KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY
KUMASI

COLLEGE OF ARCHITECTURE AND PLANNING (DEPARTMENT OF BUILDING TECHNOLOGY)

MSC. CONSTRUCTION MANAGEMENT PROGRAMME

EXTENT OF UTILISATION OF THE LINEAR PROGRAMME PLANNING TECHNIQUE FOR SCHEDULING ROAD CONSTRUCTION WORKS IN GHANA

BY

CYPRIAN ATTA NYAMEKYE

MSc. Applied Polymer Science, M.L.U. – HALLE-WITTENBERG (GERMANY)

BSc. (Hons) Building Technology, K.N.U.S.T – KUMASI (GHANA)

A PROJECT SUBMITTED TO THE DEPARTMENT OF BUILDING TECHNOLOGY, KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN CONSTRUCTION MANAGEMENT

APRIL, 2013

DECLARATION

I hereby declare that, this submission is my own work towards the Msc. Degree and that, to the best of my knowledge, it contains no material previously published by another person nor material which has been accepted for the award of any degree of the university or elsewhere, except where due acknowledgement has been made in the text.

…….. …….

CYPRIAN ATTA NYAMEKYE DATE

(STUDENT)

…… ……

DR. S. OTENG-SEIFAH DATE

(FIRST SUPERVISOR)

…… ……..

DR. T. ADJEI-KUMI DATE

(SECOND SUPERVISOR)

……..…… ……..

PROF. J. AYARKWAH DATE

(HEAD OF DEPARTMENT)

DEDICATION

To the cherished memory of my late father Nana Yaw Marfo. May the good Lord keep you safe in HIS kingdom till we meet again. Amen

ACKNOWLEDGEMENTS

The author first and foremost wishes to acknowledge with all humility and respect the tremendous assistance and contributions received from the project supervisors, in the persons of Dr. Samuel Oteng-Seifah and Dr. TheophilusAdjei-Kumi both of the Department of Building Technology, KNUST, Dr. K. A. Manteau (Department of Building Technology KNUST – Kumasi).

Further appreciation goes to the following personalities for their immense and varying contributions during the preparation of this project repor; Mr. Joseph Ofosu-Appiah (Cymain Ltd.), and especially Mr. Andrew OpokuNyamekye (Senior estimator, Hanscomgould - U.S.A). I must admit that, the various roles they played in providing certain information and academic journals during the preparation of this work have been very helpful.

I wish also to thank Mrs. Nana AdwoaNyamekye (wife), Aunt Hilda, Aunt Comfort and Mr. kwabenaAsare (Department of Building Technology, KNUST) for their prayers, moral support and encouragement.

Also to all road contractors and consultants in the road sector of the economy who assisted by filling out the questionnaires and granting interviews to the author, I say ''ayekoo'' and I appreciate very much your modest contributions.

Above all, to God almighty be the glory and honour for the gift of life and strength to carry on with this piece of work.

ABSTRACT

Construction projects possess unique characteristics which make individual planning of each project essential. Planning entails the determination of how the job would be done, in what order and with what resources. There are many planning techniques available which could be applied to manage construction projects. Some of the planning techniques available for construction projects are the bar chart analysis and network analysis (suitable for simple and complex building construction works respectively). Others include line of balance analysis (for repetitive works) and linear programme analysis which is widely popular technique in the United Kingdom for scheduling road works and other linear projects like railways and tunnels. The most appropriate planning technique(s) must therefore be chosen when planning for any particular project in order to ensure optimum use of available resources, since certain planning techniques are more suitable for certain types of projects. In the Ghanaian road construction industry, there are four planning techniques available for the purposes of scheduling road works. These are; the bar chart, the network analysis, the line-of-balance and the linear programme techniques. The choice and extent of use of the available techniques for scheduling road construction works in Ghana is influenced by certain factors. Research findings indicate that, professionals in industry regard some factors as having significant influence on their choice and use of a planning technique than others. Seven factors were identified to be significant, out of a total of fifteen factors which featured in the study. The significant factors include; Client / Consultants' Preferences, Suitability of Technique, Knowledge and Flexibility of Technique, Simplicity of Technique, Efficiency of Technique, Availability and Cost of Software Package and Contractor's Preferences.

The Linear programme technique has been an effective planning tool used to schedule road or highway construction projects and other linear projects measured by chainages for many years now in some of the world's major economies like the United Kingdom. The technique has successfully been used to schedule highway construction projects where the Critical Path Method and the bar chart planning techniques have woefully failed to accurately model and manage such linear road projects.According to the research findings, the linear programme planning technique is rarely used by the road sector in Ghana for the sole purpose of scheduling and managing activities involved in

road works, despite its efficiency and suitability for managing linear projects. The state-of the- art planning technique largely used to schedule road works in the country is the traditional bar chart. Thus compared to the bar chart technique, the linear programme technique enjoys very low patronage among the professionals in the road construction industry as far as programming and scheduling road construction works in the country is concerned; a situation which could be blamed on the factors which influence professionals' decision on the choice of a planning technique for scheduling road construction works. The future prospect of the linear programme as a planning technique for scheduling road construction works in the country, nevertheless, remains auspicious, since results and feedbacks from professionals who featured in the research work indicate awareness of the existence of the linear programme technique; a very encouraging first step towards the full integration of the technique into the operations of the road construction industry in Ghana. In fact, a fraction of professionals in the industry have also actually been using the linear programme technique in combination with the bar chart, to a much lesser extent to schedule road works in the country which is also a promising and a good beginning for the linear programme in industry.A comparative description of the linear programme technique and the bar chart technique is also made using a case study of an on-going road project work in Ghana.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER ONE

1.0 INTRODUCTION

The linear programme (also referred to as *Time-Chainage Chart* in some Construction projects possess unique characteristics which make individual planning of each project essential, Askew et al. (2002). Planning entails the determination of how the job would be done, in what order and with what resources; reducing the project or part of the project to a number of activities that would be easily manageable, among other things.

There are many planning techniques available which could be applied to manage construction projects. For example, new road projects are linear in nature and can be planned following a planner's preferred technique. Experience also suggests that certain planning techniques are more suitable and useful for certain types of projects, Al-Jibouri et al. (2004). This implies that no single technique can suitably be applied to schedule every construction projects irrespective of the type and nature of the project. Hence, management is expected to select the most appropriate planning technique(s) when planning for any particular project in order to ensure optimum use of available and most economic resources [i.e. man, money, machine and materials (the 4m's)]

Some of the planning techniques available for construction projects are the bar *chart analysis* and *network analysis* (suitable for simple and complex building construction works respectively). Others include *line of balance analysis* (for repetitive works) and *linear programme analysis* which is widely popular technique in the United Kingdom for scheduling road works and other linear projects like railways and tunnels as alleged by Cooke and Williams (2004).

It is worth mentioning that, the *linear programme*asbeing considered in this research publication denotes a construction planning technique for scheduling road construction project works, and not the *linear programme* mathematical technique we know of as a topic in 'Operations Research'.

1.1 PROBLEM STATEMENT

Major work activities on typical road construction and rehabilitation projects are linear activities. The planning and scheduling of such linear activities is appropriately carried out using the linear programme technique. The linear programme technique, coupled with advances in computer technology and software has the ability to provide significant advancement to road construction project scheduling and management.

Preliminary observation of the road construction industry in Ghana by this researcher however, has identified the bar chart as the predominantly accepted planning technique applied for scheduling almost every road construction project work in the country. Unfortunately, the application of the traditional bar chart scheduling technique to road construction has quite a number of limitations because major road construction projects fundamentally consist of linear activities, which the bar chart technique is unable to accurately model, according to Harmelink and Yamin (2000).

Judging from the desirable qualities of the linear programme as a planning technique that works so well for road works scheduling, and the inability of the bar chart technique to effectively schedule road construction works, Harmelink and Yamin (2000), it is quite strange that professionals (i.e. contractors and consultants) in the road sub-sector of Ghana's economy are not applying the technique to schedule road works in the country, although the technique has been around in the construction industry for a long time.

This research is concerned with encouraging the use of the linear programme technique as an additional facility to complement the existing bar chart and other techniques for scheduling road construction works in the country, rather than as a total replacement.

1.2 JUSTIFICATION OF THE STUDY

The road construction industry, the world over has over the past decades witnessed tremendous investment regarding the design and type of planning techniques adopted for road project works schedules as some publications such as one by Harmelink and Yamin (2000) suggest. In some of these economies, especially in the United Kingdom the most

widely applied technique adopted for the purposes of planning and scheduling most major road construction works is the *linearprogramme* which has been used for many years and is considered the most appropriate planning tool, according to Cooke and Williams (2004).

Neale and Neale (1989), also observe that, experimenting with the use of the network analysis for a project as linear as the railway in East Africa proved very unsuccessful as the resulting network diagram ends up as a huge ladder of activities from which it may be difficult to make any meaningful deductions. The same problem is envisaged for similar other linear projects such as road works.

Similarly, Harmelink and Yamin (2000) assert that, the inability of the Critical Path Method and bar chart techniques to accurately model highway construction projects and other linear projects by providing relevant planning and project management information, is getting contractors and transportation officials increasingly frustrated. Furthermore, Messrs Edmonds and De Veen (1981), in a publication presented at the International LabourOrganisation (ILO) forum in Geneva in 1989, corroborates the use of the linear programme diagram (referred to in the publication as the *Time Chainage Chart*) as an ideal planning technique for road work's programming. Johnston (1981) also confirms the linear programe technique (which he called *Linear Scheduling Method or LSM*) as a tool most particularly applicable to scheduling highway projects and other linear projects.

Information obtained from www.pclarke.co.uk(2007) , Harmelink and Yamin(2000) and Messrs Edmonds and De Veen(1981) all indicates that, major world economies (particularly, the United States of America and the United Kingdom) are veering away from the use of the traditional bar chart and CPM techniques for scheduling highway construction projects and gradually integrating the linear programme technique, into their operations for the purposes of scheduling road construction projects and other linear works.

Unfortunately, the same story cannot be attributed to or said about the Ghanaian road construction industry. The road sub-sector in the country on the contrary, still applies the bar charttechnique to schedule its entire road projects as preliminary interview conducted in the industry has revealed. There is no indication to suggest that the industry intends to invest in or embrace the use of other innovative planning techniques (like the linear

programme) to schedule its road works or as a complement to the existing bar chart technique.

From the above submissions, it is obvious that the linear programme technique has come to stay and is fast gaining popularity among the major road construction industries of the world as the planning technique, most appropriate for scheduling road works. It is therefore prudent that the road construction industry in Ghana consider integrating the linear programme technique into its operations as far as scheduling and managing road construction activities is concerned.

1.3 AIM AND OBJECTIVES

1.3.1 Aim

The research is aimed at presenting the *linear programme* technique to the road construction industry in Ghana, as an appropriate planning tool for scheduling road construction works, with the hope of encouraging it usage in the industry.

1.3.2 Objectives

The main objectives of this research work are;

- To identify and examine the factors that influence the selection and application of planning technique for scheduling road projects in Ghana.
- To ascertain the extent to which the *linear programme* technique has been applied to road projects in Ghanaand assessing its potential as a planning tool for scheduling future road projects in the country.
- To make recommendations on how the *linear programme* technique can be incorporated into the operations and practices of the road construction industry of Ghana as a planning tool for scheduling road construction works.

1.4 SCOPE AND METHOD OF STUDY

1.4.1 Scope of Study

The road construction industry principally comprises three main executing agencies who administer government road project works by acting both as consultants and to lesser extent as contractors. These agencies are the Ghana Highway Authority (GHA), Department of Urban Roads (DUR) and the Department of Feeder Roads (DFR). A number of private individual consultants and contractors also constitute the industry. The contractors are classified into groups according to their financial standing and type of work they are mandated to undertake.

This research work attempts to investigate the planning technique(s) preferred by A1B1 and A2B2 contractors and consultants in the road construction industry for scheduling road works; with the view to determining the extent to which the linear programme planning technique has been applied.

Class A and B contractors are those mandated to undertake the following jobs according to Ministry of Roads and Transport classifications;

A: (Roads, Airports and Related Structures) – with 4 main financial classes, A1 to A4;
B: (Bridges, Culverts and other Concrete Structures – with 4 financial classes, B1 to B4;

Consultants here imply engineers, clients and financiers of road construction projects, and involve both private individual consultants and those consultants who work in the three main government agencies.
Information on the number and status of the category of contractors and the consultants in the study was obtained from sources like the Ghana Institute of Engineers, Registrar's General Department, Ministry of Transportation, GHA, DUR, and DFR.

The research work primarily focused on the planning technique options available to the road sub-sector for the purposes of scheduling road works in the country. *Linear programme*, as a planning technique for road works scheduling was particularly

emphasised on. Contractors and consultants views on factors that were considered as having some influence on their choice of a planning technique for scheduling road construction works were sampled. These factors were thus discussed and ranked according to the level of importance that contractors and consultants attached to them.

Four major planning techniques were discussed in this study. These are the bar chart, the network analysis system (or the Critical Path Method), the line-of-balance technique and the linear programme technique. Technical attributes of each of the planning techniques were not the main concern of the study and therefore were not addressed. However, how suitable a technique is in scheduling road works in particular was examined. Comparison of the three main other techniques versus the linear programme technique was made.

A three point scale was for the ranking. A comparative description of the linear programme technique and the traditional bar chart technique was also made using a case study of an on-going trunk road project in the country.

1.4.2 Method of Study

To realize the objectives of this research work, the following methodologies are adopted:

- Comprehensive literature review on the research work using textbooks, journals, and the internet. This is to enable the researcher obtain information on the various planning techniques and methodologies available for use in the road construction industry for scheduling projects.

- Site investigations and visits to offices to conduct interviews with the professionals in the road construction sector in order to determine which of the planning techniques they are most familiar with when scheduling for road roads.

- Design and distribution of questionnaire to professionals like consultants, contractors and financiers in the road sector in order to obtain data necessary for this research work.

The research work is organised into chapters, consisting of six chapters in all.

Chapter One is the Introduction. The chapter introduces the problem indentified in the road sector regarding the planning methodologies being used, states the aims, objectives, scope and the relevance of the study

Chapter Two, Literature Review, reviews the various planning and scheduling techniques adopted for various construction projects including road works and their suitabilities. It also discusses the concept of linear programme technique as an ideal planning technique for road works and compares it with the other major techniques available for scheduling construction works. Factors considered as being influential on the planning technique adopted for road works scheduling are highlighted.

Chapter Three depicts the Research Methodology for the study. Here, Details and contents of the questionnaire, including how the questionnaires are distributed are addressed. Other methods used to collect and analysed research data are stated, and the determination of the sample size for contractors and consultants in the industry is also provided.

Chapter Four, in this chapter, the proposed factors which influence the choice of a planning technique and their relative importance as per contractors and consultants views are discussed and ranked. The ranking is done using a three point scale. In addition, data received from the questionnaire respondents are analysed.

Chapter Five, talks about the planning technique options available to the road construction industry in Ghana, and also identifies the planning technique which is most preferred. The extent to which the *linear programme* planning technique has been used to schedule road construction works and its potential as a planning technique for scheduling road works in the road construction industry is discussed based on the research findings. Finally, a comparative analysis of the linear programme and the bar chart techniques is made using a case study.

Chapter Six, we have the Summary, Conclusions and recommendations of the research findings featuring in this chapter.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 CONSTRUCTION PLANNING

All construction projects require planning from beginning to end, from inception and feasibility study to final commissioning and handing over the completed works to client. Construction project planning is the process of identifying all the activities necessary to successfully complete the project, which often involves huge budgetary allocation of money.

Project scheduling involves the determination of the sequential order of the planned activities, assigning realistic durations to each activity, and determining the start and finish dates for each activity; Oberlender (2000). However the two terms are often used synonymously because planning and scheduling are performed interactively.

Construction planning is a fundamental, critical and highly challenging activity in the management and execution of construction projects. It entails the choice of technology, the definition of work tasks, the determination of start and finish dates of various activities, the estimation of the required resources and durations for individual activities, leading to the overall duration of the project, and the identification of any interactions among the different work task, explains Neale and Neale (1989).

In the view of Cooke and William (2004), a good construction plan is the basis for developing the budget and the schedule for work. Planning is also essential in order to deal with construction risks and devise safe working methods. Cooke and Williams (2004), further assert that without planning it would be difficult to envision the successful completion of any project or the effective control of time, money or resources.

Construction planning can be applied to the whole of a construction project, from beginning to end, from inception and feasibility study to final commissioning and handing over the completed works to the client in varying degrees depending upon the stage at which it is being carried out, Harris and McCaffer (2002). Essential aspects of construction planning include the *generation* of required activities, *analysis* of the

implications of these activities, and *choice* among the various alternative means of performing activities.

The above comments imply that planning must be undertaken before work is actually started rather than after starting work on a project. Similarly, for planning to be effective, those people who will actually do the construction work must fully be involved. Other aspects of the project (like the *scope, budget, schedule,* and *quality*) must also be considered in the planning process.

In summary, good construction project planning is the heart of good project management because it provides the central communication that co-ordinates the activities of all parties involved in the project, resulting in the completion of the project on time. Planning also establishes the benchmark for the project control system to track the quantity, cost, and timing of work required to successfully complete the project. Oberlender (2000) says that planning is a process and not a discrete activity, which implies that, as changes occur in the course of time, additional planning may be required to incorporate the changes into the schedule.

2.2 THE CONSTRUCTION PLANNING PROCESS

Planning is a creative and demanding mental activity of working out what has to be done, how, when, by whom, and with what; that is executing the job or task in the mind. Plans as found on papers represent the results of a careful thought, comprehensive discussions, decisions and actions, and a commitment made between people and contractural parties. That is, the plan is a strategy and tactics for the execution of the project, in terms of activities, time, quantities, resources and perhaps cost and value. The plan is depicted as charts/diagrams and reports, and thus forms the basis for communicating what has been planned.

The client and the contractor both have a planning process to go through. During these planning processes, a lot of considerations are made before finally coming up with a comprehensive programme or plan for the project.

Cooke and Williams (2000) identify that, there is an interface between the clients' planning process and that of the contractor at the tender stage of a traditional project, and during the administration of the project on site. However, where non-traditional procurement methods are used, there may be further interfaces to consider.

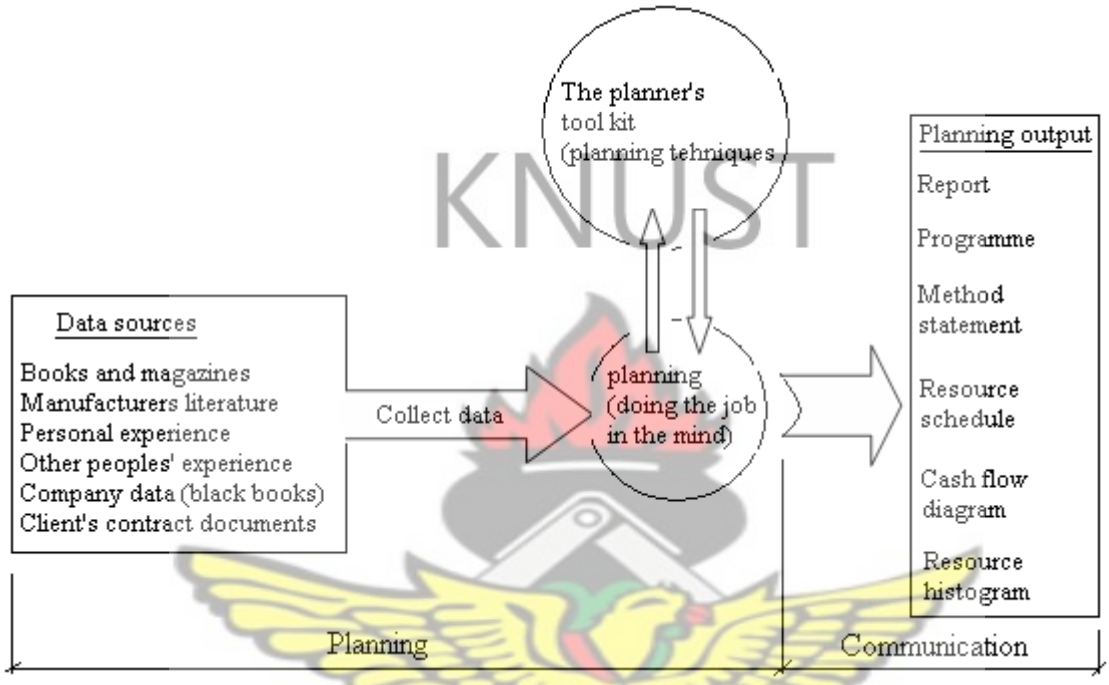


Figure 2.1: The Planning Process by *Neale and Neale (1989)*

Planning depend on data. Without reliable and relevant data, planning can only process best guesses (although this is better than no planning at all). As data acquired become more accurate, it becomes possible to plan at an appreciable level of detail that would have been quite unrealistic at the start of the project. *Figure 2.1* indicates the way in which data are used in the planning process, and typical output.

For construction work, Cooke and Williams (2004) divide planning into the following stages:

- Pre-tender planning undertaking by the tendering contractors
- Pre-contract planning carried out by the main contractor
- Contract planning, carried out by the main contractor and subcontractors.

Pre-tender planning, according to Oxley and Poskitt (2000), is undertaken to allow the estimator to arrive at an estimate of cost based on the proposed methods of working and an estimate of the time required to carry out the work; and the conversion of the estimate into a commercial bid. Programming at the pre-tender stage is usually an outline of the main operations to be considered.

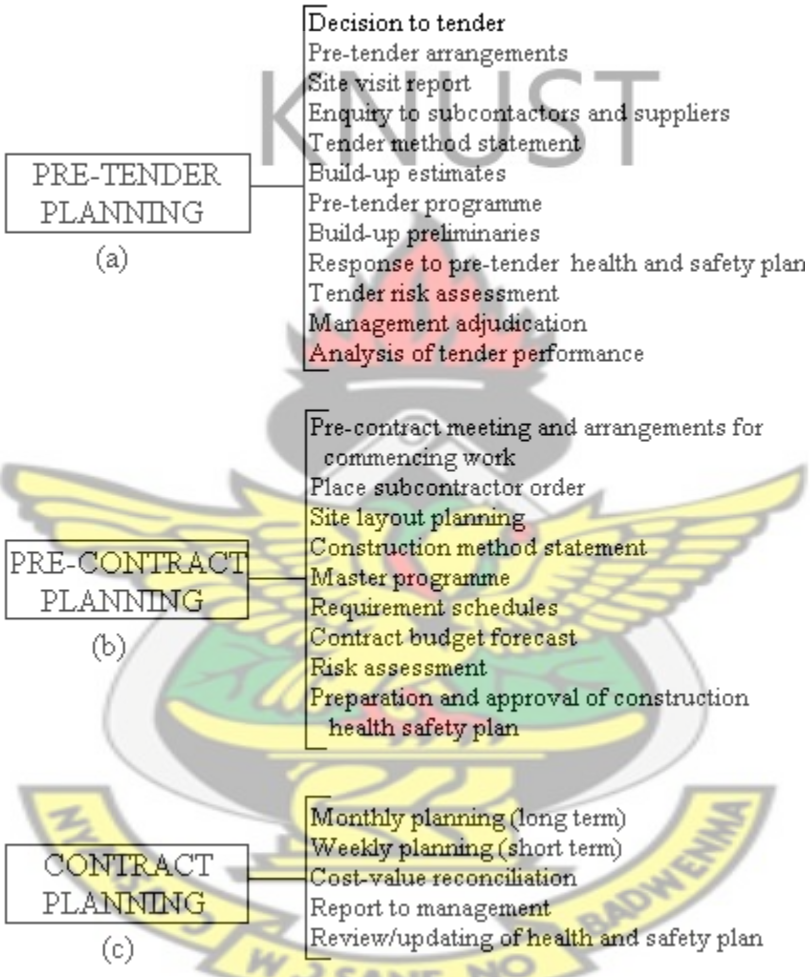


Figure 2.2: The Contractor's Levels of Planning; ***Cooke and William (2004)***.

Pre-contract planning, on the other hand, generally takes place during the period between the award of contract and commencement of work on site, when the project is considered more fully and in details. Planning at this level includes the overall programme, labour schedule, plant schedule, materials schedule and so on. The overall programme at this stage should not break the operations down excessively or it will become unrealistic.

Contract planning also referred to as *short term planning* by Oxley and Poskitt (2000), is done in greater detail normally initiated by the main contractor in order to maintain

control and ensure that the project is completed on time and within the cost limits established at the tender stage. Subcontractors contribute to the process by submitting their work programme for approval through discussion with the main contractor. Planning at this stage are broken down further into short term programmes at weekly or fortnightly intervals so as to plan day-to-day work in detail. The overall programme is thus converted into a working schedule and must be regularly updated.

2.3 OBJECTIVES OF CONSTRUCTION PLANNING

In general, the main objectives of planning as outlined by Neale and Neale (1989) are as follows;

Analysis

This is envisaging how the job will be carried out, in what order and with what resources; reducing the project, or part of the project to a number of manageable activities. Each activity should be readily identifiable as a coherent piece of work, ideally relating to the project management structure and thus the control of a specific individual.

Anticipation

This involves foreseeing potential difficulties, to plan to mitigate or overcome these difficulties, and to anticipate project risks so that their effects can be minimized. Anticipation is the major objective of construction planning as construction (civil and building) is a fairly high risk business, and the planning of many activities is fraught with uncertainty, Neale and Neale (1989).

Scheduling resources

This is to enable optimum use to be made of the available and most economic resources, for each project and taking all projects together – for the organization as a whole.

Co-ordination and control

Which provides a platform for co-ordinating the work of the parties (clients, consultants and contractors) participating in the project, and to provide a basis for forecasting and controlling time and cost.

Production of data

This allows for planning data to be acquired and documented for use in the preparation of future plans.

2.4 CONSTRUCTION PLANNING TECHNIQUE OPTIONS

The technique used for construction project planning and scheduling varies depending upon the project's size, complexity, nature, duration, personnel, and owner requirements, Oberlender (2000). This means that no one single planning technique can be used to schedule every type of construction project; implying also that a planning technique that might be suitable for programming road construction project works for instance, might not necessarily be the appropriate programming technique for say building works.

Figure 2.3 depicts a planning technique selection chart, provided by Neale and Neale (1989).

Planning techniques available for scheduling construction project works include the bar chart (sometimes called the *Gantt chart*), network analysis system, line –of- balance, and linear programme (also known as *time-chainage chart*).

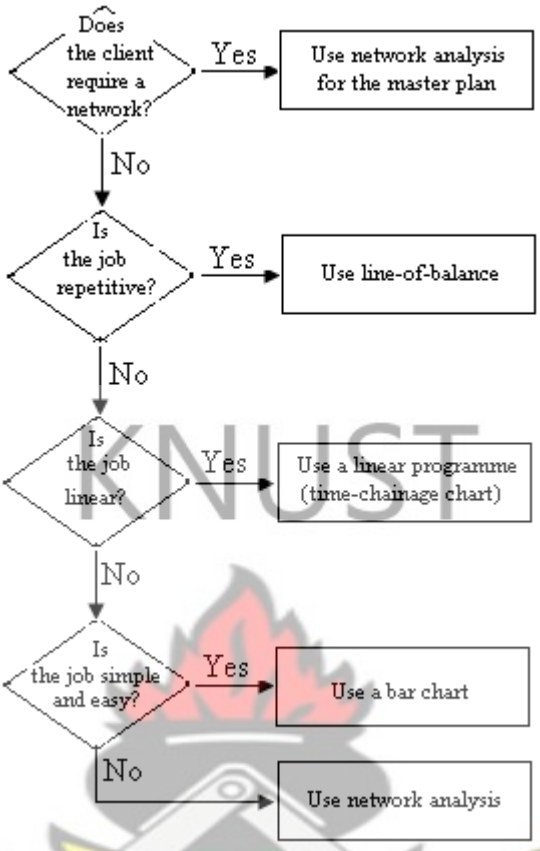


Figure 2.3: Choice of a Planning Technique, *which*? , Neale and Neale (1989)

2.4.1 The Bar Chart

As a means of planning, programming and communicating, the bar chart is everybody's favourite as it is hard to beat. It is simple in concept, easy to construct and equally easy to understand. It is best used for straightforward, well-understood construction work, with simple relationships between the activities. Even when a more sophisticated technique like network analysis is used, the eventual schedule of work is usually presented in bar chart form, Harris and McCaffer (2002). This graphical technique still forms the basis for most resource scheduling. One of the main disadvantages is that changes in plan require extensive redrafting.

According to Harris and McCaffer (2002), the level of detail of the activities depends on the intended use of the plan.

There exist basically two kinds of bar chart; (a) *the basic bar chart* and (b) *the linked bar chart*.

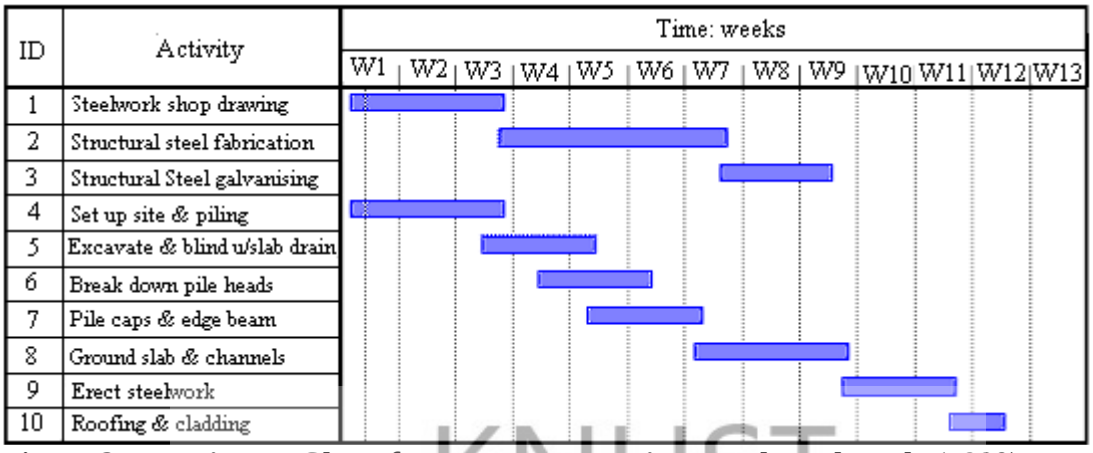


Figure 2.4: Basic Bar Chart for Factory Extension; Neale and Neale (1989)

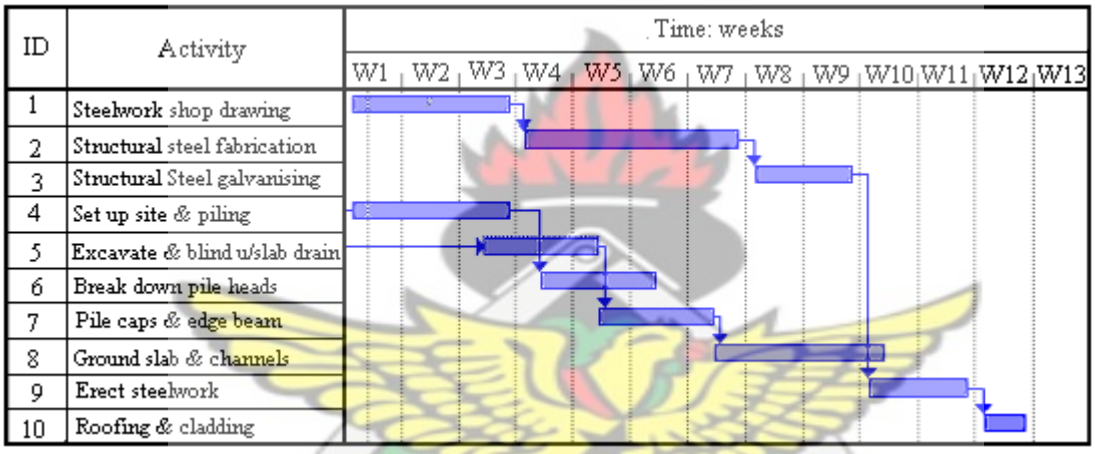


Figure 2. 5: Linked Bar Chart for a Factory Extension; Neale and Neale (1989)

The basic bar chart (*Figure 2.4*) is an excellent means of relating activities to time; however, as a planning technique, it has a number of weaknesses such as the following identified by Neale and Neale (1989);

- It does not show relationships or interdependences of activities
- It does not indicate the rate of progress within each time bar
- It does not relate activities and locations.

Oberlender (2000) also observe the following pitfalls in the use of the bar chart

- It does not integrate costs or resources with the schedule
- It is difficult to update since interrelationships of activities are not defined

- It has limited application for detailed construction work because the many interrelationships of activities required for construction work are undefined

To overcome these shortcomings of the simple bar chart, some variations to the basic bar chart have been developed; for example the linked bar chart among others.

The linked bar chart shows a link between the horizontal time bars with vertical lines (links) to indicate the construction logic. For example, in *Figure 2.5*, the link between activities 9 and 10 means that, 'the roofing and cladding activity cannot commence until the steel erection has been completed; Neale and Neale (1989).

The inclusion of links, according to Neale and Neale (1989) makes the bar chart more practical technique for site use, particularly when it becomes necessary to revise the programme.

In addition to showing the planned programme for the project, bar charts can be used to monitor the progress of work by depicting a second bar drawn for the actual dates worked.

2.4.2 The Line-of-Balance

Line-of-balance is a specialized technique for repetitive work. That is, it is a technique mostly adopted to plan the construction of a number of similar items.

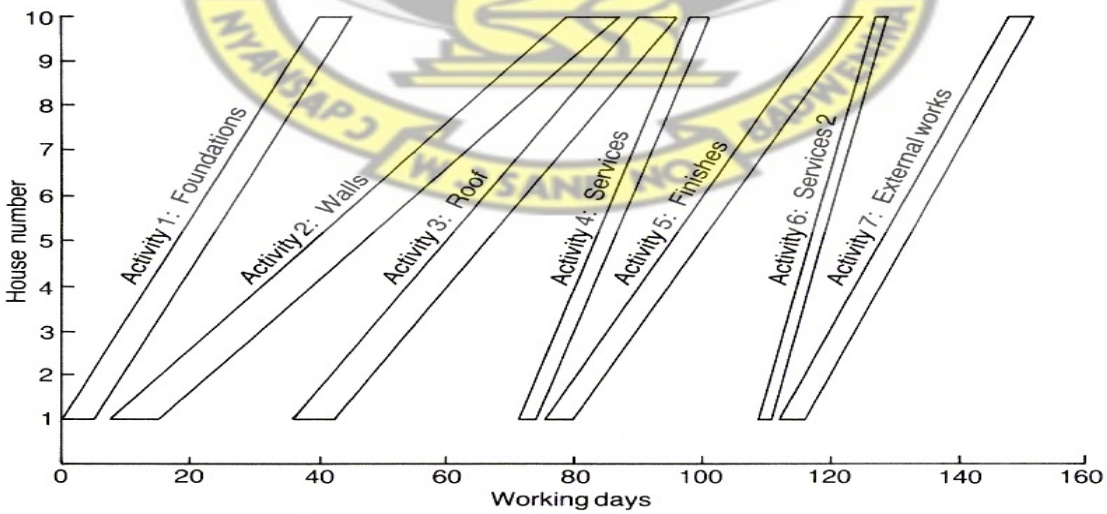


Figure 2.6: **Line-of-Balance for Ten House Project; Neale and Neale (1989)**

The technique as illustrated by Neale and Neale (1989), in *Figure2.6* is used to analyse the application of labour and plant resources to ensure that each resource can progress from one item to the next in an orderly fashion, having completed its own work on all items without being delayed, waiting for the preceding work to be completed. Thus the line-of-balance technique aims at keeping all resources in balance, each following the other productively without interference, Lumsden (1965). Similarly, according to Oxley and Poskitt (1992), the line-of-balance technique has the advantage of providing a better indication of the dependence of one activity on another.

The line-of-balance technique as indicated by Harris and McCaffer (2000) and Comican (1985) has been widely used for the planning of refurbishment work, new build housing and flats, and has also been applied to civil engineering works

2.4.3 The Network Analysis System (Critical Path Method)

Network analysis, also known in some circles as the Critical Path Method (CPM), is a powerful logical and analytical planning technique, which offers all the advantages of being able to manipulate or process the planning data by holding the data in computer files, and can also be used as an effective control tool. It is most suitable and effective when used for complicated projects, especially those with external constraints and complex interrelationships Neale and Neale (1989). In the views of Oberlender (2000), the network analysis system provides a comprehensive method for project planning, scheduling and controlling. The technique also shows interrelationship of activities and scheduling of costs and resources. Thus, the network analysis technique is based on establishing the logical relationships between construction operations and sequence of execution. With the addition of estimates of activity durations, the diagram can be analysed numerically to determine the estimated project duration. This analysis also distinguishes between those activities whose timely execution is crucial to the earliest completion of the project, and those (non-crucial activities) which may be delayed for a specific time without causing any delay in the overall project duration. The non-crucial activities provide an objective means of scheduling project activities to make the best use of the available resources.

Network analysis diagrams can be drawn or demonstrated in two ways; either *activity-on-arrow network* (*Figure 2.7*) or *precedence network* (*Figure2.8*), Neale and Neale (1989).

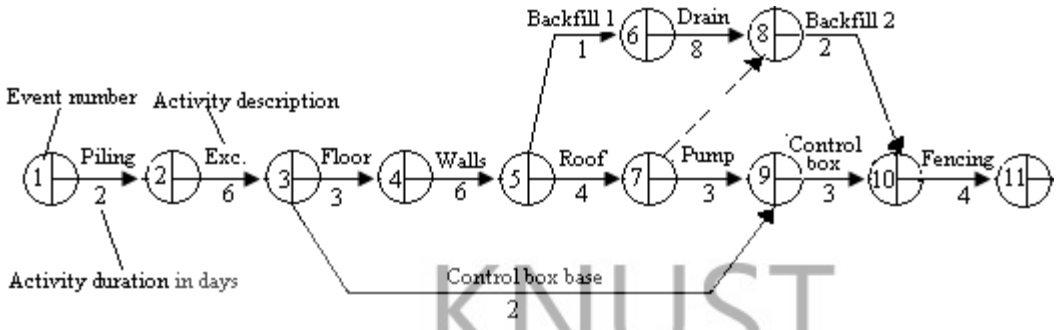


Figure 2.7:**Activity-on-Arrow Network for Land Drainage Chamber**

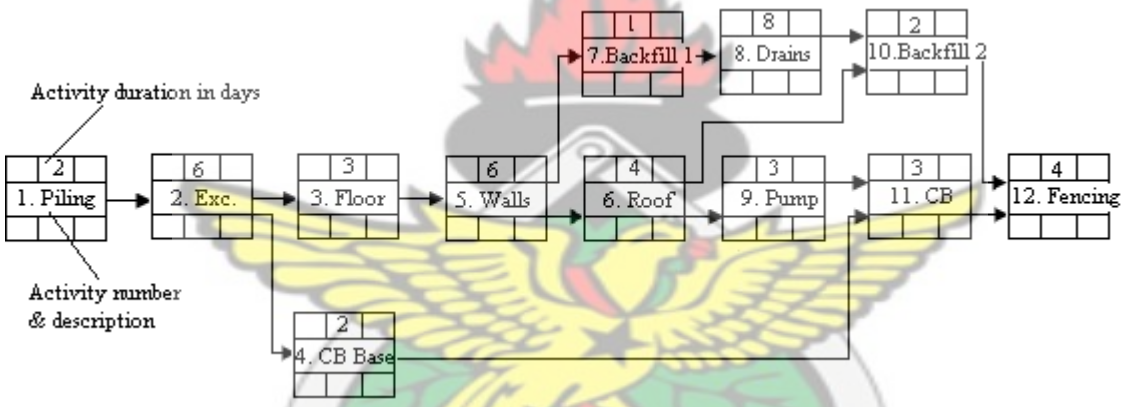


Figure 2. 8 Precedence Network for Land Drainage Chamber

2.4.4 The Linear Programme

Linear programme, in the view of Neale and Neale (1989), is a specialized and an ideal technique for linear works such as roads, railways, tunnels and other projects measured by chainage. According to Cooke and William (2004), the linear programme chart is a combination of the bar chart and line-of-balance scheduling format, and it is from these programming techniques that linear programme principles have been developed. Other names given to the linear programme chart include *Time-Location Chart* by Comican (1985), *Linear Scheduling Technique* or *LST* by Harmelink and Yamin (2000), *Linear Balance Chart* by Barrie and Paulson (1978) and Repetitive Scheduling Method or RSM by Harris and Ioannou (1998) among others.

Edmond and de Veen (1981), also see the linear programme technique as a planning method most suitable for road works. They stated further that, the technique not only visualises the timing and quantities of the work involved in road construction but also shows the location of the various activities to be undertaken. This implies that, any activity that is of repetitive nature and takes place over a known length basically lends itself to the linear programme format.

According to Harmelink and Yamin (2000), although the *Linear Scheduling Technique* (i.e. linear programme technique) has been in existence long before the Critical Path Method (CPM), it has not received the same amount of attention and effort accorded the CPM. Harmelink and Yamin (2000), observe further that the CPM technique is the predominant technique used in building construction today, and that it has only recently been applied to major road construction project. Unfortunately, the application of this traditional CPM scheduling technique to road or highway construction has been limited because major road construction project activities are linear and fundamentally different from those found in building projects, Harmelink and Yamin (2000).

In the view of Harmelink and Yamin (2000), the inability of the CPM and bar chart planning techniques to accurately model linear projects such as road works, has contributed to the development and increasing use of the linear programme technique. This accordingly, has brought a source of relief to transport officials and other professionals in the road construction industry who were looking out for an appropriate project management technique or method for highway projects. Mawdesely et al. (1989), also reveal that, several road contractors are changing from network based programming or scheduling to linear programme ones.

Information gathered also from www.pclarke.co.uk, however suggests that the linear programme technique is not often used by professionals in the road construction industry to schedule road works, although the technique has been around for a very long time. One probable reason assigned for limited use of the linear programme technique (referred to as *Time-Chainage Chart* in the presentation) is that, the linear programme chart is not generated by any of the ‘’industry standard’’ planning tools such as Primavera P3 or Microsoft Project. Other reason identified by Harris and Ioannou (1998), is the fact that there is not an acceptable algorithm or process for identifying the projects critical path

which determines the completion time. As a result of unavailability of a planning tool to generate the linear programme charts, users have over the years attempted a variety of methods to generate them, including *hand drawing, drawing using a CAD system, colouring grid cells in spreadsheet;(* www.pclarke.co.uk).

Although the linear programme technique can completely be used standalone, it is fully capable of operating in conjunction with other techniques such as the bar chart, (www.pclarke.co.uk).

The Linear programme chart is a simple two-dimensional graphical technique which displays activities against both time and distance. The principal benefit of the linear programme technique is the management of work in confined spaces where typically only one operation can be performed at a time, Cooke and William, (2004). In essence, the technique is to plot all activities showing planned progress against time and location. The chart also takes full account of weekends, holidays and any other non-working days.

Linear activities are represented with a line or bar which is positioned on the chart to show its commencement and chainages, and is inclined in the direction of progress at an angle consistent with the anticipated duration of the operation. Thus, linear programme charts show location and rates of progress in addition to start and end dates. This makes the charts extremely useful when planning or analyzing a construction project.

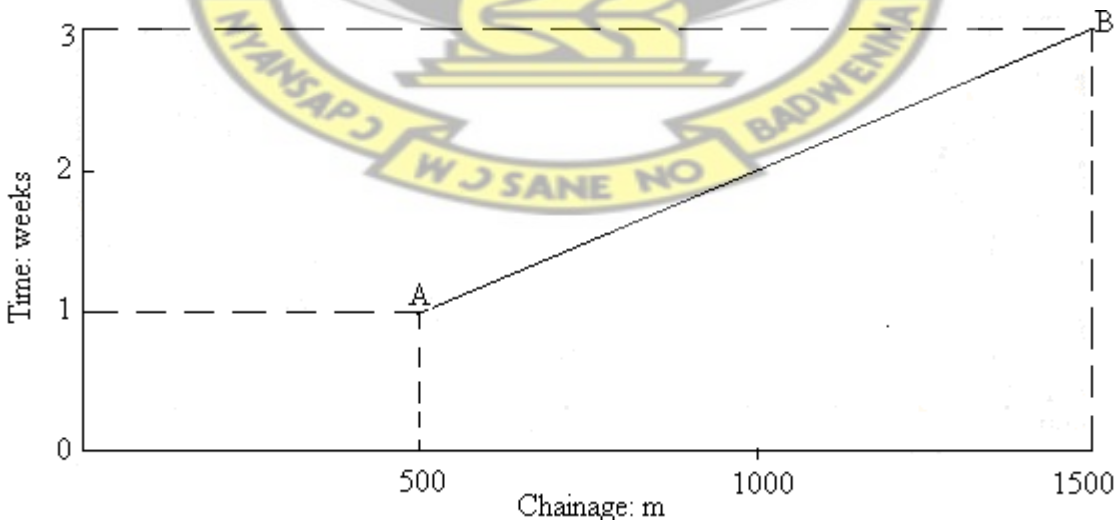


Figure 2.9: Linear Programme Format; *Neale and Neale (1989)*

Figure 2.9 represents the linear programme format for activity say AB, (denoted by the inclined line) which is planned to commence at chainage 500 at the beginning of week one and to end at chainage 1500 at the end of week three.

The following can be deduced from the graph; that

- The slope of the inclined line gives the rate of progress of the activity. Thus, for activity AB, the rate is 500m/week; [i.e. (1500 - 500) / (3 -1)]
- The expected position of the gang undertaking the activity can be obtained at any given time by reading off the chainage against the time scale.

To represent the project activities realistically, it is a best practice to classify them into the following four types, according to Neale and Neale (1989); (a) compact activity, (b) extended activity, (c) extensive activity and (d) static activity, as illustrated in *Figure 2.10*

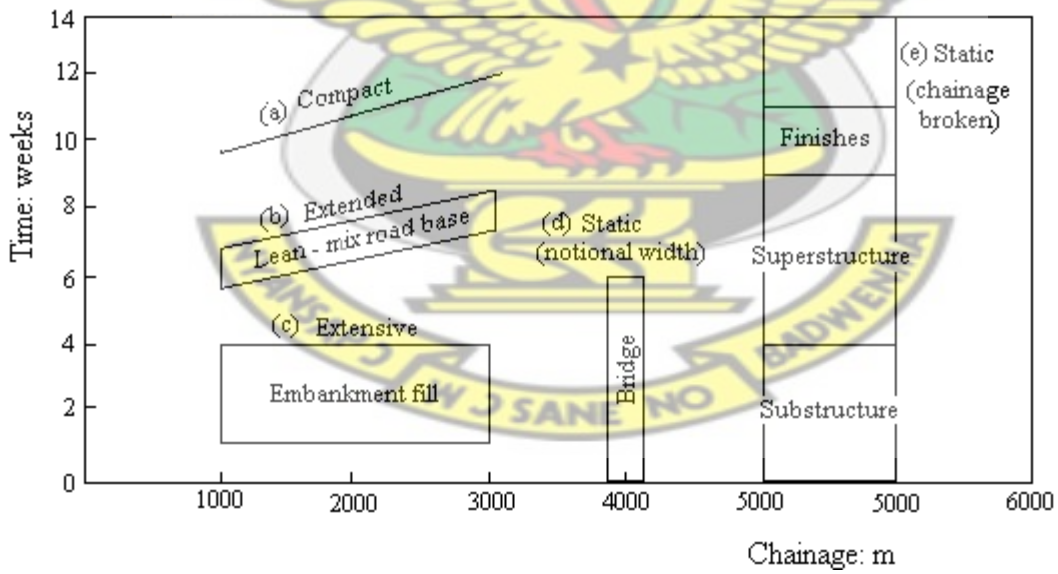


Figure 2. 10: Linear Programme Activities: Neale & Neale (1989)

Compact activityis the activity which for any given time, occupies only a short length of the project, e.g. kerb laying. It may be represented as a single line as shown in *Figure 2.10(a).*

Extended activity is used where the operation may be carried out over a considerable distance, for example, laying of lean mix concrete road base. Two parallel lines may be drawn to represent an extended activity, each line indicating the start and completion of the activity. *Figure 2.10(b)* illustrates this.

Extensive activity is one where the work for the activity occupies the entire chainage throughout its duration. For example, the construction of a 1000m long embankment occupies the whole of the section until the last grading of the formation. An extensive activity is represented by a block [*Figure 2.10 (c)*].

The above three activities progress along the project and can thus be said to be continuous activities. In addition to the continuous activities, there is a static activity which takes place once only at a certain chainage; for example a culvert or a bridge across the road or an underpass.

Static activity may be represented on the linear programme by a vertical bar of notional width, with the duration of the activity expressed by the length of the line or the bar. If the bar needs to be widened (to provide more space for the description), the chainage may be stopped on the left of the bar and restarted on the right as shown in *Figure2.10(d).*

According to Cooke and Williams (2004), activity labels are annotated on the respective line or bar to distinguish one operation from another. With a linear programme it is easy to show constraints as non-activities. Before starting to plot activities, all the data that may be required are collected together and transferred on to the chart.

Below is *Figure 2.11*, as produced by Neale and Neale (1989) which depict how data obtained from drawings may be used to schedule a road project work using the linear programme technique of planning. When all the data have been abstracted from the drawings and transferred onto the chart, the next level is to identify and plot the constraints.

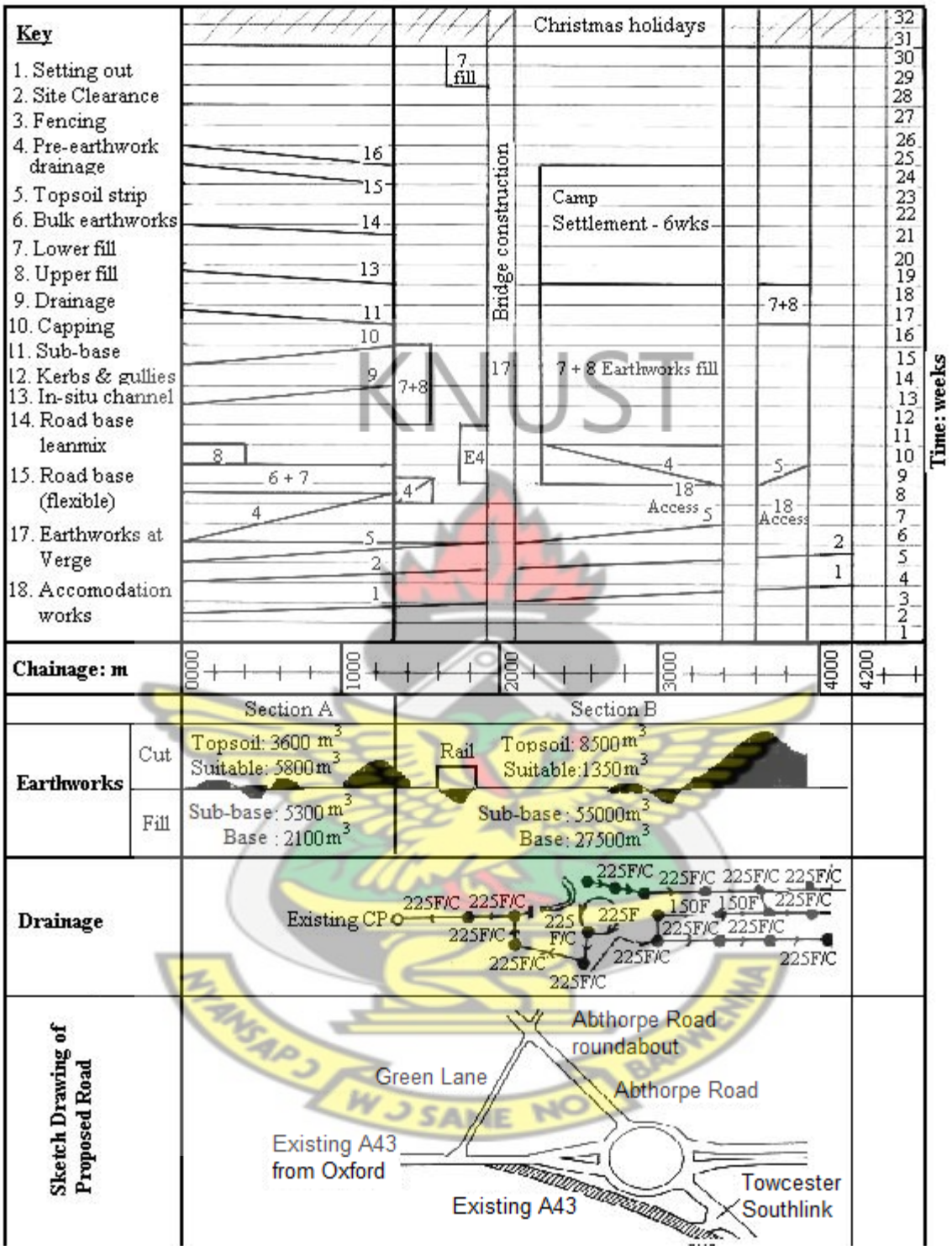


Figure 2. **11:Linear Programme for Road Scheme Showing Activities from Chainage0000 to 4200**

2.4.4.1 Principles of the Linear Programme Technique

The linear programme form of presentation enables the time dependencies between activities to be shown, together with their order and direction of progress along the job. These diagrams are the most usefully employed as a planning tool on projects such as motorways and major highway jobs and other linear projects, suggest Cooke and Williams (2004).Projects of this nature can be viewed as mainly linear in nature, that is, the construction starts at one point and proceeds in an orderly fashion towards another location. This would be typified on a highway project by activities such as fencing, drainage, and road surfacing and road markings. Cooke and Williams, (2004) argue that, this type of work to some extent calls for a different planning technique because bar charts would not be useful in giving locational information and also precedence or arrow diagrams would not reflect the time-location relationship which clearly exists on such projects. In this respect, most operations take place on a forward travel basis with the gang starting at one point/chainage and moving along the job. As one activity leaves a particular location, other activities can take its place. This ensures the correct construction sequence and avoids over intensive activity in one location. Information obtained from www.pclarke.co.uk also indicates that, the key to linear programme chart is the definition of the chainage points that are used to determine the horizontal axis of the chart. On the linear programme chart, most of the lines have no appreciable thickness, contend Cooke and William, (2004). According to them, this is because the time spent by each gang at a particular location is relatively small and the gang moves along the site quite quickly. Examples of this are drainage, road surfacing and safety barrier erection on a motorway.

Retaining walls also constitute a linear activity but would tend to occupy any particular location/chainage for a more appreciable time due to the nature and duration of the construction operation involved. With earthworks *'cut and fill'* operations, the situation is different in that earthworks plant will occupy a particular cut or fill zone for some time before moving to another location, observed Cooke and William, (2004).

Bridges, culverts and underpasses on the other hand are 'static' operations and can be viewed as individual *'sites'* in their own right. Such activities act as restrictions and forward travel activities may have to be programmed around them. For instance, on a

highway project, drainage work may be interrupted by a bridge site and consequently the contractor will have to return later and finish the drainage once the bridge nears completion.

Activities, such as cable laying that require a protection zone around them for the whole period of the work can be displayed on the linear programme diagram by using shaded blocks or any other convenient convention to identify them. Similarly, complex or ‘’no entry’’ zones can be represented. These are zones where the work is expected to progress quicker (www.pclarke.co.uk).

2.4.4.2Developing a Linear Programme Diagram

Cooke and William, (2004) recommend the following sequential steps in trying to construct a linear program chart;

1. Consult the project layout drawings and note the chainage positions. Main chainages on a highway projects are at 100m intervals.

2. Draw an outline linear programme diagram with time along one axis and distance or chainage along the other. Add holiday periods, as for example; allowing two weeks for Christmas and a week for Easter.

3. List main programme activities or operations in approximate construction sequence. Include activities for site set up or mobilization and site clearance at the end. Estimate the duration of each programme in weeks.

4. Fill in the site ‘set-up’ and ‘clear site’ activities on the linear programme diagram using a preferred format, the appropriate number of weeks over the entire length or chainage of the project is plotted.

5. Decide in turn where and when each activity will take place. For linear activities such as drainage, start at the appropriate location (chainage) and week number and draw a line for the correct distance (chainage) and time (weeks). For static

activities (e.g. bridgeworks), draw a box of notional width (*Figure 2.10d*) at the appropriate chainage with a length representing the activity duration.

6. Complete all activities on the list. It is sometime helpful if an outline bar chart programme is produced to help clarify the correct linear programme display.

The following are software packages available for the generation of linear programme chart.

- Tilos linear scheduling (www.tilos.org)
- LinearPlus (www.pcfltd.co.uk)
- TimeChainage
- QEI Exec (www.pcfltd.co.uk)
- Purdue University Linear Scheduling Software (PULSS)

2.4.4.3 Linear Programme versus Bar Chart

The standard bar chart displays time horizontally and a list of tasks vertically. The spacing of task lines vertically is not related to any physical location, (www.powerproject.nl). The bar chart provides only limited amount of information in modeling projects, and typically does not readily reflect the production rate or speed with which sections or units are being processed in linear projects, Halpin and Riggs (1992).

The linear programme chart, on the other hand provides a second dimension to an event by adding the start and end measurements to the start date, end date and duration. This additional dimension makes it easier to visualize what is happening at a given location at any time and what processes are passing through any position, (www.powerproject.nl). The linear program chart also shows a clearer and more easily understood picture or information of a project than a bar chart. This is because; linear programme diagrams have a more graphical structure than the bar chart, information obtained from (www.tilos.org).

Similarly, because of the two dimensional character or nature of the linear programme diagram, relative progress rates are easily depicted and thus can be compared with different areas or between planned and actual. Also, very complex projects can be displayed on a single chart and still provide a clear picture of what is going on. The linear programme diagram, however, does not identify easily the critical activities; that is, critical activities are not visible from the chart.

A bar chart uses the X-axis of the chart to represent time, so that it displays each activity as a horizontal line (*Figure 2.4*). This format provides basic information about the relative timing of activities, but gives no indication of where they take place or any possible conflict that might exist, (www.pclarke.co.uk). This is a potentially serious problem for those working on linear projects like road construction. To address this worrying situation, linear programme chart was designed to use one of the axes of the conventional bar chart to reflect the physical location of an activity (*Figure 2.9*). This concept provides management and project planners' key additional location-related information required to be able to tackle the complexities of linear projects like motorway or road construction, (www.pclarke.co.uk).

Although the linear programme technique can completely be used standalone, it is fully capable of operating in conjunction with other techniques like the bar chart.

2.4.4.4 Linear Programme versus Line-of- Balance

The linear programme planning technique was basically developed to schedule projects that are linear in nature. On the other hand, the line-of-balance technique has been found to be the most appropriate and effective technique for planning and programming for repetitive works / job such as high rise building construction (where we have similar floors at various levels of the building) and housing projects of the same type of buildings, explains Neale and Neale (1989). Although some aspects of linear jobs are repetitive in nature, coupled with the fact that the linear programme technique was developed from the line-of-balance and the bar chart techniques, Comican (1985), the line-of-balance technique lacks the capacity and capability to schedule linear projects such as road works. However, both techniques show clearly the relative rate of progress

of an activity, with the linear programme diagram displaying also the location of activities along the entire chainage or length of project.

2.4.4.5 Linear Programme versus Network Analysis

The linear programme technique as we are already aware of is appropriately used to schedule projects where large proportion of activities or works involve change in location as activity progresses. On the other hand, the network analysis technique is used to schedule construction projects which are larger and more complex to plan and manage.

The network analysis diagram does not reflect the time-location relationship of activities, such a relationship however exist in the linear programme diagram. Also, the information derived from the network analysis diagram is not clearly understood as it is in the case of linear programme. This (information) is usually converted to bar chart for general use. However, compared with the linear programme technique, the network analysis technique provides a powerful control tool especially for large numbers of contractors and also lends itself to most computer systems contends Cooke and Williams (2004).

One other major difference that exists between the linear programme and the network analysis planning techniques is the ability of the network analysis technique to identify those critical activities whose delay adversely can affect the total project duration. However, the inability of the network analysis techniques for scheduling linear projects effectively necessitated the research into and the development of the linear programme technique which has proven to be efficient for the purposes of managing linear projects such as road works. Although attempts have been made in the past to use network analysis to programme linear projects, the exercise has not been successful. It is however, very interesting to note that, network diagrams instead could be drawn from a linear programme.

Ipsilandis (2007) explains that the objective of Critical Path Method (CPM) is to minimize the duration of the project through the determination of the critical path and the optimum time/cost tradeoffs of the project by means of crashing the critical activities. Therefore, the CPM schedule cannot guarantee work continuity for projects consisting

primarily of linear activities such as road works. Further, the CPM or the network analysis technique based project control makes it impractical for monitoring the location and production rate of each activity as it progresses along the entire length of the project. Such linear projects are best managed using the linear programme technique of scheduling, as in ensures uninterrupted utilization of resources, Harris and Ioannou (1998). Nevertheless, contend Harris and Ioannou (1998), Repetitive Scheduling Method (or the linear programme technique) has its limitations and there are situations of a project where it may be desirable to model part of a project by CPM and other parts by RSM. This is refered to as integrated projects.

2.5 FACTORS AFFECTING THE CONSTRUCTION PLANNING TECHNIQUES

The factors listed below have been identified as having influences on the choice of a planning technique for a construction project (road projects for that matter). A number of these factors were discovered in the (road) construction industry of Ghana by this researcher via preliminary interviewing of professionals in the industry and also by virtue of the authors own past association with the road construction industry. Other factors however, were discovered through literature search; Cooke and William (2004), Oberlender (2000) and journals; Harmelink and Yamin (2000).

The factors proposed by Oberlender (2004) include; *project size, complexity of project, duration of project, personnel availability and quality, owners/clients requirements, simplicity of technique, ease of technique development.*

Cooke and Williams also identified *personal preference (i.e. contractor' preference)*as one other factor in addition to factors such as *project location, quality requirement of project, popularity of technique, knowledge and flexibility of technique, efficiency of technique, availability and cost of software for technique.*

CHAPTER THREE

3.0 RESEARCH METHODOLOGY

3.1 INTRODUCTION

In this chapter, various methods and techniques which were used to address the research questions by finding answers to them were discussed.

The main concern of this study was to promote the use of the linear programme technique as an appropriate tool for scheduling road construction works in Ghana. To realize this aim, some definite objectives were addressed in the study. These objectives sought to:

- Identify the factors that influence the selection and application of planning technique for scheduling road construction works in Ghana.
- Ascertain the extent to which the linear programme technique has been used to schedule road works in Ghana
- Make recommendations on how the linear programme technique can be integrated into the operations of the road construction industry in Ghana.

As a first step towards identifying those factors that affect choice of a planning technique to schedule road works in the country and determining the planning technique(s) in use in the construction industry in the country to programme road works, preliminary interview via telephone with professionals in the road sub-sector was conducted. A lot more information (including those on the linear programme technique) was also obtained mainly through literature search from text books, journals and the internet.

Professionals in the road sub-sector were classified into two main groups which consisted of consultants and contractors. For the purposes of this research work consultants were defined as those professionals like civil engineers, clients and financiers of road construction project works. These consultants comprised both private individual consulting firms and those consultants working in the government agencies like the

Ghana Highway Authority, Department of Urban Roads and the Department of Feeder Roads.

Contractors considered for the study comprised only A1B1 and A2B2 class of contractors. These are contractors with the requisite knowledge and resources and therefore are mandated by authority to undertake the construction of all types of road works, including the construction of trunk roads, urban roads, and feeder roads.

Questionnaires were designed and administered mainly through post to consultants and A1B1, A2B2 contractors in the industry. Responses obtained from respondents were separated into two groups of contractors and consultants and analysed. Statistical approaches like the mean, variance, severity index, coefficient of variations, relative important indices and rank correlation were used to do the analyses of the responses received.

The factors considered for the study are; *Complexity of project,Size and value of project, Project duration, Project location,Quality requirement of project,Simplicity of technique,Suitability of technique,Popularity of technique,Knowledge and flexibility of technique,Availability of qualified personnel,Availability and cost of software,Efficiency of technique,Speed and ease of development of technique,Client / consultant's preference andContractor's preference.*

A three point scale method of ranking was used to determine the level of importance that respondents attach to these factors.

3.2 RESEARCH QUESTION AND METHODS

3.2.1 Research Question

In this research work, the fundamental question that the study sought to investigate into and find possible answer(s) to, was the determination of the extent to which the linear programme planning technique has been applied to schedule road construction works in the country.

3.2.2 Research Methods

The research objectives were dealt with by applying the following methods:

Structured Questionnaire

The first and the second objectives of this research work were addressed predominantly through structured questionnaire administration to professionals working in the road construction industry of Ghana.

Two sets of questionnaires were thus designed and administered, one set meant for contractors and the other set addressed to consultants. Although the contents of these two sets of questionnaires slightly differed from each other, their structures were fundamentally the same. The contents of the questionnaires administered to contractors in both the A1B1 and A2B2 categories were also the same. Questionnaires addressed to consultants also have the same structure and contents. The questionnaires were sent out to the proposed professionals through post and by personal submission.

Responses obtained from respondents were separated into groups of consultants and contractors. Each group was then independently analysed. Statistical methods like the mean, variance, relative importance index, severity index, and coefficient of variations, test of concordance and *Student's t-Distribution* test were used to do the analyses.

Objective 1

To approach the first objective of the research, respondents to questionnaire were asked to rank the 15 major factors which were considered in the study as having some influence on the choice of a planning technique to be used to schedule road works. The rankings were to be done using a three point scale which were interpreted as: 1- *not important,* 2 - *important* and 3 - *very important.* Responses to questionnaire sent out to professionals were thus analysed using the Relative Importance Indices (or RII) computed for each factor. The values of the RII were used to rank the factors according to their level of importance. The Spearman's Rank Correlation Coefficient was also used to determine the degree of agreement between the rankings by professionals (i.e. consultants and

contractors). The most significant factors were identified by performing a test of significance at a 5% significant level using the student t-distribution.

Objective 2

The second objective of the study was carried out by asking respondents to the questionnaires to indicate and rank their; *a) preference for a planning technique* and *b) level of knowledge in the use of the planning technique for the purposes of managing road works*. Rankings of planning techniques by professionals were required based on three point scale explained as;

1 – *Not used often /not recommended /low knowledge,*
2 – *Used quite often /recommended /high knowledge,* and
3 – *Used very often /highly recommended /very high knowledge.*

The relative importance indices were used in the analysis of responses received from respondent groups to determine the overall level of importance that professionals attach to each planning technique as far as road works scheduling is concerned. The extent of use of each planning technique was discussed based primarily on their relative importance indices.

Objective 3

Recommendations on how to promote the linear programme technique for use to schedule road works in Ghana constituted the third part of the research objectives. The recommendations were proposed on the basis of critically examining the outcome of results analysis for the first two research objectives.

3.3 QUESTIONNAIRE DEVELOPMENT AND DISTRIBUTION

3.3.1 Questionnaire Development

The questionnaires were developed with the aim of the research in mind. The structure of the questionnaire was meant to identify the factors which most influence the use of a

planning technique for scheduling road works and also to ascertain the extent to which the *linear programme* technique has been applied to schedule road works in Ghana. The questionnaires were distributed to consultants and contractors in the road sub-sector.

In the questionnaire, both contractors and consultants were asked to indicate the education level acquired, agency they worked for, their designation and years of experience in current position and number of road works handled within the past five years of operations, in order to assess the level of experience and qualifications of professionals in the industry. Similarly, questions such as; which planning technique(s) are you most familiar with, how often do you use or recommend for use the planning technique specified, and how would you rate your knowledge in the technique were put forward. The objective for these types of questions was to determine the frequency of use of each technique. Respondents were also to rank the factors using a three point scale according to the level of importance Contractors were further requested to indicate whether their firm was a locally owned one, foreign owned or local/foreign partnership, and whether their construction firms have a well structured planning department which does all the programming of their road works.

3.3.2 Questionnaire Distribution

The number of classified contractors in the AIBI and A2B2 category was obtained through search at the Ministry of Transportation website. According to the Ministry of Transportation's website (www.mrt.gov.gh), the total number of approved classified road contractors in the A1B1 and A2B2 category as at October, 2007 in the road sub-sector was 70, which is composed of the following;

A1B1 – 18, A1B1C – 1, A1B1S2M1L1 – 1, A2B2 – 49, and A2B2C – 1.

In the case of consultants, there were about 270 of them who worked in both government agencies and private consulting firms. This number was distributed as: *G. H. A – 100, D. U. R – 80, D. F. R – 40 and Private Consulting Firms – 5*0.

Well structured questionnaires were thus addressed and distributed to both contractors and consultants. Professionals whose firms were located far away from the research centre have their questionnaires sent to them via post. This method was adopted because of proximity reasons, thus avoiding having to travel long and tiring distances for

information which could otherwise be obtained cheaply and more readily by post. On the other hand, those firms that were situated within the easy reach of this researcher were personally handed the questionnaires.

3.4 DETERMINATION OF THE SAMPLE SIZE

To obtain the ideal number of questionnaire to be distributed to respondents, the Kish formula (Kish, 1965) as depicted in equation 3.1, was used to determine the sample size for the population of each group of respondents. The Kish's formula reads;

$$n = \frac{nl}{1+\frac{nl}{N}} \quad \text{..... (3.1)}$$

Where; n = sample size

N = population size

nl = s^2 / v^2

s = the maximum standard deviation in the population element (i.e. total error of 5% at a confidence level of 95%)

v = the standard error of sampling distribution = 0.05

s^2 = P(1-P) = (0.5) (1-0.5) = 0.25; (P being proportion of population elements belonging to a defined class)

nl = $0.25 / (0.05)^2 = 100$

Applying the Kish's formula, the sample sizes for contractors and consultants were computed to be 41 and 73, respectively, where N=70 for contractors and N=270 for consultants.

The sample size as obtained from the Kish formula above suggested that, selecting 41 contractors would have been enough for the purposes of this study. However, due to the possibility of obtaining a low response rate from respondents, and the desire of the researcher to include as many contractors as possible in this research work, all the 70 contractors in the A1B1 and A2B2 categories were considered for the study. Total

number of questionnaire sent out to consultants was 80 instead of 73 to compensate for the possibility of obtaining a low rate of response.

It is anticipated that, the outcome of this study, would provide a general overview of the prevailing conditions in the road sub-sector of the economy; more especially with regard to the extent with which the *linear programme* planning technique has been applied for scheduling road works.

3.5 CHALLENGES FACED IN THE COLLECTION OF RESEARCH DATA

In any research work, one cannot expect to have obtained all the necessary information required without encountering some difficulties. This research work is no exception as the researcher encountered quite a number of challenges, some of which were very frustrating. The following are examples of problems faced during the data collection stage of this research:

- Some of the professionals who were approached in person during the preliminary stages of the study were apathetic to the whole exercise and were just not prepared to provide information about their firm nor their operations. A few of them who were willing to co-operate asked the researcher to go and come another time since they were either busy or had to do some consultations first. These developments were a source of worry and frustration to this researcher.

- The researcher also encountered disturbing comments from some of these professionals. Quite a few of them (especially those in the private firms) flatly refused to talk to the researcher when approached, for the mere reason that researchers most times do not give them (i.e. respondents) feedbacks on the findings of their study. Hence, they did not see any point in trying to be part of the research work. Not even the assurances by the researcher to provide them with a copy of the research findings if they so wish, would change their stance.

- In an attempt to gather data, the researcher was tossed about to and fro among government agencies, consulting and construction firms. Some consulting firms when approached would ask the researcher to go to another firm or agencies for

information since they were only acting as consultants to those agencies or firms directed to. This and such situations somehow affected the pace of this work during the initial stages of the research.

- Most respondents to questionnaires took unusually long time to respond to them. In fact, some of them did misplace the first questionnaire sent out to them and had to be provided with a new one. These developments actually delayed the overall progress of this research work

CHAPTER FOUR

4.0 CONSTRUCTION PLANNING TECHNIQUE OPTIONS AND THE FACTORS INFLUENCING THEIR CHOICE FOR SCHEDULING ROAD CONSTRUCTION WORKS IN GHANA

Outcome of Questionnaire Distribution

A total of 150 questionnaires were sent out to contractors and consultants (comprising: *contractors = 70, consultants = 80*); out of which 78 fully answered questionnaires were received, representing 52% of the total number of questionnaires distributed. Of the 78 number questionnaires received, 41 came from contractors representing 52.56% of the total number of questionnaires received, and 58.57% of total number of questionnaires administered to contractors. The remaining 47.44% which translates into 37 number questionnaires were obtained from consultants. This number represents 46.25% of questionnaires addressed and sent out to consultants. *See table 4.1 below*.

The analysis of this research work is thus based on this total number of respondents received, which is the 78. It should be noted that out of the 41 questionnaires received from contractors, 38 came from fully locally owned contractors whiles 3 came from local/foreign partnership firms.

Table4.1: Outcome of Questionnaires

Category of Professionals	**Questionnaire Sent Out**	**Questionnaire Received**	**Percentage Questionnaire Received**
Contractors	70	41	58.57%
Consultants	80	37	46.25%
Total	**150**	**78**	**52%**

Contractors' Background

Of the 41 contractors who actually responded to the questionnaire, 38 of them occupy senior management positions (such as director, deputy director, general manager, project manager etc.) in their respective companies representing a whopping 92.68%, ,whiles only 3 hold positions such as assistant quantity surveyor, site foreman etc. Similarly, of the 41 number of respondents who represent contractors, 40 of them have university education with only one having a Higher National Diploma. 14 of the university graduates possess M.Sc. degrees while the remaining are B.Sc. holders. Majority of respondents here have been in industry for more than five years.

Consultants' Background

Consultants here comprise those professionals working in both government agencies and private firms. In the case of consultants, all those who answered the questionnaire have university education with qualifications ranging from B.Sc. to PhDs degrees distributed as: B.Sc. – 28; M.Sc. - 7 and PhD – 2. About 90% of consultants hold senior management positions in their firms or organizations whiles the remaining 10% plays the role of assistants.

It should be noted that, majority of private consulting firms also double as project consultants for the government agencies on most of their projects.

From the above bio data on the professionals in the road sub sector, it is clearly seen that the industry is endowed with qualified and experienced personnel with higher educational background, most of whom also occupy high positions in their respective organisations.

Results obtained from the questionnaire survey are displayed in tabular forms. Questionnaire respondents were asked to rank their level of knowledge in the use of planning techniques and how often they use those techniques in scheduling projects, especially road project works. One other question posed to respondents require them to indicate whether a factor they consider as having influence on their choice of a planning technique for use for scheduling road projects is to them *not important,fairly important* or *very important.*

4.1 RANKING OF FACTORS BY RESPONDENTS

Tables 4.2 and *4.3* depict respectively, the factors that affect consultants and contractors decisions to opt for a planning technique for scheduling road works in Ghana and the relative importance of these factors in their respective views.

Table 4.2: **Responds Obtained from Consultants.**

Code No.	Factors	Frequency (f)			Total Response (n)
		Not Important	Important	Very Important	
		Ranking (r)			
		1	2	3	
1.0	**Project Characteristics**				
1.1	Complexity of project	10	11	16	37
1.2	Size and value of project	17	13	7	37
1.3	Project duration	14	19	4	37
1.4	Project location	27	6	4	37
1.5	Quality requirement of project	15	13	9	37
2.0	**Features of Technique**				
2.1	Simplicity in use of technique	4	9	24	37
2.2	Suitability of technique for type of work	-	12	25	37
2.3	Popularity of technique in industry	8	14	15	37
2.4	Knowledge & flexibility of technique usage	1	12	24	37
2.5	Availability of qualified personnel to apply t	9	15	13	37
2.6	Availability & cost of software for technique	4	15	18	37
2.7	Efficiency of technique in scheduling road projects	6	11	20	37
2.8	Speed & ease of development of technique	11	12	14	37
3.0	**Preferences**				
3.1	Client /Consultants' preference	-	11	26	37
3.2	Contractor's preference	17	10	10	37

Table 4.3:**Responds Obtained from Contractors.**

Code No.	Factors	Frequency (f)			Total Response (n)
		Not Important	Important	Very Important	
		Ranking (r)			
		1	2	3	
1.0	**Project Characteristics**				
1.1	Complexity of project	23	8	10	41
1.2	Size and value of project	26	7	8	41
1.3	Project duration	31	6	4	41
1.4	Project location	29	7	5	41
1.5	Quality requirement of project	16	9	16	41
2.0	**Features of Technique**				
2.1	Simplicity in use of technique	4	10	27	41
2.2	Suitability of technique for type of work	1	14	26	41
2.3	Popularity of technique in industry	8	13	20	41
2.4	Knowledge & flexibility of technique usage	3	14	24	41
2.5	Availability of qualified personnel to apply technique	9	17	15	41
2.6	Availability & cost of software for technique	5	16	20	41
2.7	Efficiency of technique in scheduling road projects	6	12	23	41
2.8	Speed & ease of development of technique	16	14	11	41
3.0	**Preferences**				
3.1	Client /Consultants' preference	-	11	30	41
3.2	Contractor's preference	1	15	25	41

Table 4.4 and *Table 4.5*, show the analysis of the responses obtained from consultants and contractors respectively.

4.2 ANALYSIS OF FACTORS BY RELATIVE IMPORTANCE INDEX RANKING TECHNIQUE

The computation of the Relative Importance Index (i.e. RII) was used to rank the factors according to their level of importance. The RII for the factors were obtained from the combined rankings assigned by respondents to each factor using a three point scale (*Tables 4.2 and 4.3*). The RII were converted into scores (by multiplying by 100) which gives the Severity Indices (SI) of the factors, (*Equation 4.1*). The relative importance of the factors was then determined based on their total score. A score or SI value of 67% or more is considered relevant, observed Elhagc and Boussabaine (2002).

The Relative Importance Index is also an indication of the significance of the factor and is obtained as:

$$RII = \frac{\sum W}{A \times N} \quad ; (0 \leq \text{RII} \leq 1) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4.1)$$

Where;

$\sum W$ = summation of the weightings for each factor

A = highest figure of the rankings (in this case 3)

N = total number of respondents for each factor

Thus,

$$SI = \left(\frac{\sum W}{A \times N}\right) \times 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4.2)$$

The relative rankings of the factors which influence choice of a planning technique adopted by professionals for scheduling road works are displayed in Tables 4.4 and 4.5. The rankings were done based on the RII.

The degree of agreement among respondents group regarding a factor was also determined using the coefficient of variation (COV).

Coefficient of variation expresses the standard deviation as a percentage of the mean, and it is useful in comparing relative variability of different responses, Nudge (2004). The value of COV is computed based on the equation below;

$$COV = \frac{\sigma}{\bar{X}} \times 100\% \quad \text{..... (4.3)}$$

Where;

σ= standard deviation

$\bar{X}$ = weighted mean of sample

A relatively low COV is a good indication that there is relatively high agreement among the responses of interviewees.

Table 4.4: **Analysis of Factors Influencing Consultants' Choice of Planning Technique for Scheduling Road Construction Works in Ghana** by Ranking Using the Relative Importance Index Technique

Code No.	Factors	Frequency (f_i)			Mean	Standard Deviation	Coefficient of Variation	Relative Importance Indices(RII)	Category of Ranking	Overall Ranking	Strength of Category
		Not important	Important	Very important							
		Ranking (r_i)									
		1	2	3							
1.0	**Project Characteristics**										**66.67 (3)**
1.1	Complexity of Project	10	11	16	2.162	0.676	31.27	0.7207	1	8	
1.2	Size & value of project	17	13	7	1.730	0.576	33.29	0.4324	5	15	
1.3	Project duration	14	19	4	1.730	0.413	23.87	0.5766	3	13	
1.4	Project location	27	6	4	1.378	0.451	32.73	0.4594	4	14	
1.5	Quality requirement of project	15	13	9	1.838	0.622	33.84	0.6126	2	11	
2.0	**Features of Technique**										**88.29 (1)**
2.1	Simplicity of technique	4	9	24	2.541	0.465	16.33	0.8469	3	4	
2.2	Suitability of technique	-	12	25	2.676	0.219	8.18	0.8919	1	2	
2.3	Popularity of technique	8	14	15	2.189	0.586	26.77	0.7297	6	7	
2.4	Knowledge & flexibility of technique	1	12	24	2.622	0.289	11.02	0.8739	2	3	
2.5	Availability of qualified personnel	9	15	13	2.108	0.583	27.66	0.7027	7	9	
2.6	Availability & cost of software	4	15	18	2.378	0.451	18.97	0.7928	4.5	5.5	
2.7	Efficiency of technique	6	11	20	2.378	0.560	23.55	0.7928	4.5	5.5	
2.8	Speed & ease of technique development	11	12	14	2.081	0.669	32.15	0.6937	8	10	
3.0	**Preferences**										**75.23 (2)**
3.1	Client preference	-	11	26	2.702	0.209	7.74	0.9009	1	1	
3.2	Contractors' preferences	17	10	10	1.811	0.694	38.32	0.6036	2	12	

Table 4.5: **Analysis of Factors Influencing Contractors' Choice of Planning Technique for Scheduling Road Construction Works in Ghana** by Ranking Using the Relative Importance Index Technique

Code No.	Factors	Frequency (f_i)			Mean	Standard Deviation	Coefficient of Variation	Relative Importance Indices (RII)	Category of Ranking	Overall Ranking	Strength of Category
		Not important	Important	Very important							
		Ranking (r_i)									
		1	2	3							
1.0	**Project Characteristics**										**61.39 (3)**
1.1	Complexity of Project	23	8	10	1.683	0.704	41.83	0.5610	2	12	
1.2	Size & value of project	26	7	8	1.902	0.753	39.59	0.5203	3	13	
1.3	Project duration	31	6	4	1.341	0.420	31.32	0.4471	5	15	
1.4	Project location	29	7	5	1.415	0.487	34.42	0.4715	4	14	
1.5	Quality requirement of project	16	9	16	2.000	0.780	39.00	0.6667	1	10	
2.0	**Features of Technique**										**86.18 (2)**
2.1	Simplicity of technique	4	10	27	2.561	0.441	17.22	0.8537	2	4	
2.2	Suitability of technique	1	14	26	2.610	0.287	11.00	0.8699	1	2	
2.3	Popularity of technique	8	13	20	2.293	0.597	26.04	0.7642	6	8	
2.4	Knowledge & flexibility of technique	3	14	24	2.512	0.396	15.76	0.8374	3	5	
2.5	Availability of qualified personnel	9	17	15	2.146	0.564	26.28	0.7155	7	9	
2.6	Availability & cost of software	5	16	20	2.366	0.476	20.11	0.7886	5	7	
2.7	Efficiency of technique	6	12	23	2.415	0.535	22.15	0.8049	4	6	
2.8	Speed & ease of technique development	16	14	11	1.878	0.644	34.29	0.6260	8	11	
3.0	**Preferences**										**88.62 (1)**
3.1	Client preference	-	11	30	2.000	0.732	36.60	0.9106	1	1	
3.2	Contractors' preferences	1	15	25	2.585	0.291	11.26	0.8618	2	3	

4.3 DISCUSSIONS OF FACTORS THAT INFLUENCE CONSULTANTS' DECISION FOR A CONSTRUCTION PLANNING TECHNIQUE FOR SCHEDULING ROAD WORKS IN GHANA

4.3.1 CATEGORY OF FACTORS

4.3.1.1 Project Characteristics

Project characteristics, with a rank of 3, is the least ranked category among the three categories of factors. This has a score of 66.67%. There are five determining factors under this category and they have coefficient of variations in the range of between 23% and 34% which is considered very high. The high coefficient of variations is an indication that there is a varying degree of agreement among consultants with respect to ranking of the factors under this category.

With the exception of only one factor which has severity index greater than the threshold index of 67%, the other four factors have indices in the range of 43% and 62%; which makes these factors not significant enough to have any major influence on consultants regarding the choice of a planning technique to adopt for scheduling road construction works, since the individual severity indices are less than the threshold index.

The overall ranking of the factors lies within the extremes of 8 and 15, with 15 being the lowest ranked factor and hence the least significant among rankings. Thus with the overall ranking of 3, representing the least ranked category, *project characteristics* (in the view of consultants) can be considered as not having any significant influence on the choice of technique adopted for road works and hence can be ignored without affecting the pace or progress of their work.

4.3.1.2 Technique Characteristics and Features

This category is composed of factors that describe some of the desirable characteristic features of a planning technique. This category is ranked first with a score of 88.29%. The category is composed of 8 main factors, all of which have weighted means above the neutral point of 2, an indication of how significant these 8 factors are, (*Table 4.4*). All the

factors in this category also have their severity indices greater than the threshold index of 67%; the highest index being 89.19% and the least being 69.37%. The coefficient of variations lies within the range of between 8% and 33%. The low values of coefficient of variations indicate that, consultants share almost the same views and opinions when it comes to the discussion of factors under this category. Overall ranking of factors found in this category is within the range of between 2 and 10.

Thus to consultants in the road construction sector, the factors listed in this category are all vital when it comes to making decisions on which planning technique to adopt for their design considerations and for the purposes of scheduling road construction works in Ghana.

4.3.1.3 Preference

Preference is the second highest ranked category in the list, with a total score of 75.23%. Included in this category are two factors, one of which maintains a mean weighted average greater than 2, an indication of how significant the factor is whiles the other has mean average less than 2. The severity indices of the factors are 90.09% and 60.36% with their respective overall rankings of 1 and 10; the number 1 being the highest ranked number. There is also a good degree of agreement among consultants in this category since very low coefficient of variation of 7.74% and 38.32% is recorded between them. With a very high severity indices of 90.09% and the rank of 1, clients' preference according to consultants is too important a factor to be ignored (compared to contractors' preference) when considering which planning technique to adopt for road works.

Summary

In summary, *technique characteristics / features*, being assigned a ranking of 1,is the most essential of all the three category of factors; that according to consultants would influence their choice for planning technique to be adopted for scheduling road construction project works. This clearly means that anything which concerns the ability and capability of a planning technique, (including all the other factors under the category of *"technique characteristics")* in scheduling road works is of outmost priority to consultants.

Table 4.6 is a summary of the categories of factors which are arranged in order of importance, with the most significant category being accorded an overall ranking of 1.

Table 4.6: **Ranking of Category of Factors in Order of Importance by Consultants**

Code No.	Category of Factors	Overall Ranking
3.0	Technique Characteristics / Features	1
2.0	Preference	2
1.0	Project Characteristics	3

4.3.2 DISCUSSION OF MAJOR FACTORS

The relevant factors under the three major categories are analysed and discussed below from the consultants' point of view. These comprise the first 10 factors each of which has a score or severity index greater than the threshold severity index of 67%.

4.3.2.1 Complexity of Project

Complexity of project is one of the ten major factors. It has a severity index of 72.07% and an overall ranking of 8, thus making the factor one of the significant factors which influence consultants' decisions on the type of a planning technique to be adopted for scheduling road construction projects. This means that, to consultants, complexity of projects would to some extent dictate the planning technique they would normally adopt for road project works, such as the highway. However, consultants' opinions on this factor differ slightly from each other, since a high coefficient of variation of 31.27% is recorded.

4.3.2.2 Simplicity of Technique

This has an overall ranking of 4 with a high severity index of 84.69%, which suggest the importance consultants attach to *simplicity of technique* when looking out for a planning technique to use for road works scheduling. The low coefficient of variation of 16.33% implies that consultants have similar views on this factor. In short, a simple technique is one that is expected to enjoy high patronage in industry. It is therefore no surprise that

consultants regard this factor as one of the crucial factors to be considered when making a decision as to which planning technique to use for scheduling road works.

4.3.2.3 Suitability of Technique

Suitability of planning technique is one of the crucial factors that cannot be ignored when making a decision on which planning technique to adopt and use for scheduling road construction works, according to consultants in the road construction industry. This is assigned an overall ranking of 2 by consultants, corresponding to a high severity index of 89.19 (*Table 4.7*); an indication of how important this factor is to consultants in scheduling and managing road works. Similarly, the relatively low value of coefficient of variation 8.18% indicates how consultants very much are in agreement with each other on their responses to this factor.

4.3.2.4 Popularity of Technique

Popularity of technique is assigned an overall ranking of 7 and a severity index of 72.97 by consultants. This means that when making a decision as to which planning technique to adopt for scheduling road construction project works, consultants naturally would consider how familiar the planning technique is within the industry before making a recommendation for its application. However, quite a number of consultants differ in opinions with regard to this factor. This is evident in the coefficient of variation's value of 26.77% obtained.

4.3.2.5 Knowledge and Flexibility of Technique

Knowledge and flexibility of technique has a severity index of 87.39%, and an overall ranking of 3, thus making it among the most important factors. Knowledge and flexibility of technique therefore plays a vital role in consultants' choice of technique for programming and scheduling road works. There is also a high degree of agreement amongst consultants as far as selection and use of a planning technique for modeling road works is concerned. This is confirmed with a relatively low coefficient of variation of 11.02%.

4.3.2.6 Availability of Qualified Personnel

Availability of qualified personnel to handle a technique is also one of the vital determining factors that consultants observed. A planning technique might possess all the excellent requisite attributes, however if people are not trained to use it, then the technique can simply not be applied. Thus with a severity index of 70.27% and an overall ranking of 9, this factor evidently is one of the significant factors which cannot be ignored as suggested by consultants; although coefficient of variation of 27.66%means clearly that quite a small percentage of consultants do not share the same opinions on this factor.

4.3.2.7 Availability and Cost of Software for Technique

Consultants' decision to select a planning technique to schedule road works is also influenced by the availability and cost of software for the technique. The factor is credited with a severity index of 79.28, culminating in an overall ranking of 5.5. The 18.97% coefficient of variation value also indicates that, there is a close level of agreement among consultants.

4.3.2.8 Efficiency of Technique

It is not surprising that the above factor is among the critical factors consultants consider in making decisions concerning which planning technique to select for scheduling road project works as the factor is giving a severity index of 79.28, which is far above the threshold index and ranked 5.5. Consultants' opinion on this factor slightly differs, with a coefficient of variation of 23.55.

4.3.2.9 Speed and Ease of Technique Development

Consultants also attach significance to speed and ease of developing a planning technique in their choice or search for a planning technique to adopt for scheduling road construction works. With a severity index of 69.37% above the threshold index corresponding to an overall ranking of 10, speed and ease of technique development is essentially one of the important factors to consultants in the selection process of a

planning technique for scheduling road works. The high coefficient value of 32.15 indicates disagreement amongst respondents.

4.3.2.10 Client / Consultant's Preference

The preference of client or his representative (i.e. consultant), is the most paramount factor to consider when making a choice for a planning technique by consultants. With a high severity index of 90.09%, this factor is given the highest overall ranking of 1, an indication of the importance and recognition consultants attach to this factor. There is also high degree of agreement among respondent group when it comes to this factor. Hence a relatively low coefficient value of 7.74 is recorded among them

Summary

Below in *Table 4.7* is a summary of the ranking of major factors arranged in order of importance or significance. These are factors with scores or severity indices or scores greater than the threshold index of 67%.

Table 4.7: **Rankings of Major Factors in Order of Importance by Consultants**

Code No.	Factor	Overall Ranking
3.1	Client / Consultants' Preference	1
2.2	Suitability of Technique	2
2.4	Knowledge and Flexibility of Technique	3
2.1	Simplicity of Technique	4
2.6	Availability and Cost of Software for Technique	5.5
2.7	Efficiency of Technique in Scheduling Projects	5.5
2.3	Popularity of Technique in Industry	7
1.1	Complexity of Project	8
2.5	Availability of Qualified Personnel	9
2.8	Speed and Ease of Technique Development	10

4.4 DISCUSSION OF FACTORS THAT INFLUENCE CONTRACTORS' DECISION FOR A CONSTRUCTION PLANNING TECHNIQUE FOR SCHEDULING ROAD WORKS IN GHANA

4.4.1 CATEGORY OF FACTORS

4.4.1.1 Project Characteristics

'Project characteristics' is ranked third by contractors. Having a score of 61.39%, it is the least ranked among the three major categories. The five determining factors under this category all have severity index which is less than the threshold index; a clear indication of the irrelevant roles these factors play in the contractors' decision to adopt a planning technique for scheduling road construction works. The high coefficients of variation recorded among these factors shows varying degree of agreement among contractors, the range of coefficient of variation lying within the limit of 31% and 42%. The values for the overall ranking of all the factors under this category are among the lowest ranked factors. The overall ranking can be located within the extremes of 10 and 15; where 15 is the least overall ranked number and hence the least significant factor. It can be concluded that contractors are least concerned with '*project characteristics'* as a significant factor which influence their choice of planning technique for road works and hence can be ignored without affecting the pace or progress of work.

4.4.1.2 Technique Characteristics and Features

With a score of 86.18%, *technique characteristic and features* is ranked second in the three categories by contractors. The factors which constitute this category have coefficient of variations in the range 11% and 35% between them. The relatively low coefficient recorded among the factors shows a high level of agreement among contractors. Also, except for only one factor with severity index less than the threshold index of 67%, the remaining seven other factors all have severity index far above the threshold index, thus making these factors very significant to contractors when making choices for planning technique to adopt for road works scheduling. The range of severity index among the factors with severity index greater than the threshold index is found in

the range of 71% and 87%. Overall ranking of the factors within this category also lies within 2 and 11.

From the above results, it is evident that contractors in the road construction industry regard *features of technique* an important category since it iscomposed of factors which have significant influence on their choice of a planning technique for scheduling road construction works.

4.4.1.3 Preference

Preference is the highest ranked category in the list, scoring a total mark of 88.62%. Included in this category are two factors, both of which have very high severity index compared with the threshold index of 67%. The severity indices of these two factors are 91.06% and 86.18%, the former being the highest recorded severity index among all the factors captured in this research work. The high values of severity index between the factors means that contractors attach very high premium to these factors when it comes to making a selection for the planning technique to use for scheduling road construction works. Similarly, low coefficient of variation of 11% and 36% obtained for these factors indicates that degree of agreement among contractors is high. These factors are ranked first and third in the overall ranking by contractors; a further confirmation of how significant these factors are to contractors.

Summary

In summary among the three categories of factors, and with a ranking of 1, *preference* is the most significant category of factors according to contractors, (*see Table 4.8 below*).

There are two major factors under this category; client's preference and contractors' preference. This implies that, contractors respect very much the preferences of clients and would do everything possible to ensure that their (clients) requirements are met. Similarly, when given the opportunity, contractors would almost invariably employ those methods and planning techniques that they are most comfortable and familiar with in the execution of their road construction project works.

Table 4.8: **Ranking of Category of Factors in Order of Importance by Contractors**

Code No.	Category of Factors	Overall Ranking
3.0	Preference	1
2.0	Technique Characteristics / Features	2
1.0	Project Characteristics	3

4.4.2 DISCUSSION OF MAJOR FACTORS

The relevant / major factors are discussed below. These constitute only the factors with severity indices greater than the threshold severity index of 67%.

4.4.2.1 Simplicity of Technique

With a high severity index of 85.37%, corresponding to an overall ranking of 4, simplicity of technique is one of the major factors which affect contractors' decision to choose a planning technique suitable for scheduling road construction works in the country. This suggests that, contractors are more aware of the benefits of a technique which is simple to use or apply, as already captured in this research work. The coefficient of variation of 17.22 recorded shows how close contractors are in agreement in considering this factor.

4.4.2.2 Suitability of Technique

Suitability of planning technique, having a high severity index of 86.99% is undoubtedly one of the crucial factors contractors attach importance to as it affects their choice of planning technique for scheduling road construction works to a greater extent. According to contractors, suitability of technique is the second most influencing factor as it is placed second in the overall ranking. Coefficient of variation of 11 indicates concordance among contractors.

4.4.2.3 Popularity of Technique

This is assigned an overall ranking of 8 by contractors with a corresponding severity index of 76.42. With a severity index above the threshold index, popularity of technique is considered by contractors as one of those factors which actually would affect the kind of planning technique they would select for the purposes of scheduling road construction works; although this factor is ranked 8th in the overall ranking of factors. Contractors however differ slightly in opinion on the significance of this factor judging, coefficient of variation being 26.04

4.4.2.4 Knowledge and Flexibility of Technique

Knowledge and flexibility of technique plays a vital role in the contractors' decision to choose a planning technique for programming and scheduling road construction works in the road construction works in the country. This is confirmed by a whooping severity index of 83.73%, far above the threshold index. This factor places fifth in the overall ranking category. This factor records 15.76 as a coefficient of variation, implying relatively high agreement in ranking this factor as one of the most influencing by contractors

4.4.2.5 Availability of Qualified Personnel

With severity index strength of 71.55%, availability of qualified personnel for technique use for scheduling road construction works in the country is obviously one of the determining factors which influence contractors' search and selection for a suitable planning technique for managing road works in Ghana. This factor is positioned 9th on the overall ranking ladder. The coefficient of variation is slightly higher at 26.28, indicating differing opinions held by contractors when it comes to choice of this factor as among the significant ones.

4.4.2.6 Availability and Cost of Software for Technique

Contractors' responds to questionnaire identified this factor as being one of the significant factors which also influences the planning technique they would normally

adopt for managing and scheduling road construction project works. With a severity index of 78.86%, this factor is ranked 7th in the overall ranking by contractors in the road construction industry. The coefficient of variation recorded is relatively high (20.11), suggesting differing views by contractors concerning the significance of this factor as far as making a choice of a planning technique for road works is concerned.

4.4.2.7 Efficiency of Technique

Efficiency of planning technique is very significant factor to consider as it very much influences contractors' decision regarding the planning technique to use for scheduling road construction works. Accordingly, this factor is accorded a severity index of 80.49% and placed 6th in the overall ranking category by contractors. However, the high coefficient of variation value of 22.15 shows disagreement among respondents regarding the significance of this factor when it comes to deciding on which planning technique to use to schedule road works in Ghana.

4.4.2.8 Client / Consultants' Preference

Clients' preference or his representative (i.e. consultants), enjoys a high rating by contractors in the industry. A severity index of 91.06% is significantly high, thus making the factor the number one in the overall ranking list. The high coefficient of variation of 36.60 however means low agreement within this group of professionals so far as planning technique selection and application is concerned.

4.4.2.9 Contractor's Preference

Contractors' preference is also too important a factor to be ignored. With an overall ranking of 3, culminating from a high severity index of 86.18%, this factor is clearly one of the crucial factors for a successful execution of road construction project works. The high significance accorded this factor is an opinion shared by quite a large number of contractors as indicated by the value of the coefficient of variation, which is 11.26.

The major factors with severity index greater than the threshold index of 67% as identified by contractors are ranked below in *Table 4.9* in order of their importance.

Table 4.9: **Ranking of Major Factors in Order of Importance by Contractors**

Code No.	Factor	Overall Ranking
3.1	Client / Consultants' Preference	1
3.2	Suitability of Technique	2
2.4	Contractors' Preference	3
2.1	Simplicity of Technique	4
2.4	Knowledge and Flexibility of Technique	5
2.7	Efficiency of Technique in Scheduling Projects	6
2.6	Availability and Cost of Software	7
2.3	Popularity of Technique	8
2.5	Availability of Qualified Personnel	9

Table 4.10: Overall Ratings of Major Factors by Professionals Using the RII Technique

Code No.	Factors	Consultants		Contractors		Overall	
		RII	Rank	RII	Rank	RII	Rank
1.0	**Project Characteristics**						
1.1	Complexity of Project	0.7207	8	0.5610	12	0.6409	11
1.2	Size & value of project	0.4324	15	0.5203	13	0.4764	14
1.3	Project duration	0.5766	13	0.4471	15	0.5119	13
1.4	Project location	0.4594	14	0.4715	14	0.4655	15
1.5	Quality requirement of project	0.6126	11	0.6667	10	0.6397	12
2.0	**Features of Technique**						
2.1	Simplicity of technique	0.8469	4	0.8537	4	0.8503	4
2.2	Suitability of Technique	0.8919	2	0.8699	2	0.8809	2
2.3	Popularity of technique	0.7297	7	0.7642	8	0.7470	7
2.4	Knowledge &Flexibility of Technique	0.8739	3	0.8374	5	0.8557	3
2.5	Availability of qualified personnel	0.7027	9	0.7155	9	0.7091	9
2.6	Availability & Cost of Software for Technique	0.7928	5.5	0.7886	7	0.7907	6
2.7	Efficiency of Technique	0.7928	5.5	0.8049	6	0.7989	5
2.8	Speed & ease of technique development	0.6937	10	0.6260	11	0.6599	10
3.0	**Preferences**						
3.1	Clients'' Preference	0.9009	1	0.9106	1	0.9058	1
3.2	Contractors' Preference	0.6036	12	0.8618	3	0.7327	8

4.5 MEASUREMENT OF CONCORDANCE BETWEEN CONTRACTORS' AND CONSULTANTS' RANKINGS OF FACTORS.

To determine whether professionals (respondents) views with respect to ranking of the factors differ from each other or not, a concordance test was conducted using the Spearman's Rank Correlation Coefficient

The Spearman's Rank Correlation Coefficient or R_s is a non-parametric statistical method which measures the degree of association or agreement between two variables. R_s requires that both variables be measured in at least an ordinal scale, so that the factors under study may be ranked in two ordered series; Siegel (1956).

The value of R_s ranges from -1 to +1. A value of $R_s = \pm 1$ indicates perfect concordance between the two variables; the plus sign occurring for identical rankings and the minus sign occurring for reverse rankings. When R_s is close to zero, we conclude that the variables are uncorrelated.

The measure of R_s of association between two variables according to Walpole et al. (2007) is estimated mathematically as:

$$R_S = 1 - \frac{6\sum_{i=1}^{k} d^2}{N(N^2-1)} \quad \text{..... (3.4).}$$

Where;

d = the difference between the rankings assigned to proposed factors by respondents (i.e. $d = X_i - Y_i$)

N = 15 (number of factors ranked)

i = 1and 2; representing consultants and contractors respectively.

K = 3 (number of set of rankings).

Below is *Table 4.11* for the determination of the Spearman's rank correlation coefficient between rankings by contractors and consultants of the 15 factors.

Table 4.11: **Determination of Spearman's Rank Coefficient of Correlation**

Code No.	Proposed Factors	Rankings of Proposed Factors		$d_i = (X_i - Y_i)$	d_i^2
		Consultants' Rankings (X_i)	Contractors' Rankings (Y_i)		
1.1	Complexity of Project	8	12	-4	16
1.2	Size & Value of Project	15	13	2	4
1.3	Project Duration	13	15	-2	4
1.4	Project Location	14	14	0	0
1.5	Project's Quality Requirements	11	10	1	1
2.1	Simplicity of Technique	4	4	0	0
2.2	Suitability of Technique	2	2	0	0
2.3	Popularity of Technique	7	8	-1	1
2.4	Knowledge & Flexibility of Technique	3	5	- 2	4
2.5	Availability of Qualified Personnel	9	9	0	0
2.6	Availability & Cost of Software	5.5	7	- 1.5	2.25
2.7	Efficiency of Technique	5.5	6	- 0.5	0.25
2.8	Speed & Ease of Technique Development	10	11	-1	1
3.1	Clients/Consultants' Preference	1	1	0	0
3.2	Contractor's Preference	12	3	9	81
			$\sum d_i^2$		**=114.5**

$$R_s = 1 - \frac{6\sum_{i=1}^{N} d^2}{N(N^2 - 1)}$$

$$= 0.796$$

The correlation coefficient $R_s = +0.796$ indicates strong agreement between rankings of major factors by respondents (consultants and contractor).

This means that the criteria used by respondents in ranking the factors may be essentially the same.

4.5.1 Significance Test forthe Spearman's Rank Correlation Coefficient

The appropriate hypotheses to test for the significance of the Spearman's Rank Correlation Coefficient; R_s are the null hypothesisH_0 and the alternative hypothesis H_1. The null hypothesis is rejected if the test statistics R_s is greater than r_α. *H_0 and H1 are* defined as:

H_0: $b_1 = 0$ (R_s is **not** significant)

H_1: $b_1 > 0$ (R_s is significant)

***α* = 0.05** (level of significance)

Test statistics: $R_s = +0.796$

Critical value: $r_\alpha = r_{0.05} = 0.441$ from *Table A1* in the appendix; for *n* = 15

Decision: $R_s > r_\alpha$; $H_0$is rejected (since R_s is far into the critical/rejection region; *Figure A1* in the appendix). There is significant correlation between the rankings by consultants and contractors. Essentially the same criteria are used in ranking the factors by both categories of professionals.

4.6 DETERMINING THE SIGNIFICANCE OF FACTORS

The major factors which featured in the research were also analysed for their significance as per view by each group of respondents. For each factor, a significance test method was carried out to determine its significance. The test involved the formulation of a null and alternative hypothesis denoted respectively as H_0 and H_1, computation of the test statistics (*t*) and the probability of observing a value of the test statistics (t_α).

The t_α was determined by evaluating the test statistics at 5% significance level and (n-1) degree of freedom. The null hypothesis is rejected if the test statistics is greater than$t_{\alpha(n-1)}$.

Computation of the Test Statistics

The test statistics was calculated from equation 4.4 according to Walpole et al. (2007)

$$t = \frac{\bar{x}-\mu}{(\sigma/\sqrt{n})} \text{.....4.4}$$

t = test statistics; $\bar{X}$= the sample mean; $(\sigma/\sqrt{n})$ = standard error of the mean

σ= standard deviation of the ranking; n= number of respondents for each factor

μ= population mean (i.e. mean of the means of all 15 factors in the study).

The test of significance for clients and consultant responses to the 15 factors are described below. A one-tailed test of significance was used. The results are depicted in *Tables 4.12* and *4.13* respectively. *Table 4.14* however, is a summary of the significant factors identified by the respondents and arranged in order of importance based on their RII values.

The appropriate hypotheses and procedure for the significance test are as below:

***H_0*:** ''the factor is **not** significant to influence the choice of a planning technique for scheduling road construction works''.

***H_1*:**'' the factor is significant to influence the choice of a planning technique for scheduling road construction works''.

***α* = 0.05**

Test statistics = t

***Critical values*:** $(t_{\alpha(n-1)})$ =1.688 and 1.684 (*for consultants and contractors respectively, where n = 37 and 41).* Refer to *Table A2* for the critical values.

Conclusion:since $t > \left(t_{\alpha(n-1)}\right)$ for factors with code Nos. ***2.1, 2.2, 2.4, 2.6, 2.7, 3.1 & 3.2*** which are highlighted in red (*Tables 4.6 & 4.7*); H_0 is not accepted as $t > \left(t_{\alpha(n-1)}\right)$ falls in the rejection region, (*Appendix A2*). H_1isthus accepted.

Table 4.12: Test of Significance of Factors Ranked by Consultants

Code No.	Factors	Frequency (f_i)			Mean	Standard Deviation	Relative importance Index	Test Statistics	Level of Significance	Significance of Factor
		Not important	Important	Very important						
		Ranking (r_i)								
		1	2	3						
1.0	**Project Characteristics**									
1.1	Complexity of Project	10	11	16	2.162	0.676	0.7207	0.040	1.688	Not Significant
1.2	Size & value of project	17	13	7	1.730	0.576	0.4324	-2.852	1.688	Not Significant
1.3	Project duration	14	19	4	1.730	0.413	0.5766	-3.972	1.688	Not Significant
1.4	Project location	27	6	4	1.378	0.451	0.4594	-6.673	1.688	Not Significant
1.5	Quality requirement of project	15	13	9	1.838	0.622	0.6126	-1.974	1.688	Not Significant
2.0	**Features of Technique**									
2.1	Simplicity of technique	4	9	24	2.541	0.465	0.8469	3.215	1.688	Significant
2.2	Suitability of technique	-	12	25	2.676	0.219	0.8919	9.214	1.688	Significant
2.3	Popularity of technique	8	14	15	2.189	0.586	0.7297	0.223	1.688	Not Significant
2.4	Knowledge & flexibility of technique	1	12	24	2.622	0.289	0.8739	6.258	1.688	Significant
2.5	Availability of qualified personnel	9	15	13	2.108	0.583	0.7027	-0.312	1.688	Not Significant
2.6	Availability & cost of software	4	15	18	2.378	0.451	0.7928	1.915	1.688	Significant
2.7	Efficiency of technique	6	11	20	2.378	0.560	0.7928	1.542	1.688	Not Significant
2.8	Speed & ease of technique development	11	12	14	2.081	0.669	0.6937	-0.428	1.688	Not Significant
3.0	**Preferences**									
3.1	Client preference	-	11	26	2.702	0.209	0.9009	10.137	1.688	Significant
3.2	Contractors' preferences	17	10	10	1.811	0.694	0.6036	-1.920	1.688	Not Significant

* μ = 2.155

Table 4.13: Test of Significance of Factors Ranked by Contractors

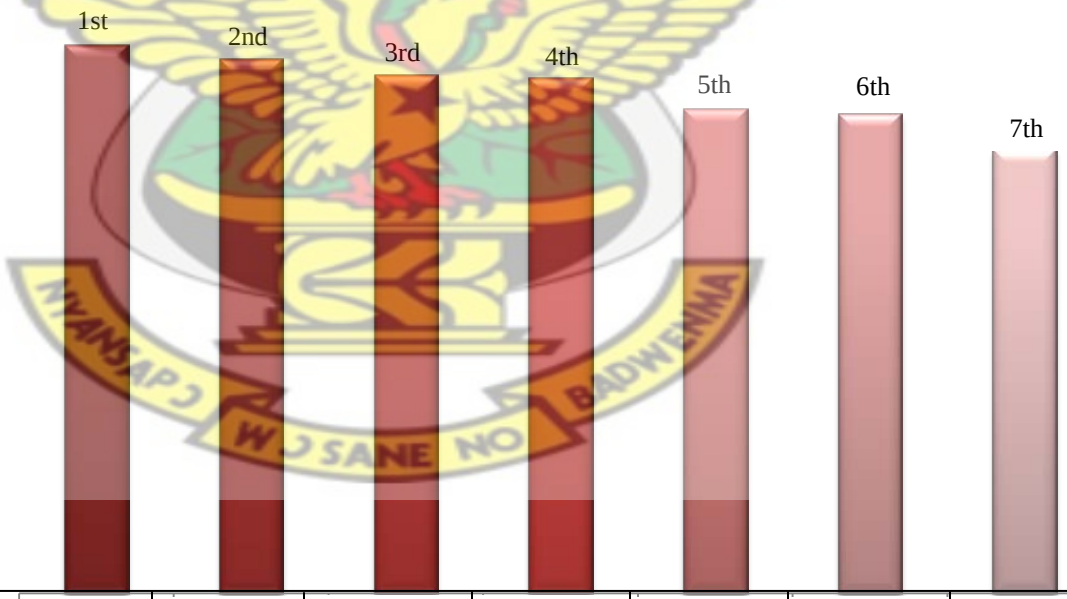
Code No.	Factors	Frequency (f_i)			Mean	Standard Deviation	Relative importance Index	Test Statistics	Level of Significance	Significance of Factor
		Not important	Important	Very important						
		Ranking (r_i)								
		1	2	3						
1.0	**Project Characteristics**									
1.1	Complexity of Project	23	8	10	1.683	0.704	0.5610	-2.371	1.684	Not Significant
1.2	Size & value of project	26	7	8	1.902	0.753	0.5203	-1.090	1.684	Not Significant
1.3	Project duration	31	6	4	1.341	0.420	0.4471	-7.128	1.684	Not Significant
1.4	Project location	29	7	5	1.415	0.487	0.4715	-5.559	1.684	Not Significant
1.5	Quality requirement of project	16	9	16	2.000	0.780	0.6667	-0.566	1.684	Not Significant
2.0	**Features of Technique**									
2.1	Simplicity of technique	4	10	27	2.561	0.441	0.8537	4.101	1.684	Significant
2.2	Suitability of technique	1	14	26	2.610	0.287	0.8699	6.693	1.684	Significant
2.3	Popularity of technique	8	13	20	2.293	0.597	0.7642	1.161	1.684	Not Significant
2.4	Knowledge & flexibility of technique	3	14	24	2.512	0.396	0.8374	3.893	1.684	Significant
2.5	Availability of qualified personnel	9	17	15	2.146	0.564	0.7155	0.220	1.684	Not Significant
2.6	Availability & cost of software	5	16	20	2.366	0.476	0.7886	2.050	1.684	Significant
2.7	Efficiency of technique	6	12	23	2.415	0.535	0.8049	2.179	1.684	Significant
2.8	Speed & ease of technique development	16	14	11	1.878	0.644	0.6260	-1.419	1.684	Not Significant
3.0	**Preferences**									
3.1	Client preference	-	11	30	2.000	0.732	0.9106	-0.603	1.684	Not Significant
3.2	Contractors' preferences	1	15	25	2.585	0.291	0.8618	6.269	1.684	Significant

*μ=2.114

Table 4.14:**Ranking of Significant Factors by Overall RII**

Code No.	Factors	Test Statistics (t)		Average *(t)*	Average Critical Value $t_{\alpha(n-1)}$	Relative Importance Index (RII)		Overall RII	Rank
2.0	**Features of Technique**	Contractors	Consultants			Contractors	Consultants		
2.1	Simplicity of technique	4.101	3.215	3.658	1.686	0.8537	0.8469	0.8503	4
2.2	Suitability of technique	6.693	9.214	7.9535	1.686	0.8699	0.8919	0.8809	2
2.4	Knowledge & Flexibility	3.893	6.258	5.0755	1.686	0.8374	0.8739	0.8557	3
2.6	Availability & cost of software	2.05	1.915	1.9825	1.686	0.7886	0.7928	0.7907	6
2.7	Efficiency of technique	2.179	1.542	1.8605	1.686	0.8049	0.7928	0.7989	5
3.0	**Preferences**								
3.1	Client's Preference	-0.603	10.137	4.767	1.686	0.9106	0.9009	0.9058	1
3.2	Contractor's Preference	6.269	-1.92	2.1745	1.686	0.8618	0.6036	0.7327	7

Graph 4.1: Significant Factors in Decreasing Order of Influence



Significant Factors	Client's Preference	Suitability of Technique	Knowledge & Flexibility	Simplicity of Technique	Efficiency of Technique	Availability & Cost of Software	Contractors Preference
Overall RII	0.9058	0.8809	0.8557	0.8503	0.7989	0.7907	0.7327

4.7 DISCUSSION OF SIGNIFICANT FACTORS

4.7.1 Simplicity of Technique

A simple technique is one that easily processes and conveys information which is readily understood and can be interpreted by all users. It is therefore obvious that any technique that is simple to use would be everybody's favourite as it is most likely to attract more users.

4.7.2 Suitability of Technique

Suitability of a planning technique is dependent on the nature of the project and the project requirements to some degree. A suitable technique can be described as one that is more practically appropriate for the kind of job that it has been designed for. Thus, suitable techniques are designed to perform specific task(s). Some techniques, however, are more suitable for a particular job than others. It is therefore prudent that, one determines the technique that would be most appropriate for the task at hand before he proceeds to use it. The use of a suitable technique to schedule construction works ensures best results for the project in terms of cost, time and performance. However, applying the wrong kind of technique to manage works may cause difficulty and eventual failure of the project. It is therefore not surprising that suitability of a planning technique is one of the significant factors that influence respondents' choice of a planning technique to schedule road works.

4.7.3 Knowledge and Flexibility of Technique

The more information that is readily available and accessible on a planning technique, the likelihood it becomes that the technique would be accepted for use in industry. As the level of information increases, the degree of flexibility in the application of the technique also increases. This means that more and more people would become more knowledgeable in the application of the technique. The technique eventually would become very popular in the industry. The contrary is true; that is where little or no information is available on a planning technique, it is clear that the technique would not

be patronised. This is because; nobody would want to work with a technique that he is not familiar with.

4.7.4 Availability and Cost of Software

To design and develop software package(s) for a planning technique can be very costly; and depending on the capabilities or features of the software, this cost may be high. Apart from the cost, availability of software for the technique can also affect the popularity in use of the technique. Software for a technique might be available but the cost however, may discourage its usage in industry. Therefore, techniques for which software packages are not only available but also affordable are most likely to be accepted and applied in industry.

4.7.5 Efficiency of Technique

Planning technique that is efficient is capable of capturing and providing all the needed information about the project and communicates it quite easily to the recipients of the information. Such information should also be readily understood and interpreted by the recipients. Efficient techniques are also able to model accurately, construction projects for which they are intended for. Thus an efficient technique is most likely to enjoy high patronage from the industry.

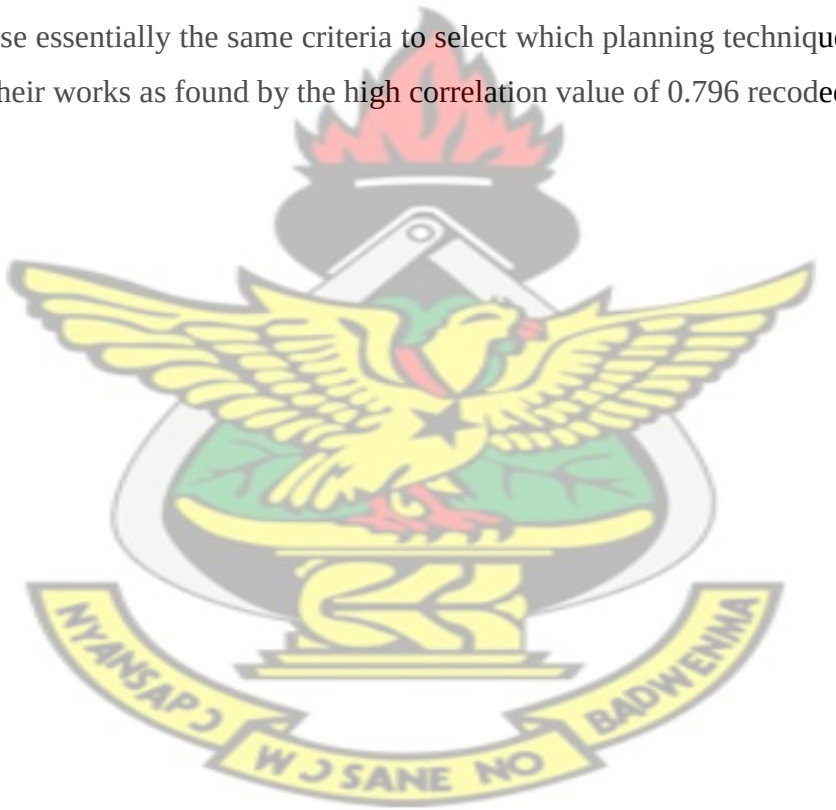
4.7.6 Client/Consultants' Preference

Every construction project is initiated and financed by the client. It is the client's preferences that usually form the basis of the contract and which all parties to the contract must respect and abide by. This implies therefore that, the client or his representative (i.e. consultant) can play a major role in deciding which planning technique to use to schedule projects. Thus, as an initiator and financier of construction projects, client is the most important party to the contract and the success of the project mostly depend on the client and his relationships with other parties to the contract. Failure on the part of contractors to respect clients' briefs or preferences by incorporating them in the final product can jeopardize their relationship with the client or his representative regarding future projects. Hence the preferences of client cannot be ignored if the project is to proceed smoothly.

4.7.7 Contractors' Preference

In most contractual agreements, contractors are allowed the flexibility by consultants to select own planning technique and method for the management and execution of the work. Naturally, a contractor would employ those planning techniques and methods he is most familiar with to schedule his works in order to attain best results for his construction projects so as to stay competitively in business by maintaining good relationships with employers.

It should be noted that, most significant factors by consultants are also considered as significant factors by contractors; thus confirming the fact that consultants and contractors use essentially the same criteria to select which planning technique to employ to schedule their works as found by the high correlation value of 0.796 recoded



CHAPTER FIVE

5.0 EXTENT OF UTILIZATION OF THE LINEAR PROGRAMME TECHNIQUE FOR SCHEDULING ROAD CONSTRUCTION WORKS INGHANA

The data obtained from consultants and contractors in some selected road construction and consulting firms in the road sub-sector of the construction industry of Ghana are compiled and analysed in the following tabular forms.

Tables 5.1 and *5.2* indicate respectively, the results and analysis of the planning techniques employed by contractors and recommended by consultants for scheduling road project works in Ghana according to their RII. Similarly, *Tables 5.3* and *5.4* show the respective level of knowledge of contractors and consultants in the use of a planning technique for scheduling road works.

Table 5.1: Planning Technique Most Preferred by Contractors for Scheduling Road Construction Works in Ghana.

Planning Technique Options	Frequency (f_i)			Total Response (N)	Weighting ($\sum$ W)	RII = ($\frac{\sum W}{A \times N}$)	Overall Ranking
	Not Used Often	Used Often	Used very Often				
	Ranking (r_i)						
	1	2	3				
Linear Programme	33	6	2	41	51	0.4146	4
Bar (Gantt) Chart	-	2	39	41	121	0.9837	1
Network Analysis Diagram	21	17	3	41	64	0.5203	2
Line – of – Balance	37	3	1	41	46	0.3740	5
**Others	23	14	4	41	63	0.5122	3

*** Combination of any two of the known planning techniques*

Table 5.2: Planning TechniqueMost Preferred by Consultants forScheduling Road Construction Works in Ghana.

Planning Technique Options	Frequency (f_i)			Total Response (N)	Weighting ($\sum W$)	RII = ($\frac{\sum W}{A \times N}$)	Overall Ranking
	Not Recommended	Recommended	Often Recommended				
	Ranking (r_i)						
	1	2	3				
Linear Programme	35	2	-	37	39	0.3514	4
Bar (Gantt) Chart	-	1	36	37	110	0.9910	1
Network Analysis Diagram	29	6	2	37	47	0.4234	2
Line – of – Balance	37	-	-	37	37	0.3333	5
**Others	28	9	-	37	46	0.4144	3

Table 5.3: Contractors Level of Knowledge in Planning Technique Usage for Scheduling Road Construction Works in Ghana.

Planning Technique Options	Frequency (f_i)			Total Response (N)	Weighting ($\sum W$)	RII = ($\frac{\sum W}{A \times N}$)	Overall Ranking
	Low	High	Very High				
	Ranking (r_i)						
	1	2	3				
Linear Programme	22	12	7	41	67	0.5447	3
Bar (Gantt) Chart	-	10	31	41	113	0.9187	1
Network Analysis Diagram	2	24	15	41	95	0.7724	2
Line – of – Balance	32	8	1	41	51	0.4146	4
**Others	-	-	-	41	-	-	-

** *Combination of any two of the known planning techniques*

Table 5.4:Consultants Level of Knowledge in Planning Technique Usage for Scheduling Road Construction Works in Ghana.

Planning Technique Options	Frequency (f_i)			Total Response (N)	Weighting ($\sum W$)	RII = ($\frac{\sum W}{A \times N}$)	Overall Ranking
	Low	High	Very High				
	Ranking (r_i)						
	1	2	3				
Linear Programme	22	12	7	41	67	0.5447	3
Bar (Gantt) Chart	-	10	31	41	113	0.9187	1
Network Analysis Diagram	2	24	15	41	95	0.7724	2
Line – of – Balance	32	8	1	41	51	0.4146	4
**Others	-	-	-	41	-	-	-

Tables 5.1 and *5.2* show the planning techniques that are employed within the road construction industry of Ghana to schedule road works.

5.1.1The Most Applied Planning Technique for Scheduling Road ConstructionWorks in Ghana

With the relative importance indices of 0.9837 and 0.3740, corresponding to the overall rankings of 1 and 5 respectively, the bar chart is the predominantly employed planning technique by contractors in the road sub-sector for scheduling road construction projects in Ghana; whiles the line-of-balance is the least applied technique for the same purpose (*Table 5.1*). The *linear programme* technique is the second least applied planning technique for scheduling road works. The *linear programme* technique is thus ranked 4th by contractors, with a relative importance index of 0.4146. In fact, out of a total number of 41 contractors who responded to the questionnaire, 33 of them or 80.48% admitted not having used the linear programme planning technique to schedule road project works. The Network analysis technique follows the bar chart technique as the second most employed planning technique by contractors in the industry, having an overall rank of 2

culminating from relative importance index of 0.5203. The application of any two of the four main planning techniques is also possible for scheduling road project works in the industry as indicated. This is assigned a rank of 3 by contractors and a relative importance index of 0.5122.

Similarly, *Table 5.2* contains information which shows consultants' preference for a planning technique they would normally recommend for use for scheduling road construction works. Clearly, the bar chart is the consultants' preferred planning technique. The bar chart technique is thus ranked No. 1 by consultants and as such accorded a relative importance index value of 0.9910, which is the highest. According to consultants, the *linear programme* technique is the fourth ranked technique; with the Line-of-balance technique being given a rank of 5 which is the least ranked number. Thus in terms of application, the *linear programme* and the line-of balance techniques are the least applied planning techniques for scheduling and managing road works in the country in the view of consultants. From *Table 5.2*, a large number of consultants, to be precise 35 out of the total number of 37 consultants would not recommend the *linear programme*technique for use for scheduling road construction works.

It is interesting to note that the level of importance that contractors attach to a particular planning technique and hence the ranking of that technique is coincidentally the same as that expressed by consultants. This means that, both contractors and consultants apply essentially the same planning technique as a tool for scheduling road works in Ghana, implying also that the planning technique which contractors are most familiar with and hence would normally use to prepare their programme of (road) works is the technique consultants understand, and therefore would normally also recommend for use.

Respondents' knowledge in the use of a planning technique for scheduling road projects is captured in *Tables 5.3* and *Table 5.4*. Clearly, a large number of professionals (consultants and contractors) providing services in the road sub-sector of the Ghanaian construction industry are very knowledgeable in the application of the bar chart technique for scheduling road project works than any of the other known techniques. This is confirmed by the highest ranking of 1 assigned to the bar chart technique by both contractors and consultants (*Tables 5.3* and *5.4*). Knowledge in the application of network analysis technique is also high among respondents. This is evident in the ranking

position of 2 occupied by this technique in both *Table 5.3* and *Table 5.4*. Furthermore, *Tables 5.3* and *5.4* indicate clearly that, contractors and consultants' knowledge with regard to the use of the *linear programme* and line-of-balance planning techniques are low. These two techniques therefore are given the lowest ratings in the tables.

The trend seen in the result tables where the network analysis technique always follows the bar chart technique as the second most applied and known planning technique for managing road works in the road sub-sector by professionals in the industry could be attributed to the fact that, the bar chart programme could be generated (automatically) from the network analysis diagram. This means that, professionals can work around both techniques at the same time for programming of works.

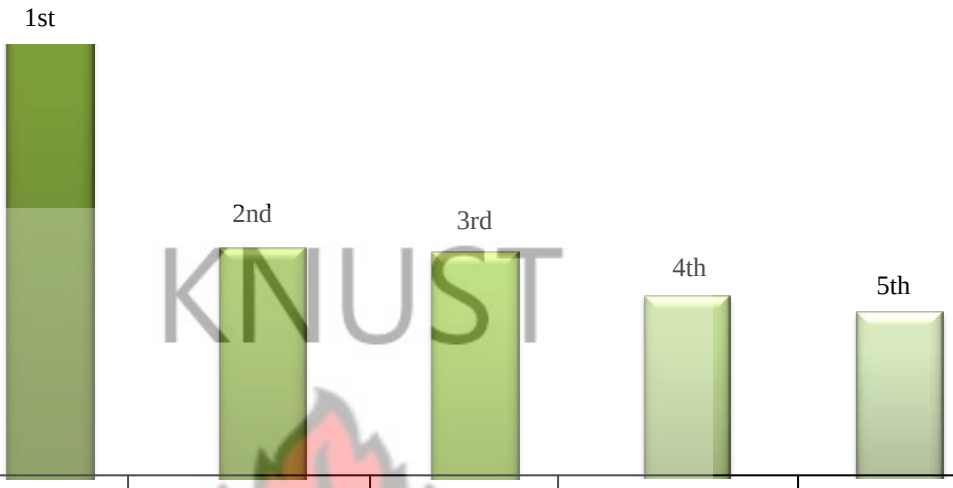
Summary

The bar chart is the most preferred and widely employed planning technique by professionals in the road sub-sector of Ghana for the purposes of scheduling road works as it is assigned the highest ranking of 1 by both contractors and consultants in the industry (*Table 5.5*) which is a summary of *Tables 5.1* and *5.2*.

Table 5.5: Ranking of Planning Technique by Professionals in Order of Preference

Planning Technique Options	Relative Importance index (RII)		Overall Relative Importance Index (Average)	Rank
	Contractors	Consultants		
Bar Chart	0.9837	0.991	0.9874	1
Network Analysis	0.5203	0.4234	0.4719	2
**Others	0.5122	0.4144	0.4633	3
Linear Programme	0.4146	0.3514	0.3830	4
Line - of – Balance	0.374	0.3333	0.3537	5

Graph 5.1: Planning Techniques for Scheduling Road Works in Decreasing Order of Preference



Planning Technique	Bar Chart	Network Analysis	Others	Linear Programme	Line-of-Balance
Overall RII	0.9874	0.4719	0.4633	0.3830	0.3537

5.1.2 Linear Programme Planning Technique for Scheduling Road Construction Works in Ghana

L*inear programme* as a planning technique has not been exploited to any larger extent by the road construction industry of Ghana for the purposes of scheduling and managing road project works. Results from *Tables 5.3 and 5.4* have revealed that, knowledge of the *linear programme* technique as a planning tool for managing road construction works is low among professionals in the industry compared with say the bar chart which is the most popular and readily preferred technique, *(Table 5.5)*. Thus, lack of knowledge of the linear programme planning technique may have accounted for some of the reasons why thetechnique is not being applied to any appreciable extent in the industry as results in *Tables 5.2 and 5.2* indicate. This may suggest that contractors who normally are the ones who draw up programmes for their works are just not using the linear programme technique for such purposes. Other possible reasons why the linear programmetechnique is not being employed in the road construction industry for scheduling road works could also be attributed to the (seven) major significant factors already identified in the study; which includes *suitability of technique, simplicity of technique, knowledge and flexibility of technique, availability and cost of software, efficiency of technique, client preferences*

and contractor's preferences and popularity of technique in industry, which could be explained as:

Simplicity

A simple technique is one that easily processes and conveys information which is readily understood and can be interpreted by all users. The linear programme planning technique may not be the preferred technique among professionals in the industry probably because it lacks some of the attributes of a simple technique.

Suitability

Suitability of a planning technique is dependent on the nature of the project and the project requirements to some degree. In Ghana, the traditional bar chart technique is the most largely applied technique for scheduling construction work. This means that, to the Ghanaian road construction professional, the bar chart is essentially the ideal and therefore most suitable technique for scheduling road works rather than the linear programme technique. This may have accounted for the reason why the linear programme technique is not given the attention it deserves by the road sub-sector.

Knowledge and Flexibility

It could also happen that, the road construction industry in the country is possibly not fully aware of certain detailed information on the linear programme technique, regarding for instance, the suitability, ability and capability of the technique as far as scheduling road works is concerned. Contractors and consultants in the industry therefore are not being flexible towards the application of the linear programme technique, probably because they are not knowledgeable in some of the desirable qualities of the linear programme technique that makes it an appropriate technique for modeling road construction project works and other such linear works as already identified in the research work.

Availability and Cost of Software

Software packages like PULSS among others, which can be used to generate the linear programme diagram may either not be available on the Ghanaian market, or if available, are too costly and therefore not easily affordable or both. On the contrary, Microsoft Project software for developing the bar chart is readily available and affordable on the Ghanaian market. Thus, non-availability of the software coupled with the cost of the software for generating the linear programme technique may have contributed to the low popularity and patronage enjoyed by the linear programme technique in the road sub-sector as a planning technique for road works schedule compared with the bar chart technique.

Efficiency of Technique

Planning technique that is efficient is capable of capturing and providing all the needed information or data about the project and to communicate it quite easily to the recipients of the information. Such information should be readily understood and interpreted by the recipients. Thus an efficient technique is most likely to be accepted by all in industry as it is able to accomplish the task for which it has been designed. Professionals in the road construction industry in Ghana may perceive the linear programme as a less efficient planning technique which does not provide them with the anticipated information as far as road scheduling are concerned; thereby limiting its usage in the road sub-sector.

Client's Preferences

Every construction project is initiated and financed by the client. In fact, it is the client's preferences that usually form the basis of the contract and which all parties to the contract must respect and abide by. In Ghana, the government is the single largest client in the road construction industry. Government road project works are managed and supervised by the G.H.A, D.U.R and D.F.R who act as consultants or have private consultants acting on their behalf.

It is obvious that the linear programme technique is not the preferred choice of consultants in the road construction industry as far as scheduling road works in Ghana is

concerned. The perception created is that consultants in the road sub-sector are themselves not aware of the excellent attributes of the linear programme technique as an appropriate planning tool for the purposes of scheduling road works. Hence they are not in a position to help promote the application of the technique in the industry by either specifying or recommending it to contractors.

Contractor's Preference

In most contractual agreements, contractors are allowed the flexibility by consultants to select own planning technique and method for the management and execution of the work. Naturally, a contractor would employ those planning techniques and methods he is most familiar with to schedule his works. The near absence of the linear programme as a planning technique to schedule road construction works in the country clearly demonstrates that it is not the technique most favoured by the majority of contractors in the road construction industry.

Summary

Literature search has revealed that the *linear programme* is an appropriate planning technique for scheduling road projects and other linear works. However, the technique has not been and is still not being accorded the recognition it deserves by the road construction industry of Ghana. The search also identifies the *linear programme* technique as being a simple and an efficient one, but analysis of survey results obtained from respondents suggests that despite all these desirable attributes, the *linear programme* technique is as yet to make any major impact on the road construction industry in the country as a major planning technique. This means that, professionals in the road sub-sector of the construction industry have not actually tried and tested (as the study has revealed) the *linear programme* technique to such an extent as would enable them to explore the efficacy of the technique as far as road works scheduling is concerned.

Although very few respondents, especially those who work in foreign and foreign/local partnership firms, admitted ever using the linear programme technique for the purposes

of scheduling road works; this they do in combination with other techniques, especially in combination with the bar chart technique. Thus the linear programme as a planning tool is not being applied solely and predominantly for road works schedules, although a large number of contractors covered in the research admitted having well structured planning departments in their outfit which are managed by qualified personnel. About 46% of professionals; which constitute a total number of 36 (*i.e. consultants = 17 and contractors = 19;* refer *to Tables 5.3 and 5.4*) out of the sum total of 78 number respondents who claim to have knowledge in the linear programme technique know them by theory. They actually have not applied the technique in their professional practices to schedule road works.

It is obvious that, there is a real absence of the linear programme technique usage in the road sector for programming and scheduling purposes. This state of affairs prevailing in the road sub-sector may have resulted from the fact that, professionals in the industry are not very much conversant with the linear programme technique as an ideal planning tool for managing road works, and therefore are not comfortable with its application, although almost all of the professionals interviewed during the preliminary stages of the study claimed to be aware of the existence of the technique.

As has always been the practice, contractors are often allowed the flexibility to determine their own construction method(s), and hence the planning technique to adopt for programming their works. These works programmes prepared by contractors are subsequently submitted to project consultants for their perusal or inputs. Therefore, as the linear programme technique is not being applied in the industry, contractors could partly be blamed for not helping to promote the technique usage since they fail to use the technique to programme their works.

Considering the numerous benefits of the linear programme technique in scheduling linear projects; such as its ability to monitor the relative progress of work quite easily and also the capacity to provide and to communicate all the necessary information, it is quite strange that the technique is not being given the necessary recognition that it deserves by the Ghanaian road sector.

5.2LINEAR PROGRAMME AND BAR CHART TECHNIQUES COMPARED (*CASE STUDY*)

With the availability of all the relevant information, the linear programme technique can be demonstrated graphically. Since the bar chart planning technique is the technique most widely used for scheduling road construction project works in the country, according to the research findings, it is appropriate that the bar chart technique and the linear programme technique be compared using a graphical demonstration. For this purpose, we consider below a road construction project work that is on-going in certain part of the country as a case study. The details of the project are as outlined below:

PROJECT DETAILS:

The project details for this case study as obtained from MessrCymain (Gh.) Ltd. the construction firm that undertook the actual project are as found below:

Client: GHANA HIGHWAY AUTHORITY (MINISTRY OF ROAD AND TRANSPORT) OF THE REPUBLIC OF GHANA.

Project: REHABILITATION AND MAINTENANCE OF TRUNK ROADS IN THE ASHANTI REGION OF THE REPUBLIC OF GHANA.

Contract: UPGRADING OF OBOGU – OFOASE ROAD (KM. 1.0 – 7.0) IN THE ASANTE AKYEM SOUTH DISTRICT OF THE ASHANTI REGION OF THE REPUBLIC OF GHANA.

Contractor: MESSRS CYMAIN (GH.) LTD. (AUGUST, 2006)

Contract No.: GHA / MRT / PH.01 / 2004/06

Contract Sum: TWELVE BILLION AND SEVENTY MILLION, FIVE HUNDRED AND TWENTY FOUR THOUSAND, SIX HUNDRED AND THIRTEEN CEDIS, TWENTY PESEWAS (**¢12,070,524,613.20)**

Contract Completion Period: TWELVE CALENDER MONTHS

Commencement Date: 14TH SEPTEMBER, 2006

Completion Date: 13TH SEPTEMBER, 2007

General Description

The proposed upgrading of Obogu – Ofoase trunk road is to be built according to the standard of the Ghana Highway Authority specifications for highway works. The road surface type should be gravel. The direction is from Obogu to Ofoase. Under the conditions of contract, the contractor is required to submit a programme of works to the engineer within 21 days of the award of contract. Additionally, if requested by the engineer, the contractor is required to submit details of his proposed methods of construction, including temporary works and contractor's equipment. There may be no haul roads in and plant and other heavy machines may have to be brought in to the site through Kyempo and Asuboi access points.

Figure 5.1 depicts the line diagram for the project whiles *Figure 5.2* shows the physical programme of works and their associated durations using the Bar (Gantt) chart. Figures 5.1 and 5.2 were reproductions from MessrCymain (Gh.) Ltd. A typical method statements for the project is shown in *Table 5.1*

The linear programme works schedule (*Figure 5.3*) was generated from the information obtained from *Figures 5.1* and *5.2* using Microsoft Word programme by the researcher.

Table 5.6: Method Statement for Obogu – Ofoase Road Project

Operation	Quantity	Output	Duration	Method	Resources		Remarks
					Plant	Labour	
Clear site of Vegetation	90000m^2	9200m^2 per day	10 days	Dozer to uproot trees and tree stumps including other vegetation and topsoil stripping. Stockpile waste on-site in temporary spoil heaps using the dozer. Grader to shape the striped surface.	1No. D7 dozer 1No. Cat 120 A grader	Site foreman 5 labourers	
Demolish existing concrete structures	185m^3	32m^3 per day	6 days	Existing concrete structures to be demolished using an excavator and the debris loaded into waiting trucks (using excavator) to be deposited off-site.	1No. Mobile excavator 2No. Tipper trucks	Site foreman 2 labourers	*Structures to be demolished include existing box and pipe culverts buried in the ground*
Earthworks	63674m^3	620m^3per day	103 days	Provide dozer to cut surface of road to formation and an excavator to dig trenches and ditches. Load excavated or filling materials into waiting trucks using a payloader machine. Unsuitable materials to be tipped off-site and suitable materials to be used as fill materials. Fill embankments and road surface to formation with suitable cut / borrowed gravel material. Use grader to spread fill material and to shape road surface. Compact road surface with roller. Water surface using water tanker to reduce rising dust and to make road surface more compact. Excavate trench for pipe culvert and drains using an excavator.	1No. D7 dozer 1No. Cat 120A grader 2No. Bomag MW16R pneumatic roller 1No. Water tanker 1No. Volvo L70E payloader 6No. Tipper trucks 1No. excavator	Site foreman (Banksman) 2 labourers	*Earthworks involve cuttings, excavations for drains, for culverts and V-shaped ditches and embankment fillings.*

Concrete Works	720m^3	12m^3 per day	60 days	Provide concrete bed in trench to receive pipe culverts. Pour concrete (against formwork) around pipe culvert, box culvert and into U-drains and headwalls. Backfill behind walls after removal of formworks. Fix precast concrete cover slabs into position over drain.	1No. Concrete mixer (10/7) 4No. Wheelbarrow 1No. 100mmΦ poker vibrator	2 masons 4 carpenters 12 labourers 2 steel-benders	*Concrete works comprise pouring concrete into U-drains and box culverts and concrete surrounds to pipe culverts. Included also is the provision of 70No. concrete cover slabs for the 600mmΦ U-drain*
Pipe Culvert	125m	4m per day	30 days	Lower and lay pipe culvert into concrete bed trenches using a small mobile crane. Join ends of pipe culvert using cement and sand mortar mix (1:4). Pour concrete around culverts and backfill wall with suitable gravel material	Mobile crane	2 masons 4 labourers	*Pipe culvert is made of concrete pipe of varying diameters 1200mm and 900mm laid on concrete bed & concrete surrounds*
Stone Pitching	1100m^2	37m^2 per day	30 days	Level surface of V-shaped ditch and compact. Provide and lay approved quarry stones to sides and bottom of ditch in approved pattern in cement and sand mortar mix (1:4).		2 masons 4 labourers	

Pavement	74900m^2	1250m^3 per day	60 days	Provide and lay sub-base suitable gravel material. Spread material over road surface using grader. Water and compact road surface with a roller machine. Repeat operation until sub-base is 150mm thick. Following the same process above, provide and lay a 200mm thick base material over the sub-base layer and compact .	1No. D7 dozer 1No. Cat 120A grader 2No. Bomag MW16R roller 1No. Water tanker 1No. Volvo L70E payloader 6No. Tipper trucks	Site foreman 4 labourers	*Paved surface comprises a 150mmth sub-base natural gravel material and 200mmth stabilized gravel* *Base (60%gravel, 40% crushed rock) both obtained from approved borrow pit*
Surfacing	80469 litres	1350 lit. per day	60 days	1. Shape and level road surface using grader and remove debris and other unsuitable material from road surface with a rotary broom. Water road surface. 2. Spray pre-heated bitumen (at a suitable rate) over road surface using a bitumen distributor. Load chipping spreader truck with chippings (using a payloader). Closely follow the bitumen distributor with the chipping spreader machine and spread a 10mm chipping over the bituminous road surface. Compact surface with a roller machine. 3. Repeat process 2 above but this time, blind with a 14mm seal chippings and compact surface. Manually spray bitumen and spread chippings at road shoulders where is not possible to use the spreaders	1No. Cat 120A grader 1No. Water tanker 1no. Bitumen distributor 1No. Chippings spreader 2No. Tipper trucks 1No. Volvo L70E payloader 1No. 1No. roller 1No. Rotary broom 2No. Bomag MW16R roller	Site foreman 6 labourers	*Surfacing is composed of primerseal layer consisting of 10mmchippings and seal layer which is made up of 14mm chippings.* *Rate of spread of both bitumen and chippings to be determined.* *Chippings to be pre-coated on site with solution consisting of 95% diesel and 5% bitumen.* *Bituminous material contains 16% kerosene and 84% bitumen*

Figure 5.1: Line Diagram forObogu – Ofoase Road Project ***[Messrs. Cymain (Gh.) Ltd.]***

CONTRACT:UPGRADING OF OBOGU – OFOASE ROAD (KM 1.0 – 7.0)
JOB: UPGRADING
NAME OF ROAD: OBOGU – OFOASE
ROAD SURFACE TYPES: GRAVEL
DIRECTION FROM: OBOGU
DIRECTION TO: OFOASE
DISTRICT: ASANTE AKYEM SOUTH
REGION: ASHANTI

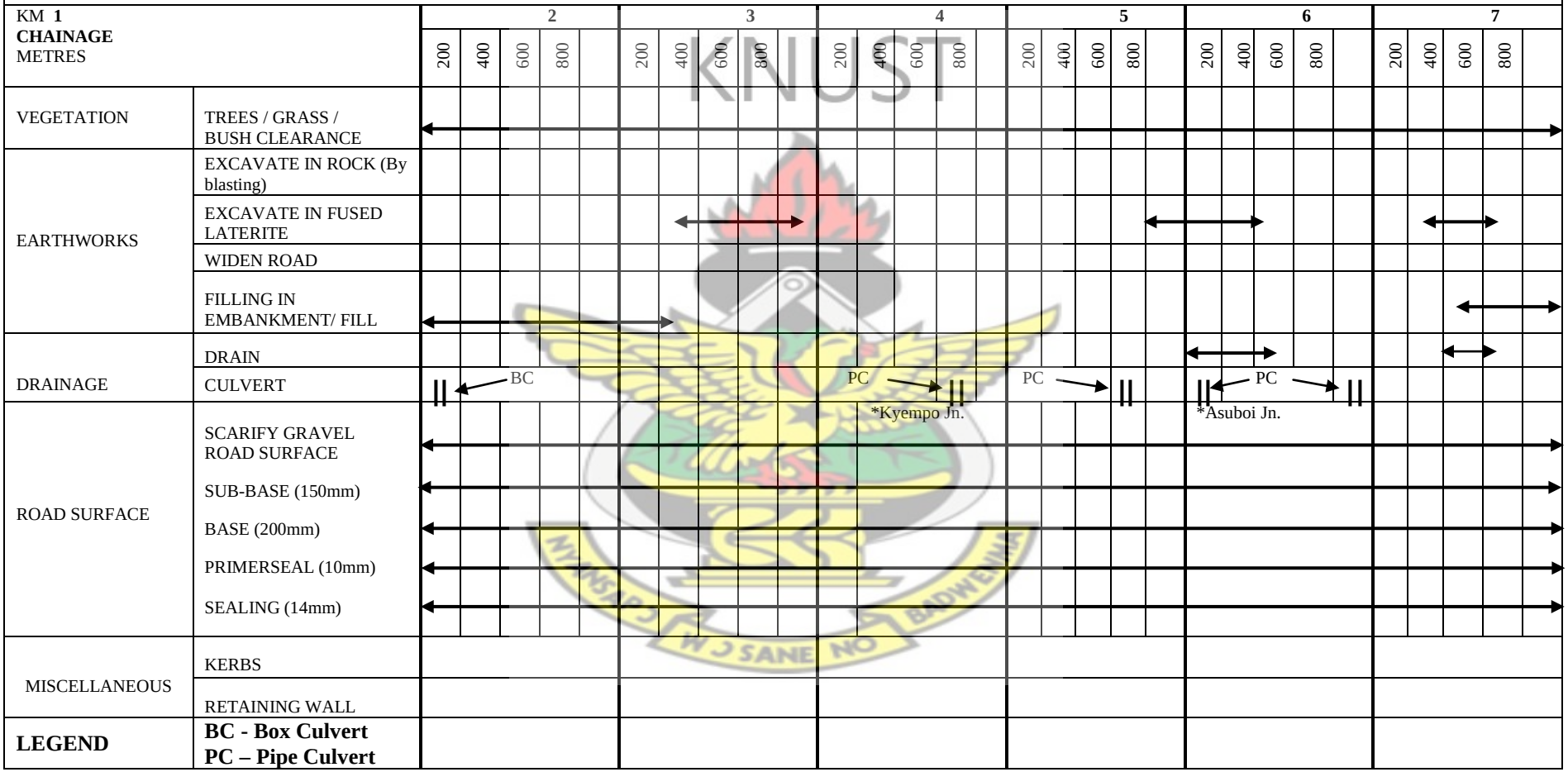


Figure 5.2: Physical Works Programme for Obogu-Ofoase Road Project Using the Bar Chart *[Messrs. Cymain (Gh.) Ltd]*

ID	Task Name	Duration	Quantity
1	**Prelims & General Items**	169 days	
2	**Site Clearance & Demolition**	16 days	
3	- Clear Vegetation	10 days	9 ha
4	- Demolish Concrete Structure	6 days	185 m3
5	**Earthworks**	58 days	
6	- Excavate for Cuttings	31 days	12,462 m3
7	- Excavate Fdn for Drain	12 days	3,252 m3
8	- Filling in Embankment	40 days	38,710 m3
9	- Excavate V-shaped ditches	20 days	9,250 m3
10	**Concrete Works**	60 days	
11	- 600mm Drain & Box Culvert	60 days	720 m3
12	- Pipe Culvert	30 days	125 m
13	- Stone Pitching	30 days	1,100 m2
14	**Pavement**	45 days	
15	- Sub-base (150mm thick)	30 days	39,200 m2
16	- Base (200mm thick)	30 days	35,700 m2
17	**Surfacing**	45 days	
18	Primerseal (10mm chippings)	30 days	31,750 lit
19	- Seal (14mm chippings)	30 days	48, 719 lit
20	**Demobilisation & Handing Over**	6 days	

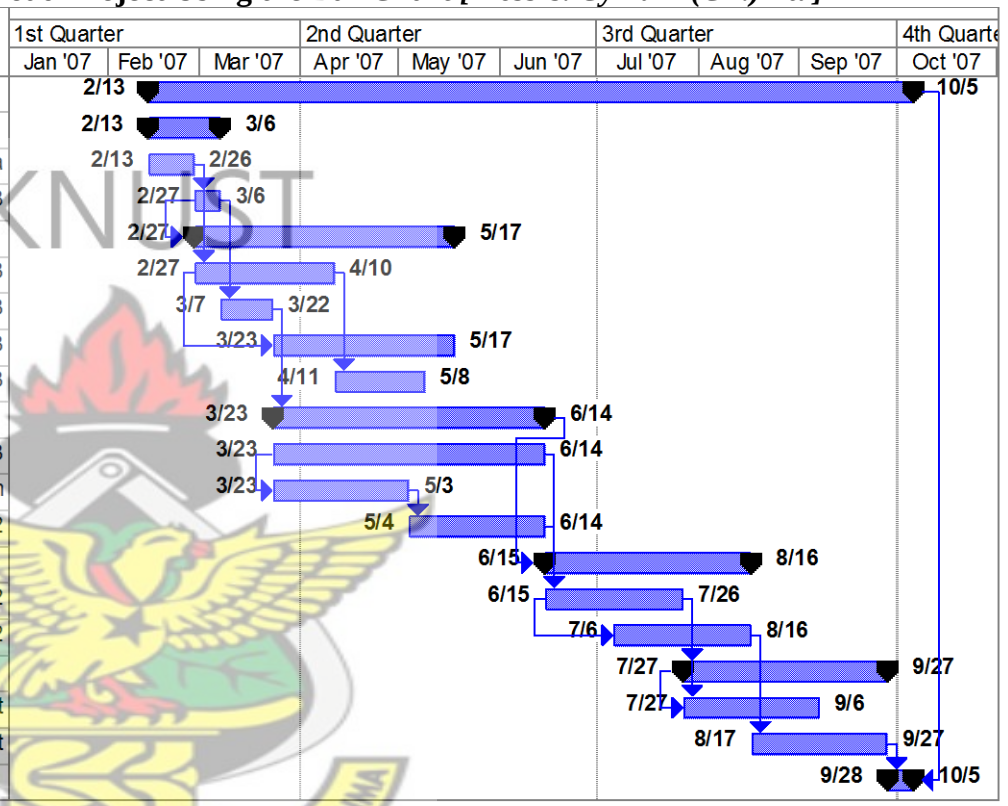
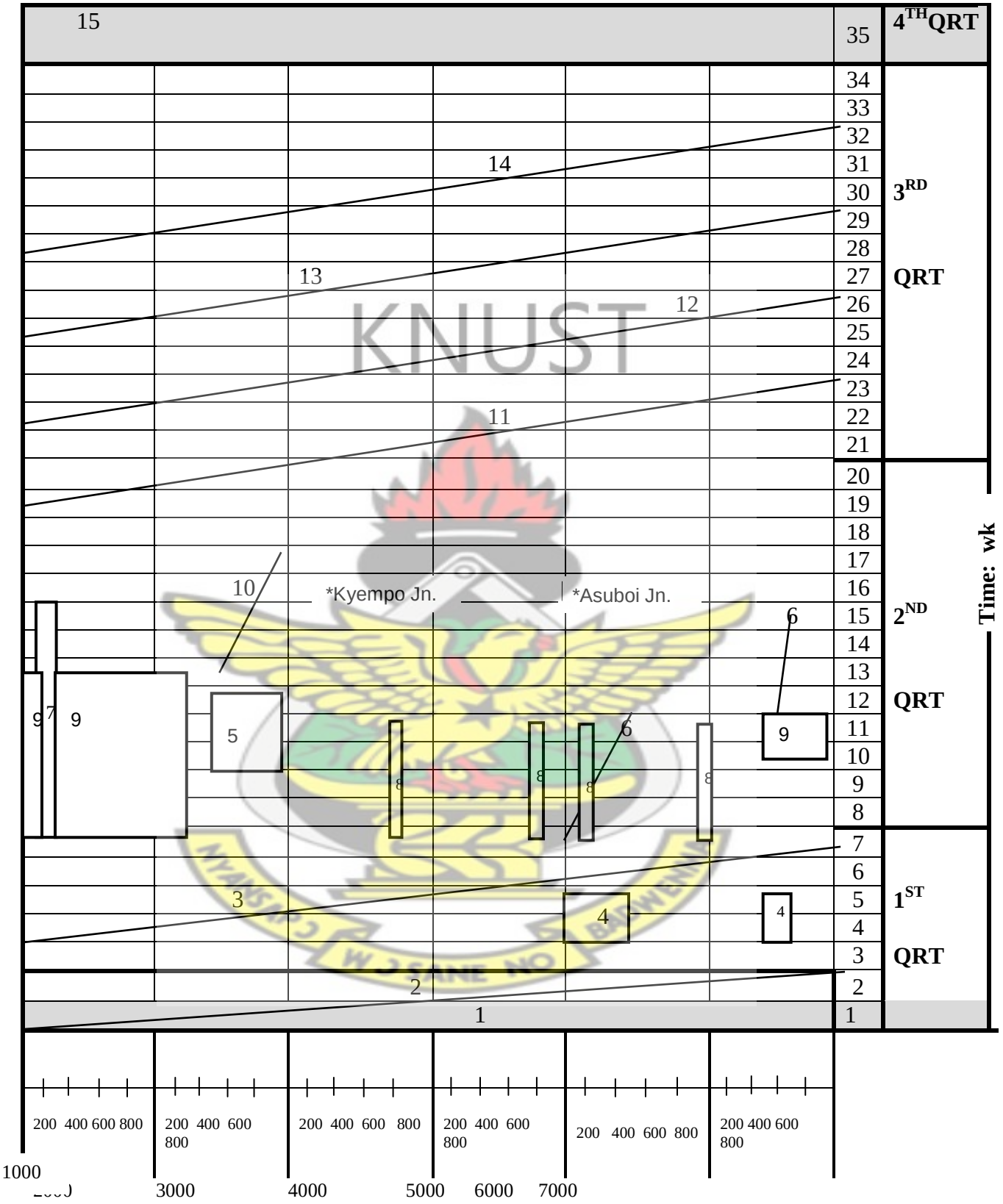


Figure 5.3: Proposed *Linear Programme* Diagram for Obogu-Ofoase Road Project



KEY

1. Set up site/Mobilisation
2. Site clearance
3. Cuttings / topsoil strip
4. Excavate U-drain
5. Excavate V-shaped drain
6. Concrete in U-drain
7. Box culvert
8. Pipe culvert
9. Embankment / fill
10. Stone pitching
11. Sub-base
12. Base
13. Primer seal
14. Seal
15. Demobilisation& handing over

Constraints

Some of the possible constraints in a road construction and rehabilitation works such as this would be the problem of diversion of traffic, especially during the construction of culverts and earthworks activities. To ease heavy traffic jams in order to limit or avoid probable inconveniences to motorist and/or pedestrians, an access road could be provided for temporary use by motorist until the rehabilitation work has fully been completed. However, provision of access roads may be very expensive. In such a situation where access roads are not economically recommended, the rehabilitation work could be done in sections; i.e. whiles work is on-going in one side of the road, the other side could be opened to traffic. Such a measure definitely would impede the progress of work and expose the lives of workers to danger from recalcitrant and reckless drivers. Motorists are similarly vulnerable to potential injuries by the heavy trucks and equipment used by contractor's operatives.

Other possible constraints may include the weather window (especially during the raining season it becomes difficult to undertake earthwork activities), environmental restrictions (i.e. areas where restrictions may apply over noise, dust weekend work and night work), timing (which include project start, finish and sectional completion dates), third parties (comprising works carried out by other contractors and statutory undertakers), diversion of existing services such as buried services like pipes, power and telephone cables among others.

The following information can be deduced from the bar chart and the linear programme diagram:

The bar Chart

- Activities on the chart are indicated by horizontal bar
- Length of bar denotes activity duration I
- Activity names are arranged vertically, with each activity name writtenhorizontally against the activity
- Since activities are denoted by a bar, it is not easy to identify which activity /task is being performed by just looking at the bar without referring to the activity name

The Linear Programme Chart

- Chart consists of two axes; vertical or time axis and horizontal or distance axis
- Activities are denoted by inclined lines and boxes
- Activities represented by 'inclined' lines are those activities that take place along the chainage /road
- Activities denoted by boxes on the other hand are those which occur at a particular chainage or within a short distance along the road
- Activity names are indicated on the activity line or box
- For activities denoted by 'inclined' line, the activity start and finish dates are indicated by the bottom end and top end of the line respectively. The vertical distance between the bottom and top ends of the line thus gives the activity duration.
- Height of boxes is an indication of activity duration.

- Width of box on the other hand gives the distance that activity would cover; especially embankments / fill.

- Position of features and towns such as the Kyempo junction which occurs along the road can clearly be depicted on the linear programme chart

- The type of activity being undertaken can beimagined by just looking at the 'inclined' line or box without the activity name indicated on it (i.e

- Not easy to show interdependences of activities

.

CHAPTER SIX

6.0 SUMMARY OF RESEARCH FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

6.1 SUMMARY OF RESEARCH FINDINGS

A. The construction planning techniques available for programming and scheduling road construction works in the country, arranged in order of preference by professionals are as follows:

- Bar (Gantt) Chart Technique
- Network Analysis Technique
- Combination of any two of the techniques
- Linear Programme
- Line-of-Balance

B. The seven (7) most significant factors identified in the research, which greatly influence professionals' choices for a planning technique to be used for scheduling road project works in Ghana, are listed below in order of their relative importance. (Table 4.13).

- Client / Consultants' Preferences
- Suitability of Technique
- Knowledge and Flexibility of Technique
- Simplicity of Technique
- Efficiency of Technique
- Availability and Cost of Software Package
- Contractor's Preference

C. The three main categories of factors under which the major factors are grouped are the following:

- Preference
- Technique Characteristics / Features
- Project Characteristics

6.2 CONCLUSION

The findings of this research work clearly portray the following deductions about the construction industry of Ghana;

1.The linearprogramme is one of the least applied planning techniques for scheduling road construction works in the country by professionals in the road sub-sector of Ghana. In instances where the linear programme technique has been applied, it has been used in combination with other planning techniques, particularly the bar chart technique and not as a sole planning tool.

The future prospect of the linear programme as a technique for planning and scheduling road construction works in the country, would be promising if professionals begin to apply the knowledge they have about the technique into practice by actually applying it for scheduling their road works.

2.The operations of professionals in the road sub-sector of the construction industry of Ghana are affected by a number of factors which essentially influence to varying degrees of extent, the choice and use of planning techniques by professionals to schedule road construction works in the country. The assessment of these factors by professionals in terms of their level of significance is different and differs from one respondent group of professionals to the other.

6.3 RECOMMENDATIONS

The recommendations being proposed are not meant to say that the use of other planning techniques for scheduling road works, particularly, the bar chart technique should be discontinued, but is aimed at ensuring that there is always an alternative technique to the bar chart. Thus the two techniques, that is, the linear programme and the bar chart techniques may be used concurrently and in a manner that would produce the best results. To this end, the following recommendations are suggested for consideration and implementation if the linear programme technique is to be adopted for scheduling future road construction projects in the country:

1.As a first step towards ensuring full integration of the linear programme technique in the construction industry as the main planning tool for scheduling road construction works, factors which have been identified as having significant influence on the choice of planning technique must be critically considered. For example, as one of the major factors which influence the planning technique to be used for road works schedules in the country, the problem of cost and availability of software package for generating the linear programme diagram should be attended to by all concerned. It is hoped that if the software for the linear programme technique is made readily available in industry and at an affordable price, then will its application be encouraged in industry.

2. The government can also play a leading role in helping to promote the use of the *linear programme* technique in industry since it is the single largest investor and employer in the road construction industry. Thus, the government through its executing agencies;

a. Should make it as part of the contract requirements or compulsory for contractors who wish to bid for government road project works to submit their programme of works using the linear programme method of scheduling.

b. Ought to organise training workshops and seminars on the linear programme technique from time to time for professionals already operating in the road construction industry. To this effect, resource persons could be invited (from

countries such as the United Kingdom, where the technique has been successfully used) to conduct such training workshops and seminars.

c. Must invest in research and development of new and innovative techniques (such as the likes of the linear programme technique) which are relevant to the operations of the industry.

d. The tertiary institutions like the universities and the polytechnics can similarly be used to advance the cause of the linear programme planning technique in industry. Since these institutions are places where prospective professionals in the road sub-sector first acquire their training, the linear programme technique can be included in the schools' curriculum. This would ensure that those students who graduate from these institutions as civil engineers are knowledgeable in the use of the linear programme technique.

4. Further, professionals in the road construction industry must themselves make every determined effort to keep abreast with modern techniques and information which are relevant to their field of operations. They must as well be prepared to experiment with new methods which relate to their work packages.

It is hoped that, the above measures if followed and implemented would not only encourage professionals in the industry to acquire the requisite skills and training for using the linear programme technique but would also enhance the future prospect of the linear programme technique as a major planning tool for scheduling road works in the country.

REFERENCES

Al-Jibouri, S.H., Mawdesley, M.J., Askew, B.H. and Patterson, D.E. (2004): A Computer System for Modelling the Process of Earthwork Planning in Linear Construction Projects; *International Journal of Computer Applications Technology, Vol. 20, Nos. 1 – 3, pp.90-101 (12).*

Askew, W.H., Al-Jibouri S.H., Mawdeseley, M.J. and Patterson,D.E. *(2002)*: Planning Linear Construction Projects: Automatic method for the Generation of Earthwork Activities. *Automation in Construction; vol.11 Nos. 6 pp. 643-653 (11). Elsevier*.

Barrie, D.S. and Paulson, B. (1978): *Journal, Professional Construction Management;* McGraw-Hill Book Co, New York, pp 232-233.

Comican, D. (1985): Construction Management; *Planning and Finance*. Construction Press.

Cooke, B. and Williams, P. (2004): Construction Planning, Programming & Control; (*2nd. Edition*), *Blackwell Publishing.*

Edmonds, G.A. and De Veen, J.J. (1981): The Application of Appropriate Technology in Road Construction and Maintenance; *A Learning Methodology*. ILO, Geneva.

Elhag, T.M.S. and Boussabaine, A.H. (2002): Factors Affecting Cost and Duration of Construction Projects; *EPSRC Research Report, University of Liverpool.*

Halpin, D.W and Riggs, L.S. (1992): Planning and Analysis of Construction Operations. *John Wiley and Sons.*

Harmelink, D.J. and Rowings, J.E. (1998): Linear scheduling Model; Development of Controlling Activity Path; *Journal of Construction Engineering Management, 124(4), 263-268.*

Harmelink, D. and Yamin, R. (2000): Development and Application of Linear Scheduling Technologies to Highway Construction Projects. *Joint Transportation Research Programme; School of Civil Engineering- Purdue University.*

Harris F. and McCaffer, R. (2000): Modern Construction Management; *(5th Edition*), *Blackwell Publishing*.

Harris, R.B. and Ioannou, P.G. (1998): Scheduling Projects with Repeating Activities; *Journal of Construction Engineering Management, 125(3), 167-175.*

Ipsilandis, P.G (2007): Multiobjective Linear Programming Model for Scheduling Linear Repetitive Projects; *Journal, Construction Engineering and Management, ASCE 417.*

Johnston. D.W. (1981): Linear Scheduling Method for Highway Construction. *Journal, Construction Division, 107(2), 247-261.*

Kish, L. (1965): Survey Sampling. New York; John Wiley & Sons Inc.

Lumsden, P. (1965): Programming House Building by Line of Balance. *National Building Agency*.

Mawdeseley, M.J., Askew, W.H., Lees, J., Taylor, J. and Stevens C.M.(1989*)*: Time Chainage Charts for Scheduling Linear Projects: *Computing in Civil; Computers in Engineering Practice.* Conference Proceeding Paper, September 9, 1991. *ASCE*.

Ministry of Road and Transport, (2002): *Road Sector Development Programmes Donor's Conference,* MRT, Accra, pp 1-8, x-21

Neale, R.H. and Neale D.E. (1989): Construction Planning ;(*Engineering Management).*

Nudze, F.P.K. (2004): Factors Affecting the Implementation Success of Road Projects in Ghana, (*Dept. of Build. Tech., K.N.U.S.T).*

Oberlender, G. D. (2000): Project Management for Engineering and Construction; (*2nd. Edition), McGraw-Hill Companies.*

Oxley and Poskitt, J. (1986): Management Techniques Applied in Construction Industry; *(4th. Edition).*

Siegel, S. (1956): Nonparametric Statistics for the Behavioural Sciences (*International Student Edition); McGraw-Hil Company*.

Walpole, R.E., Myers, R.H., Myers, S.L. and Ye, K. (2007): Probability and Statistics for Engineers; *(8th Edition).*

www.mrt.gov.gh (2007)

www.pclarke.co.uk (2007): Time-Chainage Chart; *A Management Guide.*

www.powerproject.nl (2007)

BIBLIOGRAPHY

Aras, R. and Surkis, J. (March, 1964): PERT and CPM Techniques in Project Management; *ASCE Journal of the Construction Division,* Vol. 90, No. CO1.

Baker, K.R.(1974): Introduction to Sequencing and Scheduling; *John-Wiley and Sons, New York.*

Baracco-Miller, E.(1987): Planning for Construction; *Unpublished MS Thesis, Dept. of Civil Engineering, Carnegie Mellon University.*

British Standards Institutions, (1981):Use of Network Techniques in Project Management BSI, London, BS6046.

Carr, R.I. (June, 1979): Simulation of Construction Project Duration; *ASCE Journal of the Construction Division,* 105(2), 117-128.

Dressler, J. (1974): Construction Scheduling of Linear Construction Sites; Journal, Construction Division, 100(4), 125-132.

Illngworth, J. (1993): Construction Methods and Planning. E & F.N. Spon.

Jackson, M.J. (1986): Computers in Construction Planning and Control; *Allen &Unwin, London.*

Lester, A. (1982): Project Planning and Control; *Butterworth, London.*

Matilla, K.G and Bowman, M.R. (2004): Accuracy of Highway Contractors Schedule; J*ournal of Construction Engineering Management 130(5) 647-655.*

Matilla, K.G. and Park, A. (2003): Comparison of Linear Scheduling Model and Repetitive Scheduling Model; *Journal of Construction Engineering Management, 129(1), 56-64.*

Paulson, B.C., Douglas S.A., Kalk A., Touran A. and Victor G.A. (August, 1983): Simulation and Analysis of Construction Operations; ASCE *Journal of Technical Topics in Civil Engineering*, 109(2), pp. 89.

Selinger, S. (1980): Construction Planning for Linear Projects; J*ournal construction Division 106(2) 195-205.*

Uher, T.E. (2003): Programming and Scheduling Techniques; *UNSW Press.*

Yamane, T. (1967): Statistics, an Introductory Analysis; *(2nd. Edition), New York; Hamper & Row.*

APPENDIX 1

Table A1* : Critical Values for Spearman's Rank Correlation Coefficient

n	$\alpha = 0.05$	$\alpha = 0.025$	$\alpha = 0.01$	$\alpha = 0.005$
5	**0.900**			
6	**0.829**	**0.886**	**0.943**	
7	**0.714**	**0.786**	**0.893**	
8	**0.643**	**0.738**	**0.833**	**0.881**
9	**0.600**	**0.683**	**0.783**	**0.833**
10	**0.564**	**0.648**	**0.745**	**0.794**
11	**0.523**	**0.623**	**0.736**	**0.818**
12	**0.497**	**0.591**	**0.703**	**0.780**
13	**0.475**	**0.566**	**0.673**	**0.745**
14	**0.457**	**0.545**	**0.646**	**0.716**
15	**0.441**	**0.525**	**0.623**	**0.689**
16	**0.425**	**0.507**	**0.601**	**0.666**
17	**0.412**	**0.490**	**0.582**	**0.645**
18	**0.399**	**0.476**	**0.564**	**0.625**
19	**0.388**	**0.462**	**0.549**	**0.608**
20	**0.377**	**0.450**	**0.534**	**0.591**
21	**0.368**	**0.438**	**0.521**	**0.576**
22	**0.359**	**0.428**	**0.508**	**0.562**
23	**0.351**	**0.418**	**0.496**	**0.549**
24	**0.343**	**0.409**	**0.485**	**0.537**
25	**0.336**	**0.400**	**0.475**	**0.526**

***** *Reproduced from Waldpole et al. (2007)*

Table A2* : Upper Critical Values of the Student's *t*-Distribution

df	$\alpha = 0.05$	$\alpha = 0.025$	$\alpha = 0.01$	$\alpha = 0.005$
1	**6.314**	**12.706**	**31.821**	**63.657**
2	**2.920**	**4.303**	**6.965**	**9.925**
3	**2.353**	**3.182**	**4.541**	**5.841**
4	**2.132**	**2.776**	**3.747**	**4.604**
5	**2.015**	**2.571**	**3.365**	**4.032**
10	**1.812**	**2.228**	**2.764**	**3.169**
11	**1.796**	**2.201**	**2.718**	**3.106**
12	**1.782**	**2.179**	**2.681**	**3.055**
13	**1.771**	**2.160**	**2.650**	**3.012**
14	**1.761**	**2.145**	**2.624**	**2.977**
20	**1.725**	**2.086**	**2.528**	**2.845**
21	**1.721**	**2.080**	**2.518**	**2.831**
22	**1.717**	**2.074**	**2.508**	**2.819**
23	**1.714**	**2.069**	**2.500**	**2.807**
24	**1.711**	**2.064**	**2.492**	**2.797**
30	**1.697**	**2.042**	**2.457**	**2.750**
31	**1.696**	**2.040**	**2.453**	**2.744**
32	**1.694**	**2.037**	**2.449**	**2.738**
33	**1.692**	**2.035**	**2.445**	**2.733**
34	**1.691**	**2.032**	**2.441**	**2.728**
36	**1.688**	**2.028**	**2.434**	**2.719**
40	**1.684**	**2.021**	**2.423**	**2.704**
41	**1.683**	**2.020**	**2.421**	**2.701**
42	**1.682**	**2.018**	**2.418**	**2.698**
43	**1.681**	**2.017**	**2.416**	**2.695**
44	**1.680**	**2.015**	**2.414**	**2.692**
50	**1.676**	**2.009**	**2.403**	**2.678**

***** *Reproduced from Waldpole et al. (2007)*

Tests of Significance (one-tailed to the right)

A. Test of Significance of the Spearman's Rank Correlation Coefficient

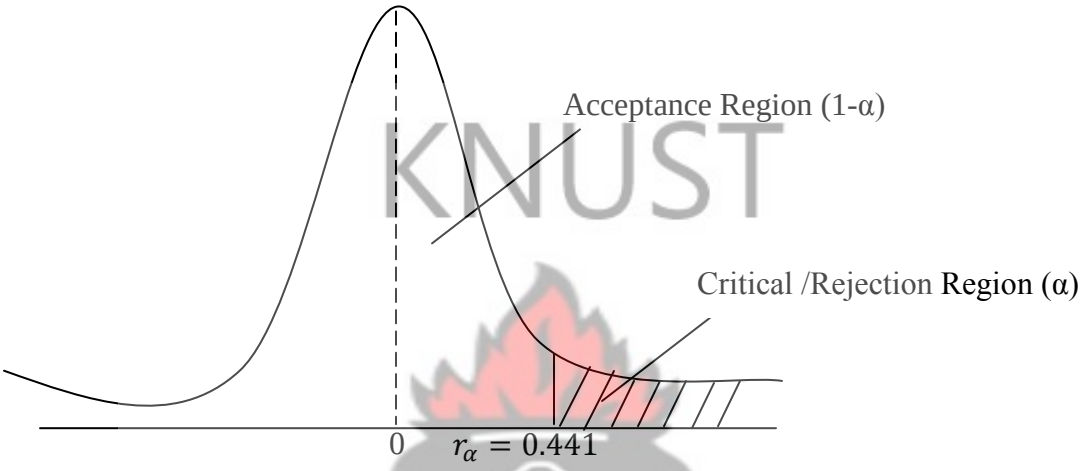


Figure A1

B. Test of Significance of the Test Statistics *t* for Factors Ranked by Consultants and Contractors Using the Students t-Distribution

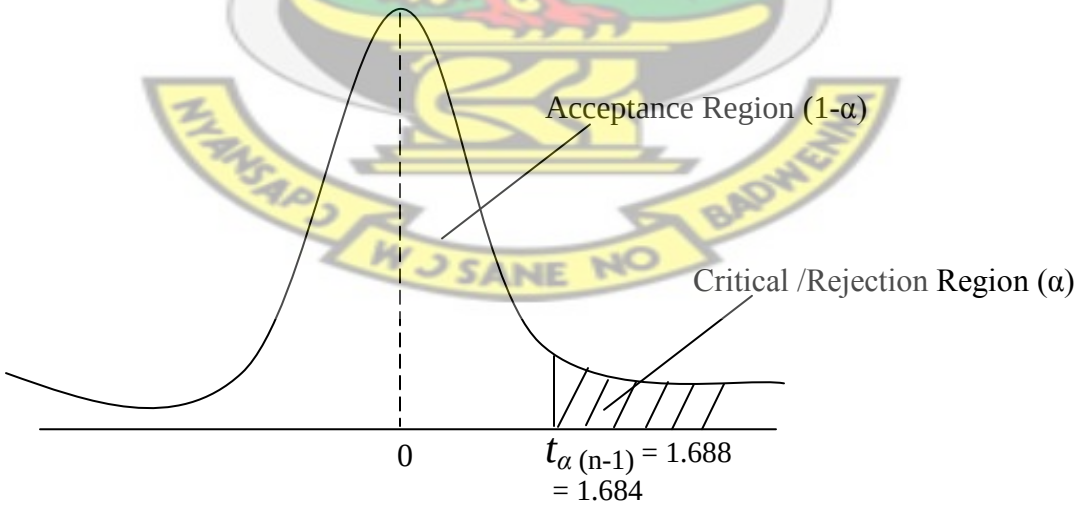


Figure A2

APPENDIX 2

FORMAT OF COVER LETTER

Dear Sir / Madam,

Introduction

As part of the requirements for the award of *MSc. Construction Management* degree, a fully completed master thesis work would have to be presented and submitted to the school at the end of the programme of study.

This questionnaire forms part of a study entitled ***"Extent of Use of the Linear Programme Planning Technique for Scheduling Road Works in Ghana".***

Linear Programme is also referred to as Time-*chainage chart* or *Time-location chart* or *Time-space diagram* in some publications.

Literature review has extensively been carried out on the topic. The participation of your prestigious firm by filling this questionnaire will help the successful execution and completion of this exercise. Your contributions will therefore be very much appreciated.

I would be most grateful if the questionnaire is completely filled out and returned within one week from the day of receipt. Enclosed is a self addressed envelope.

Thank you very much for your time and inputs. I look forward to your response.

Yours faithfully,

Cyprian Nyamekye

(Postgraduate student/topic researcher)*Contact: 024-4619298*

APPENDIX 3

FORMAT OF QUESTIONNAIRES

KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY – KSI.
COLLEGE OF ARCHITECTURE AND PLANNING
DEPARTMENT OF BUILDING TECHNOLOGY

Questionnaire for Consultants

1. Name of firm if private……
   (*ignore if you want to remain anonymous*).

2. Please, indicate the type of agency or firm you work in.

   [ ] Ghana Highway Authority
   [ ] Department of Urban Roads
   [ ] Department of Feeder Roads
   [ ] Consulting
   [ ] Others (*please specify*)…….

3. Please state type of training / education level acquired.

   [ ] B.Sc.
   [ ] M.Sc.
   [ ] Ph.D.
   [ ] H.N.D.
   [ ] Others (*please specify*)……

4. Please indicate your position or designation in firm.

   [ ] Director/Deputy director
   [ ] Contracts Manager
   [ ] Quantity surveyor
   [ ] Project manager
   [ ] Project supervisor / site supervisor / site engineer
   [ ] Others (*please specify*)…….

5. Please indicate the number of years of experience in the road construction industry.

   [ ] 1 - 5 years
   [ ] 5 – 10 years
   [ ] Over 10 years

6. Please state the number of road construction projects handled within the past five (5) years of operation.

   [ ] Less than 2
   [ ] 2 – 5
   [ ] 6 – 10
   [ ] 11 – 20
   [ ] Over 20

7. Does your firm solely specifies / decides which planning technique(s) to be used for road construction projects?

   [ ] Yes
   [ ] No

8. If answer to Que. 7 is *'No'*, then who recommend(s) the type of planning technique used for projects?

   [ ] The client
   [ ] The contractor
   [ ] The sponsoring agency / organisation
   [ ] The consultants and contractor both decide
   [ ] Others (*please specify*)……

9. Which of the following planning techniques / tools do you normally recommend for road projects?

   [ ] Linear programme*(Time – chainage chart)*
   [ ] Bar chart
   [ ] Network analysis
   [ ] Line-of-balance
   [ ] Others (*please specify*) …….

10. Why do you prefer the planning technique selected in Que. 9 above? (*Please you may tick more than one answer)*

    [ ] Provides all the necessary information in modeling linear projects
    [ ] Monitors the relative progress of work quite clearly
    [ ] Identifies quite easily the problem areas of work
    [ ] Effective planning tool in altering and updating programme
    [ ] Ability to communicate information quite easily
    [ ] Others (*please specify*)……..

11. The factors listed in the table below are considered potential factors which affect the choice of a planning technique adopted for scheduling road projects. Please rank the factors according to their order of importance, as:

(a) *Not important* *(b) Important* *(c) Very important.*

Item No.	Proposed Factors	Not Important	Important	Very Important
(1.0)	**Project Characteristics**			
1.1	Complexity of project			
1.2	Size and value of project			
1.3	Project duration			
1.4	Project location			
1.5	Quality requirement of project			
(2.0)	**Features of Technique**			
2.1	Simplicity in use of technique			
2.2	Suitability of technique for type of work			
2.3	Popularity of technique in industry			
2.4	Knowledge & flexibility of technique usage			
2.5	Availability of qualified personnel to apply technique			
2.6	Availability & cost of software for technique			
2.7	Efficiency of technique in scheduling road projects			
2.8	Speed & ease of development of technique			
(3.0)	**Preferences**			
3.1	Client /Consultants' preference			
3.2	Contractor's preference			

12. How often do you recommend the following planning technique for scheduling road projects such as road works?

a) Linear programme	[ ] Very often	[ ] Often	[ ] Not at all
b) Bar chart	[ ] Very often	[ ] Often	[ ] Not at all
c) Network analysis	[ ] Very often	[ ] Often	[ ] Not at all
d) Line-of-balance	[ ] Very often	[ ] Often	[ ] Not at all
e) Others *(specify)*	[ ] Very often	[ ] Often	[ ] Not at all

13. How would you rate your knowledge in the following planning techniques / methodologies as: *1 = Low, 2 = High,3 = Very High*

	1	2	3
a) Linear programme*(Time – chainage chart)*	…..	…..	…..
b) Bar chart	…..	…..	…..
c) Network analysis	…..	…..	…..
d) Line–of–balance	…..	…..	…..
e) Others (*please specify*)	……	…..	……

KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY – KSI

COLLEGE OF ARCHITECTURE AND PLANNING

DEPARTMENT OF BUILDING TECHNOLOGY

Questionnaire for Contractors

1. Name of firm …… (*ignore if you want to remain anonymous*).

2. Please, indicate category of your company according to Ministry of Transportation classification.

   [ ] A1B1 [ ] A2B2 [ ] Others (*Please specify*)……

3. Please state type of training / education level acquired.

   [ ] B.Sc.
   [ ] M.Sc.
   [ ] Ph.D.
   [ ] H.N.D.
   [ ] Others (*please specify*)……

4. Please indicate your position or designation in firm.

   [ ] Director/Deputy director
   [ ] Contracts Manager
   [ ] Quantity surveyor
   [ ] Project manager
   [ ] Project supervisor / site supervisor / site engineer
   [ ] Others (*please specify*)…….

5. How is the ownership of your company like?

   [ ] Fully locally owned
   [ ] Fully foreign owned
   [ ] Local and foreign partnership
   [ ] Others (*please specify*)…….

6. Please indicate the number of years of experience in the road construction industry.

   [ ] 1 - 5 years
   [ ] 5 – 10 years
   [ ] Over 10 years

7. Please state the number of road construction projects handled within the past five (5) years of operation.

   [ ] Less than 2
   [ ] 2 – 5
   [ ] 6 – 10
   [ ] 11 – 20
   [ ] Over 20

8. Do you have a planning department in your outfit?

   [ ] Yes
   [ ] No

9. If answer to Que. 8 above is 'yes', is the department being managed by qualified personnel / professionals?

   [ ] Yes
   [ ] No

10. Who does all the planning and programming for your projects?

[ ] In-house planning department (i.e. own firm)
[ ] Professional planner(s) from outside the firm
[ ] The project consultants / client
[ ] Others (*please specify*)……..

11. Which of the following planning techniques / tools do you normally use for programming yourroad projects?

[ ] Linear programme*(Time – chainage chart)*
[ ] Bar chart
[ ] Network analysis
[ ] Line-of-balance
[ ] Others (*please specify*) …….

12. Who recommend(s) the planning technique selected in Que. 11 above?

[ ] The client's consultants
[ ] The contractor (i.e. own firm)
[ ] The sponsoring agency/organisation
[ ] The consultants and contractor both decide
[ ] Others (*please specify*)……

13. In your candid opinion, do you consider the planning technique specified in Que. 11 above the most appropriate technique for schedulling road construction project works?

[ ] Yes
[ ] No

14. If answer to Que. 13 is '*Yes'*, why do you think the technique is the most appropriate? *(Please you may tick more than one answer)*

[ ] Provides all the necessary information in modeling linear projects
[ ] Monitors the relative progress of work quite clearly
[ ] Identifies quite easily the problem areas of work
[ ] Effective planning tool in altering and updating programme
[ ] Ability to communicate information quite easily
[ ] Others (*please specify*)……..

15. If answer to Que.13is *'No'*, then which of the planning techniques below, in your candid opinion would you recommend for scheduling linear projects such as road works?

[ ] Linear programme *(Time – chainage chart)*
[ ] Bar chart
[ ] Network analysis
[ ] Line-of-balance
[ ] Others (*please specify*) …….

16. Why would you prefer the technique chosen in Que. 15 above to all the other techniques for road projects? *(You may tick more than one answer)*

[ ] Provides all the necessary information in modeling linear projects
[ ] Monitors the relative progress of work quite clearly
[ ] Identifies quite easily the problem areas of work
[ ] Effective planning tool in altering and updating programme
[ ] Ability to communicate information quite easily
[ ] Others (*please specify*)……..

17. The factors listed in the table below are considered potential factors which affect the choice of a planning technique adopted for scheduling road projects. Please rank the factors according to their order of importance, as:

(a) *Not important* *(b) Important* *(c) Very important.*

Item No.	Proposed Factors	Not Important	Important	Very Important
(1.0)	**Project Characteristics**			
1.1	Complexity of project			
1.2	Size and value of project			
1.3	Project duration			
1.4	Project location			
1.5	Quality requirement of project			
(2.0)	**Features of Technique**			
2.1	Simplicity in use of technique			
2.2	Suitability of technique for type of work			
2.3	Popularity of technique in industry			
2.4	Knowledge & flexibility of technique usage			
2.5	Availability of qualified personnel to apply technique			
2.6	Availability & cost of software for technique			
2.7	Efficiency of technique in scheduling road projects			
2.8	Speed & ease of development of technique			
(3.0)	**Preferences**			
3.1	Client /Consultants' preference			
3.2	Contractor's preference			

18. How often do you use the following planning technique for scheduling linear projects such as road works?

a) Linear programme [ ] Very often [ ] Often [ ] Not at all
b) Bar chart [ ] Very often [ ] Often [ ] Not at all
c) Network analysis [ ] Very often [ ] Often [ ] Not at all
d) Line-of-balance [ ] Very often [ ] Often [ ] Not at all
e) Others (*specify*) [ ] Very often [ ] Often [ ] Not at all

19. How would you rate your knowledge in the following planning techniques / methodologies as: *1 = Low, 2 = High,3 = Very High*

	1	2	3
a) Linear programme *(Time – chainage chart)*	…..	…..	…..
b) Bar chart	…..	…..	…..
c) Network analysis	…..	…..	…..
d) Line–of–balance	…..	…..	…..
e) Others (*please specify*)	…..	…..	…..