operations which remained hidden.

There was no established concept of the resource and intermediate product flow within the power station. Had it existed, it would have facilitated the identification of the final products, and more penetrating examination of the internal operations.

DPA analysis, deals with variance components which represent apparent effects caused by action taken within the business, or by the business interaction with its environment. The more specific the variance component the more distinct is its link to the specific action which caused it, and the greater the facility to trace and affect that action.

A literature search failed to uncover a universal method which would overcome these difficulties (Chapter 2).

The conclusion was that a partitioning and modelling method must be developed, to establish sub-system models at several levels of the power station business.

Consequently, the modelling method was developed together with the various models (Chapter 3). This becomes a generic method based on a hierarchical approach, for partitioning of greater business systems into sub-systems, and simulating the resource and product flow throughout.

As soon as the modelling method and models were developed, a new integrated approach emerged which resolved the above difficulties and provided a foundation for rigorous assessment and planning of power utility performance (Chapter 5, Sections 6.3 & 6.4 and Appendix).

6.2 Validity and Utility

It has been demonstrated that the modelling and analysis method, developed in this work, is valid and useful.

The modelling method is valid, because it has been developed from basic principles in a logical sequence of reasoning (Chapter 3). Moreover, this method, together with its rationale and the resultant models, has been empirically verified and is being used for various applications within Eskom.

The portions of Deterministic Productivity Acounting combined in this work, have been logically and algebraically validated (Chapter 4). The applicability of DPA was tested in discussion, and established in practical implementation (Chapter 5).

The modelling method originated by the author, is the main benefit of this work. The experimentation and interaction which have been and are being made, indicate that participative and regular practice of such a method in any business, is bound to achieve:

(a) Better understanding and appreciation by all participants, of the factors which determine the business behaviour, as they create, develop and discuss the graphic system models. One picture says more than a thousand words, especially to the person who shared in its drawing.

(b) Facility of reporting on, and discussion of, issues and events affecting the business, ie facility of communication. An explicit picture which is shared throughout the business, helps to establish focus, direction, cohesion and synergy.

(c) Great enhancement of the applicability and usefulness, of **any method** used for performance analysis or optimisation, in terms of **any performance criterion.** The more precise the definition of the system under examination, the clearer and more meaningful the findings and inferences drawn.

(d) Facility of costing, pricing, planning and budgeting at all levels; especially of performance enhancement action and the measurement of its effect. This results from the facility provided by this method, for progressive breakdown or build-up of sub-systems, and the sharper definition of the entity flow and interaction, inside and outside the business.

(e) Clarification of the business information and data, and the appropriate information infrastructure, required to support the rigorous costing, pricing, planning and budgeting. This results from the more explicit concept of the business sub-systems, and the resource and product flow, provided by the modelling process.

6.3 Current Application

The modelling and analysis method of this work, has been developed in close co-operation with Lethabo Power Station. Consequently, the management team of that business, have adopted the method as their own, and they implement it as a matter of course for various applications:

(a) Further modelling of lower levels operations in the station. This is required for creating within the power station, a common picture and better understanding of these operations, especially in support of performance enhancement action.

(b) Analysis of and reporting on current performance; comparison with budgets and forecasts as well as historical actuals.

(c) Forward planning budgeting and forecasting.

(d) Communicating and negotiating with outside parties affecting the station's operation mode; eg Production Planning who determine the allocation of the station's capacity (spinning or reserve capacity), as well as its loading.

(e) Leading the modelling activities at Generation Group level, as the station's contribution to the corporate project of productivity measurement.

Members of the management teams of other power stations, as well as other parties in Eskom, have attended presentations and discussions on this work. Their response was generally positive, but they have not gained sufficient capability to use its method in their businesses.

Finance Group, responding to a directive of the Electricity Council, has launched at the beginning of 1990, an Eskom wide project of productivity measurement. The project team, being unable to suggest a better alternative, tacitly accept the method of this work as their basic approach. Also, the author has been given an opportunity to participate, in the modelling activities of Generation, Distribution & Marketing and Engineering Groups.

This entire experience has convinced the author, that one can understand the modelling and analysis method, and benefit from it, only through thorough practical application.

6.4 Further Application

In the modelling activities for Distribution & Marketing and Engineering Groups, it has become apparent that the general structure of the universal power station model (rev 2b), can be used for the modelling of most, if not all business systems.

In the first stage of most business systems, assets and fixed cost resources are converted into available production capacity. Then a decision is made how to split this capacity, into reserve capacity and capacity which is to be used for production. Thereafter comes the regular production stage, which converts the producing capacity and variable cost resources, into products.

Furthermore, the concept of the final operation, eg Common Plant and Facilities, is also applicable to almost any business, and it enables one to partition any business into well defined sub-system operations, in terms of allocation of costs and assets.

Experience to date suggests that the modelling method of this work is universal, ie it can be applied in a standard approach to any business system.

Moreover, this method can be used to support specific management activities, inside and outside Eskom:

(a) Product costing and pricing, including marginal costing and transfer prices.
This method partitions any business system into constituent functional operations, defines and quantifies the cost flow within it. It facilitates automatic and precise allocation of all the cost entities, thus obviating the distinction between different cost categories; variable vs fixed, direct vs indirect, operating vs capital costs, and overheads vs production costs.

(b) Production and expansion planning, including planning and engineering of performance enhancement action, especially pertaining to plant systems.
This method partitions any business system into lower level functional operations, while it maintains the context of the greater systems. This enables one to assess the sub-systems' performance, alternative operation and maintenance practices as well as different configurations and design changes, all in terms of the benefit to the business as a whole.

(c) Labour negotiations.
This method, when practiced regularly and participatively, creates an explicit picture which is shared throughout the business. It provides facility of communication, and better understanding and appreciation by all participants, of the factors which determine the business profitability. This is exactly what labour negotiators of both sides need.

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APPENDIX

The following is a discussion of a practical example, which serves to illustrate the application of the performance analysis method developed in this work:

Capacity Made Available, Planning and Budget

A power station management team, finalised their business plan and budget for 1990, at the third quarter of 1989. First, having modelled their power station in terms of the Universal Power Station System, they concentrated on its sub-system operation Capacity Made Available. A basic premise was that they had to strive at all times to maximise the station availability and durability.

The station had five generating sets in commercial operation, each of nominal sent out capacity of 600MW. The plan was to maintain station availability ratio of at least 80%, ie Total Available Capacity of 2400MW.

The station was instructed to keep one set at standstill as Cold Reserve, and four sets were to be spun and generate electrical energy.

The total fixed costs budgeted for the year, including total manpower costs, depreciation, cost of capital and other fixed costs, amounted to R960 million, ie R0.4 million per MW of total available capacity.

The fixed assets plus net current assets to be employed, amounted to R4500 million.

The interest rate, determining the cost of capital, was estimated at 16% pa, and the annual depreciation at 4% of the net total assets employed.

The average total number of employees was to be 1375, and the average total remuneration package R40000 per annum.

All other fixed costs were to amount to R1 million per set.

APPENDIX (continued)

Capacity Made Available, Actual Performance

In the third quarter of 1990, being busy with the business plan and budget for 1991, the power station management team updated their forecast of the station's performance for the whole of 1990.

Five generating sets, each of nominal sent out capacity of 600MW, have been operated throughout the year. The station availability however, attained only 64% instead of 80% or more, ie the station achieved Total Available Capacity of only 1920MW.

One set was kept at standstill as Cold Reserve, and four sets did generate electrical energy.

The total fixed costs for the year, including total manpower costs, depreciation, cost of capital and other fixed costs, did amount to R960 million, ie R0.5 million per MW of total available capacity instead of the budgeted R0.4 million per MW.

The fixed assets plus net current assets employed, amounted to only R4375 million, R125 million less than planned. This could have resulted from disposal or delay in commissioning of fixed assets, eg the coal stockyard, from reduction of current assets, eg cash, coal or spares, or from increase of current liabilities which are normally interest free.

The interest rate, determining the cost of capital, was 16% pa, and the annual depreciation was 4% of the net total assets employed.

The average number of employees was actually 1400, 25 more than the budget, and the average total remuneration package R50000 per annum, R10000 more than planned.

All other fixed costs were R3 million per set, three times the budgeted amount. This could have resulted from substantial unforeseen maintenance or training costs, or from rent for the use of assets which had been sold, etc.

APPENDIX (continued)

Capacity Made Available, Comparative Cost Statement

in R millions

	1990 Budget			1990 Actual		
	Quant Q_o	Price P_o	Value V_o	Quant Q_n	Price P_n	Value V_n
Cost of Capital	5	144	720	5	140	700
Depreciation	5	36	180	5	35	175
Manpower	1375	0.04	55	1400	0.05	70
Other Fixed Costs	5	1	5	5	3	15
Total Avail Cap (MW)	2400	0.4	960	1920	0.5	960

Capacity Made Available, Cost Variance Report

This report is derived in terms of the step by step procedure formulated in this work:.

Step 1 the product quantity relative e, is derived from the product quantities, e = 1920 / 2400 = 0.8

Step 2 the new resource quantity which would have maintained constant productivity $Q_{np} = e*Q_o$, is derived for each resource.

Step 3 Y_{new}, Z_{long}, $COST_{volume}$ and TCV are derived for each resource.

Step 4 the total cost for each period, as well as the total of Y_{new}, Z_{long}, $COST_{volume}$ and TCV for all resources, are summated and cross checked.

TCV ≡ Total Cost Variance (for one resource or for all resources)

For any resource item:

Y_{new} = cost variance due to change in productivity
Z_{long} = cost variance due to change in resource price
$COST_{volume}$ = cost variance due to change in product volume

APPENDIX (continued)

Capacity Made Available, Cost Variance Report (continued)

in R millions

Resource	Q_{np} $e{*}Q_o$	Y_{new} $(Q_{np}-Q_n){*}P_n$	Z_{long} $Q_{np}{*}(P_o-P_n)$	$COST_v$ $(Q_o-Q_{np}){*}P_o$	TCV
Cost of Capital	4	-140	16	144	20
Depreciation	4	- 35	4	36	5
Manpower	1100	- 15	-11	11	-15
Other Fixed Costs	4	- 3	- 8	1	-10
Totals		-193	1	192	0

Capacity Made Available, Performance Analysis

The output quantity which was to be maximised, Total Available Capacity, was only 80% of that planned. As the actual total cost is exactly the same as the budget amount, which may be gratifying to some people, the product cost price shot up by 25%. This has great adverse effect on Eskom's performance, as the cost of this output of all its power stations, is more than half of its total cost. Furthermore, whenever the available generating capacity is insufficient, Eskom has to curtail its maintenance programmes and accelerate new plant programmes; both practices being conducive to disaster.

The quantity of three of the resources which account for more than 90% of the total cost, is the number of generating sets in operation, which is directly related to the station nominal sent out capacity. Therefore the productivity of this operation, by its strict definition, is in essence directly related to its availability ratio. Thereby the cost variance due to productivity change, pertaining to any of the three resources and to the whole operation, can be considered as due to its availability change.

The total cost would have decreased by R192 million, had the resource prices and productivity, which in this case is synonymous with availability, been maintained as planned.

Such cost saving could not be achieved, primarily because the main resource quantity, nominal sent out capacity, cannot change when the output quantity Total Available Capacity, changes.

APPENDIX (continued)

Capacity Made Available, Performance Analysis (continued)

Nevertheless, the output quantity was less than planned and one expects to spend less than budgeted, even when considering fixed resources. This can be achieved in such a case, through prudent reduction of fixed and current assets and by minimising Other Fixed Costs.

The quantity of Cost of Capital, Depreciation and Other Fixed Costs, being the number of sets in operation, is unchangeable. Thus, when a value of these costs changes, eg resulting from cost saving action, the cost variance is reflected as due to a change in the resource price.

Hence the favourable cost variances, due to change in resource price, achieved for Cost of Capital and Depreciation, as a result of the reduction in net assets. Likewise the unfavourable cost variance for Other Fixed Costs, which resulted from the actual cost value being three times the budget value.

By their definition, Y_{new} and Z_{long} are mutually dependent. Also in reality, prices depend heavily on productivity. Prices are made attractive in a competitive market, primarily through cost savings due to productivity improvement; especially transfer prices within a group of operations. Therefore the **sum** of Y_{new} and Z_{long}, is the measure of total cost performance, in the use of each resource and for the operation as a whole.

$$COST_{long} \equiv Y_{new} + Z_{long} = (Q_{np}-Q_n)*P_n+Q_{np}*(P_o-P_n) = Q_{np}*P_o-Q_n*P_n$$

$COST_{long}$ ≡ cost variance due to change in cost performance

In this case, $COST_{long}$ for the whole operation is R192 million unfavourable, exactly offsetting the cost saving which would have been achieved, had actual productivity and resource prices been maintained as planned. This could reflect a situation where prices were as planned, but it was impossible to maintain the planned productivity, because of the rigidity of the fixed resource quantities.

Examination of $COST_{long}$ for the individual resources, provides further insight. These variances for Cost of Capital and Depreciation, are relatively less unfavourable than the one for the whole operation, because of the reduction in assets. Thus, a cost saving of R25 million, has been achieved in the use of these resources.

Conversely, the $COST_{long}$ variances for Manpower and Other Fixed Costs, are worse than the one for the whole operation. Thus a cost overrun of R25 million, has been incurred in the use of these resources.

APPENDIX (continued)

Capacity Made Available, Conclusions

The importance of maximising the quantity of the Total Available Capacity, without impairing the plant durability, cannot be over stated. A power station must at least attain availability levels in accordance with its agreed business planning, and in response to resonable demands from the national power system. It must also ensure maximum reliability, primarily to minimise the requirement for standby capacity, and to save production restoration costs.

Maximum flexibility must be built into the assets structure and operation method of this business, to facilitate cost saving especially in situations of declined availability. For example, plant suppliers own, operate and maintain major plant systems, they are paid for plant capacity made available as planned, and pay penalties for losses consequential to the unavailability and unreliability of their plant.

As manpower costs are less than 10% of the total cost, there is little to be gained in this area by efforts to save on employee numbers, skills mix, training, facilities and amenities, or rate of remuneration.

In this case therefore, the management of manpower costs, is not of great consequence. Rather, the most significant performance measure for manpower management, is the quantities and quality of the business outputs and performance, achieved by its workforce.

Manpower productivity however, has other implications which are not directly related to manpower costs. A high level of manpower productivity does not necessarily contribute to improved business performance overall. Often the drive for and attainment of higher manpower productivity, cause regression in business performance. Where a state of optimal manpower productivity exists, it is conducive to better and improving business performance overall. This is so because such a business

(a) has a stable workforce and favourable public image, and it is attractive to potential employees it needs;

(b) can afford to recruit and accommodate a desired proportion of additional employees, for current and future rquirements;

(c) is always in position to staff teams for current and future projects, and release people for training and retraining;

(d) maintains high levels of morale, confidence and motivation, and it provides space and opportunities for growth.

APPENDIX (continued)

Improved Resolution Through Further Partition

The above analysis, of the Capacity Made Available operation, is based on the model of the Universal Power Station System, thus providing performance indicators which pertain to the station as a whole. To trace root causes, one has to pursue further partitioning.

In this case, such partitioning could proceed in two independent directions:

(a) The "one block" model, could be divided into its constituent sub systems, down to the appropriate level of plant systems. This would provide the attribution of output quantities as well as the allocation of costs, to individual sub-system operations, eg to each generating set.

(b) Each of the resource entities, could be broken down into its sub-entities. For example, the various asset and liability items could be separated, thus determining different entities of Cost of Capital and Depreciation, and indicating the specific asset changes which have been effected.

Applying the performance analysis method, to the more detailed model of this operation, would provide answers to the following questions:

(a) What is the distribution, of the actual plant availability, amongst the generating sets and major common plant systems? This would indicate specific areas of favourable or poor performance. For example, it could have indicated that one set broke down and stayed unavailable for some months, while the others performed better than planned. Alternatively, the availability of all the sets, could have been uniformly impaired, by the poor performance of a common plant system.

(b) What is the distribution of cost values and resource quantities, amongst the sub-system operations?
The answer to this question, would indicate different productivity levels achieved in various areas, as well as patterns of cost saving and cost overrun.

(c) What is the distribution of resource quantities and prices, as well as cost values, amongst the sub-entities of each of the major resources?
Typically, this would be useful for further analysis of Manpower and Other Fixed Costs.

APPENDIX (continued)

Energy Conversion, Planning and Budget

The power station management team, having finalised their plan and budget for the Capacity Made Available operation, proceeded with the other major operation, Energy Conversion.

They planned to operate five generating sets throughout the year, each of nominal sent out capacity of 600MW, and of which four sets were to be spun and to send out 12600GWh.

The budgeted total cost of this operation, including Spinning Capacity costs, amounted to R1008 million, ie R80000 per GWh sent out.

The Spinning Capacity was to be 1920MW, four fifths of the 2400MW Total Available Capacity.

Coal quantity is conventionaly measured in ore tons, which can be converted into energy content units. The conversion rate depends on the specific energy content of the bulk of coal in question. Also coal price, which is normally nominated in Rands per ton, can be converted into Rands per energy content unit.

The planned coal quantity to be burnt in the year, was 44000GWh in terms of energy content units, and it was to be purchased at the price of R5000 per GWh.

45000GWh of coal, were to be delivered and handled within the station, at a price of R200 per GWh, thus increasing its coal stock by 1000GWh.

5000 tons of fuel oil were to be handled and used, at a price of R1000 per ton. The energy content of this oil is inconsequential.

30000Ml of water were to be consumed in the year. The price allowed for water purchase and treatment, was R100 per Ml for each of these activities.

Energy Conversion, Actual Performance

Only 11340GWh have been actually sent out, 10% less than planned, probably because of the declined station availability.

The total cost however, amounted to R1050 million for the year, R42 million more than the budget, and the product cost price increased to R92600 per GWh.

APPENDIX (continued)

Energy Conversion, Actual Performance (continued)

The Spinning Capacity has been only 1500MW while its cost amounted to R774 million, R6 million more than budget, probably because of extra maintenance works, provided to the plant systems used for energy generation. As the Total Available Capacity cost has been as planned, the cost overrun for Spinning Capacity, must have offset an appropriate cost saving on the Cold Reserve.

Only 40000 GWh of coal have actually been burnt, some 9% less than planned, while the purchase cost of this coal amounted to R240 million instead of R220 million.

The same quantity of coal, was delivered and handled within the station, at a price of R300 per GWh, thus maintaining the same coal stock.

16000 tons of fuel oil were handled and used, at a price of R1000 per ton.

25000Ml of water were consumed in the year. The purchase price was R120 per Ml, and the price of water treatment R200 per Ml.

Energy Conversion, Comparative Cost Statement

in R millions

		1990 Budget			1990 Actual		
		Quant Q_o	Price P_o	Value V_o	Quant Q_n	Price P_n	Value V_n
Spinning Cap	(MW)	1920	0.4	768	1500	0.516	774
Coal Burnt	(GWh)	44000	0.005	220	40000	0.006	240
Coal Handl	(GWh)	45000	0.0002	9	40000	0.0003	12
Fuel Oil	(Ton)	5000	0.001	5	16000	0.001	16
Water Consum	(Ml)	30000	0.0001	3	25000	0.00012	3
Water Treat	(Ml)	30000	0.0001	3	25000	0.0002	5
Energy Sen Out	(GWh)	12600	0.08	1008	11340	0.093	1050

APPENDIX (continued)

Energy Conversion, Cost Variance Report

The product quantity relative e, is derived from the product quantities, e = 11340 / 12600 = 0.9

in R millions

Resource	Q_{np} $e * Q_o$	Y_{new} $(Q_{np} - Q_n) * P_n$	Z_{long} $Q_{np} * (P_o - P_n)$	$COST_v$ $(Q_o - Q_{np}) * P_o$	TCV
Spinning Cap	1728	117.65	-200.45	76.8	- 6
Coal Burnt	39600	- 2.40	- 39.60	22.0	-20
Coal Handl	40500	0.15	- 4.05	0.9	- 3
Fuel Oil	4500	-11.50	0.00	0.5	-11
Water Consu	27000	0.24	- 0.54	0.3	0
Water Treat	27000	0.40	- 2.70	0.3	- 2
Totals		104.54	-247.34	100.8	-42

Energy Conversion, Performance Analysis

The quantity of the energy sent out, was 10% less than planned, which is the resultant effect of various causes.

The sent out energy of a power station, is determined primarily by the national power system planning, which is adjusted periodically, as well as by its hour by hour control.

Three major factors affect the national power system decisions:

(a) The distribution amongst the power stations, of the specific marginal costs; mainly the coal cost portion in the total cost of a GWh sent out. The lower the specific marginal cost of energy conversion in a station, the more often and the larger the energy amounts, it is called upon to send out.

(b) The distribution of station availability and reliability, amongst the power stations, and in terms of timing. The higher the station availability and its predictability, generally and at specific times, the more it is loaded.

APPENDIX (continued)

Energy Conversion, Performance Analysis (continued)

(c) The distribution of the load on the system, in terms of time and place. Though this distribution is fairly predictable, a small fluctuation of the load on the system, can be the sole reason for a 10% load reduction in an individual station; especially a station which is relatively lightly loaded as in this case, its planned load factor being less than 50%.

Therefore, the power station management team, should discuss this matter thoroughly and on an ongoing basis, with the policy makers of the national power system. In so doing, they would establish mutual awareness of the causes affecting this issue, a better understanding thereof, and an agreed rationale for planned and ad hoc action.

Though the output quantity of this operation was 10% less than planned, its total cost has overrun the budget by more than 4%, thus increasing the product cost price by almost 16% over and above the budgeted increase.

The total cost would have decreased by R100.8 million, had the resource prices and productivity been maintained as planned. In any case, an appreciable proportion of this saving should have been achieved, at least in the use of the variable resources which account for a quarter of the total cost.

In terms of cost management, this is worse than the case of the operation Capacity Made Available, where a cost saving has been achieved in the use of rigidly fixed resources, and the total cost did not exceed the budget. Moreover, the worst cost overruns in this case, were incurred in the use of resources which had the greatest facility for cost saving; coal and fuel oil.

Furthermore, there is no merit in the cost saving of R117.65 million, which was due to productivity improvement in the use of the Spinning Capacity. It is the effect of the Spinning Capacity decline to 80% of that planned, while the energy sent out was only 10% less than planned, ie the proportion of the Spinning Capacity used for energy generation, was larger than planned and hence the apparent productivity improvement in its use.

The proportion of the Spinning Capacity, NOT used for energy generation and termed Spinning Reserve, is a part of the Total Available Capacity which is used by the national power system as an instant standby capacity. The smaller the Generating Capacity the larger the Spinning Reserve and vice versa, either fraction of the Spinning Capacity, being equally useful.

APPENDIX (continued)

Energy Conversion, Performance Analysis (continued)

	Planned	Actual
Spinning Capacity (MW)	1920	1500
Generating Capacity (MW) = energy (MWh)/(24*365) =	1438	1295
Spinning Reserve (MW)	482	205

In the Energy Conversion operation, productivity in the use of Spinning Capacity, being the ratio of Generating Capacity to Spinning Capacity, is not a measure of performance.

The power station must maximise its Total Available Capacity, and thereby maximise the Spinning Capacity of its spinning sets, and disregard the productivity in the use of its Spinning Capacity.

The actual Spinning Reserve in this case, was less than a half of that planned, and less than a third of what it could have been, had the planned availability been achieved (1920 - 1295 = 625MW).

The declined Total Available Capacity, also accounts for a large proportion of the cost overrun due to the increase in Spinning Capacity price, which is an increase in product cost price in the preceding operation.

This could be anticipated as it has been stated and substantiated in this work, that "the operation's cost variance due to change in resource price, reflects the effect of change in productivity or change in resource price, in the preceding operation".

It should be noted that the quantity and cost of the Spinning Capacity, were intended each to be a proportion (80%) of the respective parameters of the Total Available Capacity. Neither of the actual amounts maintained this proportion, and both deviations increased the resource price of the Spinning Capacity and reduced the price of the Cold Reserve. It is reasonable to expect however, that the cost price of capacity used for energy generation, would be worse than that of Cold Reserve which is kept at standstill. This issue would have been more readily apparent had further partitioning, eg into individual generating sets, been implemented.

APPENDIX (continued)

Energy Conversion, Performance Analysis (continued)

The worst cost overrun was incurred in the use of coal. As the energy sent out was 10% less than planned, a cost saving of R22 million would have been achieved, had both the coal price and the productivity in its use, been maintained as planned. This should not be too difficult to achieve, at least in part, as coal is a fully variable resource in the energy conversion process.

Thus, the total cost overrun in the use of coal, should be considered to be equal to the cost variance due to change in its cost performance:

$$COST_{long}(coal) = Y_{new} + Z_{long} = (-2.4) + (-39.6) = -R42 \text{ million}$$

The amount of this overrun is equal to the total cost overrun of the Energy Conversion operation, which is also the total cost overrun for the entire power station operation. Had both the coal price and the productivity in its use, been maintained as planned, the total costs of the operation and the station, would have been exactly as budgeted.

Two factors, which are normally mutually independent, affect the coal price when it is nominated in Rands per energy content unit:

(a) The coal price in Rands per ton, is determined in terms of a coal supply contract, and thus it is fairly predictable. Such contracts usually stipulate fixed payments per period, which cause an increase in the per ton price, whenever there is a decline in the quantity purchased in a period. Often the fixed payments are relatively large, and consequently the coal marginal prices, are fairly low.

(b) The specific energy content of the bulk of coal in question can vary within an appreciable range. When the price per ton is kept unchanged, the lower the specific energy content the higher the price per energy content unit.

The coal price in this case, was 20% higher than planned, which accounted for almost 95% of the coal cost overrun. Such a large price increase must have resulted from adverse deviations in both the above factors.

APPENDIX (continued)

Energy Conversion, Performance Analysis (continued)

In this operation, where coal quantity is measured in energy content units, productivity in the use of coal is synonymous with the efficiency of the energy conversion process. It is the ratio between the electrical energy sent out and the energy contained in the coal input.

The efficiency of energy conversion is affected by four factors:

(a) The proportion of the nominal Spinning Capacity used for energy generation, generally and at specific times, accounts for changes in efficiency. Most generating sets are designed for maximum efficiency of energy conversion at full nominal load, and the lower the load the lower the efficiency. The 10% load decline of this case could well cause a part of the decline in efficiency.

(b) The better the plant operators operate the generating sets minute by minute, keeping the process parameters at optimal levels, the higher the efficiency.

(c) The better the physical condition of the generating sets, and the more effective their maintenance, the higher the efficiency.

(d) A small yet significant proportion of the electrical energy generated, is consumed by the generating plant itself, hence the term "house load". When the generated energy is kept constant, the lower the house load the more the energy sent out. As the house load is almost fixed, even when the energy output declines, it could also contribute to the decline in efficiency.

In this case, the decline in energy conversion efficiency, is fairly small, and factors (a) and (d) above must have made some contribution to it. Thus, factors (b) and (c) could not make a significant contribution, which precludes poor performance in terms of these factors.

A considerable cost overrun, was incurred in the preceding Coal Handling operation. The term preceding operation is used because it must be a full fledged operation, which is represented as one amalgamated service to the Energy Conversion operation.

As the cost overrun in the use of Coal Handling was R3 million, and R0.9 million would have been saved had productivity in its use and its price been maintained as planned, the cost overrun due to deteriorated performance, is close to R4 million.

APPENDIX (continued)

Energy Conversion, Performance Analysis (continued)

It should be noted, that the apparent productivity gain in the use of Coal Handling is false, as it resulted from the fact that the coal stock inside the station, was not increased as planned.

Therefore, the cost overrun of R4.05 million due to increase in the Coal Handling price, is the effect on the Energy Conversion operation, of the problems in the Coal Handling operation. Once again, "the operation's cost variance due to change in resource price, reflects the effect of change in productivity or change in resource price, in the preceding operation".

As the Coal Handling price was 50% higher than planned, this must have resulted from various causes:

(a) The output quantity in terms of energy content, was some 11% less than planned, thereby contributing to an increase in the price per energy content unit, if the costs declined at a lower rate. A proportion of the Coal Handling costs, has to be fixed and cannot decrease when the output quantity decreases. This must contribute to an increase in the price per output unit.

(b) Whenever the specific energy content of the coal declines, the output quantity in tons, and thus its handling costs, decrease by a smaller proportion than that of its quantity in energy content units, if at all. For the same tonnage and handling costs, the worse the specific energy content, the higher the Coal Handling price per energy content unit.

(c) The greatest uncertainty in budgeting for an operation such as Coal Handling, relates to breakdown maintenance costs, which can amount to a multiple of those budgeted for.

Fuel oil, being substantially more expensive than coal, is used in a coal fired power stations, to start up and stabilise the combustion in the boilers.

The actual useage of fuel oil quantity in this case, amounted to more than three times of that planned, which caused a cost overrun of the same proportion.

This indicates frequent occurrences of start up operations or protracted periods of unstable combustion.

APPENDIX (continued)

Energy Conversion, Conclusions

The costs which are specific to this operation, as distinct from those of Capacity Made Available, are a small proportion of the total costs of the power station.

Nevertheless, these costs are sensitive to differences in plant availability, reliability and efficiency inherent in it, as well as to the quality of plant operation and maintenance, throughout its life cycle.

The following is a scenario which emerges from the performance analysis of this case. It uses the apparent facts as stated, and the inferences made in the analysis, to link them to their underlying causes.

The analysis of the decline in efficiency of energy conversion, indicated that neither the operation of the generating sets, nor their physical condition, contributed to that decline. As the quality of that plant operation and its physical condition, were adequate to maintain its planned efficiency, it is unlikely that these could cause a deterioration in its reliability. Moreover, it is unlikely that under such circumstances, there was actually any deterioration in the reliability of the generating sets.

On the other hand, the station availability has declined, and the related costs have overrun.

The situation which suits the evidence as well as its rationale, is that frequent and protracted stoppages occurred in the Coal Handling operation.

This would explain the decline in station availability, even if the generating sets operated reliably.

It also explains the decline in the availability of the spinning sets being worse than that of the Cold Reserve. The Cold Reserve set, having had a coal stock enough for few hours of generation, was considered to be available when the spinning sets were down, due to short stoppages in the common coal supply. When the coal supply stopped for more than few hours, also the Cold Reserve set started clocking unavailability hours.

This scenario also suits various other developments within the power station, which deviated from its planning and budget:

APPENDIX (continued)

Energy Conversion, Conclusions (continued)

The stoppages in the Coal Handling operation, being frequent and protracted enough to constrict the energy sent out, reduced it to 90% of that planned. The fact that the national power system kept loading the station, even at the expense of severely reducing its Spinning Reserve, indicates that the reduction in energy sent out was not due to a decrease in demand on the station.

These stoppages also accounted for the decrease in the quantity of coal purchased. The failure to build up the coal stock in the station, strengthens the notion by which the station could generate energy and purchase coal, as much as it could move the coal from the colliery to the boilers.

The excessive useage of fuel oil, which is used to start up and stabilise the combustion in the boilers, also matches unreliable and unstable coal supply.

Overall Conclusions

This application of the performance analysis method, deals with main aspects of business performance, within a coal fired power station.

This method links real occurrences, as well as operational and technical relationships, to the conventional accounting system. It also identifies and quantifies the interactions within the business, and between it and its environment.

Thereby, its regular practice is bound to enhance understanding of that business, as it enables one to identify and quantify causes for the effects which appear in financial statements, and vice versa.

Furthermore, this method enables one to draw conclusions, which are required to support pro-active and reactive decision making, and action planning. Moreover, it can be used to simulate business operation, eg of a power station which is in its early design stage, to create and assess alternative strategic plans.

Therefore, such systems modelling and performance analysis, should be implemented in a participative process, to establish common direction, objectives and performance measures, and to reduce the need for close control by line managers, or worse, by staff functionaries.