A CONCEPTUAL PROCEDURAL FRAMEWORK FOR EFFECTIVE SCHEDULING TO ENHANCE EFFICIENT USE OF CONSTRUCTION RESOURCES ON THE JOBSITE

By

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ABSTRACT

Selection of construction methods, scheduling, site layout and component procurement arrangement affect efficiency of operations on the jobsite. Efficiency has been previously measured by such parameters as; budget, on time completion and meeting specification standards. Little attention has been given to the interim processes which create these. Efficiency in man- and machine-hour management may translate to cost and time gains and enhanced quality.

The study reported recognises that there are numerous aspects to the question of efficiency of operations. To focus the study and narrow the scope to a manageable size, the issues of efficiency that can be addressed in the scheduling process are those considered.

Extensive and thorough literature search identified guidelines for effective construction scheduling. Empirical data were collected following these guidelines to develop a scheduling procedure aimed at making the process more effective and which may enhance efficient use of construction resources on the jobsite. The developed framework show that activity criticality based on time analysis alone is a necessary condition but not usually sufficient to declare an activity critical. Other tasks not on the critical path which have very high delay potential should be considered. Therefore though the study does not out rightly refute the idea of criticality based on time analysis alone, it adds to it that if criticality means those things that should be done so as to progress the works to a scheduled finish, criticality should be re-assessed to include several other tasks not hitherto identified on the critical path.

DEDICATION

This piece of work is dedicated to the numerous students of Construction Management all over the world, particularly those aspiring and learning to sit on the Construction Scheduling Chair.

ACKNOWLEDGMENT

This MPhil submission has been made possible because of the valuable contributions of several individuals the whole list of which cannot be mentioned here for space. I remain grateful to God, the ECK and the Mahanta for mercies, and the love and support of the individuals I met during the course of this study.

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CHAPTER 1- INTRODUCTION

1.1 Background to the Research

The construction planning process involves information search and analysis, evaluation and selection of alternatives, field action and feedback, [Mawdesley-1997]. Whichever planning technique is employed the process is largely the same in generic terms. Cohenca et al (1989), Olusegun et al (1997, 1998, and 1999) opine that there has been a growing realisation that despite the development of advanced planning methods and techniques, construction planning is not achieving its goal of improving the efficiency of site operations. Thus researchers are now attempting to focus more on the construction planning process rather than only on planning techniques in order to improve the efficiency of the construction operation.

These research efforts have been directed mainly towards identifying means of improving the effectiveness of the construction planning process so that client objective is better achieved through improved planning, [Olusegun - 1997]. Though it has been argued that actual project cost and time is a product, not just of planning and chance, but also of real-time management and control; nonetheless, it is also shown that good planning significantly impacts on project outcome; just as does the implementation of the plan itself. Thus, what are the step by step procedures in construction planning and scheduling? And what are the procedural gaps that may inhibit project outcome? It is against this background that this research was set to focus on the construction planning process to identify gaps and model means to make the process more effective that events occur as planned.

1.2 Problem Statement

There seem to be a problem in the present planning system employed by construction companies and project management firms. This is evident by the wide gap between actual field operation and planned intention. This gap may be in task time, changes in methods proposed, out-of-sequence working, and resource utilising or idling patterns. New thinking in construction is that planning should encompass all stages of the project life cycle, from inception to completion. But current systems focus mainly only on the construction phase.

The system shows only value adding activities, thus hiding non-value adding activities. It only assesses utilisation of resources without also carefully considering the likely levels of idleness or non-worktime that may result from the interactions and attributes of the resources employed.

If actual field task time, method employed, proposed sequence and resource utilising and idling patterns match planned intention, then the project outcome should be as expected. This is desirable. But the problem is field experience cannot match planned intention because such factors as weather, labour and materials availability, client change order etc, are difficult to assess and plan. This poses two fundamental research questions; Is it possible to use the planning process to mitigate some of the identified problems? And in particular, how can the planning process be employed to reduce the idling levels of expensive construction resources e.g., of labour and equipment? The problem of non-worktime of man-hour and machine-hour is very common on most construction sites. Only a few studies have been reported which investigated the nature of non-worktime and the associated downtime cost of these expensive resources. The aspect of using the planning process to mitigate these has been largely un-investigated and this is where the reported research fits.

1.3 Research aim and Objectives

The purpose of this study is to develop a generic scheduling framework which may improve the effectiveness of the project planning process to enhance efficient construction operations and improve project outcome in terms of a reduction in non-worktime of construction resources. To achieve this purpose the following research objectives were set:

(i) Map current planning systems in industry and identify gaps that may exist.

(ii) Compare and learn from the "As-Built" and "As-Planned" schedules, to identify why and how plans fail, and where problems may exist in the initial schedule at the project level, the work-package level, and at the activity or task level.

(iii) Study if it is possible to mitigate these problems at the project planning phase, prior to field operations.

(iv) Identify and compare project planning time, project control time and frequency of major revisions for different project types and different project scenarios and relate how the planning process and efforts may have impacted on project outcome measured not only in terms of budget and schedule date but of non-worktime of labour and equipment

1.4 Research Scope

Construction scheduling is a broad subject with varied scope which include planning techniques; Planning in specific scenarios e.g., resource constrained and repetitive construction; Schedule evaluation; Schedule up-date; Project audit and debriefing and so on. The list is almost endless. Within this broad field the scope of this reported research is defined to be within the aspect of initial schedule development. It draws strongly on project audit and project debriefing and how the lessons learned can be applied for effective planning of future projects, particularly regarding scheduling to reduce non-worktime of labour and equipment.

Data were collected mainly from the UK and Nigeria. Data were sought for medium and large scale new build projects constructed in reinforced in-situ concrete structures. The project categories for which data were sought includes; Office complexes, Residential and Industrial Buildings. For the purpose of this study and in terms of budget; medium to large scale projects have been defined as:- projects with Budget:

£100,000-£1m ----- Medium;
over £1m ----- Large.

The scope of the study has been defined to include only this class of construction i.e. reinforced in-situ concrete structures in order to maintain a narrow boundary and focus the study on issues that relate to scheduling of this class of work. On the other hand within this narrow boundary, a broad category has been defined to include large and medium scale projects of office complexes, residential and industrial buildings. The advantage of this is to demonstrate the implications of project scope and project type on project planning, in the sense that construction methods and techniques may slightly or significantly differ for different categories and this may affect planning and scheduling. For instance, the choice of formwork systems, the choice and means of handling and placing in-situ concrete and the type and installation of M&E systems may significantly differ for different building categories. The construction of office complexes and industrial buildings may likely be in ‘frame construction’ where the structural elements of beams, columns and floors are constructed first, followed by in-filling panels in partition walls. While in the case of residential Buildings, though the “frame construction” technique may still be employed, but this will be with increasing use of large proportion of load bearing walls with less of in-filling partition walls. In contrast to this classification and categories are projects which may be constructed with precast concrete (post–tensioned, prestressed, or normally reinforced precast units); Bolted, Welded, or riveted steel structures. It is a common knowledge that all these different categories have certain implications on project planning and scheduling.

1.5 Contribution to Knowledge

Prior to this research, it was identified that field experts have the idea that poor planning and scheduling does contribute to non-worktime of construction resources. The reported study has reasonably addressed this aspect of using the scheduling process to reduce non-worktime by proposing practical start times for tasks. From literature the study developed guidelines for effective project reporting and effective project scheduling. The derived procedural framework for scheduling to reduce non-worktime can be considered a knowledge-based system which significantly replaces intuition with scientific reasoning in the scheduling decision domain.

1.6 Thesis Organisation

The thesis has been organised into eight chapters which systematically and progressively show the author’s thoughts and how the research purpose has been addressed.

Chapter 1 – Introduction

This chapter gives a preamble to the subject of investigation, the purpose and the objectives to achieve it. The novel contribution to knowledge is briefly stated.

Chapter 2- Literature: Effective Construction Planning

This chapter presents a literature over view of scheduling decision domain and what current planning practice is. It shows that there is a missed placed priority of assessing criticality based only on time analysis without adequate consideration of resource and project specific attributes. The chapter developed guidelines for effective construction Scheduling.

Chapter 3 – Literature: Schedule Review and Project Control

This is a second literature chapter. It attempts to solve the problem from looking at the possible answer. Project review shows events as occurred and likely with causal reasons so mitigating methods can be developed. Though literature supports that start and finish times, cost, duration and work should be tracked, reported studies suggest that both initial plan development and subsequent schedule control focus mainly only on time and duration. And that often resources and work are not reported. This chapter also developed effective project reporting guidelines.

Chapter 4 – Research Methodology

The approach adopted in the reported investigation and their justification are presented in this chapter. The study being a process improvement study required mapping the current process to identify loopholes needing improvement. This was done through a structured questionnaire which was subsequently administered as a semi-structured interview and opinion survey. Other research method of project document analysis generated the data which explained reasons for non-worktime of construction resources.

Chapter 5 – Mapping the Planning Process

The chapter presented the data generated from the process mapping. The process was mapped by eliciting experts opinions on scheduling procedures which may reduce non-worktime. This process mapping established the common or usual practice prevailing. Project performance and how these established procedures affect it is considered.

Chapter 6 – Case study and Document Analysis

This is the second research instrument used to investigate the domain problem. Project periodic meeting reports, production information and information release schedules were studied to identify how events have occurred on site. Though it was identified that reporting format and content defer very widely making it difficult to truly generalise and build a generic framework, results from this source support literature and the process mapping out come to a large extent. Also productivity and resource use efficiency were assessed from the case project.

Chapter 7 – Modelling the Framework and Validation

The chapter presents the three stages in deriving the framework - The identification of scheduling variables which create and affect non-worktime of construction resources, the categorisation of tasks and the differential application of scheduling options.
The need to validate the derived framework for its adequacy, its reliability, and its user friendliness is also discussed in this chapter. The method of validation using experts opinions instead of objective data was justified. Generally the model as presented was assessed that it fairly adequately addressed the important variables that create and affect non-worktime. However the validation of its reliability and its user friendliness was not as straightforward because experts' views on this vary so widely.

Chapter 8 – Conclusion and Recommendations

This chapter summarised the salient results of the research that current scheduling method do not tell the whole story. That identification of critical activities based on time analysis alone is misleading. And that if criticality means those things that should be done in order to progress the works to a scheduled completion, other parameters need to be used to assess task criticality.

CHAPTER 2 –LITERATURE: EFFECTIVE CONSTRUCTION PLANNING

… are all constraints resolved?... then that can start…

2.1 Introduction

Effectiveness of the plan means that things happen as they are planned. This is a very necessary prerequisite for efficient operations on the jobsite. Efficiency means achieving maximum output with minimum input, reducing the non-productive component of input and throughput as much as possible. This chapter has reviewed related literature on the planning and scheduling process in the context of how the process can be made effective to achieve efficient site operation.

2.2 The Need for Construction Planning

Without the master schedule, effective project control would be virtually impossible. Directing the project team would be extremely difficult if individual tasks have not been identified and the interrelationships among them defined. Turner et al (1964), said, that planning, either strategic or production planning, is a necessity in any business setting. Without it, getting a specific result by a definite date is a matter of chance. Planning reduces this undesirable element of wanting to achieve results only by chance. A plan is a detailed scheme, a method statement for attaining an objective. It is a proposed, usually tentative idea for doing something.

Pilcher (1992) sees planning as an administrative process which is capable of yielding specific instructions to instigate action to achieve a set objectives. Planning is one of the key management functions: plan, organise, execute and control, [Ahuja – 1994]. Figure 2.1 illustrates these and shows the position of the planning process. The plan or programme is used as a guide for future actions, to anticipate and avoid potential problems and to ensure efficient use of resources.

Strategic planning is planning to achieve the long-term objectives of the company. It establishes programmes and procedures for achieving them. It is a decision making process which focuses on the long-term future, which is forward looking.

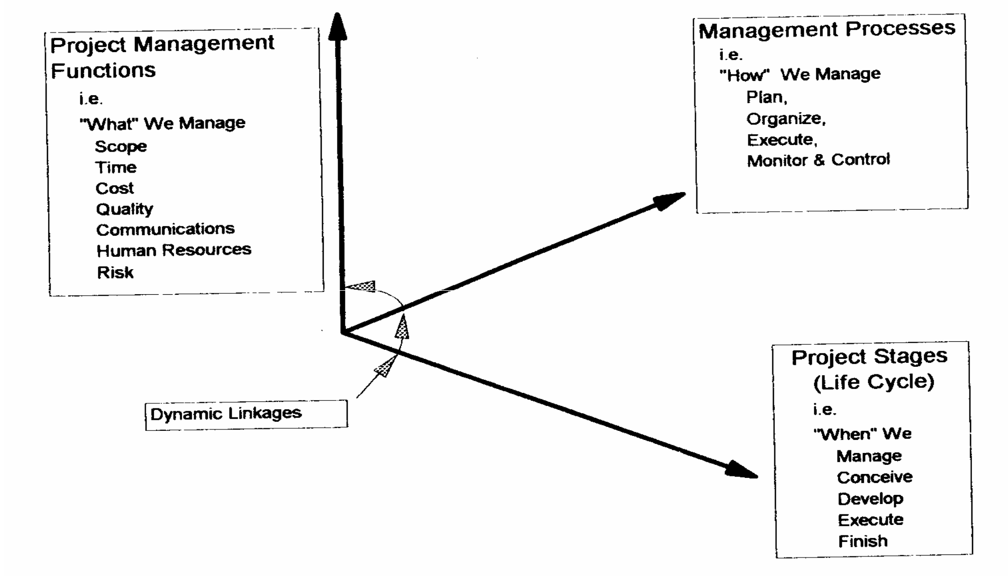

Fig. 2.1 The position of planning in the project management function
Source: Ahuja (1994)

Production planning on the other hand is planning the work face operations to ensure that resources of men, machine, materials, money, and management or supervision are efficiently employed. Construction operations planning is like production planning in many ways. It devises workable schemes of operations which are designed to accomplish a set objective. It is concerned primarily with assessing and selecting the methods, the sequential order and the resources of men, machines, money, materials and management (the 5 Ms) employed for the various tasks on the job site. Construction planning requires an intimate knowledge of construction methods, design and specification, combined with an ability to visualise discrete work elements and to establish their mutual interdependencies.

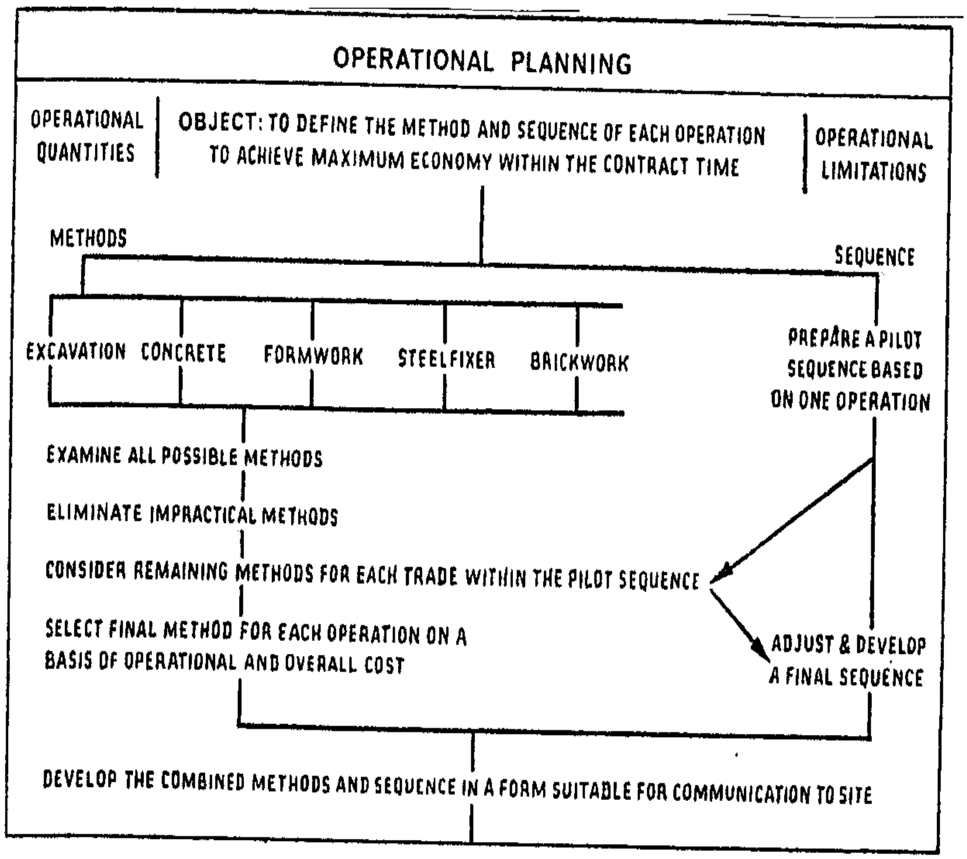

Fig. 2.2 Construction operations planning.

Source : Turner et al (1964)

Figure 2.2 illustrates construction operations planning. It shows how methods are assessed and selected and the development of pilot and final sequence for the works.

On first impression, construction planning may not appear to be particularly difficult, especially for a person with considerable field experience. It is easy enough, for example, to establish the flow of operations necessary to construct a reinforced in-situ concrete wall; setting out, fix reinforcement, fabricate forms, mix and pour concrete, initial cure, strike forms and cure again. This is true enough, but there is a significant limitation in this perception. The listed operations have series of simple dependencies and technological constraints. The planner needs to know for instance the rate of rise, how long the initial cure should take before striking forms and so on. In fact most construction operations are much more extensive, involving large numbers of job tasks whose interrelationships are intricate and complex. The problem becomes even more complex when the dimension of resource use and planning to reduce downtime is added.

Planning is of paramount importance in the success of construction projects. Several studies show that project outcome is significantly improved when effort is expended in project planning, [Olomolaiye–1997, Olusegun-1997 and 1999, Odeh–2002, Cole–1991 and Cohenca-1989]. The process provides detailed information for estimating and scheduling as well as a baseline for project control.

The master schedule, which is the output from the planning process has the following uses:

- A guide for placing focus and priority
- A forecast of resource requirement
- Providing a basis for procurement of resources
- Allowing derived short-term programme
- Allowing progress monitoring
- Providing data for resource levelling
- Providing data on risk / consequences of delay
- Generating 'what - if?' scenarios
- Identification of errors or impossibilities
- Identification of missing information

2.2.1 Difference between Planning and Scheduling

There is some confusion in literature regarding the words 'planning' and 'scheduling'. The words are often used synonymously, as in 'a planning and scheduling Engineer'. The words are not exactly synonymous, they are different but related. Literature takes the word programming as almost synonymous to scheduling. The scheduling process draws on planning results to establish a timescale for doing the work. Planning is concerned with dividing the job into its elemental tasks or parts, as in a work breakdown structure, specifying methods and sequence and selecting resources for the job. Timing at this phase is not a key consideration, only the establishment of the 'general' framework for doing the work is, at least in theory. This is the scope of planning. At the scheduling phase however a new element is introduced into the planning process. This element is time. In theory, during the development of a job plan, time is not normally considered, not with regards to overall construction period, nor the time necessary for completion of individual tasks. Scheduling therefore, is the determination of the timing and assembling sequence of operations in the project to give phase and overall timescale. Though in practice there is no separation of these two processes, the schedule is a reflection of the plan, a means of representing and communicating the planner's intention.

2.3 Form and Content of the Construction Schedule

The form and content of construction schedules is what is usually referred to as planning techniques. CIOB (1991) notes that a construction programme may well be a simple written list of activities arranged in the order in which they will be carried out. Only the most simple projects however, are scheduled this way. In most cases, to show the relationships of individual activities, one to the other, and collectively to a common timescale, some form of graphical techniques are used to display the schedule, this is the form, [Abraham-1998]. The various forms developed by planners for representing and visualising the results of their analysis are:

- The Gantt Chart
- Network Based techniques
- Line of Balance
- Space – Time diagrams
- Multiple Activity chart
- Histograms and Resource profiles
- Financial graphs
- Narrative reports
- Methods statements

2.3.1 The Gantt Chart

The Gantt chart, commonly called the Bar chart is simple and easy to understand. Developed by Henry Gantt, it is still one of the best methods for representing plans. A Gantt chart shows the activities of the project with bars which are proportional in length to the scheduled duration of the activities. Figure 2.3 illustrates a simple Gantt chart. Essentially, a bar on the chart means the activity represented is going on within the time window indicated by the beginning and ending of the bar.

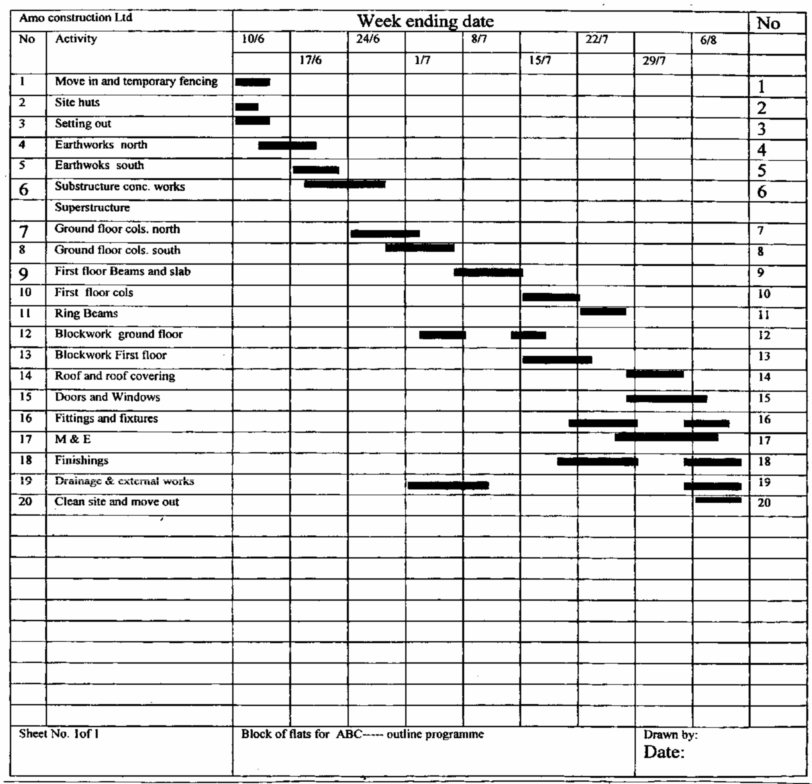

Fig. 2.3. A Simple Gantt Chart
Source: Based on Turner (1964)

Booth (1993) notes that the following assumptions are made either in the production or in interpretation of the Gantt chart:

(i) The rate of progress is constant throughout the length of the bar

(ii) The resource use is constant throughout the length of the bar

(iii) The start times shown are the times at which the activities will start, rather than when they can start.

Rarely are these assumptions stated. And with respect to them, Booth (1993) contends that although the start and finish dates for activities are displayed on the Gantt chart, no method exists to illustrate a variable rate of working, and that problems may arise concerning the proportion of the activity complete in relation to the planned time. "40% of the planned monetary value of work has been completed in 60% of allotted time, but most of the time consuming aspects of the task has been performed, so we are on schedule, remarked a regional Builder." It is difficult to assess whether the remaining 60% of the work can be achieved in the remaining 40% of the time.

Figure 2.4 illustrates the work in an activity being performed at different rates in the three time periods; 20%, 50%, and 30% during the first phase, the middle and the last phase respectively. These different work rates are due to set-up considerations, learning curve, and winding down activities. And aside from the technique being unable to represent activity work rate, it cannot also show logical relationships between activities except in the case of cascading charts and linked bar charts, although it has the ability to explicitly represent overlap of tasks more than most other scheduling techniques. This, with its simplicity is the strongest reason for its preference.

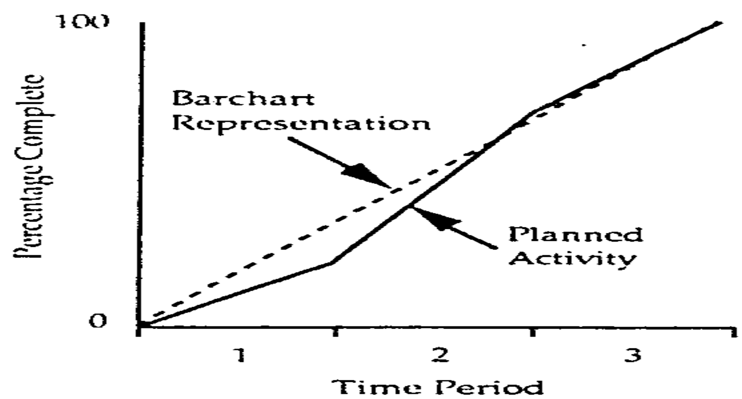

Fig. 2.4 – A Gantt Chart representation of activity work rate
Source: Booth (1993) PhD thesis

2.3.2 Network Based Techniques

The JCT (1998) and ICE (1999) conditions of contract specifically demand the builder to submit a programme of work showing how he intends to construct and complete the works. Booth (1993) observes that in the UK, construction contracts demand the provision of a Network based Schedule to accompany tenders. These Network techniques were developed in the USA and almost simultaneously in the UK and France around 1950, initially to plan and control project time, (BS 6042:Part 2 - 1992). Birrel (1980) notes that the CPM and PERT being developed for military uses in a war-like situation, the time element of the project being planned was of greater importance and urgency than the 'efficient use' of resources. They have however been extended to handle resources, uncertainty of outcome etc, and are shown to have the following benefits:

(i) Clear definition of project scope and the identification of interrelationships between tasks
(ii) A means of coordination between different organisations within the project
(iii) Both a project planning and scheduling method
(iv) A ready means of reviewing progress and exercising control over time, resources and cost
(v) Clear identification of critical and priority areas, and an excellent model for 'what-if' analysis and decision making.
(vi) Generally, networks are informative and they provide a simple means of assessing the combined effects of activity logic constraints and limited resources in meeting the project due date.

Network based techniques use two methods for estimating activity durations: The Deterministic and Probabilistic duration estimates. They also employ two diagramming formats to represent events and activities: The Activity on Arrow and the Activity on Nodes diagramming methods. The precedence diagramming method also known as Activity on Node has the ability to represent more realistically logical dependencies. It is able to represent not only finish-to-start relationship as is common in the Activity on Arrow, but it can show this and other relationships even with lead and lag which positions the method to model very closely to the real project environment.

The essentials of Network based techniques is the identification of the critical path obtained from backward pass, forward pass and float calculations. The path defined as critical enables office and work face managers to appropriately place priority in order to progress the works to a scheduled completion. Fundamentally, what determines criticality is activity duration and logic dependency. When activity duration is reduced by applying more resources, criticality tends to shift. But it is recognised also that there are some other tasks whose durations cannot be reduced by applying more resources e.g., long-lead component supply task, information requirement task, test and approval tasks etc.

Though these techniques capture fairly well the construction environment, there are still areas in which the method is deficient. Levitt et al (1985) notes that the network based techniques present only the end results of the initial schedule analysis and schedule creation. They only capture explicitly the activities, their duration, logical dependencies, scheduled start and finish dates and resource requirements. However, the expert's knowledge about the task attributes domain that was employed during schedule creation is unavailable either in interpreting the schedule or in its performance assessment. Richard (1990), citing David (1987), who investigated the use of the information provided by the critical path to effectively meet project due date concludes that the full story is not told by these techniques and that in reality in order for the project to be completed on time, both activities on the critical path and several other activities not on the critical path and which may have even higher priority deserve important consideration. But for large scope project with well over 5000 activities, priority areas needs to be identified in some way. The research question whether the time element alone is sufficient to define criticality should be carefully assessed. And if not, what other parameters should be used to declare a task critical? Some of these parameters may include task information needs, approval requirements, and long-lead supply items etc.

2.4 The Planning Process and Scheduling Decisions

Many researchers, Cohenca et al(1989), Olusegun et al(1997 and 1998), and Laufer et al(1987 & 1991), have observed that much research has been done in planning techniques and that it was time to shift research emphasis from investigating the techniques to now focus on investigating the process of planning itself. These reported studies which investigated how planning is being done, (the process) focused on measuring the quantum of effort invested in planning, frequency of major revisions and the likely project outcome. Since this call, no studies have been reported which mapped the planning process in industry, identifying it's components, practices and procedures of those who do planning, and how planning decisions are being made.

Regardless of the planning technique being adopted; whether Gantt Chart, Network based techniques, Line of Balance etc, a common process is followed. The process involves viewing general work in more specific work scope as in work breakdown structure; sequencing and logic development; task start and finish dates as in project calendar; activity duration and resource allocation. Davis et al (1997) notes that to create a schedule requires accounting for tasks attributes. They identify the process to include:

- Database Management
- Logic and Timing
- Schedule Editor
- Schedule Evaluation and
- Schedule Display

Similar to the steps listed by Davis, Cori (1985) listed seven steps in the planning process to include:

- Definition of project objectives
- Breakdown of work to be accomplished
- Sequencing the project activities
- Estimating activity durations and cost
- Reconciling the draft schedule with project time constraints
- Reconciling the draft schedule with resource constraints and
- Evaluating, validating and reviewing the schedule to optimize it.

The planning and scheduling process has long been regarded as an intuitive art. For instance, sequencing and timetabling which determines when tasks will start has options such as:

" as soon as possible" – early start programme;

" as late as possible" - late start programme Or

Other options in between these two extremes:

"Start no earlier than"

"Finish no earlier than"

"Start no later than"

"Finish no later than"

"Must start on"

"Must finish on" etc.

Choosing any of these options is often not scientifically structured. Decision is still mainly intuitive and further research should attempt to replace intuition with scientific reasoning based on information and a knowledge of the attributes of tasks being scheduled.

2.5 Resource Scheduling

To manage projects properly, it is necessary to establish a plan for the utilisation of projects' resources of manpower, materials, machine and money (Harris–1990). To do this planners use such procedures as:

- Resource allocation
- Resource levelling and
- Resource aggregation

A resource pool for a project is illustrated in Appendix A showing different levels of resource availability. The objective of resource allocation procedures is to schedule project activities so that a particular resource does not exceed a specified limit in any project time period, while holding the project duration to a minimum. The objective of resource levelling is to minimise the variation of demand while still ensuring that project is completed on schedule. These two objectives of resource scheduling: 'Not to exceed a constrained limit' and 'A reduction in demand variation' do not explicitly and adequately include for a third worthy objective; Of efficient resource use. This dimension of organising project resources to enhance efficiency, a reduced downtime has received little attention in planning literature.

Thomas et al (1999) notes that disruptions related to material management practices resulted in a reduction of crew performance of 22%. Using objective data on workflow disruptions and loss of labour efficiency, Thomas et al (2003) showed that inefficient man-hour is high due to rework and insufficient work available for upstream task. Addressing this problem, Khaled et al (2001) proposed optimum crew which makes sufficient work available for upstream task and placing a planned interruption of work to break production when there is a high delay potential, thereby releasing the firm from paying for non-worktime of resources. The problem of inefficient use of resources is partly due to the fact that resource scheduling is not adequately integrated into the project scheduling process as illustrated in table 2.1 .

Table 2.1 - Improper treatment of resource considerations in the CPM algorithm

ATTRIBUTES	CRITICAL PATH ANALYSIS	RESOURCE-CONSTRAINED SCHEDULING
1. Activity/resource relationships	Activity relationships are stable	Resource relationships are temporal and dynamic
2. Network logic	Assumes that all logic is based on natural precedence relationships	Incorporates natural precedence and environmental preferential precedence relationships
3. Critical variable(s)	Time	Time and/or resources
4. Treatment of resource constraints	Assumes infinite capacity	Recognizes finite capacity (resource constraints)
5. Treatment of activity durations	Durations are usually working days/units	Durations are usually flow days/units
6. Resource activation and utilization assumptions	Resource activation and utilization times are the same	Resource activation and utilization times can be different
7. Float times and critical paths	Based on duration and logic	Based on duration, logic, resource requirements, resource availabilities, and resource utilization patterns and processes
8. Impact of delaying critical path activities	Will lengthen the total duration of the project	Will vary depending on how resources are allocated and utilized

Source: Mark et al (1994)

Many researchers; Chua et al (2002), Chang et al (1989), Naief et al (2002), Yeo et al (2002), Robert et al (1991), Saad (2002), Mark et al (1994), Ming et al (2003), and Chelaka et al(2001), have noted that time scheduling methods like the critical path are concerned mainly only with minimising project duration. They argue that these do not consider attributes or limitation on resources. This unrealistic assumption can lead to inefficient resource use and project delays. Many of the problems with real-life projects arise when activities require resources and or information that are available only in limited supply.

A recognition of this limitation has directed researchers towards the problem of scheduling activities under resource constraints, integrating time-oriented and resource-oriented considerations (Chelaka–2001). A resource oriented process model which considers resource attributes is illustrated in figure 2.5.

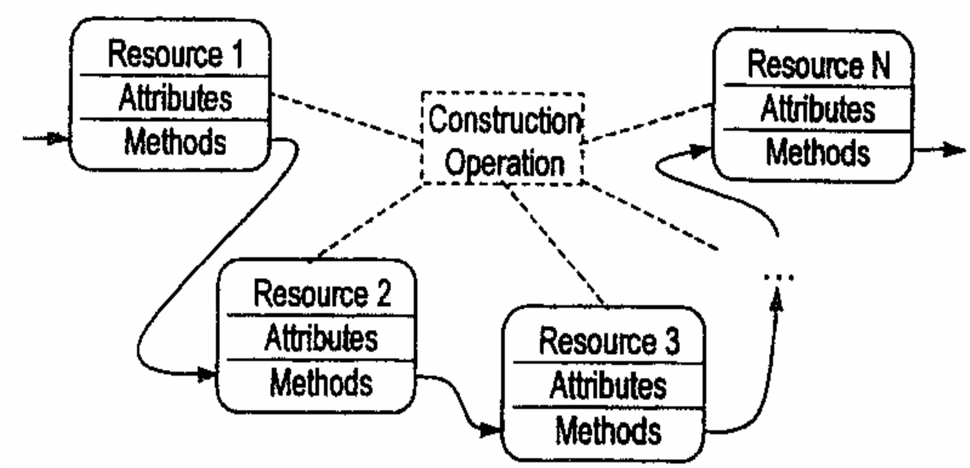

Fig. 2.5 Resource-oriented process model
Source: Chua et al (2002)

In response to this problem, i.e., inadequate recognition and consideration of resource/tasks attributes in the scheduling process, Ming et al (2003) developed a resource scheduling model called 'Resource-activity critical path method'. In this method;

(i) The dimension of resource is added to scheduling to seamlessly synchronise activity planning and resource planning.
(ii) The start/finish times and floats are defined as 'resource-activity' attributes not only as activity time attributes.
(iii) The 'resource critical' issue is addressed. Is it the resource that is critical or is it the time?

Ming concludes that effective scheduling should consider resource capabilities and availability in the schedule development. The 'resource-activity' critical path should define the start/finish times and floats as resource-activity attributes, not only of activity duration.

This conclusion is similar to the suggestion of the B.S 6046: Part 4(1992), that emphasis should be given to resource analysis rather than time analysis alone and that due consideration should be given to various forms of constraints. For effectiveness all constraints must be understood and resolved as shown in figure 2.6

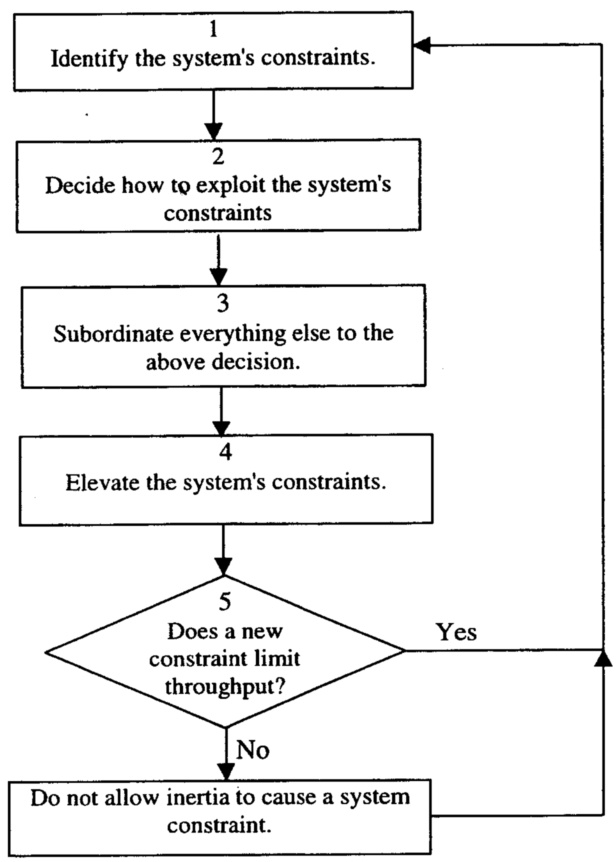

Fig. 2.6 – The constraint removing process

Source: Yeo et al (2002)

2.6 Efficiency–The Result of Effective Construction Scheduling

Detailed description of an efficient schedule and how to achieve it through effective scheduling is the subject of CIOB (1991). Most projects evaluate success in terms of the optimisation of project time, cost and quality criteria, and so, most planning and control tends to focus on these three variables. Generally, efficiency is measured by the ratio; output divided by input. An increase in this ratio means the system is more efficient. A streamlined input achieving the same or higher output. However when there is waste in the input component, increasing its quantum with constant or even a reduced output, efficiency is dropping.

Effective construction scheduling which has its objective of making the construction process efficient should yield a process model which is realistic, flexible, reliable and predictable; ensuring that events occur the way they are planned. Though the best results come from tightly programmed, speedily completed jobs, the durations and dates should be practical and realistic. As much as possible, the programmer should avoid optimism. Optimism about information coming in as required, optimism about material availability and optimism about finishing early reduce programme practicality and they result in unrealistic process model, [Clark – 1988]. To put it bluntly a pessimistic view is encouraged taking nothing for granted. Cori (1985) notes that for a schedule to be effective, it should be:

- Clear and understandable to all who use it
- Sufficiently detailed to provide a basis for measurement and control of progress
- Capable of highlighting priority and critical areas
- Flexible, easily modified and updated if desired
- Have a built-in pessimism that events may not occur as scheduled
- Knowledge – based upon reliable information and time estimates
- Conform to available resources
- Compatible with plans of other projects that share same resources
- Able, not only to account for project uncertainties in activity duration, resource requirement, resource availability, structure of the network in terms of precedence relationships etc, but it should seek to reduce all these uncertainties.

Cori concludes that the planner should be aware that many factors are considered in preparing an effective schedule. And that both obvious and non-obvious constraints needs to be considered before fixing a timescale.

2.6.1 Early / Late Start Consideration

Contractors often prefer to work to an early start schedule. The extent to which this is a practical and effective scheduling option is in question. Early start schedules consider the earliest dates activities may start. And resources of men and machines are called to site based on this arrangement and timing. In reality numerous factors such as weather, current workload, long-lead supply items and information requirement needs may call for deferring some work until the late start dates to effectively resolve some of these constraints [Diekman – 1992]. A least commitment approach for some tasks which aims to delay decisions and actions until the system has enough useful information and right conditions for making them is important for planning construction projects, [Levitt – 1989]. The idea of least-commitment planning for some tasks is fundamentally different from the thinking of Andersen (1996) who warned that detailed activity planning is hazardous to the project's health! Andersen proposed establishing milestone plans and viewing the schedule as 'targets' and not full commitment. This may enhance efficient operations as resources will be called to site only when conditions are right. But work progress is likely to be slow since no firm direction is previously laid out, and the scheduling process would seem to be starting all the time from the beginning. This is why Cori (1985) opines that detailed planning as a means of preventive action, anticipates potential difficulties and proposes how to cut the corners, making field operations fast and efficient. Herman (2000), however, maintains a similar view as Andersen. Herman notes that due to the unavailability of accurate data on activity durations, resources and other information, the development of a "perfect" project schedule is a myth. The input data into the model to simulate and optimise it are mere estimates and are by no means accurate. This means that there might be more than one scheduling solution that is feasible and is "good enough".

The argument is that except for the purpose of identifying a project due date, long-term schedules should indicate 'targets' and not full commitment. While short-term schedules should be viewed as statement of intent, of full commitment of resources and of a guide for making them available. Most advanced scheduling pieces of software such as the Primavera Project Planner and the Microsoft Project etc, have facilities for specifying use of a resource as "propose" resulting in a target schedule called for by Andersen(1996) and Herman (2000). They also have options which specify the use of resource as fully committed, yielding a firm, clearly defined timescaled schedule. The only problem with these software is that they do not support the decision making process as explained in section 2.4, when to apply early or late start, what workweek for which tasks and when should resources be fully committed or only stated as "propose" etc, are decisions which are still being made on intuition. And often young and inexperienced schedulers use only the default options as they lack the ability to chose with reason. Both "target" and "commitment" schedules have their merit and demerits and the programmer should carefully assess their application in developing both the long-term and derived short-term schedules.

2.6.2 Project Calendar, Schedule flexibility and Schedule Elasticity

The project calendar is the time a resources is specified being active on a task. This could be the number of hours in a workday or the number of days in a workweek. All scheduling software support the manipulation of both the workday and the workweek.

Generally both workdates and calendar dates are considered and applications of these could be in defining:

- A resource calendar
- A task calendar and
- A project calendar

The default calendar date is the Project calendar. Mostly, it is better to prepare a schedule initially on a workweek less than the company regular workweek for some tasks and for some resources, and increase this during schedule implementation if conditions allow. If the upper limit of workweek is used in the initial schedule development, the elastic limit has been reached and no further upwards move is possible to optimise operations. And often the large amount of Man- and Machine-hours called to site may be rendered idle for several reasons discussed in Chapter 3. Specifying a workweek less than the regular for some resources builds in a programme flexibility enough to accommodate unanticipated project delays and changes. This also serves as a reasonable safety factor against downtime of resources for some tasks.

2.6.3 Connection between Procurement and Commencement of Site Operations

The success of a project is often related to the links developed between the Suppliers, Sub-contractors and the Prime Contractor. This is particularly so for some classes of work and some classes of resources. Brian et al (2004) opine that due to the problem of manufacturing lead-time and order lead-time, effective scheduling requires the representation of the connection between procurement and start of site operations. This ensures that all lose ends are tied up and that key dates are met in relation to delivery of materials, design requirements, information flow and other intangible resources and start of work on site. This requirement is illustrated in figure 2.7, which shows the tying of the procurement programme for steel work with start of site operations.

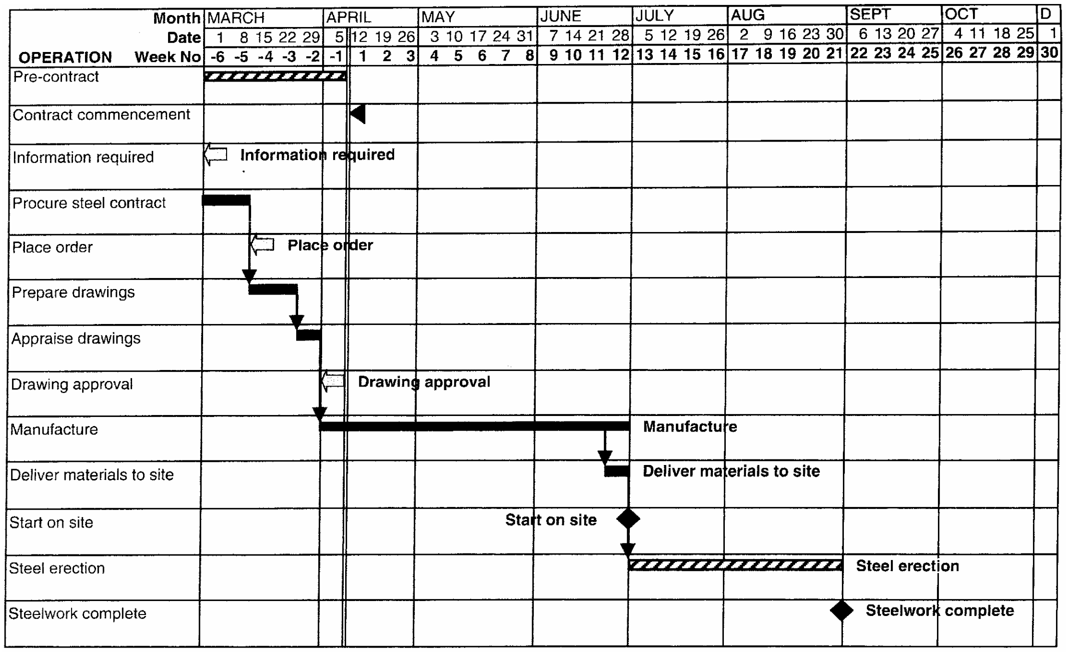

Fig. 2.7 – Integration of procurement programme with the Master schedule

Source: Brian et al (2004)

Figure 2.8 illustrates an early warning system derived from monitoring the procurement programme. The steel frame structure is scheduled to start after completion of procurement of necessary components. The figure shows a range of early warning or milestone symbols which are used to denote an occurrence which may affect a supply chain for a component supplier or a sub-contractor. It illustrates that actual data was released by the client's representative one week later than planned in respect of information and nomination. This resulted in the order being placed one week later than scheduled with possible delay in the commencement of steel erection on site.

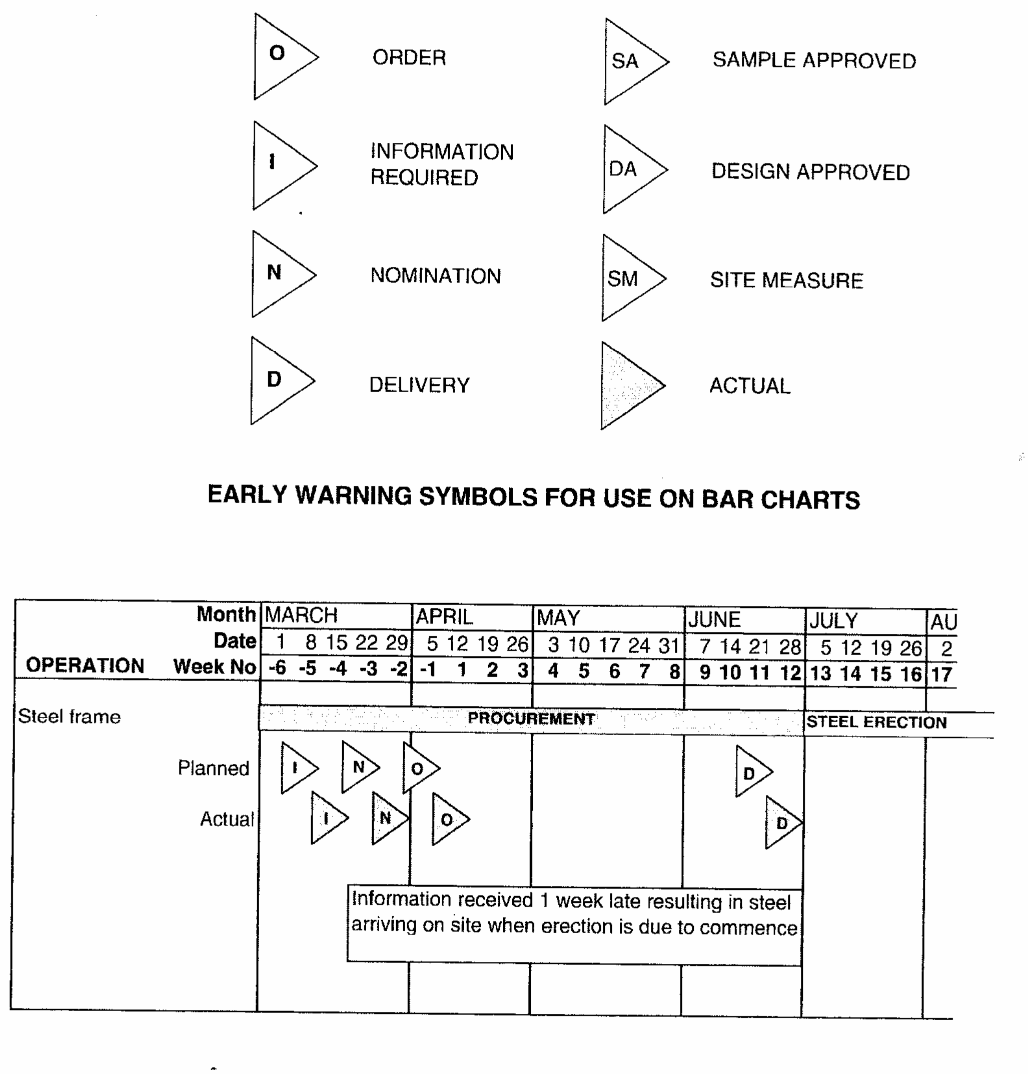

Fig. 2.8 – Early warning system for component procurement programme

Source: Brian et al (2004)

Here both the manufacturing lead-time and the order lead-time may have been accurately estimated. If they were not, and the information required by the date was missed again, the programme would have dramatically overshoot. This is why JCT clause 5.4 demands the Architect for schedule effectiveness to attend promptly to the information release schedule.

2.6.4 Weather Control

Dennis (2004) suggests that effective scheduling should arrange work so that as much exterior work as possible is accomplished during fair spells and make the building watertight as soon as possible to avoid adverse weather. Then when the adverse weather comes, the interior work or other less weather sensitive tasks can continue. The schedule should make allowance for adverse weather delays, based on the season of the year and past regional weather statistics. James et al (1999) note that the planner should have an up-to-date well documented record of anticipated workdays for each month of the year prevalent in the geographical area of the project. This chart of anticipated workdays for each month of the year is a useful guide for effective scheduling. Scheduling exterior, rain sensitive work in the months of May, June and July for 20 days each month in the Port-Harcourt area in Nigeria, which records almost 15-20 days of very heavy rains each month is not effective scheduling. The chart illustrated in Appendix B would help to place a planned interruption to break work during periods of adverse weather.

2.6.5 Schedule Evaluation

One means of ensuring effectiveness in scheduling is to evaluate and validate the process model developed. Thamhain (1989) observes that too often project leaders find their well defined plans cannot be performed as scheduled and wondered if these schedules were carefully formulated and reviewed for details, clarity, process integration and management control. Thamhain(1989) identified schedule deficiencies which evaluation should address as:

- Completeness and insufficient details
- Insufficient checkpoint and
- Poor integration points etc.

Schedule evaluation is important to the client, and his representatives as well as to the Engineer who has developed the initial schedule. It should address such issues as feasibility evaluation, technical and commercial evaluation.

First of all, the Scheduling Engineer must consider if his process model is feasible in terms of time and resource constraints. Though, most of these issues should have been resolved when the schedule was initially developed. The client and his representatives' interest at this point is to identify if the programme is not too ambitious or unnecessarily prolonged. Technical evaluation of the programme should also be performed by the Scheduling Engineer as well as the consulting Architect / Engineer representing the client. The objective is to detect errors in the logic or basic assumptions upon which the order and linking of activities depends. It is a search for mistakes of the kind that put beams into place before their supports are shown to be complete. Clark (1988) notes that an evaluation of the schedule for a Highway construction could show such errors as: Insufficient allowance for curing time between placing concrete in roof of an underpass and opening a haul route across the structure etc. Commercial evaluation on the other hand should calculate measures of schedule quality as cost, tardiness, flow time, average inventory requirement of the schedule, resource utilisation pattern and likely downtime of resources etc. The planner needs to determine the reasonableness of not only the gross amount of concrete that has to be obtained and placed within the contract period, but information from the schedule is required on the peak demand period and the frequency of large pours, [Proverbs -1996]

Booth et al (1989) summarised the criteria for evaluating the schedule for effectiveness to include:

- Logic and Timing requirement
- Resource utilisation pattern and downtime
- Cash flow and
- Plan completeness

2.7 Improving the Planning Process through Contingencies and Buffers, Lean Philosophy and the Last Planner, and Just-In-Time and the Japanese Kanban.

Schedule variability, uncertainties in the construction process, task duration uncertainties, resource requirement and resource availability uncertainties etc have called for improvement both in programme formulation and its implementation, [Tommelein-1999, Lawrence-1989, Gupta–1989, Samson–1989, Low–2001, Rene–1999, Hillman–1989, Oliver–1989 and Singh–1989]. Methods like contingency allocation and buffers; the lean philosophy and the last planner; Just-In-Time and the Kanban; and Knowledge-based systems are commonly used by planners to reduce schedule variability, process uncertainties and increase process efficiency. The extent to which these can improve the process however is not certain. In particular there is much doubt and debate if methods like Just-In-Time, the Last planner and the Lean philosophy which may work well in manufacturing industry, adequately satisfy the peculiar nature and requirement of the construction industry.

There is tendency to waste time as a result of reserves that are liberal. And work time normally expands to fill allotted time and so project buffers, feeding, activity and other forms of buffers particularly regarding time should be used very cautiously. This is because the system will gradually but definitely 'eat' into these reserves. More importantly, no method exists for monitoring and reporting on use of allotted reserves in the project reporting system.

Marc et al (1989) notes that the purpose of Just-In-Time project implementation are:

- Reduction of inventory level
- Lead time reduction and
- Through-put time reduction

Processing times and variability have a major impact on the efficiency of the production system. If average processing time is the same for all work stations, the work content is nearly evenly distributed over all work stations as in manufacturing, the production line is described as balanced and stable. Improvement in such a system is fairly easy. But where the work stations have widely varying processing time and work content, and even different work stations are not too clearly identified, as in construction, both process planning and its implementation is very difficult. This is why Marc concludes that the Just-In-Time and the Kanban systems achieve optimum performance if production environment is stable and 'deterministic'. Appendix C illustrates constant and variable processing times in different work stations. For manufacturing industry this arrangement is not only feasible but an improvement in line performance can be achieved if variable processing time stations are positioned at both ends of the line and the constant stations in the middle. Since the beginning and ending events are sure, they have less uncertainty. Thus contingency and buffer focus are directed on the middle work stations to reduce variability. However this arrangement is not easily achieved in construction because of its nature. This is why contingency and buffers; Lean philosophy and the last planner; and Just-In-Time and the Kanban methods may not work well in construction as they do in manufacturing.

2.8 Guidelines for Effective Construction Scheduling

From a broad and thorough study of text book knowledge of the scheduling domain, the following guidelines have been developed which may make the process effective, that things happen as Planned;

Guideline (i) Information is 'golden' every inch of the process should therefore be Knowledge-based.

Guideline (ii) Where this knowledge is lacking and some tasks are not too clearly defined, schedules should be regarded as 'Targets' not full 'commitment'.

Guideline (iii) Faster may not always be better in a scheduling sense therefore the process should try to understand and resolve all forms of constraints before scheduling a task. And it should integrate various aspects of the project.

Guideline (iv) The planner should avoid being optimistic about any aspect of the schedule – Duration, Logic, Resource availability, etc. A pessimistic view ensures a good factor of safety. Not just pessimistic, but should try to remove the 'cloud'.

2.9 Summary

A look at the Scheduling process, not the technique, show that researchers have pointed to two directions to make the process effective. These are priority placement and project understanding. So that scheduling yields a process model which is effective, and that things happen as planned to enhance efficiency of operations on site, some researchers have suggested the process should regard 'all activities critical' on the one extreme, removing the missed placed priority. On the other extreme, suggestion is towards the establishment of only 'target' or milestone plans. The middle position is that though these two extremes may make the process effective, there are still some problems. And so, application of project specific knowledge may help to define and categorise activities so that some are regarded as having high delay potential, some of medium or low. This knowledge-based system could help to develop least-commitment plans for undefined task and replace intuitive reasoning with scientific reasoning in decisions regarding early/late start considerations and project calendar.

CHAPTER 3 - LITERATURE: SCHEDULE REVIEW AND PROJECT CONTROL

Where are we now and Why?, Where should we be and how do we get there? … I only ask for information.

3.1 Introduction

Chapter two examined what makes scheduling effective at least in theory. Chapter three makes a retrospective assessment of how effective the process has been, what went wrong and what went right and why? By examining results and feedback from site operations, this chapter in a way looks at the answer to formulate good scheduling procedures that may achieve the desired results.

3.2 Purpose of Project Review

Like other businesses, contractors and developers have to plan and organise their day-to-day activities in order to manage effectively, [Brian -2004]. It is a fact of life that the best laid plans often go wrong. Managers who can anticipate a problem before it gets out of hand have more chance of making a success of their business than those who take the 'Mr. Macawber' approach of simply looking at excess income over expenditure as the only measure of success. Though at the top levels of management hierarchy this is usually sufficient to make strategic decisions, but at the work face level, more information is required for effective operations management.

Effective management requires control. Different degrees of control are required for different projects and usually at different levels. Many factors are considered in assessing the degree of control required for operational effectiveness. These are the size and organisation of the firm, the scale and complexity of the project in hand and specific requirement of the customer or owner. For instance the US dept. of defence contract specifically requires the builder to give periodic project status reviews on budget and schedule, [Christensen-1994]. Control is normally based on the understanding of certain project performance information. Mawdesley et al (1997) note that spotting changes, recognising lack of progress and identifying areas of poor quality are some evidence on which to act.

To monitor progress, information on actual performance needs to be collected within a structured reporting system, so that appropriate corrective action is taken if and when things go wrong. There are many aspects to the control of a business. However, in construction projects, four areas stand out for consideration. The control of:

- Time
- Money
- Quality and
- Resources

On the job site, when the works starts, reality on ground may be different from assumed conditions at the planning phase. Task start and finish dates may change because of this. Factors like information coming late, price increases, unavailability of resources, weather, emerging out-of-sequence working would make the operational model very different from the baseline plan, [Tim-1998]. More importantly, the direction of progress of the remaining works needs to be re-defined. Assessment of new dates for remaining tasks in the programme gives an early warning if deadlines are in jeopardy of not being met and resources can be given an advance notice of necessary changes or of potential delays in the schedule. This early warning helps to reduce and avoid downtime of expensive construction resources as well as guide to pull resources that are needed on time. The process of monitoring progress, measuring actual performance, updating the schedule and comparing the new schedule with baseline value helps to assess whether the project's goals will likely be met. This information may indicate a need for change in operational procedures before it is too late. Actual dates for activity start, activity finish and length of interruptions show what downtime costs of labour and equipment may have been incurred.

Project tracking will show how the project is finished early and for less cost than planned. And if it takes longer or costs more, tracking data should explain where time was lost or why cost went over budget, [Lowery-2001]. All these information if not useful for reactive control of the project in hand, will help to pro-actively control future projects. Figure 3.1 illustrates the steps in the project control process. It starts with establishing a baseline plan, which is a framework for subsequent control action. The figure shows how the project scope and quality will be accomplished on time and within budget.

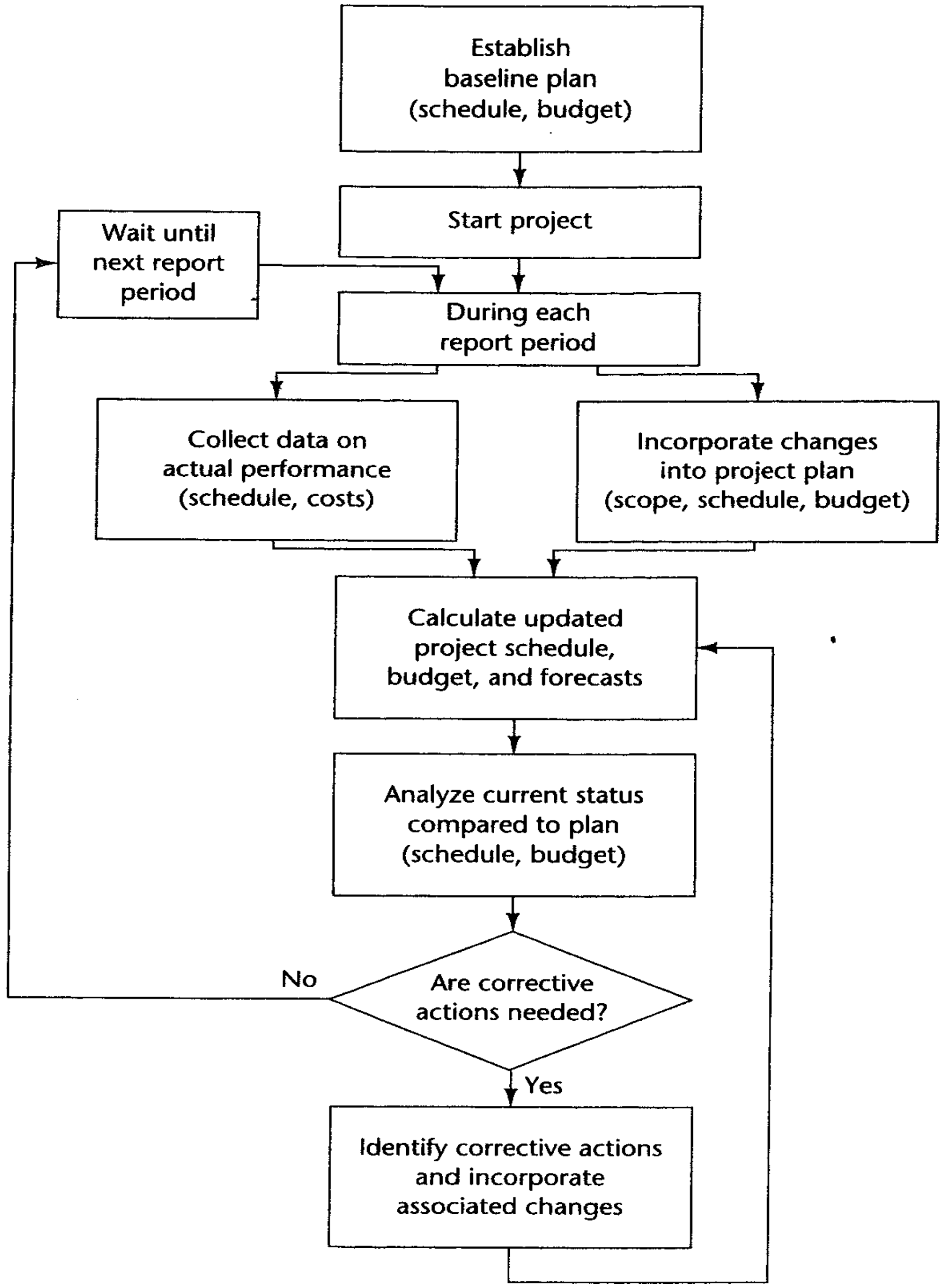

Fig. 3.1 – Project Control Process

Source: Jeffrey (1998)

3.3 Timing and Frequency of Major Revisions

Monitoring progress, reporting project status and revising the programme requires two important decisions, that of timing and frequency of these control actions. When and how frequent should they occur? Dennis (2004) observes that the use of lagging metrics instead of leading metrics to measure progress is not good enough. Once too much has been spent, it is probably too late to do much about it. A project that is too far behind schedule may be difficult to get back on track, [Jeffrey-1998].

Also, because progress is reported at different levels, frequency of monitoring for these levels will likely be different so that information for corrective actions are made available in a time frame appropriate to different management procedure. Pilcher (1992) holds that the time interval of reporting project status may vary with levels of management that receive and act on them. At the site level, it is necessary to report on a weekly basis, above this level in the organisational structure, monthly reporting intervals will suffice. The reason for this is obvious. The work face managers need to quickly correct deviations as they occur by changing operational methods, logic or expediting to bring the programme on track. While top management would want to assess the significance of the problem before formulating appropriate corrective actions, likely on long or medium term basis. This means the nature of on-site control requires immediate action while top management or office control is a little bit longer in time scope. Regular reporting periods should be established at the time the schedule is being formulated. Reporting may be daily, weekly, fortnightly or monthly depending on the complexity or duration of the project. For a project lasting a month, a daily reporting period is fine. For project spanning five years, a reporting period of a month will suffice.

The frequency of report for different control aspects needs assessment also. For instance if the control aspect is quality more frequent report, probably daily is necessary. For the control of time and resources, a little bit less frequent but sufficient to allow appropriate action. This area of assessing control of individual aspects requires further studies. Though as in project planning, integrating all aspects is a worthy objective which gives a global picture. But assessing individual aspect is also desirable to unearth and tackle certain specific issues. If reporting is done monthly, data and information should be obtained as late as possible in that month period so that when updated schedule and budget are calculated, they are based on latest information for that reporting period.

Periodic site meetings and up-date time should tie together. It is recommended that up-dates be done a day or two prior to this meeting, [James -1999].

Ronie (1990) notes that because of the efforts for compiling and updating project schedules in the ever-changing environment of construction work, some contractors dispense with it altogether or resort to it infrequently and in a superficial manner. Saad (2003) reports a study on monitoring systems and their effectiveness for project cost control in construction and shows that time lags in project reporting degrade performance. While Salapatas (1985) asks if projects can afford a full-time site based staff to monitor performance on a continuous basis, or should management wait till the end of the project to discover performance, what went wrong and what went right? The need to provide an early warning system to detect out-of-bound, exceptional performance, which will enable changes and revisions to occur in a timely manner is fundamental and has been called for by many authors, (Jeffrey-1998, James-1999, Saad-2003, and Brian-2004). Though the frequency with which construction plans are reviewed has significant potential to improve performance, Olusegun (1997), however concludes that over emphasis on project control after commencement of site operations reduces construction planning effectiveness. This conclusion is similar to results in another study, Olusegun (1999), in which increase in planning and control efforts does improve performance up to a certain point defined as optimum. Beyond this, additional planning efforts did not achieve any savings in project cost. Figure 3.2 illustrates the relationship between performance and planning effort. From point ‘o to a’, because of low planning effort, probability of poor performance is infinitely high. From ‘a to b’ it progressively reduces to a minimum at ‘b’ which is the optimum planning input. Beyond this point, probability of poor performance increases even with increasing planning effort. This finding establishes a need for assessing the quantum of planning and control effort necessary to achieve good performance.

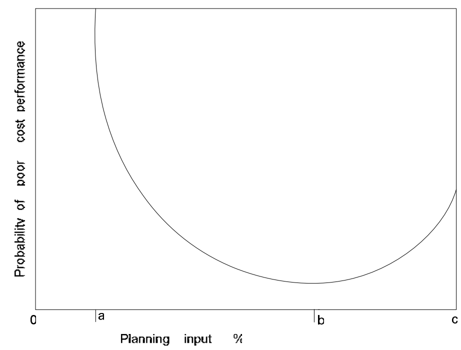

Fig. 3.2 – Relationship between Planning and Probability of Poor performance
Source: Olusegun et al (1999)

Typically, the control activities are carried out at project milestones where it is possible to clearly identify output, [Massimo-1998]. The control of output at the end of a phase is ineffective since any problem is recognised too late. Thus intermediate points of control are necessary to provide an effective in-process updates of key performance indicators, such as cost, resource use, time, work complete etc.

The timing and frequency of control activities is fundamental in defining the control system. A frequent control, besides the associated direct cost, is time consuming and diverts resources. Indeed output deviation may not be significant to place a judgment. An infrequent control on the other hand does not allow an early warning necessary to appropriately intervene.

Generally what affect frequency decisions are cost of monitoring, urgency of the project, exposure to delay situations, average time span of the tasks involved and complexity of the phase. Massimo further state that variable review periods provide several alternatives for the timing and frequency of monitoring and control actions:

a) Less intensive monitoring at the early stages and more review at the end.

b) More frequent monitoring at the beginning and less afterwards.

c) Review after completion of a major phase or key activities.

Partovi et al (1993), cited in Massimo et al (1998), reported an experimental investigation into the performance of these different alternatives and notes that monitoring and control functions are not necessarily performed concurrently. Progress data could be collected weekly while corrective control actions are initiated monthly.

3.3.1 The Effort Function and Revision Intervals

The thinking underlying the timing and frequency framework developed in Massimo et al (1998) is that the effort function for projects is not linear. Projects follow different patterns with different behaviours, making it clear that there is a need for differential allocation of control or check points along the project life cycle. Fig 3.3 illustrates four possible effort functions.

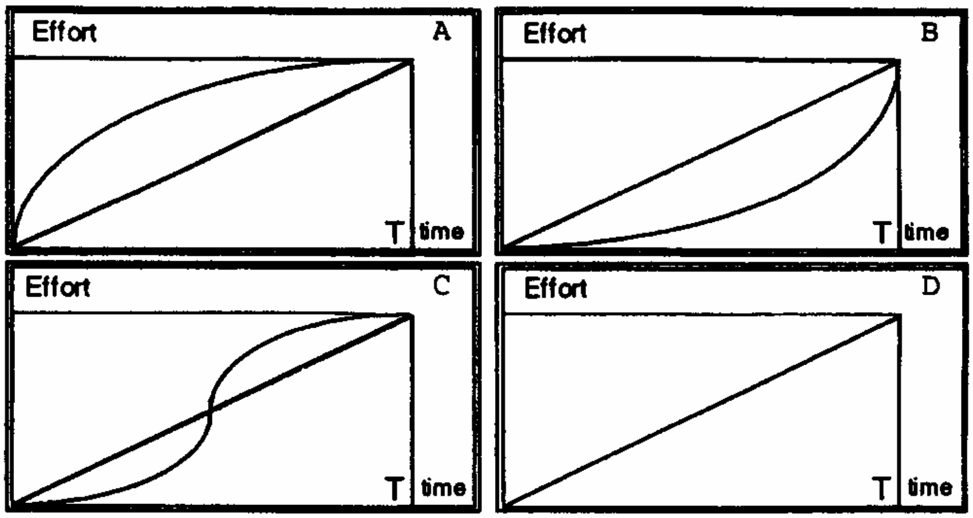

Fig. 3.3 – The Four Typical Cumulative Effort Function
Source: Massimo et al (1998)

The S-curve which shows a slow start phase, a fast progress middle and a slow winding down phase to close; presents a misleading effort function consideration for all projects or for different phases of a project. It is not unusual to have projects where most of the activities are concentrated at the end (fig 3.3 B); at the beginning (fig 3.3 A); or performed uniformly throughout the project life's cycle (fig 3.3 D). Though studies in construction tend to support that the effort function follows the S-curve, [Ahuja-1994, James-1982, Kaka-1998, and Oxley-1996]; Massimmo's definition of the effort function, classification of project, intensity of effort deviation, are relevant in defining check point in construction schedules. For instance even if the rather weak approximation of the S-curve was generally assumed (fig 3.3 C), it can be seen that the curve has three clearly defined sections. The first part, from the bottom is like an effort function in which most of the important activities are performed towards the end of that phase, the middle section represents a nearly slowly rising straight line curve, slopping at some angle in which effort progressively increases along the time continuum. The last third section represents an effort function in which most important activities are towards the beginning of that phase to end the project.

Thus, though all four functions presented may not apply to the entire project at once, they may however individually apply to some phases of the project. The study also illustrates that if effort distribution (defined in terms of man- hours or machine- hours) rather than cost distribution, which usually includes cost of expensive materials and components fixed at a short time interval, portions of construction projects schedules may show efforts in groups A, B, and D, and not necessarily only C. What defines the plot of the effort function in construction is the cost of resources. If the system is for the control of time, it is wise to plot only the cost of time dependent resources e.g., man-hours and machine-hours., since the cost of most materials and components are not that time dependent, occurring at instantaneous fixed points.

Defining the effort as a non- linear function of the total number of active operations and the total slack time, Massimo, use quantitative analysis of it's concentration to allocate monitoring and control check points. This allocation un-uniformly distributes effort between consecutive control points since effort function concentration is assessed to be non-linear. Figure 3.4 illustrates the control instants allocations at points A, B, C, D, E, F, G, H, J, and K.

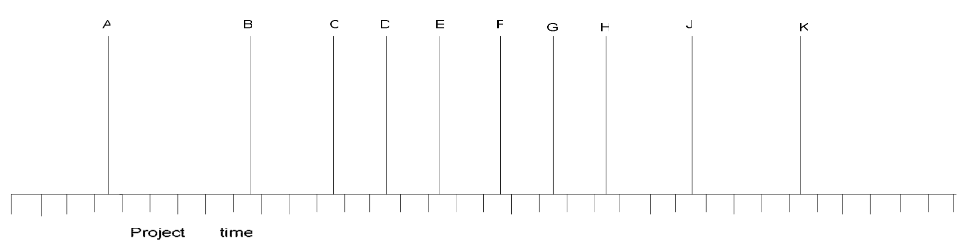

Fig. 3.4 Control Instants Allocation

Source: Massimo et al (1998)

3. 4. Delays, Interruptions and Downtime of Resources

Delays, project duration and time overruns are very closely related concepts that can be very confusing and whose differences are not too clear from literature to young researchers. Often same events or causes are cited for all three terms. However, time overruns are aftermaths of delay situations and errors in project duration estimate. The accuracy of this estimate depends on so many factors, and errors in it could result in the project finishing late or earlier than planned. This differentiation is important so that the issue of downtime of resources as a direct consequence of delays (not of project duration or time overruns) can be investigated. It is possible that the estimate of project duration is abnormally high or low, but resources are kept employed at or near optimum without a record of downtime cost. It is also possible that there is significant time overrun during which resources are being efficiently employed. Thus both the concepts of project duration and time overrun are different from the notion of delay which means a slow pace work, or a complete stop for a period. If resources have been mustered to site a downtime cost may result because of this delay situation. But resources may not be idle should a project overrun in time. They may still be employed optimally.

Strictly speaking therefore, a delay situation creates the inability to start and or finish a unit part of the works as planned which may lead eventually to finishing the entire work late. Two aspects of delays indicated in this definition are delays to completion and delay to regular progress. Most Project Managers are more concerned with delay to completion and are less sensitive to delay to regular progress of the works. Love (1983) notes that a common error in assessing project status is looking only at the total float which indicates delay to completion. As much as there is total float still left on a task the project is on track. Where as the free float should be the traffic indicator, showing red or green on likely levels of downtime of expensive resources on the job site. When the free float on a task is small, the schedule and the calling of resources for succeeding tasks should be guided by closely monitoring finishing dates of the preceding tasks and not the scheduled start dates for the succeeding tasks. This helps to reduce downtime costs.

The JCT (1998), GC/WORKS/1 (1977) and ICE (1999) conditions of contract made reference to this inability to complete either the entire works or a section of it on the due date as the delay situation. These conditions also made reference to disturbance in regular progress of the works as a delay situation or interruption.

Keith (1997) sees a delay as a situation which has adverse effect on the time for completion and would cause a prolongation of the contract period. It may be culpable delay where the delay is the fault of the contractor or non-culpable delay where the contractor is delayed due to the fault of the client or his representative. Disruption on the other hand is an adverse effect on the progress of the work, requiring a re-organisation of working methods or sequence. It may or may not lead to a prolongation of the contract duration.

Several hundreds well researched studies in construction delays have been reported in the literature. Emphasis of these studies has been in detailed classification of delay situations. Not as much has been done in a way of modelling the construction process to mitigate these delays as has been in their detailed classification. Though it is inferred that the precursor for modelling mitigating processes is this identification and classification already abundant in the literature. The Just-In-Time, Japanese Kanban Lean philosophy and last planner project implementation strategies discussed in section 2.7 are some ways of reducing schedule variability, mitigating delays and enhancing project performance. As shown in that section these do not adequately satisfy the construction environment which is unsteady flow process environment unlike the manufacturing industry, [Singh -1989, Kartam-1995, Koskela-1997, Alan-1989, Yash -1989, Harber-1989, Low-2001, Tommelein-1999, Rene-1999, Hillmann-1998, Marc -1999 and Slack-1980].

3.4.1 Direction and Emphasis of Previous Delay Studies

Emphasis of previous delay studies has been less in the aspects of means of mitigating, but more of classification of delay situations. This is with the hope that project managers could now be aware of these situations and attempt to fashion out their own ways of mitigating them. The reason for this is obvious. There are so many questions and many factors interplay in a rather undefined and unsteady way to be addressed in a single study. Some of the external and internal factors are difficult to identify, measure or model. It is also difficult to integrate all of these aspects into one model. Construction operations cannot be easily modelled to integratively address at the same time the problems of waiting for instructions or information; variation orders; M & E component procurement and construction delays; weather and design discrepancies.

Laufer et al (1998) opine that the factors that affect construction time originate in independent and interdependent areas. The role of management, the impact of design and designers, and the influence of the owner are shown to interrelate with good time performance. They developed an integrative approach which shows that even the most advanced technology will be limited in bringing about any sizeable schedule compression without effective organisation and management; both could not work without an adequate infrastructure and without allowing for uncertainty involved in and around the process environment. They conclude that contractors should attempt to improve both technology and management and make them less sensitive to the effects of environmental factors.

Harris et al (1985) reported the frequency of occurrence of problems leading to unanticipated delays in large construction projects. Figure 3.5 illustrates that waiting for information, variation orders and M & E procurement problems were ranked amongst the highest. To address the problem of material procurement difficulties of long-lead items, they recommend that supply contracts be placed earlier, as soon as specifications of what to order was clear or that start of construction be delayed to accommodate long-lead supply items.

Odeh et al (2002) looked at the causes of delays in construction projects with the traditional type contracts. They ranked the delay factors in each category according to the views of contractors and consultants and conclude that owner interference, inadequate contractor experience, financing and payments, labour productivity, slow decision making, inadequate planning and subcontractors are the most important factors. Appendices D and E illustrate the ranking of the delay factors and their categories.

Olomolaiye et al (1997) studied the frequency and severity of factors influencing construction time and cost overruns. Results show that design changes, inadequate planning and poor labour productivity ranked very high. Appendix F illustrates the 11 variables considered.

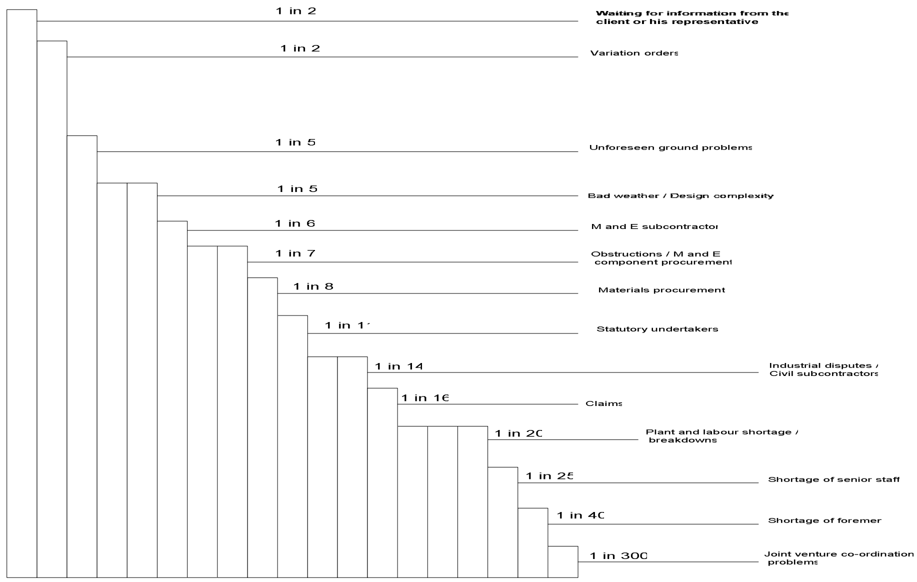

Fig. 3.5 – Proportion of large UK projects which experience delays as a result Factors shown (Contractor's View)
Source: Lewis et al (1996)

Kumaraswamy et al (2002) discussed reasons for project delays and show that project scope, project complexity, project environment and management attitude are important factors which affect project duration. Using opinion surveys, site visits and interviews of industry experts, they ranked significant factors that contribute to fast construction. Tables 3.1 shows their findings that labour management and timely delivery of materials are important to accelerate the construction process.

Table 3.1 Perceived significant factors that aids fast construction **(listed in decreasing importance)**

Rank	Client's view	Contractor's view
1.	Adequate supply of workforce	Adequate supply of workforce
2.	Appropriate labour deployment	Timely delivery of materials to site
3.	Adequate contractor's experience	Favourable site conditions
4.	Adequate skill / experience of workforce	Adequate pre-construction planning
5.	Identifying critical activities	Suitable leadership style of project manager

Source: Kumaraswamy et al (2002)

Figure 3.6 illustrates views of the client and contractors in each category of factors investigated. The client considered that identifying critical activities and setting milestones dates is most important factor in progress scheduling which will enhance fast construction. While in the views of the contractors, foreseeing possible contingencies is second most important, ranking after progress monitoring.

Lewis et al (1996) present results of an investigation into the nature, length and cost of delays that occurred in thirty building projects. They show that variation orders, components procurement problems, ambiguities in plans and specifications are common delay situations in all thirty projects studied.

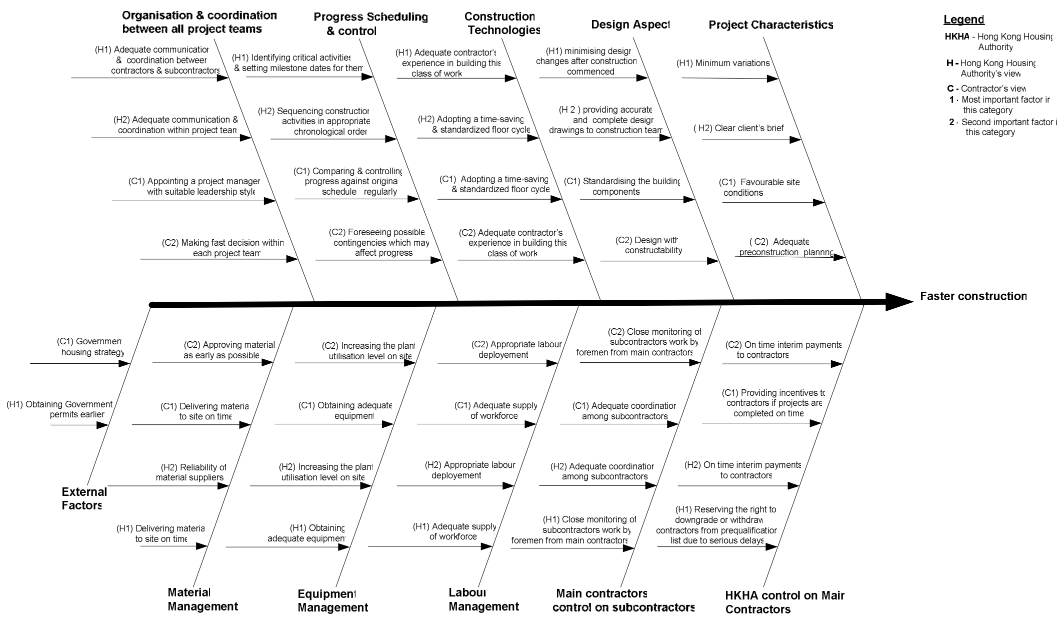

Fig. 3.6 – Fish-bone diagram showing important factors contributing to fast construction
Source: Kumaraswamy (2002)

Appendix G illustrates delay situations in all thirty projects which indicate that common delay causes are variation orders, omissions in drawings and specifications, late payment, ambiguities/errors in drawings and specifications, rework, change in sequence, and poor scheduling. Some results of the five delay studies presented above are included in the appendix and their synopses is shown below.

Delay causes from study i [Harris -1985]

1. Material procurement
2. Waiting for information
3. Variation order
4. Construction plant problems
5. M & E component procurement and construction
6. Design complexity
7. Labour problems
8. Weather
9. Physical obstructions
10. Foremen / supervision shortage
11. M & E and Civil subcontractors
12. Statutory undertakers
13. Extraneous contract conditions and claims
14. Ground problems
15. Industrial relations
16. Joint venture and co-ordination problems

Delay causes from study ii [Odeh-2002]

Category	Factors
I Client	1. Finance and payment of completed work
	2. Owner interference
	3. Slow decision making by owners
	4. Unrealistic imposed contract period
II Contractor	5. Subcontractors
	6. Site management
	7. Construction methods
	8. Inadequate planning
	9. Mistakes during construction
	10. Inadequate contractor experience
	11. Contracts management problems

study ii contd.

Category	Factors
III Consultants	12. Preparation and approval of drawings
	13. Quality assurance and control
	14. Inspection, test, and waiting time for approval etc.
IV. Material	15. Quality problems
	16. Supply problems
V. Labour and Equipment	17. Labour supply
	18. Labour productivity
	19. Equipment availability and failure
VI. Contract	20. Change orders
	21. Mistakes and discrepancies
	22. Contract document
VII. Contract relationships	23. Disputes and negotiations
	24. Inappropriate organisational structure
	25. Lack of communication between parties
VIII. External factors	26. Weather condition
	27. Regulatory changes and building code
	28. Problems with neighbour and unforeseen ground conditions

Delay causes from study iii [Olomolaiye-1997]

1. unpredictable weather conditions
2. Inaccuracy of materials estimate
3. Inaccurate prediction of craftsmen production rate
4. Inaccurate prediction of equipment production rate
5. Material supply problems
6. Equipment shortage / breakdown
7. Skilled labour shortage
8. Locational restriction of the project
9. Inadequate planning

Study iii contd.

10. Poor labour productivity
11. Design changes

Delay causes from study iv [Kummaraswamy-2002]

1. Inclement weather
2. Labour shortage / Low labour productivity
3. Poor sub-contractors performance
4. Too much of sub-contracting
5. Variation orders (design changes / Extra work)
6. Unforeseen ground conditions
7. Material shortage / late material delivery
8. Inadequate construction planning
9. Payment and financial problems
10. Delays in design work / Lack of design information
11. Poor site management
12. Impractical design / Constructability
13. Poor communication
14. Inappropriate type of contractual arrangement
15. Lack of designer's experience
16. Inaccurate estimating

Delay causes from study v [Lewis-1996]

1. Payment delays
2. Part of site not available
3. Poor work sequencing / scheduling
4. Component procurement problems
5. Manpower problems
6. Change orders / extra works request by client
7. Heavy rains / flooding of job site
8. Subsurface different from that expected
9. M & E changes
10. Errors in plans and specifications
11. Ambiguities in plans and specifications
12. Power supply problems

This synopsis of the delay situations and others abundant in the literature sets the scene for researchers to ask the following pertinent probing questions; which of these delay situations are easily identifiable and which are not? Which are measurable and which are not? How can the construction process be modelled to mitigate these factors? To which specific individual or groups of activities or work packages do they apply? Which are within the control of management and to what degree and with what tools, e.g., planning and scheduling, project implementation strategies and so on. One way to mitigate them is setting practical start dates for tasks and arranging for resources accordingly. The consequences of these delay situations on downtime is also an important study objective.

3.4.2 Productive work time and Downtime cost

Downtime of construction resources affect both project time and budget. There might result a potential reduction in time and project cost due to better man-hour and machine-hour management. Lewis et al (1996) show from their study on the analysis of construction delays, the length and cost of delays experienced in 30 selected projects. Appendix G illustrates that for project I, payment delays prolonged completion by 24 weeks and caused a budget increase of $150,000. In project XXVIII, additional works ordered by the client caused a 6 weeks delay with an increase in project cost of almost half a million dollars. These increases in cost and time may be as a direct result of the delay situation and downtime of affected tasks and resources or a consequential effect impacting on other tasks and resources, [Vorster-1980].

The relationship between project prolongation and cost is clear. A delay gives rise to some cost which may or may not linearly correlates with the length of time of the prolongation. But the relationship between productive work time and downtime is not too clear. Several researchers; Olomolaiye et al(1998), Turner et al(1964), Smith et al(1989), Vorster et al(1980), and Thomas et al(1990) investigated this issue and concluded that the relationship between productive work time, delay time and output is not linear as would normally expect. Thomas et al (1990) states that three fundamental assumptions must be satisfied for a work-study model to be a valid productivity model:

(i) Productive work time and waiting or delay time are related;

(ii) Productive work time is related to output i.e., if productive work time is known, output can be assessed;

(iii) Implying from (i) and (ii) waiting time is related to output i.e., productivity should improve as waiting time is reduced.

<table>
<tr><td colspan="3">TOTAL AVAILABLE WORK TIME</td></tr>
<tr><td rowspan="2">MAJOR DELAY TIME</td><td colspan="2">NET AVAILABLE WORK TIME</td></tr>
<tr><td>PRODUCTIVE TIME</td><td>MINOR DELAY TIME</td></tr>
</table>

Fig. 3.7 – Graphical Representation of the Delay Model
Source: Thomas et al (1990)

In a literature critique of the Delay, Activity sampling and Task models, Thomas et al (1990) opine that these work-study models borrowed from industrial engineering are inadequate and unreliable productivity models for construction works. They argue that these models emphasize mainly work methods where as the best opportunity to improve productivity is to focus on the factors that management can control and develop contingency plans and approaches to address those aspects over which management has little control. There is limited choice or control of the work method adopted. It is often, always fixed by the resources the firm holds and the work conditions. Turner et al (1964) show that in many work situations it is reasonable for the planner and work face managers to adopt methods which may be less economical to ensure that firm's resources are employed instead of hiring.

The delay model of work-study divides the workday into three major parts, allowing for a record of instances in which the work is subject to delays; These are the total available work time, the net available work time and the productive or direct work time illustrated in Figure 3.7. The delay model is best suited to close systems that have few external influences and is applied to steady-state, equipment-intensive operations. It is difficult to apply it to model labour-intensive, unstructured and unsteady work flow process like in construction [clemmans-1978], cited in Thomas et al (1990). Though studies show that delays on labour-intensive activities tend to be distributed according to a recognised pattern, the output-productive work time relationship even for simple operations is very complex. Figure 3.8 illustrates the loss of productivity for a slip-form paving operation and for masonry crews on commercial projects as a function of downtime [Smith-1989 and Horner-1989].

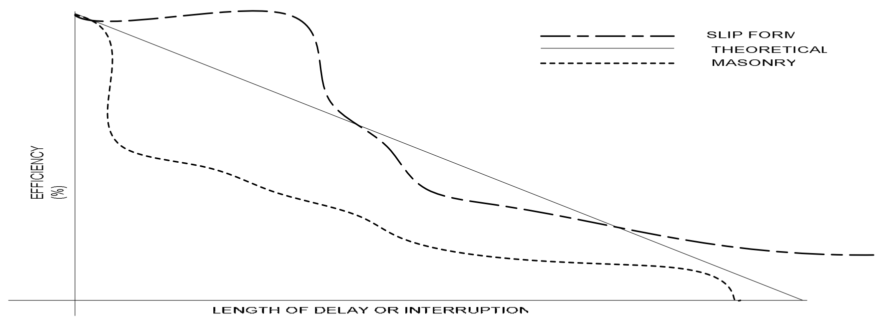

Fig. 3.8 – Relationship between Efficiency and length of Interruption
Source: Thomas et al (1990)

Obviously production output and productive time are not all that proportional. This is because interruptions do occur at random and they are outcome of many dynamic forces. Similar results have been reported by Logcher (1978) in the study of productivity of five projects involving floor tiling. Presenting objective data they show that productive work time was not related to productivity and that time spent on breaks and non-job related activities was only weakly correlated to productivity.

The activity model is based on the work-measurement technique which measures the time engaged in various activities. It is applied to labour-intensive activities like most construction works. Appendix H illustrates the distribution of the workers time according to this model. It shows that Breaks, Late start and early quits, Direct or productive work time, Instructions and reading drawings, Tools and Materials handling, Transporting components, Travelling from point to point and Waiting time represent 3.9 %, 3.0 %, 32.4 %, 6.3 %, 5.4 %, 4.6 %, 12.4 %, and 32.0 % respectively. Further work on the activity sampling model particularly with regards to its application to construction have been reported by Olomolaiye and Christain. Olomolaiye et al (1998) presented a similar configuration of the construction workers time for activities. They show that Supervision, breaks, productive time and unproductive time are 2.1%, 13 %, 55.5% and 29.4% respectively as illustrated in Appendix I. While Christian et al (1995) identify four work time categories: Effective work time, Essential contributory work time, waiting time and idle time. They argue that factors which can be easily identified and when modified leads to significant improvement in production should be the focus of management. Effective work positively influences the progress of the activity; it results in an increase in the quantity or size of the unit being constructed.

Work that has an indirect but positive influence on progress, such as preparatory, finishing, movement of materials or Equipment for essential purposes is considered essential contributory. Idle time represents a category in which the work could, but did not progress because the worker was not working. However, if a worker is unable to perform a task because of uncontrollable external factor such as late concrete delivery, information, approval etc, then the lost time is considered waiting time, not idle. They conclude that by noting whether lost productivity was due to 'waiting' or 'idle' time, it was recognised that many of the factors affecting activities' progress could be rectified or improved by a response from management. Site managers with information on factors that create inefficiencies are well positioned to organise workers to achieve good production rates. This way attention of management is not vaguely and imprecisely directed to the cause of inefficiency.

As stated previously, a valid productivity model requires that productive or direct work time and output be related in some predictable fashion. Studies show that productive work time and productivity are unrelated as figure 3.8 illustrates. Only in very few cases has relationship been identified Thomas (1983). And these occur where work scope is narrowly defined, definition of productive work time is very restrictive, detailed measurement of output is possible and the output production process is very elementary. A common assumption of work sampling is that a reduction in delays or interruptions will make more time available for productive work. This relationship was investigated by Thomas et al (1990). Results show that the notion of a linear relationship is false. It holds if and only if all other factors like breaks, time for instructions and reading drawings, handling tools etc are held constant, figure 3.9.

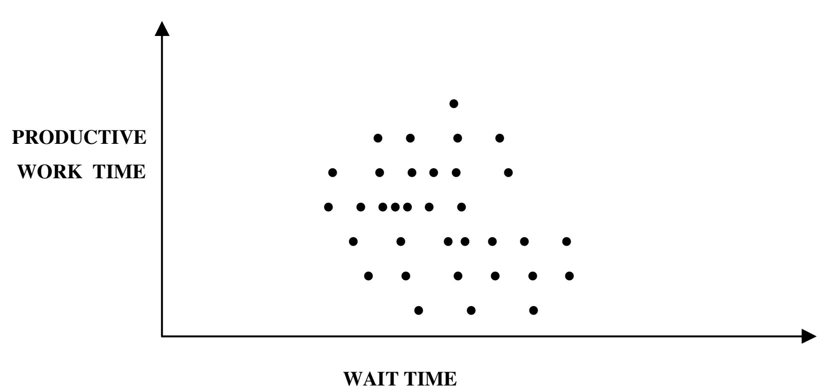

Fig.3.9 – Relationship between productive work time and wait time
source: Based on Thomas et al (1990)

This non-linear relationship is explained that any change in waiting time could be absolved or compensated for by other components of the model like late start and early quits, instructions etc. This means the effects of a reduction or increase in delay time does not always show a proportional change in productive work time. Therefore as management is focusing on reducing wait time other issues in Appendices H and I that may eat into the productive work time should be addressed as well. Rogge et al(1982) used objective data to show that productivity and wait time are only weakly related. This supports the cited works of Smith and Horner that the wait time-productivity relationship is very unclear, especially for large duration delays. This is why Christian reported a significantly different view from Thomas et al (1990) in a study recording operations in minutes. They show that crews which did not experience much interruptions had better output than crews which experienced interruptions.

Due to the dynamics of the construction environment, work-study techniques are generally unsuitable productivity models. They do not model the important external and management factors affecting productivity. Output is usually not an element of the model, and various assumptions about the relationship between delay time, productive work time and output are unsupportable except for very few cases. Many studies show that productivity can be optimised by modifying those aspects of the working environment over which management has control e.g., practical start dates, work date regime or project calendar, the method of production notwithstanding.

To improve resource use factor, Ballard (1998) suggested the use of short term planning, the weekly work plan. This is a list of work assignment to be completed within the specified week. It does enhance the reliability of the schedule since it is typically produced as near as possible to the beginning of the week. The problem with this approach however, is that it takes a fairly long time to muster resources particularly equipment, if hired. A weekly work plan as a remedy to improve labour and equipment utilisation would mean these resources are sourced only about five to seven days or even less time to the actual field operations. However experience show that in most cases it is not feasible. Instead of Ballard’s weekly work plan, assessing and setting practical start dates for tasks depending on a knowledge of their attributes may probably yield a reduction in downtime of expensive construction resources on the jobsite.

3.5 Performance Data and Project Reporting Systems

Project reporting is about information of the process operation. Schindler et al (2003) Poses the following four important questions in a project feedback and information system:

- What was supposed to happen?
- What actually happened?
- Why were there differences? and
- What can one learn?

Ronie et al (2003) citing Chrysostomou (2000) posed similar set of four relevant project control questions:

- How many hours do workers actually work?
- How productive are they?
- How many hours are resources kept idle? and
- What are the causes?

There are different reasons why companies measure performance. The Egan report (1998) States that performance measurement will improve Construction industry operations. The report introduced targets for improvements and emphasized the need to measure performance against these set targets. What gets measured gets improved. Construction performance measurement is difficult but it very important, [Unpublished M.Sc. notes of the Project Management class of the Heriot-Watt University]. Performance measurement should embrace broader issues other than the traditional time, cost, and quality metrics of performance. Downtime of resources and causal reasons is one of these.

A typical measurement process defines what to measure, how to collect process data and then evaluate it to provide the facts needed for making changes for improvement in the system. Both financial and non-financial metrics should be considered. Different metrics pose different demands on a measurement system. A system developer should consider why performance measurement is actually required before defining and implementing one. This is why Tatum (1985) suggests that evaluating project progress should involve:

- Identification of the evaluation objective
- Selection of work division needing evaluation
- Definition of earning rules and
- Implementation

Lockyer et al (1991) argues that in order to measure performance and assess the effects of any change on the construction process, one must first determine the appropriate key performance indicators to focus on and to measure its impact. Project control measurement should be appropriately precise, pertinent, fast, of consistent accuracy and should involve minimum handling ie., reduced processing stations. Measuring activities on the critical path to the nearest day is helpful since any ‘slip’ would result in an increase in overall project time. On the other hand monitoring activities with large float like this would be a useless expense. Project files of industry bulge with data that are not used. It is essential to question the use of whatever data collected. Robert et al (2003) opine that only those data which directly predict performance should be measured and reported. True assessment of construction performance is attained when key indicators are determined and carefully monitored.

Different performance indicators are relevant to different levels of the project organisational structure. To the chief executive or office manager, cost and earned value analysis are important to reveal which project will be under or over budget, and which will overrun in time. However, to the workface manager or foreman, earned hours, resource downtime and causal reasons are important track records so that the works can be re-organised to bring it on track. Cleland (1985) observes that all too often a project manager is deluged with an abundance of data about the project, but finds little relevant information that can tell the status of the project, nor measure efficiency of operations.
Measurement of results should follow a set guidelines in data collection. Cleland suggested that:

(i) The objective should be to develop measurement of project trends and results through information arising out of the management of the elements in the work breakdown structure.
(ii) Measurement should be kept to a minimum relevant to each work package in the work breakdown structure but sufficient to show not only project status, but efficiency of operations as well. There is some debate here. For construction works all operational aspects should be reported.
(iii) Measurement of work packages should be integrated into the measurement of the project as a whole.
(iv) Measurement should be developed that are applicable to both current project results and future projections. i.e., track records should be in a form in which projection into the future is both possible and easy.

(v) Measurement should be conducted around previously planned key result areas. Those areas which are of sufficient basic importance to act as "direction indicators" of the project status. E.g. Technical performance parameters, cost parameters, schedule parameters, strategic fit with organisational product strategies, finance return, productivity, and competitiveness.

3.5.1 What to Measure and Why

Identification of the evaluation objectives called for by Tatum (1985), Lockyer (1991), Robert (2003) and Cleland (1985) establishes what to measure in project performance assessment. Site operations information should be reported in the following project control aspects of :

- Time
- Quality
- Money and
- Other resources

Robert et al (2003) states that the most commonly accepted performance indicators are those that can be physically measured by money unit, quantity unit and man- or machine-hour unit. Like many other forms of business, construction companies look first to the areas which show a change in the amount of revenue generated.
This generally is the incentive for project reporting. Brian et al (2004) listed elaborately the reasons why contractors keep site records.

Traditionally, keeping of site records by the contractor is imperative for the purpose of receiving his due entitlement as prescribed in the contract conditions and to pay his sub-contractors what is due to them. Seldom is there an incentive of site records as means of 'self-checking' or 'self-assessment' of appropriateness of methods of operations. And so site records are seen as being necessary only mainly for:

- Establishing the basis for various forms of payment
- Substantiation applications for extension of time and
- Reporting progress to a site meeting

Projects are transient phenomena, a sort of 'finish-and-go'. Few companies have organisations, money, systems or practices that span them, especially for the purpose of gleaning and improving upon transferable lessons of project process, [Kenneth et al - 2002]. There is a natural incentive and pressure to get on with the next project and especially not to dwell on the failure records of the past, what worked and what did not. Thomas (2001) listed twenty four common types of records that contractors keep ; Daily site diaries, master programme update, records of resources etc. For effective project control, emphasis must be on the content of these records, the issues recorded, the aspects of production operations recorded and how these will help unveil problems in the production system.

Although, it has been established that there is a general agreement that some form of performance measurement is important for organisational control, there is no general model that conveys a precise constitution of such a system; what to measure, how to measure and what degree of detail etc is not too structured in generic terms. Different companies have different approaches and styles. Performance measurement therefore can be described in many ways. They can be simple or complex, general or specific etc. Some aspects of construction works have clearly visible progress indicators. While progress in others like bulk production and installation of engineering systems- ventilating, heating, air conditioning, plumbing and electrical works do not have clear indicators of progress. These need a different monitoring system. For this class of work, Tatum (1985) observes that three types of information are needed to evaluate progress:

(i) Scope growth in terms of quantity installed
(ii) Materials and resources supplied
(iii) Interim measures of both progress and resource use

Which progress data are reported that give the true project status and show operational efficiency needs to be carefully assessed. Saad (2003) investigated the effectiveness of some common project monitoring systems used to detect deviations from planned cost and schedule. The study shows that though the leading parameter technique, variance method and activity based ratios technique measure efficiency, they indicate only very broadly that something is wrong or right. They are not able to show where the problem is. They give global picture of the situation sufficient only for certain management strategic action. Such picture is usually inadequate for site action production planning. When progress data show only expenditure or earning, resource use efficiency resulting in low actual earning or high actual expenditure may not be readily identified in the system. This is because such low actual earnings could result from reduced work scope and the high actual expenditure may result from increased work scope. In which case data has not been able to show whether operations have been efficient or not. Performance data should show:

(i) Resource information, planned requirement, actual requirement and utilisation level.

(ii) Percent of activity complete. This could be percent of elapsed scheduled duration or percent of actual work complete.

(iii) Contractor's earning based on the portions of the activity completed.

(iv) Equipment and Labour return information. A description of major items of Construction equipment moved to site, showing type, number of units, unit capacity and schedule of time equipment worked keyed to activities on which they worked.

What progress is made since the start or the last reporting period and what changes in scope or logic have been made and which more are necessary to meet programme requirements are fundamental issues reported, [Albert -2000]. These two basic information could be gleaned from the following site production records:

- Daily site production dairy
- Time lost per period, day, week or month
- Equipment and work force records
- Instructions and confirmation of verbal Architects Instructions
- Additional work scope due to unforeseen conditions
- Drawings issuance register
- Materials and components received
- Dayworks records
- Records of other delay situations and their effects on the programme and cost

Progress tracking data can be generally grouped into:

(i) Date – Deadlines, start date, finish date and other milestone dates.

(ii) Duration – Initial total time, Elapsed time and remaining duration.

(iii) Work – Volume, Quantity.

(iv) Cost and other resources.

Fields used in tracking progress in Microsoft project are illustrated in table 3.2. It shows the initial baseline values, the current schedule, what should happen, what actually happened and the difference.

Table3.2 – The fields used in tracking in Microsoft project

Task fields			
Current schedule	Baseline	Variance	Actual
Start	Baseline start	Start Variance	Actual start
Finish	Baseline finish	Finish Variance	Actual Finish
Duration	Baseline duration	Duration Variance	Elapsed Duration
			Remaining Duration
Work	Baseline work	Work Variance	Work complete
			Remaining work
Cost	Baseline cost	Cost Variance	Cost to date
			Remaining cost

Source: Tim Pyron (1998)

3.5.2 Variance Analysis

Project reporting is really about variance reporting. The report should recognise that only if work has been completed does negative or positive variances tell the true story. Also it should recognise that variances could arise from different alternate causes:

- Level of control
- Some hidden outgoings not recorded
- Some over/under estimating when initially planning

For earned value analysis the following information should be reported.

(i) BCWP = Cumulative budgeted cost of work performed

(ii) ACWP = Cumulative actual cost of work performed

(iii) BCWS = Total budgeted cost of work scheduled

These three parameters yield

(a) The Schedule Variance (in terms of cost) = BCWP – BCWS

(b) The Cost Variance = BCWP - ACWP

These variances indicate to management the magnitude, location and reasons for current and future problems. As stated previously that it is argued that earned value analysis is useful mainly for top management functions and is of little application for control of resources at the work face level, considering the two variances together yields some useful progress information about the project. For this definition of variance:

- A negative schedule variance with zero cost variance suggests a project running late with no overspend
- A negative cost variance with zero schedule variance suggests a project which is on time with an overspend
- A negative schedule variance with a negative cost variance suggest a project running late and which is also overspent

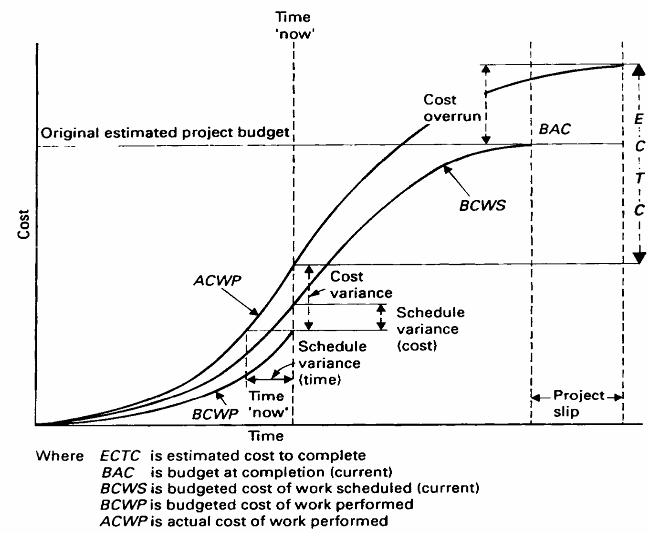

Fig. 3.10 – Cost curves showing progress status.
Source: Lockyer (1991)

If data are plotted as shown in figure 3.10 it can be very revealing showing; the planned cost, incurred cost and budgeted cost of work performed. To explore a variance more thoroughly as would be necessary to reveal downtime of resources, the variance is broken down into a set of sub-budget variances. This technique is known as Variance analysis. Estimates of expenditure are usually made up from equipment, labour, materials and overhead cost as illustrated in figure 3.11.

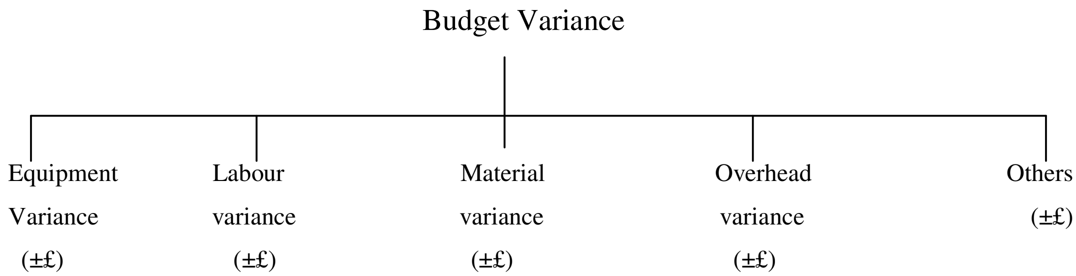

Fig. 3.11 – Subbudget Variances.
Source: Lockyer et al (1991)

If the main variance is shown in the equipment component, this variance may itself be split into equipment time variance, which may include downtime and use time; equipment hire rate variance; and equipment running cost variance. As indicated, equipment hours variance may be split further into use time and downtime variances if required. So can the materials, overheads and labour components. The entire budget itself may have been changed during the course of the project and a budget revision variance may be appropriate. This way a complex triangle of variance analysis is built up. Project reporting recognises that whilst variance analysis is an invaluable technique which enables investigation to be focused on trouble areas, care should be taken to carry the analysis no further than is useful. It is tempting to erect a highly detailed triangle displaying every possible sub-variance, but this may cluster the information system. It is better to start small and enlarge only when it seems useful.

3.5.3 Effective Project Reporting Guidelines

Records normally assume greater importance after the event than during it. Adequate records during projects are necessary – guideline one. Such records should have no substitute for writing it down – guideline two. Keeping it in head memory is like no record at all [Brian- 2004]. An important understanding in project reporting is that the past is dead – guideline three. The history of the past is necessary mainly only to take steps to avoid a re-occurrence of whatever failed. This is why the focus has been on remaining work, remaining task and remaining duration etc.

It is also argued that the past is not truly dead, as such. It is still the responsible force which shapes both the present and sets the basis for the future even in a scheduling sense. And this is why undesirable variance deviations should be meticulously recorded and investigated. Guideline four – progress should be reported in simple form: 'Not complete' or 'Complete'. For the question: "Is activity X complete?" A response should either be ' Yes' or 'No'. And if 'No', then a second question; "How much time is required to complete activity X?" should be asked. Statements such as: " nearly finished", "almost finished", "In process or in progress", " just a little to do", "It'll soon be done", and so on should be eschewed. These show a sloppiness of mind and an avoidance of responsibility.

3.6 Summary

This chapter presented a general view of literature in Schedule revision in the context of downtime of construction resources. Several authors pointed out that often, dates and duration are carefully tracked but not much attention is given to track work, individual resources, and cost, [Kog -1999, and Lowery-2001]. Also, that track records show work status reasonably but are not able to show efficiency of process operations.

Status and efficiency are different ball games. Schedule revision as seen from literature does not have identification of downtime of resources as a high priority. Downtime of resources and its consequential costs are not very obvious, they are hidden, unless good effort is applied in project data collection and analysis. This explains why likely downtime is not given good attention at the initial schedule development since it is not even recorded at project review. It shows management attention is not on it at all. Schedule review literature show that setting practical starting dates for tasks based on a knowledge of task attributes and removing all constraints (at least reasonably well) before fixing a start date may help reduce the downtime of this and subsequent events significantly.

CHAPTER 4 – RESEARCH METHODOLOGY

4.1 Introduction

Chapter 2 and 3 reviewed the context literature relating to construction scheduling practices which affect non-worktime of construction resources. Those chapters developed from literature effective scheduling and effective project reporting guidelines. They established that the scheduling process and procedure does significantly impact on project performance. This chapter presents the methodology adopted to provide the data to study the scheduling process and to relate scheduling procedures to project performance. Both quantitative and qualitative research strategies have been adopted to investigate the problem. A justification of adopted methodologies is also presented.

4.2 Flow Chart of Research Methodology

The methodology used in this study is presented in figure 4.1. A preliminary literature in the domain problem and later a thorough and extensive review in this same area show that the problem of resource downtime or non-worktime can be investigated by comparing the 'As-Built' schedule with the 'As-Planned' schedule. To confirm the length and breadth of the problem and to define how best to proceed with the investigation, a scoping survey was conducted for about four months visiting field experts and discussing with them the problem of non-worktime of construction resources. The literature and the further enlightenment gained from the scoping survey helped to identify the boundary of the research problem and also to define three research approaches to investigate the issue of non-worktime of construction resources on the jobsite. These approaches are:

(a) Mapping the planning process through a questionnaire survey
(b) Case study and document analysis to establish performance as a result of the procedure followed in the planning process and,
(c) Further experts opinions to clarify and consolidate the data generated from the previous two sources.

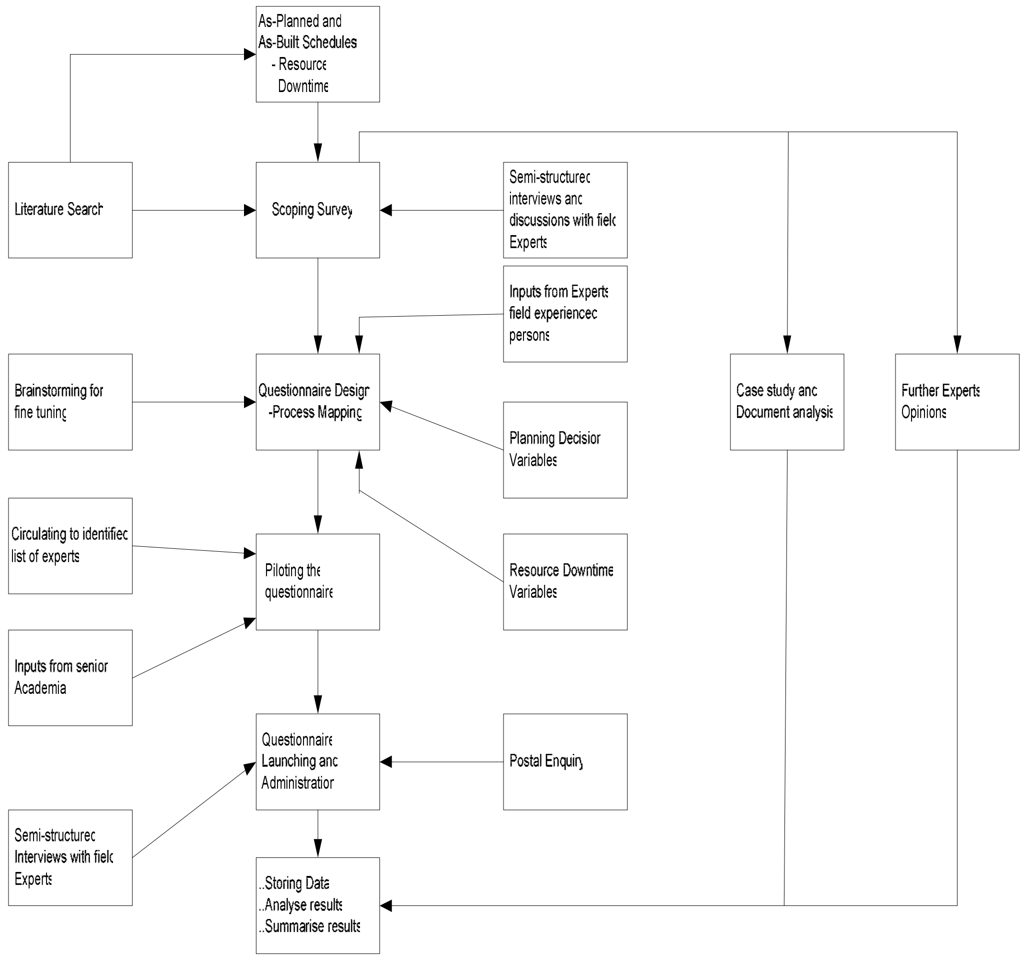

Fig 4.1 – Flow chart of study methodology

4.3 Scoping Survey

A scoping survey was conducted to give an insight into the research problem. The aim was to determine whether the problem was researchable or not and to define what methods to adopt to investigate it. The duration of the survey was approximately four months. About fifty construction companies were sent fax messages informing them of the proposed research aimed to improve the construction planning process. Eventually, at that stage, unstructured interviews were held with planning Managers of two contractor's organisations. Results suggest that there was a problem of non-worktime of construction resources on the jobsite. The magnitude of the problem at the time has not been thoroughly investigated. The experts confirmed what literature holds that resource idleness is due to poor planning as well poor plan implementation.

What is not clear is the component of non-worktime of resources which may be related to poor planning or poor plan implementation, and how the planning process could help to reduce levels of non-worktime of these resources. Most experts interviewed said the problem of poor planning was because of unavailability of relevant information and that the decision process is too intuitive rather than knowledge-based.

Finally, from the scoping survey, some insight was gained on the areas with the highest likelihood of schedule failure, that the ground works and the M & E installations have major problems followed by cladding and the finishing trades. The conclusion drawn from the scoping survey was that if samples of non-worktime of resources were studied in selected projects and identifying causal reasons, it may be possible to build a decision rule model for planning to reduce non-worktime of construction resources. And that such key variables as construction methods, sequence, location and sizing of buffers were thought to be important components of such a framework.

4.4 Research Context and Initial Strategy Consideration

Research strategy is the determination of the method for investigating a research problem. The 'how' question is assessed according to the nature of the problem investigated, purpose of the study and the nature and availability of relevant data. Strategies for doing research may be quantitative, qualitative or some sort of pluralistic approach employing a hybrid or a triangulation of quantitative and qualitative strategies to investigate the problem.

Purpose of investigation may be exploratory study – seeking to know new facts; confirmatory study – consolidating previously existing knowledge or idea and a process improvement study- building incremental improvement upon existing knowledge. Naoum (1998) defines quantitative research as an objective measurement of the problem. It investigates variables which are countable, having units of measure, and tries to establish relationships between them. On the other hand, qualitative research is a subjective assessment of the problem. It takes the form of opinion survey, views, perception or attitude towards objects. Objects being defined in this respect as attributes, variables and factors.

The reported study is more of a process improvement investigation. But it includes some exploratory as well as confirmatory studies. Some aspects of the problem investigated deals with attitude of firms regarding construction planning, the practices and procedures of this process common to firms. For this aspect, a qualitative research approach using postal questionnaire survey instrument was initially considered to map the planning process. While a quantitative research approach involving counting such variables as man-hour, machine-hour, as-built and as-planned was initially considered to assess causal reasons for non-worktime of construction resources.

4.5 Questionnaire Survey – Process Mapping

The aim of the investigation is to build a procedural framework for scheduling which may improve project performance. From literature there is a wealth of knowledge on what makes a construction plan good and how to achieve it. As an initial step therefore, the study mapped current planning methods used by several contractors. The purpose was to study if the problem of construction schedule failure was due to a procedural gap or whether specific knowledge aspect may be lacking in the scheduling domain. The process mapping was conducted with the use of semi-structured questionnaire interview surveys. The survey method was selected because a fairly large sample size was required to investigate the problem. The postal questionnaire was to provide a broad based attitude of firms and their procedures for scheduling construction works. While the interview survey was to clarify certain issues of procedures adopted by firms and to investigate why. On piloting the questionnaire, it was found necessary to administer it both as a postal survey and semi-structure interview with the drawn questions forming the basis. This is because test respondents during piloting considered some of the questions needed a bit further explanations that a postal option could not provide. A questionnaire containing 37 questions, mainly 'closed-ended' type questions of multi-option format was designed to elicit the data required to assess current industry practice, as illustrated in appendix J . The questions were grouped into four parts:

- Company and respondents related information
- Initial schedule development
- Schedule up-date and control and
- Schedule performance assessment

The objective of the questionnaire was to identify how scheduling decisions are being made and to generate data to model to replace intuition with some sort of knowledge-base application. The questionnaire was administered both in the United Kingdom and in Nigeria to provide a comparative study of procedure in one country which uses more of precast and off-site production technique and the other country which uses mainly in-situ, site based methods. Twenty three of the top 100 UK construction companies were sent the piloted questionnaire. This was followed with telephone calls. Eventually, five responded giving a response rate of 22%. In Nigeria, semi-structured interviews were held with four of the top twenty construction companies where the same questionnaire was used as the basis. In a way the approach in Nigeria was mainly the semi-structure interview method while in UK the postal questionnaire and informal discussions with field experts was mainly employed to investigate the problem.

4.6 Case Study and Document Analysis of Archival Records

Case study or archival data is an aspect of knowledge engineering which involves extraction and consolidation of knowledge from explicitly documented sources. It has the objective of not only establishing facts and figures but relating these to causal reasons. Site diaries and case projects were obtained from four large on-going projects to investigate the problem of non-worktime of construction resources on the jobsite. The case study focused on the measurement of such variables as man-hour, machine-hour and a document analysis of site meetings which suggest a categorisation of activities depending on attributes. The purpose was to identify non-worktime of equipment and labour resources with causal reasons so that an appropriate procedural framework can be modelled that may make the scheduling process effective, ensuring that things happen as planned with minimal non-worktime of expensive construction resources.

4.7 Summary

The flow chart of the methodology used in the study shows that preliminary literature works led to a scoping survey of the problem investigated. This eventually identified the questionnaire survey; case study and archival document analysis; and expert opinions as initial consideration of research strategies which were later slightly modified.

CHAPTER 5 - MAPPING THE SCHEDULING PROCESS

5.1 Introduction

The scheduling process is a decision making process. Many decisions are necessary and options are also many. The way these decisions are made, whether intuitive, based on rule of the thumb or some sort of scientific reasoning which is knowledge-based is considered. This chapter presents the data generated from the postal questionnaire source and scheduling knowledge of the problem domain elicited from experienced practitioners through semi-structured interviews and other informal discussions. The data obtained from these experts is presented in three sections: Company and respondent related information, Scheduling decisions and significant variables which create non-worktime of construction resources.

5.1.1 Company and Respondent Related Information

The objective of this section is to give a general view of the responding companies and the background of the experts normally responsible for scheduling construction works for the company. It is thought that size of company, scope of projects handled and construction sector in which the company operates may affect style of scheduling work.

(a) Those who Do Scheduling

During the field interview stage one Architect and one Quantity Surveyor were encountered who do scheduling for their company. Most others are Building and Civil Engineers. The Quantity Surveyor occupied this position by virtue of the fact that he is the sole director of the company. He owns the business and it was appropriate for him to plan and schedule his operations and resources for the job as this will offer him opportunity for keeping a close eye. The Architect, working for a multi-national company was initially in the procurement department for finishing trades materials. And because of a need for close liaison of tying his materials procurement programme with the master schedule, he was drafted to begin preparing master schedules for the company when this position became vacant. The Building and Civil Engineers were observed to have developed in their day-to-day work operations and gradually grew into this position of scheduling construction works for their companies.

And though the response rate from the postal questionnaire is not representative of industry population, it however suggests that scheduling is a Building/Civil Engineering domain. This to a large extent guarantees good project understanding. Architects and

Quantity Surveyors and other members of the Building team wanting to sit on the scheduling chair should not only learn the syntax and language of scheduling but should brush up their construction technology which they would have had nearly sufficient in training.

Table 5.1 - Those who do scheduling

Profession	No. of respondent
Architect	0
Building Engr.	2
Civil Engr.	7
Q.S	0
Others	0
Total	9

(b) Number of Company Employees

Selected companies are the leading industry participants and respondents show that all nine employ over 500 workers. This suggests that these companies contribute a fair share of construction work which is also reflected in the enquiry on the size of projects undertaken

Table 5.2 - Size of company

No. of employees	No. of respondent
Under 50 employees	0
50 – 100 "	0
100 – 500 "	0
Over 500 "	9
Total	9

(c) Size of Projects Handled

Using the cost criteria for assessing project scope, respondents were asked in question 9 to indicate the size of projects they undertake. Respondents indicated they normally undertake work in all three categories, small, large and medium. But some said they do work only in the categories of medium and large and would turn down invitation for tender for small works. The implication of this for the reported study is that the identified procedures could be regarded as those common to large projects of the construction sector presented in (d)

Table 5.3 - Size of projects handled

Size of project	No. of respondent
Small (under £100,000)	1
Medium (£100,000-£1M)	4
Large(over £1M)	8

(d) Construction Sector

Question 8 requested respondents to indicate the class of work normally performed. Most of the respondents indicated they do work in more than one of the listed categories. This suggests that observed scheduling procedure from subsequent questions should apply to types of new builds indicated with more emphasis on residential and educational projects.

Table 5.4 - Number of respondents in each Construction Sector

Type of new build projects	No. of respondent
Residential	8
Office/Commercial	7
Industrial/Factory	6
Educational	8
Hospital	7
others (Sports Arena)	1

5.2 Scheduling Decisions

Construction planning decisions and construction scheduling decisions are very closely related. Planning decisions bear more on the process technology, choice between alternate methods, materials and equipment; while scheduling decisions relate more to the timing element. Though it does relate too to aspects of technology at least as it affect timing of the process. Examples of scheduling decisions are early/late start and calendar date considerations. Though options are provided in most pieces of scheduling software these do not support the decision making process. And as noted previously young and inexperienced scheduling engineers are unable to make choices beyond the default option.

5.2.1 Ranking Planning Decision Criteria

Many criteria affect planning and scheduling decisions to optimise different project objective function; reduction in idle worktime, matching resource availability with requirement and meeting project due date. Respondents were asked in question 20 to score 8 variables in order in which they consider them to be important decision criteria in the scheduling process. Though different objective functions have different weighting from project to project, enquiry suggests that planners ranked the need to meet project due date first. This is followed by the need to meet health and safety requirement; and the optimisation of cost and duration – the old traditional triangle of cost-time- quality. The study suggests that the need to reduce idle worktime and efficient use of resources have a low ranking of 7 and 5 respectively. This is in agreement to a large extent with literature that current practice in scheduling emphasis more time consideration than resource consideration.

Table 5.5 Ranking planning decision criteria

Variables	Rank
Need to reduce Idle worktime	7
Need to maintain equal amount of production for each period of Project life cycle	6
Need to enhance efficient resource use level	5
Need to meet completion date	1
Need to minimise material storage on site	8
Need to meet health and safety requirement	2
Need to optimise cost and duration	2
Need to match resource availability with requirement	4

5.2.2 Early/Late Start Considerations

Though literature supports that the non-worktime of construction resources is best controlled at schedule implementation than during initial schedule development, there seem to be some opportunity to reduce non-worktime by appropriate choice of early/late start considerations; project calendar; and allotment of time buffers between procurement of long-lead items and start of site operations. In question 18 Respondents were asked to indicate whether they use late or early start schedules. There was a generally agreement that in resource levelling, late start schedules seem to have a more levelled and reliable profile than an early start schedule. This agreement is significantly different from results obtained in interviews with experts in which the field experienced persons confirmed that companies prefer the early start option, scheduling virtually all works as soon as possible (This is a default option in Microsoft project). This according to them sets an early temple, brings in earnings early and has some room to correct the inevitable changes that often occur.

Table 5.6 Early/Late Start Choice

Start consideration	No. of respondent who use this option
Early	3
Late	7
No preference	1
Total	9

5.2.3 Workday Hours – Project Calendar

The quantity of workhours scheduled for men and machines is determined by the specified time these resources are to work. The default calendar is the project calendar. But when required other calendar options may be specified. Different resource calendar and task calendars specified may show a plot of workhours for labour and equipment for the entire project life cycle. This plot could show that when the schedule is formulated on a large project calendar, large amount of workhours for men and machines are called to site during each period.

And a comparison of scheduled workhours for men and machine could be made for different calendar options. The argument is that though it may be necessary to progress the works speedily by applying large calendar dates, it is also necessary to be cautious not to call too much men- and machine-hours to site which may become idle. From question 19 of the questionnaire survey and subsequent interviews it was identified that most companies adopt a 5-day workweek and an 8-hour workday. The interview clarified that these default project calendar is applied ‘across board’ affecting all tasks and all resources without due consideration for project specific, task specific and resource specific attributes.

Table 5.7 - Project calendar

Workday Hours	No. of respondents using option
8-Hour workday	4
9-Hour workday	2
10-Hour workday	3
12-Hour workday	0
others	0
Total	9

5.2.4 Buffers between Procurement and Start of On-site Operations

One of the important scheduling decisions is fixing of start time for activities depending on when materials and components can be made available for the start and completion of these operations. There is no point calling large hours of expensive resources of labour and plant to site when long-lead supply items are not in hand. The tying of procurement programme with site production programme may help. But even then an allowance should be made to define a practical start time for this class of work. Respondents were asked in question 23 to indicate what buffer allotment periods to allow for different categories of materials and components. Results from suggest that up to a month period is necessary for items like lifts, about two weeks for purpose made, client specified components and a week for standard materials as illustrated in table 5.8.

Table 5.8 Average time buffer allotment between procurement and on-site operations

Material/Component	Average buffer allotment
Standard materials	1 Week
Made to order Materials	2 Weeks
Engineered to order components	5 Weeks

5.2.5 Variables which Create Non-Worktime and those which Reduce non-worktime

The utilisation rate of Man- and Machine-hours are affected by variables which are related to initial planning decisions as well as those related to subsequent project implementation and project control. For the initial plan development, the ranking of response in questions 21 and 22 where respondents were asked to score variables that are thought to create non-worktime suggests that activity precedence relationship, buffers between activities and the use of multi-skilled labour are ranked low means of scheduling to reduce idle worktime, as illustrated in table 5.9. This is because organising the work sequence to enhance efficient operations in terms of reduced idle worktime must consider and satisfy not only resource constraints, but technology and space constraints.

Table 5.9 Ranking variables which reduce idle worktime

Variables	Rank
Precedence relationship	9
Buffers between on-site activities	7
Use of Multi-skill labour	7
Space requirement planning	6
Buffers between delivery of materials and related on-site activities	5
Type and number of resources used for each activity	1
Buffers between engineering design information and on-site activities	1
Resource levelling	4
Use of off-site production techniques	1

This was noted in the literature that there is not much latitude in the choice of sequence, it being fixed most of the time by the nature of work and the resources the firm holds. The high ranking for type and number of resources used for each activity and engineering information suggest that scheduling should consider task attributes as well as resource attributes in initial scheduling decisions. Table 5.10 presents the ranking of factors which create non-worktime. From the ranking in question 22 respondents show that late delivery of materials and information coming late rank high. Labour disputes and restrictions in work space were ranked low factors which create idle worktime.

Table 5.10 Ranking variables which create idle worktime

Variables	Rank
Late delivery of materials	2
Sequence of activities leading to a prolonged use of plant	5
Restriction in work space	7
Over allocation of resources to some activities	6
Instructions and information coming late	1
Delays in preceding activities	3
Equipment break down	4
Labour disputes	8

5.3 Summary of the Process Mapping and Implications for the Framework Development

The chapter presented the data generated from mapping the planning process. The process was mapped by eliciting experts' opinions on scheduling procedures which may reduce non-worktime of construction resources. Results from this research instrument of semi-structured interviews and postal questionnaires suggest that current practice emphasis more time consideration than resource considerations. The early/late start consideration, project calendar and time buffer allotment were considered important criteria which could affect worktime levels.

Though sample size is not representative of industry population this process mapping results suggest common practice and prevailing procedures. The process mapping shows that there is likely no gap as such in the construction scheduling knowledge domain. The only gap that may exist could be in procedure in that different procedures may enhance or inhibit project performance and so the scheduling engineer need to assess carefully when to apply early/late start and choice of differential application of project calendar for different tasks and different resources. Process mapping results show that information release requirements and buffer allotment between component procurement and start of on-site activities are important scheduling considerations which the proposed framework would address. Project performance and how these established procedures affect it is considered in chapter 6 which presents document analysis and case studies in the domain problem.

CHAPTER 6 - CASE STUDY AND DOCUMENT ANALYSIS

6.1 Introduction

Project performance in terms of labour and equipment worktime has been extracted from a detailed document analysis and case studies of production information from four large sites in Nigeria. The objective is to assess and develop productivity efficiency ratios, resource use efficiency ratios and downtime cost for leading or dominant construction resources. These are compared between different similar project and the scheduling procedures that have yielded these outcomes. From this archival source it was observed that different scheduling Engineers and different companies have different styles of reporting production information. Some emphasise recording labour or equipment information, others focus only on recording work content accomplished during each project period. While a majority monitor and report time elapsed mainly. This difference in style particularly made data collection difficult to study the defined problem in different project scenarios and to link them for comparative analysis between sites. This is why an action research was initially proposed in which a data collection instrument was designed to collect the data as they are generated. This approach was met with much difficulty, both here in the UK and in Nigeria. And to outwit the problem, this aspect of the research on resource use was then based on document analysis of historical data with supporting interviews and discussions to clarify and confirm grey areas.

The lack of uniformity and different emphasis of project reporting means uniform data could not be obtained from different case projects. Different aspects of the research problem therefore is addressed in different case projects because no project could offer all aspects necessary to investigate the problem. This made linking and comparison difficult. This in a way made the data highly statistically insignificant to truly take a defendable stand on the issues addressed as they only superficially point to the direction of the solution. Attempt to reduce this problem was made by going round some of the sites to elicit further views on the problem domain aspects in which the data lacked and which are thought to be important in formulating the framework.

6.2 Case Project 1

This case project involved the construction of two blocks of flats in reinforced in-situ concrete each having three floors. The project was estimated to cost around N500 Million, an equivalent of about £2 Million with initial contract duration of 24 months. Two key data are obtained from this source: Daily rainfall data and daily production information showing various equipment utilisation and non-worktime.

6.2.1 Utilisation and Weekly Time Lost For Crane

These data from this source were analysed for the months of July, August, September and October 2004. The information gleaned from the data are:

(a) Weekly utilisation of equipment focusing on the Crane as a dominant resource

(b) Downtime cost and causal reasons and

(c) Monthly productivity and efficiency of resource use.

Table 6.1 illustrates the rainfall data and production information for the concrete work placement. The amount of rainfall was recorded in hours to show the length of work disruption instead of the normal millimetres or inch of rain. Most contractors operating in the rain belt of Nigeria prefer to record the amount of rainfall in number of hours indicating whether the rain was heavy, light or just showery, and whether it disturbed work progress or not. In this case project it was observed that even large concrete pour were recorded during heavy rain lasting around three hours in some days.

Table 6.1 Rain data and Daily production information for July 2004

Date and serial number			Rain during workg hour	Vol. Placed	Comments
Mon	1	28.06.04	No rain		
Tue	2	29.06	2.5 Hours (S)		S= Light/shower
Wed	3	30.06	No rain		
Thu	4	1.07.04	“		
Fri	5	2.07	2.5 Hours (S)		
Sat	6	3.07	No record		Site closed
			Wkly total = 5 hours		
Mon	7	5.07	No rain		
Tue	8	6.07	3.5 Hours (S)		
Wed	9	7.07	No rain		
Thu	10	8.07	1 Hour (S)		
Fri	11	9.07	1 Hour (S)		
Sat	12	10.07	1 Hour (S)		
			Wkly total =6.5 hours		
Mon	13	12.07	No rain		
Tue	14	13.07	1.5 Hours (S)		
Wed	15	14.07	4 “ (S)		Mobile crane on site from today
Thu	16	15.07	1.5 “ (S)		
Fri	17	16.07	No rain		
Sat	18	17.07	6 Hours (S)		
			wkly total =13 hours		

Table 6.1 Contd.

Date and serial number			Rain during workg hour	Vol. placed	Comments
Mon	19	19.07.04	7 Hours (S)		
Tue	20	20.07	5 " (S)		
Wed	21	21.07	2 " (S)		
Thu	22	22.07	3 " (S)		
Fri	23	23.07	0.5 " (S)		
Sat	24	24.07	1 " (S)		
			wkly total =18.5 Hours		
Mon	25	26.07	3 Hours (S)		
Tue	26	27.07	6 " (S)		
Wed	27	28.07	3 " (H)	3.75 cu.m	H= Heavy rain
Thu	28	29.07	No rain	1.76 "	
Fri	29	30.07	4 Hours (S)	12.78 "	
Sat	30	31.07	No rain	-	Site closed for weekend
			wkly total =16 Hours	Wkly total=18.29	
			Monthly total =59 Hrs	**Monthly total=18.29**	

The table is presented on a 6-day workweek calendar and shows the weekly rainfall and weekly production. Recording operations for the week ending dates and starting from the last Monday of June, it is observed that 30 days were worked during the month of July. Actual concrete pour started on the 27th. And for the week ending 30th of July total production was around 18 cu.m.

Table 6.2 Daily Cranage for July 2004

Date and serial number			Worktime (hrs)	Non-Worktime (Hrs)	Comments
Mon	1	28.06.04			
Tue	2	29.06			
Wed	3	30.06			
Thu	4	1.07.04			
Fri	5	2.07			
Sat	6	3.07			
Mon	7	5.07			
Tue	8	6.07			
Wed	9	7.07			
Thu	10	8.07			
Fri	11	9.07			
Sat	12	10.07			
Mon	13	12.07			
Tue	14	13.07			
Wed	15	14.07	0	8 (N/A)	Mobile crane on site from today
Thu	16	15.07	0	8 "	N/A = NON- ACTIVITY
Fri	17	16.07	0	8 "	BR = BREAKDOWN
Sat	18	17.07	3	5 "	
			Wkly total = 3 hrs	Wkly total = 29 hours	

Table 6.2 Contd.

Date and serial number			Worktime (hours)	Non-Worktime (Hours)	Comments
Mon	19	19.07.04	0	8 (N/A)	N/A = NON- ACTIVITY
Tue	20	20.07	0	8 "	BR = BREAKDOWN
Wed	21	21.07	5	3 "	
Thu	22	22.07	4	4 "	
Fri	23	23.07	5	3 "	
Sat	24	24.07	3	5 "	
			Wkly total = 17	Wkly total = 31	
Mon	25	26.07	6	2 (N/A)	
Tue	26	27.07	3	5 "	
Wed	27	28.07	4	4 "	
Thu	28	29.07	6	2 "	
Fri	29	30.07	4	4 "	
Sat	30	31.07	0 "	8 "	Site closed for weekend
			Wkly total=23	Wkly total= 25	
			Monthly =43 Hrs	**Monthly total=85 Hrs**	

Site record show that the crane was on site as from the 14th of July. It was not used for three days, Wednesday to Friday due to non-activity. It was used for only 3 hours on Saturday. For the week ending 17th Of July utilisation was only 3 hours while non-worktime mainly due to non-activity was 29 hours. Records show the equipment did not breakdown during that week. From the data it is possible to assess the work productivity of the crane by dividing output, quantity of concrete pour and the distribution and handling of other materials like formwork and rebar by input hours. The main problem is the quantification of the unit of output, e.g., cubic metre or square metre of form and kilogramme of rebar.

To simplify this quantification only the amount of concrete pour was used to assess work productivity. The assessment of crane utilisation efficiency is fairly easy as it relates the work time and the non-worktime. From the data, for the week ending 31st of July:

(a) Crane productivity $= \frac{\text{input hour}}{\text{output}} = \frac{48}{18.29} =$ 3 machine-hour / cu.m

(b) Resource use efficiency $= \frac{\text{Paid hour – Idle time}}{\text{Paid hour}} = \frac{48 - 25}{48} \times 100\ \%$

$= 47.91\ \% = 48\ \%$

(c) Downtime cost for July = 85 Hrs ÷ 8 x N3000 = N31,875 {Where 8- hour workday,
{N3000 crane daily hire cost

This assessment could be done for each week of the month and for the entire month. And relating events of the period, what could be done from a planning point to improve productivity and resource use efficiency may be determined. For this analysis the crane equipment has been used because it is a dominant resource. On this site no records were available for possible downtime of labour resource.

Table 6.3 Rain data and Daily production information for August 2004

Date and serial number			Rain during workg hour	Vol. Placed	Comments
Mon	1	2.08.04	No rain	9.41 cu.m	
Tue	2	3.08	0.5 Hours (S)	-	S=Light shower rain
Wed	3	4.08	1 " "	3.74	
Thu	4	5.08	3 " (H)	0.59	H= Heavy rain
Fri	5	6.08	0.5 " (S)	0.43	
Sat	6	7.08	1.5 " (S)	1.99	
			Wkly rain = 6.5 hours	Wkly Production=16.16 cu.m	
Mon	7	9.08	4 Hours (S)	9.36 cu.m	
Tue	8	10.08	4 " "	13.54	
Wed	9	11.0	No rain	6.73	
Thu	10	12.08	"	7.69	
Fri	11	13.08	1.5 Hour (S)	0.30	
Sat	12	14.08	7 " (H)	12.66 cu.m	? heavy rain but so much work
			Wkly rain =16.5 hours	Wkly Production=50.29 cu.m	
Mon	13	16.08	0.5 Hours (S)	4.70 cu.m	
Tue	14	17.08	0.5 " "	1.40	
Wed	15	18.08	No rain	1.56	
Thu	16	19.08	2 Hours (H)	0.97	
Fri	17	20.08	No rain	8.78	
Sat	18	21.08	1 Hour (S)	6.59	
			Wkly rain = 4 hours	WklyProduction=24.08 cu.m	

Table 6.3 Contd.

Date and serial number			Rain during workg hour	Vol. placed	Comments
Mon	19	23.08.04	No rain	8.87 cu.m	
Tue	20	24.08	4 Hours (H)	0.17	
Wed	21	25.08	No rain	7.31	
Thu	22	26.08	0.5 Hours (S)	9.30	
Fri	23	27.08	2 " "	5.89	
Sat	24	28.08	7 " "	6.94	
			Wkly rain=13.5 Hours	Wkly Production= 38.48 cu.m	
			Monthly total=40.50 Hrs	**Monthly total= 128.99 cu.m**	

Table 6.3 shows the rain data and daily production for the month of August. There was production every week of the month and events on site show that production pattern is only weakly correlated to rainfall. Though it could be observed that during heavy rains production is generally low, except for the 14th of August which recorded a production output around 13 cu.m and a period of heavy rainfall for about 7 of the 8 working hours. Also from the data a relationship could be established between production output and cranage time. Generally higher production demands more cranage time. Though on two occasions, the 19th and 24th of August, cranage of 6 and 8 hours were recorded while a very low production output of less than a cubic metre was recorded. The explanation for this is that the crane may have been used to handle and distribute forms and rebar etc.

Table 6.4 Daily cranage For August 2004

Date and serial number			Worktime (Hrs)	Non-Worktime (Hrs)	Comments
Mon	1	2.08.04	7	1 (N/A)	N/A= Non-activity
Tue	2	3.08	7	1 "	Equipment breakdown at 5.30pm
Wed	3	4.08	0	8 (BR)	BR = BREAKDOWN
Thu	4	5.08.	0	8 (BR)	
Fri	5	6.08	2	6 (N/A)	
Sat	6	7.08	5	3 "	
			Wkly total=48	Wkly total=27	
Mon	7	9.08	3	5 (N/A)	
Tue	8	10.08	6	2 (N/A)	
Wed	9	11.08	7	1 (N/A)	
Thu	10	12.08	6	2 (N/A)	
Fri	11	13.08	8	0	
Sat	12	14.08	-	-	Mobile crane moved to Abuja
			Wkly total=30	Wkly total=10	
Mon	13	16.08	-	-	
Tue	14	17.08	-	-	
Wed	15	18.08	6	2 (N/A)	Tower crane installed on site today
Thu	16	19.08	6	2 (N/A)	
Fri	17	20.08	8	0	
Sat	18	21.08	8	0	A second tower crane being mounted
			Wkly total=28	Wkly total=4	

Table 6.4 Contd.

Date and serial number			Worktime (Hrs)	Non-Worktime (Hrs)	Comments
Mon	19	23.08.04	8	0	
Tue	20	24.08	8	0	
Wed	21	25.08	8	0	
Thu	22	26.08	8	0	
Fri	23	27.08	8	0	
Sat	24	28.08	8	0	
			Wkly total=28	Wkly total=28	
			Monthly total=87 Hrs	**Monthly total=41 Hrs**	

Productivity and resource use efficiency is assessed for the month as:

(a) Crane productivity $= \dfrac{\text{input hours}}{\text{output}}$

$= \dfrac{168}{129} =$ 1 Machine-hour/ cu.m

(b) Resource use efficiency $= \dfrac{\text{Paid hour – Idle time}}{\text{Paid hour}} = \dfrac{168 - 41}{168} \times 100\ \% = 76\ \%$

(c) Downtime cost $= \dfrac{41}{8} \times 3000 =$ N15,375 {Where 8 =hour in a workday

{and N3000 =daily hire cost of crane

Table 6.5 Rain data and Daily production information for September 2004

Date and serial number			Rain during workg hour	Vol. of conc.Placed	Comments
Mon	1	30.08.04	No rain	-	Youth crisis
Tue	2	31.08	3 (S)	-	"
Wed	3	1.09	3 (S)	-	"
Thu	4	2.09	No rain	0.30 cu.m	
Fri	5	3.09	2 (S)	-	S=Light shower rain
Sat	6	4.09	No rain	-	Site closed
			Wkly rain = 8 hours	Wkly total = 0.3 cu.m	
Mon	7	6.09	No rain		
Tue	8	7.09	"		
Wed	9	8.09	1 (S)		
Thu	10	9.09	2.5 (H)	7.13 cu.m	H= Heavy rain
Fri	11	10.09	No rain	2.55	
Sat	12	11.09	"	7.24	
			Wkly rain =3.5 hours	Wkly total =16.93 cu.m	
Mon	13	13.09	2 (H)	9.21 cu.m	
Tue	14	14.09	1 (S)	4.33	
Wed	15	15.09	No rain	9.20	
Thu	16	16.09	"	5.71	
Fri	17	17.09	0.5 (S)	17.07	
Sat	18	18.09	6.5 (S)	4.26	
			Wkly rain=10 hours	Wkly total = 49.79 cu.m	

Table 6.5 contd.

Date and serial number			Rain during workg hour	Vol. of conc. Placed	Comments
Mon	19	20.09.04	0.5 (H)	10.51 cu.m	
Tue	20	21.09	No rain	9.05	
Wed	21	22.09	3 (S)	17.25	
Thu	22	23.09	0.67 (40mins) (H)	8.66	
Fri	23	24.09	3 "	28.57	
Sat	24	25.09	No rain	11.10	
*Sun	25	19.09	No record	2.34	Not a normal working day
			Wkly total= 7.17 Hrs	Wkly total= 87.48 cu.m	
			Monthly total= 20.67 Hrs	**Monthly total= 154.50 cu.m**	

Table 6.6 Daily Cranage for September 2004

Date and serial number			Worktime (Hrs)	Non-Worktime (Hrs)	Comments
Mon	1	30.08.04	0	8 (N/A)	Youth crisis}strike action
Tue	2	31.08	0	8 (N/A)	" } "
Wed	3	1.09	0	8 (N/A)	" } "
Thu	4	2.09	0	8 (N/A)	
Fri	5	3.09	6	2 (N/A)	
Sat	6	4.09	0	8 (N/A)	
			Wkly total= 6 Hrs	Wkly total= 42Hrs	
Mon	7	6.09	8	0	
Tue	8	7.09	8	0	
Wed	9	8.09	A=0, B=0	16 (BR)	A second tower crane installed on site
Thu	10	9.09	A=6, B=0	10 (BR)	BR = BREAKDOWN
Fri	11	10.09	A=0, B=0	16 (N/A)	N/A= Non-activity
Sat	12	11.09	A=8, B=8	0	
			Wkly total= 38 Hrs	Wkly total= 42 Hrs	
Mon	13	13.09	A=6, B=0	10 (BR)	
Tue	14	14.09	A=6, B=8	2 (BR)	
Wed	15	15.09	A=8, B=8	0	
Thu	16	16.09	A=8, B=8	0	
Fri	17	17.09	A=8, B=8	0	
Sat	18	18.09	A=8, B=5	3 (N/A)	
			Wkly total= 81 Hrs	Wkly total=15 Hrs	

Table 6.6 contd.

Date and serial number			Worktime (Hrs)	Non-Worktime (Hrs)	Comments
Mon	19	20.09.04	A=8, B=2	6 (N/A)	
Tue	20	21.09	A=8, B=8	0	
Wed	21	22.09	A=8, B=8	0	
Thu	22	23.09	A=8, B=8	0	
Fri	23	24.09	A=8, B=7	1 (N/A)	
Sat	24	25.09	A=8, B=8	0	
*Sun	25	19.09	No record of crane operation	-	Not a normal working day
			Wkly total= 89 Hrs	Wkly total= 7	
			Monthly total=214 Hrs	**Monthly total=106**	

During the month of September a second tower crane was installed on site. This makes the total machine-hour (crane) on site to be potentially 320. Several statistics can be computed to show efficiency of operations for the different months. For August total non-worktime was 41 hours, for September it was 106. Though percentage of worktime to non-worktime for both months is 47 and 49 respectively. Out of the 106 non-worktime for September 32 was due to youth strike, 38 due to equipment breakdown and 36 due to non-activity. This seems to be an improvement over when only one equipment was on site. This type of assessment could help to determine when it is appropriate to move large resource-hours to site.

(a) Crane productivity $= \frac{320}{154.5} = 2$ Machine-hour/cu.m

(b) Resource use efficiency $= \frac{214}{320} \times 100\,\% = 67\,\%$

(c) Downtime cost $= \frac{106}{8} \times 4000 =$ N53,000

Operations for the month of August was 76% efficient with a high productivity of 1 machine-hour/cu.m. While for the month of September due to high machine-hour potentially present on site and labour strike, efficiency dropped to 67% with a productivity of 2Machine-hour/cu.m. The implication of this result for planning is that pulling too much resources to site may make the resources less efficient. If not for the reach of cranage, one crane may have performed more efficiently. In this regards, assessing work quantity should match production capacity of equipment and labour resources called to site.

Events in October are similar to those of September. There was a major dispute from the 10^{th} to the 17^{th} of this month. And there were no production record for the last two weeks of the month. The same type of assessment and comparison can be made as described in the previous paragraph. Tables 6.7, 6.8, and 6.9 present events for the month of October and a summary of potential worktime and lost workhour for cranage.

Table 6.7 Rain data and Daily production information for October 2004

Date and serial number			Rain during workg hr	Vol. of conc.Placed	Comments
Mon	1	27.09.04	No rain	0.41cu.m	
Tue	2	28.09	"	1.13	
Wed	3	29.09	"	19.20	
Thu	4	30.09	"	4.53	
Fri	5	01.10	-	-	NATIONAL DAY
Sat	6	02.10	-	-	Site closed
			Wkly rain = 0 hrs	Wkly total = 25.27 cu.m	
Mon	7	04.10	No rain	10.50	
Tue	8	05.10	0.5	14.52	
Wed	9	06.10	0.5	14.17	
Thu	10	07.10	0.75 (45mins)	17.52	
Fri	11	08.10	1	20.54	
Sat	12	09.10	No rain	-	
			Wkly rain=2.75 hrs	Wkly total =77.24 cu.m	
Mon	13	11.10			} Labour strike
Tue	14	12.10			}
Wed	15	13.10			}
Thu	16	14.10			}
Fri	17	15.10			}
Sat	18	16.10			}
			Wkly rain= - hours	Wkly total = - cu.m	

Table 6.7Contd.

Date and serial number			Rain during workg hour	Vol. of conc.Placed	Comments
Mon	19	18.10.04	0.5		}No production record
Tue	20	19.10	1		} “
Wed	21	20.10	No rain		}
Thu	22	21.10	2.5		}
Fri	23	22.10	4		}
Sat	24	23.10	1		} “
			Wkly total = 9	Wkly total = No record	}
Mon	25	25.10	No rain		} “
Tue	26	26.10	“		}
Wed	27	27.10	“		}
Thu	28	28.10	“		}
Fri	29	29.10	20 Mins		}
Sat	30	30.10	No rain		} “
			Wkly total= 0.33 Hrs	Wkly total= No record	
			Monthly total =12.08 Hrs	**Monthly total=102.51 Hrs**	

Table 6.8 Daily Cranage for October 2004

Date and serial number			Worktime (hrs)	Non-Worktime (Hrs)	Comments
Mon	1	27.09.04	A=8, B=8	0	
Tue	2	28.09	A=8, B=8	0	
Wed	3	29.09	A=8, B=8	0	
Thu	4	30.09	A=8, B=8	0	
Fri	5	01.10	-	16	National Day
Sat	6	02.10	-	16	
			Wkly total= 64 hrs	Wkly total= 32 hrs	
Mon	7	04.10	A=8, B=6	2 (N/A)	
Tue	8	05.10	A=8, B=8	0	
Wed	9	06.10	A=8, B=8	0	
Thu	10	07.10	A=8, B=8	0	
Fri	11	08.10	A=8, B=0	8 (N/A)	
Sat	12	09.10	A=8, B=0	8 (N/A)	
			Wkly total =78 hrs	Wkly total = 18 hrs	
Mon	13	11.10			} Labour dispute
Tue	14	12.10			} “
Wed	15	13.10			} “
Thu	16	14..10			} “
Fri	17	15.10			} “
Sat	18	16.10			} “
			wkly total= - hrs	wkly total= - hrs	

Table 6.8 contd.

Date and serial number			Worktime (hours)	Non-Worktime (Hrs)	Comments
Mon	19	18.10.04	A=0, B=0	16	
Tue	20	19.10	A=8, B=8	0	
Wed	21	20.10	A=8, B=6	2	
Thu	22	21.10	A=8, B=8	0	
Fri	23	22.10	A=6, B=4	6	
Sat	24	23.10	A=0, B=0	16	
			Wkly total = 56 Hrs	Wkly total = 40 Hrs	
Mon	25	25.10	A=8, B=8	0	
Tue	26	26.10	A=0, B=0	16	
Wed	27	27.10	A=8, B=7	1	
Thu	28	28.10	A=8, B=8	0	
Fri	29	29.10	A=4, B=6	6	
Sat	30	30.10	A=0, B=0	16	
			Wkly total=57	Wkly total= 39	
			Monthly =43 Hrs	**Monthly total=85 Hrs**	

Table 6.9 Potential Workhours and lost Time for cranage

Week ending	Potential work hrs	Actual work time	Non-Worktime (hrs)			Work description and output	comments
			Mech. Fail.	Rain	Non-Activity		
July							
17/7	32	3	-	[13]	29	Forms & rebar	
24/7	48	17	-	[18.5]	31	Ditto	
31/7	48	23	-	[16]	25	Forms, rebar & 18 cu.m of conc.	
Monthly total	**128**	**43**	**-**	**[59]**	**85**	**18 cu.m**	
August							
7/8	48	21	(16)	[6.5]	27	16.16 cu.m	
14/8	40	30	-	[16.5]	10	50.29	
21/8	32	28	-	[4]	4	24.08	
28/8	48	48	-	[13.5]	0	38.47	
Monthly total	**168**	**127**	**(16)**	**[40.50]**	**41**	**129 cu.m**	

Table 6.9 Contd.

Week ending	Potential work hrs	Actual work time	Non-Worktime (hours)			Work description and output	comments
			Mech. Fail.	Rain	Non-Activity		
Sept							
4/9	48	6	-	[8]	42	0.30 cu.m	
11/9	80	38	(24)	[3.5]	42	16.93	
18/9	96	81	(8)	[10]	15	49.79	
25/9	96	89	(6)	[7.17]	7	87.48	
Monthly total	**320**	**214**	**(38)**	**[20.67]**	**106**	**154.50 cu.m**	
Oct							
2/10	96	64	-	[0]	32	25.27 cu.m	
9/10	96	78	-	[2.75]	18	77.24	
16/10	96	0	-	[no record]	96	24.08	}dispute
23/10	96	56	(2)	[9]	40		
30/10	96	57	-	[0.33]	39		
Monthly total	**480**	**255**	**(16)**	**[40.50]**	**225**	**102 cu.m**	

6.2.2 Implications of results from case project for scheduling Procedures

The reported case project was scheduled using an 8-hour workday and a 6-day workweek. This sets the pace of work and the basis on which resources are called to site. On another project with different workday hours and workweek days, a comparison of resource productivity, resource use efficiency and cost of downtime of resources could provide a very direct implications for procedures on performance. A summary of the production information in table 6.9 show that when a second tower crane was installed on the 8th of September a 320 potential work hours of cranage became available on site. Out of which actual worktime was 214 and a downtime of 106 machine-hours. Downtime cost was assessed to be N53,000. While total production, poured concrete was 155cu.m. This operational information can be compared to events during the month of August and July when only one crane operated on site. Obviously operations are more efficient during August. Even with only one crane on site providing a potential 168 machine-hour, a use time of 127 hours and a production of 129 cu.m. The situation during October could be described as worse and during this period the best thing to do is to move one of the cranes from site to release the contractor from paying unnecessary non-worktime. From this case project it is learnt that a reduction in downtime could be achieved if resources particularly equipment are called to site on a least commitment contingency basis. Similar to the weekly work plan of Ballard (1998), except that in this regards, calling them to site only when the conditions are right. Also a selective differential application of project workdate regime may be considered for tasks which have high delay potential thereby reducing available man-machine-hour that could be down in delay event.

6.3 Case Project 2

This project involved the construction of a four floor judiciary complex with auxiliary buildings. The works is of in-situ construction with substantial precast concrete elements. The project was estimated to cost around three Billion Naira (N3 B) an equivalent of around £12 M. The initial contract duration was three and half years, April 2004 to August 2007. The works was scheduled on a 10-hour workday and a 6-dayworkweek. This default project calendar was applied to all tasks and all resources and resources were also called to site based on this arrangement and timing. From this source the following data were obtained for study and analysis:

(i) The initial master programme and subsequent revisions of it including revisions A, B, C, D and E.

(ii) Daily concrete placement for the months of December 2004 and January 2005

(iii) Site equipment monthly punching for December 2004 and January 2005

(iv) Site meeting minutes for July 2004 to July 2005 and

(v) Progress reports showing request for information schedule and submittals.

Key information gleaned from this source are:

- Resource use efficiency
- Categorisation of activities and resources based on request for information and approval length of submittals.

6.3.1 The Initial Master Programme and its Subsequent Revisions

The master programme for the works in this case project was prepared using the Gantt chart technique. It has 260 tasks, showing milestone dates and subtasks for the project as illustrated in appendix K. It was based on a 10-hour workday and a 6-day workweek, working only around 8 hours on Saturday. The Gantt chart technique does not offer considerations for early or late start of tasks and so the effects of this procedure on performance could not be assessed. Tasks in this technique are scheduled as soon as conditions are right and they tend to follow only the finish-to-start linking with any desired degree of overlapping.

6.3.2 Productivity and Resource Use Efficiency

Productivity and operational efficiency on this site is high. This is because a combination of substantial precast elements with in-situ construction was employed creating a balance between wet and dry construction and maximising advantage of both. During each day of the month, record of concrete works were kept. Placed precast units were described and recorded in cubic metres making productivity and efficiency assessment easy. Tables 6.10a, 6.10b, 6.11a and 6.11b illustrate concrete production and crane utilisation for the months of December 2004 and January 2005. The data show that equipment was used 100% of potential time.

This is a very rear feat. Also a very high productivity for both months was achieved:

(a) $\frac{590}{1494}$ = 0.39 Machine-Hours/cu.m

(b) $\frac{690}{1275}$ = 0.54 Machine-Hours/cu.m

A direct comparison of efficiency between case project 1 and 2 was not possible because of the precast element in project 2. The stage of the works reported can be described as contractor controlled as he does not need much information from other members of the building team, the client, subcontractor, or design consultants. This explains why work progressed well during this phase. As the work progressed, it was observed that even the concrete trade which is normally thought to be 100% contractor controlled was substantially delayed for up to 3 -6 months because the M & E subcontractor packed out of site and the superstructure column embedment and inserts could not be fixed.

Table 6.10a – Daily Concrete Production for December 2004

Date and serial number			Vol. of conc. Placed (cu.m)	Comments
Mon	1	29.11.04	100.5	
Tue	2	30.11	37.75	
Wed	3	1.12.04	169.25	
Thu	4	2.12	117.25	
Fri	5	3.12	115.75	
Sat	6	4.12	82.00	
			Wkly Production= 622.50 cu.m	
Mon	7	6.12	68.50	
Tue	8	7.12	98.00	
Wed	9	8.12	162.25	
Thu	10	9.12	122.00	
Fri	11	10.12	?	
Sat	12	11.12	39.50	
			Wkly Production= 490.25 cu.m	
Mon	13	13.12	68.25	
Tue	14	14.12	81.25	
Wed	15	15.12	15.25	
Thu	16	16.12	68.75	
Fri	17	17.12	58.50	
Sat	18	18.12	89.25	
			Wkly Production=381.25 cu.m	

Table 6.10a Contd.

Date and serial number			Vol. of conc. placed	Comments
Mon	19	20.12		} Site closed for Christmas
Tue	20	21.12		} "
Wed	21	22.12		} "
Thu	22	23.12		} "
Fri	23	24.12		} "
Sat	24	25.12		} "
			Wkly Production= 0 cu.m	
			Monthly total= 1494 cu.m	

Table 6.10b – Daily Cranage Hours for December 2004

Date and serial number			Hours worked	Comments
Mon	1	29.11.04	-	
Tue	2	30.11	-	
Wed	3	1.12.04	40	
Thu	4	2.12	40	
Fri	5	3.12	40	
Sat	6	4.12	40	
			Wkly total = 200 hours	
Mon	7	6.12	30	
Tue	8	7.12	30	
Wed	9	8.12	30	
Thu	10	9.12	30	
Fri	11	10.12	30	
Sat	12	11.12	30	
			Wkly total =180 hours	
Mon	13	13.12	30	
Tue	14	14.12	30	
Wed	15	15.12	30	
Thu	16	16.12	30	
Fri	17	17.12	30	
Sat	18	18.12	30	
			Wkly total =180 hours	

Table 6.10b – contd.

Date and serial number			Hours worked	Comments
Mon	19	20.12	30	
Tue	20	21.12		} Christmas holidays
Wed	21	22.12		}
Thu	22	23.12		}
Fri	23	24.12		}
Sat	24	25.12		}
			Wkly total = 30 Hrs	
			Monthly total= 590 hrs	

Table 6.11a – Daily Concrete Production for January 2005

Date and serial number			Vol. of conc. Placed (cu.m)	Comments
Mon	1	3.01.05		Christmas holidays
Tue	2	4.01	64.00	}Work includes: precast conc.
Wed	3	5.01	77.75	}beams, precsat slab, in-situ conc
Thu	4	6.01	82.75	}in footing, cols, retaining walls,
Fri	5	7.01	101.25	}blinding etc
Sat	6	8.01	88.75	
			Wkly Production=414.50 cu.m	
Mon	7	10.01	100.75	
Tue	8	11.01	107.25	
Wed	9	12.01	74.25	
Thu	10	13.01	98.75	
Fri	11	14.01	63.50	
Sat	12	15.01	60.75	
			Wkly Production= 505.25 cu.m	
Mon	13	17.01	57.75	
Tue	14	18.01	-	
Wed	15	19.01	-	
Thu	16	20.01	-	
Fri	17	21.01	-	
Sat	18	22.01	-	
			Wkly Production= 57.75 cu.m	

Table. 6.11a– contd.

Date and serial number			Vol. of conc. Placed (cu.m)	Comments
Mon	19	24.01.05	61.50	
Tue	20	25.01	44.75	
Wed	21	26.01	60.75	
Thu	22	27.01	67.75	
Fri	23	28.01	63.00	
Sat	24	29.01	-	
			Wkly Production= 297.75 cu.m	
			Monthly total=1275.25cu.m	

Table 6.11b – Daily Cranage hours For January 2005

Date and serial number			Hours worked	Comments
Mon	1	3.01.05		} Christmas Holidays
Tue	2	4.01.05	30	
Wed	3	5.01.05	30	
Thu	4	6.01.05	30	
Fri	5	7.01.05	30	
Sat	6	8.01.05	30	
			Wkly total=150 Hrs	
Mon	7	10.01.05	30	
Tue	8	11.01.05	30	
Wed	9	12.01.05	30	
Thu	10	13.01.05	30	
Fri	11	14.01.05	30	
Sat	12	15.01.05	30	
			Wkly total= 180 Hrs	
Mon	13	17.01.05	30	
Tue	14	18.01.05	30	
Wed	15	19.01.05	30	
Thu	16	20.01.05	30	
Fri	17	21.01.05	30	
Sat	18	22.01.05	30	
			Wkly total= 180 Hrs	

Table 6.11b – contd.

Date and serial number			Hours worked	Comments
Mon	19	23.01.05	30	
Tue	20	24.01.05	30	
Wed	21	25.01.05	30	
Thu	22	26.01.05	30	
Fri	23	27.01.05	30	
Sat	24	28.01.05	30	
			Wkly total= 180 Hrs	
			Monthly total=690 Hrs	

6.3.3 Progress Report and Categorisation of Tasks and Resources

Progress reports and minutes of site meetings aside from showing percent complete of works during previous and current reporting periods, highlight important aspects of events in the project:

- Inadequate subcontract arrangement
- Delays in approval of submittals particularly regarding the M&E trade
- Information request schedule
- Expected and actual dates for receipts of correspondences and the effects of these on the programme.

The M&E trade was initially awarded to the main contractor who appropriately employed his domestic subcontractor to perform the works. During the early stage, there was no problem, all necessary conduiting and concealed plumbing pipe works needed to be embedded in the columns, beams and floors were performed as planned and the civil works proceeded well. The subcontract was revoked and re-awarded to a Nominated subcontractor on a mutual basis, without formal subcontract arrangements. Eventually there were problems and the subcontractor wanted a formalisation of the subcontract arrangement. He pressed for this and when it was not forthcoming he slowed down work for the months of March and April 2005, and eventually stopped work and moved out of site during the period of May to July 2005.

The works involved in the M&E first fix comprises of Electrical conduit and embedding of plumbing pipe works, some of which ran in columns, beams and floors. As at the latest programme revision, revision E, this class of work was scheduled to have been completed by February 2005 though it had a lee-way till July 2005. And at the time the latest report was given in July 2005, only 35% of the M&E first fix was complete. Initially, though some of the M&E first fix needs to tie in with some aspects of the civil works because of conduits and embedments, some civil works only managed to go on for a while. And eventually when the M&E subcontractor moved out of site in May – July, most civil works also stopped. During this time, labour being more fluid than equipment was fairly easily re-assigned to some other sites if there openings at the time. Those operatives who could not be re-assigned were paid-off and some key personnel like foremen, supervisors, Engineers and skilled masons were kept on 'stood-off' or 'stand-by' with half pay to manage until conditions improve. During the period there were four cranes on site each having a hire cost of N4000 – N5000 a day. After a while, one of the cranes was moved from site and the remaining three stayed on for May, June and July.

The downtime cost to the contractor =3 x 5000 x 25 x 3 {where: 3no. cranes; 25 days per month and
{ N5000 per day

= N45, 000 (about £180)

6.3.4 Submittals and information request schedule

Table 6.15 illustrates that approval of submittals of aluminium roof covering was delayed for 15 days, metal doors for 9 days and underground retaining wall expected on the 12th of November 2004, was still pending as at April 2005. Table 6.16 also show that approval for submittal for plumbing and electrical fittings were delayed average 10 days. Delays in receipt of correspondences and request for information are illustrated in Tables 6.18 and 6.17. All these delays when related to programmed events reveal that they are the main cause for problems. In the case project, because approval and component procurement, information release schedule were not integrated and built into the master schedule there were problem with request for information, approval of submittals and receipt of correspondences particularly of the M & E and the ground works This produced secondary effects on the tasks and resources of the civil works which are regarded as nearly 100% contractor controlled in the normal course of events.

6.3.5 Implications of results from case project 2 for scheduling Procedures

This case project yielded two important implications for scheduling. Namely the categorisation of tasks for selective differential applications of scheduling options and the importance of information release schedule in project implementation. From the case project tasks needing approval of submittals are very soft points of the programme and needs attention in the schedule formulation. Tasks needing further information, shifting production control from the prime contractor's domain also need special attention.

6.4 Case Project 3

This case project involved the construction of residential accommodation for company staff. The works includes 50 housing units comprising Terrace houses, Bungalows, Town houses, Swimming Pool, Tennis Court and other external works. It was estimated to cost around N5 Billion (an equivalent of £20 Million) and a project duration of Two and half years, from September 2003 to February 2005. Though this site was handled by the same contractor in case project 1, data showed that methods of reporting performance by different project Managers and scheduling Engineers were significantly different. In this site for instance equipment use was recorded in days not hour of use as in case project 1 which showed use time, breakdown time and other non-use time due to non-activity as explained in section 6.1.

A document analysis for cranage time showed only hire date, date off-hire, breakdown period, hire rate/day and number of days actually worked each month. Certainly the days worked each month would have included hours of non-work due to unavailability of work for the equipment and several other factors discussed in chapters 3, 4 and 5 of this thesis. This project reporting style creates a limit in analysis of performance problem for proactive planning of future projects. Also production during each month period was unavailable to do a kind of productivity and efficiency analysis as was possible for case projects 1 and 2.

The project was scheduled on a 6-day workweek and an 8-hours workday, being the normal or regular company project calendar. A document analysis on data of equipment use for the period October 2003 to October 2004 show that only one mobile crane was on site scheduled potentially to be used for around 27 days each month, as illustrated in table 6.12. Data during the year were unavailable for the months of November 2003, January, March, August, and September 2004. And as noted previously, though a use time of 27 days in the month of December is feasible, this time will almost certainly include some non-work hours which needs to be recorded for a comprehensive operational assessment.

Table 6.12 Use days and breakdown days for crane

Month	Breakdown (days)	Use days
Oct. 2003	-	27
Dec.	-	27
Feb. 2004	-	24
April	24	2
May	2	24
June	5	21
July	-	27
Oct. 2004	-	26

Further, observations from a document study of periodic progress reports from January 2004 to February 2005 suggest a consistent trend that some categories of tasks are completed well ahead schedule while others are completed several weeks behind schedule. Those normally completed ahead are those which can be regarded as reasonably under the control of the contractor for instance the civil works as illustrated in table 6.13.

Table 6.13 – Tasks Consistently ahead of schedule

Lower Roof beams	100%	-	12 weeks behind
Lower Roof steel frames	100%	-	11 weeks behind
Capping beams & solid blockwork	100%	-	10 weeks behind
Fix Roof Insulation	90%	-	9 weeks behind
1st fix services	60%	60%	on programme
CLUB HOUSE (*Substructures*)			
Basement tank wall & floor Tiling	100%	100%	completed
Blockwall around the plasprufe membrane		100%	
Basement wall beams		100%	
Staircase (straight & curved flight)	100%	70%	
1st fix services	100%	65%	
Basement surrounds filling & Compaction		80%	
FRC Ground Floor Slab	100%	80%	
SWIMMING POOL			
Base Slab	100%	100%	completed
Wall & Perimeter channel	100%	100%	completed
1st fix services	100%	90%	Awaiting pool light fittings
Filling to surrounds of pool & pool deck		50%	
4 – BEDROOM TOWN HOUSES			
Substructure: Setting out	100%	100%	completed
Excavation & Blinding	100%	40%	Awaiting STNL instruction to
Wall foundation	100%	40%	proceed on trial hole.
Lower Solid blockwork	100%	40%	
Compacted Fill / Hardcore	100%	40%	
Retaining wall	100%	50%	completed to building gable end
3 – BEDROOM TOWN HOUSES			
Substructures	100%	100%	completed
Superstructures :			
Ground floor solid blockwork	100%	50%	8 weeks behind
1st floor beam / slab	100%	-	7 weeks behind
Staircase	100%	-	6 weeks behind
STEWARD QUARTERS			
Substructures :			
Setting out	-	100%	1 week ahead
Excavation & Blinding	-	100%	2 weeks ahead
Column & Wall footing	-	100%	3 weeks ahead
Solid Blockwork	-	100%	4 weeks ahead
Compacted fill	-	90%	5 weeks ahead
1st fix M & E	-	80%	6 weeks ahead
FRC of ground floor slab	-	70%	7 weeks ahead
Superstructures :			
Ground floor column	-	20%	7 weeks ahead
BUNGALOWS (*Substructures*)			
Setting out	100%	100%	completed
Excavation & Blinding	60%	75%	1 week ahead
Columns & wall footing	50%	60%	2 weeks ahead
Stub column & solid blockwork	40%	60%	3 weeks ahead
Compacted fill	30%	50%	4 weeks ahead
Ground floor slab	25%	50%	5 weeks ahead
Superstructures:			
Ground floor columns	10%	45%	2 weeks ahead
Blockwork		20%	3 weeks ahead
Roof beam / slab (kitchen/parking area)		20%	4 weeks ahead
EXTERNAL WORKS			
Road works - Setting out	100%	75%	On hold until design costs agreed.
PROCUREMENT			
Local - Cement	90%	87%	
Rebar	90%	87%	
Fine Aggregate (Sand)	90%	87%	

Those observed to be normally behind schedule are those for which the contractor requires further information, that need long-lead supply items which are imported or that requires approval of submittals as illustrated in table 6.14

Table 6.14 – Tasks Consistently behind schedule

1. SUMMARY
CONTRACT DATES :

Start : 1ST SEPTEMBER, 2003

Completion : 28TH FEBRUARY, 2005

SECTIONAL COMPLETION DATES:
- None

BASED ON MASTER PROGRAMME REF No :- STNL P38 / MP2
- See attached Programme of work

REPORT TO: Project Meeting No 10

PROJECT WEEK No: 43 of 78

SUMMARY OF PROGRESS

		PLANNED	*ACTUAL*	*REMARKS*
1.1	Planned Progress Monitoring			
	MAINTENANCE BUILDING			
	Substructures works :	100%	100%	
	Superstructures :			
	Modification / Alteration works		35%	
	Blockwork ground to 1st floor	100%	85%	
	FRC 1st floor beam / slab	100%	100%	completed
	1st floor Columns to Roof	100%	100%	completed
	Roof beam / slab	100%	100%	completed
	Roof felting	100%	-	
	Staircase	100%	100%	completed
	Styrofoam / Precast Pavers	100%	-	
	Blockwork 1st floor to roof	100%	80%	
	BWIC with M & E	100%	85%	
	Finishes :			
	Plastering / Rendering	100%	10%	
	Precast screen block / w. cill	100%	-	
	Alum. Doors / windows frames	100%	-	
	Metal works	100%	-	
	Timber door frame	100%	-	
	Wall / floor tiling	100%	-	
	Alum. Doors / windows panels	100%	-	
	1ST fix Services	100%	-	
	TERRACE HOUSES			
	Superstructure :			
	Ground to 1st Floor Column	100%	100%	completed
	1st floor beam / slab	100%	90%	3 weeks behind
	1st floor columns	100%	70%	3 weeks behind
	Roof beams / slab	100%	65%	Block IV in progress
	Roof Trusses	100%	35%	4 weeks behind
	Blockwork	65%	55%	4 weeks behind
	Installation of Alum. Roofing sheets	60%	-	8 weeks behind
	Roof felt & pavers	40%	-	4 weeks behind
	Staircase	35%	35%	on programme
	BWIC with M & E	55%	55%	on programme
	2 / 3 BEDROOM TOWN HOUSES			
	Superstructures :			
	Blockwork (ground to 1st floor)	100%	50%	8 weeks behind
	1st floor beam / slab	100%	100%	completed
	Staircase	100%	30%	Blocks I, II , III & IV completed
	1st floor blockwork	100%	45%	8 weeks behind

Table 6.15 – Submittal Approval: Aluminium Doors etc

SUBMITTAL STATUS REPORT (ARCH. TRADE)
WEEK 19 - 2005

S/NO	DESCRIPTION OF PRODUCT / MATERIAL	LOCATION: CWS	LOCATION: HQ	LOCATION: AD	LOCATION: EXT. W	SAMPLE REF	ACTION: AA	ACTION: CSK	ACTION: EAS	ACTION: VAS	ACTION: IEA	SELECTED	NOT SELECTED	SUBMISSION DATE	EXPECTED DATE OF REPLY	APPROVAL DATE	STATUS: DELAY	STATUS: REMARK
1	WOODEN DOOR	X				BNL/ COA / CWS /ARC TR 01	X							14-Oct-04	28-Oct-04	19-Oct-04		OK
2	ALUMINIUM WINDOW	X				BNL/ COA / CWS /ARC TR 05	X					X		14-Oct-04	28-Oct-04	19-Oct-04		OK
3	ALUMINIUM ROOF COVERING	X				BNL/ COA / CWS /ARC TR 11	X					X		20-Oct-04	03-Nov-04	18-Nov-04	15	DELAY
4	WATERPROOFING MEMBRANE FOR UNDERGROUND RETAINING WALL		X	X		BNL/ COA / CWS /ARC TR 14		X						29-Oct-04	12-Nov-04			PENDING
5	METAL DOOR WITH FRAME	X		X		BNL/ COA / CWS /ARC TR 15	X							29-Oct-04	12-Nov-04	21-Nov-04	9	DELAY
6	ROOF COVERING (COLOUR)	X				BNL/ COA / CWS /ARC TR 16	X					X		15-Nov-04	29-Nov-04	18-Nov-04		OK
7	PRECAST TERRAZZO 300 x 300	X				BNL/ COA / CWS /ARC TR 17	X							01-Dec-04	15-Dec-04	01-Dec-04		OK
8	STEEL BURGLARY GRILLES	X				BNL/ COA / CWS /ARC TR 18	X							15-Feb-05	01-Mar-05	18-Mar-05		OK
9	SECCO DOOR +FRAME.		X	X		BNL/COA/CWS/ARC TR 20	X					X		15-Apr-05	29-Apr-05			
10	ALUMINIUM WINDOWS		X	X		BNL/COA/CWS/ARC TR 20	X							15-Apr-05	29-Apr-05			

Table 6.16 Submittal Approval: Plumbing

SUBMITTAL STATUS REPORT (M E)
WEEK 19 - 2005

Today's Date 06-Jul-05

S/NO	DESCRIPTION OF PRODUCT / MATERIAL	LOCATION: CS/WS	LOCATION: HQ	LOCATION: AD	LOCATION: EXT. W	SAMPLE REF	SUPPLIER	ACTION: AA	ACTION: CSK	ACTION: ETS	ACTION: VAS	ACTION: IEA	SELECTED	NOT SELECT	SUBMISSION DATE	EXPECTED DATE OF REPLY	APPROVAL DATE	06-Jul-05: DELAY	06-Jul-05: REMARK	COMMENTS
1	250mm uPVC Pipes	X				BNL/ COA / CWS /M & E TR 01	PIVOT ENG. CO. LTD.			X					28-Sep-04	12-Oct-04	22-Oct-04	11	DELAYED	OK
2	250mm uPVC Bends	X				BNL/ COA / CWS /M & E TR 02	PIVOT ENG. CO. LTD.			X					28-Sep-04	12-Oct-04	22-Oct-04	10	DELAYED	OK
3	100mm uPVC Pipes	X				BNL/ COA / CWS /M & E TR 03	PIVOT ENG. CO. LTD.			X					28-Sep-04	12-Oct-04	22-Oct-04	10	DELAYED	OK
4	100mm uPVC Bends	X		X		BNL/ COA / CWS /M & E TR 04	PIVOT ENG. CO. LTD.			X					28-Sep-04	12-Oct-04	22-Oct-04	10	DELAYED	OK
5	100mm uPVC sockets	X				BNL/ COA / CWS /M & E TR 05	PIVOT ENG. CO. LTD.			X					28-Sep-04	12-Oct-04	22-Oct-04	10	DELAYED	OK
6	Generator	X				BNL/ COA / CWS /M & E TR 06	PIVOT ENG. CO. LTD.				X				28-Sep-04	12-Oct-04	22-Oct-04	10	DELAYED	OK
7	25mm pvc conduit pipes	X				BNL/ COA / CWS /M & E TR 07	PIVOT ENG. CO. LTD.				X				28-Sep-04	12-Oct-04	22-Oct-04	10	DELAYED	OK
8	20mm pvc couplers	X				BNL/ COA / CWS /M & E TR 08	PIVOT ENG. CO. LTD.				X				28-Sep-04	12-Oct-04	22-Oct-04	10	DELAYED	OK
9	25mm pvc couplers	X				BNL/ COA / CWS /M & E TR 09	PIVOT ENG. CO. LTD.				X				28-Sep-04	12-Oct-04	22-Oct-04	10	DELAYED	OK
10	100mm uPVC pipes	X	X	X		BNL/ COA / AD/HQ /M & E TR 11	FRATE (NIG) LTD.			X					09-Nov-04	23-Nov-04	09-Nov-04		OK	OK
11	75mm uPVC pipes		X	X		BNL/ COA / AD/HQ /M & E TR 12	FRATE (NIG) LTD.			X					09-Nov-04	23-Nov-04	09-Nov-04		OK	OK
12	150 X 100mm Y Tee		X	X		BNL/ COA / AD/HQ /M & E TR 13	FRATE (NIG) LTD.			X					09-Nov-04	23-Nov-04	09-Nov-04		OK	OK
13	UPVC Bend 100mm x 90o Diameter - 6bars			X		BNL/ COA / AD/HQ /M & E TR 14	FRATE Nig. LTD			X					18-Nov-04	02-Dec-04	23-Nov-04		OK	OK
14	UPVC Bend 150mm x 45o Diameter - 6bars			X		BNL/ COA / AD/HQ /M & E TR 15	FRATE Nig. LTD			X					18-Nov-04	02-Dec-04	23-Nov-04		OK	OK
15	UPVC Bend 100mm x 45o Diameter - 6bars			X		BNL/ COA / AD/HQ /M & E TR 16	FRATE Nig. LTD			X					18-Nov-04	02-Dec-04	23-Nov-04		OK	OK
16	Diameter - 6bars			X		BNL/ COA / AD/HQ /M & E TR 17	FRATE Nig. LTD			X					18-Nov-04	02-Dec-04	23-Nov-04		OK	OK
17	UPVC Socket x 50mm Diameter - 6bars			X		BNL/ COA / AD/HQ /M & E TR 18	FRATE Nig. LTD			X					18-Nov-04	02-Dec-04	23-Nov-04		OK	OK
18	UPVC 150mm x 100mm Diameter socket - 6bars			X		BNL/ COA / AD/HQ /M & E TR 19	FRATE Nig. LTD			X					18-Nov-04	02-Dec-04	23-Nov-04		OK	OK
19	UPVC Socket x 150mm Diameter - 6bars			X		BNL/ COA / AD/HQ /M & E TR 20	FRATE Nig. LTD			X					18-Nov-04	02-Dec-04	23-Nov-04		OK	OK
20	UPVC Plugs 100mm diameter - 6bars			X		BNL/ COA / AD/HQ /M & E TR 21	FRATE Nig. LTD			X					18-Nov-04	02-Dec-04	23-Nov-04		OK	OK
21	UPVC Plugs 150mm diameter - 6bars			X		BNL/ COA / AD/HQ /M & E TR 22	FRATE Nig. LTD			X					18-Nov-04	02-Dec-04	23-Nov-04		OK	OK
22	UPVC Plugs 50mm diameter - 6bars			X		BNL/ COA / AD/HQ /M & E TR 23	FRATE Nig. LTD			X					18-Nov-04	02-Dec-04	23-Nov-04		OK	OK
23	UPVC Pipes 150mm diameter - 6bars			X		BNL/ COA / AD/HQ /M & E TR 24	FRATE Nig. LTD			X					18-Nov-04	02-Dec-04	23-Nov-04		OK	OK
24	UPVC Pipes 100mm diameter - 6bars			X		BNL/ COA / AD/HQ /M & E TR 25	FRATE Nig. LTD			X					18-Nov-04	02-Dec-04	23-Nov-04		OK	OK
25	UPVC Pipes 75mm diameter - 6bars			X		BNL/ COA / AD/HQ /M & E TR 26	FRATE Nig. LTD			X					18-Nov-04	02-Dec-04	23-Nov-04		OK	OK
26	UPVC Pipes 50mm diameter - 6bars			X		BNL/ COA / AD/HQ /M & E TR 27	FRATE Nig. LTD			X					18-Nov-04	02-Dec-04	23-Nov-04		OK	OK
27	Earthing / Lightning Protector	X				BNL/ COA / CWS /M & E TR 28	Pivot Engineering Ltd,				X				17-Sep-04	01-Oct-04				Site installation
28	Circular Boxes (20mm)	X				BNL/ COA / CWS /M & E TR 29	Pivot Engineering Ltd,				X				06-Nov-04	20-Nov-04	26-Nov-04		OK	OK
29	Circular Boxes (25mm)	X				BNL/ COA / CWS /M & E TR 30	Pivot Engineering Ltd,				X				06-Nov-04	20-Nov-04	26-Nov-04		OK	OK
30	12 WAY Consumer Unit (D.B)	X				BNL/ COA / CWS /M & E TR 31	Pivot Engineering Ltd,				X				06-Nov-04	20-Nov-04	26-Nov-04		OK	OK
31	25mm upvc conduit pipes (Kano pipes)	X				BNL/ COA / CWS /M & E TR 32	Pivot Engineering Ltd,				X				06-Nov-04	20-Nov-04	26-Nov-04		OK	OK
32	20mm upvc conduit pipes (Kano pipes)	X				BNL/ COA / CWS /M & E TR 33	Pivot Engineering Ltd,				X				06-Nov-04	20-Nov-04	26-Nov-04		OK	OK
33	3 x3 Knock out boxes	X				BNL/ COA / CWS /M & E TR 34	Pivot Engineering Ltd,				X				06-Nov-04	20-Nov-04	26-Nov-04		OK	OK
34	Conduit accessories - 25mm coupling and 25mm		X	X		BNL/ COA / AD/HQ /M & E TR 35	Sanrouk Eng. Services			X					25-Nov-04	09-Dec-04	29-Nov-04		OK	OK

Table 6.17 - Information request schedule

PROJECT **REQUEST FOR INFORMATION (RFI) AND SITE DESIGN AMENDMENT REPORT** PREPARED BY:BOS

WEEK 19 - 2005

DATE:02/08/2005

T/NO	DESCRIPTION	LOCATION				REFERENCE	ACTION					DATE OF SUBMISSION	EXPECTED DATE OF REPLY	DATE OF REPLY	DELAY DAYS	REMARK
		CS/WS	HQ	AD	EXT. W		AA	CSK	ETS	VAS	IEA					
158	Beam 800mm As Lintel To Alu. Windows		X	X		COA.BOS/AKP62	X					14-Feb-05	28-Feb-05	15-Feb-05		OK
159	Detailed Dimentions Skylight Over Court		X	X		COA/BOS/AKP63	X					15-Feb-05	01-Mar-05	15-Feb-05		OK
160	Window Encroaching On Waffle Slab		X	X		COA/BOS/AKP64	X					15-Feb-05	01-Mar-05	15-Feb-05		OK
161	Detail Highlighted Beams		X			COA/BOS/AKP64		X				15-Feb-05	01-Mar-05	15-Feb-05		OK
162	Type Of Block Around Expansion Joint		X	X		COA/BOS/CSK65		X				16-Feb-05	02-Mar-05	18-Feb-05		OK
163	Detail Highlighted Beams			X		COA/BOS/CSK66		X				16-Feb-05	02-Mar-05	02-Feb-05		OK
164	Type Of Block For The Fence(Sandcrete/Conc B/W				X	COA/BOS/CSK67		X				16-Feb-05	02-Mar-05	17-Feb-05		OK
165	Confirm Position Of Expansion Joint				X	COA/BOS/CSK68		X				16-Feb-05	02-Mar-05	25-Feb-05		OK
166	Details Roof Gutter Connection To Roof Beams		X	X		COA/BOS/CSK69		X				17-Feb-05	03-Mar-05	18-Feb-05		OK
167	Structural Details Drainage Channel	X				SDA/BOS/19		X				17-Feb-05	03-Mar-05	17-Feb-05		OK
168	Confirm Window Sills in Main Building		X	X		COA/BOS/AKP65	X					17-Feb-05	03-Mar-05	17-Feb-05		OK
169	South Fence Details				X	SDA/BOS/19	X					18-Feb-05	04-Mar-05	21-Feb-05		OK
170	South Fence Details Column				X	SDA/BOS/20		X				21-Feb-05	07-Mar-05	21-Feb-05		OK
171	Internal partitions		X	X		COA/BOS/AKP66	X					21-Feb-05	07-Mar-05	03-Mar-05		OK
172	Expansion Joint Additional Column			X		SDA/BOS/21		X				22-Feb-05	08-Mar-05	22-Feb-05		OK
173	Concellation Of Beams			X		COA/BOS/CSK70		X				22-Feb-05	08-Mar-05	20-Mar-05		OK
174	Beam On Landing Staircase			X		COA/BOS/CSK71		X				23-Feb-05	09-Mar-05	26-Feb-05		OK
175	Detail Of Highlighted Area Around Service Duck		X			COA/BOS/CSK72		X				23-Feb-05	09-Mar-05	24-Feb-05		OK
176	Detail Of Retaining Wall Between Kitchen/LINK				X	COA/BOS/CSK/73		X				24-Feb-05	10-Mar-05	14-Mar-05		OK
177	Landing Spinewall Staircase		X	X		COA/BOS/AKP67	X					24-Feb-05	10-Mar-05			PENDING
178	Detail of Highlighted Area			X		COA.BOS/AKP68	X					24-Feb-05	10-Mar-05	03-Mar-05		OK
179	Detail Beam On New Cols Abj Div/Kitchen		X	X		COA/BOS/CSK74		X				24-Feb-05	10-Mar-05	24-Feb-05		OK
180	Acceptable Live loads on floors			X		COA/BOS/CSK75		X				01-Mar-05	15-Mar-05	20-Mar-05		OK
181	Discrepancy Windows W2			X		COA/BOS/AKP69	X					01-Mar-05	15-Mar-05	02-Mar-05		OK
182	Detail Window			X		COA/BOS/AKP70	X					01-Mar-05	15-Mar-05	02-Mar-05		OK
183	Discerepancy Window			X		COA/BOS/AKP71	X					01-Mar-05	15-Mar-05	02-Mar-05		OK
184	Steps With Ramp	X				COA/BOS/AKP72	X					01-Mar-05	15-Mar-05	02-Mar-05		OK
185	Detail Beams in Highlighted Area			X		COA/BOS/CSK76		X				02-Mar-05	16-Mar-05	03-Mar-05		OK
186	Expansion Joint Clarification			X		COA/BOS/CSK77		X				02-Mar-05	16-Mar-05	03-Mar-05		OK
187	Drainage Of Chamber in The Void Areas		X	X		COA/BOS/EB09			X			04-Mar-05	18-Mar-05	24-Mar-05		OK
188	Drainage Of The Void Areas		X	X		COA/BOS/EB10			X			04-Mar-05	18-Mar-05	24-Mar-05		OK
189	Access To Duct			X		COA/BOS/AKP73	X					04-Mar-05	18-Mar-05	15-Mar-05		OK
190	Structural Detail Of Drop Off		X			COABOS/CSK78		X				04-Mar-05	18-Mar-05			PENDING
191	Strucural Detail Of Highlighted Beams		X			COA/BOS/CSK79		X				04-Mar-05	18-Mar-05	12-Mar-05		OK
192	Detail Of Highlighted Beams		X			COA/BOS/CSK80		X				04-Mar-05	18-Mar-05	02-Mar-05		OK
193	Roof : Steel Structures Option		X	X		SDA/BOS/22		X				04-Mar-05	18-Mar-05			PENDING
194	Beams Layout in Duct Area		X			SDA/BOS/23		X				05-Mar-05	19-Mar-05	17-Mar-05		OK
195	Structural detail Of Roof Beams			X		COA/BOS/CSK81		X				07-Mar-05	21-Mar-05			PENDING
196	Discrepancy Beams in LINK		X	X		COA/BOS/CSK82		X				08-Mar-05	22-Mar-05	17-Mar-05		OK
197	Revised Precast Spiral Staircase Thread		X	X		SDA/BOS/24						08-Mar-05	22-Mar-05	17-Mar-05		OK
198	Steps Between Two Platforms	X				COA/BOS/AKP74	X					08-Mar-05	22-Mar-05	17-Mar-05		OK
199	Confirm Floor Level Of GENEST HOUSE				X	COA/BOS/AKP75						11-Mar-05	25-Mar-05	17-Mar-05		OK
200	Revised Window Sill		X	X		SDA/BOS/25	X					14-Mar-05	28-Mar-05	17-Mar-05		OK
201	Modification Columns 300X500mm Instruct.No.10		X			SDA/BOS/26		X				14-Mar-05	28-Mar-05	20-Mar-05		OK
202	Window Detail		X			COA/BOS/AKP76	X					14-Mar-05	28-Mar-05	18-Mar-05		OK
203	Increase In Reinforcement Cols C5 & C10		X			SDA/BOS/27		X				15-Mar-05	29-Mar-05	20-Mar-05		OK
204	Confirm Fascia Wall In Building Link ABD/HQ		X	X		COA/BOS/AKP77	X					15-Mar-05	29-Mar-05	20-Mar-05		OK
205	Drainage Of Soil Waste KITCHEN Areas		X	X		SDA/BOS/28			X			15-Mar-05	29-Mar-05	24-Mar-05		OK
206	Mechanical Drwgs Of Generator House.				X	COA/BOS/EB11			X			16-Mar-05	30-Mar-05			ON HOLD
207	Electrical Drwgs Of Generator House				X	COA/BOS/VEA3				X		16-Mar-05	30-Mar-05			ON HOLD
208	Petition Materials For Floors		X	X		COA/BOS/CSK83		X				17-Mar-05	31-Mar-05	24-Mar-05		OK
209	Missing Aluminium louvre Infront Gensets.				X	COA/BOS/AKP78	X					18-Mar-05	01-Apr-05	19-Mar-05		OK
210	Missing Wall For Exhaut Air.				X	COA/BOS/AKP79	X					18-Mar-05	01-Apr-05	19-Mar-05		OK
211	Missing Channel For Genset Cable				X	COA/BOS/AKP80	X					18-Mar-05	01-Apr-05	19-Mar-05		OK
212	Missing Water Drainage Channel For Genset House				X	COA/BOS/AKP81	X					18-Mar-05	01-Apr-05	19-Mar-05		OK
213	Confirm Roof Covering Over Genset Area				X	COA/BOS/AKP82	X					18-Mar-05	01-Apr-05	19-Mar-05		OK
214	Missing Emergency Exit Doors.				X	COA/BOSAKP83	X					18-Mar-05	01-Apr-05	19-Mar-05		OK
215	Parking For Cars (Number And Dimentions).				X	COA/BOS/AKP84	X					18-Mar-05	01-Apr-05	19-Mar-05		OK
216	Fence Wall Top Finishing	X				COA/BOS/AKP85	X					18-Mar-05	01-Apr-05	18-Mar-05		OK
217	Reinforcement Details For WAFFLE Slab/Beams.		X			COA/BOS/CSK84		X				21-Mar-05	04-Apr-05	21-Mar-05		OK
218	Detail Beam/Column Connection 2nd Floor.			X		COA/BOS/CSK85		X				21-Mar-05	04-Apr-05	21-Mar-05		OK
219	Void Over Toilet			X		COA/BOS/AKP86	X					21-Mar-05	04-Apr-05	22-Mar-05		OK
220	Section Detail Over Waffle Slab 3rd Floor		X			COA/BOS/CSK86		X				22-Mar-05	05-Apr-05	21-Mar-05		OK
221	Service Ducks Area:Reservations.		X	X		COA/BOS/EB12			X			23-Mar-05	06-Apr-05	21-Mar-05		OK
222	Structural Detail Of Staircase.		X	X		COA/BOS/CSK87		X				22-Mar-05	05-Apr-05	30-Mar-05		OK
223	Location Of SOIL WATER MANHOLE.				X	COA/BOS/EB13			X			24-Mar-05	07-Apr-05	24-Mar-05		OK
224	Discrepancy Drwgs ARCH/STR Drwgs 2nd Floor			X		COA/BOS/CSK88		X				24-Mar-05	07-Apr-05	04-Apr-05		OK
225	Details Fascia Wall Slab/Roof Slab.		X			COA/BOS/AKP87	X					24-Mar-05	07-Apr-05	29-Mar-05		OK
226	Fascia Wall Over Skylight Roof 1st,2nd,3rd Floor		X			COA/BOS/AKP88	X					24-Mar-05	07-Apr-05	29-Mar-05		OK
227	Position Of Covered Walkway On Site Plan				X	COA/BOS/AKP89	X					29-Mar-05	12-Apr-05	25-Apr-05		OK
228	Detail Of Highlighted Area		X			COA/BOS/AKP90	X					30-Mar-05	13-Apr-05	30-Mar-05		OK
229	Confirm Levels Outside Buildings				X	COA/BOS/AKP91	X					30-Mar-05	13-Apr-05	13-Apr-05		OK
230	Detail Of Beams Support Half Landing Staircase.		X			COA/BOS/CSK89		X				30-Mar-05	13-Apr-05	01-Apr-05		OK
231	Modification Columns 300X500mm Instruct.No.10		X			SDA/BOS/29		X				30-Mar-05	13-Apr-05	01-Apr-05		OK
232	Additional Beam Along Lift Wall As Per Insr.No.7			X		SDA/BOS/30		X				30-Mar-05	13-Apr-05	02-Apr-05		OK
233	Extention Retaining Wall.		X			SDA/BOS/31		X				30-Mar-05	13-Apr-05	02-Apr-05		OK
234	Final Revised Spiral Staircase as executed		X	X		SDA/BOS/32	X					01-Apr-05	15-Apr-05	06-Apr-05		OK
235	Levels And Retaining Wall outside Buildings.				X	SDA/BOS/33	X					01-Apr-05	15-Apr-05	15-Apr-05		OK
236	Openings In Court Wall.		X	X		COA/BOS/EB14			X			01-Apr-05	15-Apr-05			PENDING
237	Insulation Details Roofed Areas		X	X		COA/BOS/AKP92	X					01-Apr-05	15-Apr-05			PENDING
238	Top Position Of Retaining Wall.		X	X		COA/BOS/CSK90		X				05-Apr-05	19-Apr-05	06-Apr-05		OK
239	Detail Of Beams in Highlighted Area Of 2nd Floor			X		COA/BOS/CSK91		X				06-Apr-05	20-Apr-05	06-Apr-05		OK
240	Type Of Cover to MANHOLE NF12 or Precast Cover.				X	COA/BOS/EB15			X			06-Apr-05	20-Apr-05	14-Apr-05		OK
241	Detail Of Balcony Slab Snacks Bar Area Of LINK.		X	X		COA/BOS/CSK92		X				06-Apr-05	20-Apr-05	06-Apr-05		OK
242	Dimention Of Manhole For Cables		X			COA/BOS/VEA4				X		06-Apr-05	20-Apr-05	13-Apr-05		OK
243	Detail Of Highlighted Area Of 1st Fir HQ		X			COA/BOS/AKP93	X					06-Apr-05	20-Apr-05	07-Apr-05		OK
244	Detail Of Beam in Highlighted Area Of !st Fir HQ		X			COA/BOS/CSK93		X				07-Apr-05	21-Apr-05	22-Apr-05		OK
245	Handrails On Spirale Staircase		X	X		COA/BOS/AKP94	X					11-Apr-05	25-Apr-05	22-Apr-05		OK
246	Parking Space For Vehicle		X	X		COA/BOS/AKP95	X					11-Apr-05	25-Apr-05	25-Apr-05		OK

Table 6.18 – Correspondence report

CORRESPONDENTS REPORT

WEEK 19 - 2005

S/NO		SUBJECT	LOCATION				REFERNCE NO.	ACTION						DATE OF SUBMISSION	EXPECTED DATE OF REPLY	DATE OF REPLY	STATUS		COMMENTS
			CWS	HQ	AD	EXT. W		AA	CSK	CA	ETS	VAS	IEA				DELAY	REMARK	
1		Quotation 2:Fence, Gates & Gate house				X	COA/BDA/GAK/MCO/04/037	X		X			X	13-Sep-04	27-Sep-04	03-Dec-04	66	DELAYED	OK
2		Quotation 5:Service pit at CS/WS B	X				COA/BDA/GAK/MCO/04/051	X		X				06-Oct-04	20-Oct-04	03-Dec-04	43	DELAYED	OK
3		Quotation 6:Cable trenches at CS/WS B	X				COA/BDA/GAK/MCO/04/052	X		X		X		06-Oct-04	20-Oct-04	03-Dec-04	44	DELAYED	OK
4		Quotation 7:Earthworks				X	COA/BDA/GAK/MCO/04/055	X	X	X				23-Sep-04	07-Oct-04	30-Nov-04	272	PENDING	
5		Quotation 1:Re:Permanent water connection to site				X	COA/BDA/GAK/MCO/04/060	X					X	29-Oct-04	12-Nov-04	01-Dec-04	236	PENDING	
6		Drwg.No.AKP 213/16A: Door/Window schedule			X		COA/BDA/GAK/MCO/04/062	X						01-Nov-04	15-Nov-04	02-Dec-04	233	PENDING	
7		Quotation 6A (review)	X				COA/BDA/GAK/MCO/04/063						X	02-Nov-04	16-Nov-04	03-Dec-04	17	DELAYED	OK
8		Central store door frames	X				COA/BDA/GAK/MCO/04/084	X						22-Nov-04	06-Dec-04	04-Dec-04		PENDING	
9		Central store floor finishings	X				COA/BDA/GAK/MCO/04/085	X						22-Nov-04	06-Dec-04	05-Dec-04		PENDING	
10		Re:Quotation No. 6A					COA/BDA/GAK/MCO/04/087						X	23-Nov-04	07-Dec-04	03-Dec-04			OK
11		Aluminium roof flashings	X				COA/BDA/GAK/MCO/04/091	X						23-Nov-04	07-Dec-04	04-Dec-04		PENDING	
12		Waterproofing of retention wall		X			COA/BDA/GAK/MCO/04/094	X						25-Nov-04	09-Dec-04	05-Dec-04		PENDING	
13		Re:Certificate of fumigation					COA/BDA/GAK/MCO/04/092						X	24-Nov-04	08-Dec-04	06-Dec-04			
14		Waterproofing of retention walls		x	x		COA/BDA/GAK/MCO/04/094	x						25-Nov-04	09-Dec-04	07-Dec-04			
15		Valuation no.3 for month of November					COA/BDA/GAK/MCO/04/097						X	26-Nov-04	10-Dec-04	08-Dec-04			
16		Relocation of permanent main access to the premises				x	COA/BDA/GAK/MCO/04/100						X	01-Dec-04	15-Dec-04	09-Dec-04			
17		Divergence from Original Contract.					COA/BDA/GAK/MCO/04/102						X	01-Dec-04	15-Dec-04	10-Dec-04			
18		Response time to contractors request.					COA/BDA/GAK/MCO/04/103						X	01-Dec-04	15-Dec-04	11-Dec-04			
19		Finishing Schedule	x	x	x		COA/BDA/GAK/MC0/04/104	X						01-Dec-04	15-Dec-04	12-Dec-04			
20		Concrete Results-10					COA/BDA/GAK/MCO/04/105		X					01-Dec-04	15-Dec-04	13-Dec-04			
21		Re:Invitation to Tender					COA/BDA/GAK/MCO/04/106						X	03-Dec-04	17-Dec-04	14-Dec-04			
22		Revised interm valuation No.1					COA/BDA/GAKMCO/04107						X	08-Dec-04	22-Dec-04	15-Dec-04			
23		Quotation No 9 waterproofing to retaining wall at HQ		x			COA/BDA/GAK/MCO/04/108						X	04-Dec-04	18-Dec-04	16-Dec-04			
24		Distribution board DB-A Location					COA/BDA/GAK/MCO/05/117					X		14-Jan-05	28-Jan-05	17-Dec-04			
25		Re: instruction no 3					COA/BDA/GAK/MCO/05/118		X					14-Jan-05	28-Jan-05	18-Dec-04			
26		Re: Advance pament bond of 50% for COA project					COA/BDA/GAK/MCO/05/119						X	17-Jan-05	31-Jan-05	19-Dec-04			
27		Re: Interim Certificate Valuation No 1					COA/BDA/GAK/MCO/05/121						X	18-Jan-05	01-Feb-05	20-Dec-04			
28		Re: Security Guard Charges					COA/BDA/GAK/MCO/05/127						X	24-Jan-05	07-Feb-05	21-Dec-04			
29		Quotation No 1A for permanent water connection					COA/BDA/GAK/MCO/05/129						X	25-Jan-05	08-Feb-05	22-Dec-04			
30		Quotation No 10 for Extention of Central store/Workshop					COA/BDA/GAK/MCO/05/130			X				26-Jan-05	09-Feb-05	23-Dec-04			
31		Interim Valuation No 2 for month of December '04					COA/BDA/GAK/MCO/05/131						X	26-Jan-05	09-Feb-05	24-Dec-04			
32		Re: Assessment for sewage connection				x	COA/BDA/GAK/MCO/05/132				X			31-Jan-05	14-Feb-05	25-Dec-04			

6.4.1 Implications of results from case project 3 for Planning Procedures

This case project has clearly shown that some tasks are consistently ahead while others are consistently behind schedule. The research question is why is this so? Results also suggest a classification and categorisation of activities in planning and ranking them in certain scales. Such an attempt similar to those in case projects 2 and 3 may include:

Category 1 Tasks– Activities using components/materials that require client approval and are imported e.g, Lift, M&E etc. These should be regarded as critical and an application of late start consideration is encouraged for this class. The works involved in this class requires appropriate monitoring of information release schedule.

Category 2 Tasks – Activities that depend on completion and or start of category 1 tasks. These may be with varying degrees of lead or lag. Criticality index for this group is higher than category 1 tasks and should need a closer liaison of information required schedule and establishment of lead time that may be required between order point and receipt of needed materials.

Category 3 Tasks – Activities using components/materials requiring client's approval and may be sourced locally.

Category 4 tasks – Activities using imported materials not requiring client Approval etc.

Generally, this type of categorisation and classification of activities and their resources will help to reduce or replace intuitive reasoning with scientific, knowledge-based reasoning in the scheduling process as shown in the framework developed in chapter 7

6.5 Case Project 4

This case project involved the construction of a six floor office complex initially estimated to cost around N3 Billion, equivalent of around £12 Million. Initial contract duration was 24 months. The contract was let initially on a turnkey, design and build contract. It was eventually changed to a fixed price traditional form contract with the option of the prime contractor having to construct virtually all the works by himself or his domestic sub-contractors.

This case project did not offer much data for the reported study except that interviews and informal discussions with the project engineers revealed that the pattern of sub-contracting significantly affected progress. The reported works in this case project progressed ahead of schedule because the prime contractor was responsible for a substantial part of the works, more so that most other aspects were constructed by his domestic sub-contractors. This significantly reduced the problems of request for information and components approval procedures, etc. However the reporting system for this case project focused only on time reporting and saying virtually nothing on resources.

CHAPTER 7 – FRAMEWORK DEVELOPMENT AND VALIDATION

7.1 Introduction and Modelling Assumption

From a literature search which identified the problem domain, the data generated with various research instruments and which largely support literature, a procedural framework has been developed which may reduce non-worktime of construction resources. A fundamental assumption in the development of the framework is that it is for application to in-situ construction of a wide variety of building works of medium to large scope projects and focuses on initial schedule development issues of the problem domain.

7.2 Stages in Modelling the Framework

The framework is derived in three stages, namely identification of scheduling variables which create and reduce nonworktime, categorisation of tasks and resources based on the identified variables and the differential application of scheduling options of start time, workdate and contingency. The first stage identifies scheduling variables which create and affect non-worktime of construction resources. From table 5.10 instructions and information; late delivery of materials; and delays in preceding activities were ranked most important factors which create nonworktime. While off-site production techniques; buffers; and type and number of resources were ranked most important factors which reduce nonworktime. The further results of the process mapping presented in chapter 5 suggest that a consideration of practical start time and application of reasonable workdate regime are important in reducing this non-worktime as illustrated in tables 5.6 to 5.10. For instance, late start schedules better accommodate Instructions and information coming late and also makes room for long-lead supply items. Ensuring that resources have not been called to site which may become idle, and that preceding activities have not been scheduled to start when all important constraints have not been resolved. Tasks which require further information, approval or instructions needs to be scheduled cautiously, anticipating and attempting to remove or resolve all these constraints before scheduling so that things happen as planned.

The result of the process mapping is further confirmed with the objective data generated from document analysis of on-going projects as illustrated in tables 6.13 - 6.18. These illustrate that some tasks are consistently achieved ahead of schedule while others are consistently behind. The reason from this data source is due to information release, lapse in correspondence, submittal approval problems and long-lead supply items.

The understanding of these variables which cause delays and create non-worktime of expensive resources naturally leads to the question of which tasks and which resources require more instructions, are long-lead supply items etc. Using simple question and answer routine to assess task attributes, they are grouped into certain categories. This categorisation of tasks and resources is the second stage of deriving the framework and it has the objective of relating task specific attributes to scheduling decisions. These routine questions have been formulated from the identified variables which create and reduce nonworktime. Thus a task that answers 'no' to the first routine question, "Does task require further information from design team and depends on detailed sub-soil investigation" has qualified to be classified as a category 'A' task. It means such a task has satisfied that requirement. If the answer is yes, it has not satisfied this requirement and a second question, "Does task require approval of shop drawings etc." may be applied. If the answer is 'no' to the second question, a category 'B' task is defined. And tasks in this group need further information but do not need approval as such.

This process of categorisation by simple routine question and answer can go on to classify tasks and their resources for the purpose of making scheduling decisions on a near scientific basis. This is the third stage of deriving the framework, and it has the objective of applying differentially scheduling options based on a knowledge of task and resource attributes. Category C tasks answered yes to the first two routine questions and 'no' to the third. It satisfies only the third requirement. While category D tasks can be regarded as undefined in that they require further information, approval may come late and resources needed to perform them are long-lead supply items. This condition makes tasks in this group highly susceptible that events may not occur as planned. And so apart from applying a late start schedule option to accommodate this, defining a resource or task calendar different from normal company regular one, and a least commitment contingency plan is proposed in which to delay decisions and actions until the conditions are appropriate or right so that resources are more efficiently employed with minimal non-worktime. The resource calendar should be smaller than the regular company calendar and increase this during project implementation if conditions allow. This is the least commitment contingency plan.

7.3 Benefits of the Framework

Up till now, it is observed that most scheduling software have facilities and capabilities for choice of start time and project calendar. What was lacking before now is the basis of application of that choice. These are decisions often made based on intuition and company idiosyncrasies. Stage three of the framework development attempts to solve this problem and tries to replace intuitive reasoning with some sort of scientific reasoning which is knowledge-based. Figure 7.1 illustrates a flow chart of the developed framework for effective construction scheduling. This procedural scheduling framework has the following advantages:

(i) It attempts to integrate budget and schedule by considering resources- the cost and time for information, approval time, long-lead supply items- the time.

(ii) It proposes a long-term approach to solve a seemingly short-term problem.

(iii) It is flexible and tries to incorporate both the principles of Just-In-Time as well as making reasonable allowance for some contingency arrangement, two principles often viewed in construction planning as directly opposite and are difficult to include in a single system.

(iv) Being knowledge-based, the framework will shift according to the knowledge domain of task specific attributes. Scheduling decisions are no more vague, based only on rule of the thumb, but are now made based on project specific attributes. This will enhance its reliability in solving the domain problem which is efficient use of resources on the jobsite through a reduction of non-worktime.

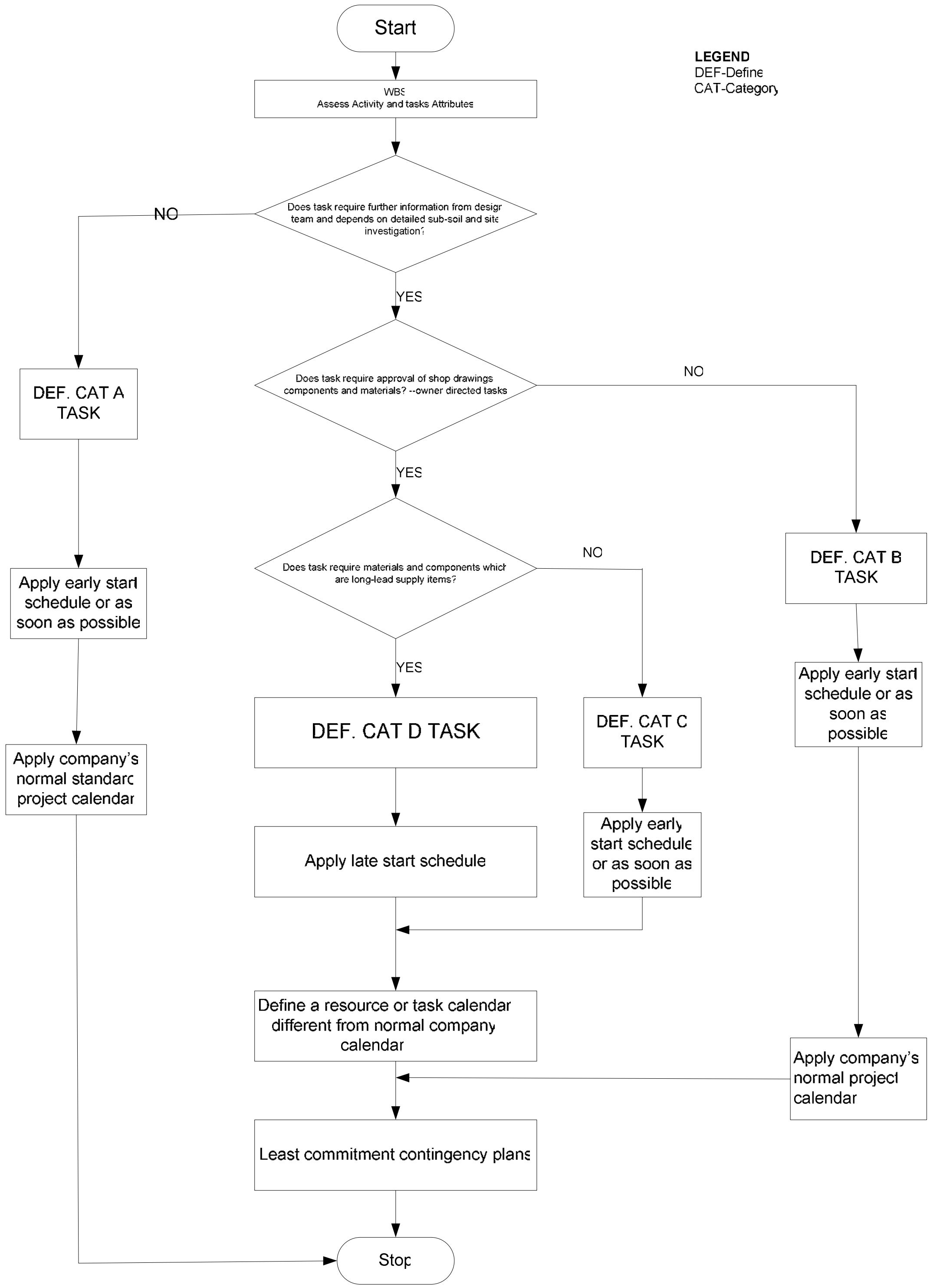

Fig7.1–A knowledge-Based Procedural Framework for Construction Scheduling to Reduce Non-Worktime of Construction Resources on the Jobsite

7.4 Need for Validation

Downtime of construction resources is a complex problem because it is affected by varying factors of different scope and nature. Though a rigorous and adequate procedures have been followed to develop the reported framework, the framework is still largely regarded as proposing a simple solution to solve a rather complex problem. Thus a rigorous validation enquiry is necessary both to test the adequacy of the framework, its reliability and determine to what extent it is user friendly with reduced clumsiness.

7.5 Adequacy Validation

The reported study could be largely regarded as a process improvement study which attempts to improve the planning process with the objective function of reducing non-worktime of expensive construction resources. The study identified those decision variables which form the scheduling procedures and how these create and affect project performance. This is the basis of the derived framework, ie., improving procedures to get a better performance. Therefore, an aspect of validating is to check if all important scheduling variables in the domain problem have been adequately addressed. This is the adequacy validation. It is a check that those variables in tables 5.6 - 5.10 and the findings from the objective data presented in chapter 6 have been built appropriately into the framework.

7.6 Reliability Validation

Construction scheduling is a broad field and there are several models to address different project objective functions. The objective function of the reported framework is reduction in project delays that events occur as planned so that a reduction of non-worktime is possible. If event occur as planned, resources of men and machine moved to site will not have to wait, incurring downtime cost.

This is the philosophy behind the framework. And it will need to validate if the framework as presented has a significant potential to reduce non-worktime. If it can, to what extent? This aspect of validation should also include an assessment of how user friendly the framework is. That it is not too clumsy in field application after determining that it can perform the function of reducing non-worktime of construction resources.

7.7 Validation with Objective Data or Experts Opinions

Results from the process mapping show that different procedures and different attitudes are adopted by different firms depending on company idiosyncrasies. Objective data from document analysis confirmed this and further suggests that different performance is achieved depending on different procedures followed in the scheduling process. Therefore validating by comparing procedure with performance, analysing objective data would provide a very sound assessment of the framework. Such a validation will study scheduling procedures, decisions, scenarios and actual performance. This type of objective data for on-going projects would be needed for well over three to four years or probably even five to glean reasonable outcome of procedure and performance for different projects. This is why an experts' opinions approach has been adopted to validate the framework. Experts are field experienced persons and from their wealth of knowledge they have assessed how the framework may effectively meet its objective function.

Five short questions were drawn to test the validity of the framework in two key aspects, adequacy and reliability as explained in section 7.5 and 7.6. The validation enquiry illustrated in Appendix L was sent to ten leading UK construction companies. This was followed up with some telephone calls. Eventually four completed questionnaires were returned with elaborate comments. Two respondents said the framework adequately addressed the important variable which create and affect non-worktime. One each said it is only fairly adequate; and poorly adequate. The response on reliability was not this straightforward as all four respondents held four different views.

These views held by the different respondents are that;

(i) It has no bearing with reduction of non-worktime

(ii) It is not reliable

(iii) Could not significantly reduce non-worktime and

(iv) Only fairly reliable.

This response from field experts though suggests that there is some sense in the developed framework, and provides further evidence that rigorous and adequate research procedures were followed to investigate the problem, validating, particularly its reliability needs objective data or large sample size of subjective data like experts opinions as attempted in which procedure and performance are assessed..

CHAPTER 8 – CONCLUSION AND RECOMMENDATIONS

8.1 Summary

The reported research represents an incremental knowledge building on the cited works of Thomas , Lewis, Odeh, Cohenca, Olusegun, Levitt, Laufer, Chua, Ming and Vorster in improving and formalising common sense experiential and experts knowledge that is normally hidden beneath the subconscious decision-making process and rules of the thumb of experts in the scheduling process. Previous works which investigated the scheduling process, not the techniques, have focused on other mechanics of the process, like allocation of scheduling resources, frequency of major revisions, information gathering and analysis etc. Those works did not actually address the salient scheduling decision issues and how they affect project performance as attempted in this research.

The scheduling process could be investigated to improve it for different objective functions. In the reported work, the process has been investigated for the objective function of using it to reduce non-worktime of construction resources, which, it is hoped may improve budget and schedule performance. This dissertation is an exploratory study, a confirmatory study and a process improvement study which advances scheduling decision process in which intuitive reasoning is replaced with knowledge based, scientific reasoning. Though it will not be easy for current scheduling software to support this kind of decision, the reported work suggests a library of tasks/resource attributes is a sound basis on which several scheduling decisions could be based. Current practice as gleaned from literature and confirmed with field data suggests that young inexperienced practitioners often use the default options of the several alternatives provided in the scheduling software. For example the default option of start time is commonly applied and differential application of multiple calendar is not common. Even though other options may enhance schedule effectiveness.

A knowledge-based procedural framework for construction scheduling has been developed from literature and field data. This framework which categorised tasks and applied selectively scheduling decision options may help to reduce non-worktime of expensive construction resources.

Though validation results, particularly reliability validation suggests that using objective data instead of subjective experts opinions are necessary with additional development to produce a truly complete and practical tool, testing and validating the framework provides further evidence that a rigorous and appropriate procedures were followed in the reported investigation.

8.2 Conclusions

From literature a strong argument was developed on whether the time element alone is sufficient to define task criticality. The objective data also strongly support this emerging view. And that if criticality would mean those things that should be addressed timely in order to progress the works to a scheduled completion, then the notion of criticality assessment as it is currently viewed should be re-assessed. This is because objective data show that a lot of the time tasks assessed as non-critical are often behind schedule causing project prolongation. While other tasks regarded as critical, may be ahead for the reason that they are almost entirely under the contractor control. These tasks are usually declared critical in the first instance because of their linking and duration due to their quantity. This to a scheduling sense is erroneous. For effective scheduling therefore, task attributes and resource attribute should guide decisions. This is an incremental contribution to the cited works of Ming and Chua who developed the resource-critical path method. The implication for scheduling practice is therefore that task attributes may require differential application of scheduling options of start time and choice of multiple calendar for different tasks and different resources instead of using the default start time and the default calendar options for all tasks and all resources.

8.3 Self Research Assessment

Aside from the usual constraints of cost, time and availability of field data, a retrospective assessment of results and approaches adopted in this investigation shows that envisioned results have been achieved and there are no serious problems with procedures adopted for the investigation except that most contractors do not normally keep the type of data sought as explained previously that styles and approaches for project reporting vary a lot across industry. Also it was observed that the initial focus particularly on field data was on a work trade (the concrete trade) which is contractor controlled having little delay and minimal non-worktime. A too narrow view was initially thought of. This weakness of the study is presented here so that prospective researchers who may want to build on the reported work may carefully consider it to make results better. Concentration on limited number of criteria hides a vast array of factors which may impact on performance. A free mind towards the issue of non-worktime, that it could occur in any work trade was the ideal thing to do. Though this did not limit results the initial of research instrument had to be redesigned.

8.4 Suggested Areas of Further Research

The sound conclusion drawn from this research arguments is that current methods of judging and placing priority in the scheduling process is misleading and not effective. This therefore sets the starting point to looking at the issue more closely and seeking for other means of assessing task criticality so that scheduling is effective. In a nutshell, is it only those tasks assessed as critical by time analysis the important aspects or things to attend to timely in order to progress the works to a scheduled completion? This needs further study. Also the study is reported at a completion stage in which a rigorous validation with object data of the resulting framework is necessary to assess scheduling procedure and project performance regarding the issue of reducing non-worktime of construction resources.

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APPENDICES

Appendix A – Resource Pool For a Project

Resource level	Resource 1 — Grader	Resource 2 — Shovel	Resource 3 — Lorry	Resource 4 — Pile rig	Resource 5 — Steel fixer	Resource 6 — Excavator	Resource 7 — Carpenter	Resource 8 — Labourer	Resource 9 — Dumper	Resource 10 — Crane	Resource 11 — Sub-contractor
1	2	2	4	4	9	2	9	13	3	3	1
2	3	3	6	4	17	4	18	25	5	3	2
3	6	6	12	8	34	8	36	50	10	6	4
4	10	8	20	16	42	12	42	58	16	12	6
5	14	10	28	24	50	16	48	66	22	18	8
6	18	12	36	32	58	20	54	72	28	24	10

Source: Harris (1990)

Appendix B – Anticipated workday each Month of the year

Month	Workdays	Cumulative Workdays	Cumulative Calendar days
Jan	2	2	31
Feb	2	4	59
Mar	7	11	90
Apr	12	23	120
May	18	41	151
Jun	18	59	181
Jul	18	77	212
Aug	18	95	243
Sept	18	113	273
Oct	15	128	304
Nov	5	133	334
Dec	2	135	365

Source: James, J. O'Brien et al (1999)

Appendix C- Example of Variable and constant processing work stations

Work stations	1	2	3	4	5	6
Average processing time	9	9	9	15	9	9

Source: Marc et al (1989)

Appendix D - Relative importance index and ranking of delay factors.

Category	Factor	Contractors Index	Contractors Rank	Consultants Index	Consultants Rank
Client	Finance and payment of completed work	3.30	4	3.32	2
	Owner interference	3.51	2	3.21	4
	Slow decision making by owners	3.24	8	3.16	5
	Unrealistic imposed contract duration	3.08	13	3.11	6
Contractor	Subcontractors	3.21	9	3.26	3
	Site management	3.29	5	2.58	13
	Construction methods	3.29	5	2.37	17
	Inadequate planning	3.14	10	2.95	8
	Mistakes during construction	2.56	17	2.74	11
	Inadequate contractor experience	3.37	3	3.37	1
Consultant	Contract management	3.10	12	3.00	7
	Preparation and approval of drawings	2.32	21	2.21	9
	Quality assurance / control	2.06	25	2.11	21
	Waiting time for approval of tests and inspections	2.46	18	2.47	15
Material	Quality of material	1.75	26	2.00	23
	Shortage in material	3.11	11	2.79	10
Labour and Equipment	Labour supply	2.63	16	2.63	12
	Labour productivity	3.60	1	2.89	9
	Equipment availability and failure	3.25	7	2.42	16
Contract	Change orders	2.40	19	1.79	26
	Mistakes and discrepancies in contract documents	3.05	14	2.05	22
Contractual relationships	Major disputes and negotiations	2.94	15	2.16	20
	Inappropriate overall organisational structure	2.27	22	2.26	18
	Lack of communication between the parties	2.38	20	2.53	14
External factors	Weather condition	2.19	23	1.95	24
	Regulatory changes and building code	1.7	27	1.16	28
	Problems with neighbours	1.59	28	1.58	27
	Unforeseen ground conditions	2.10	24	1.84	25

Source: Odeh et al (2002)

Appendix E
Importance index and ranking of major delay categories

Category	Contractors Index	Contractors Rank	Consultants Index	Consultants Rank
Client	3.28	1	3.20	1
Contractor	3.14	3	2.88	2
Consultant	2.48	6	2.45	4
Material	2.43	7	2.39	5
Labour and Equipment	3.16	2	2.65	3
Contract	2.72	4	1.92	7
Contractual relationships	2.53	5	2.32	6
External factors	1.89	8	1.63	8

Source: Odeh et al (2002)

Appendix F - Variables of delays and their importance, frequency, and severity in construction in Indonesia

Delay situations	Importance		Frequency		Severity	
	Index	Rank	Index	Rank	Index	Rank
1. Unpredictable weather conditions	0.60	11	0.39	11	0.24	11
2. Inaccuracy of materials estimate	0.88	3	0.56	7	0.51	5
3. Inaccurate prediction of craftsmen production rate	0.80	5	0.60	5	0.49	6
4. Inaccurate prediction of equipment production rate	0.69	9	0.43	10	0.33	10
5. Materials shortage	0.79	6	0.63	3	0.52	4
6. Equipment shortage	0.68	10	0.45	9	0.33	9
7. Skilled labour shortage	0.72	7	0.58	6	0.43	7
8 . Locational restriction of the project	0.72	8	0.52	8	0.40	8
9. Inadequate planning	0.88	2	0.61	4	0.55	3
10.Poor labour productivity	0.87	4	0.74	2	0.65	2
11. Design changes	0.93	1	0.98	1	0.91	1
Mean	**0.78**		**0.59**		**0.48**	

Note: The scale of indices ranges from 0 to 1

SOURCE: Olomolaiye et al (1997)

Appendix G – Nature, Type, Cost and length of Delays experienced in 30 projects studied.

Project No.	Nature of delay	Type *	Cost ($)	Length (wks)
I	Payment delays by client	E/C	150,000	24
	Part of site not available	E/C	100,000	24
II	Payment delays by client	E/C	110,000	24
	Part of site not available	E/C	100,000	12
III	Poor work sequencing	NE		
	Component procurement failures by main contractor	NE		24
	Lack of manpower by Contractor	NE		16
	Payment delay	E/C	60,000	8
	Extra works	E/C	150,000	
IV	Heavy rains / flooding of Job site	E/C		2
V	Subsurface different from that expected	E/C		0.5
	Heavy rains	E/NC		1
	Component procurement failures by subcontractor	NE		1.5
VI	Additional work demanded by client			
	Furniture changes	E/C	8,000	8
	Equipment changes	E/C	2,375	3
	Structural works	E/C	5,461	2
VII	Additional work demanded by client			
	Plumbing changes	E/C	3,000	3
	Structural works	E/C	4,229	3
	Electrical works	E/C	3,000	4
	Cupboards changes	E/C	1,771	2
VIII	Errors in plans and specifications	E/C	22,784	
	Ambiguities in plans and specifications	E/C	35,896	
	Change in sequence by Contractor	NE	20,000	
	Additional work request by owner	E/C	18044	4
IX	Ambiguities in plans and specifications	E/C	3,250	1
	Omissions in plans and specifications	E/C	19,637	4
	Errors in interpretation (floor finishes)	E/NC	4,200	2
	Additional work (client brief)	E/C	22,142	2
	Change order by client	E/C	33,538	4
X	Change of sequence by Contractor	NE		11
	Utility not available	E/C	12,700	3
XI	Change method by contractor	NE		
	Poor scheduling	NE	16,000	8
XII	Change method by Contractor	NE		
	Utility not available by Owner	E/C		
	Rework	NE	8,000	4
XIII	Change sequence by Contractor	NE		2.5
XIV	Procurement failures by Contractor	NE		4
XV	Lack of productivity by Contractor	NE		3
XVI	Lack of productivity by Contractor	NE		5
XVII	Additional work request by client	E/C	1,285	2
XVIII	Change sequence by Contractor	NE		4.5
XIX	Heavy rains	E/NC	18,591	1.5
	Omissions in plans and specifications	E/C	160,000	2.5
	Procurement failures by main Contractor	NE	36,000	4
	Consultant change scope of work	E/C	60,000	4
	Late power supply Connections	E/C	4,000	4
XX	Errors in plans and specifications	E/C	12,400	1
	Ambiguities in plans and specifications	E/C	14,600	1
	Omissions in plans and specifications	E/C	23,700	2
	Strikes by General Contractor’s own force	E/C	10,000	4
	Additional works	E/C	102,300	4
	Rework	NE	27,000	2

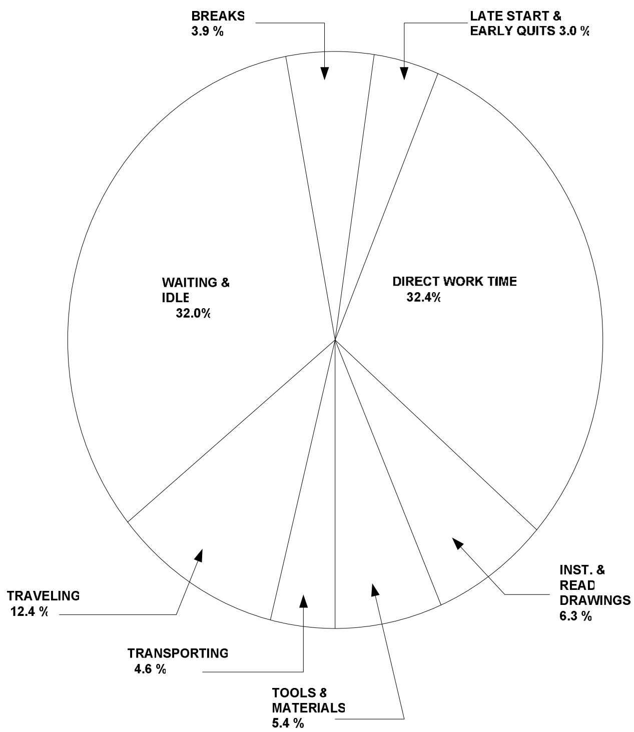
Appendix G contd.

Project No.	Nature of delays	Type *	Cost ($)	Length (wks)
XXI	Ambiguities in plans and specifications	E/C	106,000	2
	Omissions in plans and specifications	E/C	170,000	3.5
	Dayworks	E/C	200,000	4.5
	Extra painting / variation orders	E/C	500,000	17
	Rework	NE	84,000	2
XXII	Heavy rains	E/NC	1,000	3
	Omissions in plans and specifications	E/C	4,000	2
	Change in sequence by Contractor	NE	4,000	2
	Procurement failure by Contractor	NE	3,000	2
	Strikes by contractor's own force	E/C	2,600	8
	Rework damaged by strike	E/C	10,000	4
	Additional work request by client	E/C	50,400	7
XXIII	Errors in plans and specifications	E/C	20,000	4
	Ambiguities in plans and specifications	E/C	5,000	3
	Omissions in plans and specifications	E/C	100,000	7
	Procurement failures by Contractor	NE	**	4
	Additional work by client	E/C	260,000	20
	Late approval of shop drawings by Consultant	E/C	**	1
	Claims for loss and expense	E/C	80,000	
XXIV	Errors in plans and specifications	E/C	17,750	4
	Ambiguities in plans and specifications	E/C	15,000	4
	Omissions in plans and specifications	E/C	31,948	2
	Heavy rains no work	E/NC	**	4
	Procurement failures by Contractor	NE	**	4
	Additional work by client	E/C	280,314	18
	Claims for loss and expense	E/C	500,000	
XXV	Poor sequencing of work by Contractor	NE		2
	Procurement failure by Contractor	NE		2
	Procurement failure by Subcontractor	NE		3
	Poor scheduling of work by Contractor	NE		1
XXVI	Procurement failures by Contractor	NE		
	Lack of manpower	NE		4
XXVII	Poor work sequencing by Contractor			2
	Lack of space	?		2
XXVIII	Slow change in project brief requirement	E/C		4
	Poor work sequencing by Contractor	NE	**	6
	Additional work request by client	E/C	500,000	6
XXIX	Poor work sequencing by Contractor	NE	6,200	3
	Additional work request	E/C	43,800	3
XXX	Errors in plans and specifications	E/C	2,200	2
	Additional work request by client	E/C	17,848	2

* E / C = Excusable Compensable; E / NC = Excusable Non-compensable and NE = Non-Excusable
** Difficult to quantify

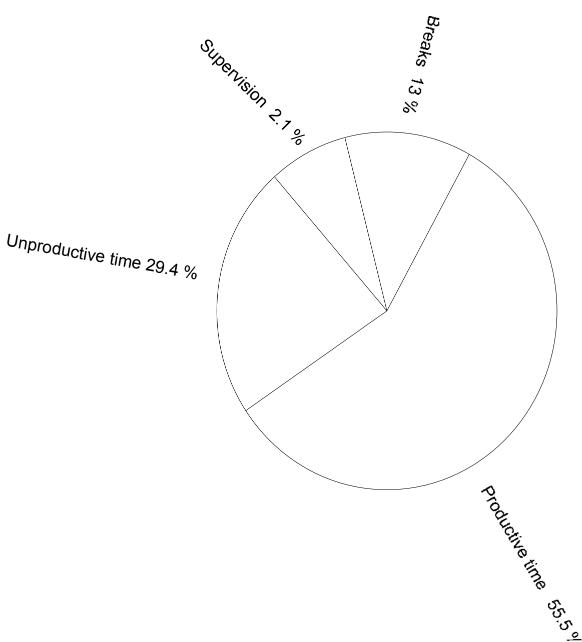
SOURCE: LEWIS

Appendix H – Graphical representation of Activity model



Source: Randolph et al (1989)

Appendix I – Construction worker's time for an Activity



Source: Olomolaiye et al (1998)

APPENDIX J - QUESTIONNAIRE SURVEY

JAS/MG

Date as postmark

To Whom It May Concern

Academic research data for Mr. Friday Efole

Mr Friday Efole is currently a PhD student in the School of the Built Environment, Heriot-Watt University. At the moment he is carrying out research in the field of project planning and control. His research topic is, "Construction Projects Scheduling: A Study of 'As-Built' and 'As-Planned' schedules. We would be grateful if you could supply Mr Efole with research data/information from your completed and on-going projects. The data supplied will only be used by Mr Efole for the sole purpose of academic research. The final research report will be available to you and it will not mention any names or the locations of the case study projects.

Thank you for your assistance with this matter.

Yours faithfully

Professor John Swaffield
Head of School

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APPENDIX J - QUESTIONNAIRE SURVEY

The School of Built Environment,
Heriot-Watt University,
Edinburgh; EH14 4AS,
United Kingdom
13.04.04

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

Dear sir/Madam,

<u>Re: Postal Research Questionnaire - Introduction</u>

I am a research student in the School of Built Environment of the Heriot-Watt University. As a PhD study, I am researching the problem of resource utilising and idling patterns of construction resources. This questionnaire is a module of the study aimed at mapping the planning process of construction companies and project management firms in Nigeria and the UK. The purpose of the survey is to learn construction planning as it is done in industry and to study if the problem of resource utilising and idling patterns can be addressed by the scheduling process. Analysis will focus on: (i) Identifying key decisions necessary in planning to enhance efficient resource use and (ii) pattern recognition and trends of procedure and practices common amongst companies and why companies adopt certain practices or why they do things the way they do. Eventually, the study hopes to develop a procedural framework for planning to reduce idle time of labour and plant.

Please peruse the questionnaire and give your response as genuinely as you can. I do appreciate that some of the questions may be ambiguous or may not be too clear to you. In all please try the much you can to give a response. You may ignore any question if you so wish, though I'll appreciate if you can give a response to all questions. As you will observe no mention of name and address of company has been requested. This is to assure you of confidentiality of data generated via this means. Enclosed is a self-addressed and stamped envelope for your urgent response please.

I thank you for your co-operation.

Yours faithfully,

Friday Efole.
e-mail: feel@hw.ac.uk OR
efolef@yahoo.com
phone: 08036272214

APPENDIX J - QUESTIONNAIRE SURVEY

QUESTIONNAIRE ON A SURVEY MAPPING THE PLANNING PROCEDURE OF SELECTED CONSTRUCTION COMPANIES AND PROJECT MANAGEMENT FIRMS IN NIGERIA AND THE UNITED KINGDOM

Part I – Respondent & company related information

1. Please specify profession of responding officer
   (a) Architect
   (b) Building Engineer ✓
   (c) Civil Engineer
   (d) Quantity Surveyor
   (e) Others (please state) ....

2. Position of responding officer in the company
   (a) Company Director
   (b) Construction/Project Manager
   (c) Commercial Manager
   (d) Chief Scheduling Engineer ✓
   (e) Assistant Scheduling Engineer
   (f) Others (please specify) ....

3. How long have you held this position?
   (a) Less than 1 year
   (b) 1 – 5 years
   (c) Over 5 years ✓

4. Company Business
   (a) Building and Civil Engineering Contractors ✓
   (b) Project Management
   (c) Others (please specify) ....

5. How long has the company been in Business
   (a) Less than 10 years
   (b) 10 - 20 "
   (c) 20 - 50 "
   (d) Over 50 " ✓

6. Name of City/Town where company head office is located........London...............................

7. Average size of company employees
   (a) Under 50 employees
   (b) 50 – 100 "
   (c) 100 – 500 "
   (d) over 500 " ✓

8. Nature of new Build projects you undertake. Please tick one or more.
   (a) Residential ☑
   (b) Office ☑
   (c) Industrial / Factory ☑
   (d) Educational ☑
   (e) Hospital ☑
   (f) Others (please specify) ....Retail, Sports Arenas, Infrastructure............................

9. Please indicate the size of projects you undertake. You may indicate one or more.
   (a) Less than £1.0 M
   (b) £1.0 - £10.0 M ✓
   (c) Over £10.0 M ✓

Part II - Initial Schedule development related information

10. In average, how many activities would you consider in a 7 floors Block of flat constructed in-situ concrete?
    (a) Under 300 ✓ Tender Stage
    (b) 300 – 500 ✓ Construction Stage
    (c) 500 – 1000 ✓ Construction Stage
    (d) Over 1000

11. Tick the appropriate option common to your company practice. You may tick one or more. How do you determine the activity duration estimate?
    (a) The person responsible for performing or supervising the particular activity, e.g., Sectional foreman, Sectional Manager or Sectional head.
    (b) Duration estimates based on historical data of specific similar projects performed in the past. ✓
    (c) Duration estimates based on company's general work study data files ✓ Discussion with specialist sub contractors.

12. Would you consider a long chain of activities, one activity after another, with no branching and with only one thing happening at a time a bad planning? YES ☑ ; NO ☐ ; CANNOT SAY ☐ .

13. The relationship between activities determines which other activities must come before, must come after or can go on at the same time as the activity being defined. In activity sequence or logic development how often do you use:

	very often	Often	Rarely
(d) Activity Splitting	☑	☐	☐
(e) Activity Stretching	☐	☐	☑
(f) Activity Branching	☐	☑	☐

14. Activity splitting, i.e., breaking down an activity with a long duration into smaller parts for the purpose of: (i)Allocating and meeting resource restrictions (ii) Clarifying and satisfying dependency/logic and work space requirements (iii) Accelerating project completion and (iv) Others. Do you consider activity splitting a good scheduling approach? YES ☑ ; NO ☐ ; CANNOT SAY ☐ .

15. For which of the listed reasons (i – iv) in question 14, do you commonly split activities in your schedule development or plan? (Please specify if others)..(ii)..+(i)...............................

16. In developing the work sequence, please score the following factors that may constrain the sequence in the order of their relative importance, in a scale of 1 to 5 with '5' being most important and 1 being least.

Sequence determinants	Score				
	1	2	3	4	5
(a) Construction technology constrained sequence	□	□	□	□	☑
(b) Resource constrained sequence	□	□	☑	□	□
(c) Space constrained sequence	□	□	☑	□	□

17. At the initial schedule development stage, to what extent do you consider limitation on resource availability. LOW ☑; AVERAGE □ ; HIGH □

18. In resource levelling, resources are taken from activities with large floats and added to near critical activities. It is observed that late start schedules seem to have a more levelled resource profile than early start schedules. From your field experience, is this so?
YES ☑ ; NO □ ; CANNOT SAY □ More time to play with

APPENDIX J - QUESTIONNAIRE SURVEY

19. Many Contractors use a 10-hour workday and a 4-day workweek schedules. This leaves a 3-day weekend, Fridays being usually used as make-up or catch-up days for critical activities that are behind schedule. Which of these systems does your company adopts?
    (a) An 8 – hour workday schedule (with 1 hour lunch break) ✓
    (b) A 9 - hour " " (")
    (c) A 10 – hour " " (")
    (d) A 12 – hour " " (with 1.5 hours lunch break)
    (e) Others (please specify) ....

20. What are the most important criteria affecting your planning decisions. Please score the following criteria in a scale of 1 to 5 with '5' being most important and 1 of least importance.

Variables	Importance				
	1	2	3	4	5
(1) Need to reduce down time or idle time, wait time and slow working	☐	☐	☑	☐	☐
(2) Need to maintain equal amount of production for each period of the project life cycle	☐	☑	☐	☐	☐
(3) Need to enhance resource utilisation level	☐	☐	☑	☐	☐
(4) Need to meet project duration	☐	☐	☐	☐	☑
(5) Need to minimize material storage on site	☐	☑	☐	☐	☐
(6) Need to meet health and safety requirement	☐	☐	☐	☑	☐
(7) Need to optimise cost and duration	☐	☐	☐	☐	☑
(8) Need to match resource availability, planned and actual utilisation	☐	☐	☐	☑	☐

21. The resource utilisation rate, e.g., of Man-hour and Machine-hour are affected by variables directly related to planning decisions. Please score the following variables in a scale of 1 to 5 with '5' being of most effect and 1 of least effect.

Variables	Effect on resource utilisation rate				
	1	2	3	4	5
(1) Activity relationship or sequence	☐	☐	☐	☐	✓
(2) Buffers between on-site activities	☐	✓	☐	☐	☐
(3) Use of multi- skill labour	☐	☐	✓	☐	☐
(4) Space requirement/planning	☐	✓	☐	☐	☐
(5) Buffers between delivery of materials and related on-site activities.	☐	☐	☐	✓	☐
(6) Type and number of resources used for each activity	☐	☐	☐	✓	☐
(7) Buffers between engineering design information and on-site activities	☐	✓	☐	☐	☐
(8) Resource levelling	☐	☐	☐	✓	☐
(9) Use of off-site production techniques	☐	☐	✓	☐	☐

APPENDIX J - QUESTIONNAIRE SURVEY

22. The idle/wait or down time of construction resources is caused by a number of variables. Please score the following variables in a scale of 1 to 5 with '5' being most important and 1 being least important contribution to idle time.

Variables	Contribution to idle time				
	1	2	3	4	5
(1) Late delivery of materials	☐	☐	☐	☑	☐
(2) Sequence of activities leading to a prolonged use of plant	☐	☐	☑	☐	☐
(3) Restriction in work space	☐	☑	☐	☐	☐
(4) Over allocation of resources to some activities (e.g., due to a desire to speed up progress) leading to some of the resources being idle	☐	☑	☐	☐	☐
(5) Instruction and information coming late (e.g., engineering design and working drawings)	☐	☐	☐	☐	☑
(6) Delays in preceding activities	☐	☐	☐	☑	☐
(7) Equipment down time, making labour to wait	☐	☐	☑	☐	☐
(8) Labour disputes, making equipment to wait	☑	☐	☐	☐	☐
(9) Others (please specify and score.................... ....)	☐	☐	☐	☐	☐

23. In order to ensure continuity of work and minimise disruption and idle time, planners allocate time buffers between the dates when materials/information or preceding activities are scheduled to arrive on site (or completed in case of activities) and the subsequent activities that use these materials. Please state the number of days on average you allocate as buffers for the followings:

(a) Standard materials (e.g.,Cement, Sand, Steel Reinforcement etc) ....7............
(b) Made to order materials (e.g.,Timber and Metal Doors, Windows etc) ....14............
(c) Engineered to order materials (e.g., Lifts, Escalators etc) ....14............

Part III - Schedule Management, Up-date, and schedule control

24. Please score the following short – term plan periods in order of their relative schedule efficiency measured in terms of it's reliability and resource utilising patterns in a scale of 1 to 5 with '5' being most reliable and enhancing more efficient resource use.

Short – term plan periods	Reliability & efficiency of resource use				
	1	2	3	4	5
(a) A 5 – day or weekly short – term plan	☐	☐	☐	☑	☐
(b) A 10 – day or fortnightly short – term plan	☐	☐	☐	☐	☑
(c) A 30 – day or monthly short – term plan	☐	☐	☑	☐	☐

25. Which do you prefer as a means for planning to reduce project duration. (use both)
(a) Apply more resources, i.e., increase crew size, work overtime and night shift.
(b) Schedule to perform activities concurrently i.e., overlap activities where possible. ✓

26. Which of the following options would you adopt to solve the scheduling problem if resources required for the project cannot be made available at the normal price to maintain the project early completion date.
(a) Reschedule the activities and target the project imposed contractual due date ✓ 1st
(i.e., Project late finish date)
(b) Depending on the economics of delayed completion i.e., Liquidated and ascertained damages ✓ 2nd
consider making resources available at a premium price e.g., extended shift:- A 10- hour workday, A 12- hour workday; extended workweek:-A 6 or 7 – day workweek and overtime payment.

APPENDIX J - QUESTIONNAIRE SURVEY

27. Please list about five construction materials you consider as long-lead items whose late delivery may render man-hour and machine-hour idle.
    (a) ....Stone Cladding..........
    (b) ....Curtain walling..........
    (c) ....[illegible] Seam Roofing..........
    (d) ....M&E Plant..........
    (e) ....Steelwork..........

28. How would you define a dominant or a driving resource of an activity. Please tick one or more.
    (a) The length of time the resource is being employed ✓
    (b) The cost of the resource in relation to other resources deployed for the operation
    (c) The space occupied by the resource

29. The master plan defines milestones and fulfils the long-term objective of the project. While short-term planning ensures efficient use of project resources. Which of the following methods do you prefer for short-term planning.
    (c) Period planning, in which any period within the project life - cycle, e.g., the middle, the beginning or the ending is amplified in detail. use
    (d) Stage planning, in which only a stage, a work package or a work trade is amplified in detail. both

30. Please score the following factors responsible for changes in activity sequence in order of their relative importance in a scale of 1- 5, with '5' being most important.

Sequence change determinants	Score				
	1	2	3	4	5
(a) Changes in work scope	☐	☐	☐	☐	✓
(b) Late delivery of materials	☐	☐	☐	✓	☐
(c) Lower or higher productivity	☐	☐	✓	☐	☐
(d) Work space requirement	☐	✓	☐	☐	☐

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31. It is the main Contractor's responsibility to resolve scheduling disputes and conflicts between the different sub-contractors as well as within the contractor's own forces. ~~Rank~~ Score the process of doing this in a scale of 1-5, with '5' being most preferred by you.

Sequence change determinants	Score				
	1	2	3	4	5
(a) Soliciting input from different concerned parties	☐	☐	☐	☐	☑
(b) Seeking and confirming commitment	☐	☐	☐	☐	☑
(c) Drafting a rough scheduling and circulating it to all concerned	☐	☐	☐	☐	☑

Part IV – Schedule performance assessment

32. The followings have been suggested as measurement parameters of a schedule performance. which does your company adopt? Please tick one or both.
    (a) Is the project ahead or behind schedule with respect to time? i.e., Elapsed time measuring actual time spent (as at TIME-NOW) in relation to the quantity installed ✓
    (b) Is the project ahead or behind schedule in terms of the resources or cost expended up to the DATA DATE.

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33. During which of the following stages in project control is the problem of resource utilising best tackled?
    (a) Initial planning or initial schedule development ✓
    (b) Schedule management, monitoring and control.

34. Productivity is lost when a sub-contractor has to constantly mobilize and demobilize, particularly with regards to machine set-up and dismantling cost. In this case which is more critical when considering activity resource utilising factor.
    (a) Machine-hour
    (b) Man-hour
    Depends on activity and dependance on plant

35. Please list four construction activities/operations in which you experience multiple stops and multiple starts.
    (a) ....Groundworks / Foundations – weather........
    (b) ....Above Ground operation – weather........
    (c) ....Blockwork – Openings, Service penetrations........
    (d) ....Ceilings – M&E Installations........

36. The entire scheduling process should be looked at from the point of view of efficient use of time, money and other resources. Please score the following efficiency measures used by your company in a scale of 1 to 5, with '5' being most preferred and 1 least preferred.

Efficiency measure of the schedule	Score				
	1	2	3	4	5
(a) Efficiency measured in terms of Time elapsed	□	□	□	□	✓
(b) Efficiency measured in terms of Money expended	□	□	□	□	✓
(c) Efficiency measured in terms Resource utilising pattern	□	□	✓	□	□

37. Score the following contract procurement routes in a scale of 1-5, with '5' being most important in order in which you consider their schedules to offer opportunity for efficient resource utilising & schedule reliability.

Variables	Contribution to idle time				
	1	2	3	4	5
(a) Negotiated Contract with BOQ	☐	☐	☐	☐	☑
(b) Negotiated Contract without BOQ	☐	☐	☐	☐	☐
(c) Traditional form of Contract based on firm BOQ e.g., Fixed price contract	☐	☐	☐	☐	☑
(d) Phased Contracts	☐	☐	☑	☐	☐
(e) Fast – track with varying degrees of concurrency	☑	☐	☐	☐	☐
(f) Design and Build Contracts	☐	☐	☐	☑	☐
(g) Management Contracts	☐	☐	☐	☐	☑

APPENDIX L- Validation Enquiry

School of the Built Environment,
Heriot-Watt University.
Riccarton,
Edinburgh; EH14 4AS
UK
10.04.06

Dear Sir/Madam,

MODEL VALIDATION ENQUIRY

Attached is a model validation enquiry for a model developed from a study on means of reducing downtime of construction resources on the job site. Kindly peruse the introduction and answer the five validation questions drawn to test the validity of the model in two aspects: (i) Adequacy – whether the model has adequately addressed all important variables in the problem domain and (ii) Reliability – whether the model can perform the function of reducing downtime of construction resources and to what degree.

I am sure completing the questionnaire will take only a few minutes of your time. Please kindly help to give your candid response and post back in the stamp and addressed envelope. The submission of the report is due for end of April I'll appreciate if you mail your response as soon as possible

I thank you for your kind co-operation.

Yours' Sincerely,

Efole Jr.

Friday Efole. (Research student)

Mobile: 07706106919
e-mail: efolef@yahoo.com

APPENDIX L- Validation Enquiry

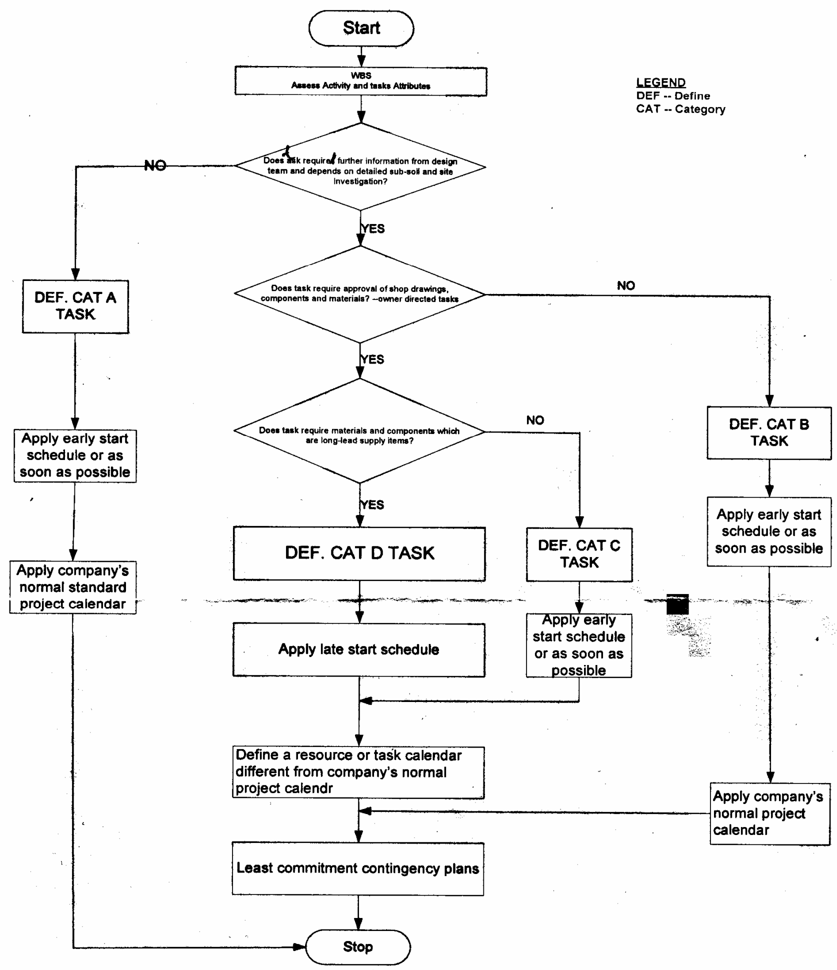

Fig. 1 - A Knowledge-based procedural model for construction planning to reduce downtime of construction resources on the job site

MODEL VALIDATION ENQUIRY

RESEARCH TOPIC: A CONCEPTUAL MODEL FOR EFFECTIVE PLANNING FOR EFFICIENT USE OF CONSTRUCTION RESOURCES ON THE JOBSITE

Introduction

A knowledge – based procedural model has been developed for Construction planning to reduce Downtime of Construction resources on the jobsite. A fundamental assumption in the development of the model is that it is for application to in-situ construction of a wide variety of Building works of medium scope projects and focuses on planning issues of the problem domain. The model is a simple one which uses a question and answer routine to assess tasks attributes, defines tasks into certain categories and suggests ways of scheduling tasks in each group which will help to reduce downtime of construction resources in project implementation.

Three research methodologies are adopted in the investigation:

(a) Mapping planning procedure with a postal questionnaire to identify attitude and procedures in Construction planning process
(b) Interviews with experts on procedures and practices in Construction planning Which will enhance efficient resource use
(c) Case study of four on-going projects on production outputs, resources and work interruptions.

Results show that different procedures and different attitudes are adopted by different Firms depending on company idiosyncrasies. Both the experts opinions and procedure mapping show that firms adopt a style of scheduling, say early start and apply this to all projects and all activities not really considering project and tasks specific attributes. This to A large extent is reasonable as it will seem too cosmetic to apply selectively early start to some tasks and late start to others. Or to change normal company procedure from project to project.

APPENDIX L- Validation Enquiry

However case study data from document analysis of periodic site meetings show a different view. This view is that if some of the tasks have been scheduled with late start and a definition of individual resource calendars for labour and equipment instead of applying normal company project calendar for all tasks and all resources, wait time may have been significantly reduced for these resources.

Downtime of Construction resources is a complex problem because it is affected by varying factors of different scope and nature. Proposing a simple model like this to solve a rather Complex problem needs a rigorous validation enquiry. Due to time constraints experts opinions has been adopted to validate the model. This is because validating with objective data will take another four to five years of procedure and data study.

The two aspects of the model to be assessed by experienced persons are:

(a) Based on the assumptions made on study scope, has the model adequately addressed all important variables that define and affect downtime of Construction resources?

(b) Does the model as it is presented have a significant potential to reduce downtime and enhance efficient use of Construction resources?

Advantages of the model

1. It attempts to integrate budget and schedule
2. It proposes a long – term approach to solve a seemingly short – term problem. Downtime of Construction resources occur during instantaneous, relatively short time periods. Not usually spanning the entire project duration. But resources cannot be mustered on a short notice. Long-lead time is required. Hence the long-term approach proposed.
3. It is flexible and tries to incorporate both the principle of Just-in-time as well as making reasonable allowance for some contingency arrangements, two principles often viewed in Construction planning as directly opposite and are difficult to include in a single system.
4. Being knowledge-based, the model will shift according to the specific knowledge domain of task attributes. This will enhance it's reliability in solving the domain problem which is reduction in downtime and efficient use of resources on the jobsite. Also, Scheduling decisions are no more vague, based only on rule of the thumb, but are now made on the project and task specific attributes.

Q.1 Aside from weather sensitive activities and those variables in the question routines, list any number of other variables you consider may contribute to wait time of construction resources.

1. SITE RESTRICTIONS OUTWITH DESIGN TEAMS HANDS ie LOCAL AUTHORITY / SHARED GROUNDS
2. STATUTORY AUTHORITIES
3. HUMAN ERRORS

…………………………………………………………………………………………

…………………………………………………………………………………………

Q2. When such tasks as component procurement, information requirement, shop drawings approval are planned and scheduled, do you still consider the framework a necessary tool to yield a better reliability in project schedule implementation?

- YES [ ]
- NO [x]
- YES and NO [ ]
- CANNOT SAY [ ]

Q.3. From your field experience, to what extent would you consider the variables in the Question routine adequately address wait time parameters?

- Very Adequate [ ]
- Adequate [x]
- Only fairly Adequate [ ]
- Poorly Adequate [ ]

Q.4. The model suggests that tasks without 'strings' could start as soon as possible, those with little strings could still start as soon as possible but with a contingency arrangement in place should….. While those tasks with much strings and undefined nature should start late, with a defined resource calendar different from the normal company project calendar, and in addition a contingency arrangement in place. To what extent from your field experience will this model enhance a more reliable schedule, that things happen when they are scheduled?

Very Reliable	☐
Reliable	☑
Only fairly Reliable	☐
Not Reliable	☐
No bearing at all	☐

Q.5. Generally rate the suitability of this procedural model as a means of reducing wait time expensive construction resources on the jobsite.

Very High	☐
Moderate	☑
Low	☐
Very Very Low (cannot reduce wait time at all)	☐