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Heilbrunn, Bernhard Emil

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A REVIEW AND ANALYSIS OF SOFTWARE AVAILABLE FOR PROJECT MANAGEMENT ON PERSONAL COMPUTERS

Bernhard Emil Heilbrunn

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

Johannesburg, 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.

31 July 1986.

ABSTRACT

Current micro - computer based project management software is based on the concept of a fully integrated project management information and control system. This represents a major advance away from the project scheduling and planning package that was available for project managers up until a few years ago.

The purpose of this project report is to :

1. Describe project management information and control systems.
2. Lay down ground rules for project management system software selection.
3. Analyse current software usage in the service sector, the construction industry, and in maintenance engineering.
4. Evaluate some currently available software.
5. Provide recommendations as to project management systems and to suggest future trends for such systems.

Research methods involved learning to use various systems. Furthermore, discussions were held with individual project managers as well as project engineering consultants. Other sources of

information were obtained from recently published local computer and construction industry journals as well as technical publications.

The project management information and control system should be regarded as a tool that is indispensable when administering a complex project. The selection of such a system however should be based on a number of criteria relating to the organization and the projects it undertakes.

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To my parents.

ACKNOWLEDGEMENTS

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CONTENTS Page

DECLARATION ii

ABSTRACT iii

DEDICATION v

ACKNOWLEDGEMENTS vi

CONTENTS vii

LIST OF FIGURES xi

LIST OF TABLES xii

1 *INTRODUCTION* 1

1.1 A History of Project Scheduling and Controlling 1

1.1.1 Programme Evaluation and Review Technique 2

1.1.2 Critical Path Method 4

1.1.3 Activity on Node Networking 5

1.2 The Project Management Environment 6

1.3 *A Critical Look at CPM* 11

1.3.1 Perceived Disadvantages of CPM 12

1.3.2 The Capabilities of CPM in Fulfilling Planning and Control Functions 14

1.3.3 Conclusion 16

1.4 Suggested Further Re 17

CONTENTS

		Page
2	PROJECT MANAGEMENT INFORMATION AND CONTROL SYSTEMS	19
2.1	*The Information System*	22
2.2	The Control System	27
2.3	Suggested Further Reading	29
3	PROJECT MANAGEMENT SOFTWARE ANALYSIS	30
3.1	*The System Programme* Plan	30
3.2	Project Management Software	32
3.3	Discussion	39
4	COMPUTERISED PROJECT MANAGEMENT IN PRACTICE	41
4.1	*Project Management* Computer Software	41
4.2	A Profile of the Computerised Project Management Organization	44
4.2.1	Company Size	44
4.2.2	Project Size	45
4.2.3	Company Structure	45
4.2.4	Staff Involvement	46
4.3	Current Practices in the Construction Industry	48
4.3.1	Introduction	48

CONTENTS

		Page
4.3.2	Current Issues in Computerised Project Management	49
4.4	Project Management in the Service Sector	50
4.4.1	The Hospital Environment	51
4.4.2	Current Issues in Computerised Project Management	52
4.5	Project Management in Maintenance Engineering	53
4.5.1	Introduction	53
4.5.2	Current Issues in Computerised Project Management	54
4.6	Conclusions	56
5	CONCLUSION	57
5.1	Trends in Project Management Software	57
5.1.1	Interactive Decision Support Systems	57
5.1.2	Expert Systems	58
5.2	Summary and Recommendations	60
5.3	Suggested Further Reading	62
APPENDIX A	INTEGRATED PROJECT MANAGEMENT SYSTEM - APPLICATION EXAMPLES :	64
	PROCUREMENT COST FORECASTING	64
	MATERIALS CONTROL	66
	PROGRESS AND EARNED VALUE ANALYSIS	68

CONTENTS

		Page
APPENDIX B	FUNCTIONAL SPECIFICATIONS FOR :	
	SCHEDULING AND PLANNING	70
	DATABASE	74
	SPREADSHEET	78
APPENDIX C	DEFINITIONS OF SCHEDULING SOFTWARE ATTRIBUTES.	82
REFERENCES		88

LIST OF FIGURES

Figure		Page
1.1	The Evolution of Network Analysis	7
1.2	CPM in Relation to Other Manufacturing Strategies	10
2.1	Information System Software Configuration	24
A1	Procurement Cost Forecasting	65
A2	Materials Control	67
A3	Progress and Earned Value Analysis	69

LIST OF TABLES

Table		Page
3.1	Schedule Type System - Software Specifications	35
3.2	Schedule Type System - Network Specifications and Hardware Requirements	36
3.3	Integrated Type System - Software Specifications	37
3.4	Integrated Type System - Network Specifications and Hardware Requirements	38
4.1	Use of Computerised Techniques as a Function of Project Size	45
4.2	Percentage Breakdown of Disciplines Involved in the Decision Making Process	47
4.3	Percentage Breakdown of those Responsible for Project Software	47

LIST OF TABLES

Table		Page
3.1	Schedule Type System - Software Specifications	35
3.2	Schedule Type System - Network Specifications and Hardware Requirements	36
3.3	Integrated Type System - Software Specifications	37
3.4	Integrated Type System - Network Specifications and Hardware Requirements	38
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4.3	Percentage Breakdown of those Responsible for Project Software	47

1 INTRODUCTION

1.1 A History of Project Scheduling and Controlling

With the increasing sophistication of technology, has come the necessity to administer ever larger and more complex projects. The quest has been on since the turn of the century to put managers in a position to do this. High technology has, over the past decade, been harnessed to control the projects it made possible.

A type of bar chart, developed around 1900 by Henry Gantt, was the first attempt at a formal procedure to aid in the management of projects (1). Although still considered a useful tool, the Gantt chart is inadequate as a means of depicting interrelationships between project activities. This inadequacy was overcome by Karol Adamiecki in 1931 (2). He developed a methodology in a form he termed the Harmony graph - essentially a rotated bar chart with a vertical time scale, a column (movable strip) for each activity and a means of showing activity interrelationships. This contribution to project management has, however, always been overlooked.

A further three project management techniques came into existence after World War II. These original systems were developed and adapted to suit different circumstances. There are now, in existence, a large number of acronyms which refer to various systems derived from the original ones :

1. Programme Evaluation and Review Technique (PERT)
2. Critical Path Method (CPM)
3. Activity - On - Node

1.1.1 Programme Evaluation and Review Technique

The theory and operating techniques of PERT were developed by the Special Projects Office of the United States Navy. This office, concerned with the development of complete weapons systems, was in 1956 given responsibility for the Fleet Ballistic Missile (Polaris Submarine) Programme. In December) ~search team was set up by the Special Projects Office to ~p a system of progress evaluation for the Polaris project (3). Two contractors participated in the team : Booz, Allen and Hamilton Management Consultants and the Lockheed Missile and Space Division - main contractors for the missile.

After overcoming a considerable number of difficulties the decision was taken in October 1958 to implement PERT on the complete Polaris project. By mid 1959 the technique was in operation in most areas of the weapons programme; 23 networks covering a total of more than 2000 events were installed and operating (4).

The part played by PERT in the ultimate success of the Polaris project cannot be evaluated, but the programme was a particularly succesful one from the point of view of both technical achievement

and project management. PERT was credited by those managing the programme with making it possible for the navy to produce an operational, ballistic missile firing submarine years ahead of schedule (Archibald op cit).

The exposure of private industry to the use of PERT, initially through defence contracts, led to its increasing adoption, sometimes obligatory, by organizations in the commercial and industrial areas.

The characteristics of the PERT approach were its identification of events rather than activities in the construction of the network as well as the use of three time estimates for activity duration. The project for which PERT was developed was a research and development one in which a high degree of uncertainty existed about how long activities would take to complete, and even what these activities involved. Hence three time estimating was used in order to quantify this uncertainty and to help disassociate the engineer from his knowledge of the existing schedule (McLaren op cit).

Following upon the success of PERT, the U.S. Department of Defence initiated the design and development of a system for integrating the time data available from the PERT system with associated financial data to provide a means of cost control. By 1964 the use of the PERT/cost system had become obligatory for certain research and development projects (5) and interest in it was growing in private industry, particularly in the civil engineering field.

1.1.2 Critical Path Method

CPM was developed by E.I. du Pont du Nemours and Co. of America. In late 1956 the Integrated Engineering Control Company of du Pont initiated a survey of the prospects of applying computers as an aid to coping with the complexities of managing engineering projects. Assistance was obtained in this from Remington Rand (Archibald op cit).

After an analysis of the traditional approaches to planning and scheduling, a new approach was developed. This involved the construction of an abstract model for a project which represented the activities and the relationships between them in the form of a network diagram (McLaren op cit). By associating time and costs with each activity it was found possible to present to management a range of possible schedules each with a known project duration and cost. This technique was given the name Critical Path Method because of the important part played by the critical activities in the method.

The important aspect of CPM lies herein. Initially a project cost for the project duration based on normal times is derived. A reduction in the total project duration is then produced by expediting those critical jobs that raise project cost at a minimum rate (otherwise known as project " crashing ").

In general, applications of this technique have concentrated on the more fundamental aspects of the construction of the network and the identification of the critical path. The reasons for this being the

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difficulty in gathering basic cost data (Kerzner op cit). Thus while certain users, particularly civil engineering contractors, attempted to adopt the approach in full, the majority have been content to use CPM as a basic planning and control tool without becoming involved in the cost aspect of the technique.

In this respect there were obvious similiarities between CPM and PERT. As each became modified through usage, the distinctions between the two, at least in practice, largely disappeared.

1.1.3 Activity - On - Node Networking

The activity - on - node network or activity box method differs from PERT and CPM in the diagrammatical representation of the network, being merely the reversal of these two. In this case nodes on the diagram represent activities, while connecting arrows denote precedence relations. Also early and late start times for activities are calculated, instead of event times.

This method has certain advantages. In particular :

1. Complex relations between activities are more easily drawn since no dummy arrows are required.
2. The time analysis procedure gives the activity times directly instead of via the event times, and these activity times appear on the network.
3. Many managers agree that the concept of activity-on-node network is easier to grasp than that of the activity on arrow network (6).

4. Modification and correction of activity-on-node networks is easier than for activity-on-arrow networks (6).
5. A line that connects two activity nodes can have a time duration. This feature tends to reduce the number of activities that must be included in a network (6).

The main disadvantage of the method is the concentration of all the data, other than perhaps the activity duration, in the nodes or boxes.

An extension to the original activity-on-node concept called precedance networking appeared around 1964 in the users manual for an IBM 1440 computer program (7). Extensive development of this procedure has since been conducted by K.C. Crandall (8). This procedure extends the PERT/CPM network logic from a single type of dependancy (the basic finish to start relationship) to include three other types. These are the lead/lag dependancies : start to start, finish to finish and start to finish. These lead/lag relationships allow for a very much more realistic representation of the linkages between activities in a project. Figure 1.1, based on McLaren's (op cit) diagram shows the evolution of network based project planning and control systems from the early beginnings through to todays computerised management information and control systems.

1.2 The Project Management Environment

The environmental conditions where project management techniques may be used are many and varied. It is crucial however to ascertain

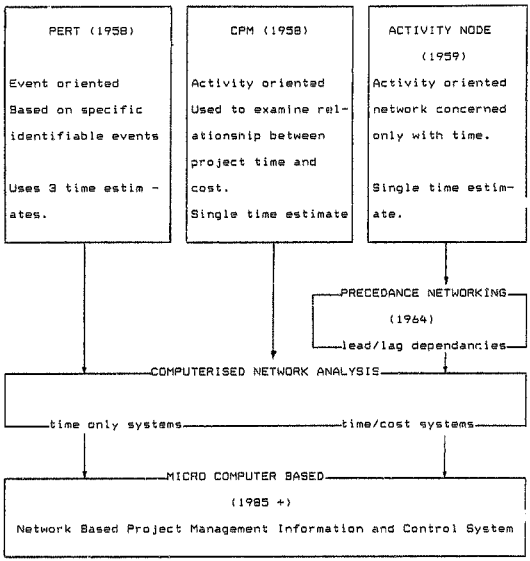


Figure 1.1 The Evolution of Network Analysis

whether the environment one is concerned with will support project management methods before one decides to implement them. Cleland and King (9) give the following checklist to determine whether project management techniques may be employed in a particular organization:

1. Magnitude of the effort - " When an undertaking requires substantially more resources (people, money, equipment) than are normally available in the business, project techniques are clearly required. "

2. Unfamiliarity - " An undertaking is not a project unless it is something out of the ordinary, different from a normal, routine affair in the organization. The overhaul of a major product ..., would probably require project management." In this case : "...the changes in cost, schedule and technology would require a central management office (a project office) to bring together the functional activities required and relate them for compatibility."

3. Interrelatedness - " Another decisive criterion for establishing a project is the degree of interdependence existing between the tasks of the effort. If the effort calls for many functionally separated activities to be pulled together, and if these activities are so closely related that moving one affects the others, project techniques are clearly needed."

4. Organizational reputation - " The organization's stake in the undertaking is a crucial factor in the decision of whether or not to use project techniques...if a failure to complete a contract on time and within the cost and performance limits would seriously damage the company's image and result in stockholder dissatisfaction, the case for using project management is strong."

It is important to realise that no company would take a purely project or purely functional approach. Project management is not the answer to all problems. Most companies are a mix of the two, tending more toward one or the other depending on the work environment. In some cases a project may take on the characteristics of a permanent functional organization.

Cleland and King (op cit) list a number of other circumstances under which project management techniques would be desirable :

- where a multilateral objective exists, toward which many people and many relatively independant organizations work together.

- where there are pressures to improve the product and/or to advance the state of the industry.

- where plans are subject to change, requiring organizational flexibility.

- where risks are high and prediction of the future is made with a high degree of uncertainty.

- where project integration requires the concurrent contribution of two or more functional departments.

- where the project is of a type requiring feasibility studies.

Bolander (10) gives the following diagram upon which can be clearly shown the position of the project management approach in relation to other types of manufacturing strategies :

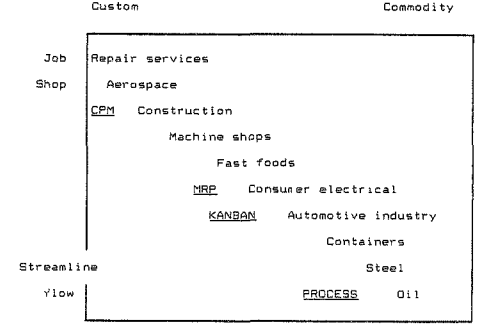


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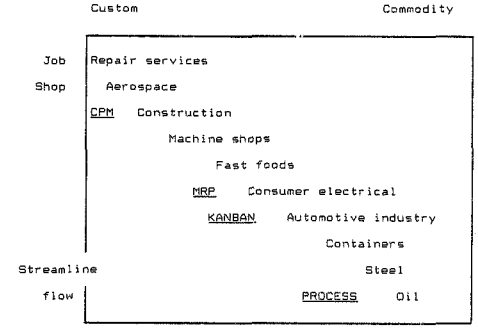


Figure 1.2 CPM in Relation To Other Manufacturing Strategies.

It is the author's opinion that with the release of the latest generation of project management software, the lines of demarcation between this strategy and other manufacturing management strategies are not as clear as they once used to be. This is the result of two factors:

1. The enhanced speed and capacity of computer processing having been made available, via the microcomputer, to all levels of end user.
2. The trend in the domain of project management software to integrate the many disciplines that comprise the complete project (e.g. scheduling, materials control accounting etc.) into one central project management information and control system.

1.3 A Critical Look At CPM

The construction and civil engineering industries, having had the most exposure to project management with CPM, are the industries to which I have referred in determining what criticism there is of CPM.

Koontz, et al (11) and Jaafari (12) list the following important functions for planning in general :

1. Offset uncertainty and change.
2. Focus attention on objectives.
3. Gain economical operation.

4. Facilitate control.
5. Allocate contractual responsibilities.
6. Provide for clear lines of communication.
7. Co-ordinate contributions from various groups.
8. Resolve delay and change order disputes on a pre-defined, quantifiable and equitable basis.

1.3.1 Perceived Disadvantages of CPM

A number of arguments have been put forward in recent years advocating the replacement of CPM with other scheduling techniques. The reasons advanced to support these arguments are as follows :

1. The basic assumptions of project activities having fixed time and discrete nature are unrealistic (13,14).
2. Construction planning, essentially involves giving equal attention to all, and perhaps making most activities or processes critical (cost wise), and not just determining an incidental path related to the activity durations (13,14).
3. Resource allocation, smoothing or leveling procedures are incapable of ensuring full continuity for a production crew or process, which is the backbone of operational planning in construction processes, especially in repetitive cases (13,14).
4. CPM scheduling is expensive to run. Status reports take time to reach managers and, by the time they receive these the information contained in them, tend to be out of date (15).

5. Practical integration of CPM based progress and cost control has been extremely difficult, expensive and nonproductive (16).

6. In the case of linear projects (e.g. highways, pipelines etc.) it is advantageous to use linear scheduling method instead of CPM (13,17).

The abovementioned problems are however not problems inherent to CPM but arise rather as a result of the erroneous ways in which CPM is applied in practice. Jaafari (op cit) explains why these problems manifest themselves and how they can be avoided :

1. The concept of assuming a project comprising a set of discrete interfaced activities in which each activity may contain a stream of similiar operations is valid providing :
   Realistic estimations of the productivity of crews is made (see Jaafari for a detailed discussion of this plus job management efficiency factors) and
   Sufficient time buffers between dissimiliar trades is included; this to simulate actual field conditions which indicate delay in startup of new operations

2. As preferances are often reflected in the interfacing of activities, some for pure convenience others for economical reasons, the point may be concluded that planners induce their own critical path through the set of decisions they make at the time of planning. Thus the critical path is neither irrelevant nor incidental.

3. Resource allocation procedures are valid if activities are interfaced so as to secure a continued passage of work for crews. Thus continuity of work should be ensured as far as possible.

4. In reporting of project status , the problem does not lie so much with CPM as it does in the amount of effort needed to verify the situation. By the time progress on a particular activity is recorded and analysed in project terms, very little work remains for that activity.

5. Jaafari agrees that the problem of the integrated progress/cost control CPM system, although not insurmountable, still exists. It is evident however from software released since the publication of his article that this problem has been significantly reduced.

6. CPM is most useful in linear projects. This is because they are "... seldom as uniform in cross section or material composition as they first appear to be." Thus one can divide linear structures into discrete sections; continuity of work of a crew can be maintained by linking the end of the work in one section to the start in another (see also 1.4 O'Brien et al)

1.3.2 The Capabilities of CPM in Fulfilling Planning and Control Functions

Jaafari concludes that CPM is indeed capable of fulfilling the

required functions :

1. Offsetting Uncertainty and Change - If activities are planned in broad terms the CPM schedule will be less sensitive to variations in daily performance. Major disturbances can be easily measured by this tool, and the effects expressed in units of time and money.
2. Focusing Attention on Objectives - As a major emphasis in CPM scheduling is on criticality of the project duration, it will naturally concentrate attention onto criticality of principal operations.
3. Gaining Economical Operation - Site productivity must be monitored using work sampling techniques to ensure that planned processes are effective. If a particular process planned beforehand was found to be expensive or incapable of meeting the schedule date , improvement may be sought. Emphasis must be placed on continuity of work of crews when considering the processes and sequence of activities.
4. Facilitating Control - Control here means not only control of the actual performance of crews on site, but also items such as provision for materials, shopdrawings, cash flow etc. As has been confirmed by many authors (e.g. Melin, et al (18)) there is no alternative method for control of the total process but a logical network.
5. Allocating Contractual Responsibilities - As the network is an inter-related time-event model of the project, it is the best means of allocating, communicating, and

required functions :

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5. Allocating Contractual Responsibilities - As the network is an inter-related time-event model of the project, it is the best means of allocating, communicating, and

controlling contractual reponsibilities.

6. Coordinating Contributions from Various Groups - Many of the projects undertaken today are complex and require input from a variety of disciplines. The only formal method of coordinating such an extensive array of works and services is through an interrelated network of activities.

7. Resolving Delay and Change Order Disputes - The very concept of critical path can be used to resolve claims related to delays. Noncritical activities may be exempt from time extension claims up to the time they become critical. Events beyond the control of the owner and contractors qualify for contract time extension but without monetary compensation to either party.

1.3.3 Conclusion

The research of Wolf and Hauck (19) suggests that among the major advantages of CPM one could list :

1. It forces a thorough pre-planning of each task.
2. Better coordination of work to be performed is achieved.
3. Problems are resolved on paper before they occur.
4. It focuses management's attention on critical path activities.
5. The thorough pre-planning required reduces the chance of omission of a task.
6. The network diagram is a working model which may be easily understood.

7. The scope of the entire project may be readily seen on a summary network.
8. The added cost of crashing critical activities can be determined.

From all of the above one may conclude that there is nothing inherently wrong in either the CPM concept or the subsequent schedules resulting from it's analysis, the fault lies with the way it is applied in practice. For CPM planning and scheduling to fulfill the functions in planning and controlling one must pay attention to the organization, people, and their attitudes.

Involvement of people and inadequate knowledge of the future means that planning must be a dynamic process. CPM scheduling, if kept to manageable size, and operated on interactive software, can respond well to this need.

1.4 Suggested Further Reading

Harris, Robert. B.
Precedance and Arrow Networking Techniques for Construction.
(John Wiley and Sons, Inc., New York, 1978)

Moder, Joseph. J.
Network Techniques in Project Management
Chap. 16, Project Management Handbook
Edited by Cleland, D.I. and King, W.R.
(Van Nostrand Reinhold, New York, 1983)

Kerzner, Harold.
Chaps. 8-10, Project Management - A Systems Approach to Planning Scheduling and Controlling.
(Van Nostrand Reinhold, New York, 1979)

O'Brien, James. J., Kreitzberg, Fred. C., Fellows, ASCE and Mikes, Wesley. F.
Network Scheduling Variations for Repetitive Work.
Journal of Construction Engineering and Management
Vol. 111, No.2, June 1985

2 PROJECT MANAGEMENT INFORMATION AND CONTROL SYSTEMS

Before investigating the structures of project management information and control systems upon which the latest computer software is based, it must be clearly established that the need for such a system exists. In view of the large investments that have been made by corporations in the development of management information systems in recent years, one would question the need for the development of yet another system within the corporate environment.

Traditionally management information systems have been designed primarily to support functional units within the corporate structure. The computerised accounting system, the computer supported systems for marketing and sales in addition to the material requirements planning systems developed for the operational side of the business, are all examples of these. In more advanced management information systems the Data Base Management System (DBMS) has come to the fore in an attempt among other things to efficiently share information between functions. However for the most part information systems in today's corporate environment are designed to support decision making in the traditional organizational structure.

By the very nature of project management the project manager must cut across functional organization lines to accomplish his goal of integrating and directing specific organization resources towards a

specific goal. Thus the question arises as to whether he can do this effectively utilizing traditional available management information systems.

For relatively small projects the project manager acts either in a staff capacity to top management or in a line capacity within a functional organization. The project manager's information needs are limited and, generally, are of a summary nature. Even in the line function, the project manager is woking in an environment where he can rely on the information system already in place. However as projects become larger and more complex, companies establish large project organizations which function either deliberately or indirectly in matrix fashion with the total organization. In this environment project managers have attempted to carry out their responsibilities utilizing the information systems already in place. For the most part project managers have found that these information systems are severely limited. Tuman (20) lists some typical problems encountered by project managers relying on existing management information systems :

1. Usefulness - existing corporate management information systems do not generate the specific information required by the project manager and other project participants.

2. Quality vs. Quantity - too much detailed information is generated; it is difficult to get exception reports especially when several functions may be involved.

3. Integration - there is little uniformity between corporate systems. Hence it is difficult to develop a total project picture where several different companies are involved. Even within one organization's management information system it is difficult to reconcile information between diverse functions.

4. Responsiveness - the existing information systems are not structured to integrate across functions to produce timely exception reports.

One can conclude from the above that integrated information systems unique to the project management environment have become a necessity in large - project industries. In addition to this, however, one should state that the decision as to size and "integratedness' of such a system would best be taken by individual corporations on the basis of whether projects were a major or minor part of the corporate business strategy.

The project management system can be broken down into two sub - systems :

1. The information sub-system (see 2.1 below).
2. The control sub-system (see 2.2 below).

The function of control in this process is management. Management's responsibility is to allocate to the project only those resources

required /to do a good job, no more and no less. The problems thus left for management to solve are : to determine the quantity of resources to allocate to the project and to decide whether or not these resources are being used effectively in terms of project goals. This is done via outputs from the information system. It is particularly important to note that these two distinct and different elements are mutually related and dependant on each other (Tuman op cit). The information system concerns itself primarily with the task of processing data to produce timely, accurate, structured information regarding the cost, schedule, and performance aspects of the project. The control system on the other hand is concerned primarily with using the information supplied to trigger decision making and to give direction relative to future utilization of resources. Information and control systems are designed so as to be mutually compatible.

2.1 The Information System

Information system software can be sub - divided into three major categories. Figure 2.1 gives a diagrammatical representation of this breakdown.

The first is the data base management system (dbms) software which, being the heart of the system, comprises :

1. A data base containing all information related to the project. Examples of this data would be resource costs,

procurement lead times, engineering drawing register etc.

2. Data base routines which are programs written within the dbms. These routines, or application programs, by accessing the above mentioned types of data as well as the project network, allow for updating, monitoring and reporting of project disciplines. Examples of these functions are procurement cost forecasting, materials control etc.(see Appendix A for a more detailed discussion of some of these application programs).

The second is the project planning and scheduling software, and the third provides the estimating, cost analysis and project accounting function.

Each project discipline becomes responsible for inputting their own data. They can then validate their data and compare it with inputs from other disciplines. Thus for example, when an engineer changes a design, the materials quantity list produced from his manual listing automatically changes the purchase quantity requirements. The next procurement exception report will highlight the change clearly, concisely, and automatically.

Although the accounting system is designed to operate in tandem to any existing accounts department, many companies find that the interfacing of project accounting data and company general ledger accounting data is a complex and time consuming clerical process which has many anomalies and inaccuracies (Tuman op cit). This

process normally requires many years of effort.

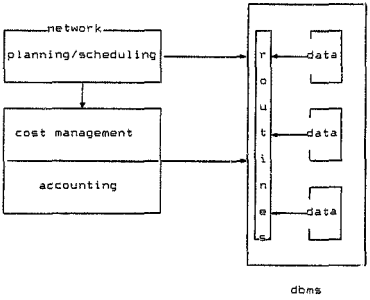


Figure 2.1 Information System Software Configuration.

Tuman (op cit) describes the various modules of an information system as follows :

1. Planning and Scheduling - This module will normally utilize CPM scheduling techniques with, as a minimum, resource levelling and target scheduling to provide the tools for planning and monitoring the project. As mentioned above information generated by this module also provides the keys for more detailed monitoring and analysis of various project disciplines (see Appendix A).

2. Estimating/Cost Management - Effective cost management for a project requires that the system provide an efficient method for making comparisons between current and budget estimates, and scheduled and actual cash flows. Typical outputs of this module, which may be derived from either spreadsheet or database software are:

Summary estimates - Detailed estimates summarized into work packages.

Updated estimate/cost report - Updated estimate, at the account level, providing a comparison of the new estimate with the previous estimate.

Functional cost report - Cost report by major functional categories.

Outstanding committment report - A comprehensive profile showing the total, actual and outstanding committment against each purchase order.

Cash requirement forecast - Cash flow forecasts over specific time periods. These periods, for example weekly, quarterly etc. are specified by the user.

The project management database system can provide comprehensive cost control mechanisms which highlight by exception, all probable overspend situations. These mechanisms operate within the integrated system by comparing probable costs, derived from manhour forecasts, bill - of - material quantities and unit rates, with the authorised levels of expenditure which are laid down against the project budget. Thus in addition to comprehensive cost reporting, the project manager also has early warning exception reports so that he can genuinely control the costs of his project.

3. Project Accounting - However this is implemented, the project will require a formalised method to monitor, record, and report all costs. In addition the final cost records, upon completion of the project, will have to be developed. Typical outputs might be :

   Commitments and invoice record of purchase orders and contracts - Used to determine the cost status of each purchase order and contract, and through appropriate coding techniques, to keep track of change orders against these orders.

   Statements of commitments and recorded expenditure - Provides a quick reference to the status of all purchase orders and contracts including base

amounts, change orders, recorded costs, remaining commitments and retentions.

Project general ledger - A detailed cost record of the project.

Statement of recorded expenditure by account - A list, at the account code level, of all actual expenditures, current estimates and current balances for the project.

2.2 The Control System

The purpose of the control system is to ensure that events conform to plan. Controlling involves locating or identifying deviations from plan and taking corrective action to achieve the desired results. To be able to control, the project manager must have some frame of reference to measure against. He should also have some way of determining when he deviates from this reference. Thus the control methods used within systems are based upon the following routine :

1. A specified expected performance.
2. Measurement of actual performance.
3. Comparison of expected to actual.
4. A deviation report to the relevant management level.

5. A developed set of accepted actions that the manager can take based on an agreed set of decision rules.

The function of the control system then is to receive inputs from the information system relative to the actual state of project progress. Generally these inputs will be in terms of the cost, schedule, and performance aspects of the project. Each discrete status input is measured against the established project plan for that period to determine if a variance exists. If variances do exist an estimate at completion may be calculated via variance analysis. One of the key parameters used in variance analysis is the earned value concept. Earned value is a forecasting variable used to predict whether the project will finish over or under budget (See 2.3, Kerzner, for a detailed discussion of variance analysis).

The tangible actions that can be initiated by a project manager to change the course of events of the project are few. The following are aspects which the project manager should look to, in attempting to influence actual schedule, costs, or performance :

1. The allocation of resources to project participants.
2. Increasing or decreasing the amount of work or the type of work to be done.
3. Establishing or changing the methods, techniques, policies, procedures and tools used on the project.
4. Modifying project plans and/or standards.

Finally, the results or outputs from the project management information and control system are decisions by project management which essentially deal with one or more of the above four factors.

2.3 Suggested Further Reading

Kerzner, Harold.
Chap. 12, Project Management - A Systems Approach to Planning Scheduling and Controlling.
(Van Nostrand Reinhold, New York, 1979, pp.426-453)

Mathews, Mark. D.
Networking and Information Management : It's Use by the Project Planning Function.
Information and Management
Vol. 10, No.1, January 1986

3 PROJECT MANAGEMENT SOFTWARE ANALYSIS

The best method of arriving at a suitable computerised project management system is to formulate a step - by - step programme plan. The object of this exercise is to define the needs of the individual project/s, to develop appropriate criteria, and then to choose the software which offers the features, options and capabilities most closely suited to management's needs. It should be sufficiently detailed to serve as a long range blue print for the total programme and furthermore it should serve as a mechanism for obtaining continued top management support. The effort will have a much greater chance of survival if top management have a good understanding of what the system will eventually do for the company.

3.1 The System Programme Plan

Tuman (op cit) regards the following elements as being the minimum which should be contained within the programme plan :

1. System Objectives - This should give a concise description of what the system is supposed to accomplish and for whom. The system objective should define the functions, disciplines and levels of management to be served by the system, as well as the types of information to be provided. One reason for establishing

system objectives is to determine the scope and complexity of the system to be developed.

2. System Criteria - Comprehensive criteria are established here to define system parameters. All the disciplines to be included in the system (i.e. planning, scheduling, estimating, accounting, cost management, materials management, etc.) should be defined, as well as the level of detail of information that will be addressed by these disciplines.

3. Work Plan - The basic segments of work related to the design, development, implementation and maintenance of the system should be spelled out here. Also, the organizational groups responsible for doing the work must be identified.

4. Schedule and Budget - A general phasing schedule covering the major blocks of work and a gross overall budget should be dealt with here.

The most important step in the succesful development of an effective information and control system is defining the nature of the system itself and the environment it must operate in. Finally, those disciplines included in the system must be closely consulted as to relevant system requirements.

3.2 Project Management Software

In attempting to provide a breakdown of project management software I have narrowed down the many features provided by the whole spectrum of packages available, to what are regarded as the most important (see Appendix B for a more comprehensive listing). The following list of 23 attributes was arrived at after many discussions with individual project managers as well as with project management and project engineering consultants. Relevant journals were also a source of information here. Refer to Appendix C for definitions of the following features :

1. Computes critical path.
2. Generates network diagram.
3. Creates a network schedule.
4. Project may be defined and administered in Work Breakdown Structure (WBS) format.
5. Schedule restraint may be specified.
6. Returns labour cost breakout.
7. Returns capital/equipment cost breakout.
8. Assign/report planned costs.
9. Assign/report actual costs.
10. Provides data windows.
11. Custom report generator.
12. Business graphics capability.
13. Provides project network.
14. Provides Gantt chart.
15. Outputs resource histograms.

16. Outputs S curves.
17. A definable project calendar.
18. A resourse levelling algorithm.
19. Sub-project capability.
20. Resource allocation by percentage.
21. Variable schedule time base.
22. Specific network format.
23. Number of tasks per project.

Until very recently ease of use has been considered a major factor amongst those looking for project management software, and justifiably so. Many of the programs had been downloaded from mainframes to micro-computers and were so difficult to learn to use that they were often not used at all. There has been a noticeable trend, however over the last few years to more user friendly software, this has also been the case in the project management domain. The most recent releases of project management packages have been conspicuous by their ease of use, clear and concise documentation and well structured training sessions via on line tutorials.

Tables 3.1 to 3.4 give a breakdown of six project management software systems currently available in South Africa. The comparison is sub-divided into two sets of tables. The first set (tables 3.1 and 3.2) pertain to that class of software which consists essentially of the schedule (or networking) program, but which may be easily interfaced to a Management Information System by the user. The second set (tables 3.3 and 3.4) comprise fully

integrated systems, i.e. the packages have their own database (operate within a database environment) and spreadsheet (see Appendix B for Scheduling, Database, and Spreadsheet functional specifications).

In some cases, as for example OpenPlan, the software is supported locally by project management consultants. This is beneficial, in that the user may approach the consultant to add additional applications to his system (see Appendix A for DBMS application examples).

Timeline is a trademark of Breakthrough Software
Microsoft is a trademark of Microsoft Corporation
Hornet is a trademark of Aha Software
OpenPlan is a trademark of Welcom Software Technology
Superproject Plus a trademark of IUS/Sorcim
Panorama is a trademark of Heron Software

FEATURES	TRADE NAME		
	Timeline	Superproj. +	MicrosoftProj
System Software :			
Relational database Interface to MIS dbase	*	*[1]	*[2]
Interface to MIS sprdsht	*	*	*
Interface to word proc.	*	*	*
Creates DIF files	*	*	*
Creates ASCII files	*	*	*
Software Attributes :			
Computes critical path	*	*	*
Creates network diagram	*	*	*
Generates network sched.	*	*	*
Work breakdown structure		*	
Specifies sched. restr-aints	*	*	*
Labour cost breakout		*	*
Capital/equipment cost breakout			*
Assign/report plan costs	*	*	
Assign/report actual "	*	*	
Windows	*		
Custom report generator			
Business graphic "		*	
Project network	*	*	*
Gantt chart	*	*	*
Resource histograms	*		*
Resource S curves			
Project calendar	*	*	*
Resource levelling	*	*	
Sub projects	*	*	*
Resource allocation by %	*		*

Table 3.1 Schedule Type System - Software Specifications

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[1] export only
[2] via Microsoft family software

	TRADE NAME		
FEATURES	Timeline	Superproj. +	MicrosoftProj
Schedule Specifications			
Tasks/project	640k 1000	420bytes/tsk	200 + 200/64k
Milestones/project			200
Resources/project	unlimited	unlimited	255
Resources/task	12	unlimited	8
Time base	variable	variable	variable
Network format		a.o.n/a.o.a	a.o.n
Hardware Requirements			
Computer model	IBM pc/xt/at	pc/xt/at etc	IBM/Wang/etc.
Minimum RAM	256k	512k	256k
Disc storage	2 disk drives	2 disk drive	2 disk drives
Graphics card			
DOS version	pc DOS 2.0	pc/ms DOS 2	pc/ms DOS 2.0
Program language	Modula - 2	C	Microsoft C
Modifiable source code	no	no	no

Table 3.2 Schedule Type System - Network Specifications and Hardware Requirements

Note : a.o.n = Activity on Node
a.o.a = Activity on Arrow
unlimited means that the particular specification is not limited by the program, however the memory constraints still exist.

	TRADE NAME		
FEATURES	Hornet	OpenPlan	Panorama
System Software :			
Relational database	*	*	*
Interface to MIS dbase	*	*	*
Interface to MIS sprdsht	*	*	*
Interface to word proc.	*		
Creates DIF files			
Creates ASCII files	*	*	*
Software Attributes :			
Computes critical path	*	*	*
Creates network diagram	*	*	*
Generates network sched.	*	*	*
Work breakdown structure	*	*	*
Specifies sched. restr-aints	*	*	*
Labour cost breakout	*	*	*
Capital/equipment cost breakout	*	*	*
Assign/report plan costs	*	*	*
Assign/report actual "	*	*	*
Windows	*	*	*
Custom report generator	*	*	*
Business graphic "	*	*	*
Project network	*	*	*
Gantt chart	*	*	*
Resource histograms	*	*	*
Resource S curves	*	*	*
Project calendar	*	*	*
Resource levelling	*	*	*
Sub projects	*	*	*
Resource allocation by %	*	*	*

Table 3.3 Integrated Type System - Software Specifications

Note : Hornet does not run a pure database (see 3.3 Discussion).

	TRADE NAME		
FEATURES	Hornet	OpenPlan	Panorama
Schedule Specifications			
Tasks/project	255	32 000	10 000
Milestones/p	255	32 000	10 000
Resources/pr	128	1 000	unlimited
Resources/ta	6	500	unlimited
Time base	variable	variable	variabl
Network format	a.o.n	a.o.n/a.o.a	a.o.n/a.o.a
Hardware Requirements			
Computer model	pc/xt/at HP	xt/at	pc/xt/at
Minimum RAM	256k	256k	256k
Disc storage	hard disk	hard disk	hard disk
Graphics card		yes	
DOS version	pc/ms DOS 2	pc/ms DOS 2	ms DOS 2
Program language	ms basic	Fort.77/dBa3	C/ Oracle
Modifiable source code	no	yes, dBase3	yes, Oracle

Table 3.4 Integrated Type System - Network Specifications and Hardware Requirements

Note : Refer to Appendix C - Tasks/project for an explanation on how to circumvent this constraint.

3.3 Discussion

With regard to software specifications for scheduling type sofware (Table 3.1), the attributes listed give the user the option to select the package which most meets his own needs. It is always advisable however to test a particular package by entering a typical project or part of a project schedule into the package, and then making further changes and printing reports before deciding to purchase. This may take some time, but is regarded by experienced project managers as time well worthwhile spending.

The packages as listed in Table 3.3 deserve further discussion as to their respective advantages and disadvantages.

As HORNET does not run a proper database, further applications cannot be added by the user via database structures. It is anticipated however that the next release of HORNET software will run a pure relational database. The reporting capabilities of this package are extensive, and this is important to many users. The constraint on the number of activities allowed per network, although avoidable (see Appendix C - Number of tasks per project) still remains a source of irritation for those networking large projects.

As computer processing time has always been of concern to those running large networks on a micro-computer OPENPLAN must be noted here for it's very high speed of processing. It's intended use is as a single user package, however it can be run on a local area

network. A version for mini-computers to run under the UNIX operating system will be available soon.

PANORAMA is a typical example of a package which has been downloaded from it's mainframe version. Although transportability is a big advantage here, i.e. applications developed on micro-computers may be directly run on minis and mainframes, performance of the software on a micro-computer is degraded due to the original software being designed and coded for mainframe operation. It is however well geared to the multi-user environment, and provides extensive data security. Full data dictionary facilities are also provided.

4 COMPUTERISED PROJECT MANAGEMENT IN PRACTICE

4.1 Project Management Computer Software

Microcomputers can of course be utilized in a number of project management capacities. These include :

1. Estimating.
2. Cash flow analysis.
3. Scheduling.
4. Bid analysis.
5. Inventory control.
6. Job cost management.
7. Equipment replacement analysis.
8. Investment analysis.
9. Reporting.

As has been suggested above , software employed by todays project managers encompasses :

1. Scheduling (CPM) packages.
2. Database management systems.
3. Spreadsheet programs.

Broken down into three project management software categories :

1. Stand alone scheduling and planning.

2. Scheduling software that will directly interface to database and/or spreadsheet
3. Scheduling software that operates within a database environment (i.e. fully integrated).

The need for an integrated software approach is becoming increasingly evident within the project industry. Better planning can be achieved with the new generation of integrated project management software. Without this approach the time saved in running the analysis on computer is lost in transferring data from one program to the other. Furthermore data becomes corrupted in the human transfer of data.

"What-if" scenarios, accomplished via the spreadsheet, can be generated for analysis and decision making. The sophisticated reporting capabilities of the database allows the user to generate only those items necessary in the analysis.

Cash flow analysis, project cost estimating, bid analysis and equipment replacement analysis are examples of tasks that are easily adapted to the spreadsheets computational format. Project cost estimating is especially well suited to spreadsheets because the program user can format the estimate calculations to fit the estimating procedures of his or her own particular firm. Sensitivity analysis or investigations, that are so important in estimating computations, are easily performed with spreadsheets. For example, the effects of alternate crew compositions and different labour productivity rates can be determined in a number

of seconds. Furthermore a spreadsheet package may graph project data and can also be useful in project tracking. Database programs may be used to store standard costs and resources as well as historic data relating to crew efficiency or productivity. In the case of the linear project environment, databases may be used to store everything that is relevant to the project. New schedules are then easily constructed - with direct software interface to the database. Also database management systems can be used to create custom reports, if this facility is not provided by the project management package itself.

Spreadsheet programs are available for almost all brands of microcomputers, as is the case with database software. Both spreadsheet and database programs have been developed over a considerable period of time and the better routines are now well established and relatively well known (See Appendix B). New versions of these are continually being released.

The situation regarding software available for scheduling is very different. There are approximately 40 packages available in the U.S.A. and about half that amount locally. A lot of development is still being done and new packages appear regularly.

Bearing in mind the state of the art of project management and project management related software I have attempted to develop a user profile of computerised project management techniques. Furthermore by examining the use of these techniques in three distinct and seperate environments I have attempted to highlight

current problems and trends. The three environments examined were :

1. The manufacturing sector - specifically the civil engineering and construction industry.
2. The service sector - specifically medical services and
3. Maintenance - specifically of large rotating machinery.

4.2 A Profile of the Computerised Project Management Organisation

Two independant surveys of computerised CPM users were studied. The surveys are those of :

1. Heydenrych (21) completed in South Africa in the PWV area in 1983 and
2. Wolf and Hauck (19) carried out in Ohio, U.S.A towards the end of 1984.

4.2.1 Company Size

Both surveys link company size, given in terms of number of employees, to use of computerised techniques. There is agreement that as size increases so does the tendency to employ more sophisticated techniques; this is most probably because of company growth resulting from increased projects size and complexity. A discrepancy does exist however between the number of respondants indicating use of computerised CPM (Heydenrych~65%; Wolf~38%).

4.2.2 Project Size

The following table given by Wolf and Hauck indicates the opinion of users as to the the minimum size of the project in order to justify the use of computerised network based planning and control methods (note that project size is given in 1985 U.S. $):

Project Size ($ 000)	Cumulative Affirmative % (users)
25- 50	33.3
50- 100	37.5
100- 250	50.0
250- 500	58.3
500-1000	75.0
1000 +	100.0

Table 4.1 Use of Computerised Techniques as a Function of Project Size

4.2.3 Company Structure

Two respondants of Hedenrych's survey (N=51) felt that without a matrix structure no computerised project management system could be successful. This belief however cannot be regarded as being generally true since the survey found that other companies

possessing excellent planning functions had other structures. It was found that 31% of the organizational structures were of the matrix type, while 48% were structured on functional lines.

Relevant literature, including this survey, indicate however that the matrix structure is the most suitable when implementing a project management function. Grinnell and Apple (22) define four situations where it is most practical to consider the matrix :

1. When complex, short-run products are the organization's primary output.
2. When a complicated design calls for both innovation and timely completion.
3. When several kinds of sophisticated skills are needed in designing, building, and testing the products; skills then need constant updating and development.
4. When a rapidly changing marketplace calls for significant changes in products, perhaps between the time they are conceived and delivered.

It is interesting to note that current integrated project management software is well accomodated by the matrix structure concept.

4.2.4 Staff Involvement

Heydenrych shows that the percentage breakdown of disciplines involved in the decision making process is as follows :

Discipline	%
Project planner	36
Project team	60
Site personnel only	4

Table 4.2 Percentage Breakdown of Disciplines Involved in the Decision Making Process

He concludes that more should be done to promote participative decision making (i.e. to include site personnel) :-"Participants in the decision making process will make every effort to keep to dates, budgets etc. they made during the decision making process." In respect of persons actually responsible for running the project planning software the percentage breakdown was as follows :

Persons/Dept.	%
Project manager and staff or planning engineer	58
Data processing	27
Special data processing staff reporting to project manager	9
Consultants/bureaus etc.	6

Table 4.3 Percentage Breakdown of those Responsible for Project Software

4.3 Current Practices in the Construction Industry

4.3.1 Introduction

Critical path methods were first introduced to the local construction industry in the mid 1960's and are now well known by construction engineers, managers, planners and cost estimators. Where critical path methods have been introduced, considerable reductions in project times and costs have resulted both in small and large projects. Antill and Woodhead (23) state that the employment of CPM in the construction industry in the U.S.A. has lead to decreases of up to 20% in project times over similiar projects not employing CPM as a management tool.

Many contract specifications nowdays demand that the contractor submit Gantt charts indicating the critical path, at the commencement of the works, also some contractors have been including CPM in their bids for some time. Furthermore assessment of bonus and penalty provisions in contract work is easily obtained via CPM (see section 1.3.2).

Towards the end of 1985 the ASCE Task Committee on the Application of Small Computers in Construction (24) affirmed that : "Not only does the manager need decision making tools for selecting a small computer, but there also exists a need for evaluating software. Current information makes it very difficult to compare hardware or software products. Lists of products with evaluations of quality, ability, cost and usage modes would be a valuable service."

It is with the rapid proliferation of personal computers, since the beginning of the decade, that project planning and control has taken on a new meaning. It is from this point of view that project management will be examined, with the object in mind of assessing current software needs within the industry.

4.3.2 Current Issues in Computerised Project Management

The construction industry has for long lived with a number of major problem areas. Among these the ASCE Task Committee (op cit) lists :

1. Low productivity.
2. A high bankruptcy rate.
3. High interest rates.

Having to deal with these problems has compelled those in the forefront of project management within the industry to seek better solutions. The following issues have been highlighted by management as deserving of further attention :

1. The need for on site network planning (21).
2. Communications (25).
3. Scheduling and planning (25).
4. Project accounting systems (20).
5. Project audit (26).

Items (1) and (2) above are connected in that via improved communications, not only network planning data, but other relevant

project information may be exchanged between head office and site. This means that project management software will have to be designed to run efficiently under current and future communications' software systems. I believe that problem (3) above has been significantly reduced over the past few years by the introduction of integrated software, thus allowing the planning function to encompass most project disciplines. Items (4) and (5) however still effectively elude the project manager and auditor. Much work is still to be done in this area of project related software.

4.4 Project Management in the Service Sector

The service sector has for many years been encouraged by those involved in improving productivity to take a manufacturing approach to service activities, one that substitutes "... technology and systems for people and serendipity " (27).

The hospital environment was chosen as the candidate for study here because of the very positive and successful project management programme being conducted by the Department of Clinical Engineering at Groote Schuur Hospital; the teaching hospital associated with the University of Cape Town. According to Muller[a], Groote Schuur is the only hospital in South Africa presently employing computerised project management methods.

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[a]Muller, J.H. PrEng, MSAIEE,MSAACE
Dept. of Clinical Engineering,
Groote Schuur Hospital.

4.4.1 The Hospital Environment

Johannides (28) provides an activity list which summarizes the majority of services provided by health system engineers. Among them :

1. Establishment of work standards for determining staffing patterns, personnel utilization and costs.

2. Economic analysis of alternative combinations of personnel, materials and equipment and development of models to optimise such combinations.

3. Development of data-processing procedures and management reports in order to establish information systems for managerial control on a continuing basis.

4. Performance of general staff work for the administrator for use in policy determination, fiscal budgeting, building plans and public relations.

Over and above these pointers to the use of project management in hospitals most of the general ia as outlined in section 1.2 (The Project Management E are conformed to in the hospital environment.

Being a conservative working environment, only in very recent years were manual attempts made at implementing project management

techniques on sizeable projects. Typical examples of such projects were :

1. Building and equipment maintenance.
2. New equipment installation.
3. Materials procurement.
4. Procurement of high technology systems.

At Groote Schuur many manual attempts have been made at project management, however without employing an official project office or formal computerised techniques certain deficiencies manifested themselves. Muller (29) enumerates these as :

1. Delays
2. Poor scheduling
3. Purchased equipment incompatibility
4. Inadequate resources
5. A lack of consolidated documentation
6. Undefined responsibilities

4.4.2 Current Issues in Computerised Project Management

While Groote Schuur presently employs micro computer based CPM in managing the above mentioned types of project, Muller anticipates the use of project management software in applications more directly related to hospital services. Amongst these he lists :

1. Clinical procedures.
2. Hospital strategic planning.

From his experience gained in the use of micro computer based project management methods in the hospital environment, Muller has identified the following requirements :

1. The need for a better user interface.
2. The need to communicate project information over a wide area.

It is interesting to note that while "user friendliness" is no longer considered a problem by those in the construction sector, it still regarded as such by those involved in the provision of services. This is most probably attributable to the fact that those involved in the manufacturing sector have acquired many years of computer literacy, as opposed to those in the sevice sector. Again the requirement to improve project communications is highlighted. Groote Schuur is currently implementing project management software on a local area network.

4.5 Project Management in Maintenance Engineering

4.5.1 Introduction

The maintenance function has been a problem area from the point of view of planning and scheduling. Planning is only possible if the maintenance department employs a strict preventitive maintenance programme, as opposed to either breakdown maintenance or predictive maintenance.

Scheduling in any of these cases represents a problem, which arises out of the conflicting interests of the maintenance department and the department or section requiring maintenance of a certain item of machinery. The former, if cost of maintenance is a consideration, is concerned with obtaining maximum utilization of maintenance equipment. The latter on the other hand is primarily concerned with having the item back in service as soon as possible, or by a certain given target date. Taking into account the capacity restriction of any workshop, these two objectives inevitably clash.

Up until very recently ESCOM's maintenance workshops at Rosherville, having treated each maintenance operation as a project in it's own right, had been more concerned with time than with cost of maintenance. With the restructuring of these workshops to run on a more competitive and businesslike basis, cost of maintenance has become a major criterion, and the above mentioned problem has been brought sharply into focus.

4.5.2 Current Issues in Computerised Project Management

In terms of computerised maintenance practices the trend is towards smaller, less expensive, micro-computer based systems (30). As the trend within ESCOM is towards decentralization of services in general, their workshops could ultimately be moving in the direction of self reliance in computing in terms of both hardware and software. A local area network linking micro-computers in the workshop and project office would be advantageous in the

application of maintenance by project.

Considering the fact that many of the maintenance projects are similiar in nature and consist mostly of not more than 30 activities*, a standard maintenance database could be established employing historical data related to maintenance activities. This database would be categorised by project or operation, each project containing an activity list with related duration, resource, cost information etc. Before this could be applied in practice in tandem with scheduling software, preferred routings, layouts, and techniques would have to be perfected on the shop floor. As Hartmann (30 op cit) points out, "Computerised planning and scheduling, facilitates layout, work measurement, labour reporting etc. ...". The Rosherville workshops are soon to start investigating preferred routings, layout etc. by simulating workshop conditions on a micro-computer.

With the abovementioned information on hand, a system comprising at least the following attributes might be considered :

1. A management or project office information database wherein each project is broken down into it's activities.
2. Resource levelling with the ability to prioritise projects or activities.
3. A multiple project capability.

---

*Hattingh, Glen and Barnes, Gordon
ESCOM Maintenance Workshops
Rosherville

The ideal system however seems to be some hybrid of MRP and CPM whereby priority sequencing rules may be defined or selected by the user. This would most probably be the most appropriate solution to the problems experienced by maintenance workshops.

4.6 Conclusions

Suckarieh (31) states that with the above mentioned (see 4.1) types of software, "....microcomputers can provide estimators and construction managers with a control system comparable to management control systems provided by more sophisticated software prepared for mainframes and minicomputers." The relatively large number of project management systems being used by the relatively small number of user types, however, makes it impossible to relate any specific package to a user profile. This does not mean to say that a standard is not developing. Purely because of the intense competition in the project management software market, packages that appeared only 18 months ago, are now regarded as outdated; hence the evolution to the standard program which will most probably include all features as options.

5 CONCLUSION

5.1 Trends in Project Management Software

Many contractors feel that computers are not capable of making the subjective judgements required throughout the project monitoring process. Computers are considered to be a helpful aid when executing a standard function with a very well defined algorithmic procedure, but are thought of as being incapable of performing the judgemental and higher level aspects of project management (32).

The truth of the matter is that, although the computer cannot substitute for the project manager, it can perform beyond it's current algorithmic functions. Present developments in the field of artificial intelligence are likely to lead to the use of :

1. Decision Support and
2. Expert

systems in the not too distant future. Experimental systems in the construction industry have indicated the very positive role that such systems will soon be playing in the area of construction project management (see 5.3 McGartland and Hendrickson).

5.1.1 Interactive Decision Support Systems

A decision support system provides the functions which the user (decision maker) employ. to explore alternatives. By posing "what if" type questions to the system the decision maker may arrive

eventually at a better decision by noting the probable results of any decision he might choose to take. In conjunction with the management information system which supplies information to the DSS, unstructured problems (those which defy algorithmic solution and need the judgement of a human decision maker to solve) may be dealt with. Turban (33) gives the major characteristics of decision support systems as follows :

1. An interactive mode permits on line dialogue between user and computer.
2. The user's judgement is supported rather than replaced.
3. DSS attempts to improve the effectiveness of decision making rather than it's efficiency.
4. The decision process is generally not automated with predefined problems, objectives and solutions. Rather it is a flexible process that can deal with unstructured problems.
5. The system structure allows for a dialogue based on the user's concepts, vocabulary, and definition of the decision problems.

Thus decision support systems are personalised managerial specific tools for improving the effectiveness of decision making.

5.1.2 Expert Systems

Expert systems take the decision making process one step further. This is accomplished by suggesting viable alternatives to the decision maker. It thus serves as an electronic advisor or

consultant. Given the extensive judgement required and the lack of formal structure, project management problems are well suited to the application of `knowledge based expert systems (McGartland op cit).

Expert systems comprise, basically, an information set (or data) that is based on subjective experience in a particular field of expertise, and a set of rules which define how best to use this information. Thus, knowledge based expert systems are programs that can undertake intelligent tasks currently performed by highly skilled people.

Current experimental expert sy[illegible] project management (32,34) are employed in the following areas :

1. Cost control - produces a plan that optimizes the project cash flow according to a strategy selected in conjunction with the user.
2. Time control - via enhanced productivity estimation arrives at improved time forecasting; a more advanced expert system will recognise time slippage problems and cost overruns and will diagnose potential causes.
3. Purchasing and inventory control - determines appropriate inventory levels by comparing the cost of storing materials in inventory versus the cost of not having the material available when it is required, thus minimising overall material costs.

After the developments of large project management data bases and related software, the application of knowledge based expert systems is a desirable extension. It is interesting to note that both decision support and expert systems employ information from project management/CPM systems as pa t of their data input.

5.2 Summary and Recommendations

Research (35) carried out at the beginning of 1985 suggested that most users of project management software on micro computers were managing projects comprising :

1. Fewer than 200 activities.
2. Several different types of resources.
3. Several different organizational functions.
4. Durations of several months or more.
5. Budgets of at least $ 50 000.

As has been suggested the computerised project management scenario is changing rapidly. Personal computer project management software now caters for much larger and more complex projects, previously administered via mainframe or mini computer systems. The availability of such programs on micro computers now literally means that full scale computerised project management is no longer the proprietary possesion of the data processing deparment, but resides with the project manager and project office. Furthermore it is now accessible by the smaller project organization.

The project management software market is going through a terrific growth period. Future Computing Inc. estimates it will grow by 77% in 1986 (36). This will make project management software the second fastest growing software application, second only to communications.

This rapid growth of project management software has presented the project manager with the difficult task of ascertaining which particular program or programs will, more than any other, suit his particular needs. A solution to this problem is attempted elsewhere in this report. To summarise however, the following should be considered :

1. Scheduling and planning.
2. Project cost and performance control.
3. The need to further manipulate project information via access to a database, spreadsheet, wordprocessor etc.
4. The need for an integrated project management system, i.e. one that includes all project disciplines.

Although CPM software and additions have been credited with having a positive impact on organizational profits and turnover (Heydenrych op cit), much work is still to be done in fine tuning these systems to, for example, project accounting , unstructured problem solving, and project audit requirements. This will come about as a result of improved communications between those who produce and those who use project management software.

5.3 Suggested Further Reading

Wiest, Jerome. D. and Levy, Ferdinand. K.
Chap. 8, A Management Guide to PERT/CPM
(Prentice Hall Inc., New Jersey, 1969)

Hughes, Michael. William.
Why Projects Fail: The Effects of Ignoring the Obvious
Industrial Engineering
April 1986

Viviers, Francois
Interaktiewe Besluitneming by Gevorderde Tegnologie-Projekte
Proceedings of the SAIEE and SACAC Symposium on Project Management.
Johannesburg, May 1985.

McGartland, M.R. and Hendrickson, C.T.
Expert Systems for Construction Project Monitoring.
Journal of Construction Engineering and Management.
Vol. 111, No. 3, September 1985.

Vedder, Richard and Nestman, Chadwick. H.
Understanding Expert Systems: Companion to DSS and MIS
Industrial Management, March/April 1985.

Levitt, Raymond

Expert Systems in Civil Engineering

IEEE Software

March 1986

Maher, Mary Lou and Fenves, Steven. J.

Expert Systems for Structural Design

IEEE Software

March 1986

APPENDIX A

PROCUREMENT COST FORECASTING

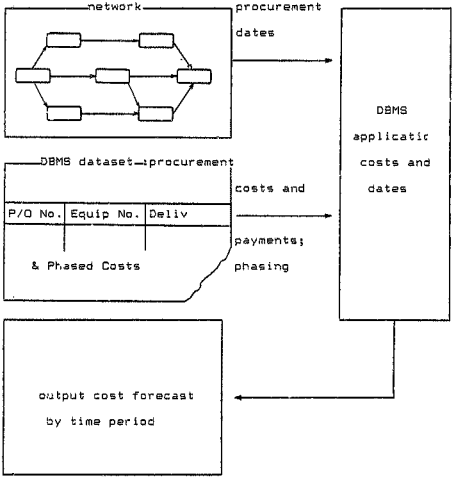
This application is designed to predict the cash outflow per period required to meet the costs of procuring major plant items.

Procurement activities are included in a network, thus providing schedule dates for the placing of purchase orders etc.

Procurement costs and phased payments data are set up in a dataset, and each purchase order in the dataset is given a particular reference code to relate it to a specific network activity. Thus information from both the network (dates) and the dataset (costs and phases) can be combined and collated automatically in the database management system, so enabling the user to produce his own analysis and output reports.

A diagram of this application is given overleaf.

PROCUREMENT COST FORECASTING[1]



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[1]Reproduced here with the kind permission of SWF - Project Management Consultants

MATERIALS CONTROL

The objective of this application is to summate material requirements to a level of detail whereby they may be compared with general availability.

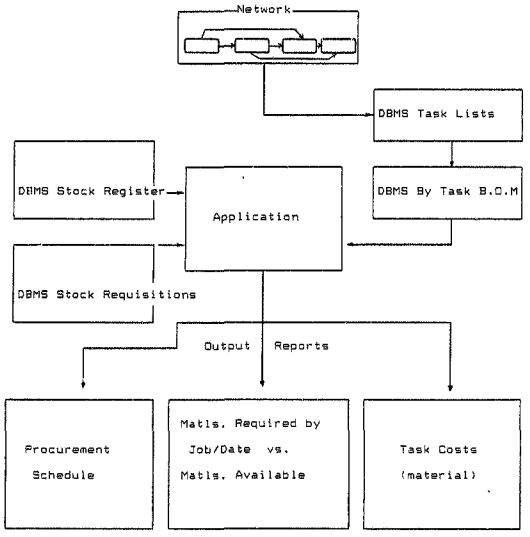
The three datasets :

project network
tasks per network activity (using WBS)
materials required per task

are combined to give a forecast of materials required by task, and by date. By inluding datasets holding warehouse stock lists and purchasing/procurement schedules, action reports highlighting those material items where there is imminent demand but insufficient stock, can be produced.

A diagram of this application is shown overleaf.

MATERIALS CONTROL*



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PROGRESS AND EARNED VALUE ANALYSIS

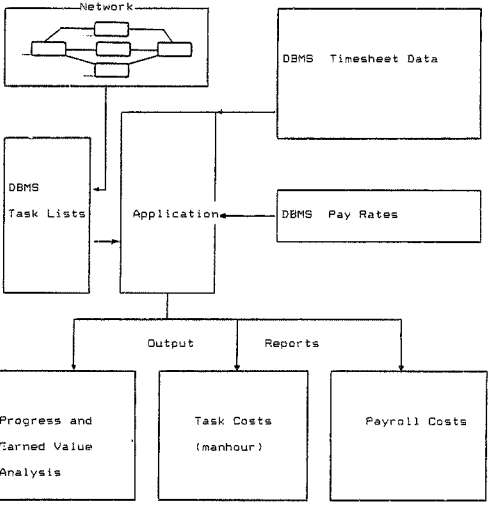
The aim of this application is to analyse expenditure versus actual progress through an activity, or project.

The tasks dataset (see overleaf) defines the Work Breakdown Structure of each network activity. The data held for each activity includes for example, a job number, a description, an estimate of manhours required and a measure of job percent complete.

Further datasets can be set up to hold details of operator grades and pay rates.

By combining these datasets through the application program the user is able to produce an analysis of Actual versus Earned hours expended to reach current completion status.

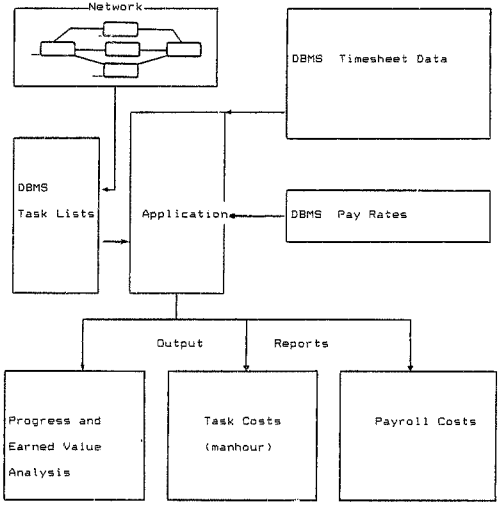
PROGRESS AND EARNED VALUE ANALYSIS*



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PROGRESS AND EARNED VALUE ANALYSIS[9]



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[9]Reproduced here with the kind permission of SWF Project Management Consultants

APPENDIX B

SCHEDULE/NETWORK

Capabilities

Insert tasks
Dependencies adjusted if tasks inserted
Levelling of slack time
Project planning
Project planning and control
Several projects using same resources
Merge projects
Task delay

Information per task

Task number
Task description
Notes per task
Sort key per task
Earliest start date
Latest start date
Earliest end date
Latest end date
Milestones allowed

Inter-dependencies

Task prerequisites allowed

Task prerequisites optional

Task successors allowed

Task successors optional

Partial prerequisites allowed

Start to start

Finish to start

Start to finish

Finish ti finish

As late as possible tasks

As soon as possible tasks

Fixed date tasks

Span tasks

Priority of tasks

Plan backwards

Resources

Max. no. of resources/schedule

Max. no. of resources/task

Decimals of resources allowed/task

Resource costing

Resource levelling/shows conflicts

Resource capacity

Costing

Allocate costs to tasks

Allocate costs by resourre

Fixed costs

Variable costs

All at start

All at end

Pro-rate costs over time

Billable costs

Costs per different time units

Calendar

Extended work week

Different work weeks/resource

Holidays

Store multiple calendars

Store calendar/resource

Reporting

Custom report generator

Gantt chart

Change time units on time based reports

Pert chart

Resource chart

Task list

Cost summary list

-by resource

-by task

-by time period

Preview reports on screen

Report sort options

Report select options

Actual vs. planned report

Print report in background mode

Graphics used in printing

Horizontal print of schedule

Vertical print of schedule

DATABASE

Capabilities

Max no. of characters/field

Max no. of fields/record

Max no. of characters/record

Max no. of records/file

Max no. of files open simultaneously

Max no. of key fields

Max length of key fields

General

Menu driven

Linked files

Terminal customization

Printer customization

Installation of printer control codes

Availability of programming constructs

User defined data entry screens

Help command

Data security and passwords

Command file

Sort function

Edit mask

Data Field Details

Field naming

Field data types supported

Validation types

Multi-field keys

Modification allowed

File Maintenance

Updates one record at a time

Multi record updates

System triggered updates

Global updates

Audit trail

Selection

Conditions on one field

Conditions on multiple fields

Complex nested conditions

Maximum number of conditions allowed

Storage of selection criteria

Report Generator

Predefined format

Maximum number of predefined formats

Multiple input files

Title

Heading

Footing

Page numbering

Column width specifications

Text inserts

Margins

Lines between records

Summary breakpoints

Sums

Means

Minimums

Maximums

Roots

Statistics

Average

Record numbering

SPREADSHEET

General

Memory requirements
Screensize (columns)
Product disk resident
Macro facility

Capabilities

Max text cell size
No. of decimal places
Delineating types of input
  Value
  Formula
  Text
Protected cells
Hidden cells
Graphical output

Mathematical *Functions*

Lookup tables

Linear regression

Min/Max value

Choose

Count

Net present value

Boolian logic

Absolute value

Internal rate of return

Square roots

Trigonometric functions

Average

Exponential

Integer

Pi

Sum

Technical Details

Multi user capability

Hard disk compatible

Menu driven terminal table

Menu driven printer table

Terminal setup

Commands

Automatic recalc. on/off

Copying

- row/s
- column/s
- blocks
- values
- formula adjustment
- relative adjustment

Editing

- addressable
- insert
- change
- delete
- formula adjustment

Formatting

- row/s
- column/s
- column width
- dollar/cents
- decimal precision
- scientific notation

Printing

- formula display
- part of worksheet

printer specifications
Sorting
no. of fields
Windowing
horizontal
vertical

APPENDIX C

1. Critical path - The sequence of tasks or activities whose durations when added consume the most time in reaching the end event are known as critical tasks. In computing the critical path the software will highlight these tasks as being critical (or on the critical path).

2. Network diagram - A diagram showing all activities and their precedance relationships.

3. Network schedule - A tabular listing of all activities showing as a minimum : earliest and latest start/finish dates as well as scheduled start and finish; slack time for non-critical jobs is also indicated.

4. Work Breakdown Structure - The ability to assign ID codes to each task in the project, and thereby to administer the project via a number of levels of tasks. Kerzner (see 1.4) states that the most common WBS is the five level indentured structure :

level 1	Total programme
level 2	Project
level 3	Task
level 4	Subtask
level 5	Work package

If the software does not specifically cater for WBS (via ID codes etc.), one may get around this restriction by inserting, for example, a code in the task description field and using the often excellent sorting and extracting (filtering) capabilities provided.

5. Schedule restraints - The ability to constrain certain activities or an entire project. Examples of such constraints would be to : assign a particular start date to a specific activity, or a particular finish date to a project (thus scheduling backwards in time to pinpoint project required project start date).

6. Labour cost breakout - An aspect of resource management. In software terms this includes the capability to assign codes to resources in order to produce resource type breakdowns. The program can then output cost reports, man hour reports etc. for a particular resource type. An example of this would be : expected cumulative costs for all level 1 engineers.

7. Capital/equipment cost breakout - Similiar to labour cost breakout above, but pertaining to disciplines, or phases, within the project incurring capital/equipment costs.

8. Assign/report planned costs - The ability to specify and to obtain a comprehensive report as to planned project costs. These may be resource costs, variable costs, unit costs etc. Some programs provide the additional advantage of allowing the user to specify multiple rates for a single resource. Most provide

the user with the option to pro-rate costs over the duration of the activity, or to accrue them at the beginning or end of it.

9. Assign/report actual costs - An aspect of project control. Similiar to 8 above but pertaining to actual expenses incurred as opposed to planned expenses.

10. Windows - The ability to obtain different sets of data, contained within boxes or windows, on the computer screen at the same time; for example when assigning resources to an activity the user may with this facility call up a window containing all resources available.

11. Custom report generator - The ability to format one's own reports. This includes not only what information will appear in the report, but also how it will be presented. As the formatting of these reports is based on database report structures, the ability to mathematically massage report data is of course also possible.

12. Business graphics capability - The outputting of report information in grahical format. This includes bar charts, line graphs, pie charts, S-curves etc.

13. Project network - The ability to indicate activity relationships on a project chart (e.g. PERT chart, Gantt chart).

14. Gantt chart - A bar chart representation of the total project, depicting each activity as a horizontal bar extending along the time axis.

15. Resource histograms - Normally a bar chart. Showing resource commitment along the vertical axis and time along the horizontal axis.

16. S curves - A line graph showing cumulative consumption of a resource versus time; for example the cumulative expected cash flow over the project duration, or the cumulative actual manhours accrued by a particular department.

17. Project calendar - This provides the user with the capability of defining the project calendar for the duration of the project. This means the assignment of holidays, days not worked, weekends worked etc. Some packages allow the user to specify working hours per day if required while the more sophisticated software provides for multiple calendars; for example one could have seperate calendars for R&D and operations personnel.

18. Resource levelling - The process of smoothing out the use of resources over time. Most programs will allow the user to specify resource limits, and will then if requested automatically calculate the best use of these resources over time via a levelling or smoothing algorithm (see 5.3 Wiest and Levy, Chap. 7). This feature should not be confused with the

resource restriction feature of some programs, which only indicates that the maximum available of a certain resource has been exceeded at a particular time, but leaves the user to sort this problem out on his own.

19. Sub projects - Also termed Multiple project, this feature provides the capability to plan and control several projects, sharing a common resource pool etc. Note that if the number of tasks allowed per schedule by the software is a limiting factor, the ability to create sub or multiple projects would be a way around this restriction. Also sub project schedule creation is valuable in constructing the Work Breakdown Structure often used in planning and controlling of major projects.

20. Resource allocation by percentage - The ability to assign partial resources to an activity; for example .5 of resource A to activity 001.

21. Number of tasks per project - A limiting factor imposed by the software on the number of activities which may comprise one schedule or network (see 19 above).

22. Adjustable time base - The ability to alter project time units. Most provide for units of days, weeks, months and years while some provide for minutes as well. This can be very useful when requesting cost reports; i.e. costs can be examined over week, month, or year periods as requested by the user.

23. Network format - This refers to either the activity on arrow (AOA) or activity on node (AON) type of network. AON allows for the more realistic representation of project activity relationships.

REFERENCES

1. Archibald, Russel. D. and Villoria, Richard. L.
Network Based Management Systems (PERT/CPM)
(John Wiley and Sons Inc, New York, 1967)

2. Adamiecki, Karol
Harmonygraph
Przeglad Organizacji (Polish Journal of Organizational Review)
(1931)

3. Fazar, Williard
The Origins of PERT
The Controller
Vol. 30, Dec. 1962, p598

4. McLaren, K.G. and Buesnel, E.L.
Chap. 14, Network Analysis in Project Management
An Introductory Manual Based on Unilever Experience
(Cassel and Co. Ltd., London, 1969)

5. Kerzner, Harold
Chap. 10, Project Management - A Systems Approach to Planning
Scheduling and Controlling
(Van Nostrand Reinhold, New York, 1979)

6. Bennett, F. Lawrence.
Critical Path Precedance Networks
A Handbook on Activity-On-Node Networking for the Construction Industry
(Van Nostrand Reinhold Co., New York, 1977)

7. Moder, Joseph. J.
Network Techniques in Project Management
Chap. 16, Project Management Handbook
Edited by Cleland, D.I. and King, W.R.
(Van Nostrand Reinhold, New York, 1983)

8. Crandall, Keith C.
Project Planning with Precedance Lead/Lag Factors
Project Management Quarterly
6(3), 1973, pp 18 - 27

9. Cleland, David I. and King, William R.
Systems Analysis and Project Management
Mcgraw Hill, 1975
pp. 198 - 201

10. Bolander, Steven F., Taylor, Sam G. and Seward, Samuel M.
Why the Process Industries are Different
Production and Inventory Management
Fourth Quarter, 1981, pp. 9 - 24

11.Koontz, H., O'Donnel, C. and Weihrich, H.
Management, 7 th Ed.
McGraw Hill, New York, 1980
pp. 1[illegible] - 171

12.Jaafari, A.
Criticis[illegible] CPM for Project Planning Analysis
Journal of Construction Engineering and Management
Vol. 110, No. 2, June 1984

13.Birrell, G. S.
Construction Planning Beyond the Critical Path
Journal of the Construction Division, ASCE
Vol. 106, No. CO., September 1980

14.Peer, S.
Network Analysis and Construction Planning
Journal of the Construction Division, ASCE
Vol. 100, No. C03, September 1974

15.Popescu, C.
Pitfalls of GSA - CMCS Software
Journal of the Construction Division ASCE
Vol. 105, No. CO1, March 1979

16.*Gilbert, G. P.*
The Project Environment
International Journal of Project Management
Vol. 1, No. 2, May 1983

17.Selinger, S.

Construction Planning for Linear Projects

Journal of the Construction Division, ASCE

Vol. 106, No. CO2, June 1980

18.Melin, J. W. and Whiteaker, B.

Fencing a Bar Chart

Journal of the Construction Division, ASCE

Vol. 107, No. CO3, September 1981

19.Wolf, Gary, L. and Hauck, Warren, C.

PERT/CPM : A Tool for Managing Projects

Industrial Management

Vol. 27, No. 1, 1985

20.Tuman, J.

Development and Implementation of Project Management Information and Control Systems

In: Cleland, David I. and King, William R.

Project Management Handbook

Van Nostrand Reinhold Company, New York, 1983

21.Heydenrych, P.J.

Selecting Project Network Packages

A Dissertation Submitted to the Faculty of Business Administration

University of the Witwatersrand, Johannesburg, 1983

22.Grinnell, S.K. and Apple, H.P.
When Two Bosses Are Better Than One
Machine Design
January 1975

23.Antill, James N. and Woodhead, Ronald W.
Critical Path Methods in Construction
Wiley Interscience, New York, 1982

24.ASCE Task Committee on the Application of Small Computers in Construction
Application of Small Computers in Construction
Journal of Construction Engineering and Management
Vol. 111, No. 3, September 1985

25.Choromokos, J. and McKee, K. E.
Construction Productivity Improvement
Journal of the Construction Division, ASCE
Vol. 107, No. C01, March 1981

26.Ruskin, Arnold. M. and Estes, W. Eugene.
The Project Management Audit : It's Role and Conduct
Engineering Management International
No. 2, 1984

27.Levitt, Theodore.
Production Line Approach to Service
Harvard Business Review
September-October 1972

28.Johannides, David F.
Cost Containment Through Systems Engineering
Aspon Systems Corp., Maryland, 1979

29.Muller, J. H.
Project Management at a Large Teaching Hospital
Proceedings of the SAIEE and SACAC Symposium on Project Management
Johannesburg, May 1985

30.Filley, Richard. D.
IE's Have Tremendous Opportunities for Improving Company's Maintenance Function
Industrial Engineering
February 1986

31.Suckarieh, George
Construction Management Control with Microcomputers
Journal of Construction Engineering and Management
Vol. 110, No. 1, March 1984

32.McGartland, M.R. and Hendrickson, C.T.
Expert Systems for Construction Project Management
Journal of Construction Engineering and Management
Vol. 111, No. 3, September 1985

33.Turban, E

Decision Support Systems, A New Frontier for Industrial Engineering

Computing and Industrial Engineering

Vol. 7, No. 1, 1983

34.Nel, B.M. and Nel, A.L.

The Application of Expert Systems to Project Management

Proceedings of the SAIEE and SACAC Symposium on Project Management

Johannesburg, May 1985

35.Davis, Edward. W. and Martin, Russel. D.

Project Management Software for the Personal Computer :

An Evaluation

Industrial Management

January-February 1985

36.Wheelwright, James. C.

How to Choose the Project Management Software That's Right for You

Industrial Engineering

January 1986

Author Heilbrunn Bernhard Emil
Name of thesis A Review And Analysis Of Software Available For Project Management On Personal Computers. 1986

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