THE INFLUENCE OF PROJECT STRUCTURAL FACTORS ON THE TIME MANAGEMENT OF ELECTRONIC ENGINEERING PROJECTS IN THE SOUTH WESTERN CAPE

BY

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I, **Bibi Hamida Sarah Jane Fakira**, submit this thesis in partial fulfilment of the degree of Master of Science in Engineering. I claim that this is my original work and that it has not been submitted in this form for a degree at any university.

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ABSTRACT

Time management is certainly the most invaluable tool in projecting time-phased resource utilisation requirements as well as providing a basis for tracking performance. It allows optimal integration of all the resources in a project such that synergy is produced. Consequently, an effective time management system is crucial to the success of a project. This research highlights the major requirements for setting up an effective time management system for electronic engineering companies in the South Western Cape. It includes a literature review which shows the influence of the project structural factors on time management and the project performance. The research also uses an industrial survey to uncover the current impact of the project structural factors on electronic engineering projects. The effectiveness of alternative time control system is examined as well. From the findings of this research study, it has been possible to set up guidelines for selecting time control techniques which are pertinent to the current project structural factors of electronic engineering projects.

GLOSSARY

1. **Balanced matrix**: A person is assigned to oversee the project and interacts on an equal basis with functional managers. This person, and the functional managers jointly direct work flow segments and approve technical and operational decisions.

2. **Charting techniques**: These comprise the time control techniques which employ charts to show project progress with respect to time, e.g, Bar Charts, Gantt Charts.

3. **Client's satisfaction**: This factor reflects whether the client is happy or not with the end-product. It depends on whether the client's requirements have been met.

4. **CPA**: Critical Path Analysis. It is a time control technique which is based on a work breakdown structure.

5. **Financial viability study**: establishing how expensive and how profitable the project is.

6. **Functional matrix**: A person is formally designated to oversee the project across different functional areas. This person has limited authority over the functional people involved and serves primarily to plan and coordinate the project.
   The functional managers retain primary responsibility for their specific segments of the project, within their own functions.

7. **Functional structure**: the project is divided into segments and assigned to relevant functional areas and/or groups within functional areas. The project is coordinated by upper levels of management, i.e. no specific project manager is assigned.

8. **Motivational factors**: Factors that act as an energetic driving force. Such factors drive a person to accomplish a task or achieve an objective, with a feeling of satisfaction.

9. **Operational study**: A study to determine if the completed project will meet the required operating specifications.

10. **PERT**: Program Evaluation Review Technique. It is a time control technique.

11. **Project organisational structure**: The organisation of the managerial responsibility and task allocation within the project.

12. **Project structural factors**: These correspond to

    i) the factors which characterise the project itself, such as the complexity level; and

    ii) the factors which correspond to the way the project is being managed, such as, the allocation of responsibility.

13. **Project team**: A manager is put in charge of a project team composed of a core group of personnel from several functional areas and/or groups, assigned on a full-time basis. The functional managers have no formal involvement.

14. **Risk sensitivity analysis**: An analysis of the potential risk factors in a project, the consequences of such factors if they occur, and the determination of contingency strategies to counteract these negative consequences.

15. **Technical feasibility study**: A study of the technical factors necessary to successfully accomplish a project.

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1. INTRODUCTION

This thesis sets out the procedures and results of a research study into the time management of electronic projects in the South Western Cape. The major features which make electronic engineering projects different to other engineering projects are explained in chapter 3.

The aim of this study was to

- examine the impact of some major factors on time management and thus,
- establish a time management system which minimises the probability of time delay.

The major reason for attempting to derive a sound time management system, is because inefficient time control leads to the following :

- escalation of budgeted costs;
- increased stress of project team;
- decline in technical performance;
- specifications are not met;
- dissatisfaction of clients; and
- overall reputation of the organisation is damaged.

Thus, with a sound time management system, enormous savings in terms of time and money would be achieved. Quality improvement can also be reached. Consequently, the organisation would more effectively handle intense competition and other environmental changes.

Time management is a broad issue which is influenced by various factors within and outside the project management environment. This research concentrated on two fundamental factors having considerable impact on time management. These factors are :

i) the project structural factors; and
ii) the application of time control techniques.

The project structural factors comprise mainly of the organisational structure of the project and its complexity level. These factors also account for the communication system and team structure of the project. Time control techniques consist of the techniques that form the basis of a time control system.

The objectives of this thesis were to

i) establish, to some extent, how the project performance is affected by the project structural factors;
ii) find out how these structural factors interact with the application of time control techniques;
iii) determine the effect of the application of time control techniques on the project performance;
iv) find out other factors leading to poor time performance;
v) find out how time delay can be avoided; and
vi) draw appropriate conclusions and recommendation on the time management of electronic projects.

The information on which this thesis is based, was gathered by means of:

i) A literature survey of previous studies on time management.
ii) An industrial survey on the present time management system in electronic companies in the South Western Cape.

Scope of the Industrial Survey

The survey was limited to the electronic engineering companies in the South Western Cape area because

- lack of finance prohibited a nationwide survey;
- the close proximity of the researcher to the relevant companies made follow-up interviews easy; and
- electronic engineering projects are a challenge to time management principles because they are strongly influenced by rapid technological changes.

In order to obtain a significant sample with minimum repetition of the same projects, the questionnaires were distributed to many different companies. The range of electronic engineering applications encountered was also quite wide.

Major Difficulties

The main difficulties encountered during this survey were that:

1. Project management is still but a theoretical concept to many electrical companies in South Africa. It follows that only a few of the engineering staff could fully answer the questionnaire.
2. Many companies feared that the survey would reveal the confidential aspects of their business.
3. Many companies feared that the survey would indicate that their managerial system is not an efficient one.

Research Methodology

The following methods and procedures were used to achieve the objectives of the thesis :

i) Carry out a literature survey on the relevant issues.

ii) Compare the findings of the literature survey with the objectives of this research study.

iii) Design a questionnaire that will complement as well as validate the facts gathered from the literature survey.

iv) Distribute the questionnaires to electronic engineering companies in the South Western Cape.

v) Carry out a graphical analysis of the data from the industrial survey.

vi) Perform statistical analyses to uncover specific relationships between the following:

- The project structural factors and the application of time control techniques.
- The application of time control techniques and the project performance.

viii) Draw appropriate conclusions and recommendation from the graphical and statistical analyses.

2. LITERATURE REVIEW

An investigation into previous studies was made to establish the following major aspects on time management :

i) The influence of the project structural factors on the application of time control techniques as well as on the project performance.

ii) The effectiveness of alternative time control techniques.

Prior to undertaking this investigation, it was necessary to understand :

- the role of time management within the concept of project management; and
- the functions constituting a time management system.

2.1 THE ROLE OF TIME MANAGEMENT WITHIN PROJECT MANAGEMENT

Tuman [24] believes that the total project management system has essentially two ingredients:

- an information system and
- a control system.

The information system provides timely, accurate and structured information on cost, schedule and performance to a control system which produces management decisions and direction.

There are three types of control system:

i) Time/schedule control system.

ii) Cost control system.

iii) Quality control system.

Kerzner [11] states that these systems are in conflict with each other, but are highly interrelated. According to Kerzner, project management consists of three basic stages:

i) Planning stage.

ii) Operation stage.

iii) Control stage.

Each control system in a project also consists of these three basic stages. Each control system is therefore, a subsystem of the project management system.

Time management is essentially the management of the schedule control system. The schedule control system is probably the single most important tool for determining how much company resources should be integrated so that synergy will be produced. It is invaluable in projecting time-phased resource utilization requirements as well as providing a basis for tracking performance. Most projects begin with the development of schedules so that accurate cost estimates can be realised.

2.1.2 The Functions Constituting the Time Management System

The time management system, being a subsystem of project management also consists of the three basic functions :

- Planning: setting down time schedules.
- Implementation and monitoring of the schedules.
- Controlling: time control.

The time control system is implemented in parallel with the operation stage. The basic purpose of the time control system is to monitor the operations and to reschedule activity times as necessary.

Cusack [4] highlighted that the planning stage is a prerequisite to the control stage. During the control stage, operations are monitored and deviations are evaluated against a planned baseline.

After the project is launched, the functions of planning, monitoring and controlling are integrated into a closed loop, so forming the control cycle. As Kerridge [10] summarises:

"No control system works unless adequate time is spent up front in planning the work, and thereafter properly monitoring and controlling against the plan."

2.2 INFLUENCE OF SOME MAJOR FORCES ON TIME MANAGEMENT AND PROJECT PERFORMANCE

The project environment and the project structural factors are the key factors influencing the project control system. The project environment is characterised by the corporate organisational structure as well as the macro-environment. The project structural factors (i.e, task allocation, complexity, objectives) reflect the corporate mission and objectives.

Both the project environment and its structural factors dictate the project control system as well as the project performance. References from previous works revealed that the project organisational structure has a direct influence on the project control system. Figure 2.1, below, shows how the project environment and structural factors influence the project control system and the ultimate project performance.

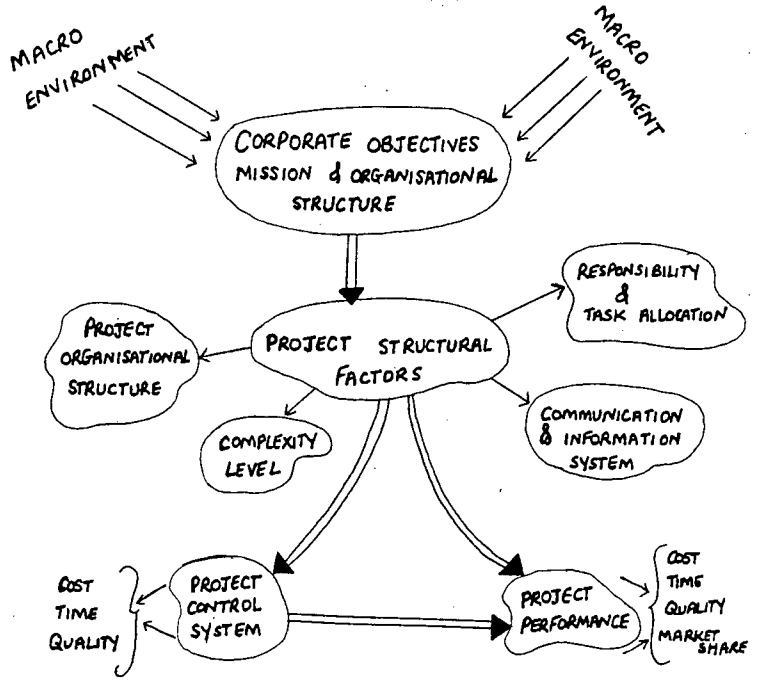


Figure 2.1: Project framework which governs the project control system and its performance.

As illustrated, the organisational structure, communication system, complexity level of the project form part of the structural factors. These factors, therefore, have an impact on the control system as well as the performance. Thus, the control system is not solely responsible for the success or failure of a project.

As Might and Fischer [16] stated: "Yet while network techniques (which are time control techniques) are obviously well-suited for improving schedule performance and can easily be adapted to address cost efficiencies within schedule-determined constraints, there is no assurance that these are really the best way to achieve project success when other criteria for success are considered."

The major relationships that were analysed in the literature survey are:

i) structural factors and project performance; and

ii) the application of time control techniques and structural factors;

The effectiveness of alternative time control techniques were also examined.

The purpose was to

i) show that the ultimate project performance is not dependent upon the control system only;

ii) describe how the project structural factors affect the time control system; and

iii) rationally evaluate the extent and the manner the time control system affects the project performance;

2.2.1 Structural Factors and Project Performance

Many authors state that the project structural factors have a definite bearing on the project performance. These structural factors account for the project information and communication system, the establishment of teamwork, conflict management, resource management as well as the management of the control systems.

Some elements of the project structural factors which were identified as having considerable bearing on the project performance are:

i) **Experience and competence of project manager(s) and project team;**

- Milligan [17], James and Griffiths [9] point out that the key to the success of small projects depends upon the utilisation of a very experienced project team.

- Milligan [17] highlights the relationship between the project performance and the competence of the functional managers as well as the attitude of the project manager to group participation.
- Might [15] claims that the administrative ability of the project manager has a high positive correlation with all measures of success. The degree of project team enthusiasm and support are also positively related to every success of measure.
- Mac Donough and Kinnunen [14] believe in the need for experienced project managers who are concerned not only with technical issues but also with the entire project.

ii) **Effective communication and information channel within the project structure as well as the organisational structure;**

- Schmidt [23] and Mac Donough et al [14] state that effective dialogue regarding project goals is necessary between different levels of management and different departments throughout the project course in order to achieve success.
- Might [15] claims that good communication patterns are positively related to the measures of overall success, schedule success and some measure of technical success.
- At Deer & Co [5], the engineers claim that any time control system is significant only if there is effective communication of project objectives.

iii) **Management support;**

- Morton [18], Schmidt [23] and Mac Donough et al [14] state that managers from the project leader upwards should be in constant touch with the project progress for successful performance.
- Might and Fischer [16] add that top management support is most beneficial when considerable authority is delegated to the project manager.

iv) **Responsiveness to clients;**

- Mac Donough and Kinnunen [14], Pinto and Slevin [21] assert that the most vital element to the project success is meeting the product specification as required by the clients.

v) **Clearly defined objectives;**

- Larson and Gobeli [12] reveal that clearly defined objectives is the strongest and most consistent predictor of project success.
- Mac Donough and Kinnunnen [14] support Larson and Gobeli's view.

Thus, some project structural factors have a considerable influence on the project performance.

2.2.2 Structural Factors and The Application of Time Control Techniques

This section gathered references from previous researchers, which prove the influence of the project structural factors on the time control system. However, no references have been encountered which show the influence of the application of time control techniques upon the project structural factors.

Might and Fisher [16] assert :

> "The structural dimensions of a project need to be considered prior to selection of specific project management control system. Recognising the interactions between control methods and situational conditions by the project manager is crucial in determining control success."

They concluded that the size of the project influences the project organisational structure. This, in turn, influences the choice of time control techniques. For example, large projects are more appropriate for the implementation of formal time control techniques than are small projects.

Veranth [25], Paulson [20], Milligan [17], Kerzner [11] and Bent [2] formulated a hypothesis about the relationship between the time control techniques and the project structural factors. They consider the following structural factors as having the greatest impact on the selection of time control techniques :

- management support, communication channel, management response and organisational structure.

Cohenca et al [3] suggest that environmental uncertainties have a major influence on planning time, controlling time and revision intervals in certain projects. The environmental uncertainties are related primarily to political, socio-economical and technological changes. These changes directly affect the mission of the enterprise as well as the project structural factors.

Larson and Gobeli's [12] study reveals that clearly defined objectives is the strongest and most consistent predictor of project success in terms of meeting cost, time and quality objectives. This implies that the time performance, and hence, the time control system is directly related to clear definition of objectives.

Mc Donough and Kinnunnen [14] stress the impact of clarity of goals and leadership of the project manager on control factors.

Might [15], however, observes that technical planning which is among the first step in time management of electrical engineering projects, is independent of the project structural factors.

Pinto and Slevin [21] assert, from their experiment, that the success of a project depends on an implementation profile consisting of both structural and control system elements.

There is thus a broad consensus that the project structural factors influence the time control system. Hence, the project structural factors must be carefully evaluated before selecting a system of time control techniques, if success is to be achieved.

2.3 EFFECTIVENESS OF ALTERNATIVE TIME CONTROL TECHNIQUES

This section examines the effectiveness of some popular time control techniques, as gathered from the literature review. The time control techniques considered are

i) Standard graphic methods (Bar chart, Gantt chart).

ii) Network techniques (CPA, PERT).

iii) Informal techniques (weekly meetings).

iv) Heuristic methods (applied in conjunction with (ii) to achieve optimal resource utilization).

Locke [13] states that there are two diametrically opposed time scheduling techniques that can be used :

- A set of estimates could be obtained and used to produce a plan from which a project completion date could be predicted.
- The end-date may be predetermined, or imposed by factors outside normal control without any regard to the work content or difficulties presented.

These two methods can be applied for any selected time control techniques.

2.3.1 Standard Graphic Techniques

The most well-known standard graphic methods are the Bar Chart, Milestone chart and Line of Balance. These are the oldest planning techniques. Below is a summary of the advantages and disadvantages of these techniques as uncovered by the literature survey.

Advantages of Standard Graphic Techniques

- Milligan [17], Harrison [8], Kerzner [11] and others acknowledge that Bar/Gantt charts are easy to draw, easy to read, easy to understand and provide visible evidence of actual progress against planned schedule.
- Locke [13] states that the visual impact of a well-displayed Bar chart schedule technique can be a powerful aid to controlling a simple project.

Disadvantages of Standard Graphic Techniques

- Many authors agree that standard graphic methods do not show the interdependencies of activities in large projects. Kerzner [11] explains that the Bar chart cannot detail the hundreds of interrelated activities of a large project. These techniques then deteriorate into a generalised picture of the project. Consequently, detailed control cannot be applied.

- Kerzner [11] elaborates that there is no indication whether a delayed activity will affect another activity later in the project.

- Kerzner [11] observes that Bar charts do not show the uncertainty involved in performing the activity and therefore, does not readily lend itself to sensitivity analysis.

- Many authors admit that Bar charts are not adaptable to non-repetitive projects involving development engineering. This is because work breakdown is not well-defined and processing or designing times are unstable.

- Many authors mention that these graphic methods cannot show the distribution of resources and cannot be used to control cost. For example, the lead time approach of Line of Balance technique results in a schedule for minimum inventory rather than the most economic batch size.

Thus, graphic techniques appear to be inconvenient for large complex projects. However, they are quite efficient for simple projects with a well-defined work breakdown structure(WBS) and correct time estimates.

2.3.2 Network Analysis Techniques

Such techniques include precedence diagrams, arrow diagrams, PERT and CPA. Network analysis techniques(NAT) were developed in the late '50's and became popular in 60's and 70's. The disadvantages and advantages uncovered by literature review are as follows:

Advantages of Network Analysis Techniques

- It is widely recognised that network analysis techniques (NAT) effectively handle the interrelationships between activities on complex projects.

- Kerzner [11] explains that network analysis techniques reveal interdependencies and problem areas which are neither obvious nor well defined by other planning methods.

- Kerzner [11] advances that network analysis techniques can provide valuable information for planning, integration of plans, time studies, scheduling and resource management. Network planning eliminates the need for crisis management by providing information about :
  - impact of late starts,
  - impact of early starts,
  - cost of a crash program, and
  - slippage in planning

- Locke [13], in his study, describes network analysis techniques as an incentive for logical progression of thinking and planning. Network analysis techniques not only provide a notational method. These techniques shed light on some activities which might otherwise have been excluded from schedules, estimates and price build-up.

- Locke [13] also observes that network techniques allow management to handle uncertainties and evaluate alternatives.

- Eppen et al [6] and Kerzner [11] agree that network analysis techniques identify activities critical to the project duration. When implemented on computer, these techniques can be easily integrated with the project information system.

- According to Kerzner [11] and Locke [13], PERT is a basic method for determining manpower, material and capital requirements as well as providing a means for checking progress.

- Hajek [7] claims that the greatest value of PERT is that it signals management in advance when any difficulties are likely to develop.

Disadvantages of Network Analysis Techniques

The enthusiasm for network analysis techniques started to drop in the late 70's.

- Many authors point out that these techniques are too complex and hence, add to implementation problems.

- Kerzner [11] ventures that there exist more data requirements for a PERT_organized reporting system than for most others. He consequently claims that PERT is an expensive item to maintain.

- Wager [26] and Morton [18] explain that the popularity of network techniques declines because the project managers found these techniques "cumbersome, inflexible and too

long to process into meaningful results".

- Morton [18] further reveals in his study that "wide gap exists between the mechanics of network analysis techniques and the realities of an organic world of constantly changing relationships".

- Kerzner [11] mentions two main disadvantages of PERT :
  i) Unless the project is repetitive, there is usually a lack of historical information upon which to base the cost estimates of most optimistic, most pessimistic and most likely times.
  ii) PERT networks are based upon the assumption that all activities start as soon as possible. This assumes that qualified personnel and equipment are available.

On the whole, all authors admit that network analysis techniques are useful for controlling time as well as cost and resources. However, they claim that network analysis techniques can be rather too academic and removed from practicability.

The most recent trend is to combine the simple graphic techniques with network techniques for a more efficient time control technique. Packages available for this purpose include CA SuperProject and Microsoft Project.

2.3.3 Informal Control Techniques (Non-Scientific Methods)

These techniques are non-scientific or non-mathematical methods of controlling the schedule of a project. Examples of such techniques are formal and informal meetings, personal monitoring, informal 'report-backs' as well as a variety of descriptive graphs. They supplement the mathematical scheduling techniques by providing instantaneous information on the project progress.

Advantages of Informal Techniques

- Cusack [4] justifies the use of such techniques by explaining that it is acceptable to sacrifice strict mathematical rigour (CPA, PERT) in favour of operational acceptability.

- Mc Donough, Kinnunnen [14] and Kerzner [11] highlight the fact that procedures such as "first hand observation, oral and written reports, technical interchange meetings," are vital in making information available for project evaluation in terms of cost, technical requirement and scheduling.

- Might, Fischer [16] and Milligan [17] claim that procedures such as schedule design reviews, periodic management reviews, periodic technical/cost/schedule reports, regular formal meetings are beneficial to the project performance.

- Mac Donough and Kinnunnen [14] state that informal and formal meetings are a means of keeping track of a project, problem solving, stimulating coordination and cooperation among departments. They explain that the frequency of these meetings varies with the experience, ability and maturity of the team members as well as with the complexity and newness of the project.

- Olin [19] discovered in a study of chemical companies in Europe that real control is exercised by close informal supervision and frequent discussion from the level of group heads to the Director of the Research.

- Mac Donough and Kinnunen [14] observed from a study of new product development projects, that personal monitoring is the only way to keep tabs on projects that present new problems daily and that require continual changes. Similarly in a rapidly changing technological environment, immediate acquisition of information through personal monitoring is beneficial.

- Work Breakdown Structure (WBS) is another widely approved non-rigorous technique. Kerzner [11] states that "whenever work is structured, understood, easily identifiable and within the capabilities of individuals, there will almost always exist a high degree of confidence that objective can be reached." Bent [2] and Paulson [20] express the same view.

Various references showed that without work breakdown, which defines all the efforts to be expended, which allows assignment of responsibility and which permits the setting up of schedules to accomplish the work, there is no basis for control.

Disadvantages of Informal Techniques

Informal reporting and formal meetings are considered to be less effective than other non-scientific methods.

Mac Donough [14] lists the following reasons against the use of informal reporting and meetings:

i) Informal reporting techniques and meetings have severe limitations in situation that are constantly changing.

ii) Owing to daily technical, materials and other problems, information via informal reports and meetings is out-of-date.

iii) Informal reports lack sufficiently detailed information that only practical experiments and observations can point out.

Except for informal reporting techniques and meetings, the literature revealed that informal time control techniques provide timely accounting of physical progress and cost expenditures and periodic re-estimation of time and cost to complete the remaining work.

2.3.4 Heuristic Procedures

Heuristic procedures are usually applied in conjunction with network analysis techniques. The purpose is to design methods of altering the scheduling network such that optimal resource allocation (cost and labour) is attained without delaying the project. The literature survey revealed that heuristic methods of optimising the project schedule, depend on certain project characteristics and structure.

Some interesting heuristic approaches uncovered by the survey are explained below :

- Cusack [4] presented a heuristic approach to the planning and control of the project duration and its cost. It uses the precedence network to define task logic and a critical path. The critical activities durations, with associated cost changes, are then altered until the critical path has a minimum cost and duration. Thus, Cusack's heuristic approach provides an 'optimal' project schedule.

- Schmidt [23] presented a technique built from PERT information. The technique compares actual time spent on a project against the percentage completion of the critical path. The actual project progress is graphed against a planned performance standard. Then, control lines which provide a warning of possible schedule overruns are built. In this way, the project progress can be monitored and reports drawn.

- At Deer & Co [5], engineers suggest that a simple control method is to draw up a logic chart, which highlights and time-phases major milestones of the project. It can also show the prerequisites to each milestone.

- Schenk [22] proposes an empirical model of the project implementation process. It consists of a series of critical project factors to be considered a-priori. The project manager is then presented with a sequential checklist or set of milestones, that enable him to track the project through each stage of its implementation process. Thus, it is possible to curb overruns caused by engineering changes.

Based on Schenk's method, it can be concluded that a time management system cannot be set, without considering the project structural factors.

Most authors acknowledge that the project manager should, however, be realistic about the time spent on planning and control techniques. Setting up and implementing heuristic methods should not increase the duration of the project.

SUMMARY

The major facts gathered from the literature review can be thus summarised:

- Time management is a subsystem of project management. It provides management with the ability to plan for best possible use of resources to achieve a given goal within time and cost limitations.
- Time management is not the only factor determining the project performance. The project structural factors play a crucial role in determining the project performance.
- The project structural factors also influence the application of the time control techniques chosen.
- Different time control techniques can be applied concurrently in a project, depending on their advantages and shortcomings.

3. RESEARCH METHOD

The goal of this thesis was to establish an effective time management system for electronic engineering projects. The literature review did not fully attain this aim because

- there was insufficient information pertaining specifically to electronic projects; and,
- the nature of the influence of the project structural factors on time management and the project performance was not defined.

On the basis of time management, the major differences between electronic engineering projects and other engineering projects are that :

- The time period is usually difficult to estimate owing to the originality of electronic engineering projects.
- There is often a wide range of alternative technologies that can be used, implying that the technical feasibility study is of vital importance for electronic engineering projects.
- A line management structure rarely exists in an electronic engineering project, because these projects involve few, but highly skilled people.

In order to fully meet the goal of the thesis, specific information on time management of electronic engineering projects was essential. It was decided that an industrial survey would provide up-to-date information relevant to the current socio-economic-technological environment.

The method of mailed questionnaires was chosen to gather relevant information from the electronic companies. Such a method offered the major advantage of reaching several respondents simultaneously, within a broad area and a relatively short span of time.

3.1 THE OBJECTIVES OF THE INDUSTRIAL SURVEY

In order to establish an effective time management system for electronic projects, this industrial survey attempted to :

i) validate the facts gathered from the literature review, namely;
   - the influence of the project structural factors on the project performance;
   - the influence of the project structural factors on the application of time control techniques; and
   - the relative use and effectiveness of the popular time control techniques.

ii) complement the findings gathered from the literature survey by :
   - focusing specifically at electronic engineering projects; and
   - verifying the exact nature of the relationships among the project structural factors, the project performance and the application of time control techniques.

Hence, this survey endeavoured to gather as much information as possible on the major forces influencing the time management system and the project performance. Then only, would it be possible to draw an effective time management system for electronic engineering projects.

3.2 SCOPE OF THE SURVEY

The scope of the industrial survey included four categories:

- geographical scope;
- demographical scope;
- statistical scope; and
- technological scope.

i) **Geographical scope**

The survey was conducted in the South Western Cape only, owing to practical considerations. For instance, the proximity of the researcher to the respondents made it easier to conduct follow-up interviews.

ii) **Demographical scope**

The questionnaire was intended for those respondents who have an accurate knowledge of;

- the procedures adopted during the planning and the control stages of the electronic projects;
- the outcome of these projects in terms of meeting time schedule, budgeted cost, technical specifications and client satisfaction; and
- the factors leading to time delay of electronic projects.

iii) **Statistical scope**

Owing to the limited number of engineering personnel who could provide relevant answers to the questionnaire, it was decided that each respondent should furnish details on at most five individual projects. In this way, a reasonably large sample of electronic projects could be gathered. Subsequently, an accurate statistical analysis could be effected.

iv) **Technological scope**

It was decided that the projects under investigation must have been conducted within the last five years. The reason is the rapid technological development in the electronic engineering field. However, demographical scope was given priority over technological scope.

The scope of this survey was thus chosen so that accurate and relevant responses could be gathered.

General rules about questionnaires construction were obtained from Alreck and Settle [1] handbook. The questionnaire was structured so as to

- facilitate the subsequent data analysis;
- allow a sensible qualitative analysis;
- determine the respondent's name and telephone number. This would make further investigations possible, if necessary; and
- to supply the researcher's name and telephone number so that the respondent could obtain more clarification, if required.

Appendix A contains a sample of the final questionnaire which was distributed to some fifty respondents. The aim was to obtain information on some 250 electronic engineering projects.

3.3 QUESTIONNAIRE CONSTRUCTION

The questions in this industrial survey should provide answers that attain the thesis objectives. In order to fulfil this requirement, the questionnaire was divided into appropriate sections. Each section pertained to one of the objectives set out for this survey. Such an exercise led to conciseness and clarity of objectives.

The questionnaire consisted of the following major sections :

i) **Project characteristics**

In this section, questions on the cost and duration of the projects were asked. These project characteristics were compared to the project performance during the data analysis stage. Then, it was possible to verify the relationship between the project characteristics and the project performance.

ii) **Project feasibility Studies**

The purpose here was to estimate

- the consideration given to feasibility studies in electronic engineering projects; and
- the subsequent effect on the project performance.

The four feasibility studies chosen, as being of high relevance to project performance, are technical feasibility study, operational suitability study, financial viability study and risk sensitivity analysis. To avoid misinterpretation, a simple explanation of each of these feasibility study was given.

iii) Project organisational structure

Under this heading, an explanation of four major project organisational structures was given and the respondent was asked to select which one was employed for his/her projects. The aim here was to

- confirm the fact that the project organisational structure has an influence on the project performance; and
- find out whether the project organisational structure has an impact on the application of time control techniques.

iv) Project schedule control techniques

In this section a list of the popular time control techniques were provided, and the respondent was asked to rate the manner of application of each control technique. Facts about the influence of the application of time control techniques on the project performance were also gathered.

v) Project performance

The purpose of this final section was to

- evaluate the consequences of time delays;
- find out other critical factors leading to poor time performance; and
- find out ways of avoiding time delays in electronic engineering projects.

The consequences of time delay were examined so as to stress the importance of a proper time management system. The causes of time delay should give an insight on some additional key factors affecting the time management system.

Hence, it should be possible to draw a guideline for managing the time control system of electronic engineering projects.

4. DATA ANALYSIS

Out of a target number of 250 electronic projects, the returned questionnaires gave information on 65 projects. That is, the response was 26%. This is very satisfactory since on average the response rate of mailed industrial surveys is normally between 10% and 18%.

The answers to each section of the returned questionnaires were evaluated against the thesis objectives. It was found that some of the answers would not contribute much towards meeting the thesis objectives. These answers were discarded during the data analysis. The applicable answers were first coded and grouped according to the sections in the questionnaire. Then the data was analysed according to three different methods:

i) Graphical analysis.
ii) Contingency Table analysis.
iii) Multiple regression analysis.

4.1 GRAPHICAL ANALYSIS

The software statistical package called Quattro Pro was used to carry out the graphical analysis. The purpose of such an analysis was to establish trends in some project structural factors and the application of time control techniques, with regard to electronic projects. Bar charts were drawn which show the frequency distribution of the following :

- the application of feasibility studies;
- some common project organisational structures;
- the application of time control techniques;
- the project performance resulting from time delay;
- some commonly cited factors leading to time delay; and
- ways of avoiding time delay.

These graphical trends were then used, in conjunction with the other statistical analyses, to understand the interaction between the application of time control techniques, the project structural factors and the project performance.

4.2 CONTINGENCY TABLE METHOD

The Contingency Table method is a powerful technique of categorical analysis which was used to verify relationships in this study. Categorical analysis is the approach of analysing sets of discreet data so as to establish the significance of relationships between these sets of data. The statistical software package called Statgraphics was used for this purpose.

4.2.1 Description of the Contingency Table method

Suppose that we wish to study the relationship between the project organisational structure and the cost performance from data pertaining to some 60 projects. Two project organisational structures, project team and functional structures are chosen. The contribution of each structure to good, average and poor cost performance is counted. The percentage observed frequencies are presented in table 4.1 below.

	Project cost performance		
	good	average	poor
Project team	24%	50%	28%
Functional	25%	45%	20%

Table 4.1 : Percentage Observed frequencies

From table 4.1, it is possible to evaluate the impact of each organisational structure on the cost performance.

Using the Statgraphics software, data relating to these two variables (organisational structure and cost performance) can be fed into the software and then, the Contingency Table analysis run. The output will be a table of percentage observed frequencies, similar to table 4.1. A detailed explanation of Contingency Table analysis can be obtained from Walpole and Meyers [28] book on Probability and Statistics.

The motivation for using the table of frequencies provided by the Contingency Table method, is that, the values given in the table are a true reflection of the actual frequency of occurrence of the relevant data. These values are calculated without making use of assumptions - which is rarely the case with other statistical approaches.

4.2.2 Establishing the Significance of a Relationship

The table of percentage observed frequencies is, but, one output of the Contingency Table analysis, as provided by the Statgraphics package. A second useful output is the level of significance of a relationship between two variables. For example, suppose we wish to establish whether there is a significant relationship between the project cost and the project performance. Firstly, a table of percentage observed frequencies of these two variables are drawn.
A null hypothesis of no relationship between the project cost and the project performance is equivalent to a model which says that the column and row categories of the table of percentage observed frequencies are independent.

The null hypothesis is tested using the Chi-Squared test at a level of significance of 5%. If the level of significance after running the test is less than 5%, the null hypothesis of no relationship is rejected. This means that a result of less than 5% indicates the existence of a relationship between the variables, project cost and project performance.

Table 4.2 below shows the results of applying the Contingency Table method to verify whether the project performance is significantly related to the project cost.

	Cost	Time	Technical specification	Client satisfaction
Project cost	0.83	0.22	0.02	0.04

Table 4.2: Results of Contingency Table analysis to establish whether the project performance is a function of the project cost.

Table 4.2 indicates that only technical specification and client satisfaction factors are significantly related to the project cost because the significance level calculated is less than 5%, for these two factors. For clarity purposes, only the relevant significance levels (i.e, less than 5%) have been quoted in chapter 5. That is, only the significance levels indicating the existence of a relationship, have been considered in this research study.

4.2.3 Application of the Contingency Table Method

The outputs of the Contingency Table method were used to examine the following :

i) whether there is a significant relationship between the project organisational structure and the application of time control techniques;

ii) how each project organisational structure contributes to the efficient application of each time control techniques considered;

iii) whether there is a significant relationship between the project organisational structure and the project performance;

iv) how each organisational structure contributes to good and excellent project performance; and

v) how the efficient application of each time control technique contributes to successful project performance.

4.3 MULTIPLE LINEAR REGRESSION ANALYSIS

Linear regression analysis consists basically of fitting a specific type of curve to specific data sets and then establishing the "goodness" of this fit, that is, correlation. In cases where relationships among more than two variables are to be established, multiple regression analysis is used.

4.3.1 Description of Multiple Linear Regression method

Suppose we wish to find out how cost performance (y) varies with project cost (x1) and project duration (x2), then the multiple regression method tries to fit observed data (from a survey) belonging to these variables onto the following linear equation :

$$y = a + b1*x1 + b2*x2$$

where a : constant

b1 : coefficient of x1

b2 : coefficient of x2

x1 and x2 are the independent variables in this equation, y is the dependent variable.

The fit of the multiple linear regression equation is reported in terms of the multiple correlation coefficient, R. This equals the correlation between the observed y-values and the y-values given by the equation. Suppose R is 0.99. This is a high value and it reflects that the y-values given by the equation are very close to the observed y-values. The higher the R value, the closer the observed values fit the equation and therefore the more reliable the equation.

4.3.2 Application of the Multiple Linear Regression Analysis

Since linear regression analysis can only be applied to sets of data with a ranking order, it could not be used with data pertaining to indicator variables, such as project organisational structure. That is, the different organisational structures cannot be assigned a ranking order. However, data relating to the application of time control techniques and the project performance were given a rank by assigning a numerical value to each discriminating level. (For example, poor = 0 , average = 1, excellent = 2).

In this study, linear regression analysis was used to establish the following multi-variable relationships:

i) the application of time control techniques and the project cost and duration;
ii) the project performance and the project cost and duration; and
iii) the application of time control techniques and the project performance.

Using the Statgraphics software, the results of the multiple regression analysis were considered as reliable for this study, only when the correlation factor R was calculated to be above 75%. For values of R less than 75%, the linear approximation model was rejected.

5. FINDINGS FROM THE INDUSTRIAL SURVEY

The aim of this thesis is to establish an effective time management system for electronic engineering projects. This is to be achieved by examining the

- influence of the project structural factors on the application of time control techniques;
- influence of the structural factors on the project performance; and
- effectiveness of alternative time control techniques.

From the literature survey, it was gathered that an effective time management system depends on the structural factors surrounding the project as well as the appropriateness of alternative time control techniques.

The main objectives of this industrial survey were to

i) verify how much the findings from the literature review are applicable to current electronic projects;

ii) complement the literature findings; especially, to try and establish the nature of the relationships between
   - the project structural factors and the application of time control techniques;
   - the project structural factors and the project performance; and
   - the application of time control techniques and the project performance.

iii) find out other key factors leading to poor time performance; and

iv) find out ways of avoiding time delay.

The data (from the returned questionnaires) that have been statistically analysed in order to meet the objectives of the industrial survey are data pertaining to

i) the duration and cost of the projects;

ii) the project organisational structure;

iii) consideration given to feasibility studies;

iv) the authority responsible of the project time planning;

v) the application of time control techniques;

vi) the project performance; and

vii) the causes of time delay and ways of avoiding time delay.

The data analysis has been conducted based on the following major sections:

i) Graphical analysis of some structural factors and the application of time control techniques.

ii) Statistical analysis of the relationship between the project structural factors and the application of time control techniques.

iii) Analysis of how the project structural factors interact with the project performance.

iv) Analysis of how the application of time control techniques interacts with the project performance.

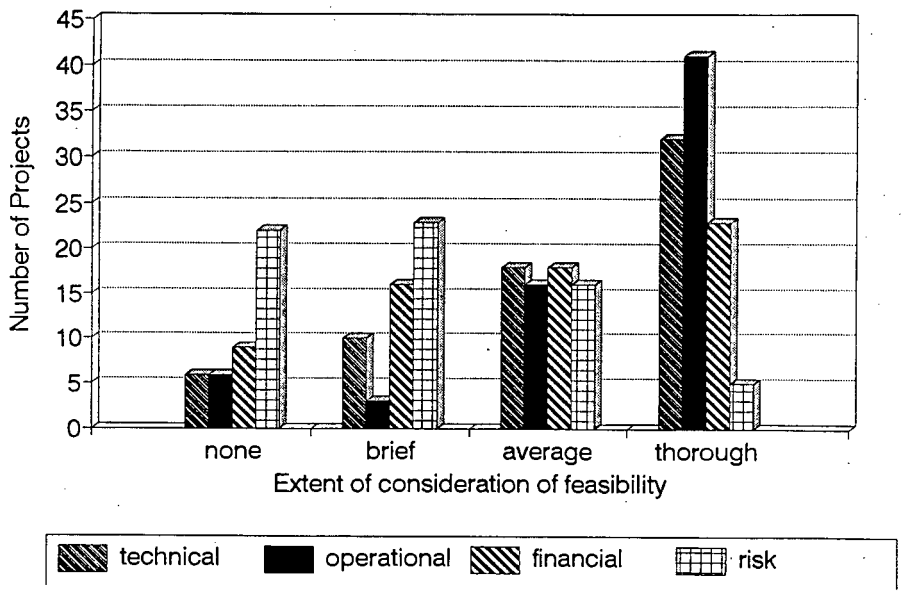
v) Graphical analysis of other critical factors leading to time delay.

vi) Graphical analysis of ways of avoiding time delay.

5.1 GRAPHICAL ANALYSIS

In order to meet the objectives of this industrial survey, the following graphical analyses have been carried out.

5.1.1 The Frequency Distribution of the Consideration given to Feasibility Studies

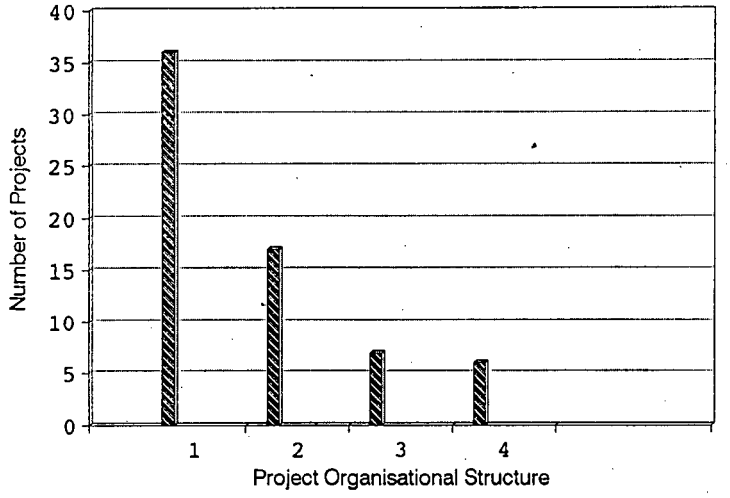


Graph 5.1: Frequency distribution of the application of the major feasibility studies.

Graph 5.1 indicates that:

- The application of risk analysis is quite rare.
- Operational and technical feasibility studies are applied thoroughly for 60% of the projects encountered.
- Financial analysis is thoroughly applied only for some 30% of these projects.

5.1.2 The Frequency Distribution of Some Common Project Organisational Structures used in Electronic Projects



Labels on the x-axis of graph 5.2

1 - Project team
2 - Functional matrix
3 - Balanced matrix
4 - Functional

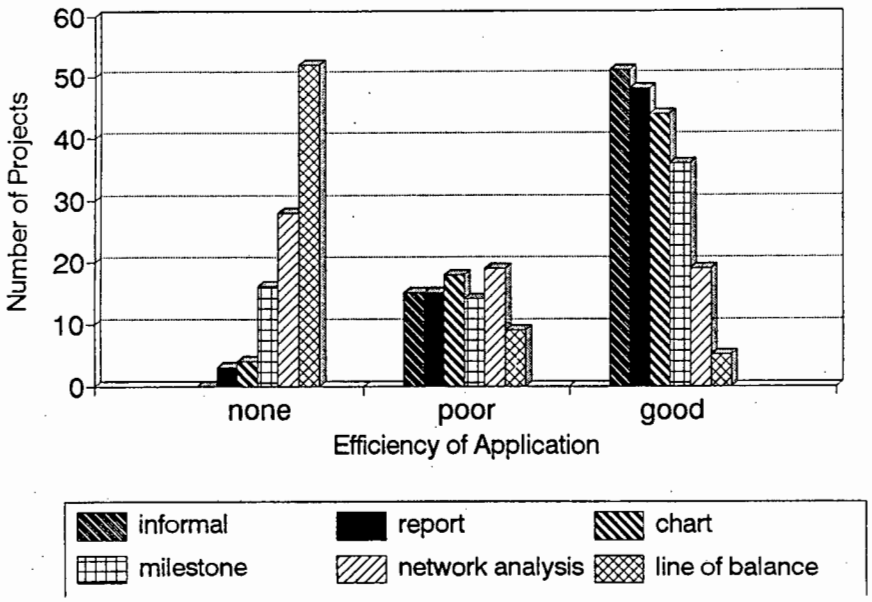
Graph 5.2: Frequency distribution of the major project organisational structures employed.

From graph 5.2, it is found that

- the most common project organisational structure for electronic projects is project team structure.

5.1.3 The Frequency Distribution of the Application of the Popular Time Control Techniques

Graph 5.3 below indicates how efficiently the selected time control techniques were applied during an electronic engineering project.



Graph 5.3: Frequency distribution of the efficiency of application of the time control techniques.

Graph 5.3 indicates that:

- Network analysis and charting techniques have been not been well applied for 70% of the projects encountered.
- Informal control techniques, formal reporting techniques and charting techniques have been used efficiently for more than 60% of these projects.
- Line of balance is the least used time control technique.

Table 5.1, below, illustrates the manner of application of these time control techniques, as encountered in this survey. The values given in the table are percentages of the total number of projects encountered.

Application of the time control	Percentages for each Time Control Techniques					
	informal	report	chart	miles-tone	line balan	net-work
well explained	9.1	7.9	0	0	0	0
throughout project	59.1	49.0	68.3	41.0	1.6	1.6
at start	9.1	6.3	22.2	27.9	31.1	44.4
highly relevant	3.0	17.5	1.6	8.2	4.9	12.7

Table 5.1: Manner of application of the time control techniques.

Table 5.2 indicates the effectiveness of the time control techniques, as rated by the users of these techniques.

Application of the time control	Percentages for each Time Control Techniques					
	informal	report	chart	miles-tone	line balan	net-work
too simple	13.6	9.5	4.8	11.5	57.4	20.6
too complex	0	7.9	1.6	1.6	3.3	4.8
too demanding	0	0	1.6	0	0	0
easily implemented	3.0	1.6	0	0	0	3.2

Table 5.2: Effectiveness of the time control techniques

From table 5.1, it is found that :

- Informal control techniques, reporting and charting techniques have been applied throughout the project for more than 45% of the encountered projects.
- Line of balance and network techniques have been used at the start only, for more than 30% of these projects.

From table 5.2, it is observed that :

- The application of line of balance has been too simple.

5.2 RELATIONSHIP BETWEEN STRUCTURAL FACTORS AND THE APPLICATION OF TIME CONTROL TECHNIQUES

The structural factors considered are the project duration, the project cost, the project organisational structure and the management of project time planning. Regression analysis was used to determine the nature of the relationship between

- the project duration and the application of time control techniques; and
- the project cost and the application of time control techniques.

In order to find whether the project organisational structure is related to the application of time control techniques and the nature of such a relationship, the Contingency Table method was used. The Contingency method was also used to establish the relationship between the management of the project time planning and the application of time control techniques.

5.2.1 Project Duration and the Application of Time Control Techniques

The linear regression analysis on the relevant data yielded the following model

Duration = -0.57(informal) + 0.56(report) + 0.18(chart) - 0.07(milestone) + 0.37(network) - 0.17(line of balance)

The model is valid for 92% of the observed data. That is, 92% of the observed data are very close to this linear approximation model. This model implies that

- the time control techniques that have the highest influence on the project duration are informal control and formal reporting techniques, because of the relatively large coefficients of these two variables;
- the project duration is inversely proportional to the application of informal control techniques. That is, for long projects, the application of informal control techniques is less effective; and
- the project duration is positively related to the use of formal reporting techniques. Formal reports become more effective, the longer the project duration.

5.2.2 Project cost and the Application of Time Control Techniques

The regression analysis of the project cost against the application of time control techniques generated a linear model which is valid for 90% of the observed data. The model is

Cost = -1.4(informal) + 1.37(report) + 0.77(chart) - 0.51(milestone) + 0.21(network) - 0.04(line of balance)

This model implies that

- the time control techniques that have the greatest impact on the project cost are informal control techniques and formal reporting techniques;
- the project cost is negatively related to the application of informal control techniques. The larger the cost of the project, the less applicable are informal control techniques; and
- the project cost is positively related to the use of formal reporting techniques, in the sense that, as the cost increases, the use of formal reporting becomes more effective.

5.2.3 Project organisational Structure and the Application of Time Control Techniques

Regression analysis could not be used to determine the relationship between the project organisational structure and the application of time control techniques because it was not possible to establish a ranking scale for the various project organisational structures. For this reason, the Contingency Table method was utilized.

The results of the determination of whether the project organisational structure is significantly related to the application of time control techniques are given in table 5.3.

The smaller the significance values given in the table, the smaller the probability of no relationship, that is, the higher the probability of a relationship existing between the organisational structure and the application of time control techniques.

	Time control techniques employed					
	Informal	report	chart	miles-tone	net-work	line of balance
Structure	0.0003	0.0009	0.032	0.0033	0.05	-

Table 5.3: Results of Contingency Table analysis used to determine whether the application of time control techniques is related to managerial structure.

From table 5.3, it is observed that

- the project organisational structure is significantly related to all the time control techniques, except for line of balance technique.

Appendix B1 gives the table of percentage observed frequencies obtained from a detailed analysis of how the application of each time control technique corresponds to each project organisational structure. This analysis was carried out by means of the Contingency Table method. The main observations were that

- 69% of good applications of informal control techniques resulted from a project team structure. Functional structure contributed to only 8% of good applications of informal techniques;
- 56% of good formal reporting applications were the outcome of using a project team structure and only 4% resulted from the use of a functional structure;
- 64% of good applications of charting techniques resulted from a project team structure;
- 58% of good applications of milestone techniques resulted from the application of a project team structure;
- 58% of good applications of network analysis techniques resulted from a functional matrix structure;
- 60% of good applications of line of balance technique resulted from the use of a project team structure; and
- Functional structure contributed very poorly to the efficient application of these time control techniques.

It must be noted that only the highest percentages are being quoted here.

5.2.4 Management of Project Time Planning and the Application of Time Control Techniques

In order to assess the relationship between the application of time control techniques and the management of the project time planning, the Contingency Table method was used, instead of regression analysis, since the management of time planning cannot be assigned a ranking scale.

Appendix B2 shows the results of a detailed analysis of how the application of each time control technique relates to the authority responsible for the project time planning. It was observed that

- 99% of good applications of informal control techniques were obtained when the project manager, the project engineer and the project personnel took charge of project time planning;

- 77% of good applications of reporting techniques resulted when the project manager, the project engineer and the planning department were responsible for the project time planning. The involvement of the project personnel in time planning also, contributed to good applications of reporting techniques;
- 72% of good applications of charting techniques were obtained when the project manager, the project engineer together with the project personnel and the planning department were in charge of the project time planning;
- 85% of good applications of milestone techniques resulted when the project manager, the project engineer, the project personnel and the planning department took care of the project time planning;
- 65% of good applications of network analysis techniques resulted when the project manager, the project engineer together with the planning department were responsible for the project time planning; and
- 90% of good applications of line of balance techniques resulted when the project manager and project engineer took care of the project time planning.

It was noted, at this stage, that quite often the respondents specified that the project engineer was the project manager.

Conclusion

- The efficient application of most of the time control techniques (except for network analysis) results primarily from the use of a project team structure.
- Functional matrix structure results in the good application of the more formal control techniques, namely, network analysis techniques.
- The good application of all the formal control techniques considered, except for network analysis techniques, is highly favoured when the project manager/project engineer, project personnel and planning department are all involved in the project time planning.
- Network analysis techniques are most efficiently applied when the project manager/project engineer together with the planning department take care of the project time planning.

5.3 RELATIONSHIP BETWEEN STRUCTURAL FACTORS AND PROJECT PERFORMANCE

Regression analysis was used to determine the relationships between the project performance and the project cost, the project performance and the project duration. To determine the relationship between the project organisational structure and the project performance as well as the relationship between the management of the project time planning and the project performance, the Contingency Table method was used.

5.3.1 Cost Performance as a function of Project Cost and Project Duration

Regression analysis, of the relevant variables, yielded the following linear approximation model which is reliable for 77% of the observed data.

Cost performance = -1.04(duration) + 0.29(cost)

This implies that :

- The project characteristic which has the highest influence on the cost performance is the project duration.
- Cost performance is inversely related to the project duration. The shorter the project duration, the better the cost performance. For instance, the probability of cost increasing owing to inflation is less if the project duration is short.

5.3.2 Time Performance as a function of Project Cost and Project Duration

Regression analysis, in this case, gave the following model

Time performance = -0.997(duration) + 0.21(cost)

This model is valid for 85% of the observed data. It implies that:

- The project duration is a stronger predictor of the time performance than the project cost.

- Time performance is negatively related to the project duration. The shorter the estimated duration, the higher the probability of meeting scheduled date.

5.3.3 Technical Performance as a function of Project Cost and Project Duration

The linear model approximation obtained from the regression analysis is

Technical performance = -0.68(duration) + 0.37(cost)

This model is valid for 80% of the observed data. It implies that :

- Technical performance is negatively related to the project duration. Better technical quality is achieved when the project period is not too long. For long duration projects, quite often the technical specifications change due to technological changes. Such alterations could lead to confusion and hence, poor performance.
- Technical performance is positively related to the project cost. Good technical performance is achieved in case of costly projects. Projects often cost a lot because management invests in good quality resources so as to fully meet the technical specifications.

5.3.4 Client Satisfaction as a function of Project Cost and Project Duration

The linear regression analysis yielded the following linear approximation model

Client satisfaction = -0.79(duration) + 0.36(cost)

This model is reliable for 80% of the observed data. It implies that

- The project duration is a stronger predictor of the client satisfaction than the project cost.
- Client satisfaction is negatively related to the project duration. The longer the project, the more difficult it is to please the customer.

- Client satisfaction is positively related to the project cost. This can be explained by the fact that the client usually associates high cost with better quality.

5.3.5 Project Organisational Structure and Project Performance

Linear regression could not be employed with data pertaining to the project organisational structure because it was not possible to assign a ranking scale to the project organisational structures. Instead, the Contingency Table method was used to establish

i) if there is any significant relationship between the project organisational structure and the performance; and
ii) the nature of the relationship, if it is significant.

The results of the Contingency Table analysis are given in table 5.4 below. As explained earlier, the smaller the significance values in the table, the higher the probability of a relationship existing between the project performance and the organisational structure.

	Project performance in terms of			
	Cost	Time	Technical	Client satisfaction
Structure	0.012	0.023	0.0002	0.033

Table 5.4: Results of the Contingency Table analysis for establishing the possibility of a relationship between project organisational structure and project performance.

Table 5.4 indicates that the project organisational structure is significantly related to all the measures of project performance considered.

Appendix C1 gives the table of observed frequencies of how each project organisational structure affects each measure of performance. From the values given in the table, it was observed that:

- 72% of good (good and excellent performance combined) cost performance resulted from the use of a project team structure.
- 65% of good time performance resulted from the application of a project team structure.
- Functional matrix structure contributed to 30% of good technical performance. Project team structure contributed to 49% of good technical performance.
- 55% of good client satisfaction factor resulted from the use of a project team structure.

5.3.6 Management of Project Time Planning and Project Performance

A detailed analysis of how each different authority responsible of the project time planning affects each measure of performance was achieved by means of the table of observed frequencies produced by the Contingency Table method. The table is illustrated in appendix C2. The following observations were made :

- 76% of good cost performance resulted when the project manager or the project engineer took care of the project time planning.
- 44% of good time performance occurred when the project manager/engineer and the project personnel were in charge of the project time planning.
- 85% of good technical performance was obtained when the project manager/engineer and the project team took care of the project time planning.
- 80% of good client satisfaction factor resulted when the project manager/engineer together with the project personnel were responsible of the project time planning.

Conclusion

- Project team structure has the highest contribution towards overall successful performance of electronic projects.
- Functional matrix structure is beneficial only in the case of meeting technical specification.
- The technical performance and client satisfaction factor are highly favoured when the project manager/engineer and the project personnel are in charge of the project

time planning.

- The cost performance is best whenever the project manager or engineer is responsible for the time planning.
- The time performance is highly successful when the project manager/engineer and the project personnel are in charge of the project time planning.

5.4 RELATIONSHIP BETWEEN PROJECT PERFORMANCE AND THE APPLICATION OF TIME CONTROL TECHNIQUES

In order to determine the nature of the relationship between the application of time control techniques and the project performance, firstly, multiple regression analysis was used. Then, a detailed examination of how the alternative time control techniques affect performance was made by means of the table of frequencies produced by the Contingency Table method.

5.4.1 Application of Time Control Techniques and Cost Performance

The regression analysis between the application of time control techniques and cost performance yielded the following linear model approximation

Cost performance = -0.42(informal) - 0.66(report) + 1.02(chart) + 0.14(milestone) - 0.7(network) + 0.43(line of balance)

This model is valid for 84% of the observed data. It indicates that :

- Charting techniques, network analysis and formal reporting techniques are among the strongest predictor of the cost performance.
- Cost performance is positively affected by the application of charting techniques. That is, good usage of charts contribute to successful cost performance.
- Cost performance is negatively affected by the application of network analysis techniques and formal reporting techniques. Cost performance does not improve with better application of network analysis or reporting techniques.

5.4.2 Application of Time Control Techniques and Time Performance

The regression analysis of the application of time control techniques and time performance gave the following model :

Time performance = -0.45(informal) - 0.9(report) + 0.89(chart) + 0.2(milestone) - 0.4(network) + 0.47(line of balance)

This model is a linear approximation of the relationship between the application of time control techniques and time performance. It is reliable for 88% of the observed data. It indicates that:

- Formal reporting and charting techniques have the highest impact on the time performance.
- Time performance is negatively affected by the use of formal reports and positively related to charts usage. Good application of charts results in good time performance. Poor time performance is attributed to extensive application of formal reporting techniques.

5.4.3 Application of Time Control Techniques and Technical Performance

The regression analysis between the technical performance and the application of time control techniques gave the following linear approximation model :

Technical performance = -0.37(informal) + 0.08(report) - 0.01(chart) + 0.03(milestone) + 0.26(network) - 0.12(line of balance)

The model is valid for 81% of the data. It implies that :

- Informal control techniques and network analysis techniques have the greatest influence on the technical performance.
- Technical performance is negatively affected by the use of informal control techniques, and positively related to the application of network analysis techniques.

This means that the extensive application of informal control techniques can lead to poor technical performance, but efficient application of network analysis techniques results in good technical performance.

5.4.4 Application of Time Control Techniques and Client Satisfaction

The regression analysis of the application of time control techniques and the client satisfaction factor yielded the following model :

Client satisfaction = 0.004(informal) - 0.17(report) + 0.29(chart) - 0.26(milestone) - 0.01(network) - 0.03(line of balance)

This linear approximation model is valid for 82% of the observed data. It implies that :

- The strongest determinants of the client satisfaction factor are the applications of charting techniques and milestone technique.
- The client satisfaction factor is positively affected by charts application. Good charts application leads to client satisfaction.
- The client satisfaction factor is negatively affected by the application of milestone technique. Better application of milestone technique does not improve the client satisfaction factor.

Conclusion

- All the measures of performance are most positively affected by the application of charting techniques, except for the technical performance .

5.4.5 Using the Contingency Table Method

A detailed analysis of how the application of each time control technique affects each measure of performance was carried out using the Contingency Table method. The table of observed frequencies is given in appendix D. The following observations were made:

5.4.5.1 Cost performance and the application of time control techniques

- Good application of informal control techniques contributed to 86% of good and excellent cost performance.
- Good application of charting techniques contributed to 86% of good and excellent cost performance.

5.4.5.2 Time performance and the application of time control techniques

- Good application of informal control techniques contributed to 80% of good (good and excellent combined) time performance.
- Good application of charting techniques contributed to 80% of good time performance.

5.4.5.3 Technical performance and the application of time control techniques

- 81% of good technical performance resulted from good application of formal reporting techniques.
- 74% of good technical performance were the outcome of good application of informal control techniques.

5.4.5.4 Client satisfaction and the application of time control techniques

- Good application of informal control techniques led to the client satisfaction, 84% of the time.
- Good application of charting techniques resulted in the client being satisfied, 76% of the time.

It was noted that the application of line of balance had no effect on the project performance of these electronic projects.

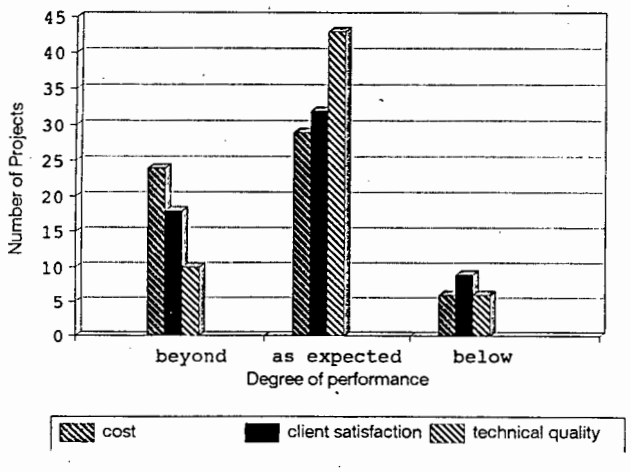
Conclusion

- The efficient application of informal control techniques has a high positive influence on all the measures of project performance considered.
- The application of charting techniques leads to improved project performance, with the exception of technical performance.

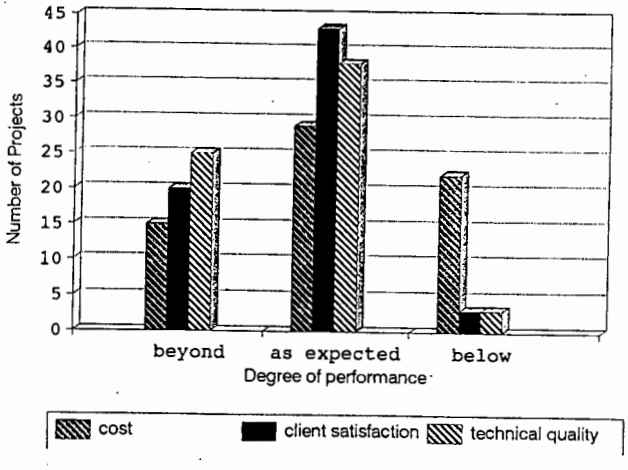
5.5 ADDITIONAL FACTORS AFFECTING TIME PERFORMANCE

From appendix E, it can be observed that 68% of the surveyed projects were completed beyond the original schedule. Graph 5.4a illustrates the performance for these delayed projects. Graph 5.4b shows the performance when there was no time delay.

Graph 5.4a:Performance in case of delay



Graph 5.4b: General performance



Graph 5.4a: Effects of time delay on some measure of the project performance.

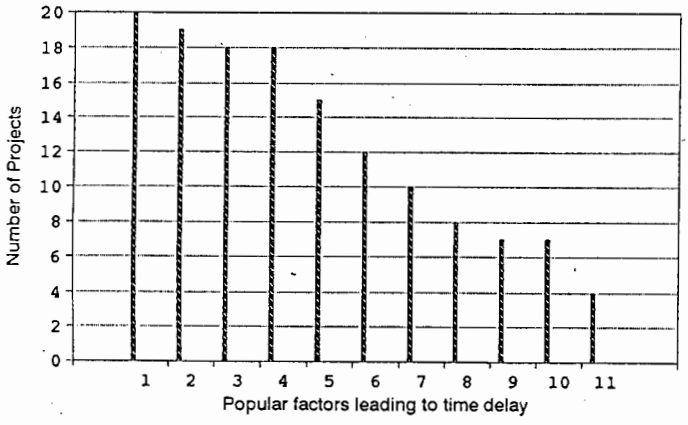
Graph 5.4b: Performance of the projects that were not delayed.

The table 5.5 below summarises the observations from graphs 5.4.

Performance in terms of budgeted cost, technical quality and client satisfaction				
	Time delayed projects		No time delayed projects	
	improved	deteriorate	improved	deteriorate
Cost	5%	24%	22%	15%
Technical	10%	6%	25%	2%
client	17%	9%	20%	2%

Table 5.5: Summary of performances in case of time delay and no time delay.

5.5.1 Frequency Distribution of Other Key Factors Leading to Poor Time Performance



Labels on the x-axis
of graph 5.5

1 - procurement delay
2 - red tape
3 - staff overloaded with work
4 - insufficient risk analysis
5 - unclear goal specifications
6 - inaccurate cost estimate
7 - improper feasibility studies
8 - insufficient skills
9 - technological changes
10 - technical problems
11 - staff absent

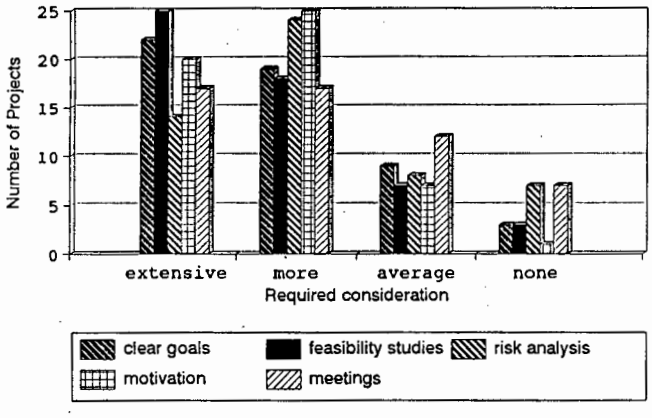
Graph 5.5: Frequency distribution of some additional reasons for time delay.

Graph 5.5 indicates that

- The most popular reasons for delay are the procurement delay, red tape, project staff being overloaded and insufficient risk analysis.

5.5.2 Possible Ways of avoiding Time Delay

Graph 5.6 illustrates the possible ways of avoiding time delay, as suggested by the questionnaire's respondent.



Graph 5.6: Frequency distribution of the consideration to be given to some key factors to avoid time delay.

From graph 5.6, it is observed that

- Clear goal specification, feasibility studies, motivational factors and risk analysis are considered as very important factors in avoiding delay.

6. DISCUSSION OF FINDINGS

Prior to discussing the results of the industrial survey, an assessment of the limitations of the survey must be made. The major limitations involved in this survey are :

i) Limitation of the survey scope.
ii) Limitation of the questionnaire construction.
iii) Limitation of the statistical procedures.

6.1 LIMITATION OF THE SURVEY SCOPE

- The demographical group aimed at was electronic engineers, project engineers and project managers. The project engineers and project managers usually have a fair knowledge of the managerial phases of a project. The engineers, on the other hand, are often assigned part of a project without much knowledge of the planning and monitoring phases. These engineers are more familiar with the technical and time performance rather than the cost performance and client satisfaction factor. This could explain why some questionnaires were only partially completed.

- For many electronic engineering companies, project management is but, a theoretical concept. This may have led to a certain degree of subjectivity in answering the questionnaire.

- The questionnaires were mailed to the companies. Mailed surveys are notorious for a low return of about 15%. This explains the limitation in the number of returned questionnaires.

6.2 LIMITATION OF THE QUESTIONNAIRE CONSTRUCTION

- The questionnaire was fairly long. The reason was to provide a fair choice of answers for each question. The length however, could have demotivated the respondents from completing the questionnaire.

- Despite the reasonable choice of answers, the respondents often added their own answers. This resulted in a more complicated database system.

- Although the scaling factors aimed at providing concise information, they might have seemed confusing to some respondents.

- The fact that a lot of the respondents are Afrikaans-speaking while the questionnaire was in English, might have led to misinterpretation.

6.3 LIMITATION OF THE STATISTICAL ANALYSIS

- The database used displays certain inadequacies. For example, the statistical procedures operate on the assumption that the data are normally distributed. There is evidence to support the normal distribution of the data, only in certain cases.

- The statistical procedures present certain limitations. For example, the graphical analysis could not be effectively used to portray relationships between the variables.

- In using the regression analysis technique, it was difficult to define which variable is the dependent one and which is the independent one. Also, the linear model obtained is but, an approximation of the actual condition.

These limitations should be kept in mind while discussing the results of the data analysis. The discussion that follows aims at clarifying some major findings from the industrial survey, so as to fulfil the objectives of the thesis, namely,

i) to establish, to some extent, how the project performance is affected by the project structural factors;

ii) to find out how these structural factors interact with the application of the time control techniques;

iii) to determine the effect of the application of time control techniques on the project performance;

iv) to find out other critical factors leading to poor time performance;

vi) to find out how time delay can be avoided; and

vii) to draw appropriate conclusions and recommendation on the time management of electronic projects.

6.4 RELATIONSHIP BETWEEN STRUCTURAL FACTORS AND THE APPLICATION OF TIME CONTROL TECHNIQUES

Both the industrial survey and the literature review revealed that the project structural factors are related to the application of time control techniques. The structural factors used to verify the nature of this relationship are the project duration, its cost, the project organisational structure and the management of the project time planning. The statistical analyses generated the following major observations:

i) **The time control techniques that have the greatest influence on the project cost and its duration, are informal control techniques and formal reporting techniques. The application of informal control techniques affects the project duration and its cost negatively, whereas, the application of formal reporting techniques is positively related to the project cost and its duration.**

This can be attributed to the fact that these two time control techniques were the most frequently applied throughout the project, as shown by table 5.1. The frequent application of these techniques is associated to the advantages they provide.

The application of informal control techniques negatively influences both, the project cost and its duration. As the project cost and its duration increase, the informal control

techniques become less applicable. The reason is that high cost or long duration projects usually involve a higher level of complexity. For such complex projects, the proper management of various resources is crucial, resulting in the need for a control technique which couples time to the management of other resources.

Thus, the application of informal control techniques alone cannot efficiently handle the complex interaction of resources in a big project. Its application becomes less effective as the cost and the duration of the project increase.

ii) **The project team structure has the strongest positive influence on the efficient application of the time control techniques considered, except for network analysis techniques.**

The use of a project team structure resulted very often in the efficient application of the time control techniques. This structure was also the most frequently encountered one (graph 5.2). The frequent application of this project organisational structure can be explained by the advantages it provides, by having a centralised management system.

In such a managerial system, because a single person is totally accountable for the entire project, there is a much better application of integrated planning and control techniques. This corresponds to the synergy effect.

iii) **The most efficient application of all the formal time control techniques considered is achieved whenever the project manager/project engineer, the project team together with the planning department are responsible for the project time planning.**

This can be explained by the fact that when the entire project team participates in the planning stage, there is better understanding and more commitment to the project. Therefore, the probability of success is stronger. That is, participative management promotes involvement and coordination which are key factors for success.

iv) **The most efficient application of network analysis techniques is obtained when the project manager together with the planning department are in charge of the project time planning.**

Network analysis techniques require a precise breakdown of the project into a comprehensive set of activities. The complex interaction of all the resources involved must also be taken into account. The planning department is thus of considerable assistance, since it has the necessary expertise and knowledge in extensive planning activities.

This also explains why network analysis techniques were more efficiently applied under a functional matrix structure. Such a structure allows experts from the planning department to assist in the complexity of its planning stage.

6.5 RELATIONSHIP BETWEEN STRUCTURAL FACTORS AND PROJECT PERFORMANCE

The project structural factors that have been considered in the statistical analyses for establishing the nature of the relationship between the project structural factors and the project performance are the project duration, its cost, the project organisational structure and the management of the project time planning.

The following major observations were made :

i) **The project duration is a stronger determinant of the project performance than the project cost.**

The reason is that the project cost itself is often dictated by the project duration. As shown by table 5.5, for 24% of the delayed projects, the cost rose beyond the expected value. Thus, if these two factors, the duration and the cost, are used to determine the project performance, the duration factor will be more dominant.

ii) **The project team structure has the highest positive influence on the project performance.**

This can again be attributed to the advantages of the centralised management system provided by the project team structure, as explained earlier.

iii) **All the measures of performance considered are more likely to be successful when the project manager/engineer and the project personnel take charge of the project time planning.**

Again this can be ascribed to the advantages of a participative management system.

6.6 RELATIONSHIP BETWEEN PROJECT PERFORMANCE AND THE APPLICATION OF TIME CONTROL TECHNIQUES

From the regression analysis between the application of time control techniques and the project performance, the following major observation was made:

- The efficient application of charting techniques has a most positive influence on all the four measures of performance considered.

From the Contingency Table analysis, it was found that

- the application of informal control techniques as well as charting techniques have the highest positive influence on the project performance.

The observations from both the regression analysis and the Contingency Table analysis can be explained by the advantages of the alternative time control techniques considered and the extent of application of each technique.

Table 5.1 and graph 5.3 indicated that, very often informal control techniques and charting techniques have been efficiently applied throughout the project duration. The popular application of these control techniques is related to their advantages and suitability for electronic engineering projects.

Charting techniques are easy to draw, easy to read and easy to update. As Locke states, "the visual impact of a well-displayed chart technique can be a powerful aid to controlling projects." Informal control techniques provide immediate concise information on the project progress.

Line of balance technique was the least used control technique in this survey. The reason is that this time control technique is more appropriate in a batch manufacturing environment than a project development condition. Hence, its rare application in the electronic engineering industry.

6.7 ADDITIONAL FACTORS AFFECTING TIME PERFORMANCE

Graph 5.4 and table 5.5 indicate the consequences of time delay on budgeted cost, technical quality and client satisfaction. All these three measures of performance are observed to have worsened in cases of time delay. The reason is that, if a project takes longer, usually the stress on the project team increases, resulting in poor technical performance. At the same time, the client becomes impatient and frustrated. Also if the team works overtime, they must be paid more. Thus, cost performance deteriorates.

6.7.1 Other key Factors Leading to Poor Time Performance

From graph 5.5, it was found that poor time performance is strongly associated to those project structural factors concerning the structure, protocol and functioning of the organisation. For example, red tape which is the result of the organisation system of protocol often delays project. The red tape factor can be partially overcome by setting up a faster communication channel within the organisation.

The project staff being overloaded with work, is another common reason for time delay. Such a problem usually prevails when the project is being implemented under a functional or functional matrix structure. This can explain why these structures were not as popularly applied as the project team structure.

Insufficient risk analysis also leads to time delay. This may be attributed to the fact that in this survey, the time control techniques which accommodate for risk analysis and a work breakdown structure, namely network analysis techniques, have been poorly applied.

Procurement delay was the strongest determinant of time delay in the survey. Procurement delay is often the outcome of improper planning and forecasting of resource requirements. The poor application of network analysis techniques could again be the reason for such procurement delay. These techniques usually shed light on the interdependencies of activities in a project. Any resource required to perform an activity can be determined in advance, and the necessary provision can be made, in advance.

6.7.2 Ways of avoiding Time Delay

From graph 5.6, it was observed that some other structural factors are considered as crucial in avoiding time delay, namely, clear goal specifications, sufficient appraisal studies and motivational factors.

Clearer goal specifications and higher motivation of the project team can be easily realised in a participative management environment. This corresponds to the earlier observation that participative management leads to a more effective application of the selected time control techniques for electronic engineering projects.

From the findings of chapter 5 and the discussion of these findings, it is clear that the project performance is not only related to the suitable application of time control techniques, but also, to the project structural factors. Thus, a time management system, aimed at enhancing the project performance, must take into account the project structural factors.

7. CONCLUSION AND RECOMMENDATION

Based on the findings of the literature review and the industrial survey, the following conclusions can be drawn:

7.1 STRUCTURAL FACTORS AND PROJECT PERFORMANCE

7.1.1 The Project Duration and its Cost and the Project Performance

- The project duration is a more important factor for determining the project performance than the project cost.
- The nature of the relationship between the project duration and the project performance is such that, the shorter the duration, the higher the probability of meeting success in terms of cost, time, technical quality and client satisfaction. The duration also dictates the project cost.

7.1.2 Project Organisational Structure and Project Performance

- Project team structure is the organisational structure that most positively influences the project success in terms of cost, time, technical quality and client satisfaction, for electronic engineering projects.

7.1.3 Management of Project Time Planning and Project Performance

- The success of the technical performance and the client satisfaction factor, for electronic engineering projects, are improved when the project manager/project engineer and the project personnel are in charge of the project time planning.
- The cost performance is best whenever the project engineer/project manager is responsible for the project time planning.
- The time performance is very successful whenever the project manager/engineer and the project personnel take care of the project time planning.

7.2 STRUCTURAL FACTORS AND THE APPLICATION OF TIME CONTROL TECHNIQUES

7.2.1 The Project Duration and its Cost and the Application of Time Control Techniques

- Informal control techniques and formal reporting techniques are the strongest determinants of the project duration.
- The project duration is negatively related to the application of informal control techniques, but positively influenced by the use of reporting techniques. As the project duration increases, the application of informal control techniques becomes less effective whereas formal reporting techniques become more effective.
- Informal control techniques and formal reporting techniques have an outstanding influence on the project cost.
- The application of informal control techniques has a negative influence on the project cost. The application of formal reporting techniques positively influences the project cost. As the project becomes more costly, the application of informal control techniques becomes less effective whereas the use of formal reporting techniques becomes more appropriate.
- The project cost and its duration are not related to the application of line of balance techniques, for electronic engineering projects.

7.2.2 The Project Organisational Structure and the Application of Time Control Techniques

- The project organisational structure is significantly related to the application of all the time control techniques considered.
- Project team structure has the strongest positive influence on the efficient application of all the time control techniques considered, except for network analysis techniques.
- The application of network analysis techniques becomes most efficient under a functional matrix structure.
- Functional structure contributes very poorly to the efficient application of all the time control techniques considered, for electronic engineering projects.

7.2.3 Management of Project Time Planning and the Application of the Time Control Techniques

- The application of informal control techniques is most efficient when the project manager/the project engineer and the project personnel are responsible for the project time planning.
- The application of the more formal control techniques such as charting techniques, is most efficient when the project manager/project engineer, the project team and the planning department are all involved in the project time planning.
- The application of network analysis techniques is most efficient when the project manager/project engineer and the planning department take care of the project time planning.

7.3 THE APPLICATION OF TIME CONTROL TECHNIQUES AND PROJECT PERFORMANCE

- Prior to selecting the type of control techniques to be applied, the advantages and shortcomings of each technique need to be evaluated. The easily understood and easily implemented techniques are popularly used throughout the project and thus, have a significant impact on the project performance. Examples are informal control techniques and charting techniques.
- The efficient application of charting techniques most positively influences the project success in terms of cost, time and client satisfaction.
- The application of informal control techniques positively influences all the measures of performance considered.
- The efficient application of network analysis techniques contributes highly to successful technical performance.

7.4 OTHER KEY FACTORS AFFECTING TIME PERFORMANCE

- Other significant structural factors that can result in poor time performance of electronic engineering projects are red tape, procurement delay and insufficient risk analysis.
- Additional key structural factors that can assist in achieving a successful time performance are:

  Clearer goal specifications, higher motivational factors, effective procurement management, adequate risk analysis studies, faster communication system.

Hence, the effectiveness of a time management system depends on

- the effectiveness of the alternative types of time control techniques;
- the efficient application of the selected time control techniques;
- the project organisational structures;
- the authority responsible of the project time planning;
- the project complexity level (i.e, the duration and value); and
- other important structural factors governing the project.

7.5 RECOMMENDATION

Based on the findings and conclusions of this research study, the following recommendations can be made

i) The Application of Time Control Techniques and the Project Structural Factors

- If the project has a high complexity level (i.e, long estimated duration and high cost), then the application of formal control techniques such as formal reporting should be given more consideration than the use of informal control techniques.
- In order to achieve an efficient application of the selected time control techniques for an electronic project, a project team structure should be used.
- In order to accomplish an efficient application of network analysis techniques, a functional matrix structure should be utilized.
- Functional structure should be avoided in order to realise the efficient application of the chosen time control techniques, for electrical engineering projects.
- The project manager/project engineer, the project personnel together with the planning department should be responsible for the project time planning in order to attain an efficient application of the formal time control techniques.
- In the case of the efficient application of informal control techniques, the project manager/project engineer and the project personnel should take care of the project time planning.
- In the case of the efficient application of network analysis techniques, the project manager/project engineer and the planning department should take care of the project time planning.
- To avoid time delay, overall risk analysis should be carefully evaluated. This can be achieved by making more efficient use of network analysis techniques. Also, participative management should be utilised in order to promote clear goal specifications and motivation, since these two factors frequently lead to time delay.

ii) The Application of Time Control techniques and the Project Performance

- In order to achieve success in terms of all the measures of performance considered, the application of informal control techniques (in the case of electronic projects which are not very complex) should be more efficient.
- In the case of electronic engineering projects with a high complexity level, the application of charting techniques and formal reporting techniques should be more thorough, in order to achieve success in terms of cost, time, technical quality and client satisfaction.
- To obtain successful technical performance, network analysis techniques should be applied more efficiently.

iii) Further Research

- An extensive research, which covers a wider geographical area, should be made.
- A more intensive survey should be conducted. It should make use of personal interviews with the relevant staff in order to investigate the validity of the guidelines that have been derived from this study.
- An investigation should be made into the effects of the macro-environment on the time management system and the project performance.

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APPENDIX A

THE QUESTIONNAIRE USED IN THE INDUSTRIAL SURVEY

SURVEY ON PROJECT TIME MANAGEMENT

Considering a range of 5 engineering projects that have been completed in the last approximately 5 years, answer each of the following questions for each project, by placing the appropriate number from the options (1) to (5) in the appropriate project column.

Example (i) : Refer to the question as stated below in (i). Suppose project 1 was completed in 1988, project 2 in 1989, projects 3 and 4 in 1990, project 5 in 1992, then the answer is marked as shown.

PROJECT NUMBER

	1	2	3	4	5
Answer to (i) :	(1)	(2)	(3)	(3)	(5)

(i) When was each project completed ?

(1) 1988

(2) 1989

(3) 1990

(4) 1991

(5) 1992

PROJECT CHARACTERISTICS

	1	2	3	4	5

1. How long was the planned time estimate of each of the five projects ?

(1) 0 - 2 months

(2) 2 - 6 months

(3) 6 months - 1 yr

(4) 1 yr - 3 yr

(5) > 3 yr

2. What was the cost of each project (including salaries)?

(1) R 0 - R 25 000

(2) R 25 000 - R 50 000

(3) R 50 000 - R 150 000

(4) R 150 000 - R 500 000

(5) R 500 000 - R 1 million

PROJECT FEASIBILITY STUDIES

3. Using the scale

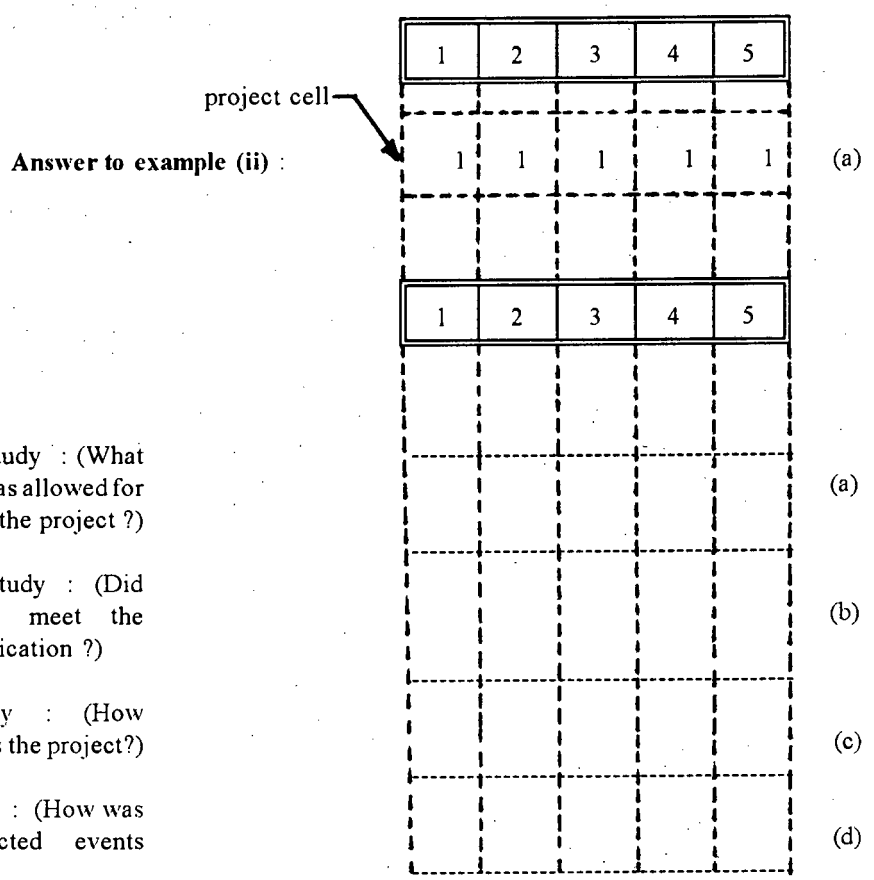
(1) None (2) Brief (3) average (4) thorough

rate the consideration given to each of the following studies (a) - (d) listed below, for each project. Indicate by placing the appropriate no. (1) - (4), in the appropriate project cell.

An example is given in (ii) below.

Example (ii) : If no technical / feasibility study was made for projects 1 - 5 then the answer for (a) will be as shown below :

PROJECT NUMBER



(a) Technical / Feasibility Study : (What technical consideration was allowed for successful completion of the project ?)

(b) Operational Suitability Study : (Did the completed project meet the required operating specification ?)

(c) Financial Viability Study : (How expensive / profitable was the project?)

(d) Risk Sensitivity Analysis : (How was provision for unexpected events made?)

4. For each project, select from the list of options (1) to (7) below, the person/people who was/were responsible for each study (a) - (d), above (see quest.3 for full description of studies (a) - (d)). Once again, enter the option in the appropriate project cell.

(1) project manager (2) project engineer (3) planning department (4) financial department

(5) administrative department (6) project personnel (7) other (please specify) .....

PROJECT NUMBER

	1	2	3	4	5	
(a)	Technical / Feasibility Study					(a)
(b)	Operational Suitability Study					(b)
(c)	Financial Viability Study					(c)
(d)	Risk Sensitivity Analysis					(d)

PROJECT ORGANISATIONAL STRUCTURE

5. Which of the following project organisational structures were used to implement each project ? Once again, this question is answered similar to question 1 and 2. Select the structure, i.e. numbers (1) - (5) below, and place it in the appropriate project column,

PROJECT NUMBER

1	2	3	4	5

(1) **Functional** : (project divided into segments and assigned to relevant functional areas and/or groups within functional areas. The project is co-ordinated by upper levels of management, i.e. no specific project manager is assigned.)

(2) **Functional Matrix** : (A person is formally designated to oversee the project across different functional areas. This person has limited authority over the functional people involved, and serves primarily to plan and co-ordinate the project. The functional managers retain primary responsibility for their specific segments of the project.) (more ->)

(3) **Balanced Matrix** : (A person is assigned to oversee the project and interacts on an equal basis with functional managers. This person, and the functional managers jointly direct work flow segments and approve technical and operational decisions.)

(4) **Project team** : (A manager is put in charge of a project team composed of a core group of personnel from several functional areas and/or groups, assigned on a full-time basis. The functional managers have no formal involvement.)

PROJECT TIME CONTROL TECHNIQUES

6. A list of time management techniques, (a)-(g), is given below on page 5. Using the scale (1) - (10) given below, for each project, rate the time management techniques applied during the project execution. Indicate by placing the chosen number (1) - (10), in the appropriate project cell. An example is shown below in (iii).

(1) too simple to be adequate.

(2) too complex to be understood.

(3) too demanding and caused stress.

(4) specifically adapted to meet specific requirement on project.

(5) widely accepted by project staff and understood.

(6) structured such that they could be easily instituted.

(7) integrated with project cost and quality control mechanisms.

(8) applied throughout the full duration of the project.

(9) applied only at the start.

(10) other (please specify below)

.....

.....

.....

Example (iii) : If, for all projects 1 - 5, informal meetings (one of the time management techniques used) were applied only at the start, then the answer to (a) will be (see next page) :

Quest. 6 contd ....

PROJECT NUMBER

1	2	3	4	5	
9	9	9	9	9	(a)
1	2	3	4	5	
					(a)
					(b)
					(c)
					(d)
					(e)
					(f)

Answer to example (iii) :

The list of time management techniques that could have been applied during the project execution are now listed. Enter the answer in the appropriate project cell.

(a) Informal Meetings

(b) Formal Reporting (to Superiors)

(c) Bar/Gannt charts indicating work duration and percentage completion.

(d) Milestone on a work breakdown structure.

(e) PERT/CPA network analysis

(f) Line of Balance

7. In the case of each project, who was responsible for project time planning ? Place the answer in the appropriate column.

1	2	3	4	5

(1) project manager

(2) project engineer

(3) planning department

(4) financial department

(5) administrative department

(6) project personnel

(7) combination of those chosen above

PROJECT PERFORMANCE

8. This question must be answered as described in example (ii) on page 2. Using the following scale :

(1) extremely successful (2) successful (3) quite successful

(4) not successful at all

determine how successful each project was in terms of

PROJECT NUMBER

1	2	3	4	5

(a) meeting budgeted costs (a)

(b) meeting time schedules (b)

(c) meeting technical specifications (eg. power, current consumption, overheating, etc.) (c)

(d) meeting client's request (d)

1	2	3	4	5

9. Using the scale, from (1) to (3),

(1) beyond the original scheduled date

(2) completed on time

(3) completed before scheduled date

state when each project was completed ? Enter the answer under the appropriate project column.

10. In the case of projects completed beyond the original scheduled date, using the scale :

(1) beyond expectations (2) as expected (3) below expectations

determine how the following factors were affected

PROJECT NUMBER

		1	2	3	4	5	
(a)	budgeted cost						(a)
(b)	client's expectation (market)						(b)
(c)	planned workload of project personnel						(c)
(d)	quality of project						(d)
(e)	enthusiasm of project personnel						(e)
(f)	other (please specify)						(f)

11. What events, according to you, led to project delay, for each project that was completed beyond scheduled date ? Indicate by placing a cross (x) in the respective project cell.

PROJECT NUMBER

		1	2	3	4	5
(1)	component/equipment not available on time (procurement delay).					
(2)	technical/project staff absent (on leave for example).					
(3)	project staff overloaded with other minor projects.					
(4)	technical problem with equipment.					
(5)	rapid change in technological environment (leading to changes in plan so as to be more competitive).					
(6)	red tape					
(7)	unclear/ambiguous specification statement.					

Question 11 contd ...

PROJECT NUMBER

1	2	3	4	5

(8) unpredicted requirement of specialised skill.

(9) other (please specify)

.....

.....

PROJECT NUMBER

1	2	3	4	5

12. Which, if any, of the following factors were responsible for project delay ? Once again, indicate by placing a cross (x) in the correct project cell, as in question 11.

(1) technological problem due to improper feasibility studies.

(2) inaccurate budget estimates.

(3) ambiguous/unclear specification requirement (unclear objectives).

(4) insufficient risk analysis. (not enough contingency planning)

(5) Other (please specify)

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13. What, according to you, should be done to avoid delays ?

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14. Using the following scale :

(1) more extensive consideration (2) more consideration

(3) some consideration (4) no consideration at all

rate the consideration to be given to the following factors, so as to avoid delays. Place the answer in the project cell.

PROJECT NUMBER

1	2	3	4	5

(a) clear definition of project objectives. (a) ----------

(b) thorough technical studies, operational, financial studies. (b) ----------

(c) sensible risk analysis involving project personnel. (c) ----------

(d) motivation of project staff (d) ----------

(e) regular meetings (e) ----------

(f) Other (please specify)
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.....
.....
..... (f) ----------

15. What engineering division are you working for ?

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.....

16. What is your grade in this division ?

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.....
.....
.....

Thank you for your support

APPENDIX B1

RESULTS OF THE CONTINGENCY TABLE ANALYSIS SHOWING HOW THE UTILISATION OF EACH PROJECT ORGANISATIONAL STRUCTURE CONTRIBUTES TO THE EFFICIENT APPLICATION OF EACH TIME CONTROL TECHNIQUE CONSIDERED.

The table below is a table of percentage observed frequencies showing how the utilisation of each project organisational structure contributes to the efficient application of each time control technique considered in the survey . This table was obtained by means of the Contingency Table analysis.

Project organisation structure	Efficient application of					
	informal	report	chart	miles-tone	net-work	line balan
functional	7.8%	4.2%	6.8%	5.6%	5.3%	0%
functional matrix	19.6%	25%	14%	30.6%	58%	40%
balanced matrix	3.9%	14.6%	15.9%	5.6%	5.3%	0%
project team	68.6%	56.3%	63.6%	58.3%	32%	60%

APPENDIX B2

RESULTS OF THE CONTINGENCY TABLE ANALYSIS SHOWING HOW THE APPLICATION OF EACH TIME CONTROL TECHNIQUE IS RELATED TO THE AUTHORITY RESPONSIBLE FOR THE PROJECT TIME PLANNING.

The table below is a table of percentage observed frequencies showing how the efficient application of each time control technique is related to the authority responsible for the project time planning.

Responsible party	Efficiency of application of					
	informal	report	chart	mile-stone	net-work	line balance
1	59%	60.4%	52.3%	61%	80%	63.2%
2	58%	50.4%	42.7%	53.9%	60%	10.5%
3	0%	6.3%	0%	8.3%	0%	15.8%
4	0%	0%	0%	0%	0%	0%
5	2%	0%	0%	0%	0%	0%
6	11.8%	12.5%	13.6%	16.7%	0%	5.3%
7	99%	77%	72%	85%	65%	90%

Legend for the column showing the responsible party for time planning (i.e, the first column).

1 - project manager
2 - project engineer
3 - planning department
4 - financial department
5 - administrative department
6 - project personnel
7 - combination of those chosen above

APPENDIX C1

RESULTS OF THE CONTINGENCY TABLE ANALYSIS SHOWING HOW THE UTILISATION OF EACH PROJECT ORGANISATIONAL STRUCTURE CONTRIBUTES TO SUCCESSFUL PROJECT PERFORMANCE.

The table below is a table of percentage observed frequencies showing how the utilisation of each project organisational structure leads to successful measures of performance.

project organisa-tional structure	Successful performance in terms of			
	Cost	Time	Technical specification	client satisfaction
functional	10%	10%	7.5%	10%
functional matrix	0%	5%	30.2%	20.4%
balanced matrix	17%	20%	13%	14.3%
project team	72%	65%	49%	55%

APPENDIX C2

RESULTS OF THE CONTINGENCY TABLE ANALYSIS SHOWING HOW EACH DIFFERENT AUTHORITY RESPONSIBLE OF THE PROJECT TIME PLANNING CONTRIBUTES TO SUCCESSFUL MEASURES OF PERFORMANCE.

The table below is a table of percentage observed frequencies showing how each different authority responsible of the project time planning contributes to successful project performance.

Responsible party	Successful performance in terms of			
	cost	time	technical specification	client satisfaction
1	45%	40%	57%	47%
2	40%	32%	53.2%	28%
3	0%	0%	5.7%	0%
4	0%	0%	0%	0%
5	3.4%	5%	0%	2%
6	6.9%	20%	13.2%	12.2%
7	14%	44%	85%	80%

Legend for the column showing the responsible party for the project time planning (i.e, the first column).

1 - project manager
2 - project engineer
3 - planning department
4 - financial department
5 - administrative department
6 - project personnel
7 - combination of those chosen above

APPENDIX D

RESULTS OF THE CONTINGENCY TABLE ANALYSIS SHOWING HOW THE EFFICIENT APPLICATION OF EACH TIME CONTROL TECHNIQUE CONTRIBUTES TO SUCCESSFUL MEASURES OF PROJECT PERFORMANCE.

The table below is a table of percentage observed freqencies showing how the efficient application of each time control technique contributes to successful project performance in terms of cost, time, technical specification and client satisfaction.

Efficient application	Successful performance in terms of			
	cost	time	technical specification	client satisfaction
informal	86%	80%	74%	84%
report	42%	27%	81%	69%
chart	86%	80%	79.6%	76%
milestone	39%	22%	79%	63.9%
network	10.5%	16%	84.2%	52.7%
line of balance	0%	35%	36%	29%

APPENDIX E

ACTUAL TIME PERFORMANCE OF THE SURVEYED PROJECTS.

ACTUAL TIME PERFORMANCE OF the Surveyed Projects