THE INTRODUCTION OF AN INTEGRATED PROJECT TIME AND COST CONTROL SYSTEM

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A project report submitted to the Faculty of Engineering, University of the Witwatersrand, in partial fulfilment of the requirements for the degree of Master of Science in Engineering.

KLERKSDORP, 1986

DECLARATION

I declare that this project report is my own, unaided work. It is being submitted for the Degree of Master of Science in Engineering in the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in any other University.

SIGNED : ____________________

1st day of October 1986.

ABSTRACT

The linking of time control and cost control into an integrated Project Control system, for use on large mining projects in Anglo American has been sought for some years. This report outlines how this was done at Vaal Reefs Gold Mine for use in new shaft sinking projects.

By using the existing cost control system, C.P.I.S, and a strategic IBM product APPLICATION SYSTEM (AS), modules were developed and introduced whereby the detailed schedule (network) could be costed from the approved estimate via C.P.I.S.

The most important outputs from the new system are S-curves for both the physical progress and expenditure which are produced from now to project completion i.e., they have a predictive ability.

The report describes the background for the need for such a system, the selection of the system, the system itself and includes throughout related capital control aspects which are to be used on the new project.

ACKNOWLEDGEMENT

The author wishes to thank the Regional General Manager, Vaal Reefs Exploration and Mining Company, Limited, for permission to publish this project report, and also the project team who worked under his direction and whose diligent work and faith in the idea made the introduction of the system a success.

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1. INTRODUCTION

1.1 SYNOPSIS

Vaal Reefs Exploration and Mining Company Limited is managed by the Anglo American Group. The mine is presently conducting feasibility studies on the viability of exploiting areas adjacent to the present lease area. Two areas have been identified as having economic potential. If these new shaft projects come to fruition they will be very large, deep, complex systems and consequently will be characterised by two aspects which to date have proved very difficult to control - high capital cost and long construction time prior to production start-up. The South African Gold Mining Industry has a reputation of creating technically excellent projects, which in the last 15 years or so, have overrun both budgets and time schedules.

To date, the capital expenditure involved in all Anglo American projects, has been "controlled" using a system called CPIS (Capital Project Information System). In the past with technically simpler, lower cost, shorter projects, this very sophisticated accounting tool has proved adequate. Time control has mainly been done using a system called K and H.

For projects such as those contemplated at Vaal Reefs, the cost and time control systems presently in use have the following major disadvantages:-

(i) CPIS is basically an historical accounting system, excellent for producing financial statements and Board documents with no predictive ability.

(ii) The K and H system permits the development of time based plans only and the monitoring of actual versus planned times. There is no link between CPIS (cost) and K and H (time), nor could one be established as CPIS costs are historical and K and H activities are futuristic.

A need for a system linking time and cost has in broad terms been accepted by Anglo American and it has been accepted that such a system will be required to control the projects envisaged at Vaal Reefs. To the best of the author's knowledge no successful proven system capable of fulfiling Vaal Reefs' requirements has been introduced to the South African Gold Mining Industry. (Anglo American has tried in the past to introduce systems with very limited success).

The only industries which have successfully introduced, and widely used, integrated systems are the American Aerospace Industry and the American Petrochemical Industry. Their systems are extremely complex. A few South African Project Management companies use systems which can control relatively small simple construction projects.

This report is a record of the project run at Vaal Reefs, by the author, to implement an integrated time and cost control system to be used on the possible new shaft projects, namely the Goedgenoeg project and the Moab project (Vaal Reefs No's 10 and 11 Shafts respectively).

It was originally planned to implement a system by April 1986. However, due to a late start and technical difficulties this was changed to mid - 1986. This date was met and currently the system is being used on one of these projects and will shortly be introduced on the other, as well as all major, say + R5 million, projects on the Vaal Reefs complex.

The report is structured around the real situation insofar as it records the management philosophy required, the present control systems used and therefore the need for an integrated system, through to the selection of such as a system and the implementation and running of it.

At Vaal Reefs this is regarded as a major breakthrough in the field of capital control and it is highly likely that Anglo American's Gold Division (if not other divisions as well) will adopt the system.

The Project Team formed to implement a system were :

J C Donald (Chairman)	-	Production Manager
P Povall	-	Project Services Co-Ordinator
I van der Merwe	-	Cost Accountant
L Jacobs	-	Assistant Cost Accountant
J Smit	-	System Analyst (Infogold)
S Pearson	-	System Controller
G V Ruthman	-	System Controller

1.2 PROJECT MANAGEMENT PHILOSOPHY

1.2.1 Concepts

A project is any number of tasks required to be carried out, in a complex pattern, in order to achieve a ONE-OFF GOAL. A new shaft project is very complex in that it draws on a wide variety of skills.

Project management is the co-ordination of resources for the successful execution of a project from inception to production.

For a new shaft project these phases are :

Inception
Feasibility
(Approval)
Engineering and Design
Procurement
Construction and shaft sinking
Commissioning
Initial operations

Project management consists of the activities required to produce a final project, timeously, within the expected cost and with the required reliability and achievement potential.

1.2.2 The Project Cycle

There is a more or less an established format for the succession of tasks for the development and successful completion of a project; this is known as the project cycle. These tasks and their duration have definite financial implications. For this reason, before any steps in the execution of the project should be undertaken, an overall master plan must be drawn up, and a detailed programme for the implementation of the plan, and methods for the control of the progress, cost and time variables of the projects must also be developed.

1.2.3 Project Planning

The aspect that probably has the most far reaching consequences for the project is the scope, *detail* and realism of project plans. Experience has taught us that most problems that develop in the course of a project can be traced back to *faulty planning* in scheduling, budgeting, provision for contingencies, prediction and project simulation, planning for changes, composition of the *organisation*, financial planning and planning for information flow.

The successful planning of the project depends on two fundamental project management principles :

1. All work can be planned and controlled.

2. The more *difficult it is to* plan work, the more essential it is that the work should be planned.

Project planning consists of four phases :

(a) The analysis of the project into work units or *tasks* and the composition of the project organisation structure.

(b) The determination of the sequence of tasks at all stages of the project. (Network planning)

(c) Drawing up of the master programme schedule. (Bar chart)

(d) Cost and resource targets for the *series of periods* the project is to cover. (Budgeting)

1.2.4 Project Implementation

The implementation of a shaft sinking project is the *physical execution* of the project, which can be divided into two principal activities, namely the Engineering and Design stage and the Construction and Shaft Sinking stage.

1.2.5 Cost and Time Control

1.2.5.1 Time Control

In order to acc[illegible]lish the project tasks efficiently, plans a[illegible] sc[illegible]ules must be drawn up. During the course [illegible] the project it will be necessary to replan and reschedule to accommodate unexpected progress, delays and technical conditions.

The aim is to plan the execution of the programme so that the cost and time required to complete the project are properly balanced. With regard to the control function, one is concerned with monitoring and expenditure of time and money in carrying out the scheduled programme as well as the resulting "product" quality of performance.

For this reason it is necessary to monitor daily and weekly progress on site and evaluate the results against the planned programme network of execution. Each activity must be analysed and the actual variations determined. The effect of individual variations on the critical path in the construction programme must be determined and problem areas flagged.

In addition to its value in monitoring physical progress and making it possible to take action on poor progress, as a means of optimising the time-cost relationship, the programme critical path network provides a powerful vehicle for the control of costs throughout the course of the project.

The project will be controlled by checking off progress against the schedule and analysing the effects of delays.

Targets in controlling physical progress are as follows :

(a) Accurate and timeous information on actual progress.

(b) Periodic comparisons between actual progress and planned progress.

(c) Delays are evaluated and possible delays identified and short-circuited.

(d) Corrective action is taken against poor progress.

(e) Critical activities are identified and intensively monitored.

(f) Timeous design inflow is ensured and design variations that would have an adverse effect on progress with construction are eliminated or minimised.

(g) A motivating influence is exercised by keeping in close touch with construction activities and proposing alternative construction methods.

(h) It is ensured that disciplinary consultants (Quality controllers) carry out inspections at effectively frequent intervals so that work can be approved or rejected timeously; and the effect on the programme minimised.

1.2.5.2 Cost Control

The most important objective in this control function is to assure that we will remain within the project budget in executing the project.

The major objectives of a cost control system are to control ongoing costs and periodically to provide a forecast of final project costs. Variance between actual and estimated costs provide an efficient means of identifying potential cost overruns.

Cost-status reports should identify cost overruns in time for corrective action. To do this they must be accurate, timeous, sufficiently detailed and concisely organised.

The control system should also serve as an indicator of any cost problem areas during the execution of the project. These "warnings" should be analysed timeously and corrective adjustments made. The steps in a cost control system are as follows :

(a) The primary budget for the project is drawn up.

(b) Final tender values are evaluated on the basis of the primary budget.

(c) The final project budget is pegged; the final contract value is built in, as are risk-calculated amounts that included design changes, claims and escalation costs.

(d) The supply of a cost statement as well as a projection of the final project cost.

1.2.5.3 Cost and Time Control

In the past the main concern in project control was to ensure that the project was completed on time. However the cost and time implications of a project can be considered simultaneously because

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1.2.5.3 Cost and Time Control

In the past the main concern in project control was to ensure that the project was completed on time. However the cost and time implications of a project can be considered simultaneously because they have a common denominator i.e. the network structure of the activities required to complete the project.

Tying costs to the project schedule enables us to generate an invaluable tool - the estimated net cash flow.

The objectives of an integrated control system are :

- to provide a direct link between the time and cost aspects.
- to provide an overall programme which optimises expenditures of time, recognises cost implications and reflects contractual obligations.
- to provide uniformity in reporting of all activities.
- to provide an early warning system of deviations from the approved plan (cost and time) and to minimise their effect by rescheduling.
- to minimise project risks.

An advantage of using an integrated system compared with conventional stand-alone systems is that information is only entered once, and used by all sub-systems with consequent uniformity of data used. Summary reporting is always done on the same cut-off date and time for all sub-systems.

2. CONTROL SYSTEMS CURRENTLY IN USE

2.1 CAPITAL EXPENDITURE CONTROL

2.1.1 Capital Code

The capital code is a "master" code and forms the basis from which all project codes within the Anglo American group are generated.

A project code is the common thread linking the various control systems within a project. It identifies and classifies all costs incurred in the execution of capital projects. It provides a consistent reference for facilities, equipment, materials, services, etc. as well as drawings, documents and correspondence.

The code is structured in such a way that it enables project work to be identified at all levels right down to commodity/activity (job) level.

This inherent detail availability allows project work to be coded to suit the level of control required by project management.

In general two steps must be taken when coding:-

- the element to be coded must be clearly defined
- a set of numbers whose definition matches that of the element must be selected from the code.

The code is t 'ommon reference in the following areas:-

- Estimating, .udgeting and forecasting
- Evaluation o. expenditure including reporting and auditing
- Planning and progress control
- Procurement
- Drawing classification
- Filing of documents and correspondance
- Project analysis.

The code consists of 18 digits which are structured in such a manner that the various project sub-divisions can be identified.

The 18 digits of the code are arranged as follows:

1 2 3	4	5 6 7 8	9 10 11 12	13 14 15	16 17	18
PROJECT NUMBER	PHASE	ESTIMATE NO.	JOB NO.	ITEM NO.	FLAG FACILITY	SPARE

2.1.2 Definitions

When preparing to code any particular cost element within a project one must first decide on the nature of the cost element and its relationship to the project as a whole. A project is sub-divided into its component parts.

Each sub-division from Phase through to Flag progressively, identifies in greater detail a smaller part of the project.

Project

A project is a complete scheme or programme for the creation, improvement, or expansion of facilities and amenities which necessitates capital expenditure.

Example: A new shaft system

Phase

When a project is divided sequentially into a number of sub-divisions or stages, these stages are called 'phases'. A project may be phased to suit, for example the financing method, the split in management responsibilities or the plant build-up to full production. A phase may also indicate the status of a section of a project (i.e. approved or unapproved).

Example: Phase 1 - work to be done in 1986

Estimate

The estimate is the primary breakdown of a project or project phase by process step or facility. In this context a facility is defined as a major physical work area.

Example: Electrical Reticulation

Job

The job is the secondary project breakdown and represents an activity/commodity. It is used for the classification and identification of all equipment, materials, (commodities) labour, services (activities) and indirect costs normally encountered in project work. It provides a more detailed breakdown of the 'estimate' control levels permitting more effective control of all activities, commodities and services involved in the project.

Example: Power Cables ~ above 1 000V

Item

The item is the tertiary project breakdown and sub-divides an activity/commodity (job) into its various elements for control purposes.

Example: 600 m of 95 mm^2 x 3 core cable 11 kV

Flag

The flag is the final breakdown and identifies the type of element cost which makes up the total cost of a project (i.e. material cost, labour cost, freight charges, etc).

Example: Material cost - copper

2.1.3 CPIS

CPIS is the common abbreviation for "CAPITAL PROJECTS INFORMATION SYSTEM".

CPIS is the data base from which reports and schedules can be drawn. These are now in a set format which has not been altered for three years.

The overall structure of the possible outputs from this date base are set out in figure 1. The five main branches of this structure are :

1. Capital status reports
2. Board documents
3. Forecast
4. Supplier's sub-system report's
5. Escalation sub-system

1. Capital status reports, are by far the most widely used of the reports and for "control" purposes by far the most important. This branch is broken into three sub-sections viz.,

    1. Ledger
    2. Monthly summaries
    3. 'A' and 'B' schedules

    These sub-sections are described in detail in figures 2, 3, and 4.

2. Quarterly report/Board documents are split between top management reports and Board reports. This is described in figure 5.

3. Forecast is broken into sub-sections in figure 6. (It should be noted that this forecast is a "thumb suck" rands only figure in no way connected to any plan or schedule).

4. Supplier's sub-systems are described in figure 7.

5. Escalation sub-system is described in figure 8.

NOTE

Before the introduction of AS, S-curves were for a short time drawn by hand for another large project, namely the No. 9 Shaft project. An example of this control report is shown in figure 9.

2.2 TIME (PROGRESS) CONTROL

2.2.1 Introduction

All major capital projects in Anglo American are planned and controlled using activity on arrow network techniques and the K and H CPM computer programme.

The essence of the planning and control is on a scale which embraces the entire project which implies an overall plan of all the various activities from feasibility studies through design, procurement, construction and commissioning.

The planning is done in two layers, viz:

FIGURE 2.1

OVERALL STRUCTURE OF CPIS REPORTS

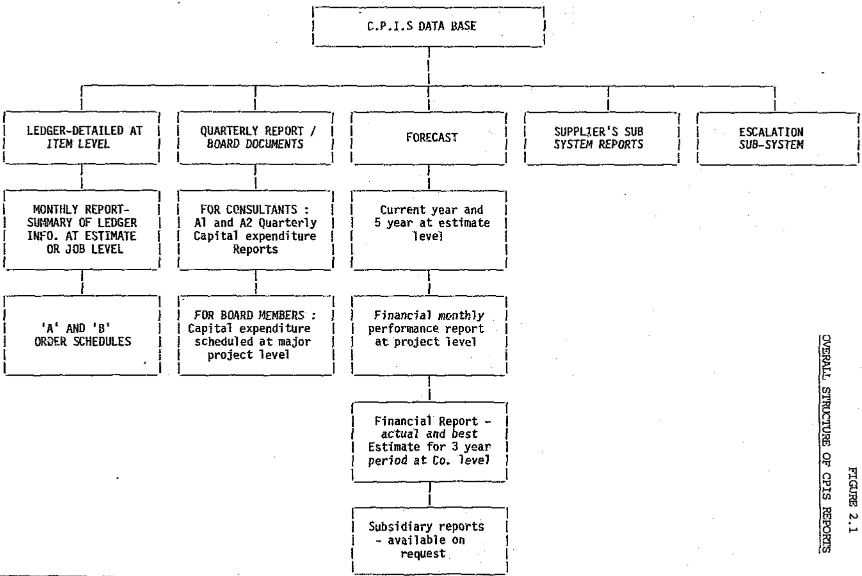


FIGURE 2.2

CAPITAL STATUS REPORTS : LEDGER

C.P.I.S DATA BASE

LEDGER-DETAILED AT ITEM LEVEL

Description of project, phase estimate, job and item. Forecast start/finish dates for cash flow

Contracts placed including work commenced on mine charges

Variances between authorised and final estimated cost

Estimated balance of expenditure to completion

Items still to be committed

Total expenditure to date

Expenditure in current month / year

Summary at estimate level of expenditure analysis, overall performance, mine charges

Claimed and reversed escalation, changes in scope

C.P.I.S DATA BASE

NOTE: THESE REPORTS CAN ALSO BE REQUESTED BY RESPONSIBILITY

Position of open capital projects report report Monthly:- Summary of ledger information at job level	Position of open capital project report - Mc thly report:- Summary of ledger information at job level, including break down of variances at estimate levele	Position of open capital projects - Monthly report:- Summary of ledger information at estimate level.
Description of project, phase estimate, job	Description of project, phase estimate job	Description of project, phase, estimate
Trend - Variances between authorised and final cost estimated	Trend - Variances between authorised and final cost estimate	Trend - Variances between authorised and final cost estimated
Commitment to date :- Contracts placed plus mine charges	Commitment to date :- Contracts placed plus mine charges	Commitment to date :- Contracts placed plus mine charges
Expenditure analysis Showing expenditure to date, previous year/current year/current month.	Expenditure analysis Showing expenditure to date, previous year/current year/current month.	Expenditure analysis Showing expenditure to date, previous year/current year/current month.
Estimated balance of expenditure to completion.	Estimated balance of expenditure to completion.	Estimated balance of expenditure to completion.
Overall performance and mine charges	Overall performance and mind charges	Overall performance and mine charges
	Variances between authorised and final cost estimated due to :- change of scope contingency claimed and reversed escalation	
	Forecast :- Year to date forecast, Original and revised Current year forecast Original and revised	

FIGURE 2.3

CAPITAL STATUS REPORTS :

MONTHLY SUMMARIES

FIGURE 2.4

CAPITAL STATUS REPORTS : A & B SCHEDULES

C.P.I.S DATA BASE

'A' AND 'B' ORDER SCHEDULES
SCHEDULES

Code number sequence report
'A' showing contracts placed
per estimate

Order number sequence report
'B' showing total contracts
placed in order sequence

Description of project, phase,
estimte, job, order number
due date

Description and value of
contract, amount raised to
date, outstanding commitment

These reports are also
available by discipline i.e.
civils, architecturals etc.

FIGURE 2.5

QUARTERLY REPORT : BOARD DOCUMENTS

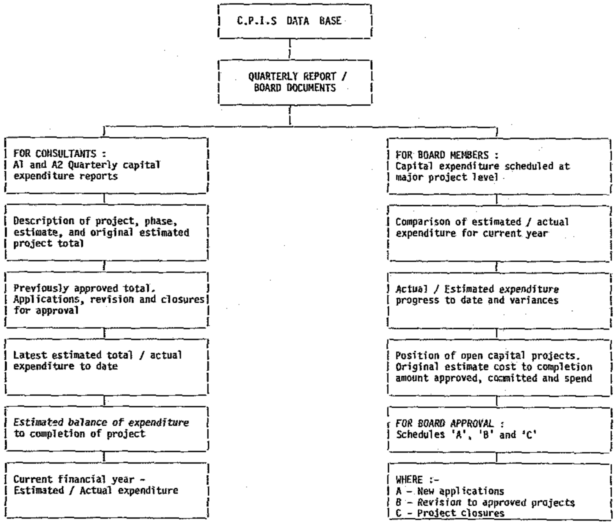


FIGURE 2.6

FORECAST

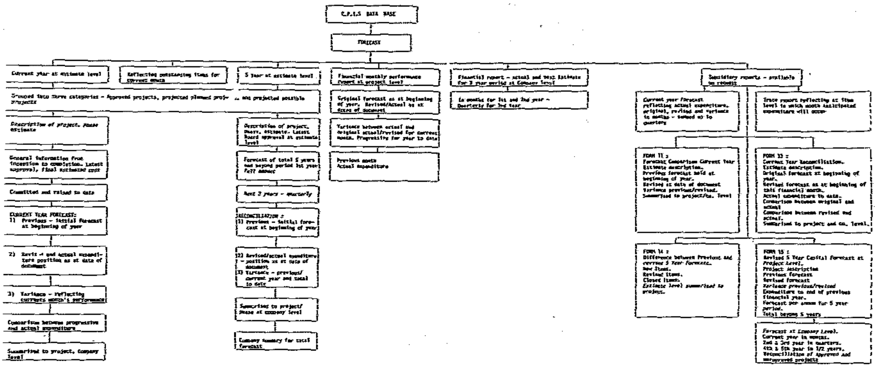
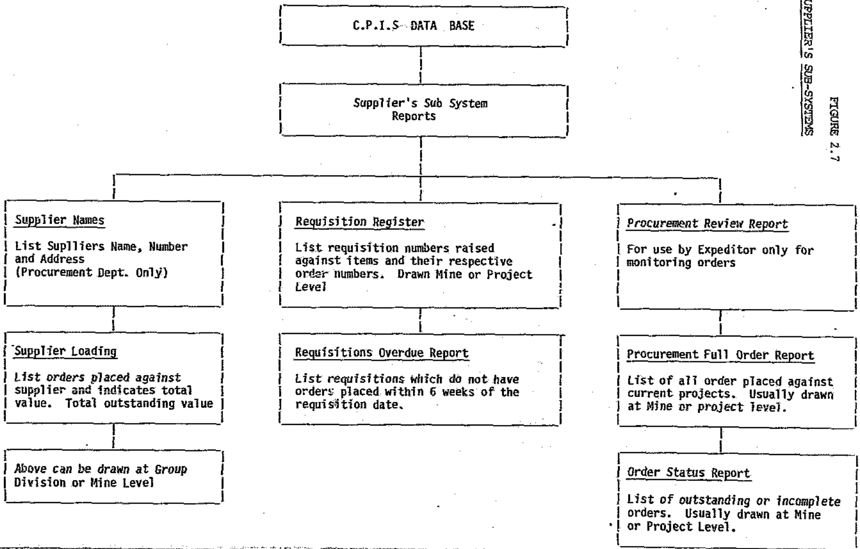


FIGURE 2.7

SUPPLIER'S SUB-SYSTEMS



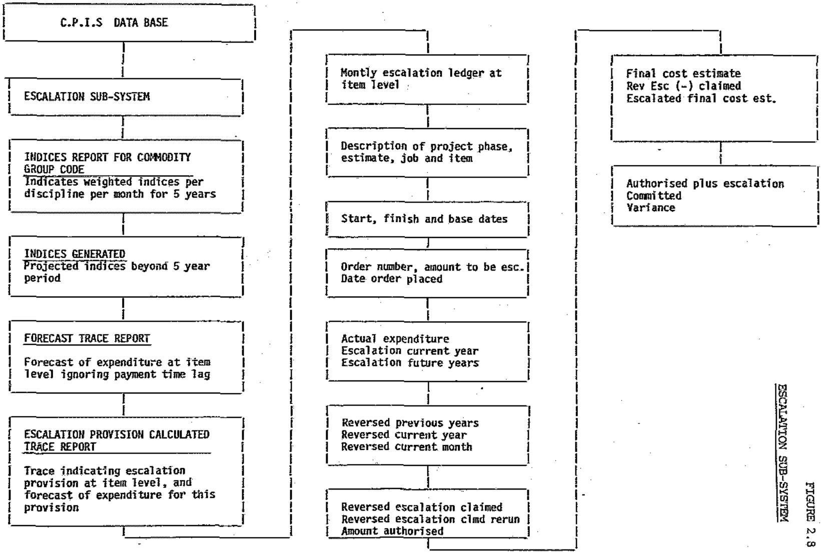


FIGURE 2.8

ESCALATION SUB-SYSTEM

HAND-DRAWN S-CURVE FIGURE 2.9

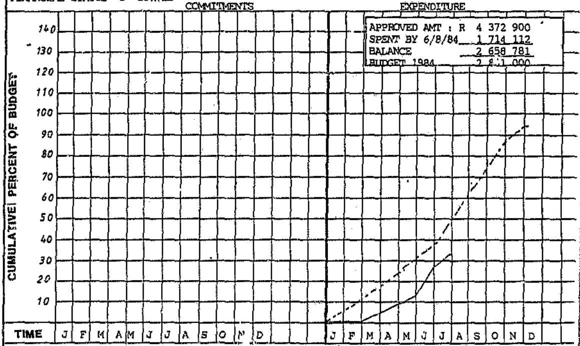
VAAL REEFS EXPLORATION AND MINING COMPANY	NUMBER 9 SHAFT SYSTEM	ESTIMATE NUMBER 024/7/8211
Description 8 SHAFT 10'C' AREA EQUIPMENT (1984)	MONTHLY STATUS REPORT	Revision Date 9-8-84

FACTOR	APPROVED	LATEST FORECAST	VARIANCE +=Unfavourable	REPORT TO	DATE	MANNER
Budget	4372900	4370138	- 2761			
Start Date						
Start Commissioning						
Hand Over						

PROGRESS SCHEDULE:

ITEM NO	DESCRIPTION		APPROVED	SPENT	SPENT	PERCENT COMPLETE (PHYSICAL) 10	20	30	40	50	60	70	80	90	100
1210	Load & excav. equip	11.3	494935	523401	105										
1510	Pumps	6.8	298919	15176	5										
2030	Locos & Roll. stock	11.6	506599	250137	49										
5000	Elect. Syst.	12.3	540150	163366	30										
6100	Piping	17.6	769164	282994	37										
		40.4	1763133	479045	27										

FINANCIAL STATUS 'S' CURVES



AREAS OF CONCERN AND PLANS OF ACTION:-

PHYSICAL PROGRESS :-	MAJOR OUTSTANDING ITEMS :-

REPORTED BY:- DATE LEGEND

PLANNED ....
ACHIEVED ———
PREDICTED - - - - - -

a) First layer

At the start of the project a master network is prepared showing all technical areas and important milestones throughout the project life cycle. Usually the critical path calculations are done manually and a bar chart is drawn up for presentation to project management.

b) Second layer

This consists of a number of networks each containing a large number of activities. The development of these networks are related to the master network and cover all phases of the project and show all activities at a level which can identify:

i) Completion of general arrangement drawings
ii) Procurement of major items of equipment
iii) Awarding of contracts
iv) Civil, structural, mechanical and electrical engineering
v) Provision and installation of services.

The detailed logic put into this plan is to a level which can be controlled by project management.

(Very limited use is made of the resource planning facility, as practically all manufacturing and construction work is done by contractors, hence placing this responsibility on them.)

<u>*Monitoring*</u>

At set time periods, normally weekly, the planner must monitor the progress of the plan by discussing with the participants, and on-site inspections and must record:

a) Activities completed.

b) Activities in progress to establish the estimated times (at time now) to complete the activity.

c) Activities not started which, due to later information available, may need duration re-estimating.

d) Any logic changes required to keep the plan up to date.

This information must be checked by the planner against the last schedule produced. In the case of straight timing he analyses the monitoring information against the float available of the activities affected. If logic changes are necessary and the activities on the critical path are increased in duration, the planner must then prepare new input data and arrange for an updated computer run in order that the latest position of the project can be reported.

<u>Project Status Report</u>

The planner must present (normally monthly) a project status report. This is prepared from an analysis of the CPM print-out and the network logic in respect of the critical and sub-critical activities, and the position of all activities with start times as at the run date. The report is based on the planner's analysis and the *evaluation of progress* in the various areas of responsibility, and problems encountered. For examble, for design the report will cover the work and drawings that are *required to* meet both enquiry dates and fabrication/construction priorities. Where drawings restrain progress on extended design being carried *out by* other sections or outside consultants, these restraints must be highlighted in the report.

In the case of equipment procurement, reporting is done on expected long deliveries of equipment in order that *enquiries or* orders can be placed before they become critical and to establish the priority delivery of equipment to site.

Where fabrication is concerned, the report will show the priority of shop detailing and *fabrication of steelwork* or equipment supplied by the contractor, including difficulties experienced, if any, on steelwork deliveries and *shortfalls of tonnage output* or delays.

The progress on construction sites will be reported with *particular* reference to contractors' resources, i.e. labour, crainage, concrete batching facilities, etc, where such resources may affect progress.

2.2.2 K and H Programme

The programme was developed in 1962 and was the first programme to be offered with resource scheduling *capabilities*. It was run on an IBM 1620 computer. The programme was designed to enable the user to process data through the computer with a minimum of input instructions; for example, on one input card for each acitivity, the planner can enter the following:-

1) The activity number.

2) Duration.

3) Responsibility codes.

4) Desciption with sort facilities.

5) "TB" (Time Before) which means that an activity carrying this instruction can start at a specified time before the completion of the preceding activity.

6) "TA" (Time After) this means that this activity ends at a specified time after the start of the succeeding activity.

7) Activity cost.

8) Resources.

The complete programme can be run on IBM, ICT, Univac or CDC computers.

A plotter programme is available to plot network logic, either for a total network or selected positions of the network requiring redrawing.

The rights of the programme for Southern Africa have been held by Anglo American since 1968, and it is loaded on their Johannesburg, Welkom, London, Zambia and Zimbabwe computers and it is also run by CSSL on a bureau basis. This gives Anglo a common system of project planning control.

It is also of interest to note that the programme was selected by the following major users of CPM in Southern Africa:-

Roberts Construction
South African Navy
CSIR Defence
Atomic Energy, Pelindaba
Iscor
AE & CI
Shell.

As with other programmes, the user can specify the reports to suit his particular requirements. Anglo have twenty-eight at present whi.h meet the needs of the various types of projects with which they deal.

2.2.3 Network Structure

The system is designed to process "i, j" or activity on arrow networks as opposed to "precedence" or activity on mode networks.

Event numbers are five digit numeric ranging from 0 - 99999 and the network can be numbered randomly or sequentially.

The main points regarding the network construction are:

a) All activities which can start, are started: unlimited resources are assumed.

b) Each activity must have a number at the head and tail.

60 ———————— 70

c) No two activities in a network can have the same numbers.

d) Dummy activities can be used to preserve logic.

2.2.4 Time Analysis

Critical Path Planning would be done after the network is constructed. The main points of this technique are:

1) Add durations of activities.

2) Calculate earliest event times forward through the diagram, from the first event using the greatest (latest) of the c...ice of times.

3) Calculate latest event times backward through the diagram from the last event(s), using the smallest (earliest) of the choice of times.

4) Calculate earliest activity dates.

5) Calculate latest activity dates.

6) Calculate total float.

(= spare time when preceeding jobs finish as early as possible and following jobs start as late as possible).

7) Calculate free float.

(= spare time when all jobs in chain start as early as possible).

8) Identify the critical activities.

These have :-

a) zero total float
b) earliest and latest event times at head and tail identical
c) difference between head and tail figures equal to duration.

9) The chain (or parallel chains) of critical activities from the beginning to the end of the diagram is the CRITICAL PATH.

2.2.5 Resource Analyses

Most capital projects are time limited and hence the resource availabilities specified must be able to be exceeded in order to meet the target end date, i.e. the programme identifies these as "exceedable resources".
Resources can also be "non-exceedable" e.g. overhead crainage.
Variable level resources can also be specified.

2.2.6 Reports Available

Both listings and bar charts are produced from the same programme. Any combination of the following parameters can be printed against each activity:

Duration
Description and Codes
Transit Times
Earliest and late start and finish
Total, free and independant float
Event numbers, targets and slacks
Schedule start and finish
Remaining Float
Remaining Free Float
Schedule and total delay
Resources
Resource cost
Material cost
Total activity cost
Cumulative cost
All the results can be calendar dated time units or both.

Bar lines can be of any characters required (e.g.)

E	showing the earliest start
...	between the earliest and schedule start
xxx	for the activity duration
ccc	for the activity duration if critical
——	between the schedule and latest finish
L	showing the late finish

Tables, histograms and curves can also be printed of any of the following result types:

Resource or cost aggregation
Resource availabilities
Resource remaining (availability - aggregation)
Cumulative costs for resources, materials, or total.

3. PROBLEMS AND REQUIREMENTS RELATED TO AN INTEGRATED TIME AND COST CONTROL SYSTEM.

3.1 PROBLEMS IN NETWORK BASED COST CONTROL

Although the concept of cost control based on the project network is not difficult, the design and implementation of a practical cost control system is not easily accomplished. The fundamental problems facing us as systems designers could be classified as follows:-

(1) those related to organisational conflicts, and
(2) those related to the necessary efficiency of the system.

The basic organisational problem is the conflict between the project approach of network cost control and the fundamental approach of cost accounting procedures used in the working cost situation on the mine. This fundamental approach has also up until now been used to "control" all capital expenditure and indeed is still used for all projects at Vaal Reefs other than the two new shaft projects ie, Moab and Goedgenoeg. The conflict was manifest particularly in the design of the input and output phases of the network control systems. The input to the system required the development of an activity accounting procedure by which actual expenditure data must be coded to provide an association with activities (or groups of activities) in the project network. The output from the system likewise must also be project-orientated to provide project summary reports, organised by time periods, areas of responsibility, and technical subdivisions of the project.

The efficiency of the system was a problem because a network-orientated system lends itself to major increases in the amount of detail available to management. One of the major objectives when designing the system was to achieve the level of detail required by Project Management for control purposes. Project personnel would find routine input data very burdensome unless special attention is paid to reducing requirements and simplifying procedures. Similar dangers lie in the data processing and output phases of the system which can become very costly in an interactive system. The use of precedence diagramming, which can reduce the number of network activities by 50 percent or more, offers some promise here.

3.1.1 ACTIVITY ACCOUNTING.

Basic CPM/PERT systems gained acceptance rapidly because the critical path concept filled a generally recognised need for improved formal procedures for project planning and scheduling. In the cost control area however, formal accounting procedures were established long before the introduction of CPM/PERT. Thus one of the greatest obstacles to the use of network-based cost control has been the difficulty of developing a network-based system compatible with the established accounting system (CPIS).

Accounting systems (such as CPIS) have been designed to plan budgets and report expenditures both by organisational unit and by project. The emphasis is on nit's account, in as much as the objectives of the accounting system are summaries of expenditures by the functional elements of the organisation. The purpose of the network approach on the other hand, is to provide more detailed information and control <u>within</u> the project.

Cost data, like time data, must be applied to project activities. The budgeting and recording of expenses both by cost item and by network activity clearly requires a more elaborate system. Not only are there more codes and figures to deal with, but there are many typical questions developed in the application of cost data to a project network.

For example :-

1. Cranes are purchased for use in several activities in the project. Should their costs be assigned entirely to the purchasing activity, when the expenditure actually occurs, or should it be allocated over the activities involving their use?

2. What code, if any, should be assigned to the curing of concrete? Approval of drawings? Negotiation of a sub-contract?

3. Should overheads be included or only direct costs? If overheads are included are they computed the same way for all activities?

4. How should the costs of project management be shown? as activities or overheads?

These questions arise because basic time-orientated networks and the project estimates represent two different sets of data. Although these sets largely overlap, many elements of the project which involve costs have not been shown in the network. This is particularly true of management and overhead costs. Certain other activities involve no direct costs but consume time and perhaps should account for a portion of the indirect costs. The various answers to these questions which have been worked out will be dealt with later after a review of the history of network-based cost control and an understanding of the concepts of work breakdown structure (WBS) and work packages is given in Section 3.3.

3.2 *SYSTEM REQUIREMENTS*

The following requirements were formulated at a two-day workshop held at Vaal Reefs for that purpose. A multi-disciplined team was formed to assist in the preparation of these requirements.

One very obvious point emerged early at the workshop, namely, having established the drawbacks of the existing systems this did not assist much in reaching an agreement on the requirements of a new control system.

Eventually the following "compromised" requirements were agreed on and given to the Project Team as a blueprint, to assist the choice of the new control system, and to form the ground rules of the new system.

The following requirements were summarised by Povall [1] :

3.2.1 Top Management Reporting

3.2.1.1 Original and Current Estimated Costs

The original cost of all reporting levels (job, estimate, project) must be "held" and readily comparible with the current estimated cost at all times. For rapid identification this can be displayed in 'S' curve format, and be also available in tabulation form.

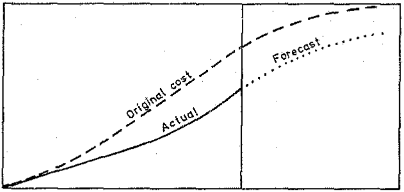


FIGURE 3.1

Comparison of original and current estimated costs.

3.2.1.2 Progress on Expenditure versus Planned

Planned expenditure must be derived by costing of the planned activities, over any given time, and be available at job, estimate and project levels.

The actual expenditure must be drawn cumulatively from the CPIS files, and such comparisons can be displayed in 'S' curve format and/or tabulated.

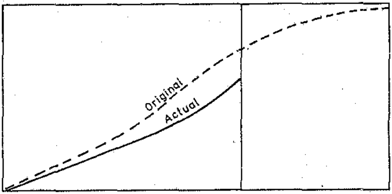


FIGURE 3.2

Progress on expenditure versus planned

3.2.1.3 Physical Milestone Reporting

Planned physical progress must be derived from the CPM network over any given time, and be available at job, estimate and project levels.

The actual physical *progress must* be derived from an on-site assessment of the various activities, which in a *cumulative from*, such comparison can be displayed in 'S' curve format.

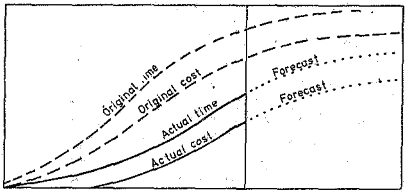


FIGURE 3.3

Physical milestone reporting (cost and time)

3.2.1.4 Scope Change Reporting

This is not really a function of the system, but an accurate history must be maintained, subject to submission and approval of the required forms. Such information must be retained within the CPIS ledger for identification, and the reasons therefore obtained from the scope change file.

3.2.2 Project Management and Control

3.2.2.1 Planned Cash Flow and Actual to Date

Planned cash flow must be derived by a costing of the planned activities, over any given time, and be available at job, estimate and project levels.

The actual expenditure to date must be drawn cumulatively from the CPIS files, and such comparisons can be displayed in 'S' curve format and/or tabulated.

The original cash flow projected must be "held" for comparison with actual, and also a projection made to completion, based on latest plan and final cost estimate of activities.

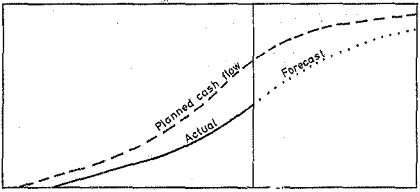


FIGURE 3.4

Planned cash flow and actual to date

3.2.2.2 *Progress against Schedule and Cost at completion and to Date*

Both the original planned physical progress and cost projections must be "held" against which progress to date can be measured, and also compared against the projected at completion in both cases.

This can be displayed in 'S' curve format and/or tabulated.

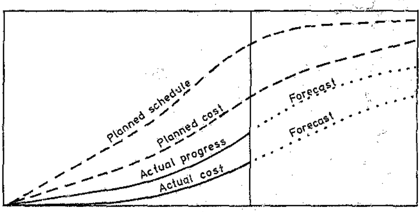


FIGURE 3.5

Progress against schedule and cost at completion and to date

3.2.2.3 Design List with Dates

This must be available from the CPM network within the system to provide a shopping list indicating at which time design should commence and be complete.

3.2.2.4 Procurement List

This must be available from the CPM network within the system to provide a shopping list indicating:-

- the dates by which tender enquiry must be effected and returned.

- the dates by which time orders should have been placed.

- the dates by which time delivery should be effected.

3.2.2.5 Progress on Deliveries

This is presently available as a sub system to CPIS.
Such reports can be drawn to indicate:-

- supplier loading, and the amount currently outstanding on orders placed with individual suppliers. Two totals give the total amount of orders placed with the supplier, and the net total amount currently outstanding.

- the status of orders placed with a supplier but not yet delivered, for which each outstanding order is reported separately.

- procurement full order report reflecting all orders placed with suppliers.

- procurements review report reflecting the orders that are to be reviewed to ensure that the supplier is not falling behind in scheduled dates for delivery or supply. The length of the review period can be varied from a default of six (6) weeks, and for which each order under review is reported separately.

- requisition register report reflecting all items which contain a requisition number, and report all requisitions which have been submitted, but for which no orders have been placed, based on a time lag greater than six (6) weeks.

3.2.2.6 Expediting Payments on Delivery Items

A procurement status report must be available and allow the actual date of delivery to be flagged if no payment is indicated against the item after a default of six (6) weeks.

3.2.2.7 Commitments and Payments

This is presently available in CPIS at item, job estimate and project levels. It is also available on orders only via the 'A' and 'B' schedules.

Commitments and corresponding payments must also be drawn from the CPIS files cumulatively, and such comparisons must be displayed in 'S' curve format and/or tabulated.

3.2.2.8 Escalation at Estimate Level

This exists within the CPIS escalation programme, but must be made available at estimate level. Management Services advise that CPIS escalation will form Phase 2 of development.

3.2.2.9 Integration of Contractor's Plan into Master Plan.

This must be available via the CPM network within the new system, allowing such contractors programmes to be incorporated.

3.2.2.10 Resource Scheduling

The system must have full ability in resource scheduling, and be capable of:-

- indicating the effects on the overall projects should a critical activity be extended or reduced.

- reporting how long each activity can be delayed without delaying the entire project, in the event that the project be required to be completed by a specific date.

- portraying what resource levels are needed to complete the project on time, and the cost of the resources required. It must also highlight any extension in project time should the resources availability be limited, and also which resources are responsible and where the delay occurs, should the project be delayed as a result of resource shortages.

- indicating the consequences should the duration of any activities change from their original estimate, or if the jobs could be done in a different order with regard to resources.

- indicating the percentage completion of any given activity and the amount of time remaining.

- indicating the overall consequences to the job, estimate or project with regard to resources.

Full graphic display must be available.

3.2.2.11 Exception Reporting

The system must have full ability in this area and allow exception reports to be designed in any required format.

3.2.2.12 Integration with CPIS

The system must be totally compatible with CPIS and capable of drawing information from CPIS.

3.2.2.13 Project Reimbursable Reporting

The engineering costs are required to be estimated under estimates 9982 (AAC reimbursables), 9983 (mine and regional project management costs) and 9984 (external project management costs). As such the same principle as previously applied is applicable, i.e. progress on expenditure vs. planned, progress against schedule and cost at completion and to date, etc., must be displayed in 'S' curve format and/or tabulated.

3.2.3 Financial Requirements

3.2.3.1 Controls

Audit Trails:	Full audit trails are available within CPIS: these must flow into AS.
Edit Listing:	Full edit listing must be available with all updates.
Transaction counts:	These must indicate total transactions effected and the number accepted and/or rejected.
Error suspense facility:	The system must not accept errors and must require re-submission.

3.2.3.2 Procedures

Errors rejection routines:	The system must have full rejection routine.
Recovery routines:	The system must maintain historical files.
Security routines:	The system must be fully secured.
Training material and support:	This must be available within Infogold.

3.2.3.3 Integration with Famis

The system must be compatible with the following existing systems in operation at Vaal Reefs.

White Payroll
Black Payroll
Matcon
Huris

3.3 HISTORICAL DEVELOPMENT OF TIME AND COST CONTROL SYSTEMS

The idea of collecting costs on the basis of network diagram activities was recognised very early as a potential means of improving project cost control. A few manual and computer programmes were developed by individual CPM and PERT users in the early 1960's. In 1962, a major boost to the interest in network-based cost control was provided by agencies of the U.S. Government. The Department of Defense and the National Aeronautics and Space Administration jointly issued a manual entitled DOD and NASA Guide, PERT/Cost Systems Design [2], which emphasized the cost control aspects of "PERT-type systems." Several companies and agencies in the aerospace field had already been working with various PERT cost procedures and computer programs, but the DOD and NASA Guide served to formalize the interest of the government and thus to inititate active development of the procedures throughout the aerospace industry. By mid-1963, the use of PERT/cost procedures had become a requirement in certain military research and development projects.

One of the key features of PERT/Cost is the utilization of a "Work Breakdown Structure" (WBS) to show the hierachy, or levels, of tasks within a project, and the definition of "work packages" at the lower or basic level of work. The DOD-NASA Guide described these concepts as follows:

"End Item Subdivisions: The development of the work breakdown structure begins at the highest level of the programme with the identification of project end items (hardware, services, equipment, or facilities). The major end items are then divided into their component parts (e.g., systems, subsystems, components), and the component parts are further divided and subdivided into more detailed units. The subdivision of the work breakdown continues to successively lower levels, reducing the dollar value and complexity of the units at each level, until it reaches the level where the end item subdivisions finally become manageable units for planning and control purposes. The end item subdivisions appearing at this level in the work breakdown structure are then divided into major work packages (e.g., engineering, manufacturing, testing)."

The DOD-NASA Guide suggested that the basic work packages might be formed by the same individual activities, or groups of activities, used in the PERT/CPM network.

The specification of network activities as the basic cost control unit was widely misinterpreted as meaning that individual network activities should always comprise work packages. This created numerous problems with respect to the acceptance of PERT/Cost. There was belated recognition of the fact that it was often impractical for contractors to budget and report costs by PERT/CPM network activities. As J R Fox(3), a member of the original PERT/Cost development team, notes:

"... the design group intended to make clear that the work breakdown structure, not the network, was the basis for cost planning and control. In retrospect this was far from clear. Confusion arose because many defense contractors as well as other government agencies were developing their own versions of PERT/Cost. Several of these versions called for the use of PERT networks in the budgeting and reporting of costs by network activities, a requirement that resulted in the collection of vast amounts of very detailed cost information.

By 1964 more than ten variations of PERT/Cost existed throughout DOD and NASA, most of which called for costing of PERT network activities and the submission of detailed cost information on a monthly basis. Contractors recognised the impracticality of these systems and created their own PERT/Cost groups to prepare reports for DOD. These groups operated separately from management teams responsible for the actual planning, scheduling, budgeting and measurement of program performance.

Government auditors decided that PERT/Cost groups were a legitimate overhead expense that could be charged to the government. Many contractors considered PERT/Cost as the basis for negotiating higher overhead rates. ..."

Because of the confusion and resistance of PERT/Cost throughout the defense industry, the Air Force, in 1964, developed simplified standards by which a contractor's internal cost management system could be measured before the company could qualify for defense work. These specifications contained some essential elements of the original PERT/Cost system, including the WBS concept, but did not include detailed reporting of cost information from PERT/CPM network activities.

The simplified criteria developed by the Air Force in 1964 were subsequently developed into an improved set of criteria. These criteria retained the advantages of some of the essential elements of PERT/Cost, and yet also reflected current industry practice. As Fox (3) notes:

> "It became clear from the PERT/cost pilot test that cost planning and control could be based on a system that was used on most large commercial development and production programs. This cost information could be based on a WBS that subdivided the program or project according to the manner in which work responsibility was assigned. Project work was traced down through several levels of work definition to the point where short-term work packages could be identified as the basis for planning and controlling manpower.
>
> Budgets were then established for each short-term work package. Costs were estimated at every level of the WBS, to arrive at a total cost estimate for the program or project.

As a contractor began a development program, actual man-hours and costs were assigned to the work packages. As work was completed the contractors could compare estimates of cost for short-term work packages with the actual man-hours and cost required to accomplish the work. Thus the contractor would keep a constant check on whether work was costing more or less than was estimated."

In line with Fox's observation, the subsequent DOD Guide (4) continued the WBS philosophy of the earlier DOD-NASA Guide, and commented on work packages as follows:

A work package is simply a lower level task or job assignment. "Work package" is the term used to identify discrete tasks which have definable end results. A work package has the following characteristics:

1. It represents the units of work at levels where work is performed.

2. It is clearly distinguished from all other work packages.

3. It is assignable to a single organisational element.

4. It has scheduled start and complete dates.

5. It has a budget of assigned value expressed in terms of rands, man-hours or other measurable units.

6. Its duration is limited to a relatively short span of time, or it is subdivided by discrete value milestones to facilitate the objective measurement of work performed.

7. It is integrated with detailed engineering, manufacturing or other schedules.

In an attempt to increase the flexibility of its cost accounting requirements the Guide included new provisions for establishment of "cost accounts" and clarified the establishment of organizational responsbilities for elements of the WBS. As the Guide [4] states:

"The lowest level at which functional responsibility for individual WBS elements exists, actual costs are accumulated and performance measurement is conducted, is referred to as the cost account level. While it is usually located immediately above the work package level, cost accounts may be located at higher level when is consonance with the contractor's method of management.

In addition to its function as a focal point for collecting costs, the cost account in a performance measurement system is also the lowest level in the structure at which comparisons of actual direct costs to budgeted costs are required, although some contractors also collect costs and make comparisons at the work package level.

While the WBS defines and organizes the work to be performed, the contractor's organizational structure reflects the way the contractor has organized the people who will accomplish the work. To assign work responsibility to appropriate organizational elements, the WBS and organizational structure must be interrelated with each other. This interrelationship may be visualized as a matrix with the functional organisation element listed on one axis and the applicable WBS elements listed on the other. Further subdivision of the effort into work packages may be accomplished by assigning work to operating units.

The WBS concept with its associated flexibility in provisions for establishing work packages and cost accounts, represent a practical compromise in the concept of activity accounting for business organizations, particularly in the aerospace industry. The approach should be applicable in many industries where network-based cost control is desired.

In the construction industry, for example, the lowest level work packages may be identical or nearly identical to the bid items in the project. In some cases the work package would be represented on the network by a single activity; in most cases it would be comprised of a group of activities within a division of the project, such as the concrete work for the first floor of a building. The specific work organisation and cost accounts established would naturally vary with the type of project, areas of responsibility of the foreman and superintendents, the capabilities of the cost accounting system, and other factors related to the particular company and its projects."

4. SELECTION OF THE SYSTEM

4.1 INTRODUCTION

An investigation, collated by Bester, [5] was done into available computerised project management systems, with the objective of recommending the best system for use on the Moab and Goedgenoeg projects. Three systems were investigated, viz. GC/CUE, AS and CIPREC.

GC/CUE and CIPREC were assessed by analysis of the system functions, demonstrations and experience of previous users, whereas AS was tested on the Vaal Reefs West Division Slimes Dam project. The main reason for doing this was to test interfacing with the CPIS Financial Control system.

A fourth system ARTEMIS was also examined but only on an informal basis after the selection of the AS system.

GC/CUE is the system which has been chosen by Anglo American Head Office Project Services personnel. It is currently being tried on several projects with very limited success.

Again a multi-disciplined team was formed to conduct this investigation which took approximately six weeks from inception of the team to acceptance of the final recommendation.

4.2 FINDINGS

4.2.1 Introduction

All three systems address the project planning and control functions comprehensively. GC/CUE and CIPREC are very similar in what they offer. AS is somewhat less sophisticated, mainly in the resource scheduling area, but meets all the foreseen requirements.
None of the three systems have a financial module which is acceptable to the auditors and will therefore have to be used in conjunction with CPIS. The possibility exists that CIPREC could be enhanced to address this problem and thus replace CPIS in the longer term. A far more detailed investigation will however be required to confirm this.
The interface between CPIS and AS has been developed for extracting data from CPIS.

4.2.2 Equipment

AS and CIPREC run on IBM equipment and would use the data communications network currently in operation. GC/CUE runs on Prime or Hewlitt Packard equipment and would require a separate network.

4.2.3 Interfaces

Interfaces between existing Infogold systems and either AS or CIPREC would be relatively easy. As mentioned the CPIS/AS interface has already been developed. A similar interface with GC/CUE would be very difficult and costly.

4.2.4 Acquisition Costs

4.2.4.1 AS/CPIS

Most of the work required to install AS has been done at Vaal Reefs and only terminals at the access points are required. AS is an installed system and there is no money payable to the vendor.

4.2.4.2 CIPREC

CIPREC would require the same ter[illegible] as AS. The purchase price of the system [illegible] 000 with a monthly maintenance charge [illegible] R3 000. In addition, the installation of the system will cost ± R25 000.

4.2.4.3 GC/CUE

GC/CUE would require PRIME terminals and a communication network to Johannesburg. Any communication with Infogold Welkom [illegible]mputers will require additional networks a[illegible] interfaces. Further investigation will be required to assess costs for this area.

4.2.5. Operating Costs

Operating costs are likely to be similar for all these systems. Testing of the AS system did not indicate any significantly high costs.

4.3 COMPARISONS OF THE SYSTEMS

4.3.1 Advantages

4.3.1.1 GC/CUE

a) *It is a sophisticated project management tool.*
b) The software is already installed and paid for by Anglo American.

4.3.1.2 CIPREC

a) It is a sophisticated project management tool.
b) The possibility of enhancing its financial module to replace CPIS exists.
c) It uses standard IBM equipment.
d) It uses current network.
e) Interfaces with other systems will not present a problem.

4.3.1.3 AS

a) It is a good project management tool, although less sophisticated than GC/CUE and CIPREC.
b) It runs on standard IBM equipment.
c) It uses current network.
d) It has been thoroughly tested at Vaal Reefs.
e) Interfaces with other systems will not present a problem. CPIS interfaces have already been developed.
f) Software has been installed and paid for.

4.3.2 *Disadvantages*

4.3.2.1 GC/CUE

a) Its financial module is *unacceptable to the* Vaal Reefs internal auditors.

b) Non standard equipment will create network and interface problems.

c) Communication with IBM equipment is problematic.

d) Depending on configuration and siting, very high equipment costs could be involved.

e) It requires a separate network.

f) Infogold may be required to duplicate existing functions to look after Prime equipment.

4.3.2.2 CIPREC

a) Its financial module is not acceptable to the Vaal Reefs internal auditors.

b) It has not been tested by AAC.

c) Software has to be bought at a one-time cost *of R112 000 plus R3 000 per month maintenance.*

d) Its installation cost would be R25 000.

e) Development of interfaces with CPIS will cost between R60 000 and R120 000.

4.3.2.3 AS

a) No financial module.

4.4 REQUIREMENTS AND MAJOR OPERATING CRITERIA OF THE SYSTEMS

4.4.1 Requirements

	GC/CUE	CPIS/AS	CIPREC
1. Communication with CPIS and the integration and interaction with sub systems (viz. stores and suppliers).	NO	YES	YES
2. Ability to produce corporate reports (Board Documents).	NO	YES	NO
3. Financial integrity and ability to conform to conventional company audit trail controls in respect of capital ledgers.	NO	YES	NO
4. Retention of one system in lieu of dual systems operating in parallel, and the probability of additional staffing arising from this. (Duplicated data capture requirements).	NO/YES	YES/NO	YES/NO
5. Maintaining current expertise of all present system users.	NO	YES	NO
6. Immediate back-up support available in-house.	NO	YES	NO
7. Maintain investment in current hardware and system users.	NO	YES	YES

4.4 REQUIREMENTS AND MAJOR OPERATING CRITERIA OF THE SYSTEMS

4.4.1 Requirements

	GC/CUE	CPIS/AS	CIPREC
1. Communication with CPIS and the integration and interaction with sub systems (viz. stores and suppliers).	NO	YES	YES
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3. Financial integrity and ability to conform to conventional company audit trail controls in respect of capital ledgers.	NO	YES	NO
4. *Retention of one system* in lieu of dual systems operating in parallel, and the probability of additional staffing arising from this. (Duplicated data capture requirements).	NO/YES	YES/NO	YES/NO
5. Maintaining current expertise of all present system users.	NO	YES	NO
6. Immediate back-up support available in-house.	NO	YES	NO
7. Maintain investment in current hardware and *system users*.	NO	YES	YES

	GC/CUE	CPIS/AS	CIPREC
8. Adequate resources available to operate system.	NO	NO	NO
9. Full and comprehensive training required.	TOTAL	PART	TOTAL

4.4.2 Major Operating Criteria

	GC/CUE	CPIS/AS	CIPREC
1. To operate as a dynamic, professional and interactive project management control system.	YES	YES	YES
2. To determine the effect on the overall project if a critical activity (that is an activity within the critical path with no float) is extended, or reduced, for any length of time.	YES	YES	YES
3. To indicate how long each activity can be delayed, without affecting the entire project, should the project be required to be completed by a specific date (plug date).	YES	YES	YES
4. To determine how long the project will take to complete and when can each individual activity be expected to start and finish.	YES	YES	YES

	GC/CUE	CPIS/AS	CIPREC
5. To indicate resource levels needed to complete the project on time and the resultant cost of resources *actually used.* To determine how long the project will be extended if the resource availability is limited - and in the event of the project being delayed as a result of resource shortages, indicate which resources are responsible and where the delay occurs.	YES	YES	YES
6. To determine the effect should the duration of any activity from its original estimate, or if the jobs were done in a *different* order, and the resource consequences.		YES	YES
7. Based on prevailing cost and time levels of information produce a trend analysis to establish a realistic projection to completion, in 'S' curve format, at a given level and period of time indicate :- - planned physical progress including actual to date and projection to completion. - planned cash flow including to date and projection to completion.	YES Duplicate Data Capture	YES	YES Duplicate Data Capture

	GC/CUE	CPIS/AS	CIPREC
- actual commitment to date. - variance from target, if any.			
8. To indicate percentage completion of any given activity, and report at any given level, including balance of time available.	YES	YES	YES
9. Complete flexibility within integrated system, and no incumbency on a "one-on-one" type of relationship. Multiple network activities may be accommodated by one cost item, or multiple cost items may be accommodated by one network activity.	YES	YES	YES
10. Stand alone project management system.	YES Financial Module not Acceptable	YES	YES Financial Module not Acceptable
* AS has the capability of drawing data from CPIS and of meeting all requirements - but does not drive it. It is entirely feasible to develop facilities for updating from AS to CPIS, subject to maintaining financial data integrity, and for which a micro will be available in September 1986.			

	GC/CUE	CPIS/AS	CIPREC
11. Recording of escalation.	YES	YES	YES
12. To provide suppliers loading, procurements status and review, requisition register and overdue reports including follow up schedules.			

4.5 RECOMMENDATIONS AND SELECTION

Considering the findings of the investigation discussed above, the project team recommended that Vaal Reefs use the AS/CPIS system for the Moab and Goedgenoeg projects.

4.5.1 Although GC/CUE is a very sophisticated project management tool, it is not recommended because of its incompatibility with the Gold Division computer system architecture. To develop interfaces with the existing systems will be complicated and costly. To use it as a total stand alone system will require duplication of all financial data capture.

4.5.2 CIPREC is equivalent to GC/CUE from a sophistication point of view and is compatible with the Gold Division system architecture. However, I question whether the degree of sophistication is required.

The recommendation is that Vaal Reefs regard CIPREC as a possible long term potential system should we want to go more sophisticated in project management and replace CPIS with the CIPREC financial module.

IBM have assured us that it will be very easy to convert a project which is running on AS to run on CIPREC.

4.5.3 At a presentation given to the Vaal Reefs Executive Committee regarding the findings and recommendations the decision to introduce AS to the Moab and Goedgenoeg projects was made.

5. IBM AS PROJECT CONTROL SYSTEM

5.1 AS OVERVIEW

Application System (AS) [6] is an information processing system which is currently available on a number of host systems as services from IBM Data Centre Services. It is an integrated set of facilities, providing an information processing system that couples access to data with user requests.

It provides the following facilities :-

- Data management
- Information retrieval
- Formal reporting
- Text processing
- Project control
- Statistics
- Business planning
- Business graphics

It provides facilities for the collection and retrieval of information and offers a range of presentation methods including formal reports, tabulations and graphical displays. AS also incorporates techniques for complex analysis, business planning and various management science applications.

Its operation is controlled by English-like commands. Most commands can be built up by answering questions posed by AS, consequently few rules need to be remembered.

Visual display units (VDUs) are linked to a mainframe (in our case a IBM - situated in Welkom at Infogold).

As AS is an interactive system instructions are processed and the results transmitted back to the same terminal.

The objective of all AS processes is to provide information. It follows therefore that it is essential to establish the requirements for these first.

Access to AS is controlled by various identification codes and passwords. There are a number of connections to be observed when entering commands and data, but error reporting and correction facilities are available.

Data Management : These facilities fall into 3 categories :-

(a) The housekeeping aspects such as defining files, entering information and correcting data.

(b) The manipulative functions which permit the creation of new items.

(c) A facility known as the Data Dictionary which enables user-defined formats, column and values to be set for each item of data.

Having a single copy of basic data and sharing with other users keeps information consistent.

Information Retrieval : Often only one or two key information items are required. Retrieval facilities include Browsing, Query, Display, and Analysis which are self-explanatory.

Formal Reporting	:	Reports given to executives must be clear, concise, accurate and timely. AS provides the capability for information retrieval with pre-defined reports, and allows for reports to be designed with the detail and layout needed. Its definition can be stored for future use.
Text Processing	:	AS allows all or selected parts of its basic data to be shared i.e. other users can receive and display the information you want them to see. It can also prepare business correspondence and company reports.
Project Control	:	Will be discussed in section 5.2.
Statistics	:	The system can calculate basic descriptive statistics, such as :- sample size, minimum, maximum, mean, medium, mode, standard deviation, skewness. It can also provide statistical analysis such as :- corrections, regressions, discounted cash flows, variables, etc., and forecasts from historical data :- linear trend, curve fitting etc.
Business Planning	:	Financial and business planning can include budgeting, cash planning, market projections and manpower allocations. Testing changes in forecasts or other assumptions can be done for strategy evaluations. Optimisation exercises can be done.

Business Graphics

AS can produce :-

Line plots
Pie charts
Histograms
Surface charts
Polar (radar) charts
Scatter diagrams

Graphics are often the best way of displaying trends, proportions and consolidations and can highlight out-of-line situations.

5.2 PROJECT CONTROL

5.2.1 Network Analysis

The new shaft projects we shall be dealing with consist of a very large complex of individual jobs. These jobs must be defined i.e. they must have clearly defined start and finish points and a duration of time that they will take to be performed.

A network is a diagram which represents the individual jobs in a project and their relationships to each other. It shows the order in which jobs could be performed assuming there are no restrictions on the use of resources.

There are two ways in which networks are conventionally drawn. One is called an arrow network and the other is called a precedence network.

AS can process both arrow and precedence networks. As Arrow networks were described in some detail in section 2.2 describing to the K and H system, precedence networks (which were in fact chosen as the Vaal Reefs AS network system) are briefly outlined below.

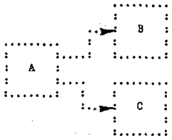
In precedence notation each activity, or work item, is represented by a box. Inside the box is written the work item number, its description, duration and other associated information. The dependencies between different work items are shown by arrows drawn between the boxes, for example:

```
.........           .........
:       :           :       :
:   A   :.........> :   B   :
:       :           :       :
:.......:           :.......:
```

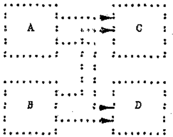
B depends on A

```
.........
:       :
:   A   :....
:       :   :   .........
:.......:   :..>:       :
                :   C   :
.........     ..>:       :
:       :     : :.......:
:   B   :.....:
:       :
:.......:
```

C depends on A and B



B and C depend on A



C and D each depend on A and B

The relationships shown in the above diagrams are called Finish to Start relationships, since they lead from the finish of one work item to the start of the next. They provide the logical constraint that the second work item cannot start until the first one has finished.

Other types of relationship are possible. If work item B is dependent on work item A, it could be constrained in any of the following ways :

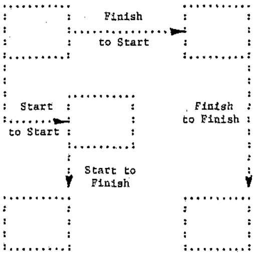
- o B cannot start until A has finished (*Finish to Start*).

- o B cannot start until A has started (Start to Start).

- o B cannot finish until A has finished (Finish to Finish).

- o B cannot finish unitl A has started (Start to Finish).

The *different relationship types are drawn* by starting the arrow at either the beginning or end of the box representing the first work item, and ending the arrow at either the beginning or end of the box representing the dependent work item :



The Finish to Start relationship is by far the most commonly required, but the other types can be useful in certain situations. For example, part of a project may involve laying a long drainage pipe underground. The three tasks of 1) digging the ditch, 2) laying the pipe, and 3) filling the ditch, must obviously be done in that order, but there is no need to wait until the entire length of the ditch is dug before starting to lay the pipe. Similarly, one can begin to re-fill the ditch as soon as the part of the pipe is laid, without waiting until it is all finished.

These three activities would therefore be better linked by Start to Start relationships than by Finish to Start relationships :

```
............
:          :
: Dig Ditch :
:          :
:..........:
:
:
:...........................
          :           :
          :  Lay pipe :
          :           :
          :...........:
          :
          :
          :...........................
                     :           :
                     :Full ditch :
                     :           :
                     :...........:
```

The use of the Start to Start *relationships in the* pipe-laying project prevents the network implying unrealistic delays before the subsequent activities can be *performed, some delay is required, to allow for a* sufficient length of ditch to be dug before any pipe is laid, and to allow for a sufficient length of pipe to be laid before the ditch is re-filled. Without any delay the three groups of workmen could all be crowded around the same small length of ditch, resulting in chaos, not progress.

A time delay, or lag, can be applied to any relationship, of whatever type. The lag represents a minimum amount of time that must elapse before the dependent work item can begin (or end, if it is a Start to Finish or Finish to Finish relationship).

Lags are a convenient way of representing spans of time which would otherwise require to be shown as separate work *items, even though they are not* tasks which have to be worked. Common examples of the use of lags are for such delays as waiting for paint to dry, or the lead time between ordering an item and its delivery.

The process of analysing a network is the same for both arrow and precedence networks. If the logical paths from one activity to the next from the beginning of the project through to the end, are traced, adding up the durations (and lags) as it is done, then the greatest of all the path durations represents the total time the project will take to complete, assuming that every activity is performed as soon as logically possible.

The path (or paths) with the longest duration is known as the critical path. Any activity which lies on the critical path must be carefully monitored, since any delay or increase in the duration of that activity will lengthen the critical path and hence the time taken for the project as a whole.

Activities which lie on the critical path are called critical activities. A somewhat wider definition of critical activities, which includes activities from other paths, is often more useful in practice, since the tendency is for attention to be concentrated on the critical activities to the exclusion of the others.

If the date when the first activity in the project will start is known, then as the paths of the network are traced *adding up the durations*, the starting dates of each activity in the path can be calculated. Since the durations are known, the estimated finish dates can also be calculated.

When all the paths have been traced through the network, dates for every activity will be known. These are known as the early dates since they represent the earliest times at which each activity can be performed. Individually they are referred to as the Early Start and Early Finish dates for the activity.

Activities which do not lie on the critical path could be delayed without necessarily *affecting the total time taken* by the project. The latest time at which they could be performed is found by starting at the end of the project and tracing the paths backwards to their starts, subtracting the durations (and lags), in a similar way to the method used for calculating the early dates. If the finish date at the end of the critical path is the starting point, it can be calculated for each activity the latest date by which it must be completed in order to achieve the overall project finish date. The dates arrived at by processing the network in reverse are called the late dates of the activities, specifically, the Late Finish and the Late Start dates.

The difference between the early dates of an activity and its late dates is known as the Total Float of the activity. The total float represents the amount by which the activity, taken in isolation, could be delayed without affecting the total project duration. Activities on the critical path will not have any float. So far only the analysis of the network in terms of the time constraints imposed by the logical order of the activities within the network has be discussed. This 'time analysis' forms the fundamental basis of the critical path technique, and for many projects provides sufficient information for a controller to manage the project.

However, since time analysis provides both an early start and a late start for each activity the project manager has to decide on an actual start somewhere between these limits. It is likely that his decision will be based on the availability of the resources required by the activity.

Suppose that two activities have the same early start and the same float, but that there are only enough resources available to start one of them. The other will have to be delayed until resources become available. It may be that the second activity will have to wait until the first one has finished. By this time the early start of the second activity will have been passed, and may even have gone beyond its late start (that is, used up all its float), and thus the overall duration of the project will be increased.

The Project Manager is now faced with three choices :

- Let the project be delayed

- Obtain more resources

- Modify the network logic to allow one activity to start sooner

The third choice will probably be unacceptable as the logic of most networks is fixed. The choice between the first two alternatives is usually fairly easy. In many projects the number or resources available is fixed, expecially if the resources are people with specific skills. The only alternative is to delay the project.

In other types of projects it may be all-important to complete by a certain target date. In this case more resources will have to be made available. This is an accepted practice in large new shaft projects as production start-up dates are normally critical to the viability of the project.

Newcomers to the field often find precedence notation easier to understand, since it seems more logical to represent activities as boxes, with arrows connecting them to indicate the logic, rather than representing activities as arrows. Precedence notation also has greater capability when it comes to describing logical relationships which are not of the simple 'finish to start' kind.

AS has the facility to convert a network prepared in arrow notation to precedence format.

The maximum size of network that can be processed is 5000 activities for arrow networks, and 7500 activities for precedence networks. For precedence networks there is also a limit of 7500 relationships; in practice there will be more relationships than activities.

The maximum number of predecessors or successors for any one activity is 255 of each. For arrow networks this means that no more than 255 activities may lead into or out of a single node, and for precedence networks no activity can have more than 255 relationships leading to it or coming from it.

Precedence networks can use any of the four relationship types:

- FS - Finish to Start
- SS - Start to Start
- FF - Finish to Finish
- SF - Start to Finish

Unless specified otherwise, all relationships are assumed to be FS - finish to start.

5.2.2 Time Analysis

In its simplest form, a time analysis of a network will calculate the early and late dates for each activity, using the estimated durations and the logical relationships to determine which activities can be done when.

A starting point is necessary before the analysis can commence : this is normally defined by specifying a date for each of the start activities. The dates for subsequent activities can then be calculated.

It is possible to impose additional date constraints upon certain activities, which should override, or in some way affect the dates which would otherwise be calculated.

The date constraints discussed below are those which are applied to activities in the future. Once the project has started and activities have been completed you will wish to specify when they actually happened. Actual dates, and other methods or recording progress, are described later in this chapter, under Progress Reporting, section 5.2.4

The system provides several different ways in which additional data constraints to particular activities can be applied. These are :

- Earliest start dates
- Latest finish dates
- Mandatory start and finish dates
- Timenow
- Maximum float values

An earliest start date acts as a constraint on the early start date of an activity. It prevents the early start from occurring before the date specified.

A latest finish date constrains the late finish of an activity. It will not be allowed to occur after the date specified.

A mandatory start date or a mandatory finish date for an activity may be specified. They represent two alternative ways of saying the same thing - that the activity must occur at a fixed point in time, regardless of the dates calculated for the preceeding the succeeding activities. Mandatory dates fix both the early and the late dates of an activity, but will be overridden by any actual dates that are provided for in-progress or completed activities. Mandatory dates are useful for key activities when it is known in advance that these must happen at a certain time - the rest of the project must bend to achieve these dates.

A 'timenow' facility is available. This is simply a device to indicate the current date, or the checkpoint date at which you are re-analysing your network. The timenow date is used as the earliest date at which any activity can start, assuming it has not started already.

This means that the system will not calculate an early start date sometime in the past when it has been told that the earliest possible start date is today.

A timenow date has the effect of an earliest start date applied thoughout the network. It will not affect the dates of activities which have already finished, or which have a mandatory date applied. It will override any specified earliest start dates for unstarted activities unless they occur later than the timenow date. Activities which have started but are not yet finished will have whatever portion that remains to be done treated as if it were a separate, as yet unstarted, activity. The early start of this sub-activity will be set to the timenow date, assuming the logic of the network does not constrain it to any later date.

An activity in the network may be only very loosely connected to the rest of the project and can be performed within a very large time span without affecting the project finish date. As a result it will be given early and late dates which are far apart, in other words, a high float value.

For convenience a maximum float value for an activity may be specified, so that it will appear to be more critical than it really is. This can be useful when reports are given to the people responsible for performing the activity - activities with a lot of float tend to be left till last; with a very high float they might be forgotten altogether.

Limiting the *float for an activity does* not affect the calculation of its early dates, but simply prevents the late dates from falling too far into the future.

5.2.3 Resource Allocation

The standard time analysis process may be extended to include resource allocation. This technique determines schedule date for each activity based on the quantities of the resources used by the activity and the total quantities available for the project. The schedule dates are based on the early dates from the time analysis and are adjusted where necessary to ensure that the activity is scheduled at a time when sufficient resources will be available. Where several activities are competing for the same resources, the resources will be allocated to those which are most critical *to the timely completion of the project*. The less important activities will be delayed until the resources are freed by the completion of earlier activities.

AS permits resource allocation to be performed in two basic modes : fixed resource scheduling and fixed time scheduling.

Fixed resource scheduling means that the activities will be scheduled such that the availability levels of the resources will never be exceeded, and that as a result the overall project duration may have to extend beyond the late finish date calculated by the time analysis process.

Fixed time scheduling means that although every attempt will be made to keep the resource usage below the availability levels, no activities will be allowed to suffer a delay greater than their total float. In other words, a resource shortage will cause an activity to be delayed until the resource becomes available, but as soon as the delayed start reaches the activity's late start the activity will be scheduled, regardless of the availability at that time. Thus the overall project schedule will stay within the late span determined by the time analysis, but there may be occasions where the resource availability levels are exceeded, indicating that additional resources will need to be found if the project is to be completed within its target.

Two types of resource may be defined. They are known as carried-forward and used-up resources.

Carried-forward resources are those which can be used by more than one activity. When one activity has finished with them they become available for another activity to use. Typical examples of carried-forward resources are men and machines.

The requirements of carried-forward resources are specified as an amount per day (or per time period) - the quantity specified is assumed to be needed for each day of the activity.

Used-up resources can only be used once. When they have been used by one activity they are no longer available for any other activity. Typical examples are money or construction materials such as bricks and cement.

The requirements for used-up resources are specified as a total amount.

The resource requirement of each activity may be defined in terms of the quantities of each different resource it uses. A maximum of 50 different resources may be defined in a single project.

Two classes of resource may be defined in the system :

a) Control resources, whose availability (or lack of) is used to determine the schedule dates of the activities,

and b) Aggregate resources, whose availability is irrelevant to the scheduling process, but for which information is still required as to how many will be needed, and when.

Before the system, can perform a resource allocation it needs to know which resources are involved and what the availability levels are for those resources which are to control the scheduling. The resource levels can be defined for each resource, and can be made to vary during the life of the project.

A common problem with many resource allocation systems (like K and H), is that once an activity has been assigned a schedule start date it is assumed that it will proceed uninterrupted until it is completed. AS does not make this assumption. This means that a non-critical activity may be interrupted and have its resources transferred to a more critical activity.

The system provides infomation regarding the results of the resource allocation. Some of this information is standard, such as the schedule start and finish dates of each activity, and other information is optional.

The optional information consists of the following items :

- Adjusted start
- Start delay
- Finish delay
- Resource delay
- Delaying resource

The adjusted start of an activity is the date to which it has been delayed owing to delays in its predecessors.

The start delay it the difference between the early start of an activity (as calculated by time analysis) and the schedule start (as calculated by resource allocation).

The finish delay is the difference between the early finish of an activity (as calculated by time analysis) and the schedule finish (as calculated by resource allocation).

The resource delay is the difference between the adjusted start and the schedule start of an acitivity.

For activities which have been delayed through resource shortages the delaying resource provides an indication of which resource caused the problem. Delaying resource is the name of one of the resources (there may in fact be more than one culprit) which first caused the activity to be delayed.

In addition to the scheduling information for each activity AS also provides information relating to the overall resource utilisation. Summary information is provided for each resource, consisting of the following items :

- the first date on which the resource was used
- the highest level of usage on any day
- the total number of days of peak usage
- the first date that peak usage occurred
- the total availability for the whole project
- the total usage for the whole project

This information is provided for all resources, that is, both for control resources and aggregate resources.

The system also produces a file of detailed resource usage information. For each day of the project, and for each resource, information is produced showing the usage and availability levels, by day and cumulative-to-date.

5.2.4 Progress Reporting

Once the project has started it is necessary to record the progress made so that the remaining activities can be re-analysed so that it can be determined whether the project is going according to plan. If delays are encountered in parts of the project the critical path(s) may change, and it is necessary to know which activities should be monitored most closely.

The progress of work can be recorded in several different ways. The different methods of progress reporting are :

- Actual start and finish dates
- Actual durations
- Percentage completion
- Duration remaining

At any stage in the project an activity can be in one of three states: it is either completely finished, or it has been started but has not yet finished, or it is still to be started.

Progress reporting consists of providing information to the system necessary to describe activities in the first two categories. Activities which have not yet started will have their early, late and schedule dates calculated in the normal way. However, it is important that these dates are based not on the original start of the project, but on the actual or expected completion dates of their immediate predecessors.

5.2.5 Calendars

The technique of network analysis is purely numerical. The project can be considered to commence at time zero, and the 'dates' for all the activities can be calculated forwards from that point, using whatever unit of duration that is chosen. 'Dates' in this respect are simply numbers which can be added and subtracted.

In practice however, the calculated times for the performance of activities and the availability of resouces are required to be represented as proper dates. Furthermore, it is probable that work will not take place every day, and therefore it is required that the calculations take into account weekends and other holidays. This is achieved by defining one or more calendars which are to be used by the system when calculating dates.

The network can be processed either using normal calendar dates or in absolute time periods, for example, day numbers, week numbers or any other numeric unit assigned to represent the passage of time.

Dated calendars will normally use a day as the smallest unit of time.

Different calendars can be made with different activities. For example, clerical tasks may only be performed on a Monday to Friday calendar, some manual tasks may work

Monday to Saturday, and other tasks might occur using a seven day week, You may also have activities which do not involve any work in the strict sense, but which represent an unavoidable passage of time, for example waiting for paint to dry. Activities such as these will of course 'work' to a seven day week calendar, with no holidays.

5.2.6 Method of Operation

The tasks involved in defining and controlling a project by means of network analysis can be classified as follows :

Network preparation

- Identify the activities and their relationships to each other.
- Estimate durations.
- Estimate resource requirements (optional - resource allocation only).
- Draw the network i.e. a manual task.

Data Preparation

- Define the data files needed.
- Enter the network data, activities and relationships
- Enter the resource definitions and availability levels (optional)
- Define any calendars required (optional)

Processing

- Analyse the network, either time analysis or resource allocation

Displaying the results

- Reports
- Barcharts
- Other analyses, including graphical displays

Updating and Progress reporting

- *Amend incorrect or changed* activities/relationships/resource levels
- Record progress of work completed
- Re-analyse the current network
- Display the updated results

5.2.7 Processing

Once the data files have been established a time analyses or resource allocation can be performed. To do this three commands must be given to the system - one command to tell if the names of the input files, one to provide the names of the output files, and one to tell it to perform the analyses.

6. AS/CPIS INTERFACE

6.1 INTRODUCTION

The AS/CPIS interface is the intergration of the time analysis function of the AS Project Control system, with the cost information on the CPIS system. The interface produces forecast and actual information for both the expenditure and physical progress of an estimate or network. It does this by linking network activities to estimate items (See figure 6.1).

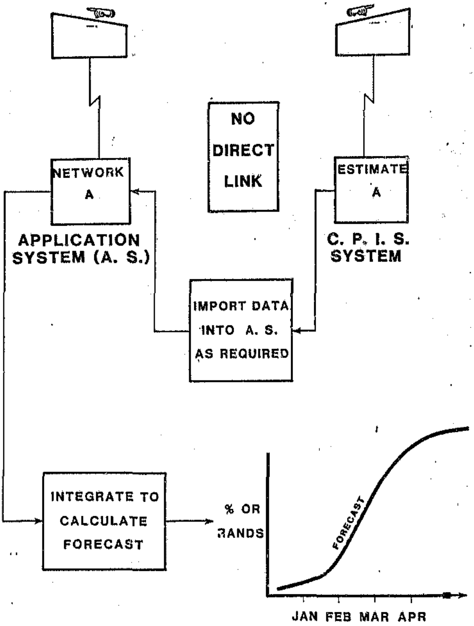
The programming to achieve this link is now documented by Jacobs and Smit [7].

The output of the interface is in the form of S-Curves, and reports displaying the plot points of the curves. All the curves can be displayed on three levels, namely, CPIS job, CPIS estimate and CPIS phase over any given monthly time period.

One AS network represents one estimate. The S-curves display information at job or estimate level for any given estimate. Any combination of estimates can be consolidated to display information at job level for these consolidated estimates.

The following diagram illustrates the different levels of reporting and the relation between the AS network and these CPIS levels. For the purpose of the illustration, a project with three estimates is used, namely phase X consisting of estimates A, B and C and job codes 1000, 2000 and 3000 for each estimate.

FIGURE 6.1


NETWORK A
APPLICATION SYSTEM (A. S.)
NO DIRECT LINK
ESTIMATE A
C. P. I. S. SYSTEM
IMPORT DATA INTO A. S. AS REQUIRED
INTEGRATE TO CALCULATE FORECAST
% OR RANDS
FORECAST
JAN FEB MAR APR

AS Network 1

CPIS Estimate A

CPIS Jobs:
1000
2000
3000
etc

AS Network 2

CPIS Estimate B

CPIS Jobs:
1000
2000
3000
etc

AS Network 3

CPIS Estimate C

CPIS Jobs:
1000
2000
3000
etc

CPIS Phase X

6.2 PHYSICAL CURVES

Three curves are available, namely:

Original planned progress
Actual progress to date
Forecast to completion

6.2.1 Original Planned Progress

The Early Start and Early Finish dates for the activities are used to determine in which month(s) the activity is active.

All durations of activities, up to and including any specific month are expressed as a percentage of the total network duration.

SCHEDULED WORK DAYS	MTH 1	2	3
Ac[illegible]y 1	25	20	15
Activity 2	20	10	-

At the end of month 1

Activity 1 should be $({}^{25}/_{60} \times 100)$ % complete
Activity 2 should be $({}^{20}/_{30} \times 100)$ % complete

The 'network' should be $\frac{(25 + 20)}{(60 + 30)} \times 100\%$ complete
$= \underline{50\ \%}$

This curve will remain fixed for the duration of the network. It is the curve computed <u>before</u> any progress is recorded on the networks.

The y-axis of the curve is in percentages from zero to 100 and the x-axis is in months.

6.2.2 Actual Progress to Date

All the completed durations of the activities are expressed as a percentage of the total network durati[illegible]n. (See above example.)

Total duration = Activity 1 duration + Activity 2 duration
= 60 + 30
= 90 days

Duration Complete
Activity 1 = 20
Activity 2 = 5
Total Complete = 25

(Duration complete = Total duration - duration left).

$\therefore$ Actual progress to date $= \frac{25}{90} \times 100\ \%$

$= \underline{27{,}8}\ \%$

This should be 50 % and the network is thus

$\frac{27{,}8}{50{,}0} \times 100\ \% \quad = \quad 55{,}6\ \%$ up to schedule

<u>or</u> (100 - 55,6) % = 44,4 % behind schedule

Only the current month percentage can be calculated. Every month's percentage is thus stored as the project progresses.

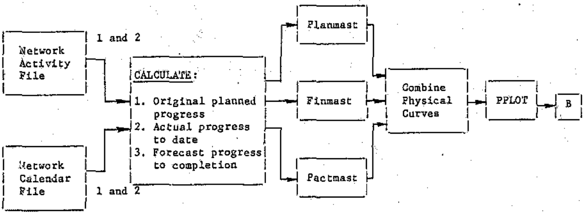
6.2.3 Forecast to Completion

The percentage point is calculated as for the planned progress, starting at the first month after the current month (time now). This curve is an extension to the actual progress to date curve.

Once the project is behind time i.e., the actual progress to date curve is below the original planned progress curve the forecast progress can only speed up if

- the critical path is changed
- durations are reduced, or
- activities are omitted.

6.2.4 System Flow Chart (Physical Progress Curves)



Each curve is calculated by individual procedures and stored on a master file for that specific curve.

The three master files are combined on to one file (PPLOT) for display purposes.

FILE	CONTENTS
ACTIVITY	Network activity data
CALENDAR	Expanded calendar file
PPLOT	Combined plot points for all physical progress curves
JOBPLAN	Original planned progress plot points
FINAL	Forecast to completion progress plot points
ACTUALS	Actual progress to date plot points

6.3 Financial Curves

Four curves are available, namely

Original planned cash flow
Actual expenditure to date
Forecast expenditure to completion
Committed expenditure to date

6.3.1 Original planned cash flow curve

The CPIS final cost estimate allocated to each activity is used in the calculation of the plot points i.e., all final cost estimate amounts or any part of them that became due according to the early start/finish dates for an activity, will be accumulated up to and including a specific month.

The module which calculates this excludes activities whose amounts are to be spread over the project duration. These activities are as follows :-

Engineering Fees
Re-imbursables
Home office costs
Escalation
Contingencies

The following is the basis for allocating a portion of the final cost estimate to a specific month.

Each activity is entitled to its proportional share of the final cost estimate amount (FCE) as totalled to its CPIS main item level.

For example:

ACTIVITY	CPIS MAIN ITEM	CPIS SUB ITEM	ACTIVITY DURATION	FCE AMOUNT FOR MAIN ITEM 001
1	001	010	30	
2	001	030	60	
		TOTAL	90	R900

Activity 1 share = $^{30}/_{90}$ x 900 = R300
Activity 2 share = $^{60}/_{90}$ x 900 = R600

These amounts are then proportionally distributed to the months over which the activity spans according to its early start/finish dates.

Only working days are taken into account in calculating the portion of the FCE for any specific month.

e.g., If activity 2 in the above example starts in May and ends in August and July has only 21 working days, then the amount allocated for July will be $^{21}/_{90}$ x R600 = R140.

Another module allocates amounts per *month* for contingencies, escalation, engineering fees, re-imbursables and escalation. These activities have a duration of zero. They are however logically linked to the first and last activity in the network.

Their early start/early finish dates thus represent the start and end dates of the estimate/network duration. These dates are used to determine the number of months over which to spread their FCE amounts.

For example:

ACTIVITY	EARLY START	EARLY FINISH	FCE AMOUNT
3	20 Feb 1985	7 July 1986	R1 800

Amount allocated per month : R1 800/18 = R100

All amounts calculated by the above module are aged by two months i.e., it is assumed that payment is made (or costs incurred) two months after the activity takes place.

The amounts accumulated are expressed as a percentage of the total final cost estimate for all activities in the network.

This curve remains fixed for the duration of the project. All other financial curves are measured against this curve for comparison during the life cycle of the estimate/network.

6.3.2 Actual expenditure to date.

All the actual expenditures imported from the CPIS system are accumulated up to and including a specific month. These are expressed as a percentage of the total original final cost estimate amounts for the whole network i.e., the original planned cash flow.

(CPIS information enters AS at sub-item level and is summarized to job and estimate level for the original cash flow and forecast to completion curves).

6.3.3 Forecast Expenditure to Completion

The origin of this curve is the last plot point of the actual expenditure curve.

To determine the monthly amount still to be spent for each activity the total actual expenditure is subtracted from the final cost estimated amount.

The early start/early finish dates of activities are used to determine the spread of cash.

The module which calculates this again excludes activities whose amounts are to be spread over the project duration. These activities are as follows :

Engineering Fees
Re-imbursable
Home office costs
Escavation
Contingencies

The following is the basis for allocating a portion of the remaining amount to a specific month. Each activity is entitled to its proportional share of the FCE amount remaining e.g.,

ACTIVITY	CPIS MAIN ITEM	Ck [illegible]	[illegible]TIVITY [illegible]ATION	FCE FOR MAIN ITEM 001	EXP TO DATE FOR MAIN ITEM 001	FCE REMAINING
1	001	010	30			
2	001	030	60			
		TOTAL	90	R900	R600	R300

Activity 1 share $= {}^{30}/_{90} \times R300 = R100$
Activity 2 share $= {}^{100}/_{90} \times R300 = R200$

These amounts are then distributed to the months over which the remainder of the activity spans.

Another module allocates amounts per month for contingencies, engineering fees, re-imbursables and escalation in exactly the same way as calculated in the original planned cash flow.

Again all amounts calculated are aged by two months.

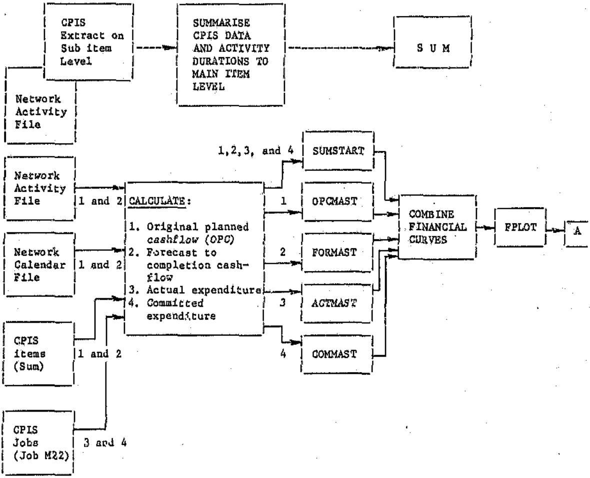
6.3.4 *Committed* Expenditure to Date.

The plot points for this curve are calculated as follows:-

The value of all orders placed plus mine charges spent up to and including any specific month are expressed as a percentage of the total original final cost estimated amount for the total network (i.e, a percentage of the original planned capital).

This curve also remains fixed for the duration of the *project*.

6.3.5 System Flow Chart (Financial Curves)



Each time CPIS is updated on AS, and when a network duration changes, it must be summarised.

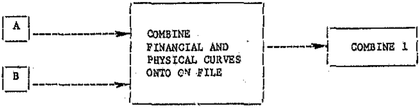
Each curve is calculated by individual procedures and stored on a master file for that specific curve.

Whenever the OPC (original planned cashflow) curve is calculated for an estimate, the data from file SUM is stored on file SUMSTART for use by the other curves.

The four financial curve master files are combined on to one file (FPLOT) for display purposes.

FILE	CONTENTS
SUM	Final cost estimate amounts and activity durations summarised up to CPIS main item level.
JOBM22	Actual expenditure and committed amounts of CPIS job level.
SUMSTART	Same as SUM as used by original planned cashflow calculations.
ACTIVITY	Network activity data.
CALENDAR	Expanded calendar
OPCMAST	Original planned cashflow per network/estimate plot.
FORMAST	Forecast expenditure to completion per network/estimate.
ACTMAST	Actual expenditure par network/estimate
COMMAST	Committed expenditure per network/estimate
FPLOT	Combined plot points for all financial expenditure curves.

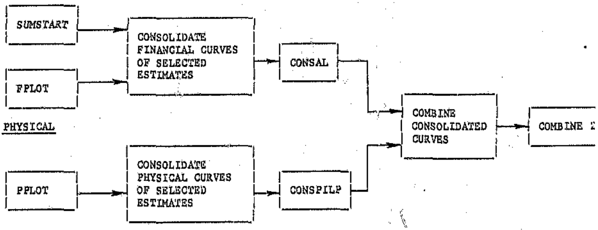
6.4 COMBINED FINANCIAL AND PHYSICAL CURVES



The financial expenditure and physical progress curves are combined on to one file for display purposes.

6.5 CONSOLIDATION (SYSTEM FLOW CHART)

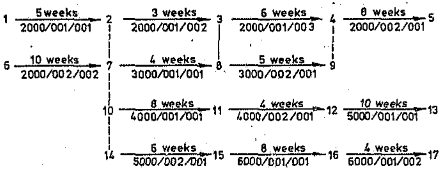
FINANCIAL

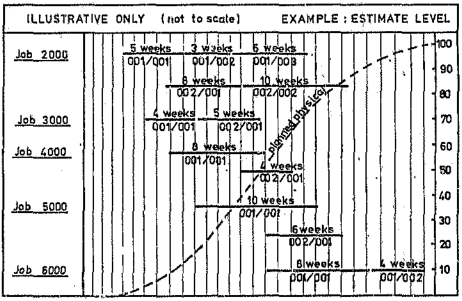


The above modules have been written to calculate the plot points for the consolidated financial and physical curves for any combination of estimates (or of course the total project).

6.6 CONSTRUCTING THE CURVES - ILLUSTRATIVE EXAMPLES

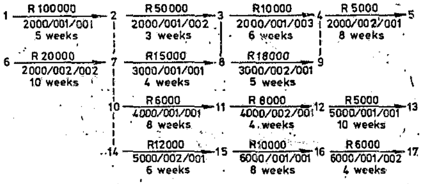
6.6.1 *Planned physical curve*

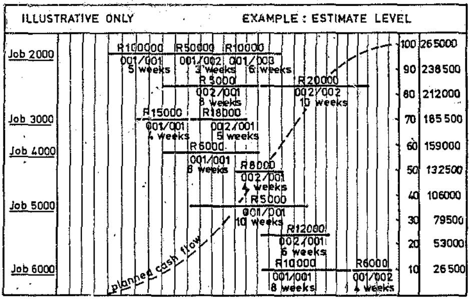




IS ALSO AVAILABLE FOR INDIVIDUAL JOBS AND TOTAL PROJECT

6.6.2 Planned Cash Flow Curve





<u>IS ALSO AVAILABLE FOR INDIVIDUAL JOBS AND TOTAL PROJECT</u>

6.6.3 *Estimate item/Physical activity link*

Example 1

One estimate item tied to one network activity.

Estimate Item:

3000/001/003 Level and terrace 31250m^2 @ R2/m^2 = R62 500
(Job/Item/Sub item)

Network:

1 ——— Level and terrace (4 weeks) ——— 2
3000/001/003

Week No.	1	2	3	4
Cash Flow	15 625	15 625	15 625	15 625

Example 2

Multiple estimate items tied to one network activity.

Estimate Items:

3000/001/001	Excavate and cut 1 500m^3 @ R5m^3 =	R 7 500
3000/001/002	Fill and compact 10 000m^3 @ R3m^3 =	R 30 000
3000/001/003	Level and terrace 3 125m^2 @ R2m^2 =	R 62 500
		R100 000

Network

1 BULK EARTHWORKS (5 WEEKS) 2

Week No.	1	2	3	4	5
Cash Flow	20 000	20 000	20 000	20 000	20 000

Example 3

Multiple network activities tied to one estimate item.

Estimate item

300/001/000 Bulk earthworks sum = R100 000

Network

1 EXCAVATE AND CUT (2 WEEKS) 2 FILL AND COMPACT (1 WEEK) 3 LEVEL AND TERRACE (2 WEEKS) 4

Week No.	1	2	3	4	5
Cash Flow	20 000	20 000	20 000	20 000	20 000

NOTES:

1. The system is capable of dealing with the following three situations:
   a) One estimate item tied to one network activity.
   b) Multiple estimate items tied to one network activity.

   and c) Multiple network activities tied to one estimate item.

2. The cash *is* evenly *distributed unless manually* overridden. If special conditions are known e.g., pre-payments, retentions etc, these can be fed into the system to give a more realistic projected cash flow.

7. REPORTS AVAILABLE

7.1 PROJECT CONTROL REPORTS

The following reports are available, and are currently being used, by the Project Team at Vaal Reefs.

NAME	REFERENCE
Network drawing	R1, R2, R3
Checklist	R 4
Time Analysis	R 5
Risk Analysis	R 6
Calendar	R 7
Edit Report	R 8
Progress Listing	R 9
Incomplete activities	R 10
Bar chart	R 11
Critical Path	R 12
S-Curve Plot Points	R 13
S-Curve	R 14

R1 - R3 Network Drawing

At present the precedence network is being drawn by hand by the Engineering Planners and the input keyed in by a system controller. In future it is intended to train the Planners to do this.

There are three levels of details possible.

The details fed into the system for each activity are:
Description
Calendar type
Early start/finish
Late start/finish

R 4 Checklist

A list of activities and their status by work item number. This report is used by the Planners for progress updating.

R 5 Time Analysis

This report provides the following information
- number of activities and relationships in the network
- the name of the calendar file used, and how many activities are used with individual calendars.
- the timenow value used, the earliest early start and the latest late finish date in the network.
- the *smallest and largest float values of* all activities in the network.
- the sum total of the duration of all activities, and an overall percentage completion for the whole project, based upon the progress information supplied for finished and partially completed activities.
- a list of all start and finish activities, showing their early and late dates and float.

R 6 **Risk Analysis**

A statistical analysis giving the most likely completion date, the earliest completion date and the latest completion date.

The module works its way through the network for a preset number of iterations (normally fifty) and it assumes a normal distribution of actual finish dates around the planned finish dates.

R 7 **Calendar**

An example of one of the three different calendars that are available in the system.

R 8 **Edit Report**

An error listing of network input coding or logic errors.

R 9 **Progress Listing**

A check list of activities in a specific network to check status.

R10 **Incomplete Activities**

A list of all incomplete activities in a network showing
- final cost estimate
- total expenditure to date
- amount outstanding

R11 **Barchart**

This is a schedule in barchart form for all activities in a particular network. This shows early start dates, late start dates, critical activities and actual days worked on that activity.

It is with this format (rather than the network draw format) that project management controls the time progress of the project.

R12 **Critical Path**

A list of all activities on the critical path ie., those with zero float. If desired this can also include near-critical activities ie., with float of up to say 10 days.

R13 **S-Curve Plot Points**

This report gives the following numeric listings per month - all figures are cumulative

- original planned cash flow %
- original planned cash flow R's
- forecast expenditure to completion %
- forecast expenditure to completion R's
- actual expenditure to date %
- actual expenditure to date R's
- committed expenditure to date %
- committed expenditure to date R's
- original planned progress %
- achieved physical progress to date %
- forecast physical progress to completion %

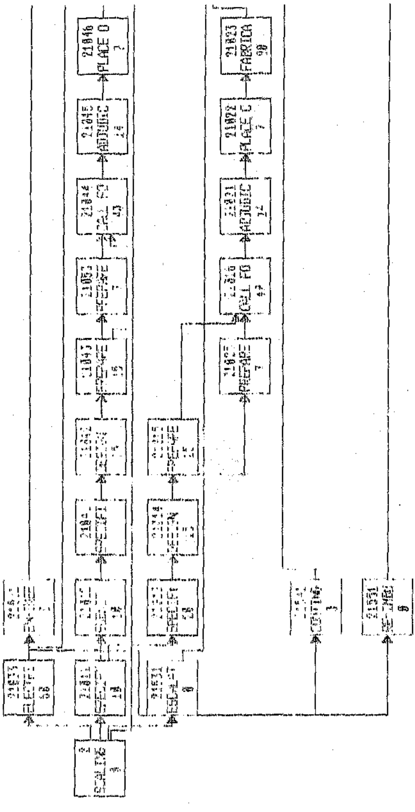
R14 *S-Curves*

See R15 example - graphs are self-explanatory.

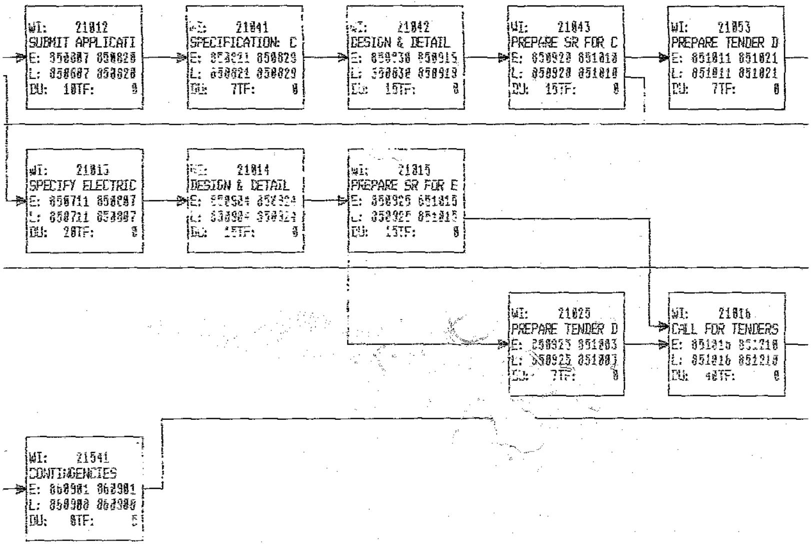
7.2 OTHER AS REPORT FORMATS

R.F 1	Radar chart
R.F 2	Pie chart
R.F 3-4	Histograms
R.F 5	Graph

Network Drawing RI



R2


WI: 21012
SUBMIT APPLICATI
E: 850807 850828
L: 850807 850828
DU: 10TF: 0
WI: 21041
SPECIFICATION: C
L: 850821 850829
DU: 7TF: 0
WI: 21042
DESIGN & DETAIL
DU: 15TF: 0
WI: 21043
PREPARE SR FOR C
E: 850920 851010
L: 850920 851010
DU: 15TF: 0
WI: 21053
PREPARE TENDER D
E: 851011 851021
L: 851011 851021
DU: 7TF: 0
WI: 21013
SPECIFY ELECTRIC
E: 850711 850807
L: 850711 850807
DU: 20TF: 0
WI: 21014
DESIGN & DETAIL
WI: 21015
PREPARE SR FOR E
E: 850925 851015
DU: 15TF: 0
WI: 21025
PREPARE TENDER D
L: 850925 851003
DU: 7TF: 0
WI: 21016
CALL FOR TENDERS
E: 851016 851210
L: 851016 851210
DU: 40TF: 0
WI: 21541
CONTINGENCIES
E: 860901 862901
L: 860900 862900
DU: 0TF: 5

R3

```
     WI:     21815   DU:   15 CAL:2
PREPARE SR FOR ELECTRICAL
        START FINISH
     E:850925 851015 TF:    0 SD:
     L:850925 851015          FD:
     S:              SC:      PD:
     A:       851014 AD:      DL:  15
     R:              DT:      PC:
```

```
     WI:     21825   DU:    7 CAL:2
PREPARE TENDER DOCUMENTS ELECT
        START FINISH
     E:850925 851003 TF:    0 SD:
     L:850925 851003          FD:
     S:              SC:      SD:
     A:       851003 AD:      DL:   7
     R:              DT:      PC:
```

REPORT PRODUCED - 08 Sep 86 AT 14:30

SHAFT WORKSHOPS (5841)

WORK ITEM	DESCRIPTION	DUR	EARLY START	EARLY FINISH	LATE START	LATE FINISH	FLOAT	CODE	CAL	DATE TYPE	TRADE TYPE
2	SCALING ACTIVITY	0	1/ 9/86		FINISHED	FINISHED	0	S			
11412	EXECUTE SOIL INVESTIGATION TO WORKSHOPS	3	17/ 2/86	19/ 2/86	FINISHED	FINISHED	0		1		C5
11421	SPECIFY & PREPARE PRELIMINARY FOR NO. 10 SHAFT WORKSHOP	3	18/ 2/86	20/ 2/86	FINISHED	FINISHED	0		1		A6
11422	OBTAIN G.A DRAWINGS DESIGN & D NO. 10 SHAFT WORKSHOPS	2	11/ 3/86	12/ 3/86	FINISHED	FINISHED	0		1		C1
11423	PREPARE S.R'S & SUBMIT TO PROC DEPARTMENT	1	20/ 2/86	20/ 2/86	FINISHED	FINISHED	0		1		C2
11424	PREPARE TENDER DOCUMENTS FOR N WORKSHOPS	5	17/ 2/86	21/ 2/86	FINISHED	FINISHED	0		1		C3
11425	CALL FOR TENDERS NO. 10 SHAFT	12	15/ 2/86	28/ 2/86	FINISHED	FINISHED	0		1		C3
11426	ADJUDICATE TENDERS NO.10 SHAFT	3	5/ 3/86	7/ 3/86	FINISHED	FINISHED	0		1		C3
11431	PLACE ORDER NO.10 SHAFT WORKSH	1	14/ 3/86	14/ 3/86	FINISHED	FINISHED	0		1		M2
11432	CONTRACTOR TO ESTABLISH SITE	2	17/ 3/86	18/ 3/86	FINISHED	FINISHED	0		1		M3
11433	SURVEY TERRACE & PEG NO.10 SHA WORKSHOPS	2	18/ 3/86	19/ 3/86	FINISHED	FINISHED	0		1		C5
11434	GENERAL PREPARATION EARTHWORKS & BACKFILL WORKSHOPS AREA	4	24/ 3/86	27/ 3/86	FINISHED	FINISHED	0		1		C5
11435	POUR BINDING FOR COLUMNS GROUN	12	7/ 6/86	20/ 6/86	FINISHED	FINISHED	0		1		C5
11436	ERECT SHUTTERING & REO FOR COL GROUND BEAM	6	21/ 6/86	27/ 6/86	FINISHED	FINISHED	0		1		C5
11442	ORDER & DELIVER RE-INFORCING & FOR NO.10 SHAFT WORKSHOPS	18	12/ 4/86	2/ 5/86	FINISHED	FINISHED	0		1		M3
11451	POUR CONCRETE COLUMNS & GROUND ALLOW FOR CURING	10	1/ 9/86	11/ 9/86	8/ 9/86	18/ 9/86	6		1		C5
11452	BACKFILL COMPACT & POUR FLOOR	10	15/ 9/86	25/ 9/86	22/ 9/86	2/10/86	6		1		C5
11453	ERECT STRUCTURAL STEELWORK	54	26/ 9/86	27/11/86	3/10/86	4/12/86	6		1		S5
11454	PAINT STRUCTURAL NO.10 SHAFT W	12	3/10/86	16/10/86	10/10/86	23/10/86	6		1		T5

Check List R4

[illegible] ANALYSIS

```
         WORK ITEMS:     30
      RELATIONSHIPS:     56
     CALENDARS USED:      1
 NO. OF REFERENCES:     30
            TIMENOW:  1SEP86
     SMALLEST FLOAT:      0
     GREATEST FLOAT:    230
   START WORK ITEMS:      1      TOTAL OF DURATIONS:  3318
  FINISH WORK ITEMS:      1      APPROX. % COMPLETE:    46
  EARLIEST      LATEST
EARLY START   LATE FINISH
  1SEP86       16JUN87
```

WORK ITEM	EARLY START	EARLY FINISH	LATE START	LATE FINISH	TOTAL FLOAT
START WORK ITEMS					
2	1SEP86	1SEP86	1SEP86	1SEP86	0
FINISH WORK ITEMS					
22264	16JUN87	16JUN87	16JUN87	16JUN87	0

Tima Analysis R5

```
                                 *
                                 **
                                 **
                        *        **          *
                        **       ****        *
                        **       *****       *
              *         **       *****       *
              *      *  **       *****       **
          **  *      *****       *****       ***
          **  *      *****       *****       *** *
          ****       *****       *****       *****
----------+----------+----------+----------+----------+----------+----------+----------
      861106     861[illegible]     861[illegible]     [illegible]     [illegible]     [illegible]     [illegible]
                         *
              [illegible]   [illegible]      [illegible]               [illegible]
ITERAT[illegible]  2      DATE       DATE       [illegible]     [illegible]     [illegible]     [illegible]
100          24Nov86    11Nov86    8Dec86     3Dec86     2Dec86     27Nov8[illegible]

ITERATIONS COMPLETED. INSERT NEW VALUE OR PRESS ENTER TO FINISH
```

WORK ITEM	CUMULATIVE	%	BEFORE	STATISTICS	DATE
21815	LEVEL 1	0	NONE	EARLIEST	18Mar86
	LEVEL 2	0	NONE	LATEST	19Mar86
	LEVEL 3	0	NONE	LIKELY	18Mar86
	PLANNED	100	18Mar86	RANGE	1
21824	LEVEL 1	0	NONE	EARLIEST	6Jan86
	LEVEL 2	0	NONE	LATEST	6Jan86
	LEVEL 3	0	NONE	LIKELY	6Jan86
	PLANNED	100	6Jan86	RANGE	1
21834	LEVEL 1	0	NONE	EARLIEST	29Nov85
	LEVEL 2	0	NONE	LATEST	29Nov85
	LEVEL 3	0	NONE	LIKELY	29Nov85
	PLANNED	100	29Nov85	RANGE	1
21844	LEVEL 1	0	NONE	EARLIEST	17Feb86
	LEVEL 2	0	NONE	LATEST	17Feb86
	LEVEL 3	0	NONE	LIKELY	17Feb86
	PLANNED	100	17Feb86	RANGE	1
21854	LEVEL 1	94	6Nov86	EARLIEST	22Oct86
	LEVEL 2	86	5Nov86	LATEST	7Nov86

```
| MO TU WE TH FR SA SU | MO TU WE TH FR SA SU | MO TU WE TH FR SA SU | MO TU WE TH FR SA SU |
|=====================================================================================|
|    DECEMBER 1986     |     JANUARY 1987     |    FEBRUARY 1987     |      MARCH 1987      |
|----------------------+----------------------+----------------------+----------------------|
|  1  2  3  4  5  6 -- |          ** **  3 -- |                   -- |                   -- |
|  8  9 10 11 12 13 -- |  5  6  7  8  9 10 -- |  2  3  4  5  6  7 -- |  2  3  4  5  6  7 -- |
| ** ** ** ** ** 20 -- | 12 13 14 15 16 17 -- |  9 10 11 12 13 14 -- |  9 10 11 12 13 14 -- |
| ** ** ** ** ** 27 -- | 19 20 21 22 23 24 -- | 16 17 18 19 20 21 -- | 16 17 18 19 20 21 -- |
| ** ** **             | 26 27 28 29 30 31    | 23 24 25 26 27 28    | 23 24 25 26 27 28 -- |
|                      |                      |                      | 30 31                |
|=====================================================================================|
|      APRIL 1987      |       MAY 1987       |      JUNE 1987       |      JULY 1987       |
|----------------------+----------------------+----------------------+----------------------|
|        1  2  3  4 -- |              1  3 -- | **  2  3  4  5  6 -- |        1  2  3  4 -- |
|  6  7  8  9 10 11 -- |  4  5  6  7  8  9 -- |  8  9 10 11 12 13 -- |  6  7  8  9 10 11 -- |
| 13 14 15 16 ** 18 -- | 11 12 13 14 15 16 -- | 15 16 17 18 19 20 -- | 13 14 15 16 17 18 -- |
| 20 21 22 23 24 25 -- | 18 19 20 21 22 23 -- | 22 23 24 25 26 27 -- | 20 21 22 23 24 25 -- |
| 27 28 29 30          | 25 26 27 28 29 30 -- | 29 30                | 27 28 29 30 31       |
|                      |                      |                      |                      |
|=====================================================================================|
|     AUGUST 1987      |    SEPTEMBER 1987    |     OCTOBER 1987     |    NOVEMBER 1987     |
|----------------------+----------------------+----------------------+----------------------|
|                 1 -- |     1  2  3  4  5 -- |           1  2  3 -- |                   -- |
|  3  4  5  6  7  8 -- |  7  8  9 10 11 12 -- |  5  6  7  8  9 10 -- |  2  3  4  5  6  7 -- |
| 10 11 12 13 14 15 -- | 14 15 16 17 18 19 -- | 12 13 14 15 16 17 -- |  9 10 11 12 13 14 -- |
| 17 18 19 20 21 22 -- | 21 22 23 24 25 26 -- | 19 20 21 22 23 24 -- | 16 17 18 19 20 21 -- |
| 24 25 26 27 28 29 -- | 28 29 30             |       28 29 30 31    | 23 24 25 26 27 28 -- |
| 31                   |                      |                      | 30                   |
|=====================================================================================|
|    DECEMBER 1987     |     JANUARY 1988     |    FEBRUARY 1988     |      MARCH 1988      |
|----------------------+----------------------+----------------------+----------------------|
|     1  2  3  4  5 -- |              1  2 -- |     2  3  4  5  6 -- |     1  2  3  4  5 -- |
|  7  8  9 10 11 12 -- |  4  5  6  7  8  9 -- |  8  9 10 11 12 13 -- |  7  8  9 10 11 12 -- |
| ** ** ** ** ** 19 -- | 11 12 13 14 15 16 -- | 15 16 17 18 19 20 -- | 14 15 16 17 18 19 -- |
| ** ** ** ** ** 26 -- | 18 19 20 21 22 23 -- | 22 23 24 25 26 27 -- | 21 22 23 24 25 26 -- |
| ** ** ** **          | 25 26 27 28 29 30 -- | 29                   | 28 29 30 31          |
|                      |                      |                      |                      |
|=====================================================================================|
|      APRIL 1988      |       MAY 1988       |      JUNE 1988       |      JULY 1988       |
|----------------------+----------------------+----------------------+----------------------|
|             **  2 -- |                   -- |        1  2  3  4 -- |              1  2 -- |
|  4  5  6  7  8  9 -- |  2  3  4  5  6  7 -- |  6  7  8  9 10 11 -- |  4  5  6  7  8  9 -- |
| 11 12 13 14 15 16 -- |  9 10 11 12 13 14 -- | 13 14 15 16 17 18 -- | 11 12 13 14 15 16 -- |
| 18 19 20 21 22 23 -- | 16 17 18 19 20 21 -- | 20 21 22 23 24 25 -- | 18 19 20 21 22 23 -- |
| 25 26 27 28 29 30    | 23 24 25 26 27 28 -- | 27 28 29 30          | 25 26 27 28 29 30 -- |
|                      | 30 **                |                      |                      |
|=====================================================================================|
```

Edit Report R8

```
YVCP22,86.254,12:30:45,YVCP22.CENFILE.REP

PGM: EDIT1        INPUT ERRORS DETECTED ON ACTIVITY FILE  ACTMC                DATE: 11 SEPTEMBE 1986    TIME: 123017
====              ==========================================
PHASEKEY;    D221097  ESTIMATE;    2743
*** ERROR ***   SPECIAL ACTIVITIES (ESCALATION ETC) MUST HAVE ZERO DURATION (CPIS MAIN ITEM CODE 09S) ** WORK ITEM =    5311
                PHASEKEY =  D221097   ESTIMATE =  2743   JOB/ITEM =  980009S000   DURATION =    2
*** ERROR ***   SPECIAL ACTIVITIES (ESCALATION ETC) MUST HAVE ZERO DURATION (CPIS MAIN ITEM CODE 09S) ** WORK ITEM =    5312
                PHASEKEY =  D221097   ESTIMATE =  2743   JOB/ITEM =  980009S001   DURATION =   14
*** ERROR ***   SPECIAL ACTIVITIES (ESCALATION ETC) MUST HAVE ZERO DURATION (CPIS MAIN ITEM CODE 09S) ** WORK ITEM =    5313
                PHASEKEY =  D221097   ESTIMATE =  2743   JOB/ITEM =  980009S002   DURATION =   21
*** ERROR ***   SPECIAL ACTIVITIES (ESCALATION ETC) MUST HAVE ZERO DURATION (CPIS MAIN ITEM CODE 09S) ** WORK ITEM =    5314
                PHASEKEY =  D221097   ESTIMATE =  2743   JOB/ITEM =  980009S003   DURATION =   15
*** ERROR ***   SPECIAL ACTIVITIES (ESCALATION ETC) MUST HAVE ZERO DURATION (CPIS MAIN ITEM CODE 09S) ** WORK ITEM =    5315
                PHASEKEY =  D221097   ESTIMATE =  2743   JOB/ITEM =  980009S004   DURATION =   15
*** ERROR ***   SPECIAL ACTIVITIES (ESCALATION ETC) MUST HAVE ZERO DURATION (CPIS MAIN ITEM CODE 09S) ** WORK ITEM =    5316
                PHASEKEY =  D221097   ESTIMATE =  2743   JOB/ITEM =  980009S005   DURATION =    7
*** ERROR ***   SPECIAL ACTIVITIES (ESCALATION ETC) MUST HAVE ZERO DURATION (CPIS MAIN ITEM CODE 09S) ** WORK ITEM =    5317
                PHASEKEY =  D221097   ESTIMATE =  2743   JOB/ITEM =  980009S006   DURATION =    7
*** ERROR ***   SPECIAL ACTIVITIES (ESCALATION ETC) MUST HAVE ZERO DURATION (CPIS MAIN ITEM CODE 09S) ** WORK ITEM =    5324
                PHASEKEY =  D221097   ESTIMATE =  2743   JOB/ITEM =  980009S007   DURATION =    7
*** ERROR ***   SPECIAL ACTIVITIES (ESCALATION ETC) MUST HAVE ZERO DURATION (CPIS MAIN ITEM CODE 09S) ** WORK ITEM =    5421
                PHASEKEY =  D221097   ESTIMATE =  2743   JOB/ITEM =  980009S008   DURATION =    2
*** ERROR ***   SPECIAL ACTIVITIES (ESCALATION ETC) MUST HAVE ZERO DURATION (CPIS MAIN ITEM CODE 09S) ** WORK ITEM =    5422
                PHASEKEY =  D221097   ESTIMATE =  2743   JOB/ITEM =  980009S009   DURATION =   15
*** ERROR ***   SPECIAL ACTIVITIES (ESCALATION ETC) MUST HAVE ZERO DURATION (CPIS MAIN ITEM CODE 09S) ** WORK ITEM =    5423
                PHASEKEY =  D221097   ESTIMATE =  2743   JOB/ITEM =  980009S010   DURATION =    7
*** ERROR ***   SPECIAL ACTIVITIES (ESCALATION ETC) MUST HAVE ZERO DURATION (CPIS MAIN ITEM CODE 09S) ** WORK ITEM =    5431
                PHASEKEY =  D221097   ESTIMATE =  2743   JOB/ITEM =  980009S011   DURATION =    2
*** ERROR ***   SPECIAL ACTIVITIES (ESCALATION ETC) MUST HAVE ZERO DURATION (CPIS MAIN ITEM CODE 09S) ** WORK ITEM =    5432
                PHASEKEY =  D221097   ESTIMATE =  2743   JOB/ITEM =  980009S012   DURATION =   15
*** ERROR ***   SPECIAL ACTIVITIES (ESCALATION ETC) MUST HAVE ZERO DURATION (CPIS MAIN ITEM CODE 09S) ** WORK ITEM =    5433
                PHASEKEY =  D221097   ESTIMATE =  2743   JOB/ITEM =  980009S013   DURATION =    7
*** ERROR ***   SPECIAL ACTIVITIES (ESCALATION ETC) MUST HAVE ZERO DURATION (CPIS MAIN ITEM CODE 09S) ** WORK ITEM =    5[illegible]
                PHASEKEY =  D221097   ESTIMATE =  2743   JOB/ITEM =  980009S014   DURATION =    2
*** ERROR ***   SPECIAL ACTIVITIES (ESCALATION ETC) MUST HAVE ZERO DURATION (CPIS MAIN ITEM CODE 09S) ** WORK ITEM =    5442
                PHASEKEY =  D221097   ESTIMATE =  2743   JOB/ITEM =  980009S015   DURATION =   15
*** ERROR ***   SPECIAL ACTIVITIES (ESCALATION ETC) MUST HAVE ZERO DURATION (CPIS MAIN ITEM CODE 09S) ** WORK ITEM =    5443
                PHASEKEY =  D221097   ESTIMATE =  2743   JOB/ITEM =  980009S016   DURATION =    7
*** ERROR ***   SPECIAL ACTIVITIES (ESCALATION ETC) MUST HAVE ZERO DURATION (CPIS MAIN ITEM CODE 09S) ** WORK ITEM =    5451
                PHASEKEY =  D221097   ESTIMATE =  2743   JOB/ITEM =  980009S017   DURATION =    2
*** ERROR ***   SPECIAL ACTIVITIES (ESCALATION ETC) MUST HAVE ZERO DURATION (CPIS MAIN ITEM CODE 09S) ** WORK ITEM =    5452
                PHASEKEY =  D221097   ESTIMATE =  2743   JOB/ITEM =  980009S018   DURATION =   15
*** ERROR ***   SPECIAL ACTIVITIES (ESCALATION ETC) MUST HAVE ZERO DURATION (CPIS MAIN ITEM CODE 09S) ** WORK ITEM =    5453
                PHASEKEY =  D221097   ESTIMATE =  2743   JOB/ITEM =  980009S019   DURATION =    7
*** ERROR ***   SPECIAL ACTIVITIES (ESCALATION ETC) MUST HAVE ZERO DURATION (CPIS MAIN ITEM CODE 09S) ** WORK ITEM =    5461
```

YVCP28,86.251,14:09:17,YVCP28.CENFILE.REP

REPORT PRODUCED - 8 SEP 86 AT 14:08
PAGE 1 CHECKLIST FOR NETWORK ACTSW SHAFT WORKSHOP (5841)

WORK ITEM	DESCRIPTION	DURN LEFT	DATE COMPL	DUR	EARLY START	EARLY FINISH	LATE START	LATE FINISH	FLOAT	CODE	CAL	DATE TYPE	DUR LEFT
2	SCALING ACTIVITY		860901	0		FINISHED		FINISHED	0	S			
			FROM:				TO:	11421 FS		CPIS:			
			FROM:				TO:	11611 SS		CPIS:			
			FROM:				TO:	11621 SS		CPIS:			
			FROM:				TO:	11641 SS		CPIS:			
			FROM:				TO:	11651 SS		CPIS:			
			FROM:				TO:	11661 FS		CPIS:			
11412	EXECUTE SOIL INVESTIGATION TO SHAFT		860219	3		FINISHED		FINISHED	0		1		
			FROM:	11421	FS		TO:	11426 FS		CPIS:	3000001012		
11421	SPECIFY & PREPARE PRELIMINARY LAYOUT		860220	3		FINISHED		FINISHED	0		1		
			FROM:	: 2	FS		TO:	11412 FS		CPIS:	3000001013		
			FROM:				TO:	11422 FS		CPIS:			
11422	OBTAIN G.A DRAWINGS DESIGN & DETAIL		860312	2		FINISHED		FINISHED	0		1		
			FROM:	11421	FS		TO:	11423 FS		CPIS:	3000001014		
			FROM:				TO:	11531 FS		CPIS:			
			FROM:				TO:	11551 FS		CPIS:			
11423	PREPARE S.R'S & SUBMIT TO PROCUREMENTS		860220	1		FINISHED		FINISHED	0		1		
			FROM:	11422	FS		TO:	11424 FS		CPIS:	3000001015		
11424	PREPARE TENDER DOCUMENTS FOR NO.10 SHAFT		860221	5		FINISHED		FINISHED	0		1		
			FROM:	11423	FS		TO:	11425 FS		CPIS:	3000001016		
11425	CALL FOR TENDERS NO. 10 SHAFT WORKSHOPS		860228	12		FINISHED		FINISHED	0		1		
			FROM:	11424	FS		TO:	11426 FS		CPIS:	3000001017		
11426	ADJUDICATE TENDERS NO.10 SHAFT WORKSHOPS		860307	3		FINISHED		FINISHED	0		1		
			FROM:	11412	FS		TO:	11431 FS		CPIS:	3000001018		
			FROM:	11425	FS		TO:			CPIS:			
11431	PLACE ORDER NO.10 SHAFT WORKSHOPS		860314	1		FINISHED		FINISHED	0		1		
			FROM:	11426	FS		TO:	11432 FS		CPIS:	3000001001		
			FROM:				TO:	11442 FS		CPIS:			
11432	CONTRACTOR TO ESTABLISH SITE		860318	2		FINISHED		FINISHED	0		1		
			FROM:	11431	FS		TO:	11433 FS		CPIS:	3000001002		
11433	SURVEY TERRACE & PEG NO.10 SHAFT		860319	2		FINISHED		FINISHED	0		1		
			FROM:	11432	FS		TO:	11434 FS		CPIS:	3000001003		
11434	GENERAL PREPARATION EARTHWORKS EXCAVATE		860327	4		FINISHED		FINISHED	0		1		
			FROM:	11433	FS		TO:	11435 FS		CPIS:	3000002000		
11435	POUR BINDING FOR COLUMNS GROUND BEAM		860620	12		FINISHED		FINISHED	0		1		
			FROM:	11434	FS		TO:	11436 FS		CPIS:	3000001007		
11436	ERECT SHUTTERING & REO FOR COLUMNS &		860627	6		FINISHED		FINISHED	0		1		
			FROM:	11435	FS		TO:	11451 FS		CPIS:	3000001009		
			FROM:	11442	FS		TO:			CPIS:			

Progress Listing B9

PAGE 2 10:47:42 860909

INCOMPLETE ACTIVITIES REMAINING IN NETWORK/ESTIMATE : ARTERIAL TRANSPORT(3220)

EST-CODE	JOB	MAIN ITEM	SUB ITEM	WORK ITEM	Description	DurN	DURN LEFT	EARLY START	EARLY FINISH	FCE	TOTAL EXP TO DATE	AMOUNT OUTSTANDING
3220	1350	001	040	1516	PAYMENT FOR ROCK WINDER MECHANICALS	1	1	14MAR87	14MAR87			
			050	1615	PAYMENT FOR MAN WINDER MECHANICALS	1	1	14MAR87	14MAR87			
		001								10150862.40	8255520.00	1895342.40
3220	1350	003	010	1526	PAYMENT FOR ROCK WINDER ELECTRICALS	1	1	14MAR87	14MAR87			
			020	1625	PAYMENT FOR MAN WINDER ELECTRICALS	1	1	26MAY87	26MAY87			
		003								10161347.84	0.00	10161347.84
3220	1350	005	010	1655	MANUFACTURE & DELIVER TO SITE SIEMENS DRIVE MOTOR BEDPLATES	48	22	5SEP86	30SEP86			
		005								40000.00	0.00	40000.00
3220	1350	007	010	1636	DELIVER TO SITE D/D VICKERS ARMSTRONG DC WINDER MECH'S FOR INSTALLATION	6	6	21FEB87	27FEB87			
		007								1366400.00	1366400.00	0.00
3220	1350	01M	000	2251	PROCURE SUNDRY STORES FOR MOTOR MAINTENANCE PLATFORMS & MG SETS BLANE & SALLIES WINDER	52	10	5SEP86	16SEP86			
		01M								15000.00	0.00	15000.00
3220	1350	010	000	1635	TRANSPORT TO STORAGE SPACE & REFURBISH D/D VICKERS ARM-STRONG DC WINDER MECHANICALS	1	1	12SEP86	12SEP86			
			010	1644	RENT STORAGE SPACE FOR D/D VICKERS ARMSTRONG DC WINDER	130	130	5SEP86	20FEB87			
			020	1711	INSTALL BLANE SERVICE WINDER MECHANICALS ON PREPARED FOUNDS FOR MAIN SHAFT	78	78	28FEB87	30MAY87			
			030	1456	COMMISSION R/VENT SHAFT ROCK WINDER AS KIBBLE WINDER	60	60	20APR87	29JUN87			
			030	1712	INSTALL BLANE SERVICE WINDER ELECTRICALS FOR MAIN SHAFT	78	78	14MAR87	15JUN87			
			040	1713	INSTALL THYRISTOR ON PREPARED FOUND'S FOR BLANE SERVICE WINDER & AUXILLIARY EQUIPT	20	20	14MAR87	6APR87			
			050	1714	COMMISSION THYRISTOR & AUXILLIARY EQUIPT FOR BLANE SERVICE WINDER MAIN SHAFT	6	6	16JUN87	22JUN87			
			060	1715	COMMISSION ON BLANE SERVICE WINDER FOR MAIN SHAFT	6	6	23JUN87	29JUN87			
		010								1065233.98	833413.44	231820.54

INCOMPLETE Activities R10

08 Sep 86 14:23 SHAFT WORKSHOP (5841) Page 1.01

Work Item	Description	6 Jun 86	14 Oct 87	20 Feb 89	30 Jun 90	7 Nov 91	16 Mar 93	24 Jul 94	1 Dec 95	9 Apr 97	17 Aug 98	25 Dec 99	4 May 01	11 Sep 02	19 Jan 04	28 May 05	5 Oct 06	12 Feb 08
		T																
11425	CALL FOR TENDERS NO. 10 SHAFT	T																
11412	EXECUTE SOIL INVESTIGATION TO	T																
11424	PREPARE TENDER DOCUMENTS FOR N	T																
11421	SPECIFY & PREPARE PRELIMINARY	T																
11423	PREPARE S.R'S & SUBMIT TO PROC	T																
11426	ADJUDICATE TENDERS NO.10 SHAFT	T																
11422	OBTAIN G.A DRAWINGS DESIGN & D	T																
11431	PLACE ORDER NO.10 SHAFT WORKSH	T																
11432	CONTRACTOR TO ESTABLISH SITE	T																
11433	SURVEY TERRACE & PEG NO.10 SHA	T																
11434	GENERAL PREPARATION EARTHWORKS	T																
11442	ORDER & DELIVER RE-INFORCING &	T																
11435	POUR BINDING FOR COLUMNS GROUN	A																
11436	ERECT SHUTTERING & REO FOR COL	A																
11532	PREPARE TENDER DOCUMENTS FOR O	A																
11531	PREPARE S.R FOR O/H CRANE 10 S	A																
11533	CALL TENDERS FOR O/H CRANE	A																
2	SCALING ACTIVITY	A																
11451	POUR CONCRETE COLUMNS & GROUND	+L																
11534	ADJUDICATE TENDERS O/H CRANE	EL																
11551	PREPARE S R FOR EXTERNAL LIGHT	EL																
11611	ESCALATION	E L																
11621	CONTINGENCIES	E L																
11641	ENGINEERING FEES	E L																
11651	REIMBURSABLES	E L																
11661	MINE STORES	CCC																
11535	PLACE ORDER FOR O/H CRANE	EL																
11532	PREPARE TENDER DOCUMENTS FOR E	E+																
11536	FABRICATE & DELIVER O/H CRANE	E+L																
11452	BACKFILL COMPACT & POUR FLOOR	T+																
11453	ERECT STRUCTURAL STEELWORK	T+																
11455	INSTALL CLADDING WORKSHOPS	TEL																
11553	CALL TENDERS FOR EXTERNAL LIGH	T+																
11454	PAINT STRUCTURAL NO.10 SHAFT W	T+																
11554	ADJUDICATE TENDERS EXTERNAL LI	T+																
11523	ERECT & COMMISSION O/H CRANE N	TEL																
11465	BUILDING BRICKWORK ALLOW FOR P	T+																
11555	PLACE THE ORDER FOR EXTERNAL L	T+																
11556	FABRICATE & DELIVER EXTERNAL L	T+L																
11466	COMPLETE BRICKWORK NO.10 SHAFT	T+L																
11511	COMPLETE INTERNAL FINISHES ELE	T++																
11521	COMPLETE INTERNAL FINISHES PLU	T++																
11566	INSTALL ALL EXTERNAL LIGHTING	TEL																
11512	CONSTRUCT FENCING 10 SHAFT WOR	T +																
11513	CLEAR SITE	T +																
11514	HAND OVER NO.10 SHAFT WORKSHOP	T C																
		T																
	Weekno:	23	42	8	26	45	11	29	48	15	34	51	18	37	3	22	40	6

KEY: E = Early, L = Late, + = Overlap, C = Critical, A = Actual, T = Timenow, . = Non-worked

Bar Chart R11

CRITAL ACTIVITIES REPORT UP TO 99 DAYS FLOAT

SHAFT WORKSHOPS (5841)

WORK ITEM	DESCRIPTION	DUR	EARLY START	EARLY FINISH	LATE START	LATE FINISH	FLOAT	CODE	CAL	DATE TYPE	TRADE TYPE
11514	HAND OVER NO.10 SHAFT WORKSHOP	6	10/ 2/87	16/ 2/87	10/ 2/87	16/ 2/87	0	F	1		C5
11451	POUR CONCRETE COLUMNS & GROUND ALLOW FOR CURING	10	1/ 9/86	11/ 9/86	8/ 9/86	18/ 9/86	6		1		C5
11452	BACKFILL COMPACT & POUR FLOOR	10	15/ 9/86	25/ 9/86	22/ 9/86	2/10/86	6		1		C5
11453	ERECT STRUCTURAL STEELWORK	54	26/ 9/86	27/11/86	3/10/86	4/12/86	6		1		C5
11454	PAINT STRUCTURAL NO.10 SHAFT W	12	3/10/86	16/10/86	10/10/86	23/10/86	6		1		[illegible]
11465	BUILDING BRICKWORK ALLOW FOR P CONDUITS	6	17/10/86	23/10/86	24/10/86	30/10/86	6		1		A5
11511	COMPLETE INTERNAL FINISHES ELE	54	24/10/86	12/ 1/87	31/10/86	19/ 1/87	6		1		A8
11512	CONSTRUCT FENCING 10 SHAFT WOR	12	13/ 1/87	26/ 1/87	20/ 1/87	2/ 2/87	6		1		C5
11513	CLEAR SITE	12	26/ 1/87	2/ 2/87	27/ 1/87	9/ 2/87	6		1		C5
11521	COMPLETE INTERNAL FINISHES PLU	50	24/10/86	7/ 1/87	5/11/86	19/ 1/87	10		1		A6
11466	COMPLETE BRICKWORK NO.10 SHAFT	30	24/10/86	27/11/86	5/12/86	26/ 1/87	36		1		A5
11551	PREPARE S R FOR EXTERNAL LIGHT	6	1/ 9/86	6/ 9/86	14/10/86	20/10/86	37		1		E2
11552	PREPARE TENDER DOCUMENTS FOR E LIGHTING	18	8/ 9/86	27/ 9/86	21/10/86	10/11/86	37		1		E3
11553	CALL TENDERS FOR EXTERNAL LIGH	12	29/ 9/86	11/10/86	11/11/86	24/11/86	37		1		E3
11554	ADJUDICATE TENDERS EXTERNAL LI WORKSHOP AREA	6	13/10/86	18/10/86	25/11/86	1/12/86	37		1		E3
11555	PLACE THE ORDER FOR EXTERNAL L WORKSHOP AREA	3	20/10/86	22/10/86	2/12/86	4/12/86	37		1		E3
11556	FABRICATE & DELIVER EXTERNAL L WORKSHOP AREA	30	23/10/86	26/11/86	5/12/86	26/ 1/87	37		1		E3
11566	INSTALL ALL EXTERNAL LIGHTING AREA	12	27/11/86	10/12/86	27/ 1/87	9/ 2/87	37		1		E5
11534	ADJUDICATE TENDERS O/H CRANE	6	1/ 9/86	6/ 9/86	27/11/86	3/12/86	75		1		M3
11535	PLACE ORDER FOR O/H CRANE	3	8/ 9/86	10/ 9/86	4/12/86	6/12/86	75		1		M3

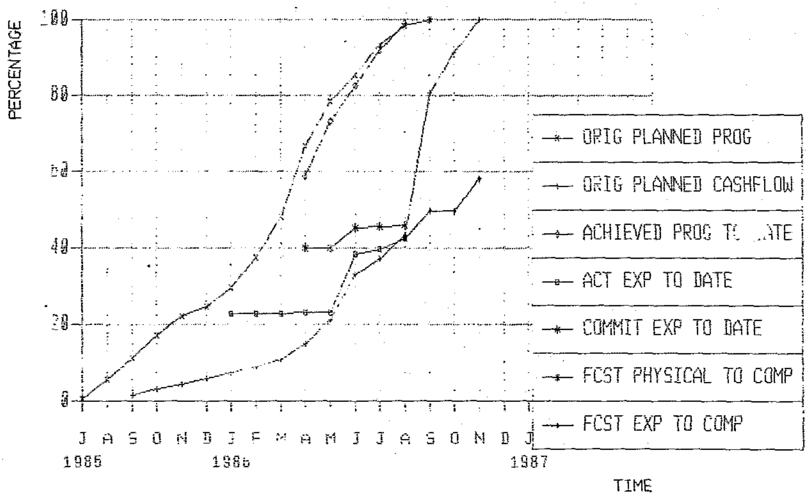
Critical Path R12

YVCP01,86.258,14:20:23,YVCP01.CENFILE.REF

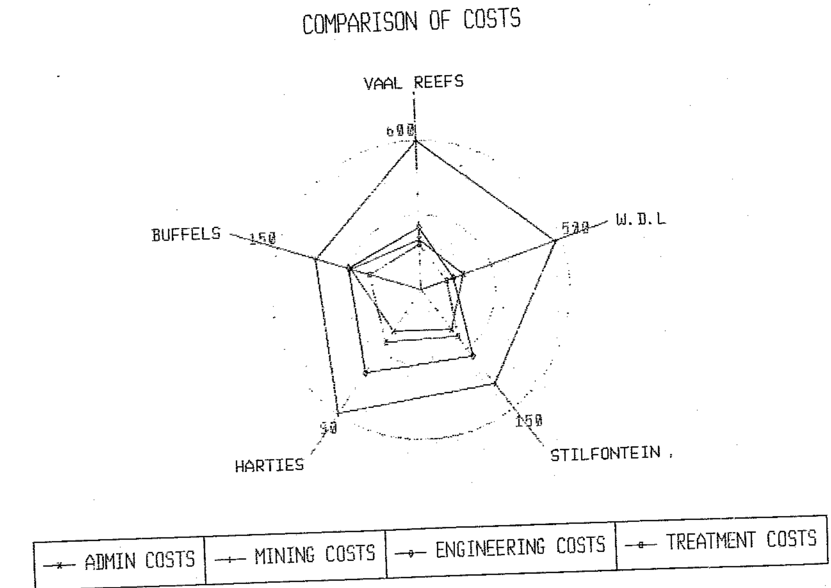
Page 1 PLOT POINTS 15 SEP 86 14:20

MONTH	ORIG PLAN CASHFLW %	ORIG PLAN CASHFLOW AMT	FCST EXP TO COMPL %	FCST EXP TO COMPL AMT	ACT EXP TO DATE %	ACT EXP TO DATE AMT	COMMIT EXP TO DATE %	COMMIT EXP TO DATE AMT
85 OCT								
85 NOV								
85 DEC	14.327	108254.12						
86 JAN	56.909	429999.19			40.953	309440.19		
86 FEB	71.167	537733.02			44.063	332936.78		
86 MAR	79.959	604164.35			51.226	387062.78		
86 APR	88.171	666214.99			51.315	387735.98	45.854	346469.79
86 MAY	94.228	711986.33			57.012	430783.33	86.623	654523.34
86 JUN	96.557	729579.56			79.486	600596.61	81.690	617244.14
86 JUL	99.047	748395.31			79.244	598769.02	80.584	608890.03
86 AUG	100.000	755597.00	79.799	602962.92	79.799	602962.92	81.139	613083.93
86 SEP			81.301	614306.46				
86 OCT								
86 NOV			89.677	677598.95				
86 DEC			96.062	725844.62				
87 JAN			96.062	725844.62				

S-Curve Plot Points R13

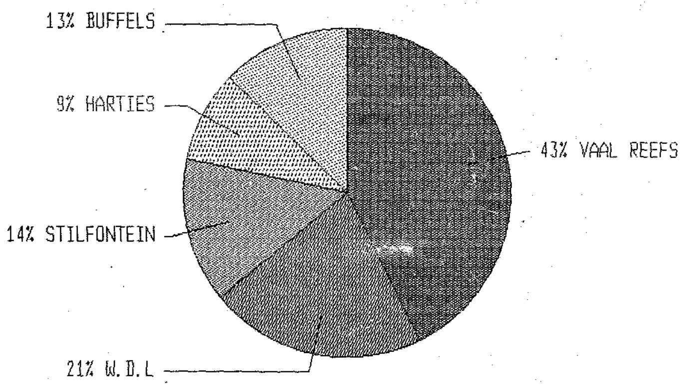


FORECAST AND ACTUAL EXPENDITURE
ESCOM YARD (8850)



Radar Chart RF1

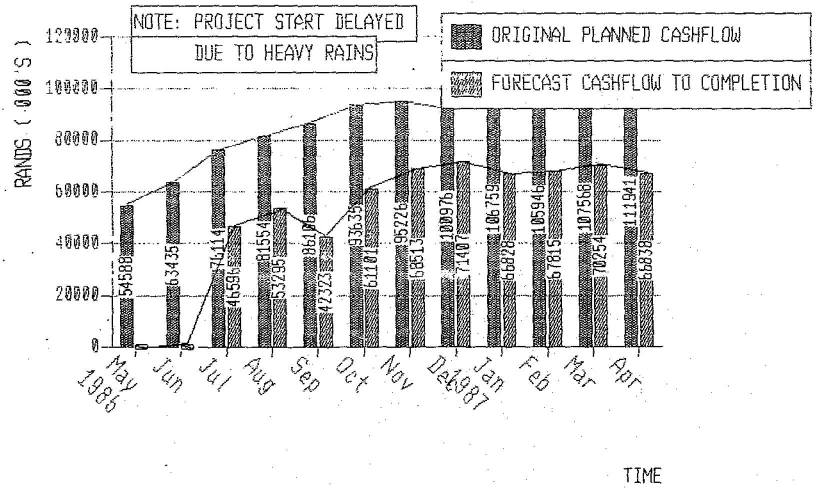
COMPARISON OF COSTS

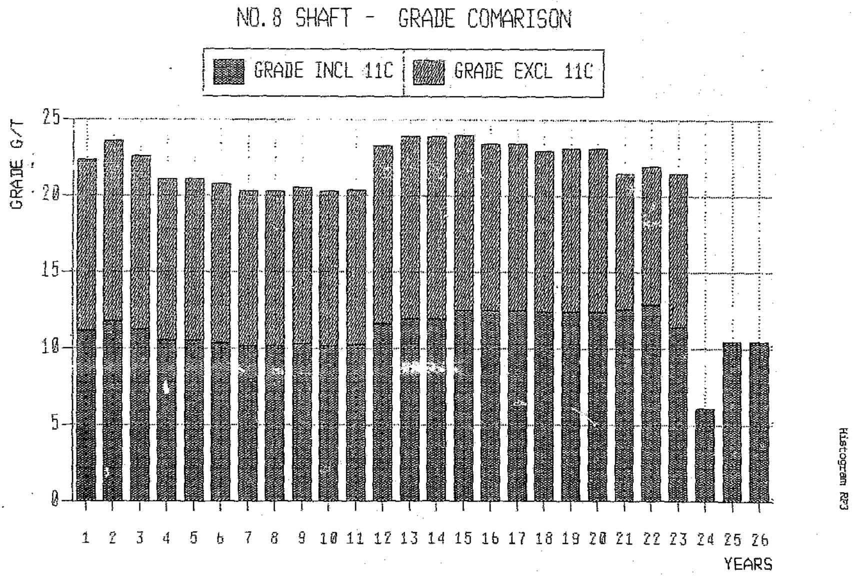


Pie Chart RF2

Histogram RF3

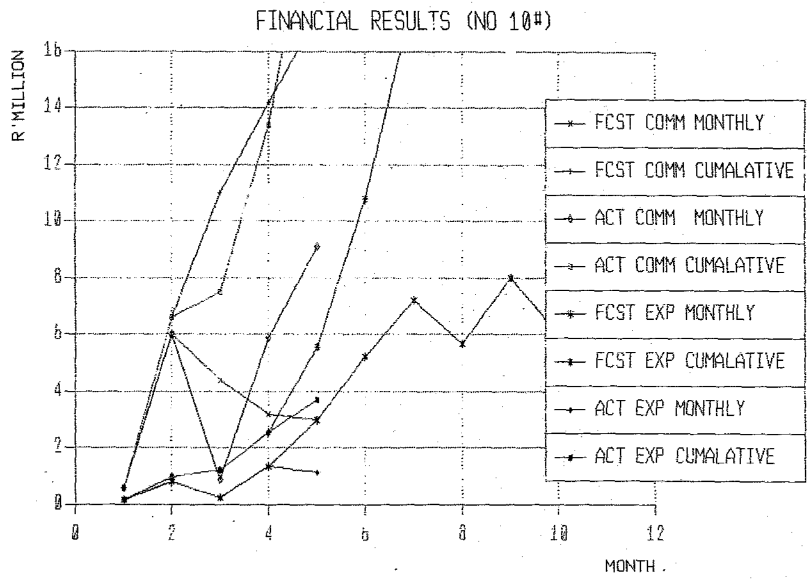
FORECAST OF CASHFLOWS (ORIGINAL VERSUS CURRENT)
SITE ESTABLISHMENT (ESTIMATE 3399)




NO. 8 SHAFT - GRADE COMARISON
GRADE INCL 11C
GRADE EXCL 11C
GRADE G/T
25
20
15
10
5
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26
YEARS
Histogram RP3

Column Identification

(1) 1986	(2) 1987	(3) 1988	(4) 1989	(5) 1990	(6) 1991
(7) 1992	(8) 1993	(9) 1994	(10) 1995	(11) 1996	(12) 1997
(13) 1998	(14) 1999	(15) 2000	(16) 2001	(17) 2002	(18) 2003
(19) 2004	(20) 2005	(21) 2006	(22) 2007	(23) 2008	(24) 2009
(25) 2010	(26) 2011				



Plot Graph RF4

8. RUNNING THE SYSTEM

8.1 STAFFING AND TRAINING

The project team listed in section 1 contained two temporary members, co-opted onto the team for the sole purpose of developing the system. L Jacobs, Assistant Cost Accountant and J Smit, System Analyst, basically set the system up as per the requirements originally set by the project team, trained the System Controllers, Planners and Estimators, and Project Management. Thereafter they were available in an advisory and trouble-shooting capacity only. The System Controllers had had extensive computer keyboard experience and project planning experience with other systems (K and H and GC CUE). The balance of the project team had considerable experience in project management in Anglo American and knew the deficencies of the current systems well.

All members of the project team plus all Planners and Estimators on the project attended the following IBM courses.

Basic AS
Intermediate AS
Project Control using AS

L Jacobs and J Smit attended more specialised AS courses.

Project Management on the two new shaft projects and senior management on the rest of Vaal Reefs were exposed to in-house seminars and presentations given by the original AS project team.

8.2 PROGRESS UPDATING

As work progresses the real situation does not necessarily adere to the plan ie., work is either on schedule, behind schedule or ahead of schedule. The network must be constantly updated to reflect a true picture of the status of the project. Progress is fed into the network for each activity after which the network is re-scheduled. This progress update is done on the activity file of the network. The following fields of the activity file are involved in progress updating.

1. Actual finish
2. Duration left
3. Percentage complete

If a specific activity has started but not yet completed, the duration left is updated.

Once progress updating is done (normally weekly) a time analysis is run to calculate the new start and finish dates.

8.3 TREATMENT OF ESCALATION

It is first important to draw the distinction between post-contract escalations and pre-contract escalations.

Approximately 92 % of all contracts placed by Vaal Reefs do not incur any claimed escalation (post-contract escalation). From this it is evident that this is built into the prices quoted.

Estimates based on costs as at "time now" are heavily hit over the ensuing period when orders are placed (pre-contract escalation).

It was essential to make due allowance for escalation over the prescribed project phase construction period and instigate rigid control measures for the identification and reporting of escalation.

Escalation is calculated for the duration of the phase in accordance with the AAC Economic Consultant's indices which are applicable to different categories of work, e.g., mechanical, electrical, civil etc. Such escalation was calculated on the projected forecast of cash flow for the phase.

Pre-contract escalation (referred to as "disguised" escalation)

This was calculated by a study of each contract and de-escalated back to base date using the ruling indices. This escalation value was allocated to a specific job number reserved only for escalation, and the balance (base contract value) to its respective job.

Commitments and payments were reflected accordingly in both the escalation and base contract por ons.

The final cost estimate less expenditure to date indicates the forecast of escalation to complete the network.

Mine charges are de-escalated on a three-monthly basis.

Post-contract escalation (-often referred to as "claimed" escalation)

This is invoiced directly by the vendor as per a preset agreement, and is booked directly to the escalation job.

These different forms of escalations are given item numbers but stay under the overall escalation job number.

ie., Job No. / Item No.

9980/001	- *Pre-contract* escalation
9980/01$	- Mine charges
9980/002	- Post-contract escalation
9980/09$	- Total escalation estimates

Mutliple orders can thus be accommodated *within their respective* categories by the use of different item numbers, together with their sub-item numbers.

S-Curves can be drawn to job level and can thus be done for escalation per estimate (or for the total project).

o.4 PROBLEM AREAS

8.4.1 CPIS ledger update

Prior to the AS Project Control system existing, CPIS was loaded monthly. However, as the AS system made available an on-line up-to-date predictive system, *its validity* depends on information it gets fed from CPIS. It soon became obvious that to derive maximum benefit from AS, CPIS would be *required to be updated* weekly.

This initially infringed on other financial systems in use at Vaal Reefs, but this has now been sorted out and is being done.

Mine charges, such as stores and payroll, are fed in on a pro-rata weekly basis and updated with actuals at the month end.

8.4.2 Costs

The system is proving expensive. AS is an interactive type system and it appears that the programme written to interface with CPIS worsens this problem.

After the system has been in operation for six months ie., in January 1987, the system costs will be fully audited.

Meanwhile, as it appears that it is the consolidation of the S-Curves that is very costly, this will only be done at estimate level and not at job level.

8.4.3 System Problems

Fixing S-Curves - original planned S-Curves and actual to date curves were being changed by new inexperienced operators. Security has now been built in to the system to make this impossible.

Error tracing - edit procedures have now been incorporated in order to trace input errors in logic or coding.

Negative float - negative float can be tolerated in some systems when an activity is required to finish before its target date. This is not so with AS as it can be caused by logic errors in the network ie., incorrect relationships. The Planners have now learnt to eliminate this.

8.5 BENEFITS

8.5.1 Predictive Ability

As the cash flows are now based on a tangible plan with a direct link into the estimate they are now meaningful, provided that the plan is realistic and up-to-date, and that the estimate was based on sufficient front-end engineering being available when it was compiled.

8.5.2 Discipline

The cash flow cannot be changed without changing the plan or the final cost estimate.

The plan has to be updated weekly or project management is provided with "old" information.

The plan and the estimate must be compiled in conjunction with one another; which gives meaning to the old saying "time is money". This leads to a unified Project Services Department with the Planners and Estimators working very closely together.

9. OTHER CAPITAL CONTROL CONSIDERATIONS

During the implementation of the CPIS/AS system for the Moab and Goedgenoeg projects the author was given the task of setting up the total capital control system for these projects. The two tasks are obviously closely interlinked. The following sections outline the basics of the capital control system introduced.

9.1 PAST EXPERIENCE

Long duration capital projects have been characterised by major variances between the original cost estimate and the final actual expenditure. The main reasons for these variances are to be found in poor definition, limited front-end engineering and inadequate cost control.

Invariably, Board approval is acquired with very limited detailed engineering design. Civil designs must follow detail mechanical designs and are therefore rarely available in time for Board approval. Architectural design generally follows both mechanical and civil design and this once again tends to result in poor cost estimating.

Board authorisation in the early stages of a project makes available large sums of money during the design stage. Under these circumstances highly skilled design teams will tend to produce technical standards beyond the required scope of the project.

Changing technology also tends to bring about major scope changes and unless carefully controlled can result in significant increases to total project cost. The longer the project endures, the less likely it is that the original project D.C.F. yield will be achieved. The Goedgenoeg project will take 8 years, and Moab

12 years, from initiation to start of production. Reporting systems previously used were designed to facilitate the collection of expenditure rather than provide controls against definite targets and well designed budgets. Annual expenditure control is in itself not an effective monitor and must be linked to measurable physical progress.

9.2 PROBLEM DEFINITION

Clearly the problems which have hampered the control of long duration projects stem from the inability to complete project definition and detail design prior to Board approval. The disadvantages associated with achieving complete project definition prior to Board approval would be the high cost and time element associated with such an exercise. Total project time would be extended resulting in potential loss of an early project return. It does not make financial or technical sense to detail design for 5 or 6 years ahead of time.

Decision-making would move into the hands of designers, who do not always possess the desired experience. The benefits of contractor participation in both design and planning stages would not be available or utilised at such an early stage.

The solution to adequate cost estimating and control lies somewhere between the two extremes and can be largely overcome by the phasing of the projects.

9.3 PHASING OF THE MOAB AND GOEDGENOEG PROJECTS

The control system to be used includes the sub-division of the projects into a series of phases. Each phase will be defined, by estimate, as a logical division embracing a specific responsibility area.

Adequate project definition is possible, provided that the project time base is sufficiently short to allow detailed planning and design to be carried through to completion. Such a time scale will vary from 12 - 15 months.

Escalation estimating becomes more realistic in that base figures are more accurately established, annual performance is estimated with a fair amount of accuracy and inflation rates are only predicted over a relatively short period of time.

Logically, therefore, it becomes necessary to consider phases in a series of time periods, each having a maximum duration of 15 months. These phases will be drawn from the project network logic and measurable end points or milestones fixed accordingly.

For senior management and Board control, phases will be closed to the Board in the same manner in which projects are currently closed, ie: a full reconciliation of actual expenditure with authorised expenditure at the completion of each phase.

The estimated project total will be updated monthly, reflecting closed phases, current phases and unapproved phases to project completion.

The resultant updated project estimate will be continuously compared to the original escalated feasibility study class I or II estimate.

This approach will allow the project team to be in a position to supply well defined and detailed class III estimates for Board approval. Control against budgets will also be effective.

When phasing the estimates within projects, realistic targets will be set to ensure that all work can be completed within the prescribed time period of the phases. These activities will be recorded in a phase definition file.

In the event that all items within the phase definition cannot be completed within the prescribed period of the phase, then that phase will remain open until such items are completed.

Only under exceptional circumstances will uncompleted work be transferred to a new phase.

A phase will be presented for approval to the October Board meeting of any year and will only be officially closed at the October Board meeting of the second year, provided all items in all estimates have been physically completed and accounted for financially.

When all physical activities within an estimate have been completed the estimate will be closed internally at the end of its respective calendar year. A phase will only be closed when all estimates within that phase have been closed.

9.4 ESTIMATES FOR APPROVAL

Only class III or class IV estimates will be submitted for Board approval based on initial design being completed and realistic costs of plant, equipment and labour included in the estimates. Estimates of cost will be prepared in accordance with standard estimate frameworks for various types of operations and commodities in accordance with the CPIS ("Capital Projects Information Systems") capital code.

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