Cash Flow Diagramming In Line of Balance Technique by Using Matlab

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ABSTRACT

Contractors often encounter with repetitive types of projects that contain several identical or similar units. These multi-unit projects are characterized by repeating activities. The known construction planning techniques such as Bar Chart and Network Diagramming method are not suitable and sufficient for repetitive types of projects. For these kinds of projects, Line of Balance planning techniques (LOB) are mainly used. For all construction projects, costs and times must be monitored and controlled, whether from the point of view of an owner, a project manager or a contractor. Cash flow is another extremely important issue, which the contractors and owners must be sensitive if they want to survive. However although there are a number of software for the Line of Balance planning technique, developing a computerized method capable of obtaining Line of Balance and drawing the LOB graphs and additionally obtains cash flow and drawing the cash flow diagrams is essential for contractors and owners. Furthermore, preparing Line of Balance scheduling and preparing the financial statements for the method is a time consuming process which can be a source of errors. The primary goal of this study was to develop a computer program by using Matlab package in Line of Balance method for clients, contractors and project managers which can be used effectively in construction projects. The Line of Balance method can be obtained easily, accurately in just few minutes. Moreover, the program has capability of obtaining cash flow and drawing cash flow diagrams for different periods of time, phase or section of project. By using the software the cash flow is determined, cumulative, daily, weekly and monthly cash flow diagrams are prepared accordingly. In order to evaluate the developed program, a Villa housing project is selected as a case study. Entering the

Line of Balance input data and preparing Line of Balance table are done in less than one hour by using the software. The Line of Balance graphs, cash flow and cash flow diagrams are prepared automatically in just few seconds. However, it takes several hours to prepare them manually without using a software. The Line of Balance table is prepared and calculated by Microsoft Excel to compare the results with the developed software. The exact and accurate results were obtained by using the developed program compared to Microsoft Excel program.

Keywords: Line of Balance technique; Cash flow; Matlab package; Microsoft Excel.

ÖZ

Müteahhitler genellikle birkaç aynı veya benzer birimler içeren projelerin tekrarlayan tipleri ile karşılaşıyorlar. Bu çoklu üniteler ihtiva eden projeler yinelenen faaliyetleri ile katakter kazanmaktadır. Çubuk diyagramı ve Network diyagramı yöntemi gibi bilinen inşaat planlama teknikleri tekrarlanan proje türleri için uygun ve yeterli değildir. Bu tür projeler için çoğunlukla Line of Balance (LOB) kullanılır. Tüm inşaat projelerinde sahibi, proje yöneticisi veya müteahhit için maliyetler ve zaman takibi yapılmalıdır. Nakit akışı mal sahibi ve sürüdürelebilir müteahhitlik yapmak isteyenler için çok önemli bir konudur. Ayrıca, el ile Line of Balance hazırlanması ve para akış diyagramı hazırlamak hem çok zaman ister ve hem de hesaplama hataları yapmak mümkündür. Bu çalışmanın temel amacı Matlab bilgisayar paketini kullanarak Line of Balance planlama tekniği üzerine bir bilgisayar programı geliştirmektir. Bu geliştirilen program Line of Balance hesaplarını yapıp gerekli tabloyu dolduracak ve sonar da her aktivite için Line of balance grafiklerini çizecektir. Daha sonra bu proje için para akış hesapları yapılacak ve istenilen zaman birimi için, günlük, haftalık veya aylık, para akış diyagramı çizilecektir. Bütün bu işler geliştirilmiş bulunan bilgisayar program ile dakikalar ile sınırlı bir zaman dilimi içinde yapılabilmektedir. Halbuki bu işlerin el ile yapılması saatler istemektedir. Geliştirilen program, örnek olarak bir villa projesi için denenmiş ve hem zaman açısından ve hem de hata yapmamak açısından çok yararlı bulunmuştur. Ayrıca, programın yaptığı tablolar Microsoft Excel ile test edilerek doğruluğu ıspatlanmıştır.

Anahtar Kelimeler: Line of Balance planlama tekniği; Nakit akışı; Matlab paket, Microsoft Excel.

Dedicated to my family

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Chapter 1

INTRODUCTION

1.1 Overview

Planning is a vital process that can be considered continuously through the entire project life time, phases and all stages. The Line of Balance (LOB) method of planning is well suited to projects that are composed of activities of a linear and repetitive nature. Network based methods such as the critical path method (CPM) are proven to be powerful scheduling and progress monitoring and controlling tools, but they are not suitable for projects of a repetitive nature. (Arditi, B.Tokdemir, & Suh, 2002). For all construction projects, costs and times must be monitored and controlled, whether from the point of view of an owner, a designer or a contractor. Inadequate or inappropriate costing is one of the most important causes of contractor failure in the construction industry. Cash flow diagram is a tool used by contractors or clients to indicate a project's finance strength. Development of a computerized method which is able to obtain cash flow diagram and financial statement in different periods of time, phases or sections of project in Line of Balance scheduling is essential for contractors and owners. However although there are a number of software for the Line of Balance planning technique, the calculation and drawing of cash flow diagram is still needed to be studied and developed.

The line of balance programming technique is rarely understood by construction managers and planners and is still very much underused in the construction industry. Line of balance tends to be favored only by those who have a through grasp of the principles and application based on experience (Cooke & Williams, 2004). Although

Line of Balance scheduling is a powerful tool in repetitive types of projects, but since there is no sufficient computerized program in preparing Line of Balance table and graphs and obtaining the financial statement or cash flow diagram of project for contractors or clients, therefore it does not have wide applications as bar charts or networks in construction industry.

The objective of this study is to set down the basic principles that can be used in development of a computerized LOB scheduling system that overcomes the problems associated with existing systems and creates solutions to encountered problems in the implementation of repetitive-unit construction. This Project is a study to apply Line of Balance planning technique and to prepare cash flow diagram using Matlab package.

Using Matlab package, a software which is able to set up Line of Balance scheduling is developed. Line of Balance table and drawing graphs can be prepared easily and correctly by using the developed software. Moreover, cash flow diagram and financial statement is automatically obtained in several time scales such as daily, weekly or monthly steps.

1.2 Objectives of Study

The primary goal of this study is to develop a computerize program for clients, contractors and project managers in Line of Balance method which is an effective planning method for repetitive types of project. This thesis is looking for achieving the objectives given below:

1. To undertake a comprehensive literature survey about the construction planning techniques, costing and controlling the construction projects.
2. To develop a computer program which can draw the line of balance diagrams, calculate cash flows, and draw cash flow diagram.

3. Evaluating the developed program in a case study, applying it on a housing project.

1.3 Works Done

In order to achieve the aims and objectives that are mentioned in section 1.2, the followings were performed:

1. Collection of necessary data by a comprehensive literature survey for construction planning techniques, cost analysis and controlling the construction projects. Existing journal papers and books are reviewed for this purpose.
2. Matlab package is selected in order to apply for the study. Matlab programming is developed in a user friendly interface. The program has capability of obtaining Line of Balance, drawing Line of Balance diagrams, calculating cash flow and drawing cash flow diagrams.
3. A repetitive type of construction project is selected as a case study project for evaluation the developed computerized method. The necessary information related to project such as Architectural and Structural plans are collected. The entire prerequisite analyses such as Bill of Quantities and Work Break Down Structure etc are done in order to prepare the case study project data for applying in Line of Balance method by the developed program. The rest of necessary information were collected from variety of resources such as books, journals, consulting and using Planning and Construction Department of government in North Cyprus. The Line of Balance method is prepared for the case

study project and Line of Balance graphs are obtained. Moreover, cash flow calculation is determined and cash flow diagram was drawn. Evaluation of computer program is prepared by using the case study project.

1.4 Achievements

The achievements of this thesis can be summarized as following:

1. A comprehensive literature survey is provided for construction planning techniques, cost analysis and controlling the construction projects in this study. These three important factors are individually discussed in details in separate literature review chapters accordingly.
2. By using the Matlab package, the developed computerized method is prepared for this study. The developed software can prepared Line of Balance table and its diagrams accurately in a short period of time. Furthermore, by using the software the cash flow is determined and cumulative, daily, weekly and monthly cash flow diagrams are prepared accordingly.
3. The entire case study project analyses are provided in details, accurately and as updated as possible in order to reduce the errors. Entering the Line of Balance input data and preparing Line of Balance table are done in less than one hour by using the software. However, it may take several hours to implement this step without the software which can be a source of error as well. The Line of Balance graphs, cash flow and cash flow diagrams are prepared automatically in just few seconds which is takes

several hours to prepare them without the software. The Line of Balance table is prepared and calculated by Microsoft Excel to compare the results with the developed software. The exact and accurate results were obtained by using developed program compare to Microsoft Excel program.

1.5 Guide to the Thesis

This thesis is a study on application of Line of Balance scheduling method and obtaining cash flow diagram by using Matlab package.

This section presents the overview of the structure and contents of this study.

Chapter 1 is the introduction of this study which is mainly focused on the objectives, works done and achievements of the thesis.

Chapter 2 focuses on Construction Planning techniques. Construction planning is explained in details. Several types of construction planning techniques such as Bar chart, Network diagram and Line of Balance are discussed. The last section of this chapter also discusses Line of Balance method in detail.

Chapter 3 is about costing of construction projects. Prerequisite steps of project costing are explained in several sections. Unit pricing and construction project costing is discussed. Different types of costs are explained. Project cost estimating and budgeting is outlined in the last part of this chapter.

Chapter 4 presents control of construction projects. Objectives of controlling construction projects described. Cost, Time, Quality and Site control are basically most important issues in a construction project which need to be accurately controlled in a project progress. However, they are the major factors of controlling the construction project that are explained mainly in this chapter.

Chapter 5 describes applications of Line of Balance by using Matlab package. Matlab package is briefly outlined. The next section will provide information related to the project that has been taken as a case study for this thesis. Several analysis is provided such as Bill of Quantity, Work break down structure (WBS), cost analysis and productivity analysis, their analysis is mainly discussed and the results of their analysis is shown in several tables. By using Microsoft project, bar chart and network diagram is obtained and the project duration is determined. The last section of this chapter focuses on the methodology used to carry out the application of Line of Balance in Matlab program. Line of balance table is obtained and it is shown in detail how to prepare Line of Balance table and their values. The application of Matlab package in this study is explained; how to run the program, how to enter the data, and how the program will perform is discussed. At the end of this section, the cash flow diagram and its values are obtained by showing the graphs in several time scales.

Chapter 6 concludes the study with a short summary of what has been done and provides a discussion of the thesis. The areas of future research are also recognized and recommended.

Chapter 2

CONSTRUCTION PLANNING TECHNIQUES

2.1 Introduction

Project management is the discipline of planning, organizing, and managing the resources to bring about the successful completion of specific project goals and objectives. Project planning is a part of project management which is related to the use of schedules such as Bar charts, to plan and then report progress within the project area. Furthermore, Schedule development denotes determining start and finish dates for project activities which use results of the time management processes to determine start and end date of the project and its activities. Its final and critical objective is to create a realistic project schedule that provides a basis for monitoring project progress for the time dimension of the project.

Without planning it is difficult to imagine the successful conclusion of any project. Furthermore, planning can provide the effective control of time, money or resources in any type of projects. Planning is also essential in order to deal with construction risks and create safe working methods.

This chapter has essentially focused on construction planning techniques. History and general information about construction planning techniques are described. Moreover, the objectives, benefits and types of construction planning techniques are defined and explained.

Project scheduling techniques are Bar chart, Network analysis and Line of balance. This chapter contains comprehensive and practical information about scheduling from history to practical uses of mentioned methods and their comparison criteria.

Although, there are several planning methods available, three methods are most predominant in practice namely bar charts and network analysis (including both arrow and precedence forms) and Line of Balance scheduling.

Bar chart is one of the oldest visual or graphic scheduling methods in construction industry. Bar charts are well suited to depicting construction sequences and are readily understood at all levels of management.

Network analysis is a general term for a graphical planning technique which shows the project as a network of its activities linked together to show their interrelationships and sequence of execution. Basically the network is a flow diagram that shows the operations' sequence of a process.

Linear scheduling method which is discussed at end of this chapter is a relatively new scheduling technique used in construction industry. Linear scheduling is a viable method on a variety of projects that contains repetitive activities.

2.2 Background to Construction Planning

The Egyptians and Romans did construction miracles in their era. Surviving ruins demonstrate to the brilliance of their architecture, but little known of their construction planning and scheduling. It can be supposed that they solved many scheduling programs by the "use of a bigger whip" philosophy. Project management has other roots reaching back into the days before pyramids. Historical project managers included Noah, Solomon, and the unknown architect who designed the tower of Babel. History records much about the construction details but little about the methods of control. In the mid-nineteenth century, at least one writer discussed a work vs. time graphical representation very similar to today's bar graphs or bar charts. The Taylor and Gantt's work was the first scientific consideration of work scheduling problems. (J.O'Brien, 1993)

Although scheduling has likely been a part of human, and perhaps animal, existence since lunar cycles were observed for hunting and gathering, modern scheduling perhaps began when Henry L. Gantt developed bar chart in 1917. Henry Gantt (1861-1919) was a pioneer of management science who is almost as well known in management science circles for his views on productivity and employee compensation as for the bar chart. (Weber, 2005)

2.3 Overview of Construction Planning

All construction projects require planning and they often require huge expenditure. Project planning is part of project management, which relates to the use of schedules such as Bar charts to plan and then report progress within the project environment.

According to Neale & Neale (1989), the term planning can be applied to the whole of a construction project, from beginning to end, from inception and feasibility study to final commissioning and handing over the completed works to client.

Planning and scheduling are basic to most activities that we do as humans in our life. Planning is the way we organize and sequence the tasks needed to accomplish a goal. There are plans for achieving common aims, for example going to work on time, moreover, there are some formal plans such as those used by companies for instance strategic plan, business, financial and marketing plan. Scheduling is one main factor of the plan and assists in visualizing the plan.

Hinze, (1998) noted that, planning can be considered as determining “what” is going to be done, “how,” ”where,” by “whom,” and “when.” Thus, when we discuss planning in the construction process, we have to focus on the “how” and, therefore, the “what,” “when,” “where,” and “who.”

Moreover, when we discuss scheduling, we are usually interested in some aspect of the time element of the plan. In essence, a schedule is a timetable of activities, such as of “what” will be done or “who” will be working. Such a time table can be considered in two ways: the first focusing on an activity, such as determining “when” a certain task will be performed relative to other activities. The second is concentrating on a specified time frame and then ascertaining “who” will be working (or needed) or “what” should be occurring at a particular time. The degree to which we carry it out and the techniques we use vary depending upon the complexity of our situations and our need and objectives.

Therefore without planning it is difficult to imagine the successful conclusion of any project. Furthermore, planning can provide the effective control of time, money or resources in any type of projects. Planning is also essential in order to deal with construction risks and create safe working methods. Planning is a vital process that can be considered continuously through the entire project life, faces and all stages such as briefing, design, tendering, construction and commissioning stages of a project.

These reasons for planning may be summarized as:

- To aid contract control
- To establish realistic standards
- To monitor performance in terms of output, time and money
- To keep the plan under constant review and take action when necessary to correct the situation. (Cooke & Williams, 2004)

According to Neale & Neale, (1989) it is most important to distinguish between planning and the use of planning techniques.

- Planning is the creative and demanding mental activity of working out what has to be done, how, when, by whom, and with what, i.e. doing the job in the mind. Plans are not just pieces of paper. Plans represent the results of careful thought, comprehensive discussion, decisions and actions, and commitments made between people and contractual parties.
- Planning techniques from the planner's tool-kit; they assist in the analysis of the plan, organizing the information, and have a crucial effect on the way in which the plan is communicated to others.

The importance of this difference between planning and the use of planning techniques is that it is clear that planners cannot plan without managers; without managerial involvement planners are reduced to theorists. It is the manager's task to plan; that is, to decide on strategies and tactics, to break down the work to be done into tasks and subtasks, and to assign the responsibility for completing these tasks to individuals or organizations.

Most planning techniques purpose to state the work to be done, to a time-scale; some also include resources, and perhaps cost and value. In simple terms, their goal is to assist control time and cost. The other major factors in project which are control and quality, is controlled by other types of control techniques.

Weber, (2005) states that the scheduling part of the construction plan requires that the tasks or activities are assigned a duration corresponding to the anticipated productivity of the crews doing the work. When tasks have durations and are put in their proper order by identifying the relationships they have with one another, a construction schedule is created. Scheduling is just one part of construction planning, which may also includes plans for safety, community relations, material storage and handling, and environmental protection along with schedule to create the overall construction plan.

Furthermore, converting the construction plan into a construction schedule will help the construction manager and estimator determine whether the selected plan and work task productivity estimates will provide a construction duration that is within the time limits established by the contract.

2.4 Objective of Construction Planning

In general, the main objectives of planning are as follows:

1. Analysis which is envisaging how the job will be done, in what order and with what resources; reducing the project, or part of the project, to a number of manageable activities. Each activity should be readily identifiable as a coherent piece of work, ideally relating to the project management structure and thus under the control of a specific individual.
2. Anticipation which is to foresee potential difficulties, to plan to overcome them, and to anticipate risks so that their effects can be minimized. It can be argued that this is the major objective of construction planning, because civil engineering is a fairly high risk business, and the planning of many activities is fraught with uncertainty.
3. Scheduling resources to enable optimum use to be made of the available and economic resources, for each project and – taking all projects together – for the organization as whole.

4. Co-ordination and control to provide a basis for coordinating the work of the parties and contractors participating in the project, and to provide a basis for predicting and controlling time and cost.
5. Production of data to enable planning data to be acquired for use in the preparation of future plans.
6. To establish a realistic time period for the construction stage
7. To monitor actual progress and take corrective action
8. To provide a broad outline plan or strategy for the project
9. To establish a construction sequences on which the master program may be based
10. To identify key project dates
11. To highlight key information requirements
12. To schedule key dates with respect to key material and subcontractor
13. To monitor the master program – monthly, weekly and daily
14. To plan site operations in detail in the short term
15. To optimize and review resources
16. To keep the project under review and report on variances.

2.5 Benefits of Construction Scheduling

The following list of possible benefits is by no means exhaustive but indicates the areas in which advantages can be gained from good planning.

- Illustrate interdependence of all tasks
- Identifies times when resources must be available
- Facilitates communication throughout the project
- Determine critical activities, critical path

- Affect client expectations through establishment of activities, milestones, and completion dates. (Celik, 2009)
- Planning predicts the timing of activities and their sequences and hence the total construction period.
- Planning enables the safety, quality and environmental impact of the work to be properly considered.
- Planning allows the risks and opportunities to be evaluated.
- Cost and therefore price are reflected by the working methods and the time taken, thus providing a basis for the estimate.
- Planning provides a basis for monitoring.
- Planning predicts flow of cash, i.e. Cost against return.
- Planning provides a basis for claims evaluation, in particular extension of time entitlement calculations.
- Planning pinpoints when materials are required, thus optimizing storage space and minimizing breakage and loss.
- Using histograms for major bulk materials, such as concrete and quarry products, provides suppliers with average and peak levels of demand.
- Planning predicts resource levels of labors, staff and plant. (Madwesley, Askew, & O'Reilly, 1997)

Additional benefits to the clients (or their consultants) are:

- Planning provides deadlines for latest dates for release of information.
- Planning yields the client's expenditure forecast, thereby predicting the flow of payments to the contractor through a monthly valuation process.

- Planning predicts the staffing levels required for adequate supervision.
- Planning assists in giving an information services to the public and in the organization of site visits for outside parties.
- Planning enables the coordination of other schemes in adjoining areas, for example in highway schemes it allows the integration of major traffic diversions and road closures. (Madwesley, Askew, & O'Reilly, 1997)

The use of scheduling tools enables the constructor to:

- Effectively visualize the planned construction work
- Use computerized what – if capabilities to analyze alternatives and make schedule adjustments
- Effectively allocate resources
- Compare budgeted and actual costs, productions, and durations (Weber, 2005)

Planning will be only being able to provide these benefits if, of course, the quality of the planning is high. This can be achieved through a planning cycle where plans are evaluated before being used and where plans are monitored in use. Feedback from these two processes (evaluation and monitoring) can be used to provide information for re-planning or future planning. (Madwesley, Askew, & O'Reilly, 1997)

2.6 Types of Schedules

A variety of programming techniques are available to the client's project manager or the contractor's planner and these can be used according to the type and complexity of the project concerned. (Cooke & Williams, 2004)

The main tools in construction scheduling are the bar chart, the Line of balance, the Network diagramming method or Critical path method (CPM) such as Arrow diagram and Precedence diagram. There are other tools, such as PERT and physical models in two and three dimensions, and computer models.

2.7 Selecting a Scheduling System

There is no strict rule as to which programming technique should be employed. This needs to be considered in the light of the size and complexity of the project in hand, any personal preferences and whether there are any stipulations in the contract documentation. There are several items to consider when selecting which scheduling system to use.

Some of the main factors include program use, type of work, size, complexity, specialization, duration, type of contract, conditions of contract, professional parties, management structure and resources.

From the various methods mentioned earlier, two methods are most predominant in practice, bar charts and network analysis, including both arrow and precedence conventions. Generally, companies tend to make selective use of network analysis, where complexity is a governing factor. Network analysis is generally employed for overall programming and bar charts for site uses. Bar charts, on the whole, seem to be the most common form of programming. They are quickly prepared, less involved and generally easily understood. Network analysis, however, has several advantages over the bar chart. The interrelationship of activities can be established, from which the various starting and finishing times can be obtained, together with the type of float for non – critical activities. (Griffith, Stephenson, & Watson, 2000)

Bar charts are the easiest to use but they can give misleading results because there is no strict logic imposed on the program. It may be better to use linked bar charts or arrow or precedence diagrams to overcome this problem. However, for repetitive work such as housing projects, line of balance may be preferred, or for road works, tunneling or repetitive civil engineering work, time–chainage diagrams could be the best application to use. (Cooke & Williams, 2004)

It is of fundamental importance to note that the level of detail of the plan and the choice of technique are related. For example, the overall program for a large and complex industrial project should be drawn as a network.

Figure 1: Which Planning Technique? (Neale & Neale, 1989)

Figure 1 is a planning technique selection chart. It will be noted that sometimes the client requires the use of network analysis, often for good reasons of his own, in which case the contractor's choice is more limited. Nevertheless, specialized techniques may still be used where required. Figure 1 asks questions about the job, not the project; the job is the work to be planned, at a specific level of detail.

Table 1: The Planner's Tool-Kit (Neale & Neale, 1989)

Technique	Planning uses	Program uses	Progress control use
Bar chart	Simple project	Good communicating tool Universally understood In common use Good basis for resource scheduling Most computer systems give bar chart from network	Absence of explicit logic relationships limits usefulness Tedious to update manually
Line of balance	Repetitive work (houses, precast, concrete production, multi-storey buildings)	Good Communicating tool Demonstrates interference	Useful planning tool Difficult to show a lot of detail clearly Illustrates general pace of work and trade interference
Linear program	Linear products(highways, tunnels, railways, viaducts)	Good Communicating tool Demonstrates interrelationship of sequential operations	Useful planning tool Progress shown easily if plan kept simple
Network analysis	Complex projects Management contracts Design management	Poor communicating tool in network form Usually converted to bar chart for general use	Powerful control tool especially for large numbers of contractors Forms basis of most computer systems

Table 1 summarizes the characteristic of the techniques, and the basic principles of the techniques will be described in the following sections.

According to Newitt (2005), many times the contract specifies the type of scheduling system to be used and the details of specific reporting requirements. It is important to remember that the schedule is made for the person receiving it, not the person preparing it. If the skilled workers or the superintendent cannot comfortably read a CPM logic diagram, give them a bar chart. If a bar chart is difficult for them, provide a daily to-do list. The level of detail in the schedule also changes with the level of experience of the management team. A less experienced management team may need a more detailed schedule than an experienced team. The scheduling method must also be flexible because there will likely be changes made during the construction process. (Newitt, 2005)

2.8 Major Components of Planning Techniques

According to Neale's (1989), brothers the major components of planning techniques are:

a) Activities: Literally, being busy, expending energy, consuming resources, taking time; in construction planning, this means a job to be done; for example preparing a drawing, an order to be placed, a hole to be dug, bricks to be laid in a wall, a flow of water to be diverted.

b) Activity duration: the time required for the completion of each activity.

c) Project Time-scale: the time structure of the project; it is usual to give each week in the project a number, and these then have to be related to calendar dates, holidays, etc.

d) Event: an occurrence at a specific point in time; for example, the granting of planning consent, or the start or end of a traffic diversion.

e) Work method: the plan must be expressed in some logical way, indicating the sequence of operations, and which activities and events are interrelated; this may be implicit (as with bar charts) or explicit (in network analysis, where work method is usually called logic).

f) Resources: often called the four Ms (men, machines, materials, and money) but can also include overheads for instance site accommodation and even such essentials as managerial skill.

g) Costs: what the work has or will cost, often derived directly from the unit costs of the individual resources.

h) Value: what has or can be earned by payment for work done derived from the bill of quantities, the estimate or an internal budget. The calculation of value-to-date can be used as an overall measure of project progress.

2.9 Bar Chart Planning Technique

One of the oldest scheduling methods used in construction industry is the bar, or Gantt, chart. It is simple in concept, easy to construct and equally easy to understand; it is hardly surprising therefore that is the most widely used technique in the planner's tool-kit.

The Development of the bar chart dates back to World War I when Henry L. Gantt used the bar chart method of scheduling to plan and control military operations and after that in order to track the progress of manufacturing operations. In honor of Gantt's early development of bar chart scheduling you will often hear the team Gantt chart when referring to a bar chart. For special purposes, the terms Gantt chart, Gantt schedule, or bar chart schedule are one and the same. (Newitt, 2005)

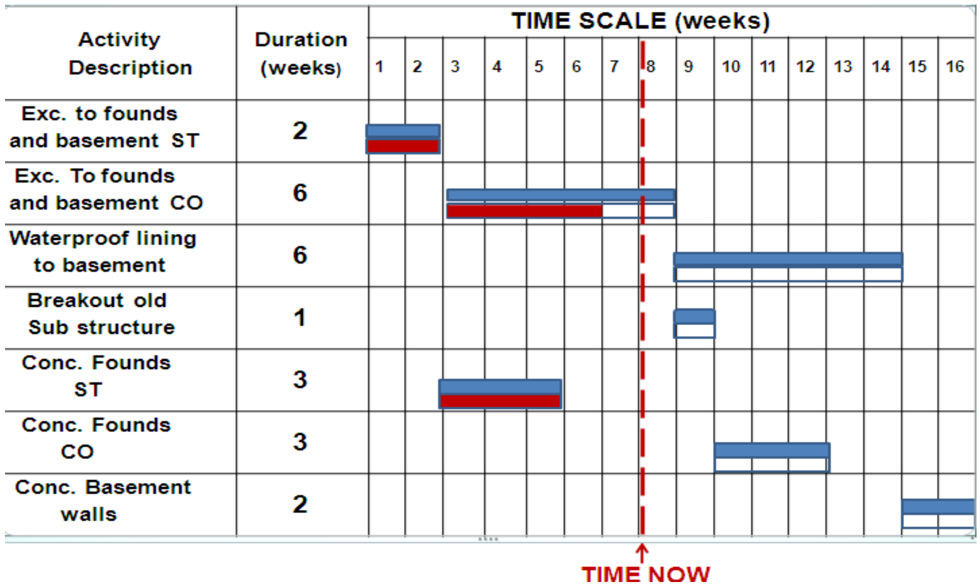


Figure 2: Typical Bar Charts (Celik, 2008)

The bar chart gives a visual or graphic representation of the project plan. It includes the activities, their durations, and the dates the activities are scheduled to happen. As a bar chart is created, the manager is forced to think through the construction process and organize the activities for successful completion of the project objectives. Bar chart schedules are easily read and understood; therefore, they are frequently the primary method used to communicate the project plan to everyone that is concerned with the schedule.

The advantages of using a bar chart include the ease with which they can communicate the project tasks, their durations, and their anticipated start and finish dates to all project participants. Reviewers of the bar chart do not need any special knowledge of scheduling to understand the status of the project, what is expected to be accomplished in the next few time periods, and when the project is expected to end.

When schedules are used for simple projects, or for complex projects that can be shown at the summary level or in part, the bar chart is quite suitable. Bar charts are easily constructed for small or simple projects. However, in most cases, bar charts created by a computer program require the construction of the network, including the relationships among the activities. (Weber, 2005)

Bar charts are well suited to depicting construction sequences and are readily understood at all levels of management. They can be used to develop the program prepared at the tender stage into the master program and likewise into the short-term planning throughout the contract period. (Cooke & Williams, 2004)

Bar charts are easily and readily updated at weekly and monthly intervals. A color coding system may be introduced for progress recording but most software packages have facilities for project tracking and updating which provides an accurate record of progress on the contract for future references. Resources may be shown on the bar chart, which clearly relates to labor, plant, and subcontractors to the rate of working and helps the manager to see problems of continuity and waste.

Before the advent of powerful modern computers, bar charts were prepared by hand, often using pre-prepared blank sheets containing a column for the project activities and squares for drawing the bar lines. (Cooke & Williams, 2004)

It is quite common to see the bar chart on the site agent’s wall in the site cabin, with progress colored in white crayon colored pencil and a vertical string pinned in place to denote the current date.

Once a list of tasks has been made and activity durations have been established, it is time to decide how the tasks relate to one another. For a bar chart, the relationships among the activities will define the placement of the bars on the chart. Although relationships must be understood in order to place the activities, the relationships are no usually included on the diagram. The length of each bar reflects the activity duration. Although activities with longer bars have longer durations than those with shorter bars, it may be difficult to discern small differences in duration when the time scale is large compared to the activity durations.

In addition to the activity bars and the time scale, most bar charts contain data in columns to the left of the time-scaled area. The activity information may include the activity's identification number, its description, and its durations. Other information that sometimes appears includes the start and end date of activities and activity attributes, such as material quantities; the required management and trade resources; and the responsible person or company. Sometimes, bar charts are combined with resource graphics. The resources related to each activity can be totaled to form histograms and line graphs.

Limitations in the power and flexibility of the bar charts resulted in the adoption of more sophisticated techniques in the 1950s and 1960s, in particular network analysis using arrow and later precedence diagrams. However, in more recent times, the development of the linked mainly as consequence of developments in project management computer software. (Cooke & Williams, 2004)

There are a number of project management software packages available which employ linked bar charts as the preferred display. These include:

- C S Project Professional-Crest Software
- Hornet Windmill- Claremont Controls
- Microsoft Project-Microsoft Corporation
- Power Project Professional-Asta Development
- Project Commander-Construct-it USA

2.10 Network Diagramming Method (CPM)

2.10.1 Overview of Critical Path Method

Network analysis is a general term for a graphical planning technique which shows the project as a network of its activities linked together to show their interrelationships and sequence of execution. With the addition of estimates of activity duration, the diagram can be analyzed numerically to determine the estimated project duration. Basically the network is a flow diagram showing the sequence of operations of a process. Each individual operation is known as an activity and each meeting point or transfer stage between one activity and another is an event or node.

Critical Path Method (CPM) it is the universal method used in the construction industry to calculate and evaluate project network schedules. It is also the predominant method used in other industries that manage projects through the use of network scheduling methods.

According to Buttelwerth (2005), technically speaking, CPM is a mathematical algorithm used to calculate the early start, early finish, late start, late finish, total float, and free float of the entire project's activities and the total project duration and critical path or paths of the project. (Buttelwerth, 2005)

Cooke and Williams (2004) state that, in 1956, the E. I. du Pont de Nemours Company established a team to study new management techniques for the company's engineering functions. One of the first areas to be considered was planning and scheduling of construction work. Data was input into a UNIVAC 1 computer in the form of construction sequences and activity durations in order to generate a schedule of work.

Furthermore, in early 1957, J .W. Mauchely, J. E. Kelley Jr and M. Walker developed the basic principles of the critical Path Method (CPM). A test group was set up to apply the new technique to a chemical plant project in Kentucky. In the UK, development work on CPM was undertaken by the Building Research Establishment and a number of papers were published by Nuttall and Jeans (1960a, b). (Cooke & Williams, 2004)

Network diagrams are basically of two types: Arrow diagrams and Precedence diagrams. Arrow networks were more popular in the 1950s and 1960s, then precedence diagrams became the choice for network scheduling. (Mubarak, 2005)

2.10.2 Arrow Diagram (Activity on Arrow AON)

The Critical Path Method can be presented in the form of an arrow diagram. Arrow networks are also called the Arrow diagramming method (ADM), Activity on arrow (AOA) networks, or the I-J method. It called I-J method because each activity is identified by the two nodes that define its start and end. The node on the left of the activity is referred to as the *i* node and the node to the right of the activity is referred to as the *j* node. The i-j nodes are numbered, which allows each activity to be identified by a unique i-j number set.

Arrows, termed activities, represent the performance of operations or tasks that consume time and the circle or node between the arrows is the events. In some cases they represent only the passage of time. They are drawn as lines, generally with arrow heads on the right end to show the direction of progress within the time-oriented diagrams; thus the term arrow diagram. The tail of arrow represents the start of the activity and the head of the arrow represents its finish. Activities consume time and most generally other resources as well. This is usually done in numerical order starting at the beginning of the network and progressing to the end, ensuring that the number at the tail of the arrow is smaller than that at the head.

Each activity is given duration, and the earliest and latest event times of the activity can be calculated by making forward and backward passes through the network. These times are recorded in the node or event circles. From this information, a schedule can be produced which will facilitate calculation of the total float or spare time for each activity. Dummy activities, which usually have no duration or value, can be introduced to indicate dependencies not shown by the arrow activities.

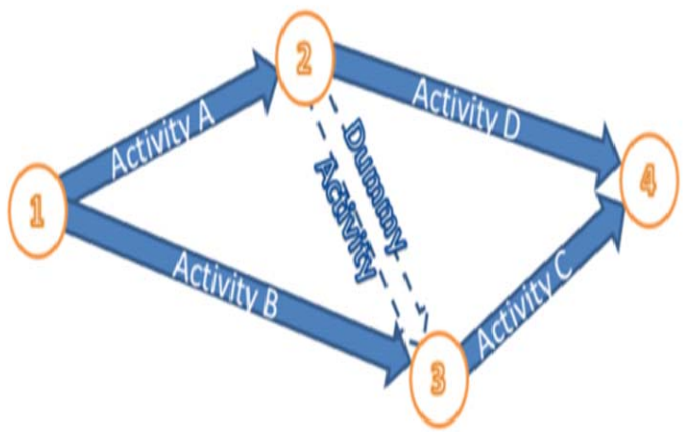


Figure 3: Arrow Diagram

2.10.3 Precedence Diagram (Activity on Node AON)

Precedence diagrams follow the same logical procedures as arrow networks except that the activities and their dependencies are drawn differently. The precedence diagram consists of a series of boxes interlinked with lines. The box or node represents the activity and the linking arrow indicates the relationships of the activities to one another. The box contains an activity label or name and duration. There is space for the earliest and latest start and finish times of the activity and a reference number may also be included if required. The network produced in this manner is called variously a ‘precedence diagram’, a ‘circle and link diagram’ or an ‘activity on node diagram’. Both boxes and the lines may be given a time value. The time given in the box represents the duration of the activity, while any time on the line or arrow adds a dependency which might be a lead or a lag as required. Precedence diagrams do not require dummies to preserve the logic of the relationships and each node is ascribed a unique activity number.

Precedence diagrams were developed in the early 1970s by the Cementation Company as an alternative approach to network analysis which could more readily be applied to works of a civil engineering nature. In practice precedence diagrams are far more widely used than arrow networks because they are more flexible and more easily reflect the ways things happen. (Cooke & Williams, 2004)

The precedence approach introduced the idea of activity boxes, rather than activity arrows, which permits a number of different relationships to be expressed between activities. This approach relates more closely to the real situation on a construction project and this practicality makes the technique more popular. The relationships which can be included are:

- Finish to start
- Start to start
- Finish to finish
- Start to finish

This makes the precedence display easier to follow and permits the introduction of time constraints on the logical links without the need to include dummies or ladders. (Cooke & Williams, 2004)

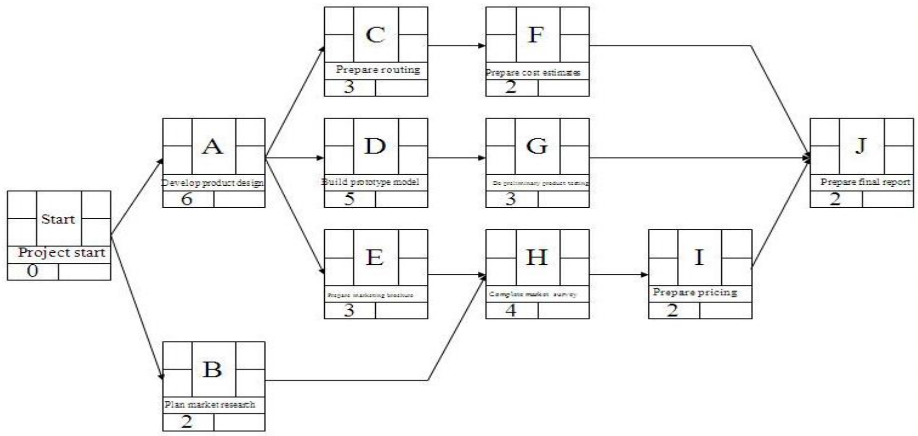


Figure 4: Precedence Diagram

Precedence diagrams have a number of advantages over arrow diagrams in that:

1. No dummies are necessary.
2. They may be easier to understand by people familiar with flow sheets.
3. Activities are identified by one number instead of two so that a new activity can be inserted between two existing activities without changing the identifying node numbers of the existing activities.
4. Overlapping activities can be shown very easily without the need for the extra dummies. (Lester, 2007)

The use of precedence diagrams as a means of expressing construction relationships has now largely replaced arrow diagrams. This is mainly due to simplicity of linking operations to each other in various ways and the ability to introduce time restraints realistically, conveniently and without overcomplicating the diagram.

When viewing a precedence network diagram, it is important to avoid confusing the link lines with activities. Similarly, no association should be made between the link lines of precedence diagrams and events (nodes) of arrow diagrams. The link lines represent dependencies only.

2.11 Line of Balance (Linear Scheduling LOB)

2.11.1 Overview of Line of Balance, History and Development

Linear schedules, sometimes called line of balance schedules, have their roots in the manufacturing industry. They are particularly well suited for projects where the activities are of a repetitive nature. This phenomenon often requires using fixed resources for the identical tasks in succession. This constraint mandates that there can be on overlap in these activities. While these can be scheduled with traditional networking techniques, they may be more effectively modeled using linear scheduling. Linear scheduling is a useful way to describe repetitive activities and it offers the additional feature of helping to identify activities that might result in conflicts.

A line of balance diagram includes a series of inclined lines which represent the rate of working between the repetitive operations in a construction sequence. Project such as highways, pipelines, and railroads are common examples. However, high-rise buildings and even residential construction could be scheduled with linear scheduling methods due to the repetitive nature of those projects. This type of scheduling helps project managers visualize time and space conflicts between activities.

According to Long and Ohsato (2008), in literature, many methods have been developed for repetitive construction projects. These methods may include: “Line of Balance- LOB” by Carr and Keyer, Arditi and Albulak, Al Sarraj, Wang and Huang; “Vertical production method” by O’Brien, Suhail and Neale; “Horizontal and vertical logic scheduling for multistory projects” by Thabet and Beliveau; “Linear scheduling methods- LSM” by Jodnston, Chrzanowski and Jodnston, Harmelink and Rowings; and “Repetitive scheduling method–RSM” by Harris and Ioannou. Huang and Sun have also presented a new method for non-unit based repetitive project scheduling in which the generalization of the logical relationships of activity groups and the usage of various resource crews for an activity group are taken into consideration. (Long & Ohsato, 2008)

Linear scheduling method used by Goodyear Tire and Rubber Company to monitor production in 1941. LOB is effective visual communicators that have been used sparingly in construction. Commercial programs for creating, displaying, updating, and reporting on linear schedule information are limited in number and seem to be less well developed than other commercial programs providing precedence networking tools. (Weber, 2005)

In construction section, this approach was developed by the National Building Agency. The application of line of balance to construction was pioneered by Lumsden (1965) and became recognized as the best planning method for repetitive work such as housing. The technique has been widely used for the planning of refurbishment works, new build housing and flats and has also been applied to civil engineering works as illustrated by Harris and McCaffer (2000) and Cormican (1985). It is not unusual to see bar chart displays incorporating a line of balance diagram to illustrate the programming of any repetitive sections of the works. (Cooke & Williams, 2004)

An early attempt to develop a computer application was made to schedule repetitive-unit construction by Arditi and Psarros (1987). (Arditi & Psarros, 1987) It was limited to solving the basic LOB problem and was not designed to deal with the many implementation-related problems that were later identified. Clearly, there was a need to develop a computerized system that would make use of the principles used by Arditi and Psarros (1987) but that would also eliminate all of the associated shortcomings. A computer program that can easily and effectively be used by contractors could improve construction productivity significantly. Since Arditi and Psarros' study in 1987, there have been several attempts to solve the various problems associated with linear scheduling. Wang and Huang (1998) introduced the multistage linear scheduling (MLS) method based on the concept of a multistage decision process. Hegazy (1993) presented an effort to enhance the capabilities of linear scheduling techniques, making them more practical and more attractive for use in construction. (Arditi, B.Tokdemir, & Suh, 2002)

According to Hinze (1998), the more traditionally accepted scheduling methods in the construction industry do not always lend themselves to effective management of these types of projects. Bar charts become complex mazes of activities and create complication in readily ascertaining space-time relationships. The critical path method (CPM) becomes very convoluted in assessing the start-start relationships and finish-finish relationships of activities. These shortcomings of traditional scheduling methods have resulted in the development of or resurgence of the use of linear scheduling. (Hinze, 1998)

The technique is used to analyze the application of labor and plant resources to ensure that each resource can progress from one item to the next in an orderly way, completing its own work on all the items without being delayed waiting for preceding work to be completed. Thus the technique aims to keep all the resources in balance, each following the other productively and having a clear run of work.

The main objective of using line of balance is to make optimum use of resources. To facilitate this is important that the activities and resources are related closely. (Neale & Neale, 1989)

Another use for the line of balance schedule is checking material orders or deliveries. If a deadline for ordering and/or receiving materials is marked on the schedule, then a simple check can be made in good time. (Harris & McCaffer, 2006)

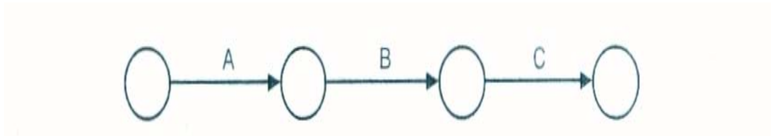


Figure 5: Logic Diagram for Sequence (Cooke & Williams, 2004)

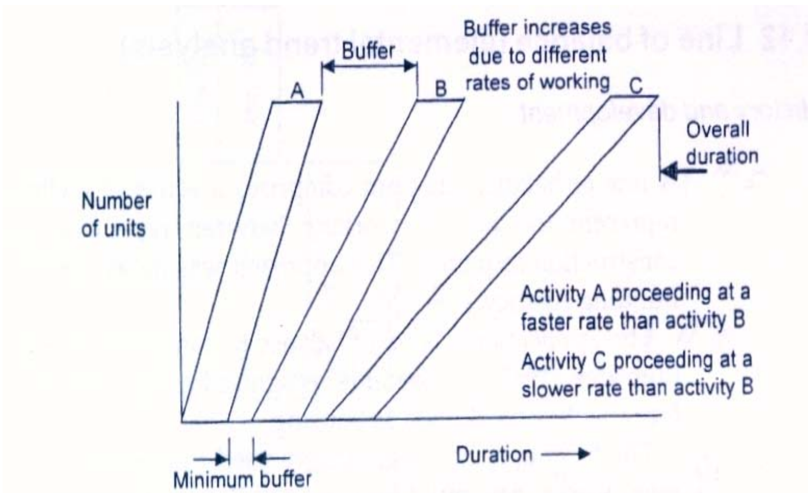


Figure 6: Line of Balance Diagram –Non Parallel Working (Cooke & Williams, 2004)

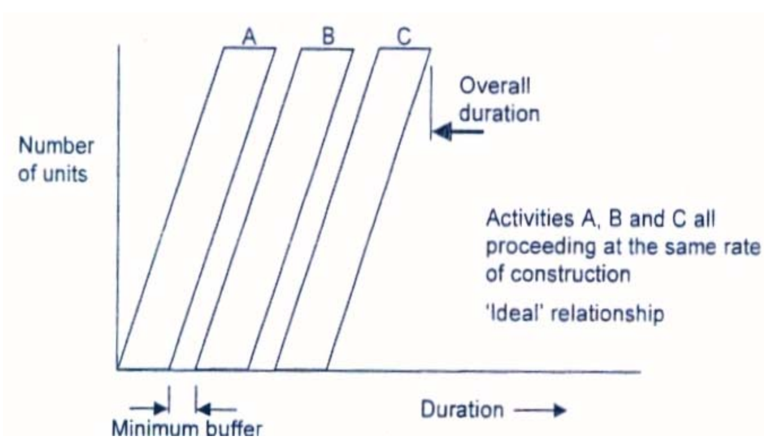


Figure 7: Line Of Balance Diagram –Ideal Relationship P150 4.43 (Cooke & Williams, 2004)

2.11.2 What Is Linear Scheduling (Line of Balance LOB)?

The linear schedule is as visually appealing as the bar chart, but it communicates more information. The linear schedule is a graphical representation of activities on two axes. One axis represents the location or number of sections of activity at any point in time. For vertical projects, the location is often a discrete measure, such as floor of a building, a house, or an apartment. For horizontal projects, the location is usually a measure of distance such as a station, mile, or mile marker. The other axis depicts time measured in hours, days, months, or years depending on the project's overall duration. Although either axis can represent time or location, this study will designate the abscissa (X-axis) for Time and ordinate (Y-axis) for number of houses.

Activities are represented as lines, with a slope showing the activity's productivity as measured by its change in location divided by the change in time. Each activity can be composed of one or more line segments, attached or detached, of constant or changing slope. Some activities, such as mobilization, demobilization, the construction of bridge, or a box culvert, are accomplished at only one location. These activities are depicted as horizontal lines at their location.

Linear scheduling is a unique means of resource leveling or allocation with a simple graphic display of time-space interaction. This technique is known by a number of other titles, including the Vertical production method, time-space scheduling method, and repetitive-unit construction. The term linear scheduling has become more widely accepted in recent years. (Hinze, 1998)

They take their name from either:

a) Involving several uniform units of work such as multiple houses or typical floors in a building,

b) Being geometrically linear such as highway, pipeline, and utility projects. (Hegazy, 2002)

Line of balance planning provides a visual display of the rate of working across the whole project and enables decisions to be made in relation to the use of labor. It enables the planner to start with a forecast handover rate per week and then to produce a forecast of the labor resources needed to achieve it. (Cooke & Williams, 2004)

The development of a linear schedule for a project is similar to any other scheduling process. The first three steps, familiar to most schedulers, are:

1. Identify activities.
2. Estimate activity production rates.
3. Develop activity sequences.

In accomplishing these three steps, one must determine whether the linear schedule method is the most appropriate. As a rule, the project will work well in linear scheduling if the vast majority of the activities can be grouped as a family of repetitive and nearly identical tasks. The activities should be defined in a level of detail comparable to that found on a bar chart. (Hinze, 1998)

The line of balance programming technique is rarely understood by construction managers and planners and is still very much underused in the construction industry. Line of balance tends to be favored only by those who have a through grasp of the principles and application based on experience. Where it is company policy to use line of balance, it will be used, but this is in only a small number of companies. Line of balance is only really applicable to repetitive operations on refurbishment and housing projects and therefore does not have the same wide application as bar charts or networks. (Cooke & Williams, 2004)

2.11.3 Advantages and Disadvantages of Line of Balance Technique

One of the benefits of the linear scheduling method is to be able to forecast and change the schedule to avoid the conflicts. This conflict likely would have been easy to determine without the linear schedule. However, with the linear schedule it can be accurately forecast when the conflict would happen. If the conflict were later in the schedule it may have been more difficult to forecast. (Newitt, 2005)

According to Weber (2005), another advantage of the linear schedule is its ability to communicate with reviewers from all organizational levels, creating a bridge of understanding. It clearly describes tasks, their durations, and their locations at any point in time. The entire project duration is clear, and the diagram can be used to identify and resolve potential conflicts between tasks. However, like a bar chart, the line of balance fails to show relationships among activities, although, in both cases, the relationships must be determined before diagrammatic construction. The LOB fails to communicate resource requirements and potential resource constraints. (Weber, 2005)

2.11.4 Steps of Preparing a Line of Balance Schedule

1. Prepare a logic diagram.
2. Estimate the labor-hours required to complete operation.
3. Choose buffer times that will guard against the risk of interference between operations.
4. Calculate the required output target in order to meet a given project completion date.
5. Complete the Line of Balance initial table which will be used to draw line of balance schedule.
6. Draw the schedule, from the information calculated in table.

7. Examine the schedule and assess possible alternatives to bring about a more ‘balanced’ schedule which might include:
   a) Changing the rate of output of one activity by reducing or increasing the gang size partway through the project.
   b) Lay-off and recall one gang.
   c) Overlap some activities.
   d) Schedule every activity to work at the same rate. (Harris & McCaffer, 2006)

2.11.5 An Example about Line of Balance Schedule Table

In the following example, after some preliminary calculations, and discussion with the senior managers, the planner decides to make a first analysis on the assumptions of a working rate of 24 houses per week, which he believed to be the practical maximum rate, and a working week of 60 hours. The calculations are set out in the form of a schedule; these calculations are explained briefly here. (Neale & Neale, 1989)

Table 2: Basic Duration Calculations Table for Line of Balance Case Example (Neale & Neale, 1989)

Activity number and description	*M*: man-h per unit	*N*	*n*	*A*	*H*	*R*	*t*: days	*T*: days	*B*: days
1. Foundation	127	50·8	6	54	9	25·5	2·1	30·3	1
2. Well	140	56	7	56	8	24·0	2·0	32·3	1
3. Plumber 1	79	31·6	4	32	8	24·3	2·0	31·8	3
4. Blockwork 1	439	175·6	12	180	15	24·6	3·7	31·5	5
5. Roofing 1	438	175·2	6	180	30	24·7	7·3	31·4	5
6. Electrician 1	28	11·2	2	12	6	25·7	1·4	30·1	1
7. Plumber 2	2	0·8	1	1	1	30·0	0·2	25·8	1
8. Rendering	651	260·4	18	270	15	24·9	3·6	31·1	4
9. Roofing 2	99	39·6	4	40	10	24·2	2·5	31·9	1
10. Flooring	130	52	8	56	7	25·8	1·6	29·9	3
11. Plumber 3	12	4·8	1	5	5	25·0	1·2	31·0	1
12. Carpenter and glazier	123	49·2	6	54	9	26·3	2·1	29·4	1
13. Electrician 2	54	21·6	2	22	11	24·4	2·7	31·7	3
14. Ext. works	465	186	8	192	24	24·8	5·8	31·2	
15. Painter	730	312	10	320	32	24·6	7·8	31·4	

Column M, man-hours per house, is derived from estimates made by the local contractor.

Column N, theoretical number of men required, is derived from the number of man-hours per housing unit, and the number of units required per week (24), divided by the number of working hours in a week, in this case 60, assuming a six- day week of ten hours per day.

Column n, men per house, is a practical estimate of the number of men required to complete each activity for one housing unit. This is based on a knowledge of the normal grouping of men in each trade (for example plumbers usually work in pairs and two masons usually work with one laborer) adjusted as necessary to achieve the necessary total output. This figure is determined by the planner and senior managers.

Column A, actual number of men, is the theoretical value N corrected by the introduction of the practical estimate of the number of men per house n. Thus, for activity 1, N is 50-8; so for n =6, realistic values of A are either 6 x 8=48 (i.e. eight groups of six men) or 6 x 9 = 54 (nine groups of six men). In this case, the planner has chosen the faster rate, so activity 1 will proceed at a rate slightly faster than the general rate of 24 houses per week.

Column H, the number of houses worked on simultaneously, is part of the calculation for column A; e.g. nine groups of six men, giving A = 54, means also that these nine groups will work on one house each.

Column R, the actual rate of house production per week, is the calculation for the adjusted, practical number of men to be used; e.g. for activity 1, the theoretical number of men is 50-8, but the realistic plan is to use nine groups of six men, i.e. 54 men. Thus the planned rate of house production per week will be increased by the factor 54—50-8. Thus activity 1 is planned to proceed at 25-5 houses per week, not the notional 24.

Column t, the time required for each trade to complete its work on one housing unit, is simply calculated from the man-hours per house divided by the man hours available per day. Thus activity 1 requires 127 man-hours per house, so a group of six men will take 127/ (6xl0) =2.1 days.

Column T is the time required from the start of the first house to the start of the last house. This calculation is necessary to determine the slope of the lines of balance for each activity. The slope is the number of housing units, less one, divided by the rate per week R expressed in days. Note that the values of T for each activity should be similar.

Column B is the minimum buffer time, based on a series of decisions made by the planner and project manager. Note that the major activities have longer buffers, a commonsense assumption; the completion of the electrical installation is also considered to be rather uncertain. (Neale & Neale, 1989)

2.11.6 Drawing the Line of Balance Diagram by a Case Study

The quickest way to explain how this planning method works is to follow a simple example.

Let's consider a medium-sized high-rise building of 40 typical floors. The construction of each typical floor, undoubtedly, involves various interrelated activities. If a CPM network is to be developed for the whole project, certainly it will be so complex and will be composed of copies of the activities in a single floor. A bar chart of the project will still be so complex and will not serve the purpose of a good communication tool between planners and execution personnel.

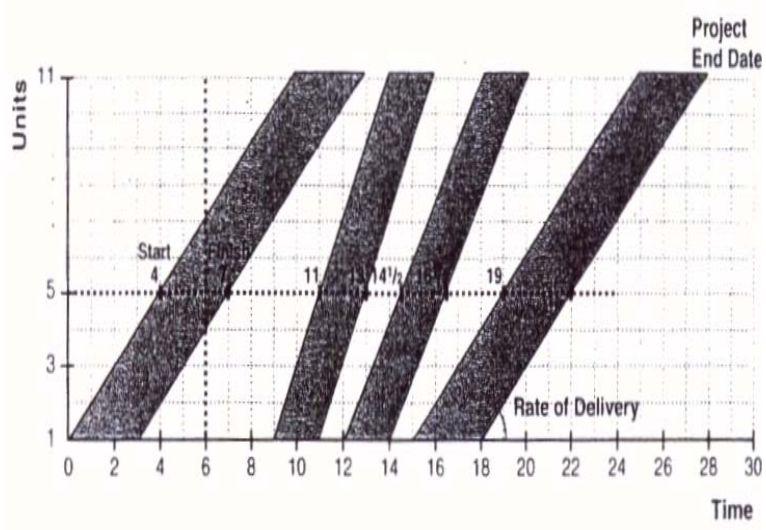


Figure 8: Basic LOB Representation (Hegazy, 2002)

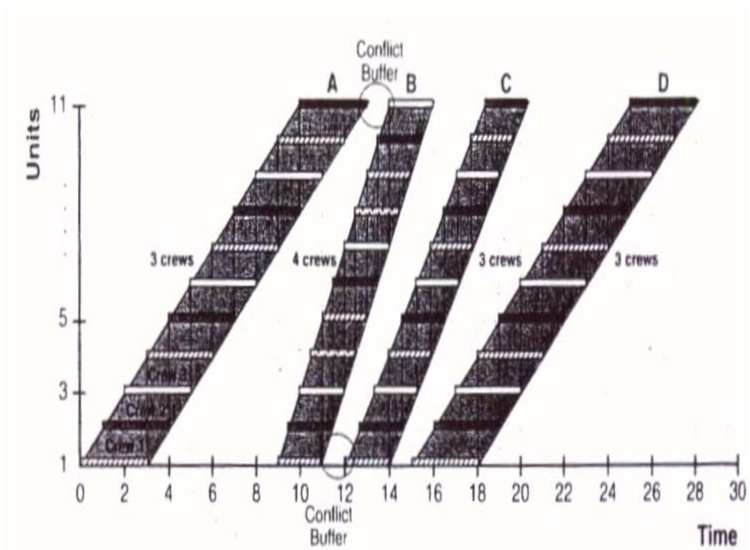


Figure 9: LOB Schedule with Crew Details (Hegazy, 2002)

A schedule representation that suits projects with repetitive activities is shown in Figure 8 between time on the horizontal axis and units on the vertical axis. This representation shows the following information:

I. Each sloping bar represents one activity (A, B, C, or D) in the project and the width of the bar is the activity duration of one unit, which is uniform along all units.

II. Activities (slopped bars) are sequential with no interference or overlapping. This is directed by the sequential logical relationships involved. These sequential activities could be the activities of any continuous path in a CPM network that is repeated for several units.

III. A horizontal line at any unit intersects with the activity bars at the planned start and finish times of the work in that unit.

IV. A vertical line at any date (time) shows the planned work that should be completed/ started before and on that date.

V. The slope of each activity represents its planned rate of progress and this is the direct function of the number of crews involved in the activity. The slope of the last activity is the rate of delivery of the various units.

VI. The finish time of the last unit in the last activity represents the end date of the project. (Hegazy, 2002)

2.11.7 Line of Balance Analysis

The purpose of this analysis is to balance the rate of progress of the activities, and to schedule the activities to eliminate interference. This is done by:

- Adjusting the rate of production for each activity, so that this approximates to a common rate of production for all activities.
- Delaying the start of those activities that (even after adjustment) proceed faster than the activity immediately preceding it, to maintain at least the minimum buffer specified at all times. (Neale & Neale, 1989)

In the classical, factory-based, line of balance analysis, it is assumed that individual resources make equal contributions to progress, regardless of the number of the resources used. Thus the rate of progress of each activity may be adjusted quite finely; consequently, the activities may be made to work at almost the same rate of progress. (Neale & Neale, 1989)

In construction, such an approach is unrealistic. Tradesmen rarely work as individuals or in large groups. Years of experience and practice have established the most effective size for a group. For example, to obtain the most efficient productivity, bricklayers usually work in a team of two bricklayers serviced by one laborer. Therefore, the balancing calculations have to be done on the basis of the output of gangs, rather than individuals. This restriction makes it more difficult to achieve a common rate of work within a plan. (Neale & Neale, 1989)

The second part of the analysis (maintaining the minimum buffer time by delaying the start of relevant activities) will be illustrated by using the unadjusted plan. To obtain the slope of the line, it is necessary to calculate T, the time required from start of work on the first house to the start of work on the last. This value is the rate of production for this activity. To plot the subsequent activity, it is necessary to compare the rate of production of the activity with the rate of the immediately preceding activity. (Neale & Neale, 1989)

2.11.8 Durations

The productivity of each activity is derived during the estimating process. The slope of the line indicating an activity in the linear schedule is a function of its productivity, generally measured in working days. Activities with steeper slopes have a higher production rate than those with flatter slopes. Each project must have productivities developed for all of its activities. These productivities must be converted to time and distance or location to use the linear scheduling method. Thus, a typical clear and grub activity may normally have its estimated costs and durations related to the area, such as the acre. (Weber, 2005)

In construction work, estimates of activity duration cannot be anything other than approximate. In repetitive construction where the activities and trades follows in sequence, any delay in the planned completion of an activity will result in following trades waiting unproductively for its completion. Therefore it is prudent to make some provision for late completion by planning a short delay or buffer between each activity.

2.11.9 Buffers

Another benefit of linear scheduling is the ability to examine and plan for time and space buffer. The management team can change the production rates or the start or finish times of each activity to obtain the amount of buffer desired.

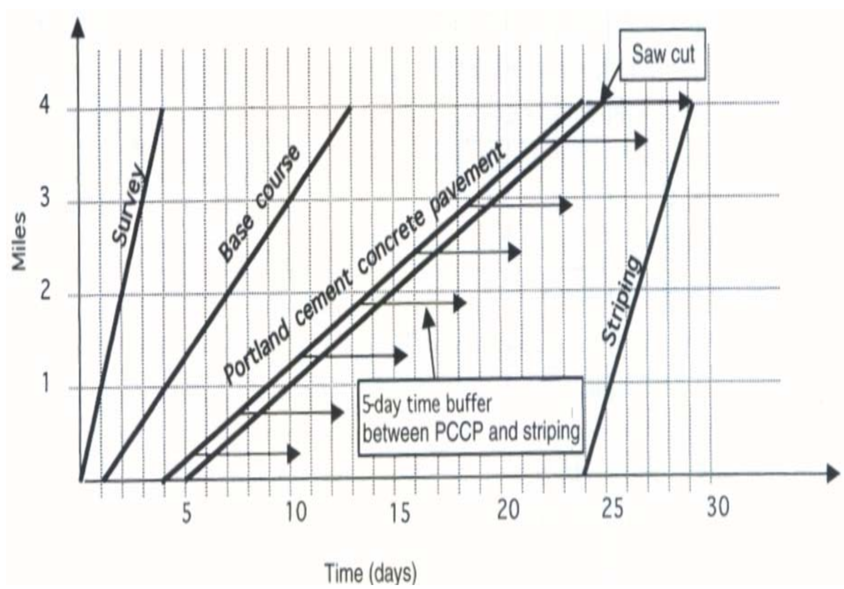


Figure 10: Time Buffer Example (Weber, 2005)

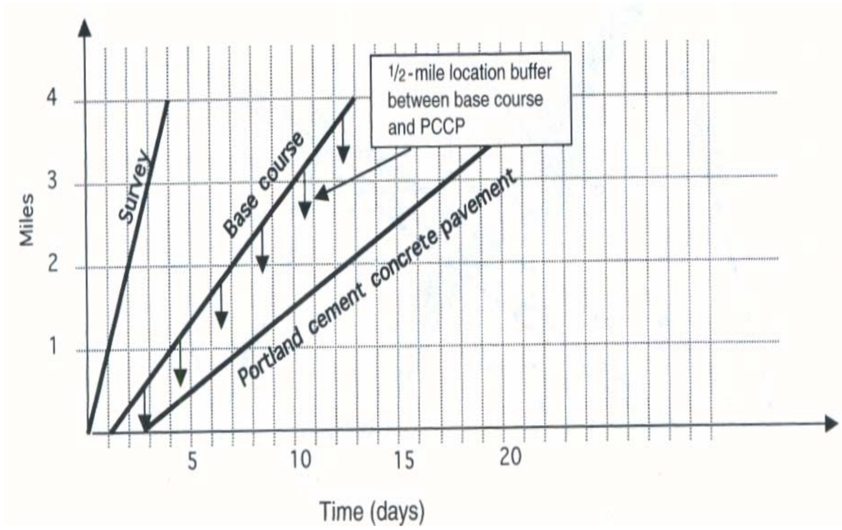


Figure 11: Location Buffer Example (Weber, 2005)

The linear schedule uses two types of buffers: the time buffer and the location, or space, buffer. A time buffer is the amount of time, horizontally, between activities at any given point. The estimate of buffer times is related to the project manager's assessment of the reliability of the estimate of activity duration; where the reliability poor, large buffers must be used. A space buffer is the amount of space, vertically, between activities at any given point. Instead of being related using only the four conventional relationship types, some activities use buffers to separate the activities. (Weber, 2005)

2.11.10 Updating

Linear schedule activities can be updated by indicating actual progress with lines of different color, texture, or dimension. The updated schedule quickly shows differences between the productivity that was expected and what was achieved. Updating a line of balance schedule once the project has started, particularly if the rates of construction prove to be different from those calculated, can be difficult and quickly becomes unclear.

Chapter 3

COSTING ON CONSTRUCTION PROJECT

3.1 Introduction

This chapter essentially focused on the issues related to costing of construction projects. In essence, costing in construction project needs accurate knowledge. Inadequate or inappropriate costing is one of the most important causes of contractor failure in the construction industry. Job costing - in its broadest sense - includes the allocation of costs; the determination of earned value and profitability; and the control of materials, subcontracts, variations and progress billing.

Rough field construction cost estimates of project features are commonly developed during pre-appraisal, reconnaissance-level assessment for the purpose of comparing alternative sites and determining/comparing the size and scope of development.

Civil engineering works of this type (reservoirs, dikes, diversions, dams, pipelines, etc.) are very site-specific. Initial cost evaluations are generally completed in a series of steps from map studies during appraisal/feasibility-level analysis, to more detailed site visits (including surveying and geologic evaluation) that support conceptual design development, and preliminary and final design. Thus, project development is an iterative process, where cost estimates are revised as more details of the site are developed. As project details are developed, the accuracy and dependability of the cost estimates increase.

Accurate costing of civil engineering construction work is very undertaking classes of work such as concreting, bricklaying, shuttering etc; or finding out the cost of undertaking separate proportions of the work such as the cost of access roads, subsidiary building, main buildings installation of machinery etc. costing involves finding charges for labor, material, plant and overheads. (Celik, 2008)

3.2 Prerequisite for Project Costing

3.2.1 Bill of Quantities

Bill of quantities is a section of contract document, which its primary goal is to define the quantity of work to be done in each type of activity of the contract. Its purpose is to accurately determine the quantity of work that needs to be performed on the project. In essence, every item is measured and quantified as accurate as possible from drawing and plans. Moreover, bill of quantity separates the work items into units of labor, material, and equipment in order to calculate the amount of the work to be done. (Celik, 2008)

According to Gould and Joyce (2003), to effectively accomplish this, the bill of quantities must use the correct units. The process requires a thorough understanding of the work involved in each of the different disciplines of the project. Often the best approach is to build the project item by item on the bill of quantity form and then quantify each item. (Gould & Joyce, 2003)

There are four main parts to a bill of quantity:

1. The classification of the work
2. Description of items of the work
3. Dimensions of the items of the work
4. Extensions of dimensions. (Humphreys, 1991)

The pages in a bill of quantities are divided, into columns. The descriptions of the work are printed clearly to enable the contract to price very item. Each priced page in totaled and carried to a “Collection”, and all the collections relating to a section of the work is carried to a "Summary". Finally all the summaries are collected at the back of the bills of quantities under a heading of "General Summary". (Celik, 2008)

3.2.1.1 Items

For large and complicated project works it is essential to split bills of quantities into separate sections of the job, therefore each group being subdivided into its various trades as listed in some standards or perhaps as listed below: (Celik, 2008)

1) Demolition work
2) Excavation and filling
3) Pipe lying
4) Roads
5) Concrete in-situ:
    - Reinforcement
    - Shuttering
    - Pre-cast
    - Pre-stressed

Brickwork, masonry, water proofing work, steelwork and Iron work, roofing and carpentry, joinery, flooring, plastering, glazing, electrical, plumping, painting, fencing.

However, the order given is not strict; it may be changed depend on the type of project but it is necessary to be accurate and reasonable as much as possible. For example, the main bill sections for a bridge might consist of:

1) Piers
2) Abutments
3) Superstructure

4) Approach roads and surfacing

5) Miscellaneous

In the following example each section must be subdivided into smaller sections such as excavation, compaction, reinforcement etc. As it has been mentioned already, the accuracy in the bill of quantity is essential but a sense of proportion must be retained in it. For instance, a main concreting work for a high rise building is likely to cost five billion dollar, it is waste of everyone's time to bill every little quantity involved in preparing formworks like the number of nails. However, if the number of nails is shown on the drawings, then it can be only billed in a single item.

3.2.1.2 Numbering Of Items

In preparing the bill of quantities, it can be normal that the engineer who prepares the bills may miss out an item or he may need to make some corrections or even add new items to the bill of quantities. If the items have been numbered right through from beginning to end then it is difficult to add a further item which has been forgotten at the proof stage of producing the bill of quantities because this would involve renumbering all items again and checking so that all cross-references are corrected. The only possible way to avoid this difficulty is to insert forgotten items as an "A" item, e.g. item 30 A or to collect these as "Late Items" at the end of a bill.

A useful way of numbering the original bill items is to use a letter prefix to each number, using different letter for each section of the bill. Thus, excavation items are numbered A1, A2, and A3...Etc; concreting items, B1, B2...Etc. and so on. Hence if, before the bill is printed, additions have to be made to it the additional items can at least be added at the end their correct section without disturbing the numbering. (Celik, 2008)

3.2.1.3 Activity Definition

Involves identifying and documenting the specific activities that must be performed in order to produce the deliverables and sub-deliverables identified in the work breakdown structure (bill of quantity). (Celik, 2008)

3.2.1.4 Activity Sequencing

Involves identifying and documenting interactivity logical relationships. Activities must be sequenced accurately in order to support later development of a realistic and achievable schedule. (Celik, 2008)

3.2.2 Drawings

Many professionals are involved in developing the drawings. For building projects, the architect coordinates and guides the efforts of all the other professionals. For highway projects or more complicated industrial efforts, the engineer plays that role. No matter who leads the effort, there are general guidelines that everyone follows so that coordination is simpler and translation in the field more predictable. For instance, the drawings normally follow general order of construction from site work to finish work. There is a similar numbering sequence: A-1 is architectural, P-1 plumping and so forth. Each section has typical symbols and abbreviations listed. Drawings are generally drawn to a marked scale, if not to scale, this will be noted. (Gould & Joyce, 2003)

Furthermore, there are often many standard details used on projects, but the aggregate of the building makes it a unique product. Therefore, firms usually have standards that they follow for numbering drawings. Not every firm follows the same standard.

3.2.3 Specifications

Ostwald (2001), states that specifications are the written items of work that complement the construction drawings. The drawings show what is to be built, and the specifications describe how the project is to be constructed and what results are expected. Historically, specifications have referred to specific statements concerning technical requirements of the project, such as:

- Materials
- Workmanship
- Operating characteristics or performance

Specifications also include the bidding and contract documents.

3.2.4 Work Break Down Structure

A work break down structure (WBS) is a foundation document in project management which is an outcome guided analysis of the work involved in a project that defines the total scope of the project. WBS defines the sequence and duration of tasks that must be done to complete the project on time and within the cost guidelines established. The primary purpose of the WBS is to sub-divide the scope of work into manageable work packages which can be estimated, planned and assigned to a responsible person or department for completion. Moreover WBS provides the basis for planning and managing project schedules, costs, and changes. (Celik, 2009)

3.2.4.1 Basic Principles for Creating Work Break Down Structure

- A unit of work should appear at only one place in the WBS.
- The work content of a WBS item is the sum of the WBS items below it.
- A WBS item is the responsibility of only one individual, even though many people may be working on it.

- The WBS must be consistent with the way in which work is actually going to be performed; it should serve the project team first and other purposes only if practical.
- Project team members should be involved in developing the WBS to ensure consistency and buy-in.
- Each WBS item must be documented to ensure accurate understanding of the scope of work included and not included in that item.
- The WBS must be a flexible tool to accommodate inevitable changes while properly maintaining control of the work content in the project according to the scope statement. (Celik, 2009)

Furthermore, WBS is simply an outline of the activities necessary to construct the project. Another benefit of the WBS is that it takes a seemingly large, complex project and turns it into many easy to manage segments. (Holm, Schaufelberger, Griffin, & Cole, 2005)

The work break down (WBS) is often the first document developed as the project manager and project team formulates a project management plan and schedule. Developing a Work break down structure is usually an iterative process. Another purpose of the work break down structure is to demonstrate clearly to all parties involved how each task is related to the whole project in terms of budgets, schedules, performance, and responsibility for the physical assets belonging to the project. However in some project managers include enough detail so that the work break down structure can be used as an instrument for scheduling, personnel assignments, resource allocations, monitoring project progress, and controlling how and when tasks are accomplished. (Angus, Gundersen, & Cullinane, 2003)

3.3 Unit pricing

The next task is to determine how much each unit will cost to produce, deliver to the site, accept and store at the site, install in the correct position, and maintain until the project is turned over to the power.

Production of the product and delivery to the site are included in the material unit price. The cost of installing the product is part of the labor unit price. The equipment necessary to move the unit into place and install it is included in the equipment unit price. Project overhead covers the costs of accepting the material, storing it at the job site, and protecting it until the project is accepted. Company overhead includes the cost of preparing the estimate, marketing the company, and providing broad based technical and administrative support for the project. (Gould & Joyce, 2003)

According to Humphreys (1991), preliminary cost estimates for building costs can be made by multiplying the square meter of floor area or the cubic meter of volume by a unit cost. A more accurate method of estimating is to use unit costs for each component of a building, such as walls, floors, and foundations; however such figures can still be in error for a specific case. (Humphreys, 1991)

3.3.1 Material Pricing

In essence, out of the entire price that need to be identified, the material prices are usually the most straightforward to determine. The most reliable source is the supplier. The material unit price multiplied by the quantity to get the total material cost in the required currency. However, the estimator must ensure that the price quoted actually covers all the specification requirements and the estimator's assumptions. (Gould & Joyce, 2003)

The following points must be verified:

- The material quoted is the correct model number, color, and finish.
- The price is valid until the scheduled delivery time.
- The price includes delivery to the job site.
- Adequate warranties and guarantees are provided.
- The lead time fits into the scheduled need on site.
- There is adequate stock available.
- Payment terms, discounts, and credits are well documented. (Gould & Joyce, 2003)

Material prices are obtained from the following sources:

a) Quotations from material manufactures and/or building supply companies. These quotations may be in the form of signed letters, or are telephoned into the contractor's office and (usually) confirmed in writing.

b) Catalog or price lists distributed to general contractors and updated periodically. (Johnston & Mansfield, 2001)

3.3.2 Labors Pricing

The price of labor is the most difficult factor to determine because both the hourly wage rate and crew productivity must be considered. The wage rate is a factor of the rates paid to a specific trade. Union rates are available from the union loads and employer bargaining groups. Nonunion labor rates are determined by each company and depend on the geographic area. In either case, wage escalation must be factored in, particularly on long-term projects. Union rates are generally negotiated for one to three years by each trade, so these agreements need to be researched. Factors to consider include the following:

- Expiration dates of the union agreements.

- Amount of overtime anticipated.
- Availability of skilled labor in the area.
- Amount and nature of any hazardous conditions. (Gould & Joyce, 2003)

3.3.3 Equipment Pricing

Equipment, which includes small tools needed to complete specific tasks, is covered item by item. However, large, mechanically driven machinery such as cranes, lift tracks, and like are usually covered on a project basis since they often are used throughout the project for different activities. Equipment costs fall into two general categories: the equipment itself and the cost of operating it. The first category covers ownership, lease or rental, interest, storage, insurance taxes and license. If not, the equipment supplier provides a quote. The second category includes gasoline, oil, periodic maintenance, transportation, and mobilization. The cost of the operator is normally covered under the labor line item. (Gould & Joyce, 2003)

3.4 Project Costing

Cost is a major consideration in all human activities and gains in importance with increasing technology and the expanding complications of society. Cost is the glue that blinds together a wide variety of components into a single structure. (Humphreys, 1991)

According to Pilcher (1994), Costing is a generic term for a process which results in the establishment of the cost of carrying out parts of a larger project or the definition of those costs related to a particular item of production or overhead. It is also concerned with the comparison of these costs with a budget or a predetermined standard of cost. (Pilcher, 1994)

Furthermore, he states that the costing process consists of recording all those expenditures which are related to specific items of work in such a way that the cost of that work, in convenient form, can readily be identified. Costing, therefore, necessitates allocating cost data to specific headings within a predetermined classification or coding system. (Pilcher, 1994)

The costing process provides a service to management. An efficient costing system is essential in order that production may proceed in a properly controlled environment. It must be understood that costing as such, is not a controlling function in itself but that is provides the data and then, after processing, the information on which control decisions can be made. (Pilcher, 1994)

3.4.1 Materials Costing

The allocation of charges for materials presents further difficulties, since the paper work on site is usually concerned only with checking the inflow of materials have been used in the separate parts of the job. The bill of quantities measurements can be assistance for calculating quantities and therefore price of materials used in the permanent works, but there are many more materials, such as timber for shuttering, scaffolding, small tools, diesel oil and fuel oil, nuts and bolts, etc., which are not used in the measurement records.

In a project construction the primary materials costs can be divided by the cost of concrete, steel and equipments.

1. Concrete: The cost of the concrete material depends on many factors. Size of job, Type of job or structure, Job site specification and many other reasons can have effect on concrete price. Each mix and specification of concrete is separately measured and identified, because different concrete mixes and proportions are costed

differently. Concrete recipes are proportioned for strength, durability, and workability. Strength and durability are determined by the water-cement ratio, the work ability of the slump, and so on. (Ostwald, 2001)

Concrete is pricing by the cubic yard or meter delivered to the job site. The vendor needs to know the concrete specifications and approximate quantity of each type being used. In addition, to see if super plasticizers or other additives that aid in the placing, finishing, or curing of the concrete can be used. (Holm, Schaufelberger, Griffin, & Cole, 2005)

However, the major cost for a concrete structure is sometimes the cost of forms. Forms are constructed from lumber, plywood, steel, aluminum, and other composition materials, either separately or in combination depending on the type and size of the concrete being constructed. (Ostwald, 2001)

To price forms by the materials used is very time-consuming and not necessary on small projects. Construction firms generally have historical records that provide data on the cost of the material per square foot of contact area. This cost includes all lumber and sheet material, bracing, kickers, and form ties. Items such as nails and form oil are priced separately. In some situations, the forms can be handled by a jobsite forklift. Multi-story projects will require a crane to lift the forms and set them. If a tower crane is to be used, it will be priced separately and does not need to be included in the concrete work. (Holm, Schaufelberger, Griffin, & Cole, 2005)

Reinforcing for concrete consists of steel bars. The cost of bars is estimated by the pound, hundred pounds, or ton, even though slight variations are found with diameter variation. An additional 5% is added for overlap and waste. There are many types, sizes, and material grades for reinforcing bars. (Ostwald, 2001)

2. Steel: Structural steel material prices are furnished as competitive bids by fabrication shops. It is important for the company to know what is included and what is not. For example, bolts, the fabricator furnishes all steel-to-steel connecting bolts and all anchor bolts embedded in concrete. The general contractor will furnish all other bolts. Another small item that is often overlooked is ship materials which are small pieces of steel plate that are placed under column base plates to set them to the proper elevation. The fabricator does not furnish the shims and company should determine their cost and include them as a line item on the recap. All structural steel needs hoisting equipment to handle it. This can be anything from a forklift to a heavy lift to a heavy lift crane or travelling derrick. The company should consult with a superintendent and an ironworker foreman to determine the type and size of the equipment that is best suited for the project. It is also important to discuss operating personnel and mobilization costs. (Holm, Schaufelberger, Griffin, & Cole, 2005)
3. Equipment: equipment that is used for a specific set of activities of work is referred to as direct equipment. A crane brought on site specifically to hoist structure steel is a piece of direct equipment, because once this work is done, it will be removed from the site. The

cost of this piece of equipment is charged only to the structure steel. Another example is a concrete pump that is used only for concrete work. On the other hand, a tower crane or jobsite forklift is used for many work activities for most of the duration of a project. Its cost is difficult to apportion to specific tasks and is therefore considered part of the jobsite overhead. Concrete pumps can be a source of confusion for the estimator or company. Concrete pumps come in various sizes, and the estimator must anticipate a placement rate. Pumps that are too large are more expensive, and those that are too small will affect the placing labor cost. Another item to consider is the amount of time a concrete truck is at job site. The price of the concrete typically includes transportation to and from the site and 20 minutes for standby and placement time. A small pump can cause additional costs by keeping the concrete truck on site too long. (Holm, Schaufelberger, Griffin, & Cole, 2005)

If the job exceeds the life of the equipment, then the evaluation of equipment cost for the job is trivial. The full cost of the equipment becomes a part of the direct job cost. Equipment costs are partitioned into:

- Ownership or rental
- Travel to and from job
- Erection and dismantling costs
- Operating
- Maintenance
- Indirect or overhead (Ostwald, 2001)

If the contractor owns the equipment, there are no rental costs, and if the contractor rents, there are no ownership costs. Most equipment will have transportation costs to and from the job. Some equipment, like truck-mounted apparatus, will have no or small setup costs. Maintenance costs of some equipment can be significant, and sometimes they may equal or exceed the other annual costs of equipment. (Ostwald, 2001)

3.4.2 Labor Costing

Labor costs are determined in one of several ways. Some of the factors of labor pricing are as follows: (Holm, Schaufelberger, Griffin, & Cole, 2005)

1) Productivity factors vs. Labor unit prices: labor costs can determined by using either labor unit prices or productivity factors and wage rates. Labor unit price are expressed as dollars per unit of quantity being priced, for example, dollars per square foot-and are subject to revision due to a change in the wage rate, fringe benefits, and/or tax rate. Productivity, on the other hand, is expressed as man-hours per unit and is constant over time for a given work task. Labor costs are calculated by entering the unit man-hours and the current wage rate without fringe benefits or labor taxes. The unit man-hours are multiplied by the quantity to get the man-hours, which in turn are multiplied by the wage rates, with the result being the labor costs. Labor cost can then be divided by the quantity to get the unit labor cost, which can be used as a check against historical information. Using current wage data, this process eliminates the need to make adjustments in labor costs over time. Fringe benefits and labor taxes are accounted for at the end of estimating process. For example, if

unit man-hours times the wage rate equals a unit labor cost of 10$ per board foot, and 0.10 $ per board foot is more in line with historical costs; the estimator knows there is an error. (Holm, Schaufelberger, Griffin, & Cole, 2005)

2) Productivity: productivity is the amount of time it takes a person to do a unit of work. Examples of productivity factors are man-hours per square foot of contact area for concrete forms or man-hours per ton of steel. They are multiplied by the quantity, the result is the man-hours needed to complete the line item. Most published estimating references show productivity factors and will delineate the crew that does the work and the daily output for the crew. The productivity in man-hours per unit and the crew makeup are important. Daily output is used in planning and scheduling after the project has been won. Furthermore, many contractors record cost information based on unit labor costs and do not bother with productivity factors. (Holm, Schaufelberger, Griffin, & Cole, 2005)

3) The Cost of labor: three basic elements that make up the cost of labor are wages, fringe benefits, and payroll taxes. Other elements that may be part of the cost are travel, per diem, and overtime. Projects performed by local contractors seldom need to account for travel and per diem, and most commercial project tend not to require overtime. Of the three basic elements, two are negotiable, and one is mandated by the government. Wages are paid based on hours worked with straight time generally being the first 8 hours worked per day up to 40 hours per week. Overtime comes generally in two multiples, time-

> and-a-half (wage×1.5) or double time (wage×2). All time over the base wage rate is classified as premium time because it represents the premium cost of working a person beyond the agreed-upon normal pay period. Fringe benefits are items such as health and welfare, pension, apprenticeship fund, and in some cases, dental insurance and/or annuity. Benefits are paid based on each hour worked and are not subject to the effects of premium time. Payroll taxes are government-mandated taxes and are based on the amount of total wages paid. (Holm, Schaufelberger, Griffin, & Cole, 2005)

One of the essential factors in determining the labor cost is to estimate how long the activity will take. Determining crew durations or productivity requires experience and the ability to visualize how the work will be done in the field. Past project experience is essential in determining these factors. An estimator needs to know the following:

- Expected efficiency rate.
- Other work occurring at the same time that could interfere with this activity.
- Expected weather conditions.
- Specific conditions of the work: that is, working on ladders or scaffolding versus working on the ground.
- Duration and frequency of overtime. (Gould & Joyce, 2003)

To apportion labor charges it is necessary for the workmen, or the section foreman acting on behalf of the men in this team, to fill up time sheets showing the hours spent each day by each day by each man on the various type of work. The hours entered in theses sheets must be priced out so that the labor cost can then be allocated under the different headings by the cost clerk. Difficulties arise in dealing with: (Celik, 2008)

- Overtime and other miscellaneous wage payments, and
- The time sheets of men such as fitters, time-checkers, flag-man, night-watchman, chairmen, storekeepers, etc., whose work cannot be directly allocated to a specific site operation. Decisions have to be made in advance of setting up the costing system as to how such men's time sheets are to be allocated. They may be separated out into different categories, of they may all be put under the heading "Site on-costs".

Thus, it is necessary to add in the various site administration charges to the account for site on costs-waters of general foreman, engineers, site clerk, water clerk, agent and sub-agent, etc., together withal such other charges as telephone, water supply, messing, sanitation, insurance of works, petty cash, etc,.

3.5 Cost Types

The cost involved in the construction of a project can be broken down into two major categories: direct and indirect. (Celik, 2008)

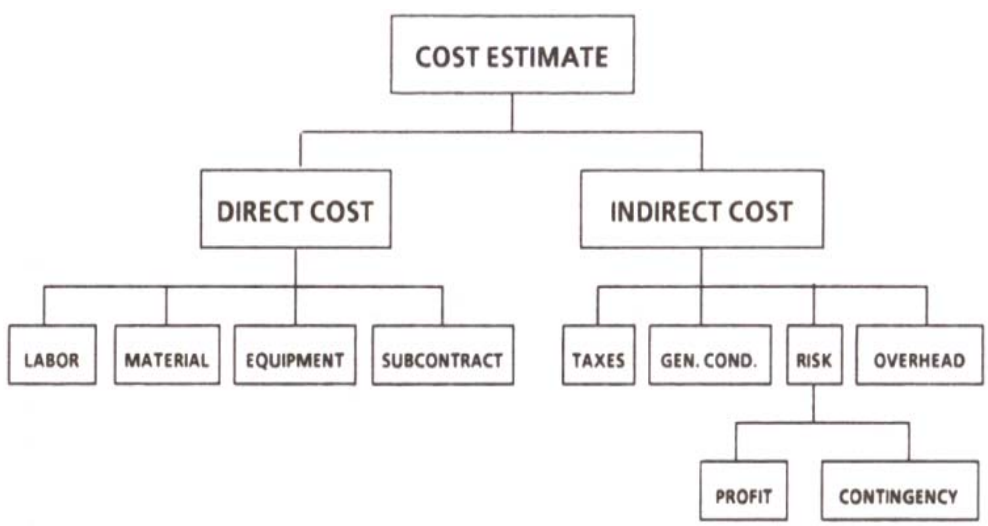


Figure 12: Components of a Cost Estimate (Ashworth, 1999)

3.5.1 Direct Cost

Direct costs are associated with the physical construction of the project and include such things as the purchasing of building materials, equipment operations, and all installation labor. As long as work proceeds, direct costs continue to accrue. Once work is stopped, direct costs generally stop as well. As the item implies, direct costs are those costs that can be specifically identified with an activity or project. Examples of direct costs are: (Gould & Joyce, 2003)

I. Direct management costs refer to the project office running costs, salaries for the project manager, project engineer, planner, accountant, secretary and quality assurance. (Kirkham, 2007)

II. Direct labor costs refer to the people working on an activity, e.g. welders, fitters, bricklayer etc. At one time these costs would have been described as wages, being almost entirely composed of this single item, but today they will include substantial payments in respect of National Insurance schemes, holiday scheme, training scheme, etc. (Kirkham, 2007)

III. Direct material costs are for the materials, consumables, components, which are used for completing an activity and an allowance for scrap and wastage. For example: roofing material, the purchase of asphalt, or the cost of landscape materials etc. (Gould & Joyce, 2003)

IV. Direct equipment costs refer to machinery, plant and tools, such as rental of a paving machine, finishing concrete etc. (Gould & Joyce, 2003)

V. Direct expenses include bought in services that are specific to the project, e.g. plant hire, subcontractor etc. (Celik, 2008)

3.5.2 Indirect Costs

Indirect costs, also called overheads, are those costs which cannot be directly booked to an activity or project, but are required to keep the company operational. Examples of indirect costs are: (Celik, 2008)

I. Indirect management costs refer to senior managers, the estimating department, sales and marketing, general office staff, secretarial, administration and the personnel department.
II. Indirect labor costs refer to the reception, maintenance, security and cleaners. Basically it includes all the employees who are required to keep the company functioning.
III. Indirect materials include stationery, cleaning materials and maintenance parts.
IV. Indirect equipment includes computers, photocopies and fax machines.
V. Indirect expenses include training, insurance, depreciation, rent etc. (Celik, 2008)

Indirect costs are usually financed by an overhead recovery charge added to the earned man hour rate and if not properly managed will eat away at the company profits.

However, indirect costs are not as easy to visualize. They are generally broken down into two categories: home office overhead and general conditions. (Gould & Joyce, 2003)

3.5.2.1 Home Office Overhead

Home office overhead includes the corporate costs associated with keeping the company in business. The expenses involved in marketing the company, necessary legal and accounting expenses, and the costs associated with bidding work are all examples. Home office overhead can be figured by comparing the volume of business that a company does in a given year with the annual costs of doing business. This home office cost, usually figured as a percentage, must be recouped by income from earned projects. A company reduces its project overhead by reducing the home office's cost or by increasing business volume. If the daily indirect costs for a project are less than the costs required to shorten a project, then the total project's costs are reduced. (Gould & Joyce, 2003)

3.5.2.2 Project Overhead (General conditions)

Indirect costs can also occur in the field. These costs are called general conditions, filed office overhead, or project overhead. They are necessary to supervise and support the job site. Examples are the rental of the job site trailer; the superintendent's salary; and the cost of security fencing, guard, and signs. Whereas direct costs are a factor of the size and quality expected of a project, indirect costs are a factor of the project's duration and the degree of supervision required. If a project increases in length or requires a high level of coordination, the indirect costs will increase. By minimum cost scheduling, project managers can determine the optimum duration for the project, minimizing the project's total cost, which equals a project's direct cost plus its indirect cost. (Gould & Joyce, 2003)

Although, the cost involved in the construction of a project are fundamentally divided into direct cost and indirect cost but costs can be categorized into a variety of categories. Some of these categories are fixed costs and variable costs, direct cost and overhead costs and rates etc, for instance:

- Fixed costs include rent, loan payments, and property taxes. The exact amount of these costs can be estimated in advance for a year or more. (Angus, Gundersen, & Cullinane, 2003)
- Variable costs include labor and employer-paid social security taxes, utilities, travel expenses, telephone calls, freight charges, and sales taxes. (Angus, Gundersen, & Cullinane, 2003)
- Direct cost: Labor (salary and hourly) and materials. (Angus, Gundersen, & Cullinane, 2003)
- Overhead costs and rates: Indirect costs, facilities, taxes and insurance. (Angus, Gundersen, & Cullinane, 2003)

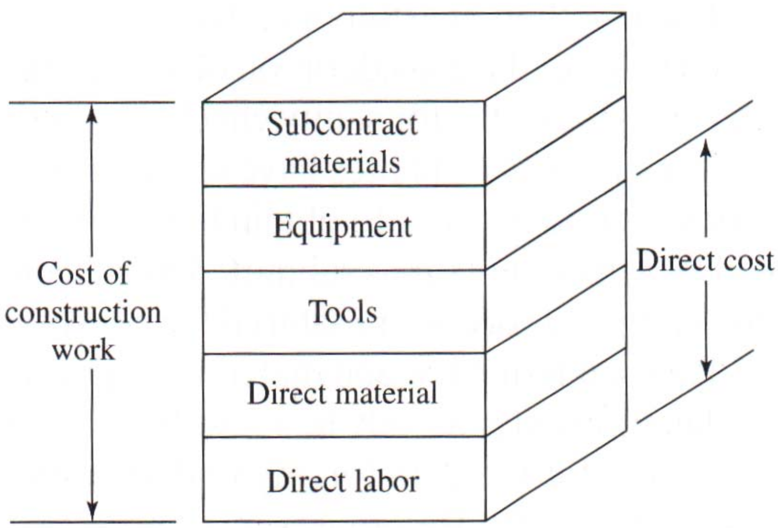


Figure13: Descriptive Layer Chart at the Elements Included In a Construction Work Estimate (Ashworth, 1999)

3.6 Project Cost Estimating and Budgeting

Cost is a resource sacrificed or fore-gone to achieve a specific objective or something given up in exchange. Costs are usually measured in monetary units like dollars. Project cost management includes processes required to ensure that the project is completed within an approved budget. (Celik, 2008)

Project Cost Management processes are:

- Resource planning: determining what resources and quantities of these should be used.
- Cost estimating: developing an estimate of the costs and resources needed to complete a project.
- Cost budgeting: allocating the overall cost estimate to individual work items to establish a baseline for measuring performance.
- Cost control: controlling changes to the project budget.

A major concern on every project is the ability to control time and costs, because time, money, and resources are directly related. Here are some of the issues that affect costs:

1. The amount of time that is charged to the entire effort by the workers.
2. The duration of time from start to completion.
3. The time lost due to:
   I. Factors that are within the control of management.
   II. Factors that are beyond the control of management.
4. The resource required to perform the project. (Angus, Gundersen, & Cullinane, 2003)

3.6.1 Cost Estimating

One of the important aspects of project cost management is a cost estimate. Cost estimating involves collecting, analyzing, and summarizing all available data in connection to a project that begins in the very early stages of project and ends when the project is turned over to the owner. Therefore, cost estimating involves developing an assessment of how much it will cost the performing organization to provide the product or service. There are several types of cost estimates, and tools and techniques to help create them. Important to develop a cost-management plan that describes how cost variances will be managed on the project. (Celik, 2008)

Moreover, cost estimating is the process of analyzing a specific scope of work and predicting the cost of performing the work. The accuracy of the estimate is a function of how well the specific scope of work is defined and the time available to the estimator. The basic challenges the construction contractor faces are to estimate the costs of constructing a project, schedule the specific construction activities, and then build the project within the estimated cost and schedule. Therefore, cost estimating and cost control skills are essential if the construction contractor is to build a project profitably. (Holm, Schaufelberger, Griffin, & Cole, 2005)

According to Humphreys (1991), estimating is the key to a successfully conceived, managed, and completed project. Estimating is not limited to construction alone, but rather is a function common to a broad spectrum of projects whereby one desires to manage cost and time. (Humphreys, 1991)

As project moves along in time, the amount of information generated increases. This information improves an estimate’s accuracy but also costs more to develop and takes more time. Estimating is critical in the development of the project because it informs the owner of costs, which in turn guide design decisions. (Gould & Joyce, 2003)

Every estimate must consider certain basis factors: project size, project quality, location, time and other market issues. Project size determines the quantities of material, labor, and equipment required for the project. Project quality determines the unit prices used. Location can be treated either by researching local prices or by using specific area cost indices. Project time and market considerations are more difficult to quantify since both depend on economic and local issues and must predict future trends. Projecting past trends to the future is often the best way to handle these factors. (Gould & Joyce, 2003)

3.6.2 Cost Budgeting

A budget is a plan that describes the authorized expenses for a specified period of time. The word budget used as a verb means "to prepare a plan of expected income and expenditure." A budget is based upon an estimate of the income expected so that related expenses can be projected or controlled and remains within a pre agreed limit or ceiling. (Angus, Gundersen, & Cullinane, 2003)

Budget cost estimates are developed throughout the design process of a construction project. Early in programming phase, the owner usually establishes a tentative project scope and a preliminary budget. The project budget includes both the estimated construction cost and other estimated owner costs. As design decisions are made and drawings created, additional budget estimates are prepared to ensure that the project being designed can be constructed within the owner's established budget. The accuracy of these estimates is a function of the degree of design completion. (Holm, Schaufelberger, Griffin, & Cole, 2005)

3.6.3 Project Cash Flow

Simply, cash flow is the different between income coming into a project and expenditure going out. A project is in a position of negative cash flow when more money is going out of the project than coming in, and vice versa for positive cash flow. The timing of a cash flow is important.

The Cash flow statement can be prepared in advance of the spending and receiving of the money, in which case the project estimate and work package are the source for the information. On the other hand, if the cash flow is for past periods, accounting records supply most of the information. (Ostwald, 2001)

To set up a cash flow for a project, we need to establish all the in- and out-of-pocket amounts and the time at which they occur. (Humphreys, 1991)

The cash flow statement is organized in two main sections. The first section typically contains the expected financial receipts generated by the project, while the second one contains the expected financial expenditures incurred to generate the receipts of the project. The project's total expenditures, also known as total outflows, are subtracted from its receipts (inflows) to provide the net cash flow from the project. (Jenkins, 2004)

Table 3: Example of Cash Flow Statement in a Dormitory project

Cash Flow Statement						
Year	-	1	2	3	4	5
Inflows						
Income from dormitory rent	-	-	4,350,000.00	4,437,000.00	4,525,740.00	4,616,254.80
Income from facilities rent	-		30,600.00	31,212.00	31,836.24	32,472.96
Income from sport facilities rent	-	-	945,000.00	963,900.00	983,178.00	1,002,841.56
Total Inflow	**-**	**-**	**5,325,600.00**	**5,432,112.00**	**5,540,754.24**	**5,651,569.32**
out flow						
Year	-	1	2	3	4	5
construction expenses	16,761,450.00	-	-	-	-	-
Operation cost	-	-	342,159.00	342,159.00	342,159.00	342,159.00
maintenance cost	-	-	-	-	-	40,000.00
Labor expenses	-	-	381,000.00	392,430.00	404,202.90	416,328.99
facilities requirement	-	1,172,500.00	-	-	-	-
interest expense	-	968,433.30	1,055,592.30	1,150,595.60	920,476.48	690,357.36
Total out flow	**16,761,450.00**	**2,140,933.30**	**1,778,751.30**	**1,885,184.60**	**1,666,838.38**	**1,488,845.35**
Year	-	1	2	3	4	5
Net cash flow	***(16,761,450.00)***	***(2,140,933.30)***	***3,546,848.70***	***3,546,927.40***	***3,873,915.86***	***4,162,723.98***
Tax			***1,418,739.48***	***1,418,770.96***	***1,549,566.34***	***1,665,089.59***
Net cash flow after TAX	***(16,761,450.00)***	***(2,140,933.30)***	***2,128,109.22***	***2,128,156.44***	***2,324,349.51***	***2,497,634.39***

NPV(Ytl)	**9,981,917.22**

For large international contracting organizations, cash flow is not so much a problem since these companies are involved in many other ventures which provide for a relatively stable overall company balance sheet. However, for smaller contractors cash flow can be critical and can be the difference between being in business or not. Poor cash flow is the antithesis of good business performance for most small contracting organizations, so accurate and effective cost planning is all the more critical. (Kirkham, 2007)

Cash flow is very meaningful term to most contractors, who must be sensitive to the issue of cash flow if they are to survive. Many construction firms who were undertaking profitable projects have failed in business simply because of serve cash flow problems. (Hinze, 1998)

3.6.4 Net Present Value (NPV)

The Net Present Value (NPV) is the algebraic sum of the present values of the incremental expected positive and negative cash flows over a project's anticipated lifetime. If this sum is equal to zero, then investors can expect to recover their incremental investment and to learn a rate of return on their capital equal to the private discount rate used to compute the present value. A NPV greater than zero means that investors can expect not only to recover their capital investment and to earn a rate of return equal to discount rate. Finally, if the NPV is less than zero, then investors cannot expect to earn a rate of return equal to the discount rate. (Jenkins, 2004)

The NPV method is one of the most well-known methods of financial appraisal and is defined in the Green Book as follows: "The discounted value of a stream of either future costs or benefits… (NPV) is used to describe the difference between the PV of a stream of a costs and a stream of benefits". (Kirkham, 2007)

The NPV method is useful for evaluating various competing long-term projects and is used widely in Life-cycle costing particular. It measures the excess or shortfall of cash flows, in Present Value terms, once financing charges are met. Strictly speaking, all projects with a positive NPV should be undertaken. However, in reality NPV will not be the only decision-making criterion; there are always other intangibles that would be considered as well. (Kirkham, 2007)

3.6.5 Cumulative Cost Graph (S-Curve)

The cumulative cost graph for a project is commonly called the S-curve, because it resembles the shape of the letter "S".A useful method for forecasting the cash requirements of a project is that which makes use of an S-curve. This curve draws its name from the fact that the cumulative expenditure for a project typically takes its shapes as that of a letter S. Because of this it is possible, as a result of observation and use of historic records, to draw up a curve on an empirical basis which predicts the way in which expenditure will occur. (Pilcher, 1994)

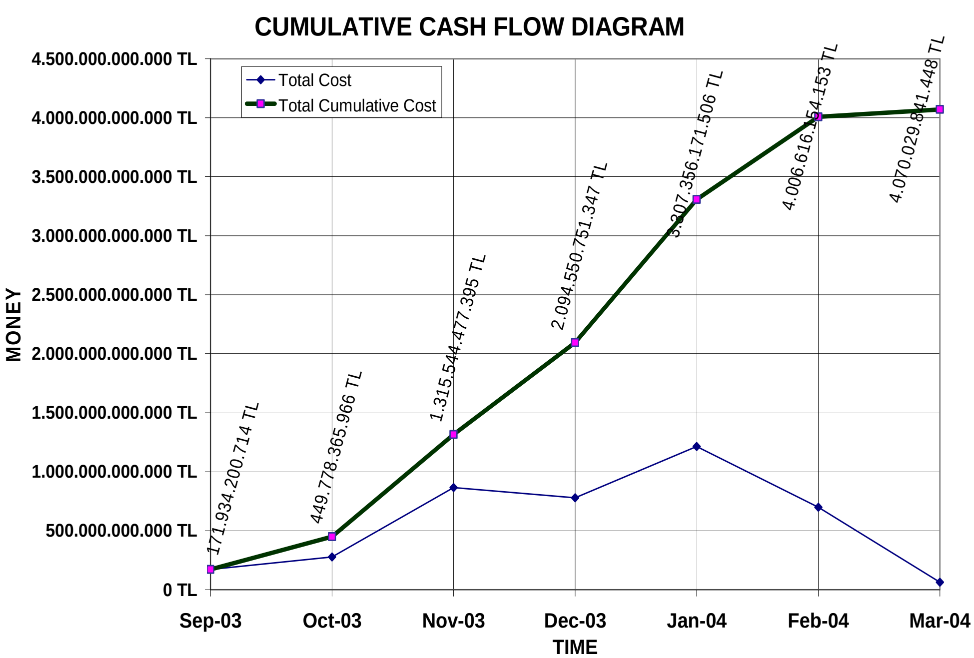


Figure 14: Cumulative Cost Graph (S-curve) (Celik, 2008)

The cumulative cost graph can be drawn in terms percent cumulative cost and percent time. Some project managers find it easy to track project progress when it is expressed in terms of percentage of cost and time. The percentage time for each day, week etc is calculated by dividing the number of the working weeks by total project duration. The percentage cost for each activity is calculated by dividing the activity cost by total project cost. (Celik, 2008)

Chapter 4

CONTROL OF CONSTRUCTION PROJECT

4.1 Introduction

Project control begins with the identification of the owner's objectives and ends when those objectives have been met. The owner, the designer, and the construction professional together design, estimate, and schedule the project to meet these objectives. This is the basis of the control system. On large or complicated projects, the control effort is a major undertaking with multiple organizations involved.

Project control measures and monitors project progress in accordance with the baseline plan. Cost, Time, Quality and Site control are basically most important issues in a construction project which need to be accurately controlled in a project progress. Following chapter is discussed all the mentioned issues and briefly explains methods of controlling of a project.

Like any other business, builders, contractors and developers have to plan and organize their day to day activities in order to manage effectively. Managers who can anticipate a problem before it becomes a crisis have more chance of succeeding in their business than someone who is simply looking at excess income over expenditure as a measure of success. Effective management requires control but every contractor has different ideas on the degree of control necessary for the projects they undertake. Many factors need to be considered, including the size and organization of firm and the scale of the project in hand. There are many aspects to control of a business but, in terms of construction projects, four essential areas stand out for special consideration. These are the control of: Time, Quality, Cost, Site area.

4.2 Objectives of Controlling Construction Project

Project control is an action based process that encourages continual monitoring of operations. The purpose of project control is to guarantee that the project's design, budget, and schedule are met by the project team. If any objective begins to slip, the control system will identify this deviation early so that the appropriate correction can be made. Project control begins with a plan that identifies the objectives of the project and specific checkpoints throughout the project cycle. The plan is a roadmap that allows the project team to constantly monitor and make corrections as necessary. It consists of design documents for quality checks, an estimate that establishes budget requirements and a schedule for project milestone dates. (Gould & Joyce, 2003)

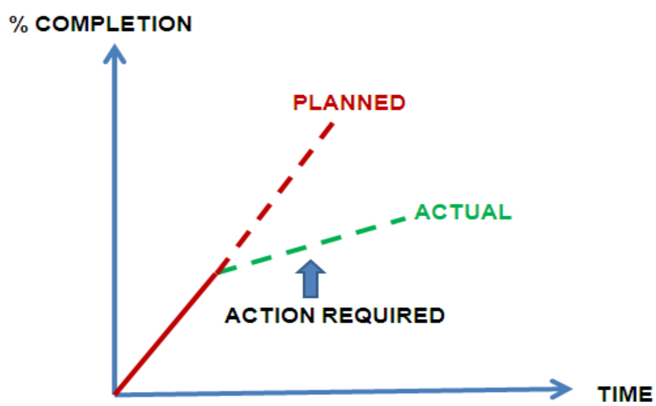


Figure 15: Control Means Monitoring Progress and Taking Appropriate Action. (Celik, 2008)

The most important use of schedules is project control: the scheduler compares actual performance with baseline performance and discerns any deviation. The project management team then deals with this deviation, analyzes it, and suggests solutions to bring the schedule back on track, if possible. (Mubarak, 2005)

Time is all-important, and the control process should aim at the early discovery of any departure from the planned course, so that adjustments can be made in time to be effective. (Celik, 2008)

To be successful, the actual work with its cost and duration must be completely and accurately documented. Comparisons should be made to project standards and variances noted. By creating such a feedback loop, adjustments can be made for upcoming activities. In addition, actual durations, costs, and important events should be recorded for use on future projects. (Gould & Joyce, 2003)

The project control process includes the following steps, which act as a feedback loop:

1) The control process documents progress and allows the project team to adjust unexpected occurrences, such as change orders, strikes, or bad weather.
2) Costs and time of completion are continually updated.
3) A reporting system notifies all necessary parties of the project status. This allows the input of outside technical experts and senior managers, who can assist and plan adjustments as necessary.
4) The project control system is iterative: the process occurs over and over, encouraging continual adjustment of the project plan. (Gould & Joyce, 2003)

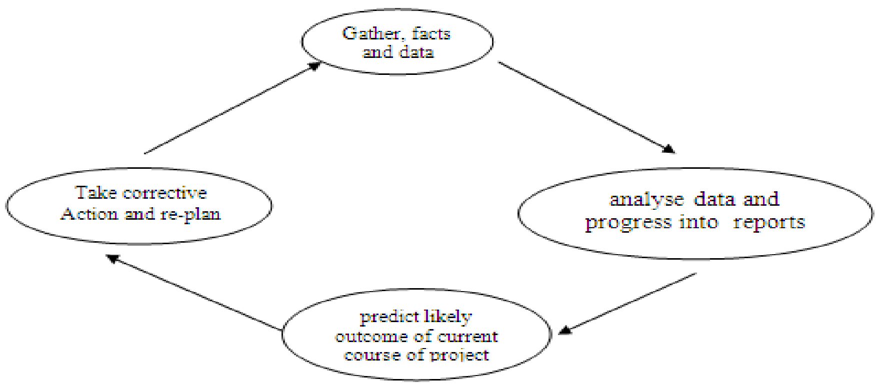


Figure 16: The Control Cycle (Celik, 2008)

The control cycle that shows in figure 16. It is a continuous process thought the life of the project, since it is very rare for any project to proceed exactly as planned. (Celik, 2008)

Control information provides a basis for management decisions, and the following requirement should be satisfied by an effective control system:

- It should draw immediate attention to significant deviations from what is planned.
- True and meaningful comparisons must be possible.
- The information should indicate what corrective action is necessary and who should take the action.
- It should be expressed in a simple form, so that those who have to make use of it readily understand it.
- Key areas of control must be chosen with care, so that the result if control is worth the time and effort expended. (Celik, 2008)

4.2.1 Standards

A system of control is essential for the successful delivery of any construction project. To begin the process, managers first establish the standards that define success for the construction project. Cost, schedule, and quality are the basis of these standards and are configured so that they are measurable and can provide direction to the project. The project team will continually use these standards to check progress and provide direction. (Gould & Joyce, 2003)

Furthermore, the standards used for control vary by project depending on the level of control necessary. Drawings and specifications define the standards for quality control. Drawings define the quantity of work required, locations and widths and heights. Specifications provide performance standards that address alignment, compression strengths, finishes, and so on. The project estimate establishes the overall budget for the project and can be broken down to specify milestone costs for each component of work. The schedule defines when specifics need to be accomplished as well as provides key milestone and delivery dates. Estimating data can be integrated with schedule information to provide additional project standards.

4.2.2 Actual

The second component of project control system is measurement of actual progress. This includes accurate cost, schedule, and quality information about the project. Actual performance compared to planned performance provides the management team with feedback about how well the project is proceeding. Also, actual cost and schedule performance information can be stored for reference when estimating and scheduling future projects. Measuring actual performance is a complicated process since the necessary information resides in many different places. Figure 17 illustrate the baseline and actual performance in a percentage scale which can be used in order to control and compare the baseline and actual performances.

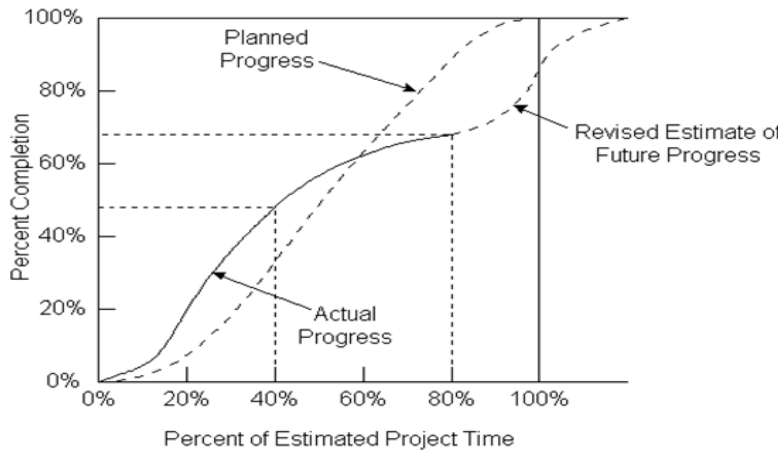


Figure 17: Illustration Of Planned Versus Actual Progress Over Time on A Project (Hendrickson, 1998)

Schedule updating is simply reflecting actual performance information including time of occurrence and amount (or percentage) of work completed on the schedule and indicating on the schedule any changes to future work. (Mubarak, 2005)

4.2.3 What Is A Baseline Schedule?

A baseline schedule is also called as planned or target schedule, is a schedule prepared usually before the start of the project by the contractor, and used for performance comparison. (Celik, 2009)

If approved by the owner, the baseline schedule usually becomes a part of the contract documents. Sometimes, the baseline schedule is the same as the as-planned schedule, but not always. In many situations, the as-planned schedule is submitted and approved, then some changes are implemented before the project starts, as a result of debugging, the owners changes, or both. The baseline schedule may be used by both general contractor, who will execute the work, and the owner, whose work is being executed. Sometimes both parties will use the baseline schedule for project control, each from his or her own prospective. A third part (professional construction management firm) may also monitor the schedule and compare it with baseline. (Mubarak, 2005)

Construction projects rarely – if ever – go as planned. Thus, we expect some deviation from the baseline. We need to know where and how much, then take corrective action whenever and wherever needed.

4.3 Cost Control of Construction Project

One of the principal objectives of most organizations is that of achievement at minimum cost. This contributes to the one essential, though not exclusively so, of all business enterprises, that of profit. For all construction projects, costs must be monitored and controlled, whether from the point of view of owner, designer or a contractor. (Pilcher, 1994)

Cost control should aim at ensuring the final cost of the project does not exceed the budget. The greatest possibility for influencing the final project cost is in the briefing and designing stages. Regular cost checks should therefore be carried out on the developing design. A good aid in this work is a cost plan, based on an approximate cost estimate, indicating the quality, quality and unit price for major cost elements such as earthworks, floors and roofs. When the design is developed in further detail, it is possible to check that the design of each element is kept within the framework set out in the cost plan.

An essential aid to cost control is a forecast to the final cost, which is regularly revised to reflect the current state of the project. If deviations between this forecast and the project budget are observed, corrective action must be taken. (Celik, 2008)

A cost control system should enable a manager to observe current cost levels, compare them with a standard plan or norm, and institute corrective action to keep cost within acceptable bounds. The system should help to identify where corrective action is necessary and to provide pointers as to what that action should be.

The cost control process involves the following series of steps:

1. Cost codes are assigned to each element of work in the cost estimate.
2. The cost estimated is corrected based upon buyout cost.
3. Actual costs are tracked for each work item using the assigned cost codes.
4. The construction process is adjusted, if necessary, to reduce cost overruns.
5. Actual quantities, costs, and productivity rates are recorded and an as-built estimate is prepared. (Holm, Schaufelberger, Griffin, & Cole, 2005)

While all costs should be monitored, the following items generally involved the greatest risk:

- Direct labor
- Equipment cost or rental
- Jobsite overhead or administration. (Holm, Schaufelberger, Griffin, & Cole, 2005)

4.3.1 The Purpose of Cost Control

The objective is not to keep the cost of each element of work under its estimated value, but to ensure that the total cost of completed project is under the estimated cost. (Holm, Schaufelberger, Griffin, & Cole, 2005)

The purpose of cost control can be generally identified as follows:

- To limit the client's expenditure to within the amount agreed. In simple terms this means that the tender sum and final account should approximately equate with the budget estimate. In many cases, the client may stipulate the maximum initial cost expenditure, or provide a detailed brief to the design team who will then determine the cost.
- To achieve a balanced design expenditure between the various elements of the buildings.
- To provide the client with a value-for-money project. This will probably necessitate the consideration of a total-cost approach.
- To see that the company's policy with regard to production is carried out which in turn will ensure that planned profit margins are maintained.
- To arrive at the cost of each stage, operation (in the case of repetitive construction), or unit, and to carry out a continuous comparison with the target to ascertain the gain or loss on each. This information must be available early enough for corrective action to be taken wherever possible.
- To provide information on cost for use in future estimating.

On small projects, many operations are of insufficient duration to allow assessment of cost in time for corrective action to be taken. However, control still needs to be exercised, as the same operations are likely to occur on future projects. (Oxley & Poskitt, 1996)

4.4 Time Control of Construction Project

The management of time is a primary consideration for any construction project. Irrespective of the type of project, its size and resourcing there will be an essential requirement to plan, monitor and control all activities against the project's duration.

However, very few plans turn out as expected and this is especially the case in construction work. Unforeseen ground conditions, delays due to weather and waiting for instructions are just some of the many reasons why this happen. It is therefore crucial to ensure that the planning process includes an element of control so that the plan can be monitored in the light of prevailing circumstances. (Cooke & Williams, 2004)

Although lacking in detail is vital problem during the briefing stage but the project manager should have prepared a time-schedule for the whole project, this will provide basic control information, such as the planned completion dates for each stage. By moving forward in project progress, detailed work plan can be prepared due to availability and updating the necessary information which can be complete by end of briefing stage. (Celik, 2008)

Similarly it should be possible to prepare a more detailed schedule for the constructing stage well before completion of the designing stage. The required completion times for the constructing stage should be written in the contract documents since they may have an important bearing on the tender price.

During the construction stage it is the contractor's responsibility to prepare a detailed work plan, which meets the requirements of the contract. The project manager should be assess the realism of the contractor's schedules, especially as regards availability of resources. It is the responsibility of the main contractor to co-ordinate the work of his subcontractors; but there may be suppliers, or indeed other main contractors, whose activities the project manager must co-ordinate. (Celik, 2008)

Schedules are an extremely effective tool for managing construction projects, especially large and complex projects. Schedules are for day – to – day managements operations. The most important use of schedules is project control which helps the scheduler compares actual performance with baseline performance and recognizes any deviation. The project management team then deals with deviation, analyze it, and suggest solutions to bring the schedule back on track if possible. (Mubarak, 2005)

The tools for progress control are the bar charts or critical path networks. Whichever technique is used, the project manager should take the following steps:

- Establish “targets” or “milestone” –times by which identifiable complete sections of work must be completed. One such target would be the completion of sketch plans during the designing stage, or the completion of all works to render a building watertight so that equipment may be safety installed.
- As each target event occurs, compare actual against targeted performance. For example where the sketch plans completed on the date planned, or two weeks before or one month after.
- Assess the effect of performance to date on future progress.
- If necessary, re-plan so as target achieve original targets or to come as near as possible to achieving term.
- Request appropriate action from these directly responsible for the various activities.

Planning and control techniques achieve nothing unless they are translated into action, and it is the responsibility of the project manager to see that this happens. (Celik, 2008)

4.5 Quality Control of Construction Project

Defects in construction projects are a vital problem which has effects on improving technology and education. The construction industry has too often in the past been discredited by bad publicity resulting from sometimes dramatic failure of both the design and the construction of its products. It must not, because of economic stringency and also because of external pressures, devote its resources to unprofitable ends by failing to achieve the desired standard of work at the first attempt. (Ashworth, 1999)

The achievement of an acceptable standard in buildings is a combination of quality of design and quality of construction. In the former, quality is determined by the engineer or architect in terms of their skill and by promoters in what they are prepared to pay. In the latter, quality is determined by the management and operative capabilities of the constructors, and by the supervisory capabilities provided by the designer with regard to standards required. Figure 18 lists some of the main points to be borne in mind when considering the implications of quality in the construction process.

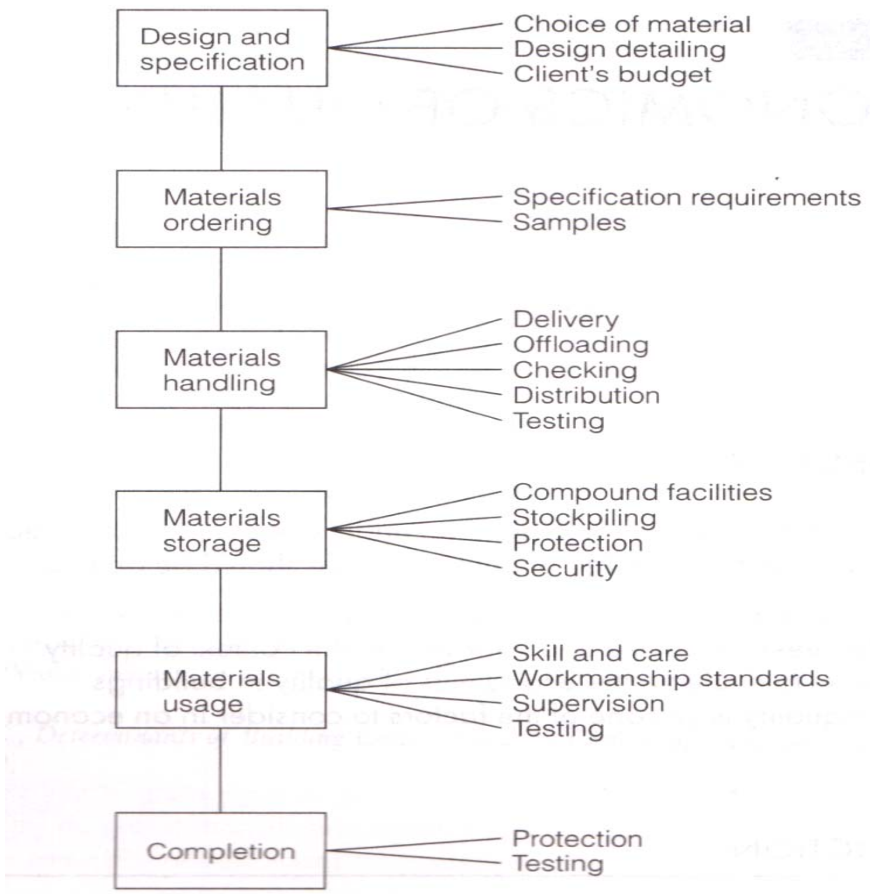


Figure 18: Quality in Construction (Ashworth, 1999)

Quality control in a construction project should aim at satisfying the client's stated needs and requirements. Quality control must be exercised during all stages of a project. Quality control during the constructing stage is usually exercised on site by a clerk of works. He is responsible for seeing that the daily activities of the contractor result in an end product, which satisfies the contract specifications. For example, he will ensure that the materials used for making concrete are up to standard that they are mixed in the correct proportions, and that tests are made on samples of the mixed concrete. It may also be necessary for designers and specialist to carry out site inspections and checks. (Celik, 2008)

4.5.1 What Is Quality?

Definition of quality by some organisations are describe as below: (Celik, 2009)

- "Providing customers with products and services that consistently meets their needs and expectations" – Boing.
- "Meeting the customer's need the first time and every time" – general services administration, US government
- "Performance to the standard expected by the customer" – Fedex.

The Oxford English Dictionary definition of quality includes the terms 'nature', 'character', 'kind' and 'attributes'. The Building Research Establishment (BRE), in attempting to answer this question related to buildings, defined it as:

"The totality of the attributes of a building which enable it to satisfy needs, including the way in which individual attributes are related, balanced and integrated in the whole building and its surroundings." (Ashworth, 1999)

The BRE report considered quality in the context of three main aspects:

1) External attributes - the effect of the project on its surroundings and vice versa.
2) Performance attributes - aspects of the project which make it operationally efficient and provide reasonable conditions for users.
3) Aesthetics and amenity – internal and external attributes of a standard higher than is needed just to meet mandatory and performance requirements. (Ashworth, 1999)

The following are general principles concerned with quality systems:

- A recognition of fitness for purpose based on agreed objectives and standards.

- The need to set quality issues with the organization’s own strategic plans.
- A recognition that quality must be planned and managed.
- All aspects need to be focused on, since quality is only as strong as the weakest link
- The need for some form of continuous monitoring system.
- An acknowledgment of the merits of the different quality control and assurance systems available.
- An emphasis on quality enhancement.
- A recognition of the importance of committed staff at all levels.
- The need for accountability to the firm’s customers.
- A concern for value for money.
- A recognition that quality and its absence both have economic consequences.

4.5.2 Quality Control

In all management processes, objectives must be set by the organization concerned in order to measure success or failure of the process. Management, therefore, carries with it the responsibility for quality and of achieving the standard required. Perfection is a word closely related to quality. Perfection may be the standard to be aimed for, but due to tolerances in the construction process it will always be out of reach. The difference therefore between perfection and achievable quality can be measured and compared. When quality is assessed in this way it can be controlled. (Ashworth, 1999)

The objectives of quality control are:

- To attain quality of design and conformance will satisfy the client, both on hand – over and during subsequent use.
- To achieve this at the lowest possible cost. (Ashworth, 1999)
- To ensure that the completed work meets the specification.
- To reduce customers' or clients' complaints.
- To improve the reliability of products or work produced.
- To increase customers' or clients' confidence.
- To reduce production costs. (Harris & McCaffer, 2006)

4.5.3 The 'M' Factors Affecting Quality

Markets: Comparability between standards provided by different firms. (Ashworth, 1999)

Men: This is perhaps the single most important factor in achieving quality: having the right men (persons) to do the job which is required. (Ashworth, 1999)

Money: Quality costs money. If an adequate amount of money is included in a budget, then the required will be difficult to obtain. (Ashworth, 1999)

Management: it is the function of management to set a company's quality policy, and this will in turn form the basis of the company's reputation in this respect. (Ashworth, 1999)

Materials: These must have been specified correctly, properly delivered to and checked on site and then stored and used in accordance with the manufacturer's instructions. (Ashworth, 1999)

Methods: The method specified must be capable of being executed in practice to the tolerance and finish required. Specifications which do not take into account these factors are unlikely to achieve their desired objectives. (Ashworth, 1999)

Machines: The correct machine for the work being carried out must be carefully selected, and to work efficiently it must be properly maintained. (Ashworth, 1999)

4.6 Site Control

The principal participants at the constructing stage are the project manager and the contractor. On a large contract the contractor may appoint a supervisor whom he may also call a project manager, so there is often confusion regarding the roles of these two main participants. “Project manager” refers to the client’s representative with overall responsibility for managing all stages of the project. “Contractor” refers to the person responsible for the construction works only. However, it is important that the project manager should understand the way in which a contractor manages a building project. (Celik, 2008)

The project manager can control site operations only within the conditions of contract. An important but often neglected aspect of site operations is that of safety. It is the prime responsibility of the contractor and other organizations working on site to ensure the safety of their employees. On a large contract the project manager and his team must therefore be located on site. On small projects where he has a number of site to look after, his site visits should be frequent and long enough to enable him to grasp fully what is going on. (Celik, 2009)

The project manager is in charge of the project from beginning to end. He provides direction to the architect’s other employees and to the sub consultants who are working on the project.

The field manager is involved in the layout of work and the interpretation of the construction documents. The field engineer may order materials and review and/or process shop drawings and submittals. He is often responsible for quality control and assurance in the project.

In jobsite quality control responsibilities often are allocated to superintendents, assistant superintendent, engineers, and field engineers, in addition to their other responsibilities. Their role in quality control should be explicitly expressed and related to their assigned activities.

The word contractor is used to denote the organization, which actually erects the building and associated works. The contractor directly controls the construction work. He assembles and organizes the necessary resources of labor, materials and plant and equipment.

The term labor indicates direct labor, or craftspeople employed by the contractor at the jobsite. The contractor provides supervision, task direction, material, and equipment for direct-labor employees. Because of this responsibility, the contractor also controls the labor and flexibility in moving employees from task to task; an effect on employees' productivity; control of duration of activities; and control in fluctuating the crew size, as necessary. The contractor does not have direct control of subcontractor's labor, as these employees are controlled by the subcontractor's management. (R.Mincks & Johnston, 1998)

Whether safety requirements are federal state or self-imposed, employers must demonstrate a commitment to safety, must have in place hazard assessment and control programs, must develop and implement safety planning, must have rules and work procedures that are pro-active and pertain to the jobsite, and must provide by the safety and health training that is thorough and applicable to the work performed by its employees. (R.Mincks & Johnston, 1998)

Plant and equipment are items which are needed temporarily during construction, such as Lorries, concrete mixers, hoists, ladders, buckets and shovels.

Jobsite organization is essential for a productive construction project. The jobsite layout has affects the cost of material handling, labor, and the use of major equipment by contractor and etc. A well organized jobsite has a positive effect on the productivity of the entire jobsite workforce. Productivity and worker morale are optimized by an effective jobsite layout. The jobsite layout plan is a plan for temporary facilities, material movement, material storage, and material handling equipment on the jobsite. (R.Mincks & Johnston, 1998)

Efficient material handling is extremely important in optimizing the construction worker's productivity. Ideally, the necessary material should be within reach for the craftsperson as it is needed for the installation. (R.Mincks & Johnston, 1998)

The jobsite needs to be secured, both for public safety and for the security of the installation and equipment. A jobsite, whether it is an excavated hole in the ground, or a steel-framed high-rise building in construction, is considered an attractive nuisance. It is the contractor's responsibility to prevent the general public from entering the jobsite. Vandalism and theft at the jobsite are major concerns for the contractor. Any construction site, in any geographical area of the country, is subject to vandalism and theft. (R.Mincks & Johnston, 1998)

Chapter 5

APPLICATION OF LINE OF BALANCE AND DRAWING CASHFLOW DIAGRAM BY USING MATLAB PACKAGE

5.1 Introduction

Repetitive construction projects are quite common in the construction industry, and may be divided into two categories: (1) projects that are repetitive due to a uniform repetition of a unit work throughout projects (multiple similar houses, high-rise building); (2) projects that are repetitive due to their geometrical layout (highways, tunnels, pipelines). Repetitive construction projects often require resources (e.g., crews) to perform the same work in various units (locations, segments) by moving from one unit to the next unit in the project. Because of this frequent resource movement, an effective schedule is important to ensure the uninterrupted usage of resources of repetitive activities between units.

Literature review of repetitive schedule and Planning: Traditional network scheduling methods, such as CPM, PERT, and bar charting are generally considered as less effective for the planning of repetitive construction projects, due to their inability to maintain resource work continuity in scheduling. Many linear, or repetitive, scheduling methods, as shown in Table 4, have been developed, with each of them featuring unique functions and/or applications. (Huang & Sun, 2005)

Table 4: Review of Previous Work (Huang & Sun, 2005)

Author(s)	Method	Unit-based	Fixed work sequence	Non-typical activity	Multiple resource assignment	Resource continuity
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Carr and Mayer (1974)	LOB	Yes	Yes	No	No	Yes
O'Brien (1975)	VPM	Yes	Yes	No	No	Yes
Selinger (1980)	Construction planning	Yes	Yes	Yes	No	Yes
Johnston (1981)	LSM	Yes	Yes	Yes	No	Suggested
Stradal and Cacha (1982)	Time space scheduling	Yes	Yes	Yes	No	Suggested
Arditi and Albulak (1986)	LOB	Yes	Yes	No	No	Yes
Chrzanowski and Johnston (1986)	LSM	Yes	Yes	Yes	No	Yes
Reda (1990)	RPM	Yes	Yes	No	No	Yes
El-Rayes and Moselhi (1998)	Resource-driven scheduling	Yes	No	Yes	No	No
Hamelink and Rowings (1998)	Linear scheduling model	Yes	Yes	No	No	Yes
Harris and Ioannou (1998)	RSM	Yes	Yes	Yes	No	No
Hegazy and Wassef (2001)	Repetitive non-serial activity scheduling	Yes	Yes	No	No	No

This chapter is focused on applying the Line of Balance construction planning technique by using Matlab package. In the first part of this chapter, Matlab program is briefly explained. The reasons of selecting Matlab for this study are discussed. Advantages of employing Matlab program on Line of Balance are defined.

The second part of this chapter is focused on method of study. This project is a study to apply the Line of Balance planning technique and to prepare cash flow diagram by using Matlab. How the program is prepared, what does the program do, How it runs and there are other questions that will be answered in this section by running the program and illustrate its application on an example. After entering the

Line of Balance data into the Matlab program, Line of Balance table and its diagram is prepared and the project financial statement such as cash flow, S curve diagram are obtained.

In the 3rd section, in order to evaluate the developed program, a villa housing project is selected as a case study. In order to achieve this aim, several prerequisite steps need to be taken such as preparing Bill of Quantity, Work Break Down Structure and Productivity analysis and etc.

In the last section of this chapter the evaluation of developed program on the case study will be discussed and results are compared. Moreover, the advantages of using the developed program are briefly explained.

5.2 Matlab Program

To computerize Line of Balance scheduling, various computer programs can be utilized such as JAVA, C++, FORTRAN, Visual Basic etc. By conducting interview with some specialists in Computer Programming and collecting historical information about computerizing method of Line of Balance scheduling, it was decided to use the Matlab package in this thesis to develop Line of Balance scheduling. Matlab Program has many advantages in comparison with other programs mentioned:

1. MATLAB allows you to focus on your engineering course work rather than on programming details.
2. It enables you to solve many numerical problems in a fraction of the time and it would take you to write a program in a lower level programming language.

3. MATLAB helps you to understand and apply the concepts in applications ranging from engineering and mathematics to chemistry, biology, and economics.
4. MATLAB products are already used successfully in a broad range of industries,including,automotive,aerospace,electronics,environmental, telecommunications, computer peripherals, finance, and medical.
5. More than 400,000 technical professionals in the world's most innovative technology companies, government research labs, financial institutions, and at more than 2,000 universities rely on MATLAB and simulating Matlab package as the fundamental tools for their engineering and scientific work.
6. MATLAB has extensive facilities for displaying vectors and matrices as graphs, as well as annotating and printing these graphs which is a vital factor in this study. (MathWorks, 1999)

5.2.1 What Is MATLAB?

MATLAB is a high-performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation. Typical uses include:

•Math and computation

•Algorithm development

•Modeling, simulation, and prototyping

•Data analysis, exploration, and visualization

•Scientific and engineering graphics

•Application development, including graphical user interface building. (MathWorks, 1999)

MATLAB is an interactive system whose basic data element is an array that does not require dimensioning. This allows you to solve many technical computing problems, especially those with matrix and vector formulations, in a fraction of the time it would take to write a program in a scalar non interactive language such as C or Fortran. (MathWorks, 1999)

The name MATLAB stands for matrix laboratory. MATLAB was originally written to provide easy access to matrix software developed by the LINPACK and EISPACK projects. Today, MATLAB uses software developed by the LAPACK and ARPACK projects, which together represent the state-of-the-art in software for matrix computation.

MATLAB has evolved over a period of years with input from many users. In university environments, it is the standard instructional tool for introductory and advanced courses in mathematics, engineering, and science. In industry, MATLAB is the tool of choice for high-productivity research, development, and analysis. (MathWorks, 1999)

5.2.2 The MATLAB System

The MATLAB system consists of five main parts: (MathWorks, 1999)

Development Environment: This is the set of tools and facilities that help you use MATLAB functions and files. Many of these tools are graphical user interfaces. It includes the MATLAB desktop and Command Window, a command history, and browsers for viewing help, the workspace, files, and the search path.

The MATLAB Mathematical Function Library: This is a vast collection of computational algorithms ranging from elementary functions like sum, sine, cosine, and complex arithmetic, to more sophisticated functions like matrix inverse, matrix Eigen values, Bessel functions, and fast Fourier transforms.

The MATLAB language: This is a high-level matrix/array language with control flow statements, functions, data structures, input/output, and object-oriented programming features. It allows both “programming in the small” to rapidly create quick and dirty throw-away programs, and “programming in the large” to create complete large and complex application programs.

Handle Graphics: This is the MATLAB graphics system. It includes high-level commands for two-dimensional and three-dimensional data visualization, image processing, animation, and presentation graphics. It also includes low-level commands that allow you to fully customize the appearance of graphics as well as to build complete graphical user interfaces on your MATLAB applications.

The MATLAB Application Program Interface (API): This is a library that allows you to write C and Fortran programs that interact with MATLAB. It include facilities for calling routines from MATLAB (dynamic linking), calling MATLAB as a computational engine, and for reading and writing MAT-files. When you start MATLAB, the MATLAB desktop appears, containing tools (graphical user interfaces) for managing files, variables, and applications associated with MATLAB.

The first time MATLAB starts, the desktop appears as shown in the figure 19, although your Launch Pad may contain different entries. (MathWorks, 1999)

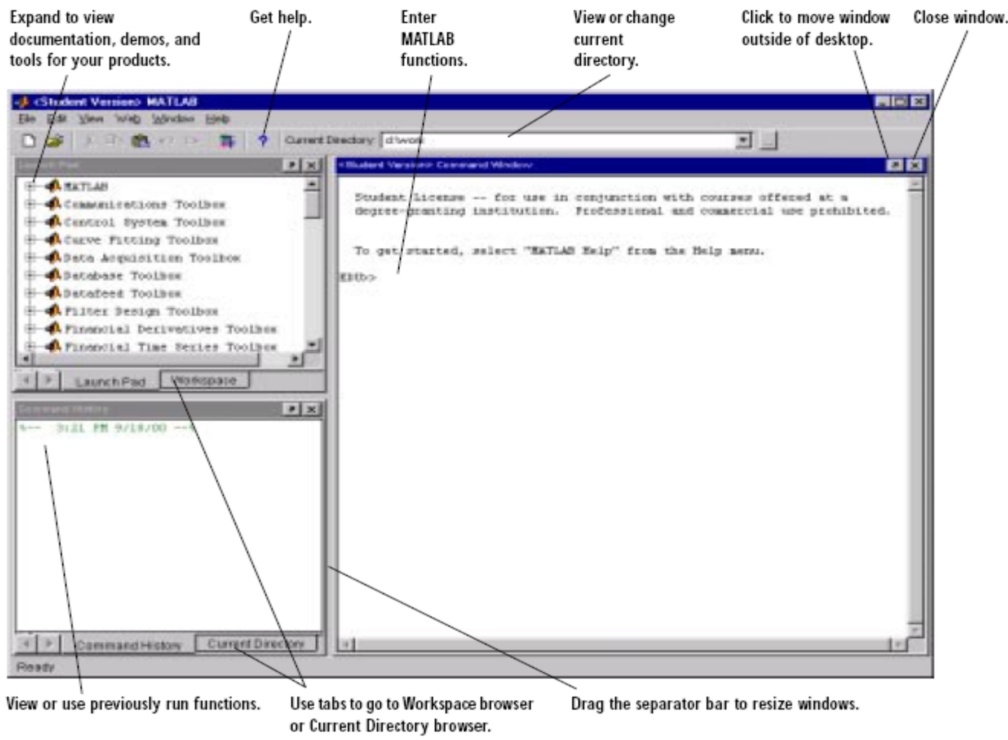


Figure 19: Matlab Window on Your Desktop (MathWorks, 1999)

You can change the way your desktop looks by opening, closing, moving, and resizing the tools in it. You can also move tools outside of the desktop or return them back inside the desktop (docking). All the desktop tools provide common features such as context menus and keyboard shortcuts. You can specify certain characteristics for the desktop tools by selecting Preferences from the File menu. For example, you can specify the font characteristics for Command Window text. For more information, click the Help button in the Preferences dialog box. (MathWorks, 1999)

5.3 Method of Study

5.3.1 Overview

Project planning is the heart of proper project management because it provides the central communication for the work of all parties. Planning also establishes the benchmark for the project control system to track the quality, cost and timing of the work required to successfully complete the project. It is also the first step to project scheduling. Project scheduling deals with the timetables preparation and the establishment of dates during which various resources, such as equipment and personnel, will perform the activities required for completing the project. Schedules were described by Shtub (1994), as the cornerstone of the planning and control system because of their importance, are often written into the contract by the customer. (Mahdi, 2003)

Contractors often encounter with repetitive types of projects that contain several identical or similar units such as floors in multistory buildings or large number of similar constructions in housing developments. These multi-unit projects are characterized by repeating activities. The known Construction planning techniques such as Bar chart and Network diagramming method are not appropriate for repetitive types of projects. For these kinds of projects, Line of Balance planning technique is mainly used.

Traditional network technique (critical path method-CPM) has many drawbacks when it is applied for scheduling repetitive construction projects: (1) First, it requires a large number of activities to represent a project. (2)Second, CPM does not guarantee maintaining the continuity of work which may result in crews being idle. (3) It does not show the location and time at which a certain crew will be working on a given activity, so it is not efficient for visually monitoring the progress of a particular crew. (Long & Ohsato, 2008)

There are different kinds of computer programs capable of calculating and drawing cash flow diagram for Network diagram scheduling. In spite of a number of available softwares for the Line of Balance planning technique, the calculation and drawing of cash flow diagram still needs to be studied and developed. As it is known cash flow diagram is a tool used by contractors or clients to indicate a project's finance strength. Development of a computerized method which is able to obtain cash flow diagram and financial statement in different periods of time, phase or section of project in Line of Balance scheduling is essential for contractors and owners.

This Project is a study to apply Line of Balance planning technique and to prepare cash flow diagram by using Matlab. Although there a number of programming languages that can be used to illustrate the Line of Balance diagram such as C++ or Visual Basics, Matlab is a useful programming language that can provide functions to obtain and visualize the Line of Balance diagram.

5.3.2 Line of Balance Analysis by Matlab Package

The line-of-balance (LOB) method of scheduling is well suited to projects that are composed of activities of a linear and repetitive nature. The objective of this study is to develop a framework that can be used in the development of a computerized LOB scheduling system and creates solutions to problems encountered in the cash flow calculations and cash flow diagram drawings.

LOB scheduling is not simple, especially when dealing with a construction project that is broken down into a large number of activities that are bound by numerous and complicated relationships and other constraints. The LOB scheduling technique makes the basic assumption that the relationship between time and the number of units produced is linear, for instance constant rate of production over time. In reality, it is not so, because the more times an operation is performed, the shorter will be the time needed to perform it.

The linear schedule is a graphical representation of activities on two axes. One axis represents the location or number of sections of activity at any point in time. For example number of houses in a housing project. The other axis represent time measured in hours, days, months, or years depending on the project's overall duration. Although either axis can represent time or location, this study will designate the abscissa (X-axis) for Days and ordinate (Y-axis) for number of sections, units or houses in a villa development project.

Matlab is a programming language and it is used to develop the computer program for calculating the Line of Balance tables, drawing its diagrams, calculating the cash flow and drawing the cash flow diagrams.

Matlab Package consists of two windows. The first phase is called Editor Window; where the Line of Balance program was written on it. This window has a Run Icon. By clicking on that Icon, the program is activated. The next window is called Command Window, as it is shown in Figure 20, where the data is entered and ordered with.

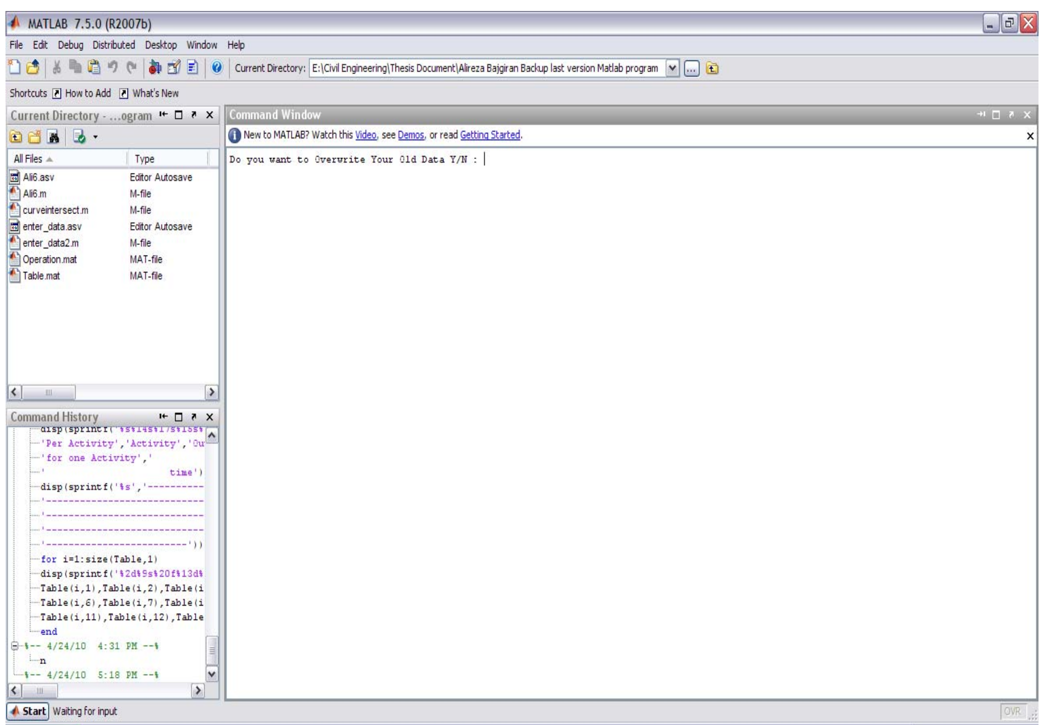


Figure 20: Command Matlab Window

As it is shown in the Figure 21, the Editor window is organized in two separate sections.

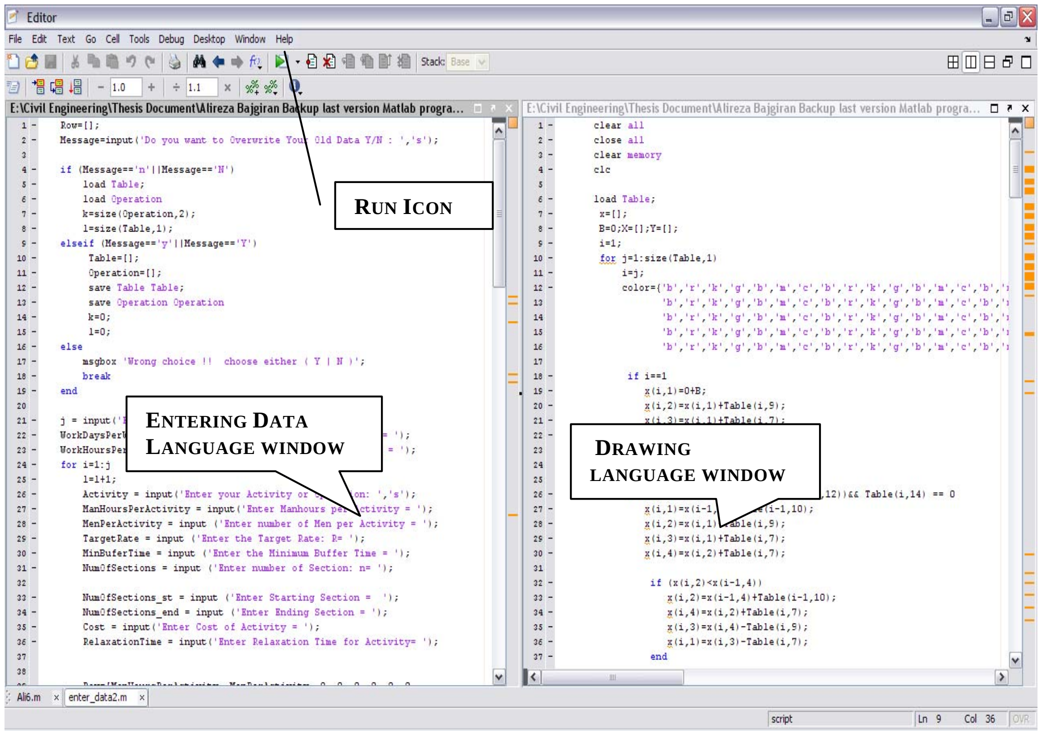


Figure 21: Editor Windows in Matlab Package

The first section of Editor Window in figure 21 (Left side), is responsible for entering the initial project data which is used for preparing Line of Balance table into the Matlab package. After the Line of Balance data has been entered, the program automatically starts to create and determine Line of Balance table.

The second section of Editor Window in figure 21 (right side) is in charge of drawing Line of Balance diagram, obtaining cash flow and S-curve diagram and their exact values.

The program will start to perform by taking the first step which is running Matlab package and Line of Balance program. As it is mentioned already the second step is clicking on Run Icon on Editor Window. After Clicking on the Icon the

Command window is appeared and it starts to ask question to form Line of Balance table.

By following this procedure, the entire data can be entered to the program and this action should continue until the program is ready to draw Line of Balance table. In the following pages the whole steps are explained by presenting images that has been taken from Matlab Package. The method to determine these data will be discussed in the following sections on a case study project. The entering data which are going to be used in this section, has been taken from the case study project.

The first four questions are asking for general formation about the project such as working hours per day etc. The 5^{th} question is asking about entering Activity or Operation name and keeps on asking questions specifically about that activity until it goes to the next activity.

As it is shown in figure 22, the first question is:

Do you want to Overwrite Your Old Data Y/N: Y

As the program run, in the first question the program wants to know that the user needs to create new Line of Balance table or use the old data that they already entered. There is always an option to modify or edit the initial data for instance adding an activity or editing quantity of an activity or etc. In order to review the previous data or modify them, the answer of this question should be NO, otherwise by responding YES, previous data will be deleted and program start to create new Line of Balance Table.

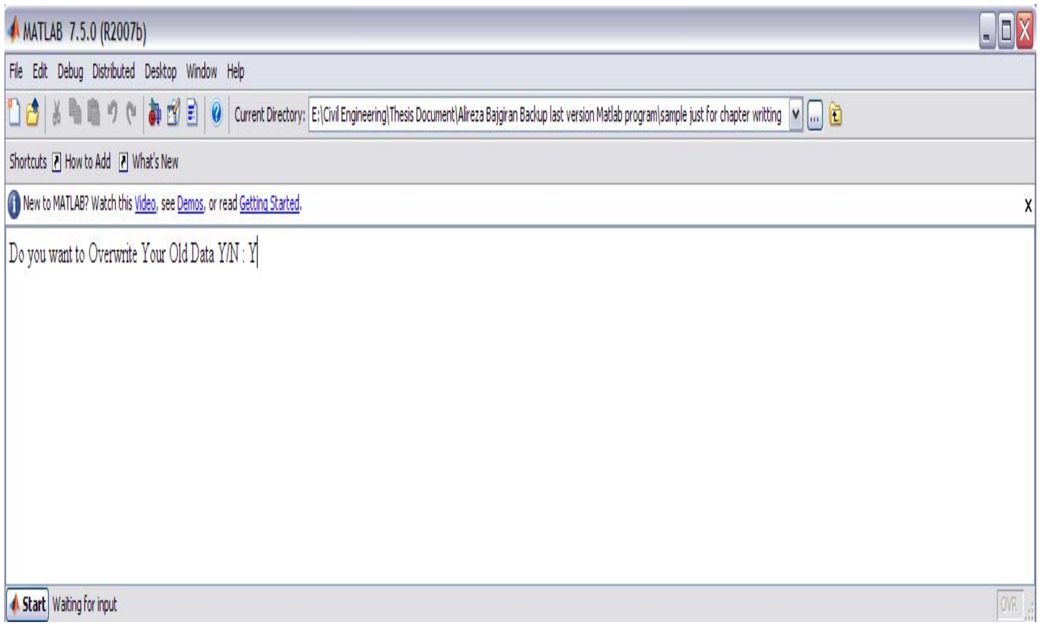


Figure 22: Entering Data 1st Question

Second question is asking about the number of activities; which is 67 activities in this study as it is shown in figure 23.

<u>Enter Number of Activities = 67</u>

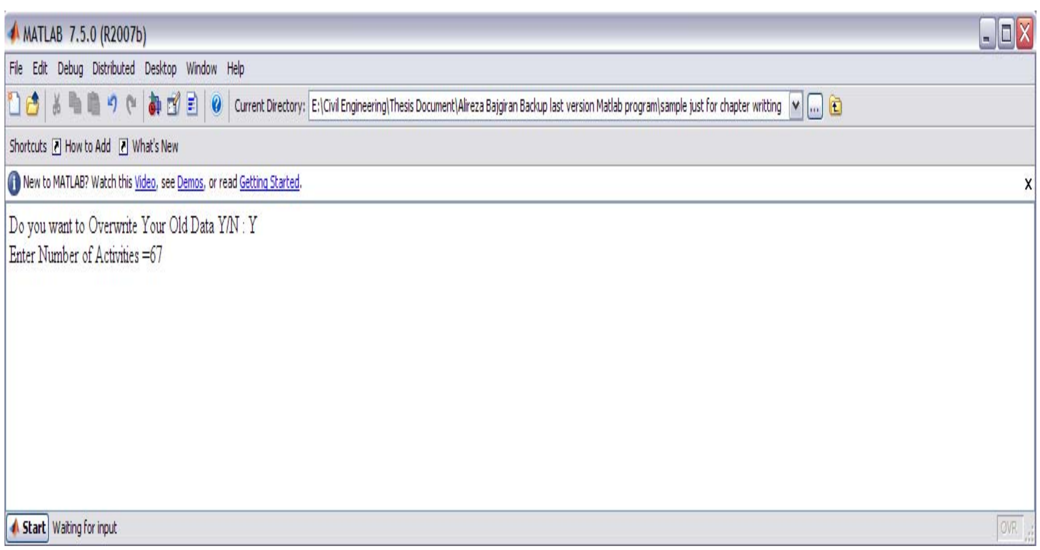


Figure 23: Entering Data 2nd Question

Next question that is shown in figure 24 related to:

<u>Enter the Working Days per Week= 6</u>

It has been discussed already that the working days per week is 6 days and 8 hours per day.

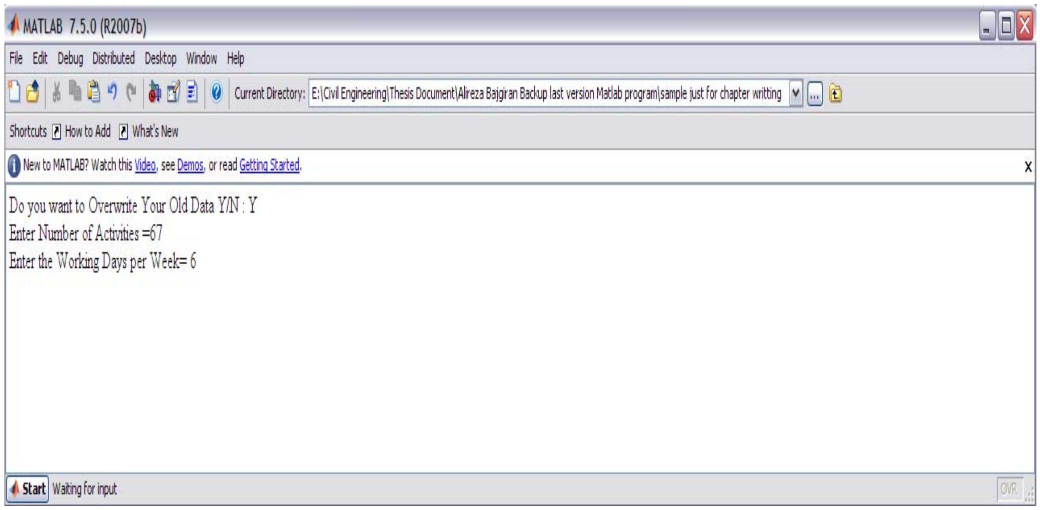


Figure 24: Entering Data 3rd Question

The next one is shown in figure 25, is the same as previous question and it asks about the working hours per day:

<u>Enter the Working Hours per Day = 8</u>

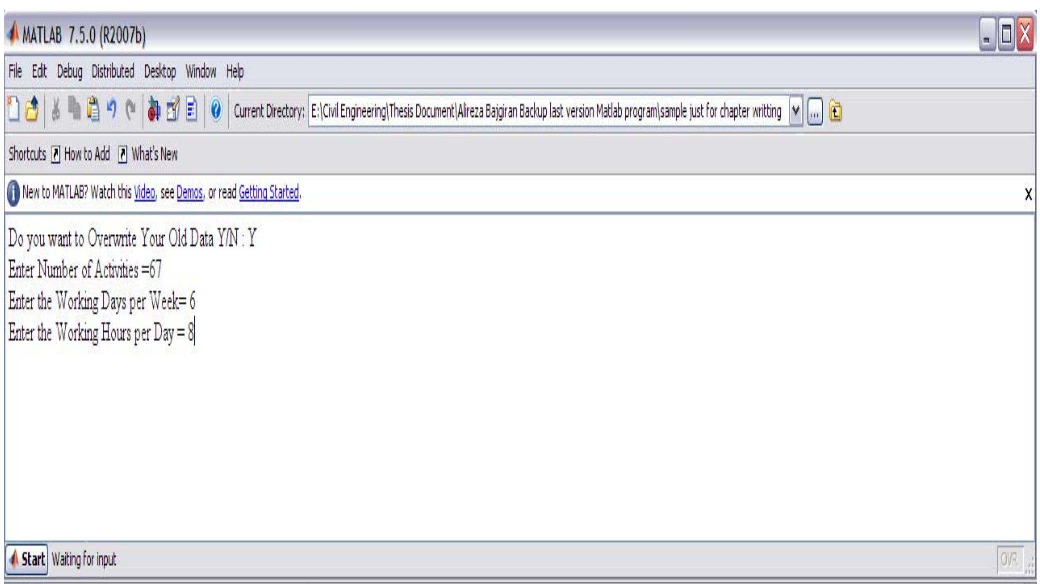


Figure 25: Entering Data 4th Question

The 5th question is asking about entering the activity or operation of project as it is illustrated in figure 26.

Enter your Activity or Operation: P.1.1

Note that there is no need to enter the activity description and instead of that, just enter the activity ID and press enter, therefore now the program starts to ask specifically questions about the activity P.1.1.

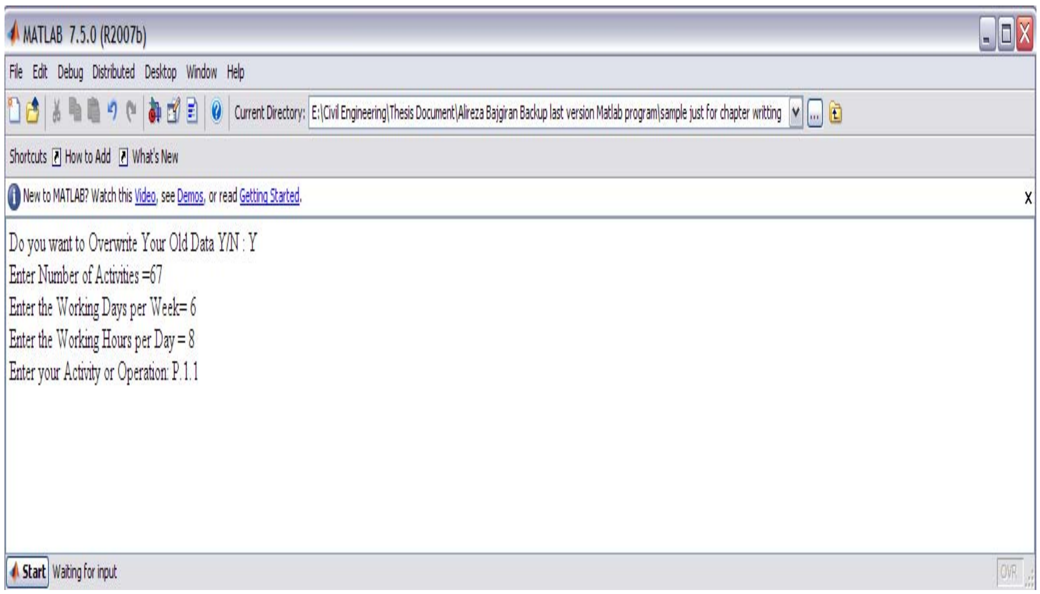


Figure 26: Entering Data 5th Question

From that point on, each activity data should be entered one by one. Since the number of activities are 67 in this study, after the program completes all questions about single activity, it will start to ask the activity ID of next one and keeps on the same procedure until all 67 activities data have been entered.

The sixth question is asking for entering the Man-hours of the P.1.1, as it is shown in figure 27.

Enter Man-hours per Activity = 10.7378

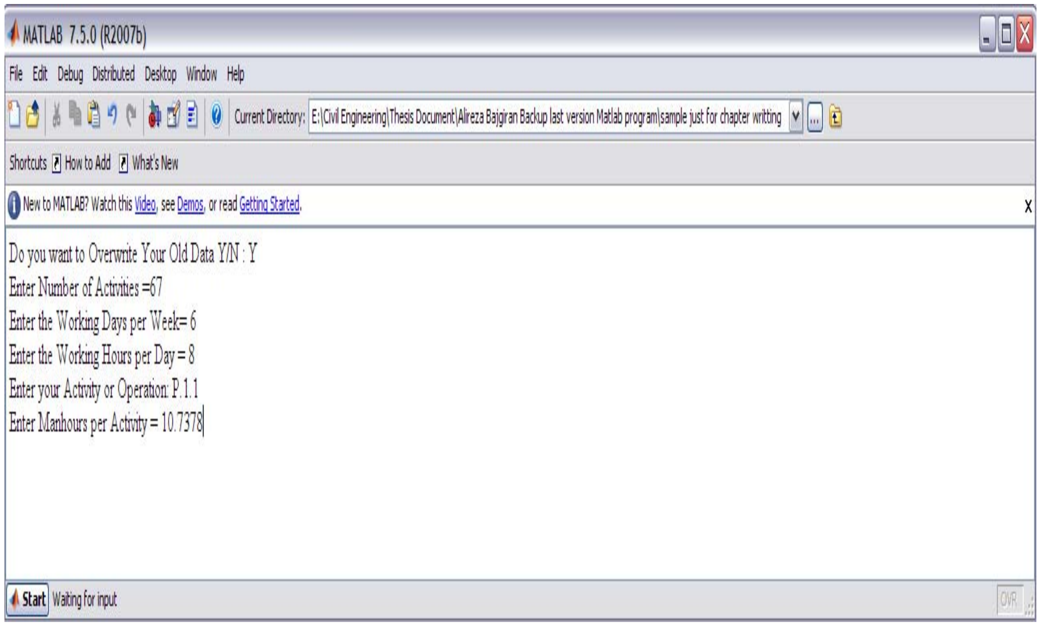


Figure 27: Entering Data 6th Question

After entering the Man-hours per activity the 7th question (figure 28) is related to Number of men per activity:

<u>Enter number of Men per Activity = 2</u>

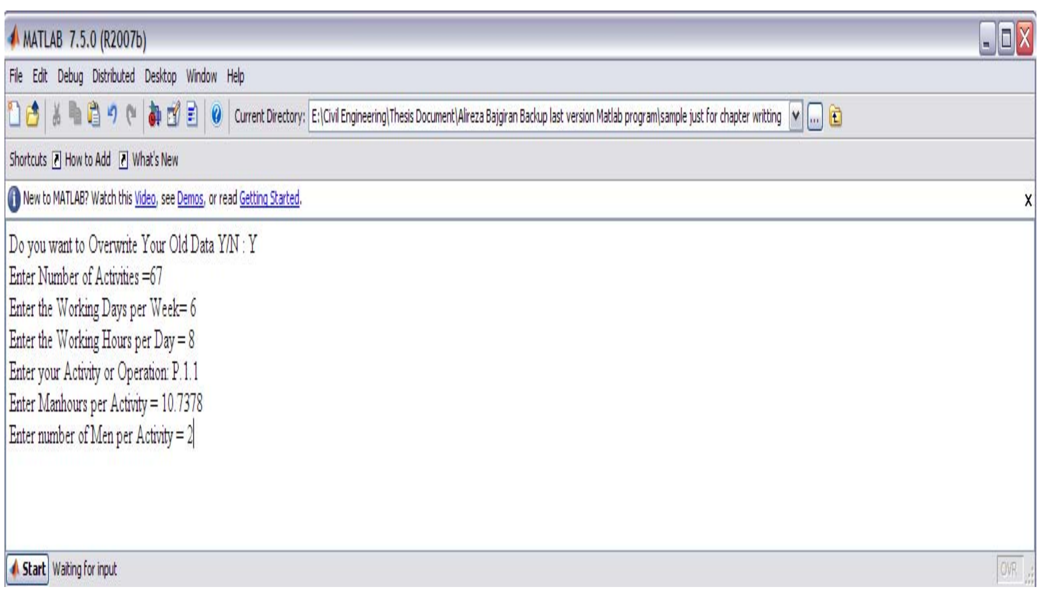


Figure 28: Entering Data 7th Question

The eighth question (figure 29) is asking about the target rate of activity:

<u>Enter the Target Rate: R= 0.1599</u>

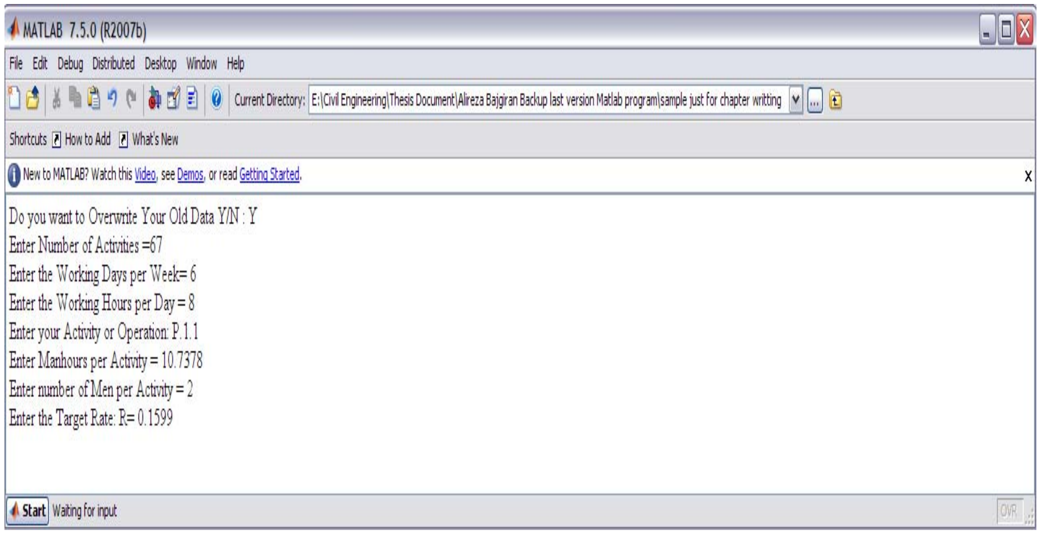


Figure 29: Entering Data 8th Question

Note that although in this study the target rate is same for all activities which is R=0.1599. In some project due to some unexpected reasons the project manager may require to change the Target Rate in order to complete project earlier or later.

The ninth question is asking about the Buffer time of activity as it is shown in figure 30.

<u>Enter the Minimum Buffer Time = 0</u>

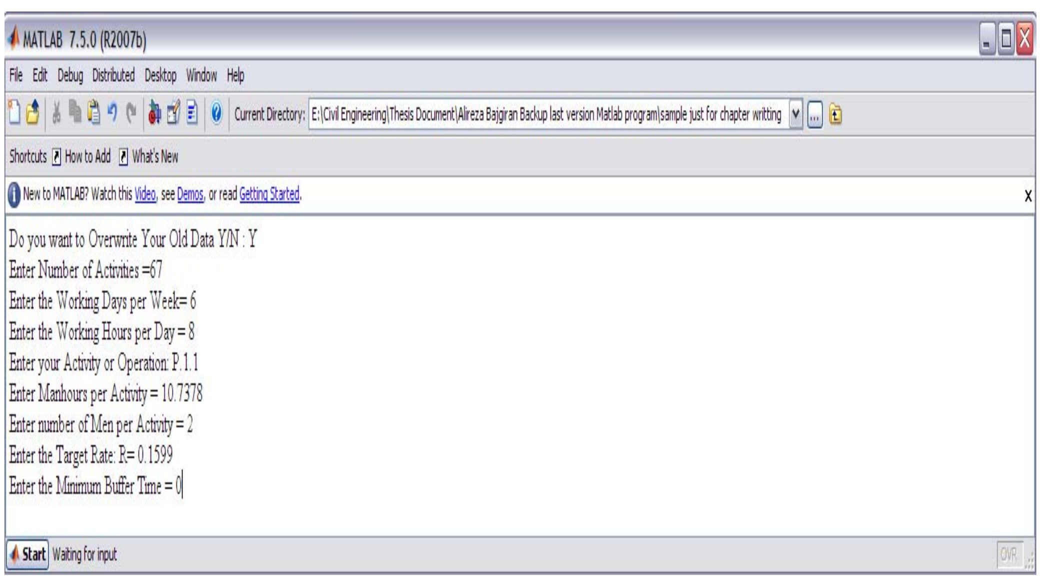


Figure 30: Entering Data 9th Question

The next question is the Number of sections as it is shown in figure 31. As it was mentioned the numbers of sections are twenty for this project.

Enter number of Section: n= 20

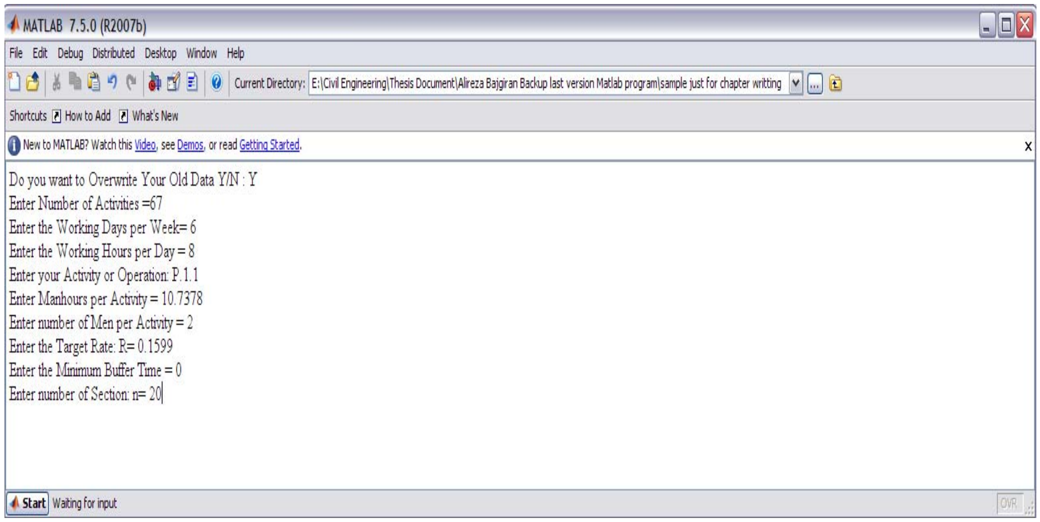


Figure 31: Entering Data 10th Question

The eleventh question (figure 32) is about the Starting Section

Enter Starting Section = 1

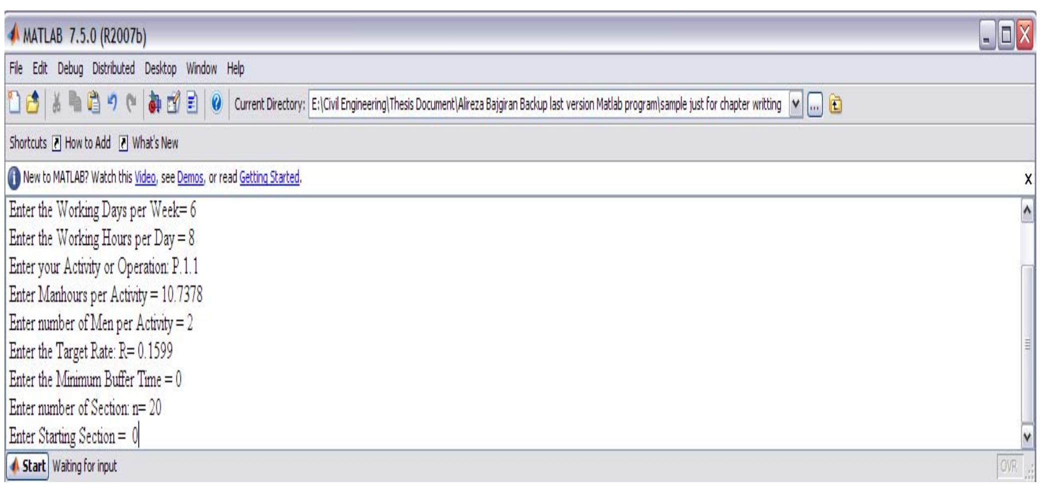


Figure 32: Entering Data 11th Question

Note that as it has been discussed in preparing the Line of Balance table, since there is no interruption in project or in any of activity, therefore the Start section for entire activities is section one and Ending section is section twenty one which is the total number of sections for project.

The 12th question is as follows as it is illustrated in figure 33:

Enter Ending Section = 21

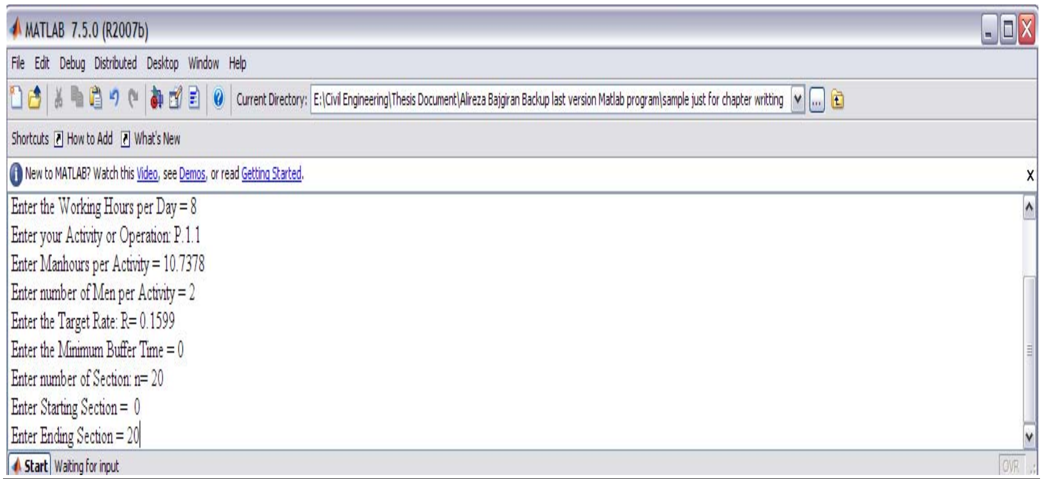


Figure 33: Entering Data 12th Question

The 13th question (figure 34) is asking about the cost of activity which is useful for preparing financial statement and the cash flow diagram.

Enter Cost of Activity = 1000

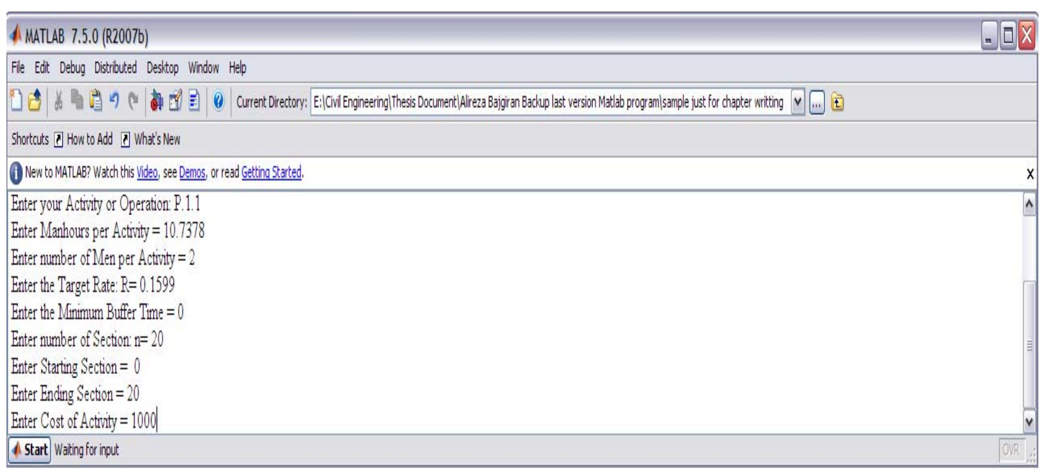


Figure 34: Entering Data 13th Question

Note that there is no need to enter units assigned for cost which means that the program will prepare financial statement unitless, therefore it depend on the project financial specification which shows that the project cost is in Dollar, Turkish Lira or etc.

In this study the cost and financial statement is prepared in Turkish Lira (TL).

The 14th question as it is shown in figure 35 is about relaxation time which is zero for the entire project and activities.

Enter Relaxation Time for Activity= 0

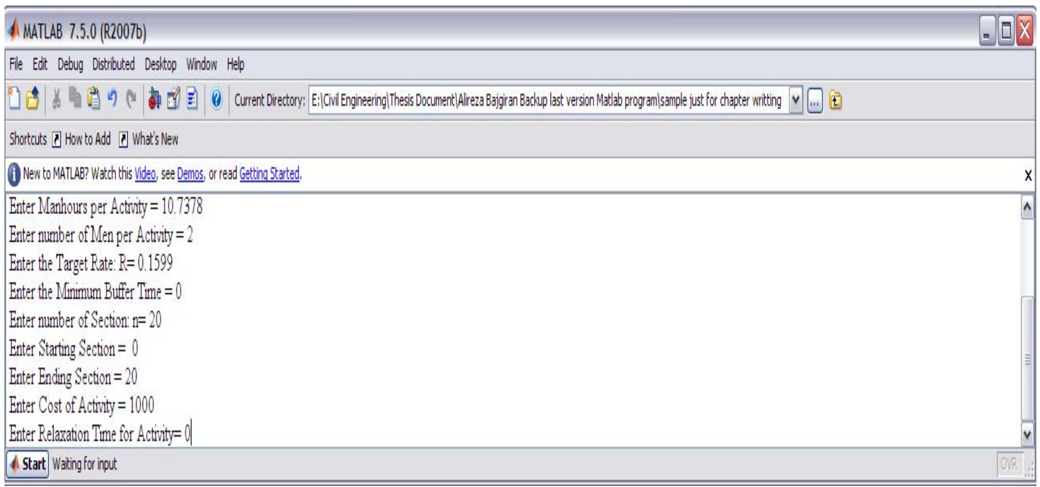


Figure 35: Entering Data 14th Question

Note that as it was explained in preparing Line of Balance data table since there is no discontinuity in the activities, relaxation time is zero which is the period of time in days that one activity stopped and started again or it's the duration that one activity dose not implement.

The next question is same as fifth question which is asking about entering the next activity and it follows by asking the same question related to each activity. Remember that since in the study there are 67 activities, the program needs to repeat these questions until the data for all the activities are entered.

After completing entering of all of the activities, the program will prepare the Line of Balance table that is given in figure 36.

MATLAB 7.5.0 (R2007b)

File Edit Debug Distributed Desktop Window Help

Current Directory: E:\Civil Engineering\Thesis Document\Alireza Bajgiran Backup last version Matlab program

Shortcuts How to Add What's New

New to MATLAB? Watch this Video, see Demos, or read Getting Started.

\# | Activity or Operation | Manhours Per Activity | Theoritical gang Men Per Activity | Size at the chosen Output Rate of R | Actual gang size | Actual Rate of Output | Time in days for one Activity | Time from start on first section to to start on last section | Minimum Buffer time | Cost of Activity | Starting section | Ending Section | Relaxation Time | Target Rate | Work

1	p.1.1	10.740000	2	0.035778	2	8.938547	0.671250	1	12.753750	13.000000	3	1000.000	0	20	0	1.599000e-001	6	8
2	p.1.2	11.120000	2	0.037043	2	8.633094	0.695000	1	13.205000	13.000000	3	292.000	0	20	0	1.599000e-001	6	8
3	p.2.1	4.540000	2	0.015124	2	21.145374	0.283750	1	5.391250	5.000000	3	1195.830	0	20	0	1.599000e-001	6	8
4	p.2.2	6.320000	3	0.021053	3	22.784810	0.263333	1	5.003333	5.000000	3	445.830	0	20	0	1.599000e-001	6	8
5	p.7.1	15.400000	3	0.051301	3	9.350649	0.641667	1	12.191667	12.000000	4	7854.000	0	20	0	1.599000e-001	6	8
6	p.4.1	44.280000	9	0.147508	9	9.756098	0.615000	1	11.685000	12.000000	3	5508.000	0	20	0	1.599000e-001	6	8
7	p.5.1	5.170000	2	0.017223	2	18.568665	0.323125	1	6.139375	6.000000	8	2918.400	0	20	0	1.599000e-001	6	8
8	p.4.2	5.950000	8	0.019821	8	64.537815	0.092969	1	1.766406	2.000000	3	1998.000	0	20	0	1.599000e-001	6	8
9	p.3.1	63.900000	5	0.212867	5	3.755869	1.597500	2	30.352500	30.000000	8	3205.300	0	20	0	1.599000e-001	6	8
10	p.5.2	8.120000	2	0.027050	2	11.822660	0.507500	1	9.642500	10.000000	3	4582.800	0	20	0	1.599000e-001	6	8
11	p.4.3	4.060000	8	0.013525	8	94.581281	0.063437	1	1.205313	1.000000	3	1364.190	0	20	0	1.599000e-001	6	8
12	p.2.3	10.360000	3	0.034512	3	13.899614	0.431667	1	8.201667	8.000000	8	358.930	0	20	0	1.599000e-001	6	8
13	p.2.4	28.810000	5	0.095973	5	8.330441	0.720250	1	13.684750	14.000000	3	978.900	0	20	0	1.599000e-001	6	8
14	p.2.5	3.940000	7	0.013125	7	85.279188	0.070357	1	1.336786	1.000000	3	640.500	0	20	0	1.599000e-001	6	8
15	p.3.2	37.970000	5	0.126488	5	6.320780	0.949250	1	18.035750	18.000000	8	2326.550	0	20	0	1.599000e-001	6	8
16	p.5.3	7.720000	2	0.025717	2	12.435233	0.482500	1	9.167500	9.000000	3	4354.800	0	20	0	1.599000e-001	6	8
17	p.4.4	17.270000	10	0.057531	10	27.793862	0.215875	1	4.101625	4.000000	3	1279.830	0	20	0	1.599000e-001	6	8
18	p.3.3	150.450000	5	0.501187	5	1.595214	3.761250	4	71.463750	71.000000	8	7546.800	0	20	0	1.599000e-001	6	8
19	p.5.4	16.240000	2	0.054099	2	5.911330	1.015000	2	19.285000	19.000000	3	9165.600	0	20	0	1.599000e-001	6	8
20	p.4.5	38.520000	12	0.128320	12	14.953271	0.401250	1	7.623750	8.000000	3	4658.670	0	20	0	1.599000e-001	6	8
21	p.3.4	31.780000	5	0.105867	5	7.551919	0.794500	1	15.095500	15.000000	8	1947.500	0	20	0	1.599000e-001	6	8
22	p.5.5	6.100000	2	0.020321	2	15.737705	0.381250	1	7.243750	7.000000	3	3442.800	0	20	0	1.599000e-001	6	8
23	p.4.6	15.790000	10	0.052600	10	30.398987	0.197375	1	3.750125	4.000000	3	1169.940	0	20	0	1.599000e-001	6	8
24	p.3.5	126.400000	5	0.421070	5	1.898734	3.160000	4	60.040000	60.000000	8	6340.300	0	20	0	1.599000e-001	6	8
25	p.5.6	12.890000	2	0.042940	2	7.447634	0.805625	1	15.306875	15.000000	3	7273.200	0	20	0	1.599000e-001	6	8
26	p.4.7	30.270000	12	0.100837	12	19.028741	0.315313	1	5.990937	6.000000	3	3660.780	0	20	0	1.599000e-001	6	8
27	p.16.1	42.670000	4	0.142144	4	4.499648	1.333438	2	25.335313	25.000000	8	1100.000	0	20	0	1.599000e-001	6	8
28	p.16.2	71.110000	4	0.236885	4	2.700042	2.222188	3	42.221563	42.000000	3	2000.000	0	20	0	1.599000e-001	6	8
29	p.16.3	6.000000	3	0.019987	3	24.000000	0.250000	1	4.750000	5.000000	3	2001.000	0	20	0	1.599000e-001	6	8
30	p.6.1	40.490000	2	0.134882	2	2.370956	2.530625	3	48.081875	48.000000	3	6944.000	0	20	0	1.599000e-001	6	8
31	p.17.1	12.000000	3	0.039975	3	12.000000	0.500000	1	9.500000	10.000000	3	4600.000	0	20	0	1.599000e-001	6	8
32	p.17.2	18.270000	3	0.060862	3	7.881773	0.761250	1	14.463750	14.000000	3	2740.000	0	20	0	1.599000e-001	6	8
33	p.15.1	6.320000	3	0.021053	3	22.784810	0.263333	1	5.003333	5.000000	3	959.000	0	20	0	1.599000e-001	6	8
34	p.6.2	28.650000	2	0.095440	2	3.350785	1.790625	2	34.021875	34.000000	3	4913.200	0	20	0	1.599000e-001	6	8
35	p.6.3	2.640000	2	0.008795	2	36.363636	0.165000	1	3.135000	3.000000	3	350.300	0	20	0	1.599000e-001	6	8
36	p.17.4	12.400000	3	0.041307	3	11.612903	0.516667	1	9.816667	10.000000	3	1860.000	0	20	0	1.599000e-001	6	8
37	p.15.4	4.290000	3	0.014291	3	33.566434	0.178750	1	3.396250	3.000000	3	651.000	0	20	0	1.599000e-001	6	8
38	p.12.1	53.330000	5	0.177656	5	4.500281	1.333250	2	25.331750	25.000000	10	4672.600	0	20	0	1.599000e-001	6	8
39	p.7.2	26.510000	3	0.088311	3	5.431912	1.104583	2	20.987083	21.000000	6	3944.000	0	20	0	1.599000e-001	6	8
40	p.7.3	24.230000	3	0.080716	3	5.943046	1.009583	2	19.182083	19.000000	6	3604.000	0	20	0	1.599000e-001	6	8
41	p.15.2	6.320000	3	0.021053	3	22.784810	0.263333	1	5.003333	5.000000	3	959.000	0	20	0	1.599000e-001	6	8
42	p.15.5	4.290000	3	0.014291	3	33.566434	0.178750	1	3.396250	3.000000	3	651.000	0	20	0	1.599000e-001	6	8
43	p.7.4	14.460000	3	0.048170	3	9.958506	0.602500	1	11.447500	11.000000	3	4636.000	0	20	0	1.599000e-001	6	8
44	p.12.2	8.000000	2	0.026650	2	12.000000	0.500000	1	9.500000	10.000000	6	1326.000	0	20	0	1.599000e-001	6	8
45	p.8.1	22.270000	3	0.074187	3	6.466098	0.927917	1	17.630417	18.000000	3	5737.200	0	20	0	1.599000e-001	6	8
46	p.8.2	18.550000	3	0.061795	3	7.762803	0.772917	1	14.685417	15.000000	3	4778.400	0	20	0	1.599000e-001	6	8
47	p.9.1	18.670000	2	0.062194	2	5.141939	1.166875	2	22.170625	22.000000	6	5625.000	0	20	0	1.599000e-001	6	8
48	p.9.2	31.260000	2	0.104135	2	3.071017	1.953750	2	37.121250	37.000000	5	2652.000	0	20	0	1.599000e-001	6	8
49	p.9.3	16.680000	2	0.055565	2	5.755396	1.042500	2	19.807500	20.000000	3	5025.000	0	20	0	1.599000e-001	6	8
50	p.9.4	23.910000	2	0.079650	2	4.015056	1.494375	2	28.393125	28.000000	3	2028.000	0	20	0	1.599000e-001	6	8
51	p.13.1	3.130000	3	0.010427	3	46.006390	0.130417	1	2.477917	2.000000	6	4230.000	0	20	0	1.599000e-001	6	8
52	p.13.2	3.000000	3	0.009994	3	48.000000	0.125000	1	2.375000	2.000000	6	628.000	0	20	0	1.599000e-001	6	8
53	p.17.6	6.000000	3	0.019987	3	24.000000	0.250000	1	4.750000	5.000000	10	2750.000	0	20	0	1.599000e-001	6	8
54	p.8.3	18.750000	3	0.062461	3	7.680000	0.781250	1	14.843750	15.000000	3	3375.000	0	20	0	1.599000e-001	6	8
55	p.10.1	23.910000	3	0.079650	3	6.022585	0.996250	1	18.928750	19.000000	3	4781.000	0	20	0	1.599000e-001	6	8
56	p.10.2	19.910000	3	0.066325	3	7.232546	0.829583	1	15.762083	16.000000	3	3982.000	0	20	0	1.599000e-001	6	8
57	p.11.1	4.570000	2	0.015224	2	21.006565	0.285625	1	5.426875	5.000000	6	1350.000	0	20	0	1.599000e-001	6	8
58	p.14.1	12.000000	3	0.039975	3	12.000000	0.500000	1	9.500000	10.000000	7	1680.000	0	20	0	1.599000e-001	6	8
59	p.14.2	4.000000	3	0.013325	3	36.000000	0.166667	1	3.166667	3.000000	5	400.000	0	20	0	1.599000e-001	6	8
60	p.15.3	6.320000	3	0.021053	3	22.784810	0.263333	1	5.003333	5.000000	8	959.000	0	20	0	1.599000e-001	6	8
61	p.15.6	4.290000	3	0.014291	3	33.566434	0.178750	1	3.396250	3.000000	8	651.000	0	20	0	1.599000e-001	6	8
62	p.17.3	6.320000	3	0.021053	3	22.784810	0.263333	1	5.003333	5.000000	9	2740.000	0	20	0	1.599000e-001	6	8
63	p.11.2	17.780000	2	0.059230	2	5.399325	1.111250	2	21.113750	21.000000	3	7920.000	0	20	0	1.599000e-001	6	8
64	p.11.3	23.330000	2	0.077718	2	4.114874	1.458125	2	27.704375	28.000000	3	11375.000	0	20	0	1.599000e-001	6	8
65	p.17.5	4.290000	3	0.014291	3	33.566434	0.178750	1	3.396250	3.000000	6	1860.000	0	20	0	1.599000e-001	6	8
66	p.10.3	21.330000	3	0.071056	3	6.751055	0.888750	1	16.886250	17.000000	10	3000.000	0	20	0	1.599000e-001	6	8
67	p.18	10.670000	2	0.035544	2	8.997188	0.666875	1	12.670625	13.000000	3	600.000	0	20	0	1.599000e-001	6	8

\>>

Start

OVR

Figure 36: Line of Balance Table In Matlab

The next step is clicking on Run Icon once more in other Editor window in order to drawing Line of Balance diagram which is appears automatically such as given in figure 37.

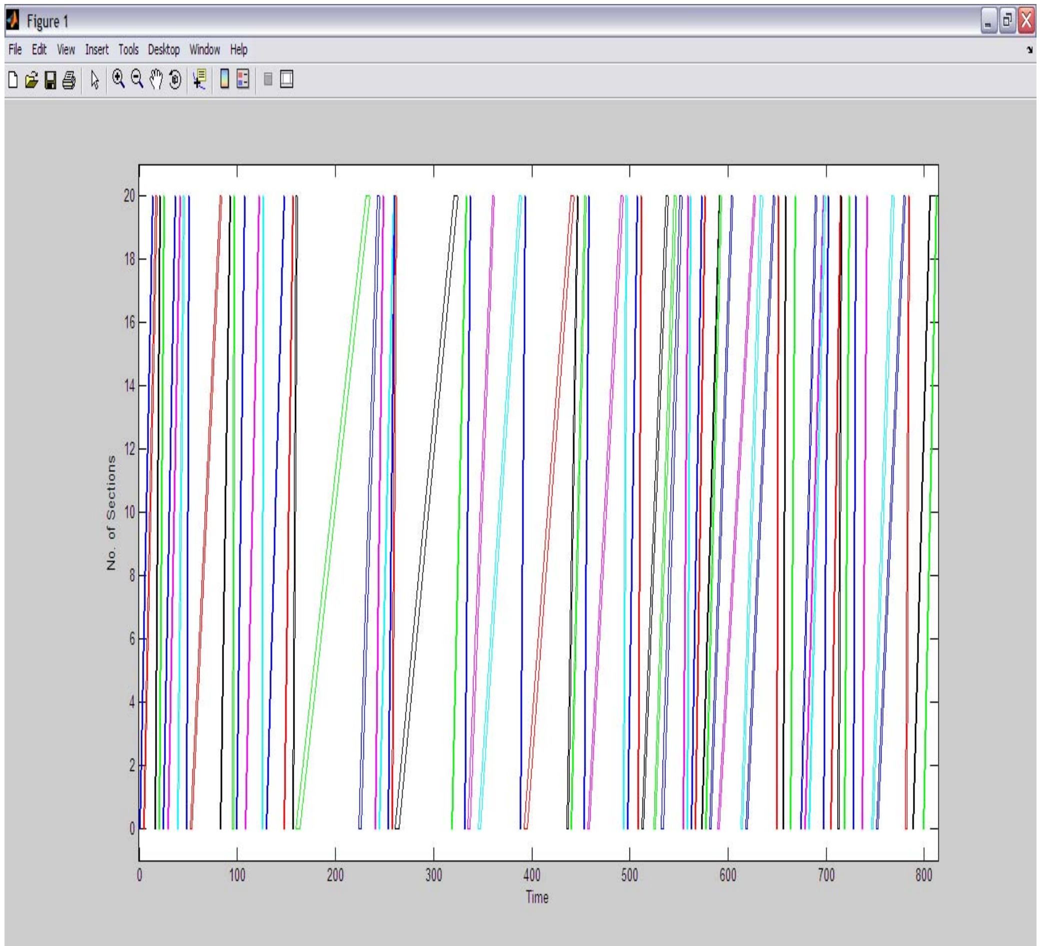


Figure 37: Line of Balance Diagram in Matlab

The Line of Balance diagram is consisting of two axes which are No. of Sections in Vertical direction and Time in Days in Horizontal direction. As it is appeared in the figure 37 the number of sections is twenty and the time is 813 which is the total project duration. Furthermore, in order to understanding that which incline line represents which activity, the name of activity or activity number or ID can be easily written for each activity in the figure. Moreover, in the Matlab program each 2 or 3 activities can be shown in a bigger size figure which helps to show the Line of

Balance figure of activities with their name written on it in a readable format. The exact duration of project will appear in the next step.

5.3.3 Cash Flow Diagramming By Using the Developed Program

Financial statement (or financial report) is a formal record of the financial activities of a business. The objective of financial statements is to provide information about the financial position, performance and changes in financial position of an enterprise that is useful to a wide range of users in making economic decisions. Financial statements should be understandable, relevant, reliable and comparable. Owners and managers require financial statements to make important business decisions that affect its continued operations. Cash flow is very meaningful for most of the contractors, who are sensitive to the issues of cash flow. Financial statement (or financial report) is a formal record of the financial activities of a business. The objective of financial statements is to provide information about the financial position, performance and changes in financial position of an enterprise that is useful to a wide range of users in making economic decisions. Financial statements should be understandable, relevant, reliable and comparable. Owners and managers require financial statements to make important business decisions that affect its continued operations. Cash flow is very meaningful for most of the contractors, who are sensitive to the issues of cash flow.

Sometimes the managers or contractors require checking the financial statement in every month. Therefore, in this program they just need to enter the exact date that they would like to obtain their cash flow statement and the program will prepare the daily, weekly or monthly and cumulative cash flow diagrams and values automatically. Moreover, as it has been discussed in previous chapter, controlling the project that can be achieved easily in the program is an important factor for contractor or project manager in order to compare the actual expenditure with the planned one. The contractor needs to prepare the planned monetary diagram before the starting date of the project and determine the actual one as the project progress. In this case, in any period of time or project phase, the user can obtain the project Line of Balance, cash flow or S Curve diagram and compare it with the planned one.

After drawing the Line of Balance diagram, in the command window the next question will appear which is asking as it is shown in figure 38:

Enter the Date to draw the CashFlow before it =900

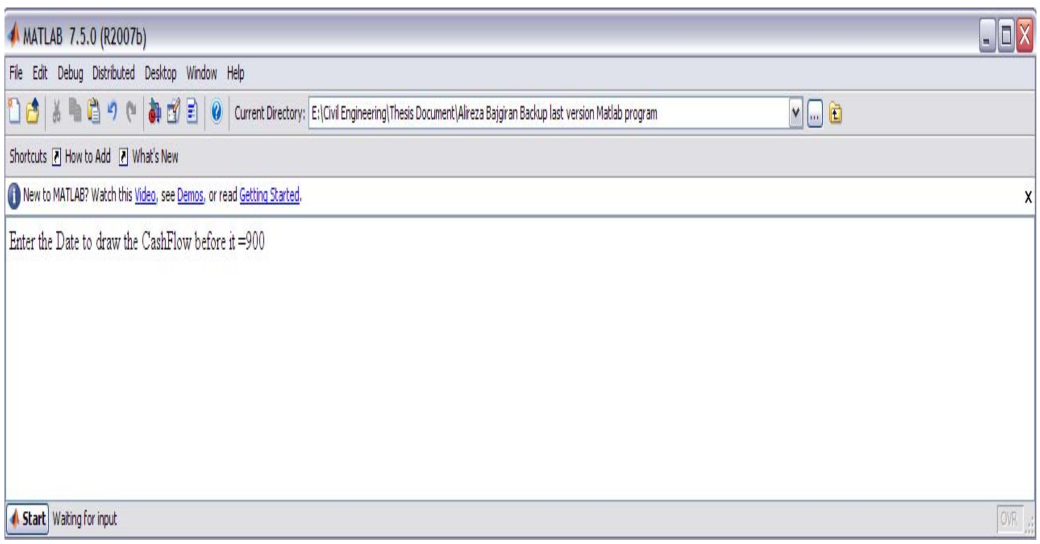


Figure 38: Question Related To Calculating Cash Flow

Note that any number can be entered to the program in order to prepare cash flow diagram according to the contractors' demand, therefore the 900 days is chosen as an example here.

In this step the program is ready to prepare financial statement according to the project manager or contractor demands. For instance by entering the number 900, the program starts to prepare Cash Flow diagram for the first 900 days of project.

Cash flow statement can be provided in different Daily, Weekly and Monthly manner. Consequently, after entering the date in the previous question, the next question will appear as it is shown in figure 39, is:

Enter your choice for CashFlow

Press d/D for daily choice

Press w/W for weekly choice

Press m/M for monthly choice

Choice is = W

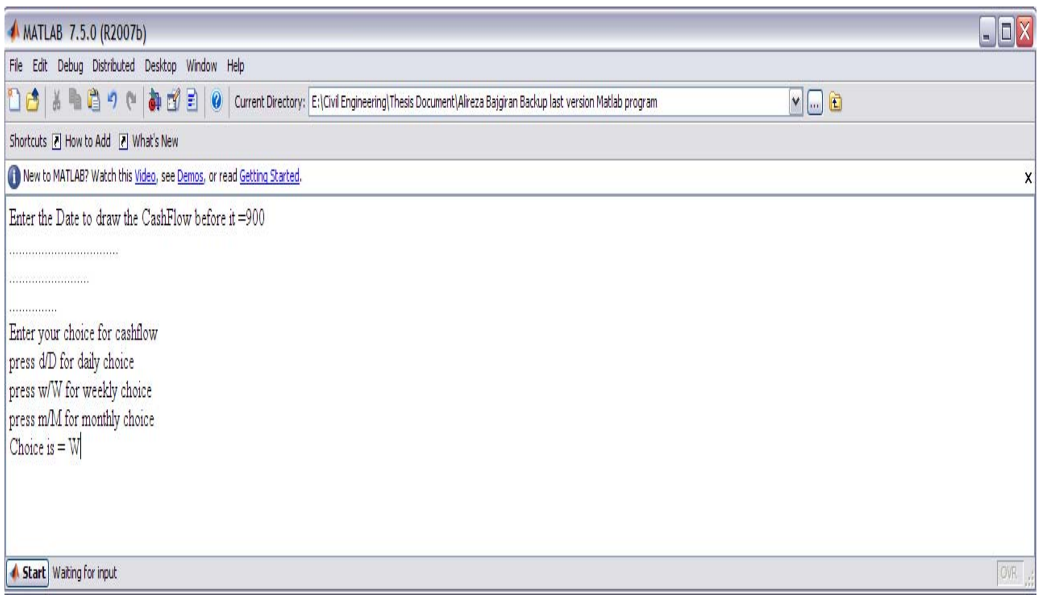


Figure 39: Entering Time Scale for Preparing Cash Flow

In order to have Cash Flow diagram in Daily, the initial letter of Daily word which is D should be entered, for Weekly, the letter W and for Monthly the letter M needs to be entered.

After entering the initial letter as it is illustrated in figure 40, the entire project duration will appear which is 813 working days in this study.

End of Project = 813 days

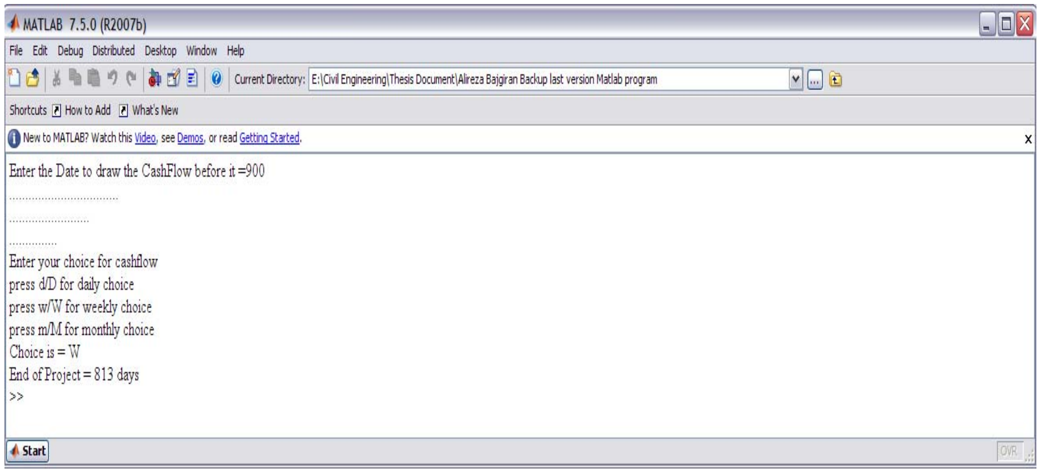


Figure 40: End of Project Date

At the same time in another window the cumulative cash flow diagram will appear which is in based on weekly manner as it was selected in the previous question as shown in figure 41.

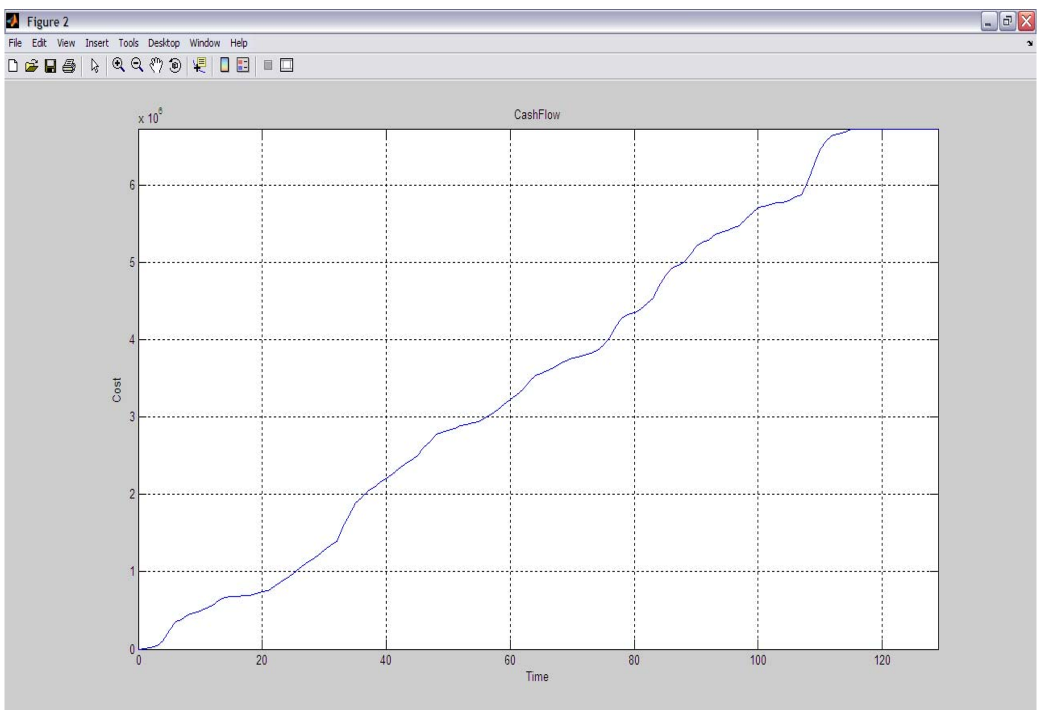


Figure 41: Weekly Cash Flow Diagram In Matlab

Note that since the weekly step was selected, the values in horizontal axis or time section will present in weekly scale.

In order to prepare cash flow diagram in any other period of time, the program has to be run again from Run Icon on Editor Window so the question “Enter the Date to draw the CashFlow before it”, will appear.

The cash flow diagrams in Daily and Monthly based are shown in figures 42 and 43:

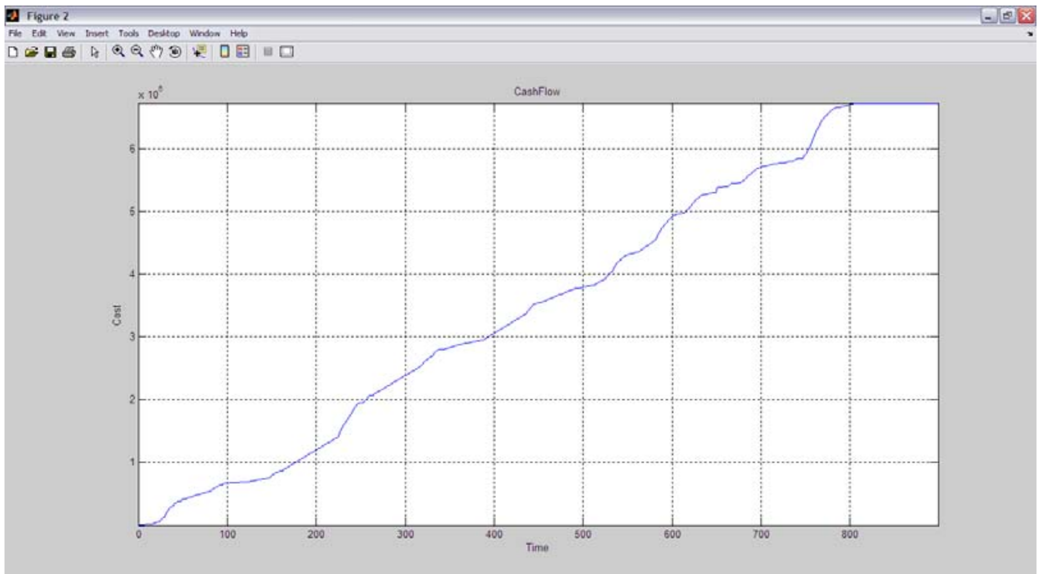


Figure 42: Daily Cash Flow Diagram

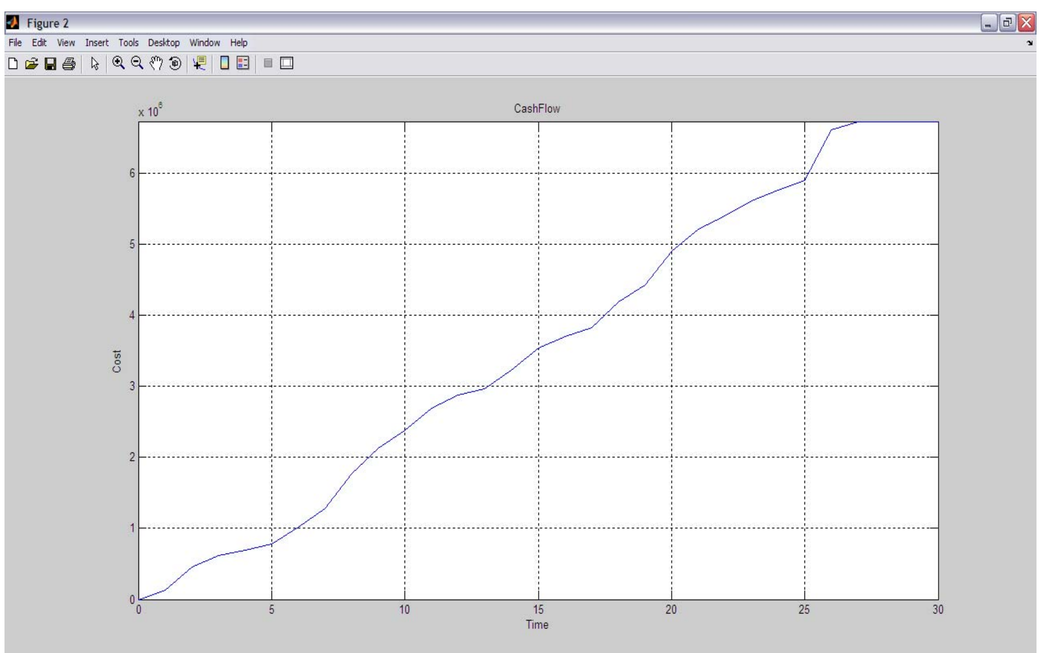


Figure 43: Monthly Cash Flow Diagram

For example if the entered date is 367 days which is counted from starting date of project the cash flow diagram will appear such as figures 44 and 45:

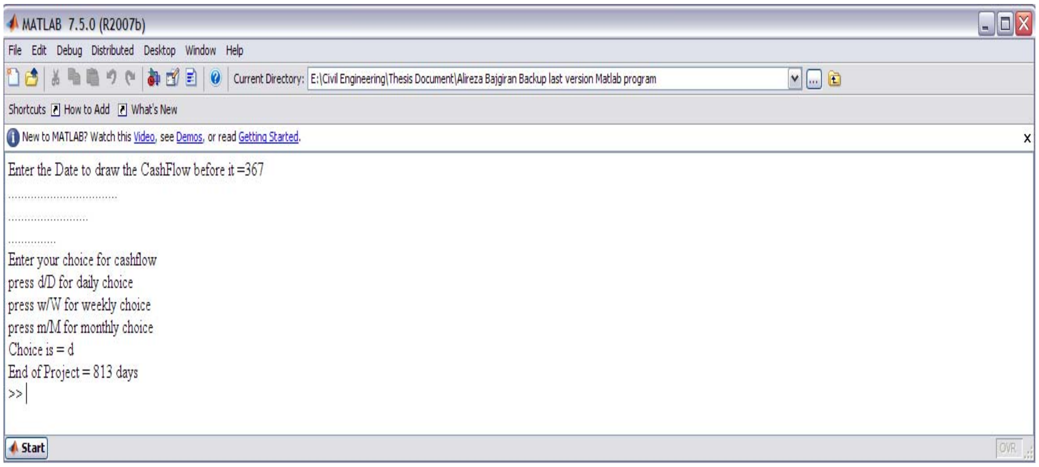


Figure 44: Cash Flow Diagram Question In 367 Days

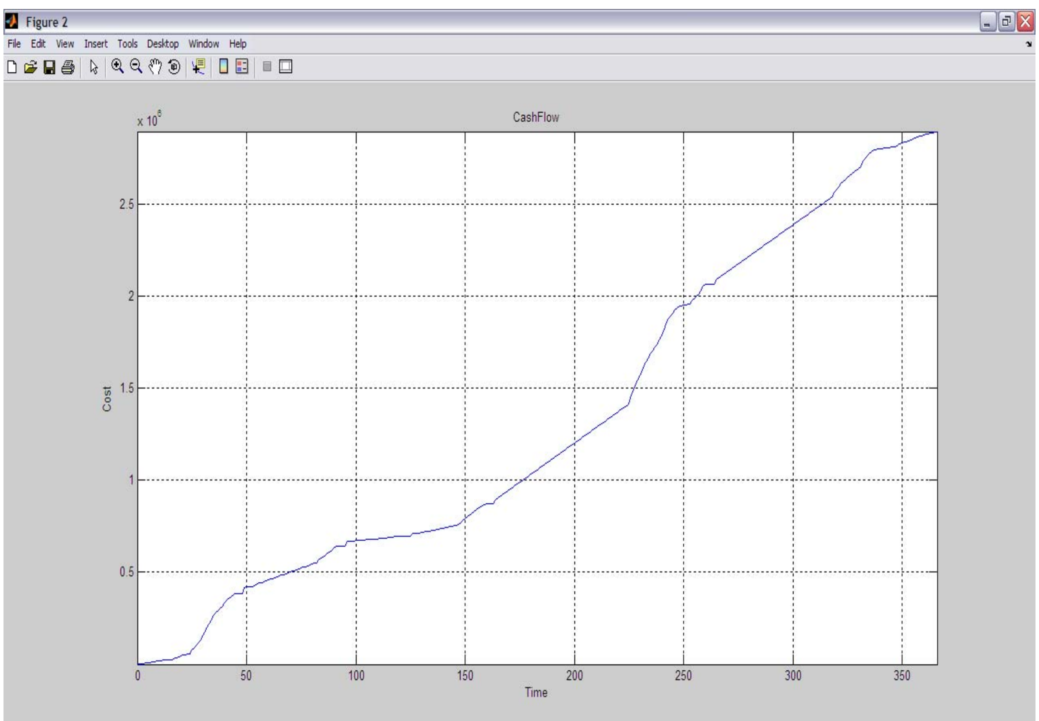


Figure 45: Cash Flow Diagram For 367 Days

For obtaining the exact values of cash flow diagram, the word “CashFlow” should be written in Command Window of Matlab and the program will automatically present the Cash Flow values as shown in figure 46:

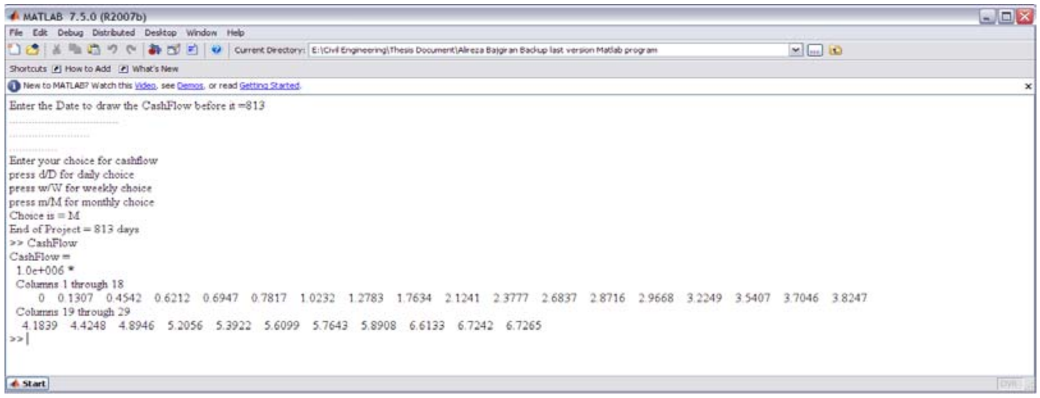


Figure 46: Cash Flow Values

Remember that the cash flow values are prepared according to the option of time scale that it was entered already, for example in the figure 46,since the period of time is Monthly, the cash flow values is appeared in monthly step, therefore it shows only twenty nine values which are the total twenty nine month of project duration.

Furthermore, the program has another advantage in preparing cash flow diagram that it can shows the Cumulative and monthly or weekly expenditure in the same graph and the exact values of cash flow diagram could be shown on the graph in figure 47:

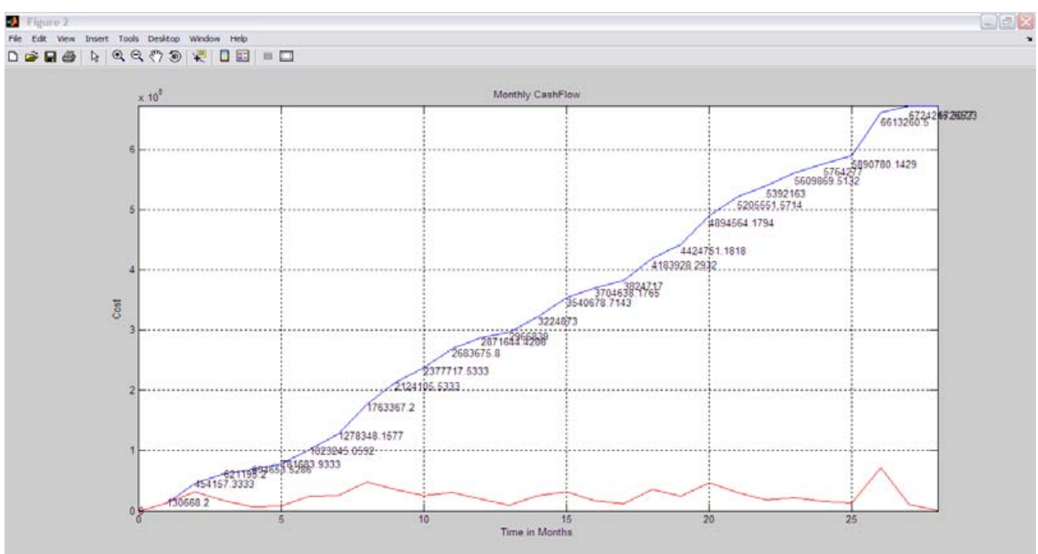


Figure 47: Cumulative and Monthly Expenditure Diagram

5.4 Application of Line of Balance on a Case Study Project

This study is carried out by collecting the initial data from a villa project in North Cyprus.

In order to carry out this study, following steps were taken:

1. Collecting initial data and necessary drawing plans for a villa project which is planned to be implemented in North Cyprus by Noyanlar Construction Company in Bogaz, Famagusta.
2. Preparing the bill of quantity table. Defining the activities regarding the project and preparing the work break down structure and cost tables.
3. Interviewing with engineers and contractors in North Cyprus in order to collect the latest unit price list which cannot be found in the unit price table published by Planning and Construction Department of Government of TRNC.
4. Indicating the resources and the crew types, their productivity output that can help us to obtain our activity duration by dividing the total quantity of each work by the daily productivity output of resources.
5. Preparing a Bar chart and a Network diagram by using Microsoft Project program in order to determine the project duration for a villa project.
6. Completing the Line of balance table and providing data requirements for developing line of balance technique. Line of Balance table is prepared by Microsoft Excel program as well in order to compare the results obtained from Matlab Package.
7. Entering the initial Line of Balance data obtained above into the developed computer program, completing the Line of Balance table and drawing Line of Balance graphs.

8. Calculating and drawing the cash flow diagram by this software. Cash flow diagram or S curve represents the time in the X-axis and cost in the Y-axis. Cash flow diagram is needed to calculate the financial statement of projects which is vital for contractors and owners of the project. Cash flow diagram can be drawn in daily, weekly and monthly time scales.

5.4.1 Introduction to Project Case Study

This study concerns the application of developed computer program on Line of Balance to a Villa project. The Villa project consists of 20 Villa construction by Noyanlar Construction Company in North Cyprus. The Villas were to be constructed in Bogaz area where is approximately 30 Km from Famagusta city.

It assumed that the construction will start on 03/02/2009 and the required duration is 1000 days.

The Architectural and Structural plans of the project used in case study was given in Appendix A.

5.4.2 Bill of Quantities of the Villa Project

The primary goal of Bill of is to define the quantity of work to be done in each type of activity of the project. Its purpose is to accurately determine the quantity of work that needs to be performed on the project. In essence, every item is measured and quantified as accurate as possible from drawing and plans. Moreover, the Bill of quantities separates the work items into units of labor, material, and equipment in order to calculate the amount of the work to be done. (Celik, 2008)

The second step in the case study is preparing project's Bill of Quantity. In the Bill of Quantity every item is measured and quantified as accurate as possible from its drawing and plans. Quantity of each activity and its description and appropriate unit of work has prepared.

The finalized Bill of Quantities are given in Appendix B.

5.4.3 Productivity Analysis

Productivity is a term that commonly associated with labor effectiveness in industry. However in a broad sense it is the ratio of output to some or all of the resources used to produce the output. Labor productivity may be defined as “output per unit time” or “output per unit labor hour”. Productivity is the rate of production which in general terms it can be, and is defined as output divided by input. “Productivity = output / input”. (Evre, 2002)

Labor productivity can be defined as the rate at which tasks are produced, especially the output per unit of labor. The goal in managing construction tasks is to produce the optimum output per labor hour. (Evre, 2002)

The difficulties of establishing productivity levels and comparing on-site productivity with established values are compounded by the existence of a large number of influencing factors with no particular limit – in other words, everything affects productivity. Some of the factors that influencing productivity is as follows: (Evre, 2002)

1. Nature of the industry
2. Impact of changes
3. The construction client
4. Environmental factors
5. Level of economic development
6. Management
7. Technology
8. Labor
9. Unions

Activity duration estimation is the process of taking information on project scope and resources and then developing durations for input to schedules. Duration includes the actual amount of time worked on an activity plus elapsed time. Furthermore, activity duration is the amount of time assigned to complete a particular activity. In addition, activity duration is expressed in terms minutes, hours, work days, or work weeks. (N.Mohamed, 2007)

After preparing Bill of Quantity analysis, the Work Break Down Structure and Activity Sequences were prepared. Productivity analysis has a fundamental role in preparing an accurate Work Break Down Structure, due to obtaining the project activities duration based on determination of the resources and their daily output. Thus, Activity duration could be determined easily by dividing activities Quantity over Resources Daily output.

Experts, construction engineers and expert construction contractors were interviewed in order to define the resources and obtaining their productivities. Meanwhile some data were taken from Mr. Mert Evre's Master Thesis (Evre, 2002), which use an effective study in Productivity and resources analysis in North Cyprus.

All the collected information for the crews, which were number of skilled and unskilled workers, type and the number of equipments, tools and machine and a proper coding system were assigned for each activity. Coding system is one of the most important aspects, which prevents any confusion within the chosen activities. Moreover, coding system is a vital factor for the studies which required identification of many items within the project. (Evre, 2002)

The coding system selected for this study contains letters and numbers which can prevent any confusion that might occur in the future while adding or deleting any item in resources table.

As it is mentioned already, after defining appropriate coding system and resources, next step is determining duration, daily total labor hours etc. of each activity which is explained hereby with an example from the study. The crew tables are given in Appendix C & D.

- Activity Description: ***External Painting***
- Activity ID: ***P.10.3***
- Crew Content:
  - *2 Painters*
  - *4 Buckets*
  - *1 Helper*
  - *2 Spatulas*
  - *2 Roller brushes*
  - *1 Spool (reel) System*
  - *2 Brushes*
- Crew Code: ***PA02***
- Unit: *m²*
- Quantity of job: 375 m²
- Daily Output: 105.50 m²
- Activity Duration (days): $\frac{\text{Quantity}}{\text{Daily Output}} = \frac{375}{105.50} = 3.55$
- Activity Duration (upper rounded number): 4
- Working hours per day: 8
- Men per Activity (no of men in one team): 3
- Daily Total labor hours: Labor hours=Men per activity $\times$ 8hr per day: $3 \times 8 = 24$
- Number of gang: 4

- ❖ Total Daily Output: Daily output $\times$ number of gang= $105.50 \times 4 = 422$
- ❖ Required day job for whole gangs: $\frac{\text{Quantity}}{\text{Total daily Output}} = \frac{375}{422} = 0.89$
- ❖ Man hours per activity: Required day job for whole gangs $\times$ Daily Total labor hour= $0.89 \times 24 = 21.33$

Note that following definitions and their values are obtained from the mentioned sources or collected by conducting interviews with construction firms and contractors:

- Crew Content
- Daily Output
- Men per Activity (no of men in one team)
- Number of gangs

5.4.4 Work Break Down Structure and Activity Sequences

A work break down structure (WBS) is a foundation document in project management which is an outcome guided analysis of the work involved in a project that defines the total scope of the project. WBS defines the sequence and duration of tasks that must be done to complete the project on time and within the cost guidelines established. The primary purpose of the WBS is to sub-divide the scope of work into manageable work packages which can be estimated, planned and assigned to a responsible person or department for completion. Moreover WBS provides the basis for planning and managing project schedules, costs, and changes. (Celik, 2009)

Activity definition involves identifying and documenting the specific activities that must be performed in order to produce the deliverables and sub-deliverables identified in the work break down structure. (N.Mohamed, 2007)

After defining activities and determining their sequence, the next step in time management is duration estimating.

Activity sequencing involves identifying and documenting interactivity logical relationships. Activities must be sequenced accurately in order to support later development of a realistic and achievable schedule.

One of the main steps in activity sequencing is defining the relationship and the buffer time between activities. In this study as it is already mentioned, the activity sequencing and their relationship type are defined by collecting information about the activities in construction from contractors and expert construction engineers or by discussing the issue with my supervisor Prof. Dr. Tahir Celik.

Although there are different types of activity relationships, in this study the relationship types between activities are used Finish to Start, Buffer time is also defined for activities. The sequences table is given in Appendix E.

5.4.5 Cost Calculation of Villa Project

Costing is a generic term for a process which results in the establishment of the cost of carrying out parts of a larger project or the definition of those costs related to a particular item of production or overhead. Furthermore, costing process consists of recording all those expenditures which are related to specific items of work in such a way that the cost of that work, in convenient form, can readily be identified. (Pilcher, 1994)

One of the important aspects of project cost management is a cost estimate. Cost estimating involves collecting, analyzing, and summarizing all available data in connection to a project that begins in the very early stages of project and ends when the project is turned over to the owner. (Celik, 2008)

Moreover, cost estimating is the process of analyzing a specific scope of work and predicting the cost of performing the work. The accuracy of the estimate is a function of how well the specific scope of work is defined and the time available to the estimator. The basic challenges the construction contractor faces are to estimate the costs of constructing a project, schedule the specific construction activities, and then build the project within the estimated cost and schedule. Therefore, cost estimating and cost control skills are essential if the construction contractor is to build a project profitably. (Holm, Schaufelberger, Griffin, & Cole, 2005)

As it has been discussed already, costing is a vital process for all parties in a construction project. The next step after preparing work break down structure is costing. In order to carry out the costing process, the first step is to collect unit prices list which gives the unit prices list of material, labor for construction activities. In this study the unit prices list of work which is published by Planning and Construction Department of Government in North Cyprus was used. Furthermore, to find all the necessary information about the items that is not available in the list, an interview was conducted with engineers or contractors who are involved in construction sector in North Cyprus.

For each activity, the quantity of job was calculated in Bill of quantity section, then it was multiplied by the unit price of each activity and the total cost per activity was determined. The unit price list was in Turkish Lira therefore the total cost of project was calculated in Turkish Lira. Moreover, for each section of job such as, Earth work, Concreting or Mechanical works etc. the percentage of the cost was compared with the total construction cost. In this way, contractor will have a cost wise feeling about each section of work.

The Cost analysis table was given in Appendix F.

5.4.6 Microsoft Project (MS) Scheduling

The Microsoft Project product family is designed to facilitate the aims, intentions, and success of project teams. In addition, MS Project meets the diverse requirement of project management. MS Project provides the core project management tools for scheduling tasks, assigning resources, tracking project progress, and reporting on project status. In addition, it enables users to quickly develop projects using guides and wizards. MS Project is targeted at planners and business managers who need to create and manage project information efficiently and who need to communicate the status of a project to team members and stakeholders on a regular basis.

MS Project provides many views to meet your information requirements. This allows you to display project information with emphasis on different project elements, such as task or resource usage, calendars, Gantt charts, or network diagrams.

In this study, in order to obtain the project duration, Microsoft Project 2007 is used and the Gant Chart and Network Diagram are provided. The network diagram was also used in developing Line of Balance graphs.

The reports of MS project were given in Appendix G.

5.4.7 Preparing Line of Balance Table for the Case Study Project

The development of a linear schedule for a project is similar to any other scheduling process. The first three steps, familiar to most schedulers, are:

1. Identify activities.
2. Estimate activity production rates.
3. Develop activity sequences.

Prior to programming Line of Balance in Matlab package, the initial step in Line of Balance is to prepare the entering data table. Line of Balance table is shown in Figure 2. In preparing a Line of Balance table, there are some factors need to be provided. There are obtained by estimators or by some preliminary calculations and discussion with contractors or construction managers. In Chapter two, it was described how to prepare Line of Balance scheduling table; however, by presenting an example from the case study project, the procedure was explained in detail in below:

- ❖ Activity number: 9

Activity number is derived from sequencing table.

- ❖ Activity ID: P.3.1

Activity ID is defined in the first steps by preparing Bill of Quantity and Work Break Down Structure Table.

- ❖ Activity description: Formwork Ground Beam

Activity Description is derived from the same tables with activity ID.

- ❖ Total Number of activities: 67

Number of activities is derived from Bill of Quantity table and Work Break Down Structure after defining the entire activities and count them.

- ❖ Number of sections or houses: 20

Number of houses or sections in defined in initial step when we select a project as case study.

- ❖ Unit of activity: m^2

Unit of activity is derived from Bill of Quantity table.

- ❖ Crew code: FW01 A

Crew Code is derived from Productivity and Resource analysis.

- ❖ Quantity or amount of job for the activity: 168.70 (unit)

Quantity of work is derived from Bill of Quantity analysis.

- ❖ Activity Duration: 5 (days)

Activity Duration is obtained from Productivity and Resource analysis which is the duration of the activity for each housing unit.

- ❖ Working hours per day: 8 (hrs)

Working hours per day is an assumption in this study which is quite standard and ordinary hours of work per day in North Cyprus.

- ❖ Working days per week: 6 (days)

Working days per week is an assumption.

- ❖ Men per activity or number of men in one team: 5 (men)

Men per activity are derived from Resources and Productivity analysis which could vary from project to project. It is named as Operatives per activity or Men per house which is the optimum number of operatives for each activity or this is the number of operatives in one team. Furthermore it is a practical estimate of the number of men required to complete each activity for one housing unit. This is based on knowledge of the normal grouping of men in each trade (for example plumbers usually work in pairs and two masons usually with one laborer) adjusted as necessary to achieve the necessary total output. This figure is determined by the planner and senior managers or contractors.

- ❖ Minimum buffer time: 3 (days)

Minimum buffer time could be defined in Productivity analysis or by defining by project manager or contractor.

- ❖ Lag Time: 5 (days)

Lag time is derived in Activity Sequences table.

- ❖ Total Buffer: 8 (days)

Total buffer time that is needed for LOB table is obtained from:

Total Buffer Time = 3 + 5= 8 (days)

- ❖ Daily output: 35.20 (activity unit, here is m^2)

Daily output is derived from Productivity analysis.

- ❖ Daily Total labor hours: 40 (labor hours)

Daily total labor hours is obtained in Productivity analysis which can be determined by:

Daily total labor hours= Men number per activity× Number of hrs per day= $5 \times 8 = 40$

- ❖ Number of Gang: 3

Number of gang is derived from Productivity analysis.

- ❖ Total Output: 105.6 (unit labor hours)

Total output is determined in Productivity analysis which can be calculated by:

Daily output × No. of gang= $35.20 \times 3 = 105.6$

- ❖ Required day job for whole gangs: 1.5975 (days)

Required day job for entire gangs is derived from Productivity analysis and can be determined by:

Required day job for entire gangs= Quantity÷ Total output

$= 168.70 \div 105.60 = 1.5975$

- ❖ Man-hours per activity: 63.9015 (hrs)

Man-hours per activity is derived from Resource and Productivity analysis which can be as follow:

Man-hours per activity= Required day job for whole gangs× Daily total labor hours = $1.60 \times 40 = 63.9015$

- ❖ Cost of Activity: 3,205.30 (TL)

Cost of activity is derived from cost analysis which can be calculated as follows:

Activity cost= Unit Price (TL/unit) × Quantity (unit) = 19.00 × 168.70= 3,205.30

- ❖ Project Duration for 1 unit (house): 287 days

Project duration for one house is derived in Microsoft Project.

- ❖ Total project duration for 20 sections (planned): 1000 days

Total project duration is a planned duration that is defined by project managers or contractor which is based on an assumption according to project activities and resources and rest of project's factors that has role in starting and completing date of a project.

- ❖ Target rate (R): 0.1599

Target rate is the rate of build or completion per week in this project, (1 week comprises six 8-hour days). Target rate is usually derived from an assumption which is based on senior managers, project planners or contractors, decisions which they believed to be the practical maximum rate on a project.

Target Rate (R) =

$$\frac{(number\ of\ sections\ or\ houses-1)}{\left(\frac{Total\ project\ duration}{Number\ of\ working\ days\ in\ a\ week}\right)-\left(\frac{Project\ duration\ for\ one\ house}{Number\ of\ working\ days\ in\ a\ week}\right)} =$$

$$\frac{(20-1)}{\left(\frac{1000}{6}\right)-\left(\frac{287}{6}\right)} = 0.1599$$

- ❖ Theoretical gang size: 0.2129 (labor)

Theoretical number of men required, is derived from :

Theoretical gang size= $\frac{Target\ rate\ (R) \times Man-hours\ per\ activity}{Working\ hrs\ in\ day \times Working\ day\ in\ week}$ =

$$\frac{0.1599 \times 63.9015}{8 \times 6} = 0.2129 \text{ (labor)}$$

- ❖ Actual gang size: 5.0 (labor)

It would be chosen as a number, which would be a multiple of the operatives required for one team near to the theoretical gang size. If the actual gang size is greater than the theoretical gang size, the rate of output will be more than the target rate, if the actual is less than the theoretical, the actual rate of output will be less than the target rate.

- Actual rate of output: 3.7558

Actual rate of output is the calculation for the adjusted, actual number of men to be used. It is obtained as follows:

Actual rate of output= $\frac{(\text{Actual gang size}\times\text{Target rate (R)})}{\text{Theoretical gang size}} = \frac{(5\times 0.1599)}{0.2129}$

=3.7558

- Time in days for one activity: 1.5975 (days)

Time in days for one activity, is the time required for each trade to complete its work on one unit. It is calculated as follow:

Time in days for one activity

$= \frac{Man\text{−}hours\ per\ activity}{\text{Men per activity or number of men in one team}\times\text{Working hrs in day}} =$

$\frac{63.9015}{5\times 8} =$1.5975

- Time from start of the first section to start of the last section: 30.3532

It is the time required from the start of the first activity of the first house to the start of the first activity of the last house. This calculation is necessary to determine the slope of the line of balance for each activity.

Time from start of the first section to start of the last section=

$\frac{(\text{Number of sections-1})\times\text{number of working days per week}}{\text{Actual rate of output}} = \frac{(20-1)\times 6}{3.7558} =$ 30.3532

- ❖ Starting section: 1

Starting section for the entire activities in this study is one.

- ❖ Ending section: 21

Ending section is follow the same role and reason like Starting section and for entire activities is 21.

- ❖ Relaxation time: 0

Relaxation time is zero for the whole activities because as it was mentioned there is no discontinuity in the activities and if so, relaxation time is the period of time in days that one activity stopped and started again or it's the duration that one activity dose not implement.

The summaries of data are given below:

- Target rate (R): **0.1599**
- Working hrs in day: **8 (hrs)**
- Working day in week: **6 (days)**
- No of section(house): **20.0**
- Project Completion: **Tuesday 05/24/2010 5:00:00 PM**
- Project start day: **Monday 3/2/2009 8:00:00 AM**
- Project Duration for 1 house: **287 (days)**
- Total project duration for 20 sections (planned): **1000.0 (days)**

The line of balance table for case study project was completed as shown in Table 5. The calculations of table and filling the table are performed by the developed computer program and the Line of Balance table and its graphs are shown in figures 36 and 37. Obtaining the cash flow and drawing its diagrams for the case study were discussed already and the results were illustrated in figures 41, 42, 43, and 47.

Table 5: Line of Balance Table

No.	Activity ID	Description of work	Unit	Quantity	Duration	crew code	Daily Output	Men per Activity (no of men in one team)	Daily Total labor hours(labor hrs=Men per activity*8hr per day)	No. of Gang	Total Output (daily output*no of gang)	Required day job for whole gangs	Man-hours per activity	Theoretical gang size	Actual gang size	Actual rate of output	Time in days for one activity	Time from start on first section to start on last section	Buffer time (B)	Lag Time	Total Buffer	Cost of Activity
1	P.1.1	Site Layout, Installation, Marking	m2	302	3	EX01 A	150	2	16	3	450	0.67	10.73	0.036	2	8.94	0.67	12.75	0	0	0	1,000.0
2	P.1.2	Cleaning and leveling	m3	73	3	EX01 B	35	2	16	3	105	0.69	11.12	0.03	2	8.63	0.70	13.21	3	0	3	292.0
3	P.2.1	Excavation footing by hand and excavator	m3	44.3	1	EX02	52	2	16	3	156	0.28	4.54	0.015	2	21.13	0.28	5.39	3	0	3	1,195.8
4	P.2.2	Laying sand on footing's base	m3	13.5	1	EX03	17.1	3	24	3	51.3	0.26	6.32	0.021	3	22.78	0.26	5.00	3	0	3	445.83
5	P.7.1	Foundation insulation	m2	231	2	IS01 A	120	3	24	3	360	0.64	15.4	0.051	3	9.35	0.64	12.19	3	1	4	7,854.0

6	P.4.1	Plain Concrete for footing	m3	54	2	CO01	43.9	9	72	2	87.8	0.61	44.28	0.14	9	9.76	0.62	11.69	3	0	3	5,508.0
7	P.5.1	Reinforcement for spread footings	tons	1.3	1	ST01	1.3	2	16	3	3.96	0.32	5.17	0.017	2	18.56	0.32	6.14	3	5	8	2,918.4
8	P.4.2	Concreting for Foundation	m3	18.0	1	CO02	96.8	8	64	2	193.6	0.093	5.95	0.02	8	64.53	0.09	1.77	3	0	3	1,998.0
9	P.3.1	Formwork Ground beam	m2	168.7	5	FW01 A	35.2	5	40	3	105.6	1.59	63.902	0.213	5	3.76	1.60	30.35	3	5	8	3,205.3
10	P.5.2	Reinforcement for Ground beam	tons	2.0	2	ST01	1.3	2	16	3	3.96	0.508	8.12	0.027	2	11.82	0.51	9.64	3	0	3	4,582.8
11	P.4.3	Concreting for Ground beam	m3	12.3	1	CO02	96.8	8	64	2	193.6	0.063	4.06	0.014	8	94.52	0.06	1.21	3	0	3	1,364.1
12	P.2.3	Back filing material	m3	32.6	2	EX05	25.2	3	24	3	75.6	0.43	10.35	0.035	3	13.9	0.43	8.20	3	5	8	358.93
13	P.2.4	Compacted soil	m3	32.6	3	EX06	15.1	5	40	3	45.3	0.72	28.81	0.096	5	8.33	0.72	13.69	3	0	3	978.9
14	P.2.5	Laying Hardcore	m3	18.3	1	EX04	130.2	7	56	2	260.4	0.07	3.93	0.013	7	85.38	0.07	1.34	3	0	3	640.5
15	P.3.2	Formwork for ground floor Columns	m2	122.5	3	FW01 B	43	5	40	3	129	0.94	37.96	0.12	5	6.32	0.95	18.04	3	5	8	2,326.5
16	P.5.3	Reinforcement for ground floor Columns	tons	1.9	2	ST01	1.3	2	16	3	3.96	0.48	7.71	0.026	2	12.44	0.48	9.16	3	0	3	4,354.8

17	P.4.4	Concreting for ground floor columns	m3	11.5	1	CO03	26.7	10	80	2	53.4	0.21	17.27	0.058	10	27.79	0.22	4.10	3	0	3	1,279.8
18	P.3.3	Formwork for ground floor Slab	m2	397.2	12	FW01 C	35.2	5	40	3	105.6	3.76	150.45	0.501	5	1.6	3.76	71.47	3	5	8	7,546.8
19	P.5.4	Reinforcement for ground floor Slab	tons	4.0	4	ST01	1.3	2	16	3	3.96	1.01	16.24	0.054	2	5.91	1.02	19.29	3	0	3	9,165.6
20	P.4.5	Concreting for ground floor slab	m3	42	1	CO04	52.3	12	96	2	104.6	0.40	38.51	0.12	12	14.95	0.40	7.62	3	0	3	4,658.6
21	P.3.4	Formwork for 1st floor columns	m2	102.5	3	FW01 D	43	5	40	3	129	0.79	31.78	0.106	5	7.55	0.79	15.1	3	5	8	1,947.5
22	P.5.5	Reinforcement for 1st floor columns	tons	1.5	2	ST01	1.3	2	16	3	3.96	0.38	6.101	0.02	2	15.74	0.38	7.24	3	0	3	3,442.8
23	P.4.6	Concreting for 1st floor columns	m3	10.5	1	CO03	26.7	10	80	2	53.4	0.19	15.79	0.053	10	30.4	0.20	3.75	3	0	3	1,169.9
24	P.3.5	Formwork for 1st floor slab	m2	333.7	10	FW01 E	35.2	5	40	3	105.6	3.16	126.402	0.42	5	1.9	3.16	60.04	3	5	8	6,340.3
25	P.5.6	Reinforcement for 1st floor Slab	tons	3.2	3	ST01	1.3	2	16	3	3.96	0.806	12.88	0.043	2	7.45	0.81	15.31	3	0	3	7,273.2
26	P.4.7	Concreting for 1st floor slab	m3	33.0	1	CO04	52.3	12	96	2	104.6	0.31	30.26	0.101	12	19.03	0.32	5.99	3	0	3	3,660.7
27	P.16.1	Septic tank	pcs	1.0	4	SW01 A	0.3	4	32	3	0.75	1.33	42.66	0.14	4	4.5	1.33	25.33	3	5	8	1,100.0
28	P.16.2	Well construction	pcs	1.0	7	SW01 B	0.2	4	32	3	0.45	2.22	71.11	0.23	4	2.7	2.22	42.22	3	0	3	2,000.0

29	P.16.3	Sewage, Mechanical plumbing work	m2	230	1	ME01 A	230	3	24	4	920	0.25	6.0	0.02	3	24	0.25	4.75	3	0	3	2,001.0
30	P.6.1	Laying Bricks for ground floor wall construction	m2	173.6	11	WA01	17.2	2	16	4	68.6	2.53	40.49	0.13	2	2.37	2.53	48.08	3	0	3	6,944.0
31	P.17.1	Pumping system, Drainage	m2	230	2	ME01 B	115	3	24	4	460	0.5	12	0.04	3	12	0.50	9.50	3	0	3	4,600.0
32	P.17.2	Plumbing job for ground floor (Mechanical)	m2	137	4	ME01 C	45	3	24	4	180	0.76	18.26	0.06	3	7.88	0.76	14.46	3	0	3	2,740.0
33	P.15.1	Piping work for ground floor (Electrical)	m2	137	2	EL01	130	3	24	4	520	0.26	6.32	0.021	3	22.77	0.26	5.01	3	0	3	959.0
34	P.6.2	Laying Bricks for 1st floor wall construction	m2	122.8	8	WA01	17.2	2	16	4	68.6	1.79	28.64	0.095	2	3.35	1.79	34.02	3	0	3	4,913.2
35	P.6.3	Laying Bricks for roof wall construction	m2	11.3	1	WA01	17.2	2	16	4	68.6	0.16	2.63	0.009	2	36.42	0.16	3.13	3	0	3	350.3
36	P.17.4	Plumbing job for 1st floor (Mechanical)	m2	93	3	ME01 D	45	3	24	4	180	0.51	12.40	0.04	3	11.61	0.52	9.82	3	0	3	1,860.0
37	P.15.4	Piping work for 1st floor (Electrical)	m2	93	1	EL01	130	3	24	4	520	0.17	4.29	0.014	3	33.55	0.18	3.4	3	0	3	651.0

38	P.12.1	Roof Structure Work	m2	244	4	WO02	61	5	40	3	183	1.33	53.33	0.17	5	4.50	1.33	25.33	3	7	10	4,672.6
39	P.7.2	Wall and toilets, Kitchen insulation for ground floor	m2	116	4	IS01 B	35	3	24	3	105	1.10	26.51	0.088	3	5.43	1.1	20.99	3	3	6	3,944.0
40	P.7.3	Wall and toilets, Kitchen insulation for 1st floor	m2	106	4	IS01 C	35	3	24	3	105	1.01	24.22	0.081	3	5.94	1.01	19.18	3	3	6	3,604.0
41	P.15.2	Wiring work for ground floor (Electrical)	m2	137	2	EL01	130	3	24	4	520	0.26	6.32	0.021	3	22.77	0.26	5.01	3	0	3	959.0
42	P.15.5	Wiring work for 1st floor (Electrical)	m2	93	1	EL01	130	3	24	4	520	0.17	4.292	0.014	3	33.55	0.18	3.40	3	0	3	651.0
43	P.7.4	Roof Insulation	m2	244	2	IS01 D	135	3	24	3	405	0.60	14.45	0.048	3	9.96	0.6	11.45	3	0	3	4,636.0
44	P.12.2	Roof Tile	Pcs	780	2	TL01 B	390	2	16	4	1560	0.50	8.0	0.027	2	12	0.5	9.5	3	3	6	1,326.0
45	P.8.1	Plastering for ground floor internal walls, ceiling	m2	478.1	4	PI01 A	128.8	3	24	4	515.2	0.92	22.27	0.07	3	6.47	0.93	17.63	3	0	3	5,737.2
46	P.8.2	Plastering for 1st floor internal walls, Ceiling	m2	398.2	4	PI01 B	128.8	3	24	4	515.2	0.77	18.55	0.062	3	7.76	0.77	14.69	3	0	3	4,778.4

47	P.9.1	Floor Tiling for ground floor	m2	112.5	5	TL01 A	24.1	2	16	4	96.4	1.16	18.67	0.06	2	5.14	1.17	22.17	3	3	6	5,625.0
48	P.9.2	Wall, toilets, kitchen Tiling for ground floor	m2	68	8	TL02	8.7	2	16	4	34.8	1.95	31.26	0.10	2	3.07	1.95	37.13	3	2	5	2,652.0
49	P.9.3	Floor Tiling for 1st floor	m2	100.5	5	TL01 A	24.1	2	16	4	96.4	1.04	16.68	0.056	2	5.76	1.04	19.81	3	0	3	5,025.0
50	P.9.4	Wall, toilets, kitchen Tiling for 1st floor	m2	52	6	TL02	8.7	2	16	4	34.8	1.49	23.90	0.08	2	4.02	1.49	28.39	3	0	3	2,028.0
51	P.13.1	Windows (Aluminum)	pcs	18	1	AL01 A	34.5	3	24	4	138	0.13	3.13	0.01	3	46	0.13	2.48	3	3	6	4,230.0
52	P.13.2	Doors (Aluminum)	pcs	2	1	AL01 B	4	3	24	4	16	0.12	3	0.01	3	48	0.13	2.38	3	3	6	628.0
53	P.17.6	Solar system	pcs	1	1	ME01 G	1	3	24	4	4	0.25	6	0.02	3	24	0.25	4.75	3	7	10	2,750.0
54	P.8.3	External Plastering	m2	375	4	PI01 C	120	3	24	4	480	0.78	18.75	0.06	3	7.68	0.78	14.84	3	0	3	3,375.0
55	P.10.1	Painting for ground floor internal area	m2	478.1	4	PA01	120	3	24	4	480	0.99	23.90	0.08	3	6.02	1.00	18.92	3	0	3	4,781.0
56	P.10.2	Painting for 1st floor internal area	m2	398.2	4	PA01	120	3	24	4	480	0.83	19.91	0.06	3	7.23	0.83	15.76	3	0	3	3,982.0
57	P.11.1	Doors (Carpentry work)	pcs	6	1	WO01 A	7	2	16	3	21	0.28	4.57	0.015	2	21	0.29	5.43	3	3	6	1,350.0

58	P.14.1	Bathroom(shower , WC) sanitary fitting work	pcs	3	2	SA01	2	3	24	3	6	0.5	12.0	0.04	3	12	0.5	9.5	3	4	7	1,680.0
59	P.14.2	Kitchen sanitary fitting work	pcs	1.0	1	SA01	2.0	3	24	3	6.0	0.16	4	0.013	3	36	0.17	3.17	3	2	5	400.0
60	P.15.3	Finishing electrical work for ground floor	m2	137	2	EL01	130	3	24	4	520	0.26	6.32	0.021	3	22.77	0.26	5.01	3	5	8	959.0
61	P.15.6	Finishing electrical work for 1st floor	m2	93	1	EL01	130	3	24	4	520	0.17	4.29	0.014	3	33.55	0.18	3.4	3	5	8	651.0
62	P.17.3	Finishing for ground floor (Mechanical)	m2	137	2	ME01 E	130	3	24	4	520	0.26	6.32	0.021	3	22.77	0.26	5.01	3	6	9	2,740.0
63	P.11.2	Cupboards (Carpentry work)	m	18	4	WO01 B	5.4	2	16	3	16.2	1.11	17.77	0.05	2	5.4	1.11	21.11	3	0	3	7,920.0
64	P.11.3	Wardrobes (Carpentry work)	m2	35	5	WO01 C	8	2	16	3	24	1.45	23.33	0.07	2	4.11	1.46	27.71	3	0	3	11,375.0
65	P.17.5	Finishing for 1st floor (Mechanical)	m2	93	1	ME01 F	130	3	24	4	520	0.17	4.29	0.014	3	33.55	0.18	3.40	3	3	6	1,860.0
66	P.10.3	External Painting	m2	375	4	PA02	105.5	3	24	4	422	0.88	21.32	0.071	3	6.75	0.89	16.88	3	7	10	3,000.0
67	P.18	Clearing and finishing	m2	300	2	CL01	150	2	16	3	450	0.66	10.66	0.036	2	9.0	0.67	12.67	3	0	3	600.0

5.5 Evaluation of the Computer Program by Using a Project Case Study

Implementing this study utilizing Matlab package selected for achieving the aims of this study in comparison with other computer programs has many advantages in application of Line of Balance method. By using the developed software, the user does not need to have any previous knowledge about the program because the user can run the program, enter the project data into it and easily obtain the results automatically in the software. The Matlab package has extensive facilities for calculating and displaying the vectors and matrices as graphs and prints them easily. These functions allow the program to calculate and obtain the output data accurately and easily in a short period of time compare to other programs that they might need several hours to enter data, to analyze them and to provide the outputs. The software consists of a user friendly interfaces which allows the user to use this program for repetitive types of projects, Line of Balance scheduling, obtaining and drawing cash flow diagrams.

Evaluating the developed computerized program by applying it on a case study project and comparing the results with manual outcomes reveals some vital points as below for this study.

The case study project consists of sixty seven activities. Employing Line of Balance method for this project is necessary since the case study was repetitive types of project. Providing the initial data for Line of Balance method and calculating the Line of Balance table for all activities of the project would take several hours to complete. Moreover, there are many possibilities of errors which can cause tremendous effects on results. In calculation process, any mistake in any section of job would force the user to calculate the Line of Balance table for project again. In addition, if the user wants to modify any data afterwards, the Line of Balance table has to be prepared once more. Preparing and obtaining the Line of Balance is a time consuming process for the contractors or project managers which might be one of the main reasons of Line of Balance method being underuse in market.

However, by using the developed program, the all sixty seven activities entered in less than one hour and in any case of making mistakes or modifying any data later on, they could be done in few second easily. After changing the data, the program automatically will calculate the Line of Balance table once more in just few seconds. In addition, the developed program easily calculates Line of Balance and draws its graphs in most accurate way. Therefore, since the time is an important factor in each project for all project parties, by using this computerized method, in a very short period of time compare to calculation by hand with possibilities of errors, the contractor can implement this computer method for the project. By comparing the line of balance table results with prepared table by using Microsoft Excel, it can be understand that there is no place for having an error or obtaining different output compare to Excel.

Project financial statement and cash flow are vital factors in any projects for all parties. Preparing these factors need a complete and accurate knowledge about them. Moreover, calculating cash flow and drawing the cash flow diagrams are not easy job in Line of Balance method. By having a small mistake, the project financial statement could be changed a lot. Furthermore, preparing these statements are time consuming as well. Determining the cash flow and draw the graphs could take several hours time to prepare.

However, the developed program provides some easy functions for contractor to prepare the project financial statements. The project financial statements can be obtained easily, fast and accurately in few seconds. Additionally, the developed program, prepare cash flow values in several time manners such as daily, weekly and monthly, and it shows their graphs in cumulative and daily, weekly or monthly based. Also, the financial statement can be easily prepared any period of time such as monthly or yearly financial bill of project.

All the output data from developed software such as Line of Balance table, cash flow values and their graphs can be transfer to other program such as Microsoft Excel for further analysis.

The developed program helps the contractors or project managers to control the scheduling and cost factors of the project. The baseline scheduling and cost analyses can be provided before starting the project and after that the actual scheduling and cost analysis can be prepared in order to compare the results and take the necessary action when it’s needed. Moreover, any conflict between activities and resources can be predicted in advance and make the changes in scheduling if it’s important for project.

Chapter 6

CONCLUSIONS & RECOMMENDATIONS

6.1 Conclusions

This thesis was a study on Line of Balance technique using Matlab package. A computer program was developed to obtain Line of Balance graphs, calculate cash flow and draw cash flow diagrams.

Line of Balance methods illustrate the project plan and schedule in an exclusive format that would be useful for contractors. The technique is used to analyze the application of labor and plant resources to ensure that each resource can progress from one item to the next in an orderly way, completing its own work on all the items without being delayed waiting for preceding work to be completed. The major benefit of the line of balance (LOB) is to show the production rate and duration information in an easily interpreted graphical format.

Several issues associated with LOB applications have been identified in this study. Scheduling of linear repetitive construction projects is not a single dimension decision process. Factors such as the duration of the project, the resource productivity output, the continuation of resource usage, and the slack time are factors that construction managers must take into consideration in deciding an optimum scheduling for the project. Furthermore, in a financial statement, the unit price list, materials unit prices and labor costs are important factors that have effect on project financial strength in a construction project for contractors.

The primary goal of this study was to develop a computer program by using Matlab package in Line of Balance method for clients, contractors and project managers which can be used effectively in construction projects. This study provided an accurate and powerful computerize method to obtain Line of Balance scheduling, determining line of balance table, drawing line of balance graphs, calculating cash flows and drawing cash flow diagrams in cumulative based on daily, weekly or monthly expenditures. Furthermore, preparing Line of Balance scheduling and preparing the financial statements for the method is a time consuming process which can be a source of errors. The Line of Balance method can be obtained easily, accurately in just few minutes. Moreover, the program has capability of obtaining cash flow and drawing cash flow diagrams for different periods of time, phase or section of project.

The computerize method that is developed for the study, is a user friendly computer program. The initial Line of Balance data can be entered, edited, modified, and removed easily by user in any time of utilizing the software. The Line of Balance graph is obtained automatically in detail.

It is presenting a colorful line of balance graph. The degree of the detail of the LOB diagram must be carefully evaluated. If too many activities are plotted, the diagrams turn out to be a complex graph filled with inclined lines that also sometimes cross each other. An alternative is proposed here was the display of the LOB diagram by the use of color-filled lines as well as vertical and horizontal grid lines. A major difficulty in preparing the LOB diagram lines in plotting overlapping activities that have the same rate of production.

A villas project was taken as a case study, Bill of Quantity, Work break down structure, cost and productivity analysis on this project were prepared. Line of balance scheduling table was obtained. The cash flow calculation and diagrams were obtained. In addition it was presented by their graphs in several time scales.

The developed computer program was evaluated with this case study and it was concluded that, the program can be used successfully. It is believed that this program is useful for contractors and project managers. Entering the Line of Balance input data and preparing Line of Balance table are done in less than one hour by using the software. The Line of Balance graphs, cash flow and cash flow diagrams are prepared automatically in just few seconds. However, it takes several hours to prepare them manually without using software. The Line of Balance table is prepared and calculated by Microsoft Excel to compare the results with the developed software. The exact and accurate results were obtained by using the developed program compared to Microsoft Excel program.

6.2 Recommendations

The developed computer program can be converted to a commercial version in further study just by modifying and adding some functions to the software.

There is possibility of creating a link between Microsoft project software and Matlab package that it would help the user just to enter project data only once into Microsoft project and it will transfer directly into Matlab package as well which would avoid repeating the entering initial project twice.

The Matlab graphical interface can be changed to a more developed one.

REFERENCES

Angus, R. B., Gundersen, N. A., & Cullinane, T. P. (2003). *Planning, Performing, and Controlling projects.* New Jersey: Pearson Education Ltd.

Arditi, D., & Psarros, M. K. (1987). SYRUS—System for repetitive unit scheduling. *Project Management* .

Arditi, D., B.Tokdemir, O., & Suh, K. (2002). Challenges in Line-of-Balance Scheduling. *TECHNICAL NOTES* , 2.

Ashworth, A. (1999). *Cost studies of buildings.* Edinburgh Gate: Pearson Education limited.

Buttelwerth, J. (2005). *Computer Integrated Construction Project Scheduling.* New Jersey: Pearson Prentice Hall.

Celik, T. (2008). *Construction Management Ce492.* Famagusta: Eastern Mediterranean University.

Celik, T. (2009). *Construction Management Ce592.* Famagusta: Eastern Mediterranean University.

Cooke, B., & Williams, P. (2004). *Construction planning, Programming and Control.* Oxford: Blackwell Publishing.

Evre, M. (2002). *Productivity Analysis of Constrution Industry in T.R.N.C.* Famagusta: Eastern Mediterranean University.

Gould, F. E., & Joyce, N. E. (2003). *Construction Project Management.* New Jersey: Prentice Hall.

Griffith, A., Stephenson, P., & Watson, P. (2000). *Management Systems for Construction.* Edinburgh Gate: Pearson Education Limited.

Harris, F., & McCaffer, R. (2006). *Modern Construction Management.* Oxford: Blackwell publishing Ltd.

Hegazy, T. (2002). *Computer-Based Construction Project Management.* Newjersey: Prentice Hall.

Hendrickson, C. (1998). *Department of Civil and Environmental Engineering, Carnegie Mellon University, Pittsburgh,.* Project management for construction: http://pmbook.ce.cmu.edu/ adresinden alınmıştır

Hinze, J. W. (1998). *Construction Planning and scheduling.* New Jersey: Prentice-Hall, Inc.

Holm, L., Schaufelberger, J. E., Griffin, D., & Cole, T. (2005). *Construction cost estimating* . New jersey: Pearson Prentice Hall.

Huang, R.-y., & Sun, K.-S. (2005). System development for non-unit based repetitive. *Automation in Construction* , 3.

Humphreys, K. K. (1991). *Jelen's Cost and optimization engineering.* New York: McGraw-Hill, Inc.

J.O'Brien, J. (1993). *CPM in Construction Management.* New York: McGraw-Hill, Inc.

Jenkins, G. (2004). *Integrated Investment Appraisal.* South Africa: Department of financial and economic development.

Johnston, H., & Mansfield, G. L. (2001). *Bidding and estimating procedures for construction.* New Jersey: Prentice Hall.

Kirkham, R. (2007). *Cost planning of Buildings.* Oxford: Blackwell Publishing.

Lester, A. (2007). *Project Management Planning and Control.* Oxford: Butterworth-Heinemann.

Long, L. D., & Ohsato, A. (2008). A genetic algorithm-based method for scheduling repetitive construction projects. *Automation in Construction* , 1.

Madwesley, M., Askew, W., & O'Reilly, M. (1997). *Planning and Controlling Construction Projects:The best laid plans.* Edinburgh Gate: Longman.

Mahdi, I. M. (2003). A new LSM approach for planning repetitive housing projects. *International Journal of Project Management* , 1.

MathWorks. (1999). *Learning MATLAB,Student Version.* 2001 tarihinde The MathWorks, Inc: www.mathworks.com adresinden alındı

Morse, W. J. (1983). *MANAGEMENT AND ACCOUNTING WEB.* 2002 tarihinde http://maaw.info/ArticleSummaries/ArtSumMorse83.htm adresinden alındı

Mubarak, S. (2005). *Construction Project Scheduling and Control.* New Jersey: Pearson Prentice Hall.

N.Mohamed, A. (2007). *Construction Project Management lecture not.* Famagusta: Eastern Mediterranean University.

Neale, R. H., & Neale, D. E. (1989). *Construction Planning.* London: Thomas Telford.

Newitt, J. S. (2005). *Construction Scheduling Principle and Practices.* New Jersey: Pearson Prentice Hall.

Ostwald, P. F. (2001). *Construction cost analysis and estimating.* New Jersey: Prentice Hall.

Oxley, R., & Poskitt, J. (1996). *Management Techniques.* Oxford: Blackwell Science Ltd.

Pilcher, R. (1994). *Project cost control in construction.* Oxford: Blackwell Scientific Publication.

R.Mincks, W., & Johnston, H. (1998). *Construction Job Site Management.* NewYork: Delmar Publishers.

Weber, S. C. (2005). *Scheduling construction projects, principle and practices.* New Jersey: Pearson Prentice Hall.

Yang, T., & Ioannou, P. (2004). Scheduling system with focus on practical concerns in repetitive projects. 619-630.

APPENDICES

Appendix A: Architectural and Structural plans of Project Case Study

Table 6: Case Study Project Details

PROJE MÜELLİFİNİN	ADI SOYADI	ÜNVANI	ODA SİCİL NO	ODA BELGE NO	BELEDİYE SİCİL NO	SORUMLULUK İMZASI
MİMAR	GÖKHAN NOYAN	YÜKSEK MİMAR	17			
STATİK	MUSTAFA NOYAN	İNŞ.MÜH.	7603			
MİMARİ MÜELLİFİNİN ADRESİ		323 SALAMİS YOLU G/MAĞUSA				
STATİK MÜELLİFİNİN ADRESİ		323 SALAMİS YOLU G/MAĞUSA				

ODA VİZESİ		

YAPININ		
	SAHİBİ	Sn. GÜRHAN GÜLER
	KULLANMA AMACI	DUBLEKS KONUT VE GARAJ

ARSANIN							
KAZA	BELEDİYE	KÖY	MAHALLESİ	SOKAK VEYA CADDESİ	ADA BLOK NO	PAFTA NO HARİTA NO	PARSEL NO
MAGUSA	MAGUSA	ATLILAR	——	——	——	23/24 W	104/14

ORTAK UYGULAMA DÜZENİ ESASLARINA GÖRE YAPININ								
İNŞAAT YAPI SINIFI		İNŞAAT SİSTEMİ	KAT ADETİ BODRUM ÇATI DAHİL	ALAN m2	BİRİM MALİYETİ	YAPININ YAKLAŞIK	KULLANMA AMACI	AZAMİ İNŞAAT SÜRESİ
MİMAR	İNŞ.MÜH.							
II	II	BETON ARME	2 1	230.00 43.56 146.80 mt	808 536 226	185.840 23.348 33.177 + 242.365	KONUT GARAJ BAHÇE DUVARI	24 AY

ÖLÇEK	MİMARİ PROJE	1/200-1/50-1/20	TARİH	PAFTA NO	IS NO
	STATİK PROJE	1/50-1/20	25/03/2008	M01	

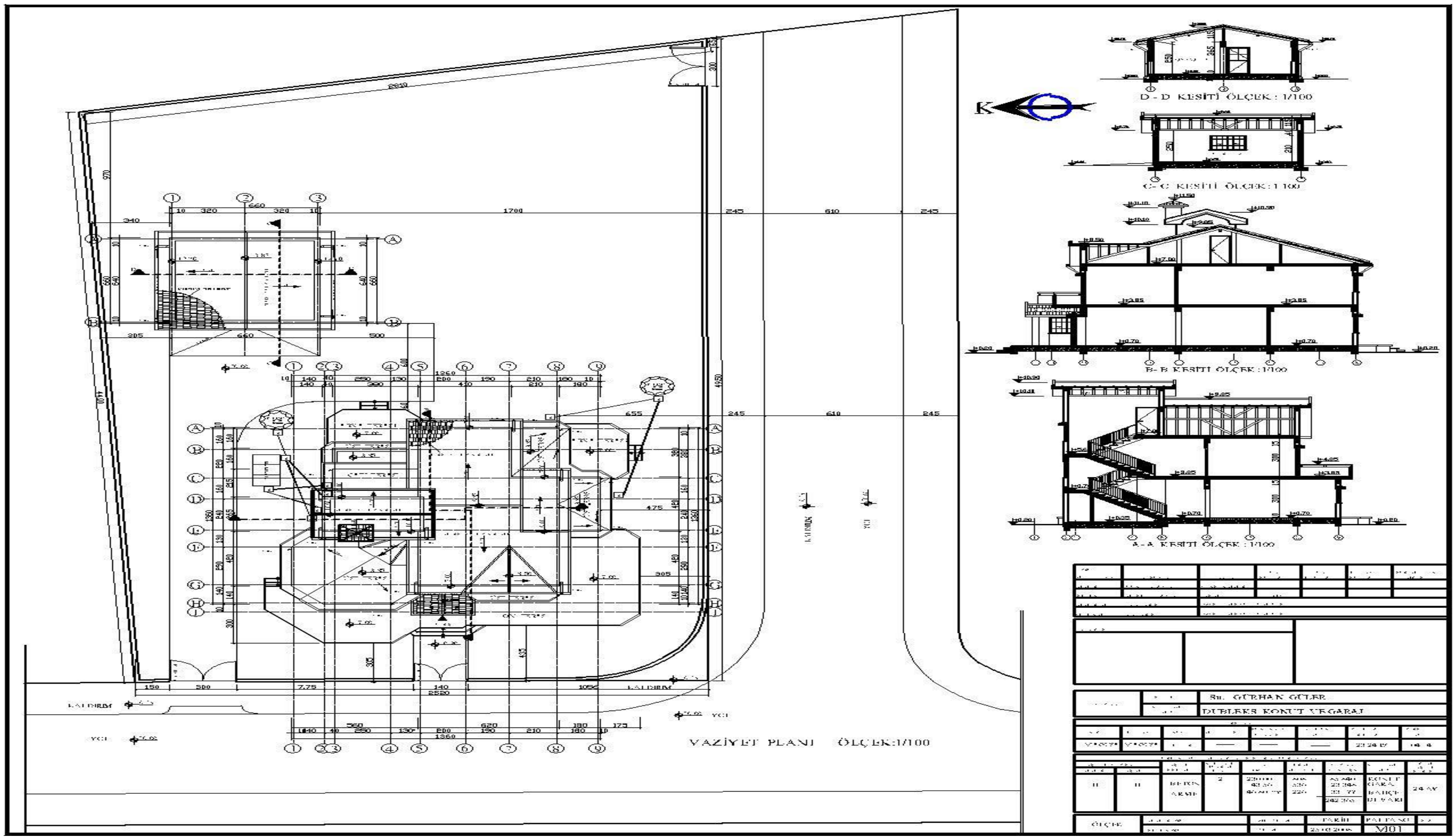


Figure 48: Site Area Plan

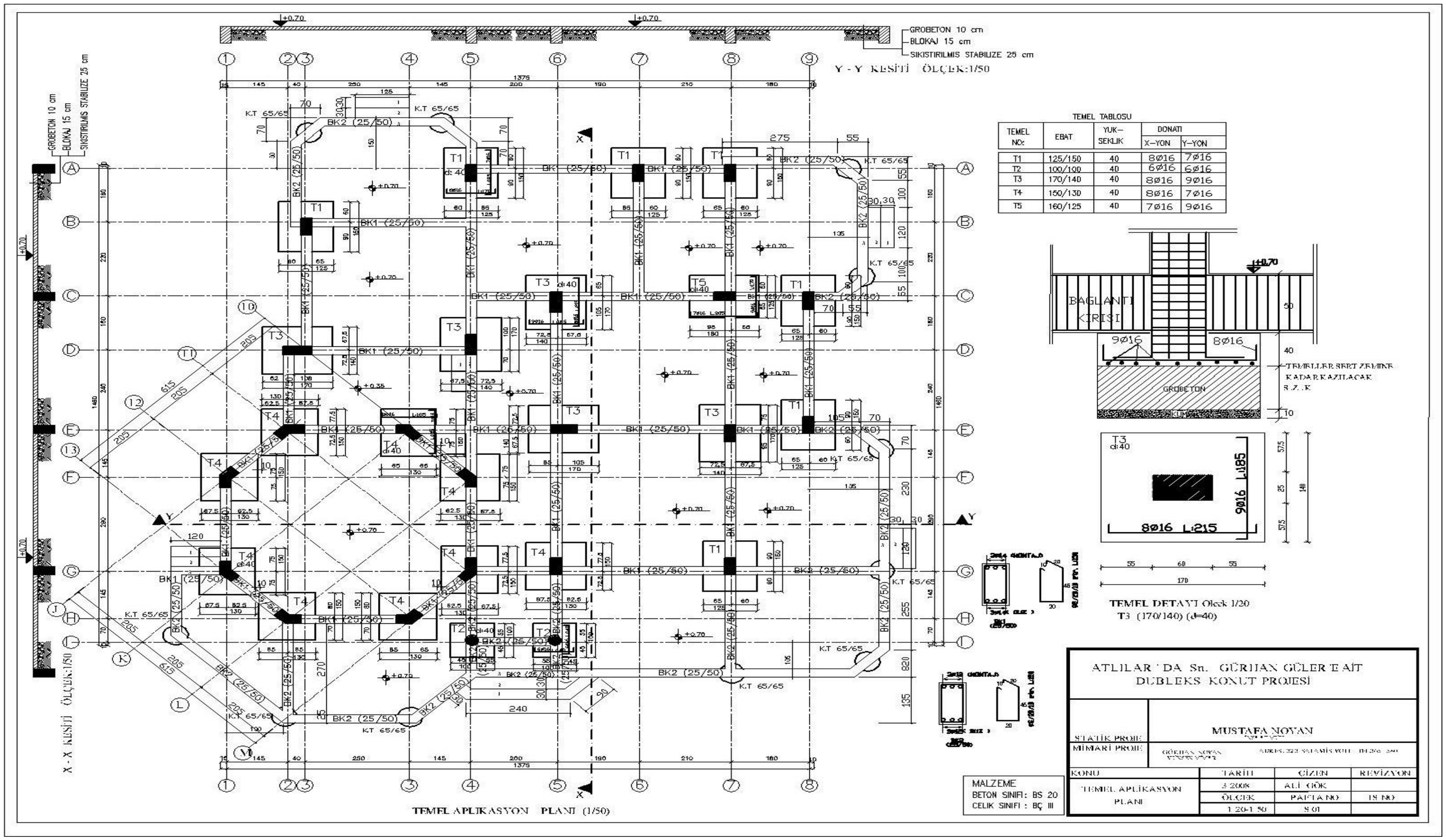


Figure 49: Foundation Plan

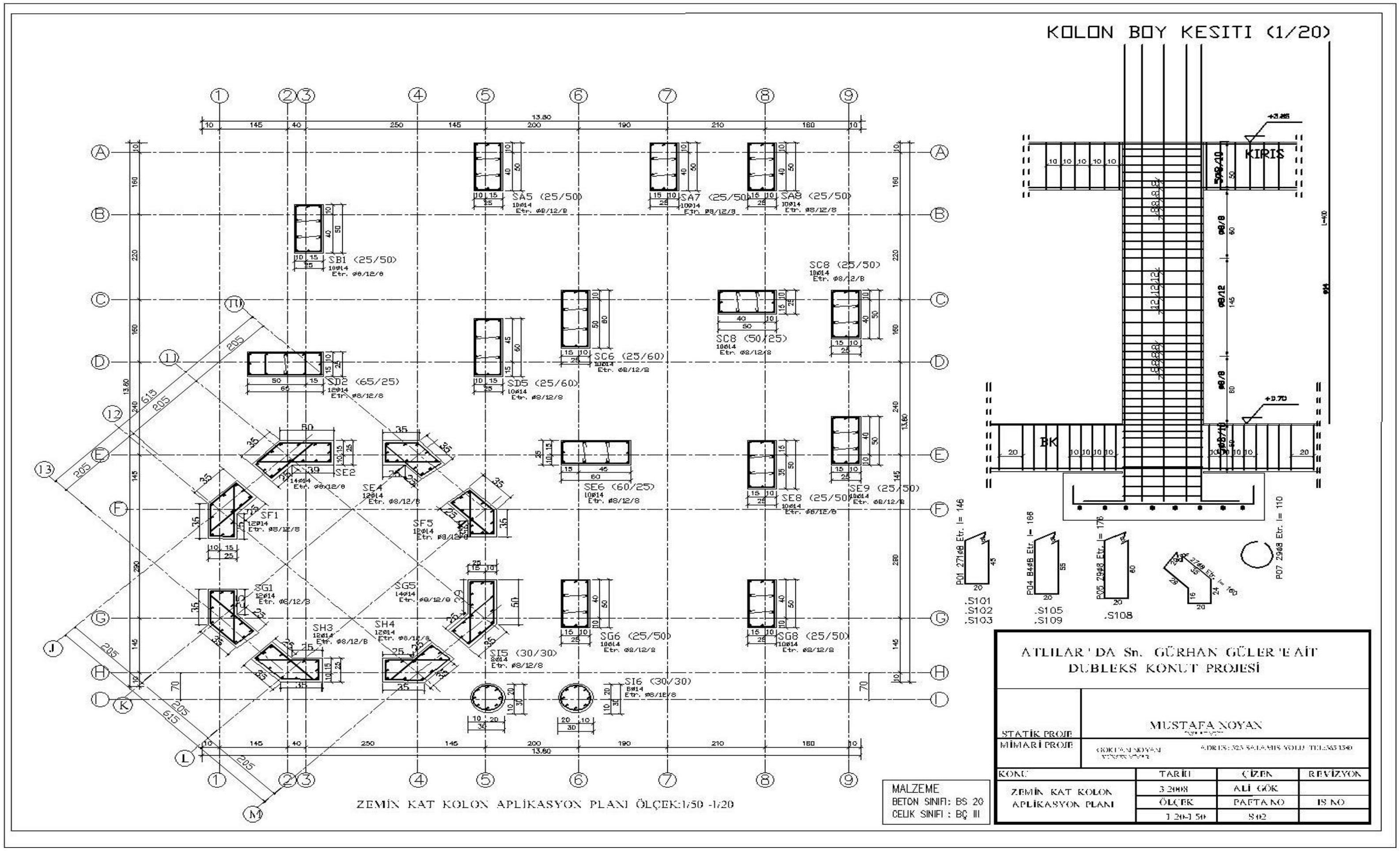


Figure 50: Structural Plan

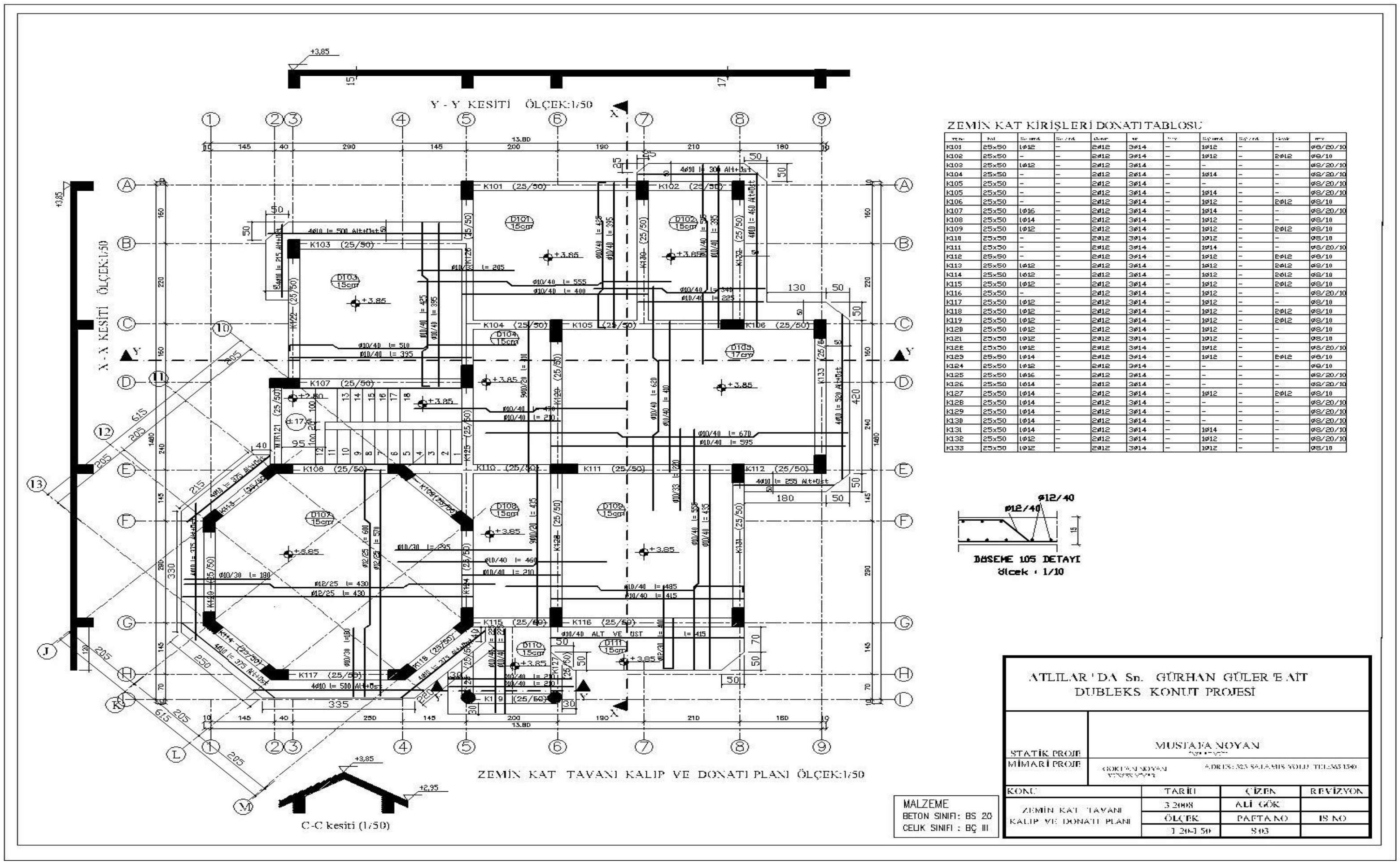


Figure 51: Structural Plan

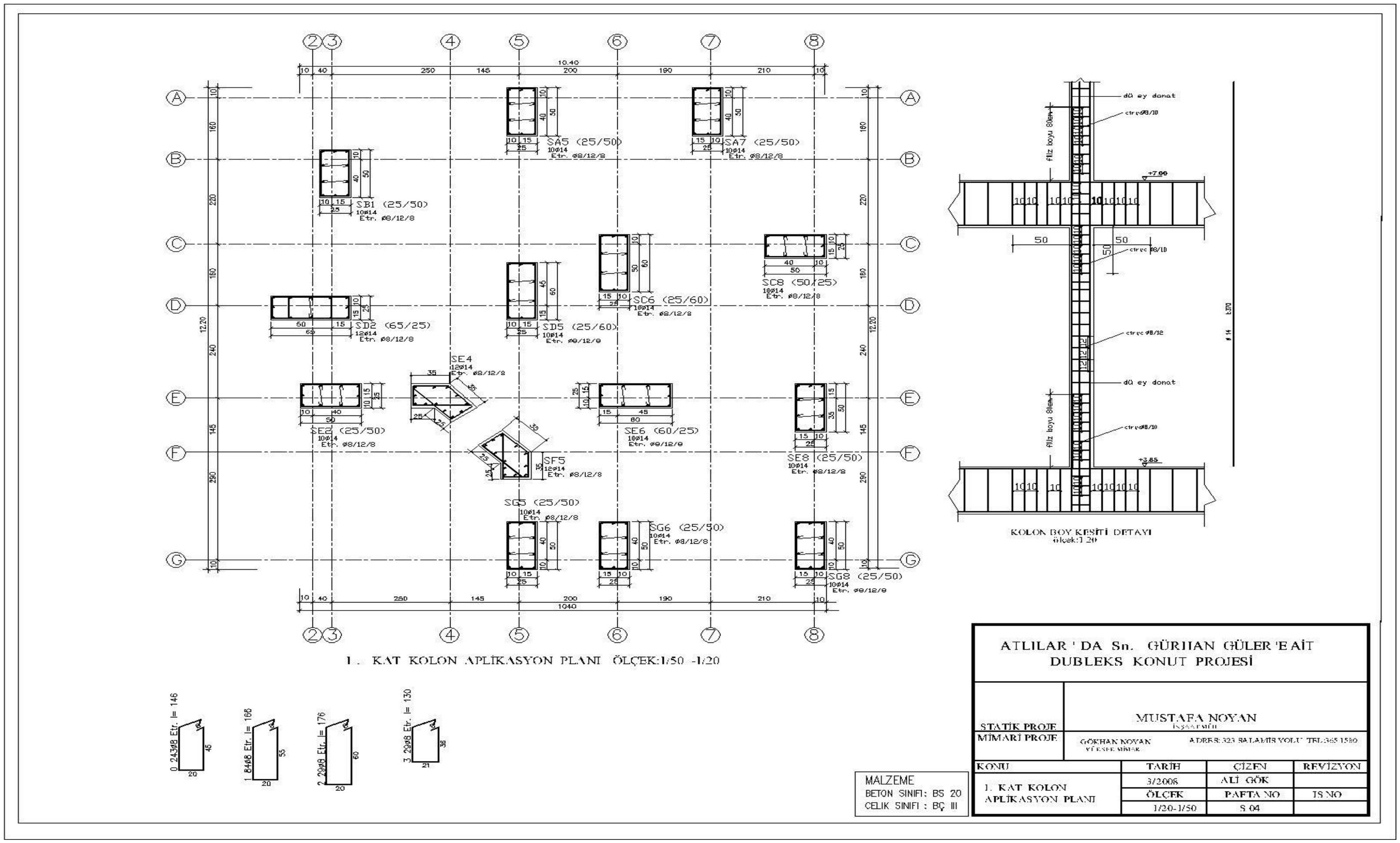


Figure 52: Structural Plan

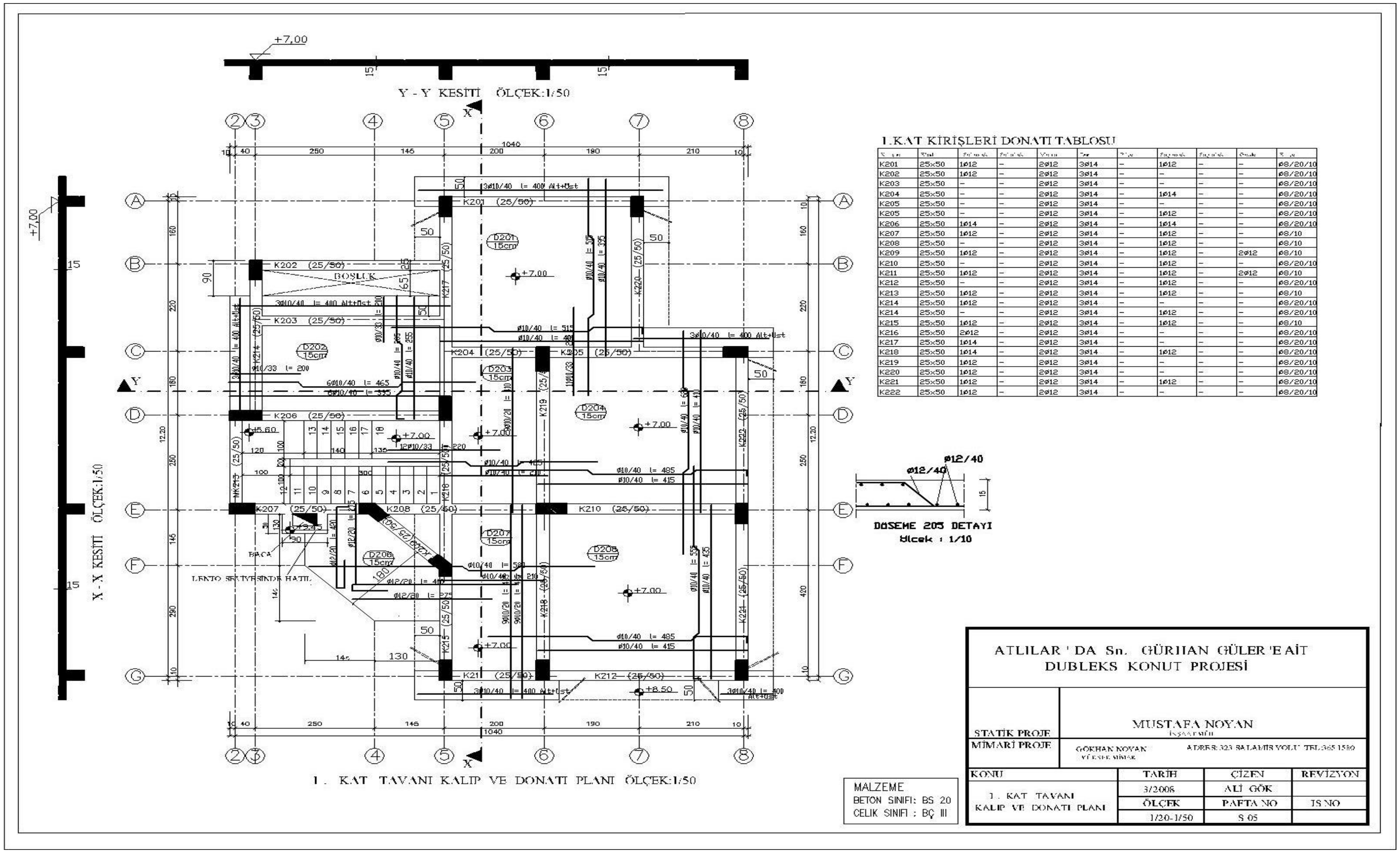


Figure 53: Structural Plan

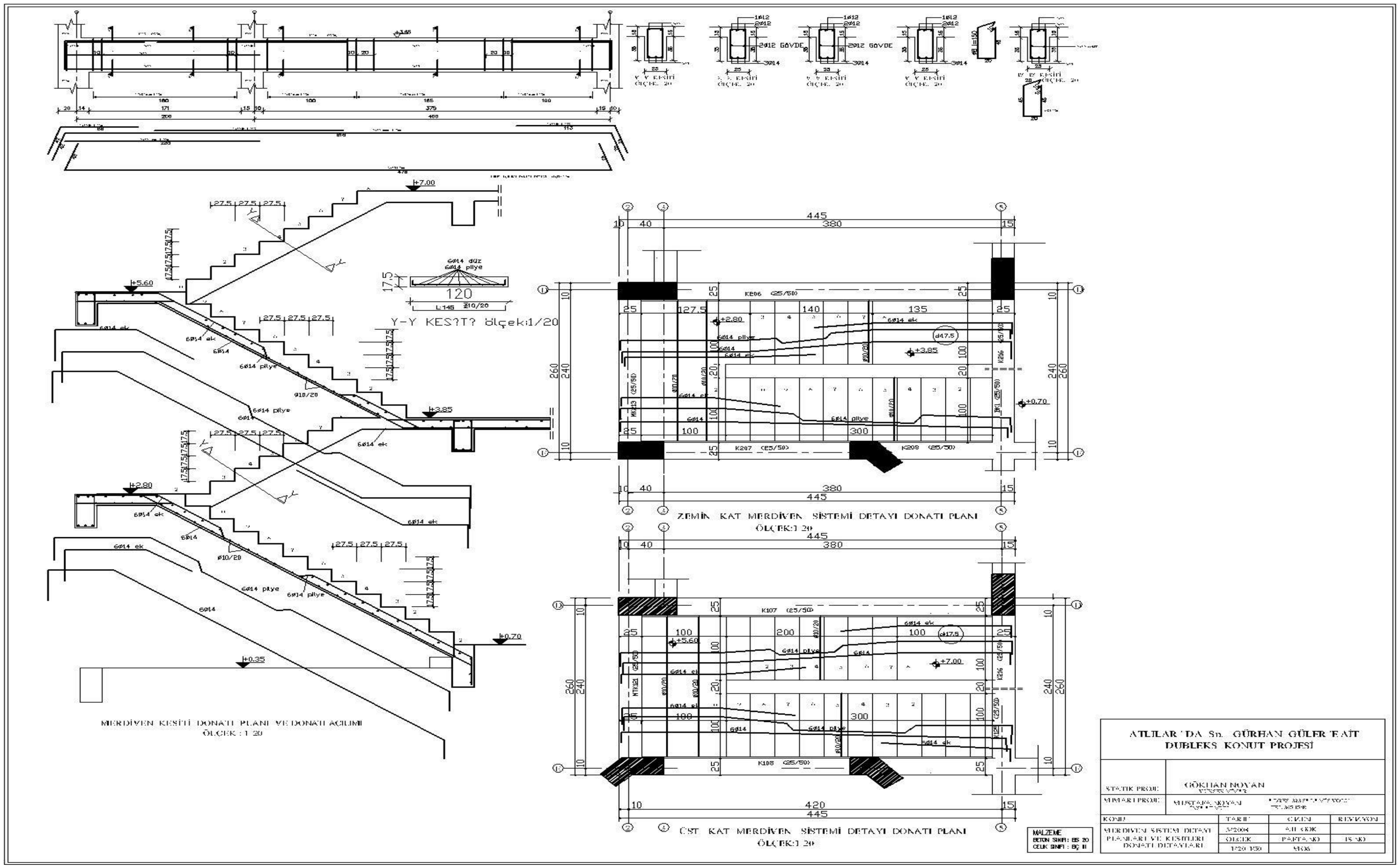


Figure 54: Stairs Plans and Sections

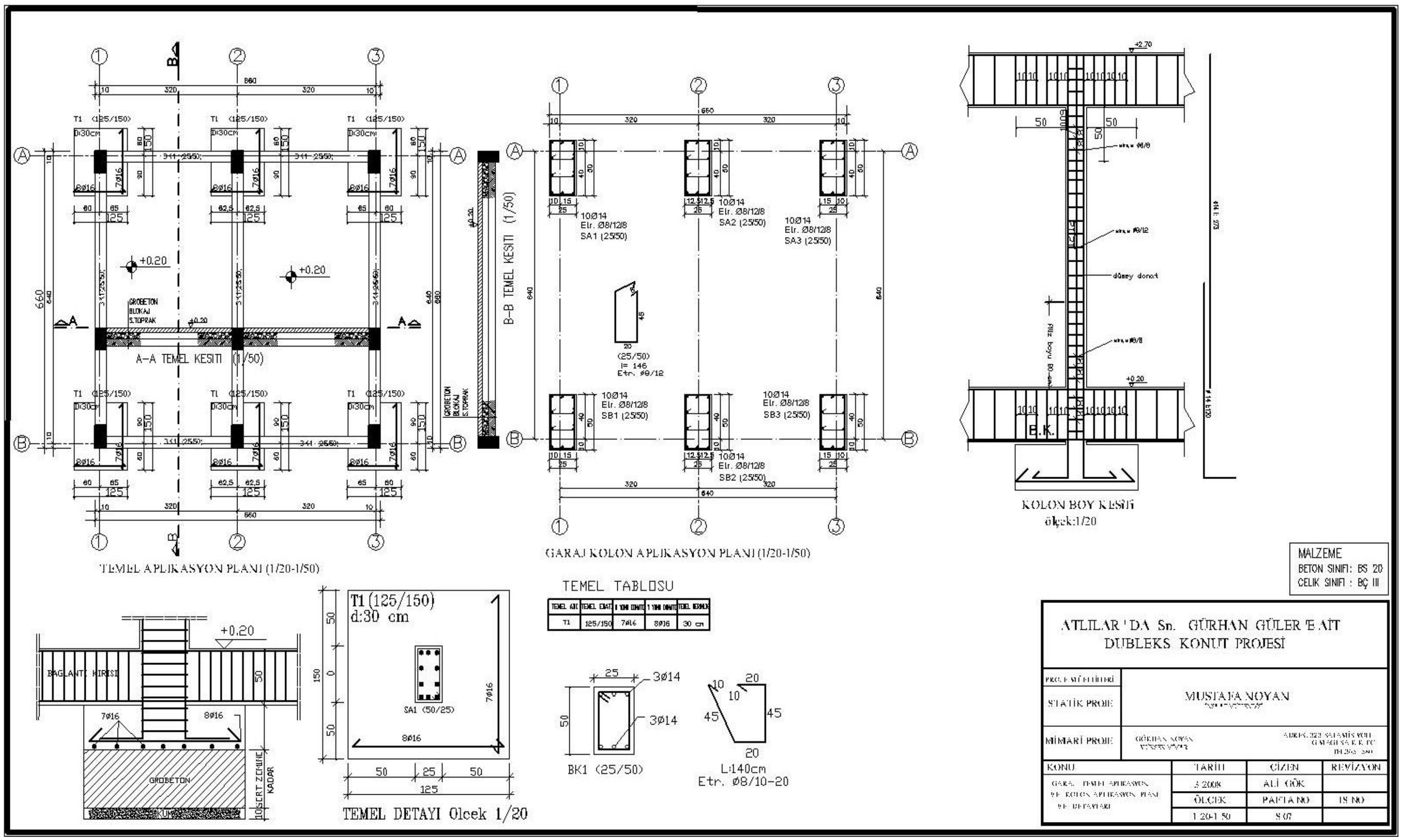


Figure 55: Structural Plan

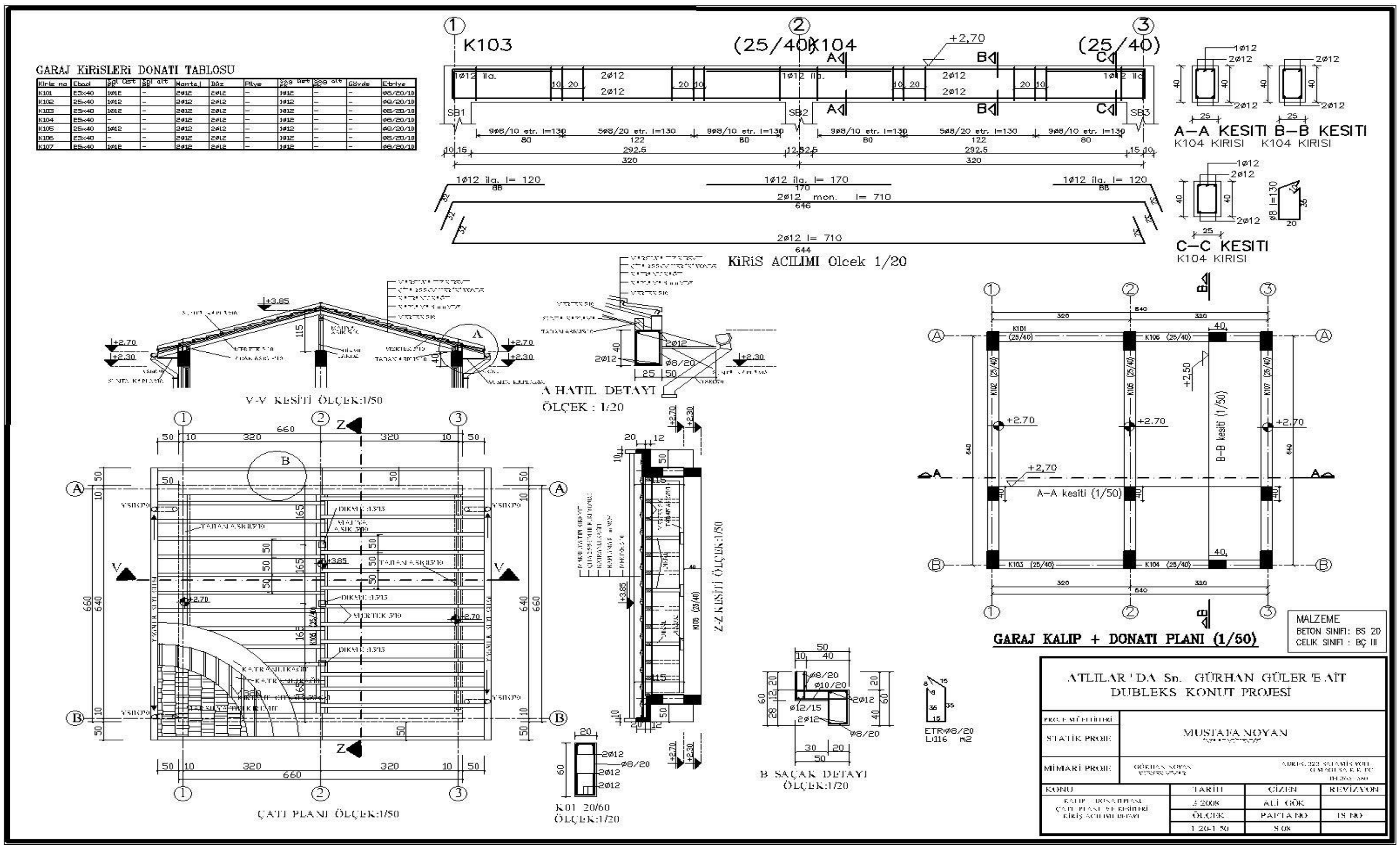


Figure 56: Roof Details

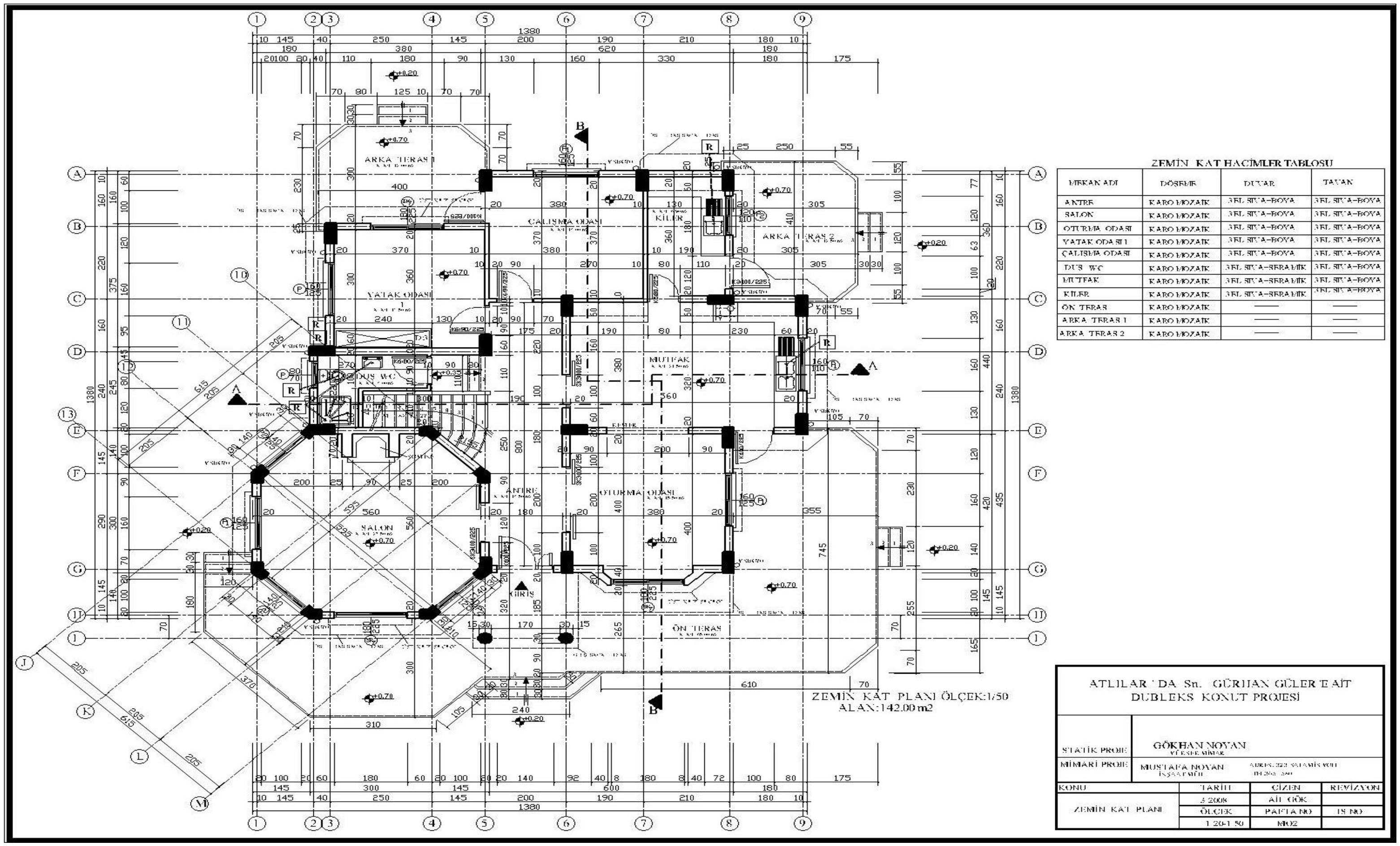


Figure 57: Structural Plan

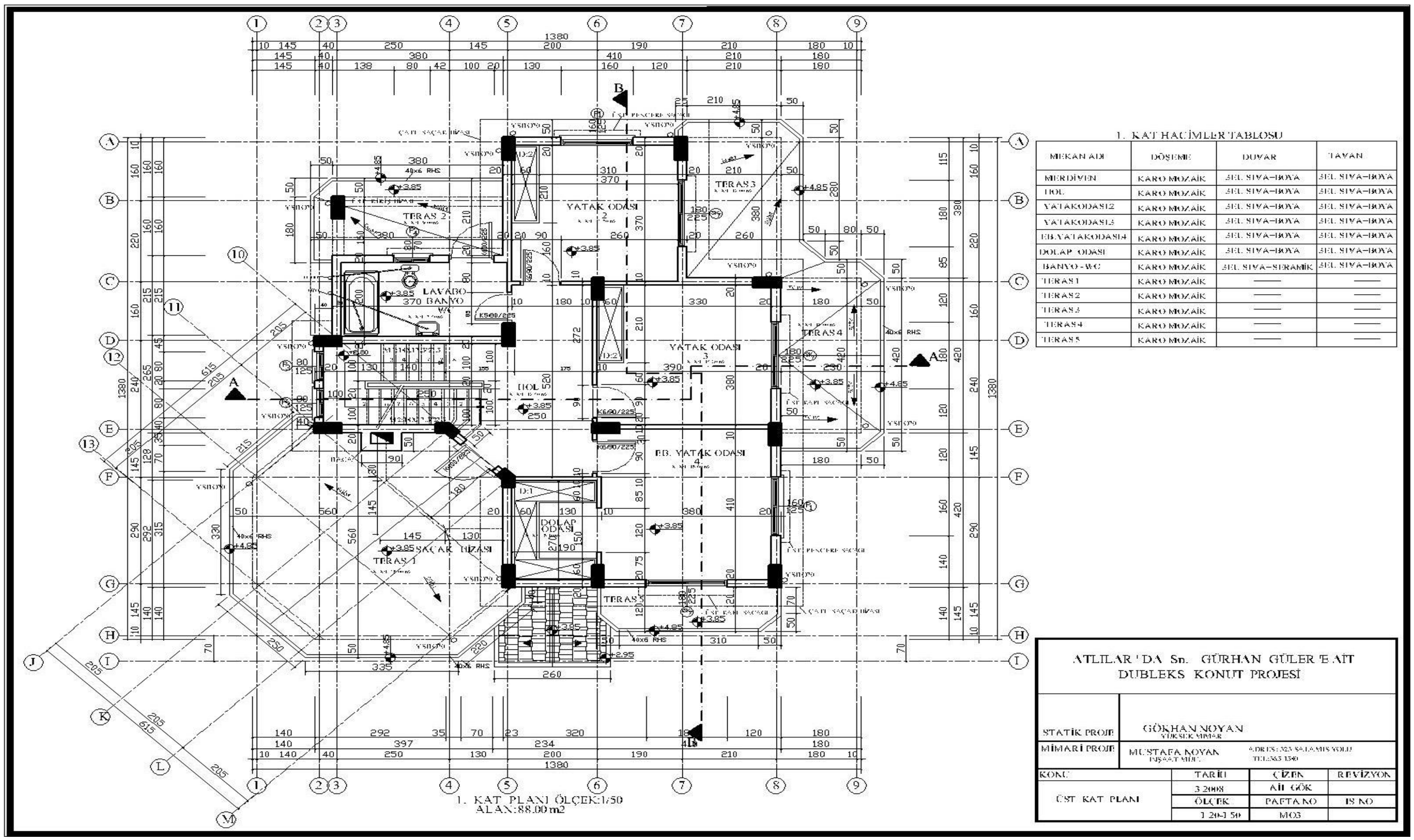


Figure 58: Structural Plan

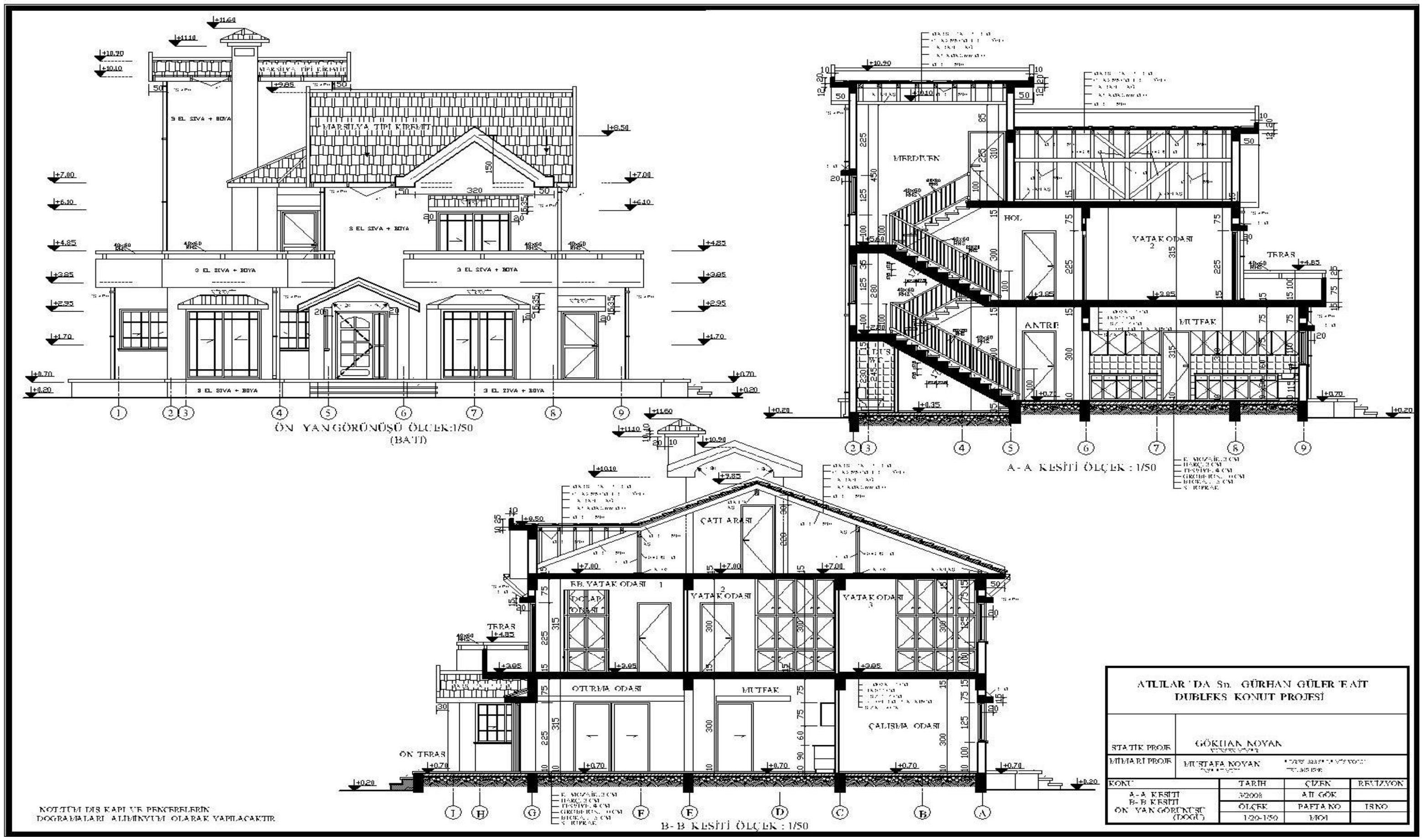


Figure 59: Section and Elevation Plans

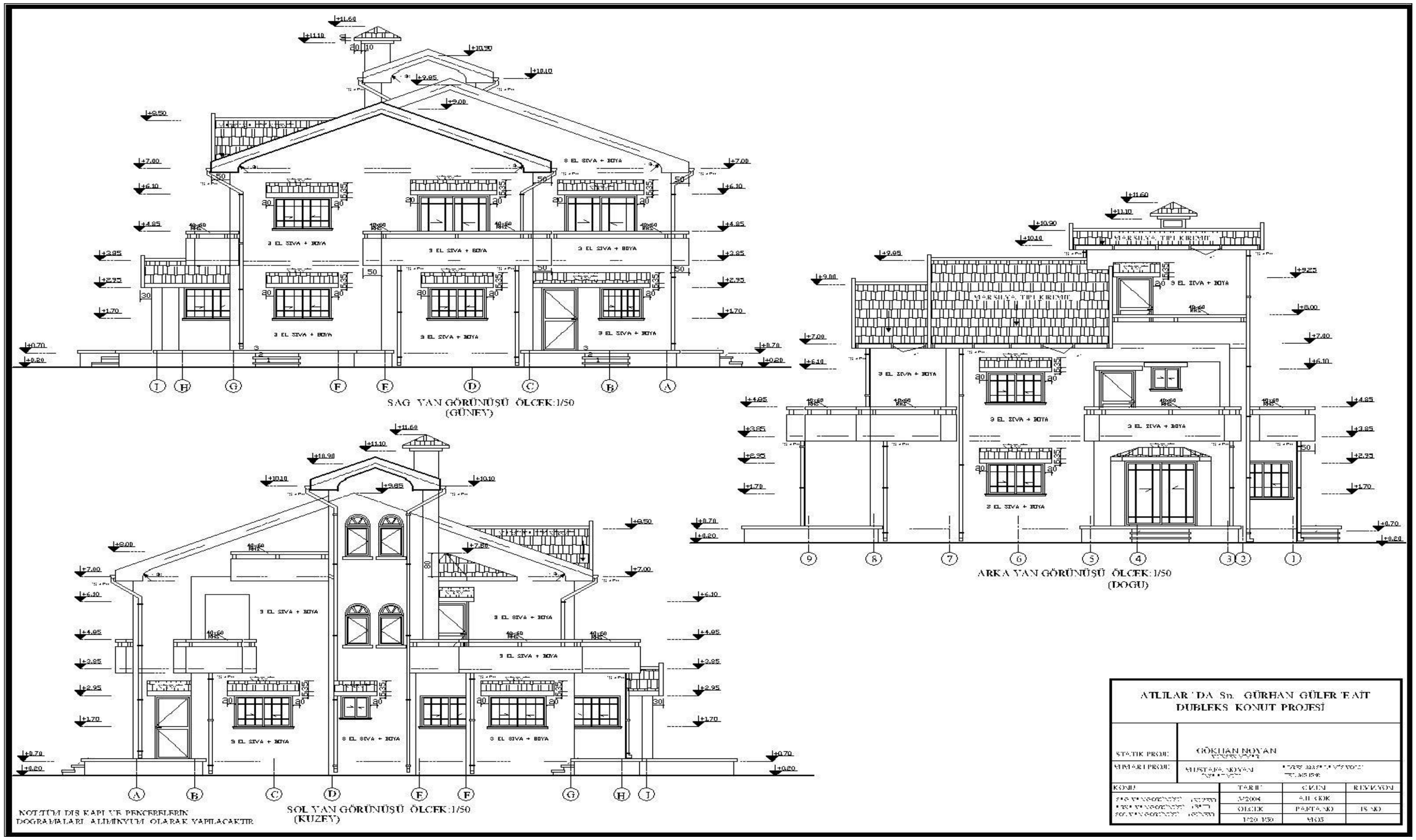


Figure 60: Elevation Plans

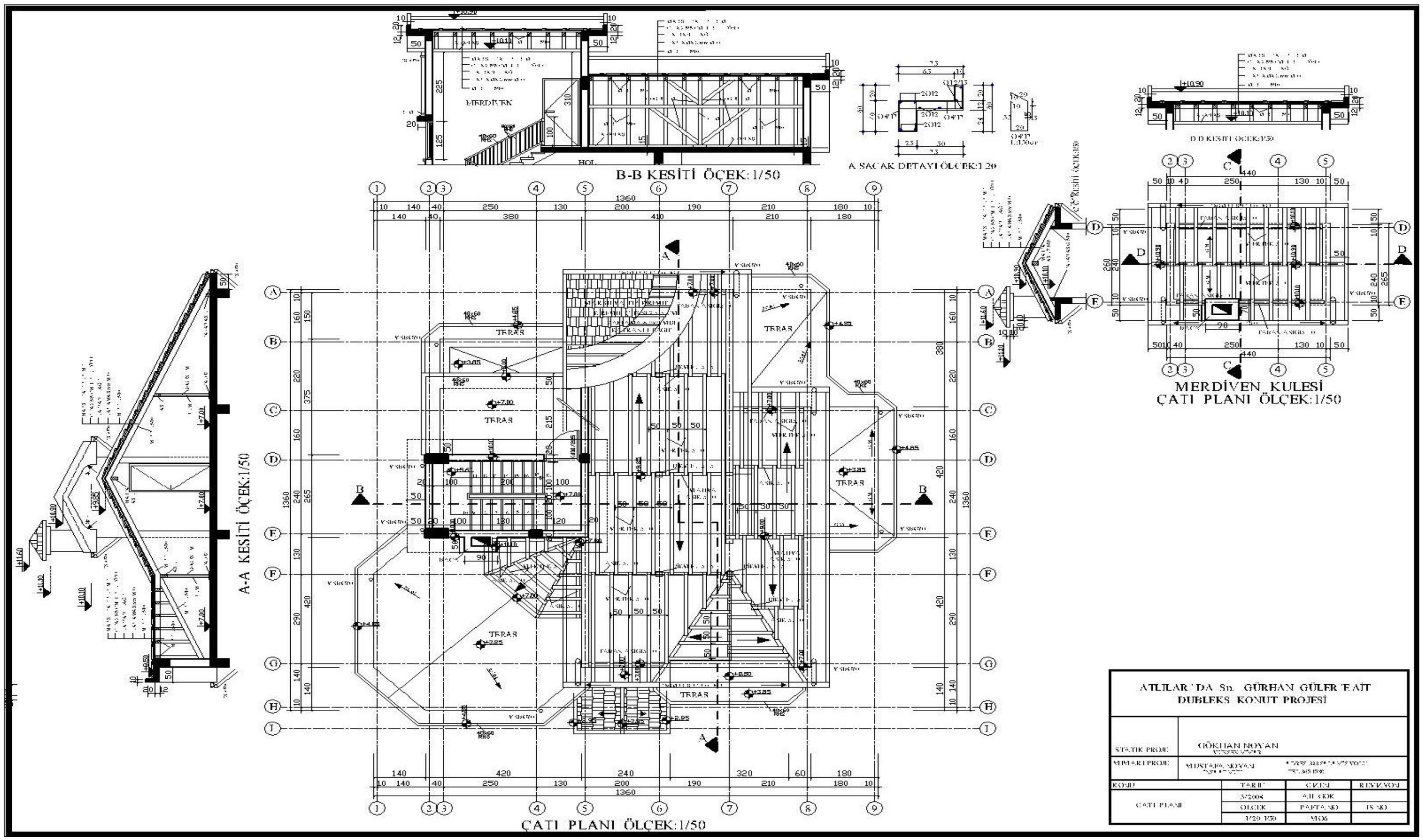


Figure 61: Roof Plan

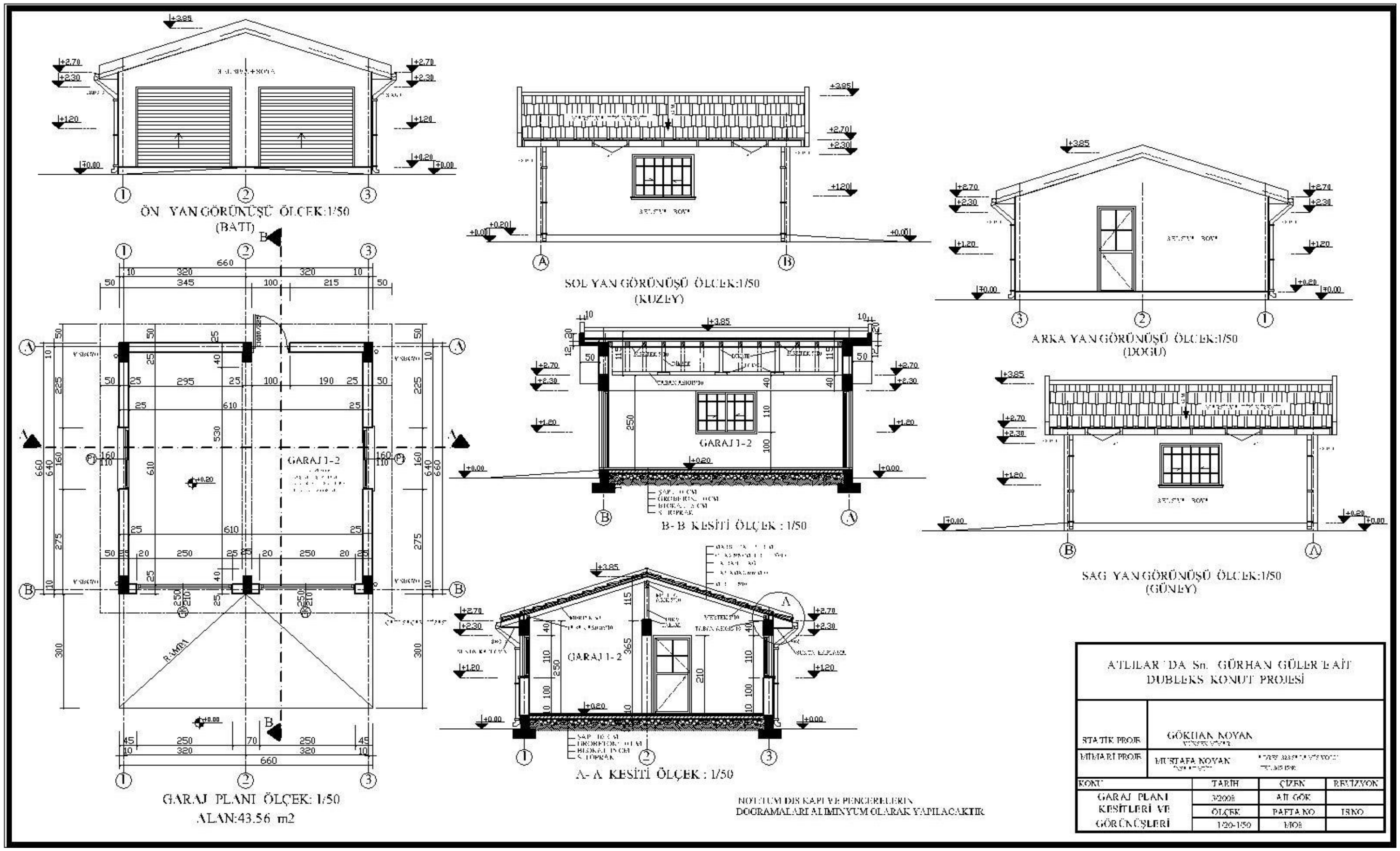


Figure 62: Parking Plan

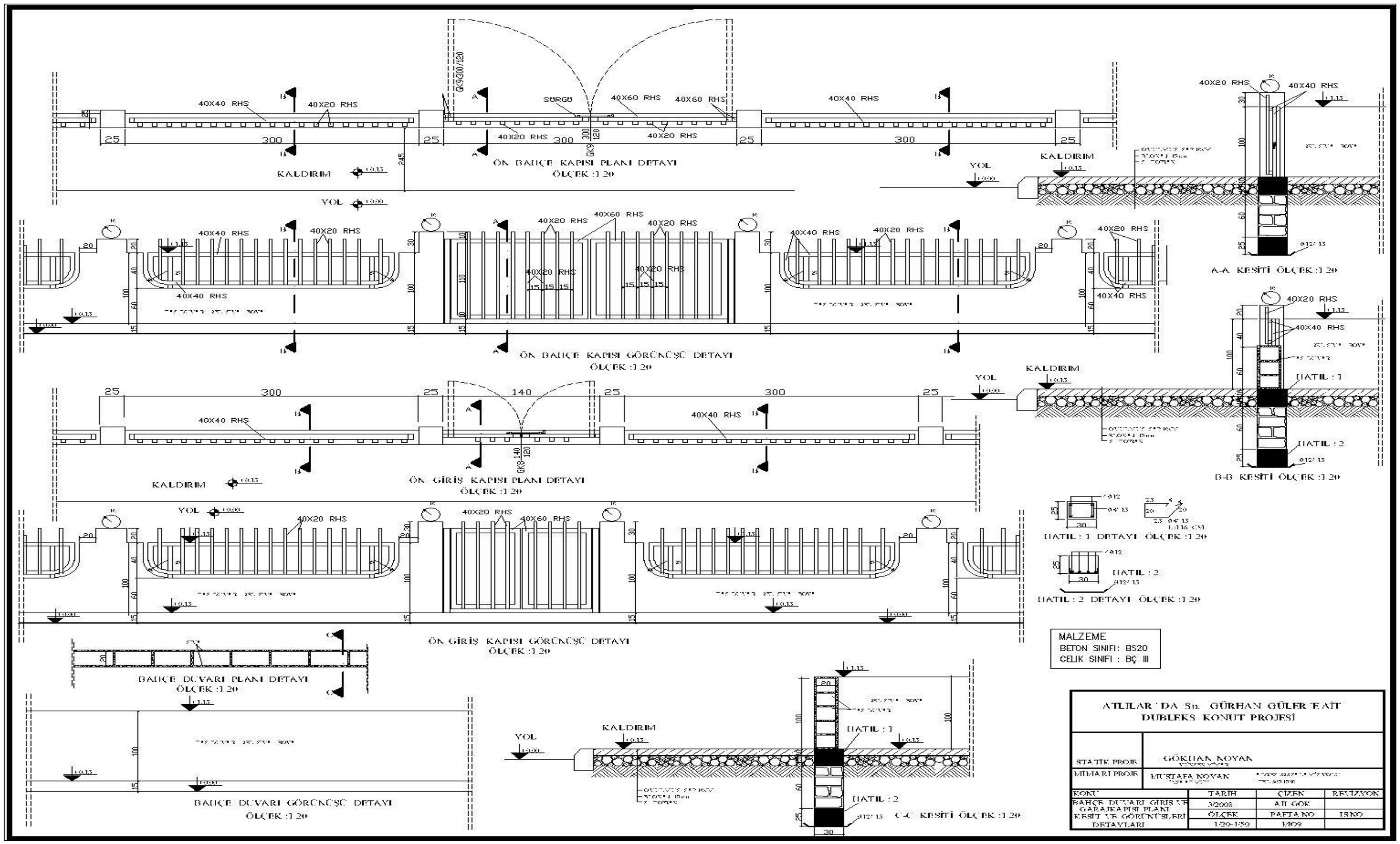


Figure 63: Doors Plan

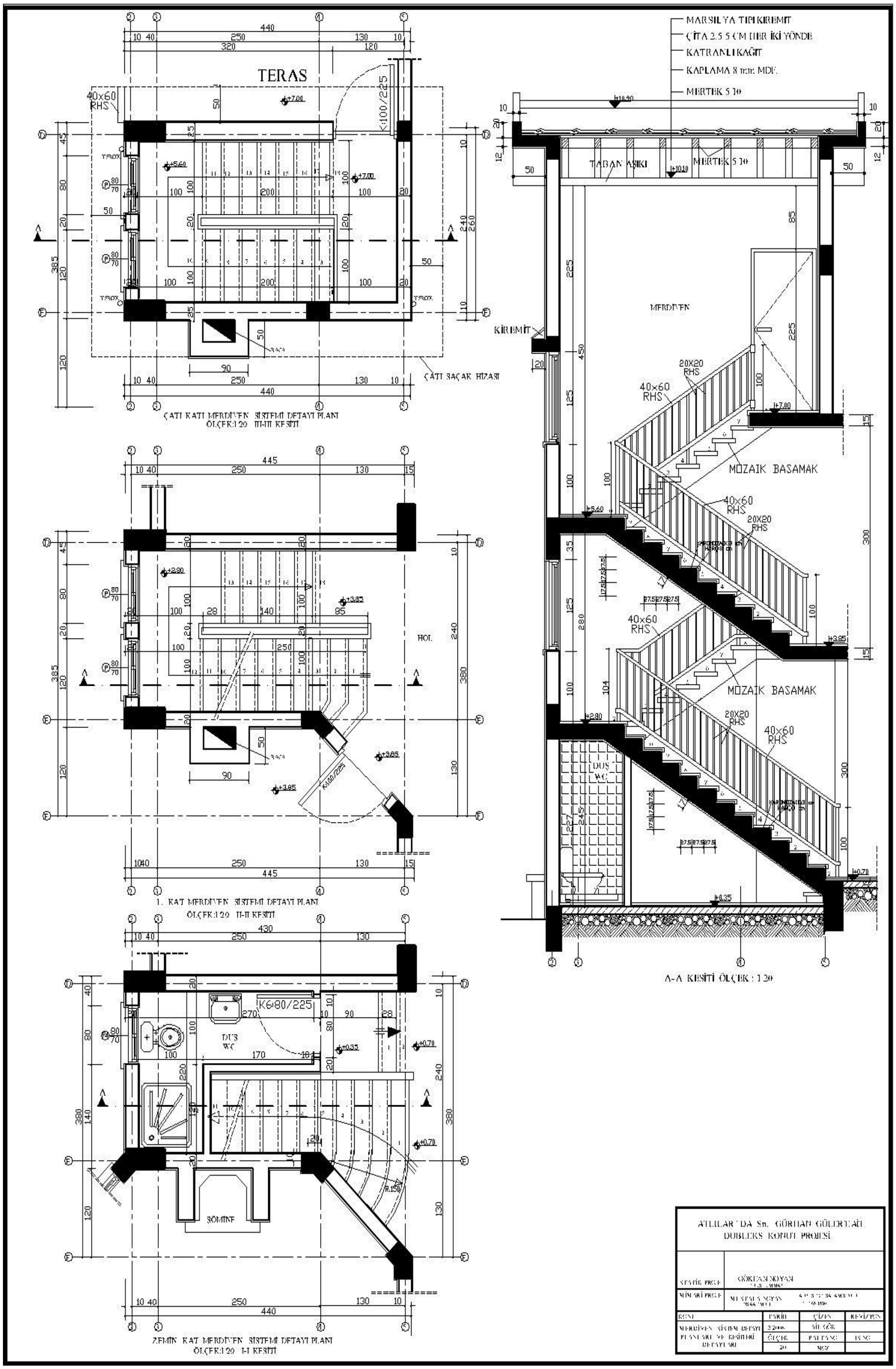


Figure 64: Stairs Plan

Appendix B: Finalized Bill of Quantities Table

Table 7: Finalized Bill of Quantities Table

No.	ID No.	Description Of Work	Unit	Quantity
	P	**Villa Project**		
	P.1	**Site Preparation**		
1	P.1.1	Site Layout, Installation, Marking	m^2	302.00
2	P.1.2	Cleaning And Leveling	m^3	73.00
	P.2	**Earth Work**		
3	P.2.1	Excavation Footing By Hand And Excavator	m^3	44.29
4	P.2.2	Laying Sand On Footing's Base	m^3	13.51
5	P.2.3	Back Filing Material	m^3	32.63
6	P.2.4	Compacted Soil	m^3	32.63
7	P.2.5	Laying Hardcore	m^3	18.30
	P.3	**Formwork Activity**		

8	P.3.1	Form Work Ground Beam	m^2	168.70
9	P.3.2	Formwork For Ground Floor Columns	m^2	122.45
10	P.3.3	Formwork For Ground Floor Slab	m^2	397.20
11	P.3.4	Formwork For 1st Floor Columns	m^2	102.50
12	P.3.5	Formwork For 1st Floor Slab	m^2	333.70
	P.4	**Concrete Work**		
13	P.4.1	Plain Concrete For Footing	m^3	54.00
14	P.4.2	Concreting For Foundation	m^3	18.00
15	P.4.3	Concreting For Ground Beams	m^3	12.29
16	P.4.4	Concreting For Ground Floor Columns	m^3	11.53
17	P.4.5	Concreting For Ground Floor Slab	m^3	41.97
18	P.4.6	Concreting For 1st Floor Columns	m^3	10.54
19	P.4.7	Concreting For 1st Floor Slab	m^3	32.98

	P.5	**Steel Works**		
20	P.5.1	Reinforcement For Spread Footings	ton	1.28
21	P.5.2	Reinforcement For Ground Beam	ton	2.01
22	P.5.3	Reinforcement For Ground Floor Columns	ton	1.91
23	P.5.4	Reinforcement For Ground Floor Slab	ton	4.02
24	P.5.5	Reinforcement For 1st Floor Columns	ton	1.51
25	P.5.6	Reinforcement For 1st Floor Slab	ton	3.19
	P.6	**Wall Construction**		
26	P.6.1	Laying Bricks For Ground Floor Wall Construction	m^2	173.60
27	P.6.2	Laying Bricks For 1st Floor Wall Construction	m^2	122.83
28	P.6.3	Laying Bricks For Roof Wall Construction	m^2	11.30
	P.7	**Insulation Works**		
29	P.7.1	Foundation Insulation	m^2	231.00

30	P.7.2	Wall And Toilets, Kitchen Insulation For Ground Floor	m²	116.00
31	P.7.3	Wall And Toilets, Kitchen Insulation For 1st Floor	m²	106.00
32	P.7.4	Roof Insulation	m²	244.00
	P.8	**Plastering Works**		
33	P.8.1	Plastering For Ground Floor Internal Walls, Ceiling	m²	478.10
34	P.8.2	Plastering For 1st Floor Internal Walls, Ceiling	m²	398.20
35	P.8.3	External Plastering	m²	375.00
	P.9	**Tiling Works**		
36	P.9.1	Floor Tiling For Ground Floor	m²	112.50
37	P.9.2	Wall, Toilets, Kitchen Tiling For Ground Floor	m²	68.00
38	P.9.3	Floor Tiling For 1st Floor	m²	100.50
39	P.9.4	Wall, Toilets, Kitchen Tiling For 1st Floor	m²	52.00

	P.10	**Painting Works**		
40	P.10.1	Painting For Ground Floor Internal Area	m²	478.10
41	P.10.2	Painting For 1st Floor Internal Area	m²	398.20
42	P.10.3	External Painting	m²	375.00
	P.11	**Carpentry Works**		
43	P.11.1	Doors	pcs	6.00
44	P.11.2	Cupboards	m	18.00
45	P.11.3	Wardrobes	m²	35.00
	P.12	**Roof Work**		
46	P.12.1	Roof Structure Work	m²	244.00
47	P.12.2	Roof Tile	pcs	780.00
	P.13	**Aluminum Works**		

48	P.13.1	Windows	pcs	18.00
49	P.13.2	Doors	pcs	2.00
	P.14	**Sanitary Fittings**		
50	P.14.1	Bathroom(Shower, WC) Work	pcs	3.00
51	P.14.2	Kitchen Work	pcs	1.00
	P.15	**Electrical Works**		
52	P.15.1	Piping Work For Ground Floor	m^2	137.00
53	P.15.2	Wiring Work For Ground Floor	m^2	137.00
54	P.15.3	Finishing Electrical Work For Ground Floor	m^2	137.00
55	P.15.4	Piping Work For 1st Floor	m^2	93.00
56	P.15.5	Wiring Work For 1st Floor	m^2	93.00
57	P.15.6	Finishing Electrical Work For 1st Floor	m^2	93.00

	P.16	**Sewage System Construction**		
58	P.16.1	Septic Tank	pcs	1.00
59	P.16.2	Well Construction	pcs	1.00
60	P.16.3	Sewage, Mechanical Plumbing Work	m²	230.00
	P.17	**Mechanical Work**		
61	P.17.1	Pumping System, Drainage	m²	230.00
62	P.17.2	Plumbing Job For Ground Floor	m²	137.00
63	P.17.3	Finishing For Ground Floor	m²	137.00
64	P.17.4	Plumbing Job For 1st Floor	m²	93.00
65	P.17.5	Finishing For 1st Floor	m²	93.00
66	P.17.6	Solar System	pcs	1.00
67	**P.18**	**Clearing And Finishing**	m²	300.00

Appendix C: Crew Table for the Assigned Activities

Table 8: Crew Table for the Assigned Activities

Crew Code	Crew Content		Activity ID	Activity Description	Unit	Quantity	Daily Output	Activity Duration (days)
Excavation & Earth Work:								
EX01 A	2 Workers 2 Shovels 1 Pickaxe	2 Buckets 1 Tape-measure	P.1.1	Site Layout, Installation, Marking	m^2	302.00	150.00	2.01
EX01 B			P.1.2	Cleaning and leveling	m^3	73.00	35.00	2.09
EX02	1 Equipment operator 1 Excavator	1 Tape-measure 1 worker	P.2.1	Excavation footing by hand and excavator	m^3	44.29	52.00	0.85
EX03	3 Workers 2 Shovels	1 Tape-measure 1 Wheelbarrow	P.2.2	Laying sand on footing's base	m^3	13.51	17.10	0.79
EX04	1 Loader driver 1 Dumper driver	5 Workers 5 Shovels	P.2.5	Laying Hardcore	m^3	18.30	130.20	0.14
EX05	3 Workers 2 Wheelbarrows	2 Shovels 1 Tape-measure	P.2.3	Back filing material	m^3	32.63	25.20	1.29

EX06	1 Hoist operator 2 Workers 1 Wheelbarrow 2 Compacting worker	2 Shovels 1 Tape-measure 1 Compactor	P.2.4	Compacted soil	m^3	32.63	15.10	2.16

Concrete Work:

CO01	1 Foremen 1 Pump operator 1 Pump controller 2 Spreading workers 2 Leveling workers 1 Mixer truck driver	1 Pump truck driver 1 Mixer truck 1 Pump truck 4 Shovels 2 Leveling stick	P.4.1	Plain Concrete for footing	m^3	54.00	43.90	1.23

CO02	1 Foremen 1 Pump operator 1 Pump controller 2 Vibrating workers 1 Mixer truck driver	1 Pump truck driver 1 Mixer truck 1 Pump truck 1 Vibrator 1 Form worker	P.4.2	Concreting for Foundation	m^3	18.00	96.80	0.19
			P.4.3	Concreting for Ground beams	m^3	12.29	96.80	0.13

CO03	1 Foremen 1 Pump operator 2 Pump controller 3 Vibrating workers 1 Form worker 1 Mixer truck driver	1 Pump truck driver 1 Mixer truck 1 Pump truck 1 Vibrator	P.4.4	Concreting for ground floor columns	m^3	11.53	26.70	0.43
			P.4.6	Concreting for 1st floor columns	m^3	10.54	26.70	0.39

CO04	1 Foremen 1 Pump operator 2 Pump controller 2 Vibrating workers 4 Shovels 1 Mixer truck driver 2 Leveling spatulas	1 Pump truck driver 1 Mixer truck 1 Pump truck 1 Vibrator 2 Spreading workers 2 Leveling workers	P.4.5	Concreting for ground floor slab	m^3	41.97	52.30	0.80
			P.4.7	Concreting for 1st floor slab	m^3	32.98	52.30	0.63

Steel Work:

ST01	2 Steel workers 1 Bending bench 2 Wire cutters(pliers) Fixing wire 1 Steel Cutting Machine 2 Tape-measures	1 Steel bending stick	P.5.1	Reinforcement for spread footings	ton	1.28	1.32	0.97
			P.5.2	Reinforcement for Ground beam	ton	2.01	1.32	1.52
			P.5.3	Reinforcement for ground floor Columns	ton	1.91	1.32	1.45
			P.5.4	Reinforcement for ground floor Slab	ton	4.02	1.32	3.05
			P.5.5	Reinforcement for 1st floor columns	ton	1.51	1.32	1.14
			P.5.6	Reinforcement for 1st floor Slab	ton	3.19	1.32	2.42

Formwork job:								
FW01 A	4 Skilled workers	Nails	P.3.1	Formwork Ground beam	m^2	168.70	35.20	4.79
FW01 B	1 Unskilled workers		P.3.2	Formwork for ground floor Columns	m^2	122.45	43.00	2.85
FW01 C	4 Hammers		P.3.3	Formwork for ground floor Slab	m^2	397.20	35.20	11.28
FW01 D	4 Tape-measure		P.3.4	Formwork for 1st floor columns	m^2	102.50	43.00	2.38
FW01 E	1 Saw		P.3.5	Formwork for 1st floor slab	m^2	333.70	35.20	9.48

Wall Construction:								
WA01	1 Brick layer	2 Buckets	P.6.1	Laying Bricks for ground floor wall construction	m^2	173.60	17.15	10.12
	1 Helper	1 Plumb line	P.6.2	Laying Bricks for 1st floor wall construction	m^2	122.83	17.15	7.16
	2 Spatulas	1 Tape-measure	P.6.3	Laying Bricks for roof wall construction	m^2	11.30	17.15	0.66

Plastering:								
Pl01 A	2 Plasterer 1 Helper	4 Buckets 1 Spool (reel) system	P.8.1	Plastering for ground floor internal walls, ceiling	m^2	478.10	128.80	3.71
Pl01 B	2 Rectangular spatulas	1 Mortar vessel	P.8.2	Plastering for 1st floor internal walls, Ceiling	m^2	398.20	128.80	3.09
Pl01 C	2 Trowels		P.8.3	External Plastering	m^2	375.00	120.00	3.13

Tiling Work:								
TL01 A	1 Tile layer 1 Helper 1 Shovel 1 Water-level	4 Buckets 1 Trowel 1 Tape-measure 1 Aluminum stick	P.9.1	Floor Tiling for ground floor	m^2	112.50	24.10	4.67
			P.9.3	Floor Tiling for 1st floor	m^2	100.50	24.10	4.17
TL01 B			P.12.2	Roof Tile	Pcs	780.00	390.00	2.00

TL02	1 Tile layer 1 Helper 1 Rectangular trowel 1 Drill hand mixer	2 Buckets 1 Mixing vessel 1 Water-level 1 Tape-measure	P.9.2	Wall, toilets, kitchen Tiling for ground floor	m^2	68.00	8.70	7.82
			P.9.4	Wall, toilets, kitchen Tiling for 1st floor	m^2	52.00	8.70	5.98

Painting Work:								
PA01	2 Painters 1 Helper 2 Roller brushes 2 Brushes	2 Buckets 2 Spatulas 1 Ladder	P.10.1	Painting for ground floor internal area	m^2	478.10	120.00	3.98
			P.10.2	Painting for 1st floor internal area	m^2	398.20	120.00	3.32

PA02	2 Painters 1 Helper 2 Roller brushes 2 Brushes	4 Buckets 2 Spatulas 1 Spool (reel) System	P.10.3	External Painting	m^2	375.00	105.50	3.55

Carpentry Works:								
WO01 A	1 Carpenter	1 Laborer	P.11.1	Doors	pcs	6.00	7.00	0.86
WO01 B	1 Drill	1 Tape-measure	P.11.2	Cupboards	m	18.00	5.40	3.33
WO01 C	1 Water-level 1 Tool bag	1 Carpenter's plane 1 Hammer	P.11.3	Wardrobes	m2	35.00	8.00	4.38

WO02	2 Carpenter 1 Drill 1 Water-level 1 Tool bag 1 Hoist	3 Laborer 1 Tape-measure 1 Carpenter's plane 1 Saw 2 Hammer	P.12.1	Roof Structure Work	m^2	244.00	61.00	4.00

Aluminum Works:								
AL01 A	1 Master workman 1 Qualified workman	1 Laborer 3 Drill(drilling, turning screws)	P.13.1	Windows	pcs	18.00	34.50	0.52
AL01 B	1 Hammer 1 Ladder	1 Tape-measure 1 Tool bag	P.13.2	Doors	pcs	2.00	4.00	0.50

Insulation Works:								
IS01 A	1 Master workman	1 Gas container	P.7.1	Foundation insulation	m^2	231.00	120.00	1.93
IS01 B	1 Fire spraying tool	1 Knife	P.7.2	Wall and toilets, Kitchen insulation for ground floor	m^2	116.00	35.00	3.31
IS01 C	1 Roller brush	2 Laborer	P.7.3	Wall and toilets, Kitchen insulation for 1st floor	m^2	106.00	35.00	3.03
IS01 D	1 Spatula		P.7.4	Roof Insulation	m^2	244.00	135.00	1.81

Electrical Works:								
EL01	1 Master workman	1 Water-level	P.15.1	Piping work for ground floor (Electrical)	m^2	137.00	130.00	1.05
	2 Laborer		P.15.2	Wiring work for ground floor (Electrical)	m^2	137.00	130.00	1.05
	1 Tape-measure		P.15.3	Finishing electrical work for ground floor	m^2	137.00	130.00	1.05
	1 Tool bag		P.15.4	Piping work for 1st floor (Electrical)	m^2	93.00	130.00	0.72
	2 Strings		P.15.5	Wiring work for 1st floor (Electrical)	m^2	93.00	130.00	0.72
	2 Pliers		P.15.6	Finishing electrical work for 1st floor	m^2	93.00	130.00	0.72

Sanitary Works:								
SA01	1 Master workman	2 Glue	P.14.1	Bathroom(shower, WC) Work	Pcs	3.00	2.00	1.50
	2 Laborer	1 Tool bag	P.14.2	Kitchen Work	pcs	1.00	2.00	0.50

Sewage system construction:								
SW01 A	1 Master workman 2 Laborer 1 Tape-measure 1 Hoist 2 Wheelbarrows	2 Glue 1 Tool bag 2 Buckets 1 Hoist operator	P.16.1	Septic tank	pcs	1.00	0.25	4.00
SW01 B			P.16.2	Well construction	pcs	1.00	0.15	6.67

Mechanical work:							
ME01 A	1 Skilled workman 2 Laborer	P.16.3	Sewage, Mechanical plumbing work	m^2	230.00	230.00	1.00
ME01 B		P.17.1	Pumping system, Drainage	m^2	230.00	115.00	2.00
ME01 C	1 Tape-measure 1 Tool bag 1 Pipe cutting machine	P.17.2	Plumbing job for ground floor (Mechanical)	m^2	137.00	45.00	3.04
ME01 D		P.17.4	Plumbing job for 1st floor (Mechanical)	m^2	93.00	45.00	2.07
ME01 E		P.17.3	Finishing for ground floor (Mechanical)	m^2	137.00	130.00	1.05
ME01 F		P.17.5	Finishing for 1st floor (Mechanical)	m^2	93.00	130.00	0.72
ME01 G		P.17.6	Solar system	pcs	1.00	1.00	1.00

Clearing and finishing:								
CL01	2 Laborer	1 Tool bag	P.18	Clearing and finishing	m^2	300.00	150.00	2.00

Appendix D: Crew Table Sorted According To Activity Sequences

Table 9: Crew Table Sorted According To Activity Sequences

No.	Activity ID	Description of work	Unit	Quantity	Resource Type	crew code	Daily Output	Activity Duration (days)	Activity Duration (Rounded days)	Men per Activity (no of men in one team)	Daily Total labor hours(labor hrs=Men per activity*8hr per day)	No. of Gang	Total Output (daily output*no of gang)	Required day job for whole gangs	Man-hours per activity
	P	**Villa Project**													
1	P.1.1	Site Layout, Installation, Marking	m2	302	Excavation & Earth Work:	EX01 A	150	2.01	3	2	16	3	450	0.67	10.74
2	P.1.2	Cleaning and leveling	m3	73	Excavation & Earth Work:	EX01 B	35	2.09	3	2	16	3	105	0.7	11.12
3	P.2.1	Excavation footing by hand and excavator	m3	44.29	Excavation & Earth Work:	EX02	52	0.85	1	2	16	3	156	0.28	4.54
4	P.2.2	Laying sand on footing's base	m3	13.51	Excavation & Earth Work:	EX03	17.1	0.79	1	3	24	3	51.3	0.26	6.32
5	P.7.1	Foundation insulation	m2	231	Insulation Works:	IS01 A	120	1.93	2	3	24	3	360	0.64	15.4
6	P.4.1	Plain Concrete for footing	m3	54	Concrete Work:	CO01	43.9	1.23	2	9	72	2	87.8	0.62	44.28

7	P.5.1	Reinforcement for spread footings	tons	1.28	Steel Work:	ST01	1.32	0.97	1	2	16	3	3.96	0.32	5.17
8	P.4.2	Concreting for Foundation	m3	18	Concrete Work:	CO02	96.8	0.19	1	8	64	2	193.6	0.09	5.95
9	P.3.1	Formwork Ground beam	m2	168.7	Formwork job:	FW01 A	35.2	4.79	5	5	40	3	105.6	1.6	63.9
10	P.5.2	Reinforcement for Ground beam	tons	2.01	Steel Work:	ST01	1.32	1.52	2	2	16	3	3.96	0.51	8.12
11	P.4.3	Concreting for Ground beam	m3	12.29	Concrete Work:	CO02	96.8	0.13	1	8	64	2	193.6	0.06	4.06
12	P.2.3	Back filing material	m3	32.63	Excavation & Earth Work:	EX05	25.2	1.29	2	3	24	3	75.6	0.43	10.36
13	P.2.4	Compacted soil	m3	32.63	Excavation & Earth Work:	EX06	15.1	2.16	3	5	40	3	45.3	0.72	28.81
14	P.2.5	Laying Hardcore	m3	18.3	Excavation & Earth Work:	EX04	130.2	0.14	1	7	56	2	260.4	0.07	3.94
15	P.3.2	Formwork for ground floor Columns	m2	122.45	Formwork job:	FW01 B	43	2.85	3	5	40	3	129	0.95	37.97
16	P.5.3	Reinforcement for ground floor Columns	tons	1.91	Steel Work:	ST01	1.32	1.45	2	2	16	3	3.96	0.48	7.72
17	P.4.4	Concreting for ground floor columns	m3	11.53	Concrete Work:	CO03	26.7	0.43	1	1	80	2	53.4	0.22	17.27
18	P.3.3	Formwork for ground floor Slab	m2	397.2	Formwork job:	FW01 C	35.2	11.28	12	5	40	3	105.6	3.76	150.45
19	P.5.4	Reinforcement for ground floor Slab	tons	4.02	Steel Work:	ST01	1.32	3.05	4	2	16	3	3.96	1.02	16.24

20	P.4.5	Concreting for ground floor slab	m3	41.97	Concrete Work:	CO04	52.3	0.80	1	12	96	2	104.6	0.4	38.52
21	P.3.4	Formwork for 1st floor columns	m2	102.5	Formwork job:	FW01 D	43	2.38	3	5	40	3	129	0.79	31.78
22	P.5.5	Reinforcement for 1st floor columns	tons	1.51	Steel Work:	ST01	1.32	1.14	2	2	16	3	3.96	0.38	6.1
23	P.4.6	Concreting for 1st floor columns	m3	10.54	Concrete Work:	CO03	26.7	0.39	1	10	80	2	53.4	0.2	15.79
24	P.3.5	Formwork for 1st floor slab	m2	333.7	Formwork job:	FW01 E	35.2	9.48	10	5	40	3	105.6	3.16	126.4
25	P.5.6	Reinforcement for 1st floor Slab	tons	3.19	Steel Work:	ST01	1.32	2.42	3	2	16	3	3.96	0.81	12.89
26	P.4.7	Concreting for 1st floor slab	m3	32.98	Concrete Work:	CO04	52.3	0.63	1	12	96	2	104.6	0.32	30.27
27	P.16.1	Septic tank	pcs	1	Sewage system construction:	SW01 A	0.25	4.00	4	4	32	3	0.75	1.33	42.67
28	P.16.2	Well construction	pcs	1	Sewage system construction:	SW01 B	0.15	6.67	7	4	32	3	0.45	2.22	71.11
29	P.16.3	Sewage, Mechanical plumbing work	m2	230	Mechanical work:	ME01 A	230	1.00	1	3	24	4	920	0.25	6
30	P.6.1	Laying Bricks for ground floor wall construction	m2	173.6	Wall Construction:	WA01	17.15	10.12	11	2	16	4	68.6	2.53	40.49
31	P.17.1	Pumping system, Drainage	m2	230	Mechanical work:	ME01 B	115	2.00	2	3	24	4	460	0.5	12
32	P.17.2	Plumbing job for ground floor (Mechanical)	m2	137	Mechanical work:	ME01 C	45	3.04	4	3	24	4	180	0.76	18.27
33	P.15.1	Piping work for ground floor (Electrical)	m2	137	Electrical Works:	EL01	130	1.05	2	3	24	4	520	0.26	6.32

34	P.6.2	Laying Bricks for 1st floor wall construction	m2	122.8	Wall Construction:	WA01	17.15	7.16	8	2	16	4	68.6	1.79	28.65
35	P.6.3	Laying Bricks for roof wall construction	m2	11.3	Wall Construction:	WA01	17.15	0.66	1	2	16	4	68.6	0.16	2.64
36	P.17.4	Plumbing job for 1st floor (Mechanical)	m2	93	Mechanical work:	ME01 D	45	2.07	3	3	24	4	180	0.52	12.4
37	P.15.4	Piping work for 1st floor (Electrical)	m2	93	Electrical Works:	EL01	130	0.72	1	3	24	4	520	0.18	4.29
38	P.12.1	Roof Structure Work	m2	244	Carpentry Works:	WO02	61	4.00	4	5	40	3	183	1.33	53.33
39	P.7.2	Wall and toilets, Kitchen insulation for ground floor	m2	116	Insulation Works:	IS01 B	35	3.31	4	3	24	3	105	1.1	26.51
40	P.7.3	Wall and toilets, Kitchen insulation for 1st floor	m2	106	Insulation Works:	IS01 C	35	3.03	4	3	24	3	105	1.01	24.23
41	P.15.2	Wiring work for ground floor (Electrical)	m2	137	Electrical Works:	EL01	130	1.05	2	3	24	4	520	0.26	6.32
42	P.15.5	Wiring work for 1st floor (Electrical)	m2	93	Electrical Works:	EL01	130	0.72	1	3	24	4	520	0.18	4.29
43	P.7.4	Roof Insulation	m2	244	Insulation Works:	IS01 D	135	1.81	2	3	24	3	405	0.6	14.46
44	P.12.2	Roof Tile	Pcs	780	Tiling Work:	TL01 B	390	2.00	2	2	16	4	1560	0.5	8
45	P.8.1	Plastering for ground floor internal walls, ceiling	m2	478.1	Plastering:	Pl01 A	128.8	3.71	4	3	24	4	515.2	0.93	22.27

46	P.8.2	Plastering for 1st floor internal walls, Ceiling	m2	398.2	Plastering:	Pl01 B	128.8	3.09	4	3	24	4	515.2	0.77	18.55
47	P.9.1	Floor Tiling for ground floor	m2	112.5	Tiling Work:	TL01 A	24.1	4.67	5	2	16	4	96.4	1.17	18.67
48	P.9.2	Wall, toilets, kitchen Tiling for ground floor	m2	68	Tiling Work:	TL02	8.7	7.82	8	2	16	4	34.8	1.95	31.26
49	P.9.3	Floor Tiling for 1st floor	m2	100.5	Tiling Work:	TL01 A	24.1	4.17	5	2	16	4	96.4	1.04	16.68
50	P.9.4	Wall, toilets, kitchen Tiling for 1st floor	m2	52	Tiling Work:	TL02	8.7	5.98	6	2	16	4	34.8	1.49	23.91
51	P.13.1	Windows (Aluminum)	pcs	18	Aluminum Works:	AL01 A	34.5	0.52	1	3	24	4	138	0.13	3.13
52	P.13.2	Doors (Aluminum)	pcs	2	Aluminum Works:	AL01 B	4	0.50	1	3	24	4	16	0.13	3
53	P.17.6	Solar system	pcs	1	Mechanical work:	ME01 G	1	1.00	1	3	24	4	4	0.25	6
54	P.8.3	External Plastering	m2	375	Plastering:	Pl01 C	120	3.13	4	3	24	4	480	0.78	18.75
55	P.10.1	Painting for ground floor internal area	m2	478.1	Painting Work:	PA01	120	3.98	4	3	24	4	480	1	23.91
56	P.10.2	Painting for 1st floor internal area	m2	398.2	Painting Work:	PA01	120	3.32	4	3	24	4	480	0.83	19.91
57	P.11.1	Doors (Carpentry work)	pcs	6	Carpentry Works:	WO01 A	7	0.86	1	2	16	3	21	0.29	4.57
58	P.14.1	Bathroom(shower, WC) sanitary fitting work	pcs	3	Sanitary Works:	SA01	2	1.50	2	3	24	3	6	0.5	12
59	P.14.2	Kitchen sanitary fitting work	pcs	1	Sanitary Works:	SA01	2	0.50	1	3	24	3	6	0.1	4
60	P.15.3	Finishing electrical work for ground floor	m2	137	Electrical Works:	EL01	130	1.05	2	3	24	4	520	0.26	6.32

61	P.15.6	Finishing electrical work for 1st floor	m2	93	Electrical Works:	EL01	130	0.72	1	3	24	4	520	0.18	4.29
62	P.17.3	Finishing for ground floor (Mechanical)	m2	137	Mechanical work:	ME01 E	130	1.05	2	3	24	4	520	0.26	6.32
63	P.11.2	Cupboards (Carpentry work)	m	18	Carpentry Works:	WO01 B	5.4	3.33	4	2	16	3	16.2	1.11	17.78
64	P.11.3	Wardrobes (Carpentry work)	m2	35	Carpentry Works:	WO01 C	8	4.38	5	2	16	3	24	1.46	23.33
65	P.17.5	Finishing for 1st floor (Mechanical)	m2	93	Mechanical work:	ME01 F	130	0.72	1	3	24	4	520	0.18	4.29
66	P.10.3	External Painting	m2	375	Painting Work:	PA02	105.5	3.55	4	3	24	4	422	0.89	21.33
67	P.18	Clearing and finishing	m2	300		CL01	150	2.00	2	2	16	3	450	0.67	10.67

Appendix E: Activity Sequencing and Activities Relationships Table

Table 10: Activity Sequencing and Activities Relationships Table

No.	ID No.	Description of work	Unit	Quantity	Duration	Predecessor (s) NO.	Predecessor (s) ID	Predecessor (s) Name	Relationship type	Lag Time	Buffer time (B)	Total Buffer
	P	**Villa Project**										
1	P.1.1	Site Layout, Installation, Marking	m2	302.00	3.00					0	0	0
2	P.1.2	Cleaning and leveling	m3	73.00	3.00	**1**	P.1.1	Site Layout, Installation, Marking	SS	0	3	3
3	P.2.1	Excavation footing by hand and excavator	m3	44.29	1.00	**2**	P.1.2	Cleaning and leveling	FS	0	3	3
4	P.2.2	Laying sand on footing's base	m3	13.51	1.00	**3**	P.2.1	Excavation footing by hand and excavator	FS	0	3	3
5	P.7.1	Foundation insulation	m2	231.00	2.00	**3**	P.2.1	Excavation footing by hand and excavator	FS	1	3	4
6	P.4.1	Plain Concrete for footing	m3	54.00	2.00	**4**	P.2.2	Laying sand on footing's base	FS	0	3	3
7	P.5.1	Reinforcement for spread footings	tons	1.28	1.00	**6**	P.4.1	Plain Concrete for footing	FS	5	3	8

8	P.4.2	Concreting for Foundation	m3	18.00	1.00	**7**	P.5.1	Reinforcement for spread footings	FS	0	3	3
9	P.3.1	Formwork Ground beam	m2	168.70	5.00	**8**	P.4.2	Concreting for Foundation	FS	5	3	8
10	P.5.2	Reinforcement for Ground beam	tons	2.01	2.00	**9**	P.3.1	Formwork Ground beam	FS	0	3	3
11	P.4.3	Concreting for Ground beam	m3	12.29	1.00	**10**	P.5.2	Reinforcement for Ground beam	FS	0	3	3
12	P.2.3	Back filing material	m3	32.63	2.00	**11**	P.4.3	Concreting for Ground beam	FS	5	3	8
13	P.2.4	Compacted soil	m3	32.63	3.00	**12**	P.2.3	Back filing material	FS	0	3	3
14	P.2.5	Laying Hardcore	m3	18.30	1.00	**13**	P.2.4	Compacted soil	FS	0	3	3
15	P.3.2	Formwork for ground floor Columns	m2	122.45	3.00	**11**	P.4.3	Concreting for Ground beam	FS	5	3	8
16	P.5.3	Reinforcement for ground floor Columns	tons	1.91	2.00	**15**	P.3.2	Formwork for ground floor Columns	FS	0	3	3
17	P.4.4	Concreting for ground floor columns	m3	11.53	1.00	**16**	P.5.3	Reinforcement for ground floor Columns	FS	0	3	3
18	P.3.3	Formwork for ground floor Slab	m2	397.20	12.00	**17**	P.4.4	Concreting for ground floor columns	FS	5	3	8
19	P.5.4	Reinforcement for ground floor Slab	tons	4.02	4.00	**18**	P.3.3	Formwork for ground floor Slab	FS	0	3	3

20	P.4.5	Concreting for ground floor slab	m3	41.97	1.00	**19**	P.5.4	Reinforcement for ground floor Slab	FS	0	3	3
21	P.3.4	Formwork for 1st floor columns	m2	102.5	3.00	**20**	P.4.5	Concreting for ground floor slab	FS	5	3	8
22	P.5.5	Reinforcement for 1st floor columns	tons	1.51	2.00	**21**	P.3.4	Formwork for 1st floor columns	FS	0	3	3
23	P.4.6	Concreting for 1st floor columns	m3	10.54	1.00	**22**	P.5.5	Reinforcement for 1st floor columns	FS	0	3	3
24	P.3.5	Formwork for 1st floor slab	m2	333.70	10.00	**23**	P.4.6	Concreting for 1st floor columns	FS	5	3	8
25	P.5.6	Reinforcement for 1st floor Slab	tons	3.19	3.00	**24**	P.3.5	Formwork for 1st floor slab	FS	0	3	3
26	P.4.7	Concreting for 1st floor slab	m3	32.98	1.00	**25**	P.5.6	Reinforcement for 1st floor Slab	FS	0	3	3
27	P.16.1	Septic tank	pcs	1.00	4.00	**26**	P.4.7	Concreting for 1st floor slab	FS	5	3	8
28	P.16.2	Well construction	pcs	1.00	7.00	**27**	P.16.1	Septic tank	SS	0	3	3
29	P.16.3	Sewage, Mechanical plumbing work	m2	230.00	1.00	**27**	P.16.1	Septic tank	SS	0	3	3
30	P.6.1	Laying Bricks for ground floor wall construction	m2	173.60	11.00	**26**	P.4.7	Concreting for 1st floor slab	FS	0	3	3
31	P.17.1	Pumping system, Drainage	m2	230.00	2.00	**26**	P.4.7	Concreting for 1st floor slab	FS	0	3	3

32	P.17.2	Plumbing job for ground floor (Mechanical)	m2	137.00	4.00	**31**	P.17.1	Pumping system, Drainage	FS	0	3	3
33	P.15.1	Piping work for ground floor (Electrical)	m2	137.00	2.00	**26**	P.4.7	Concreting for 1st floor slab	FS	0	3	3
34	P.6.2	Laying Bricks for 1st floor wall construction	m2	122.8	8.00	**30**	P.6.1	Laying Bricks for ground floor wall construction	FS	0	3	3
35	P.6.3	Laying Bricks for roof wall construction	m2	11.30	1.00	**34**	P.6.2	Laying Bricks for 1st floor wall construction	FS	0	3	3
36	P.17.4	Plumbing job for 1st floor (Mechanical)	m2	93.00	3.00	**32**	P.17.2	Plumbing job for ground floor (Mechanical)	FS	0	3	3
37	P.15.4	Piping work for 1st floor (Electrical)	m2	93.00	1.00	**33**	P.15.1	Piping work for ground floor (Electrical)	FS	0	3	3
38	P.12.1	Roof Structure Work	m2	244.00	4.00	**26**	P.4.7	Concreting for 1st floor slab	FS	7	3	10
39	P.7.2	Wall and toilets, Kitchen insulation for ground floor	m2	116.00	4.00	**30**	P.6.1	Laying Bricks for ground floor wall construction	FS	3	3	6
40	P.7.3	Wall and toilets, Kitchen insulation for 1st floor	m2	106.00	4.00	**34**	P.6.2	Laying Bricks for 1st floor wall construction	FS	3	3	6
41	P.15.2	Wiring work for ground floor (Electrical)	m2	137.00	2.00	**39**	P.7.2	Wall and toilets, Kitchen insulation for ground floor	FS	0	3	3
42	P.15.5	Wiring work for 1st floor (Electrical)	m2	93.00	1.00	**41**	P.15.2	Wiring work for ground floor (Electrical)	FS	0	3	3
43	P.7.4	Roof Insulation	m2	244.00	2.00	**38**	P.12.1	Roof Structure Work	FS	0	3	3

44	P.12.2	Roof Tile	Pcs	780.00	2.00	**43**	P.7.4	Roof Insulation	FS	3	3	6
45	P.8.1	Plastering for ground floor internal walls, ceiling	m2	478.10	4.00	**41**	P.15.2	Wiring work for ground floor (Electrical)	FS	0	3	3
46	P.8.2	Plastering for 1st floor internal walls, Ceiling	m2	398.20	4.00	**45**	P.8.1	Plastering for ground floor internal walls, ceiling	FS	0	3	3
47	P.9.1	Floor Tiling for ground floor	m2	112.50	5.00	**45**	P.8.1	Plastering for ground floor internal walls, ceiling	FS	3	3	6
48	P.9.2	Wall, toilets, kitchen Tiling for ground floor	m2	68.00	8.00	**47**	P.9.1	Floor Tiling for ground floor	SS	2	3	5
49	P.9.3	Floor Tiling for 1st floor	m2	100.50	5.00	**48**	P.9.2	Wall, toilets, kitchen Tiling for ground floor	FS	0	3	3
50	P.9.4	Wall, toilets, kitchen Tiling for 1st floor	m2	52.00	6.00	**49**	P.9.3	Floor Tiling for 1st floor	SS	0	3	3
51	P.13.1	Windows (Aluminum)	pcs	18.00	1.00	**46**	P.8.2	Plastering for 1st floor internal walls, Ceiling	FS	3	3	6
52	P.13.2	Doors (Aluminum)	pcs	2.00	1.00	**46**	P.8.2	Plastering for 1st floor internal walls, Ceiling	FS	3	3	6
53	P.17.6	Solar system	pcs	1.00	1.00	**38**	P.12.1	Roof Structure Work	FS	7	3	10
54	P.8.3	External Plastering	m2	375.00	4.00	**46**	P.8.2	Plastering for 1st floor internal walls, Ceiling	FS	0	3	3
55	P.10.1	Painting for ground floor internal area	m2	478.10	4.00	**51**	P.13.1	Windows (Aluminum)	FS	0	3	3

56	P.10.2	Painting for 1st floor internal area	m2	398.20	4.00	**55**	P.10.1	Painting for ground floor internal area	FS	0	3	3
57	P.11.1	Doors (Carpentry work)	pcs	6.00	1.00	**56**	P.10.2	Painting for 1st floor internal area	FS	3	3	6
58	P.14.1	Bathroom(shower, WC) sanitary fitting work	pcs	3.00	2.00	**56**	P.10.2	Painting for 1st floor internal area	FS	4	3	7
59	P.14.2	Kitchen sanitary fitting work	pcs	1.00	1.00	**58**	P.14.1	Bathroom(shower, WC) sanitary fitting work	SS	2	3	5
60	P.15.3	Finishing electrical work for ground floor	m2	137.00	2.00	**55**	P.10.1	Painting for ground floor internal area	FS	5	3	8
61	P.15.6	Finishing electrical work for 1st floor	m2	93.00	1.00	**56**	P.10.2	Painting for 1st floor internal area	FS	5	3	8
62	P.17.3	Finishing for ground floor (Mechanical)	m2	137.00	2.00	**55**	P.10.1	Painting for ground floor internal area	FS	6	3	9
63	P.11.2	Cupboards (Carpentry work)	m	18.00	4.00	**57**	P.11.1	Doors (Carpentry work)	FS	0	3	3
64	P.11.3	Wardrobes (Carpentry work)	m2	35.00	5.00	**57**	P.11.1	Doors (Carpentry work)	FS	0	3	3
65	P.17.5	Finishing for 1st floor (Mechanical)	m2	93.00	1.00	**56**	P.10.2	Painting for 1st floor internal area	FS	3	3	6
66	P.10.3	External Painting	m2	375.00	4.00	**54**	P.8.3	External Plastering	FS	7	3	10
67	P.18	Clearing and finishing	m2	300.00	2.00					0	3	3

Appendix F: Cost Calculations Table of Villa Project

Table 11: Cost Calculations Table of Villa Project

ID No.	Description of work	Unit	Quantity	Unit Price(TL/ unit)	Total(TL)	Total Cost / Activity (TL)	Cost Percentage
P	**Villa Project**						
P.1	**Site Preparation**						
P.1.1	Site Layout, Installation, Marking	m²	302.00	-	1,000.00		
P.1.2	Cleaning and leveling	m³	73.00	4.00	292.00		
				Sum:		**1,292.00**	**0.61%**
P.2	**Earth work**						
P.2.1	Excavation footing by hand and excavator	m³	44.29	27.00	1,195.83		
P.2.2	Laying sand on footing's base	m³	13.51	33.00	445.83		
P.2.3	Back filing material	m³	32.63	11.00	358.93		
P.2.4	Compacted soil	m³	32.63	30.00	978.90		
P.2.5	Laying Hardcore	m³	18.30	35.00	640.50		
				Sum:		**3,619.99**	**1.71%**

P.3	**Formwork Activity**						
P.3.1	Form Work Ground beam	m^2	168.70	19.00	3,205.30		
P.3.2	Formwork for ground floor Columns	m^2	122.45	19.00	2,326.55		
P.3.3	Formwork for ground floor Slab	m^2	397.20	19.00	7,546.80		
P.3.4	Formwork for 1st floor columns	m^2	102.50	19.00	1,947.50		
P.3.5	Formwork for 1st floor slab	m^2	333.70	19.00	6,340.30		
				Sum:		**21,366.45**	**10.10%**
P.4	**Concrete Work**						
P.4.1	Plain Concrete for footing	m^3	54.00	102.00	5,508.00		
P.4.2	Concreting for Foundation	m^3	18.00	111.00	1,998.00		
P.4.3	Concreting for Ground beams	m^3	12.29	111.00	1,364.19		
P.4.4	Concreting for ground floor columns	m^3	11.53	111.00	1,279.83		
P.4.5	Concreting for ground floor slab	m^3	41.97	111.00	4,658.67		
P.4.6	Concreting for 1st floor columns	m^3	10.54	111.00	1,169.94		

P.4.7	Concreting for 1st floor slab	m³	32.98	111.00	3,660.78		
				Sum:		**19,639.41**	**9.28%**
P.5	**Steel Works**						
P.5.1	Reinforcement for spread footings	ton	1.28	2,280.00	2,918.40		
P.5.2	Reinforcement for Ground beam	ton	2.01	2,280.00	4,582.80		
P.5.3	Reinforcement for ground floor Columns	ton	1.91	2,280.00	4,354.80		
P.5.4	Reinforcement for ground floor Slab	ton	4.02	2,280.00	9,165.60		
P.5.5	Reinforcement for 1st floor columns	ton	1.51	2,280.00	3,442.80		
P.5.6	Reinforcement for 1st floor Slab	ton	3.19	2,280.00	7,273.20		
				Sum:		**31,737.60**	**15.00%**
P.6	**Wall Construction**						
P.6.1	Laying Bricks for ground floor wall construction	m²	173.60	40.00	6,944.00		
P.6.2	Laying Bricks for 1st floor wall construction	m²	122.83	40.00	4,913.20		

P.6.3	Laying Bricks for roof wall construction	m²	11.30	31.00	350.30		
				Sum:		**12,207.50**	**5.77%**
P.7	**Insulation Works**						
P.7.1	Foundation insulation	m²	231.00	34.00	7,854.00		
P.7.2	Wall and toilets, Kitchen insulation for ground floor	m²	116.00	34.00	3,944.00		
P.7.3	Wall and toilets, Kitchen insulation for 1st floor	m²	106.00	34.00	3,604.00		
P.7.4	Roof Insulation	m²	244.00	19.00	4,636.00		
				Sum:		**20,038.00**	**9.47%**
P.8	**Plastering works**						
P.8.1	Plastering for ground floor internal walls, ceiling	m²	478.10	12.00	5,737.20		
P.8.2	Plastering for 1st floor internal walls, Ceiling	m²	398.20	12.00	4,778.40		
P.8.3	External Plastering	m²	375.00	9.00	3,375.00		
				Sum:		**13,890.60**	**6.57%**
P.9	**Tiling Works**						

P.9.1	Floor Tiling for ground floor	m²	112.50	50.00	5,625.00		
P.9.2	Wall, toilets, kitchen Tiling for ground floor	m²	68.00	39.00	2,652.00		
P.9.3	Floor Tiling for 1st floor	m²	100.50	50.00	5,025.00		
P.9.4	Wall, toilets, kitchen Tiling for 1st floor	m²	52.00	39.00	2,028.00		
				Sum:		**15,330.00**	**7.25%**
P.10	**Painting works**						
P.10.1	Painting for ground floor internal area	m²	478.10	10.00	4,781.00		
P.10.2	Painting for 1st floor internal area	m²	398.20	10.00	3,982.00		
P.10.3	External Painting	m²	375.00	8.00	3,000.00		
				Sum:		**11,763.00**	**5.56%**
P.11	**Carpentry works**						
P.11.1	Doors	pcs	6.00	225.00	1,350.00		
P.11.2	Cupboards	m	18.00	440.00	7,920.00		
P.11.3	Wardrobes	m²	35.00	325.00	11,375.00		
				Sum:		**20,645.00**	**9.76%**

P.12	**Roof Work**						
P.12.1	Roof Structure Work	m²	244.00	19.15	4,672.60		
P.12.2	Roof Tile	Pcs	780.00	1.70	1,326.00		
				Sum:		**5,998.60**	**2.84%**
P.13	**Aluminum Works**						
P.13.1	Windows	pcs	18.00	235.00	4,230.00		
P.13.2	Doors	pcs	2.00	314.00	628.00		
				Sum:		**4,858.00**	**2.30%**
P.14	**Sanitary Fittings**						
P.14.1	Bathroom(shower, WC) Work	pcs	3.00	560.00	1,680.00		
P.14.2	Kitchen Work	pcs	1.00	400.00	400.00		
				Sum:		**2,080.00**	**0.98%**
P.15	**Electrical Works**						
P.15.1	Piping work for ground floor	m²	137.00	7.00	959.00		
P.15.2	Wiring work for ground floor	m²	137.00	7.00	959.00		
P.15.3	Finishing electrical work for ground floor	m²	137.00	7.00	959.00		
P.15.4	Piping work for 1st floor	m²	93.00	7.00	651.00		

P.15.5	Wiring work for 1st floor	m²	93.00	7.00	651.00		
P.15.6	Finishing electrical work for 1st floor	m²	93.00	7.00	651.00		
				Sum:		**4,830.00**	**2.28%**
P.16	**Sewage system construction**						
P.16.1	Septic tank	pcs	1.00	1,100.00	1,100.00		
P.16.2	Well construction	pcs	1.00	2,000.00	2,000.00		
P.16.3	Sewage, Mechanical plumbing work	m²	230.00	8.70	2,001.00		
				Sum:		**5,101.00**	**2.41%**
P.17	**Mechanical work**						
P.17.1	Pumping system, Drainage	m²	230.00	20.00	4,600.00		
P.17.2	Plumbing job for ground floor	m²	137.00	20.00	2,740.00		
P.17.3	Finishing for ground floor	m²	137.00	20.00	2,740.00		
P.17.4	Plumbing job for 1st floor	m²	93.00	20.00	1,860.00		
P.17.5	Finishing for 1st floor	m²	93.00	20.00	1,860.00		
P.17.6	Solar system	pcs	1.00	2,750.00	2,750.00		

				Sum:		**16,550.00**	**7.82%**
P.18	**Clearing and finishing**	m²	300.00	2.00	600.00		
				Sum:		**600.00**	**0.28%**
				Total Cost (TL):		**211,547.15**	**100.00%**
				Total Area for each Villa(m^2):		**230**	
				Cost/ m^2: (TL)		**919.77**	
				Total Cost of 20 villas (TL):		**4,230,943.00**	

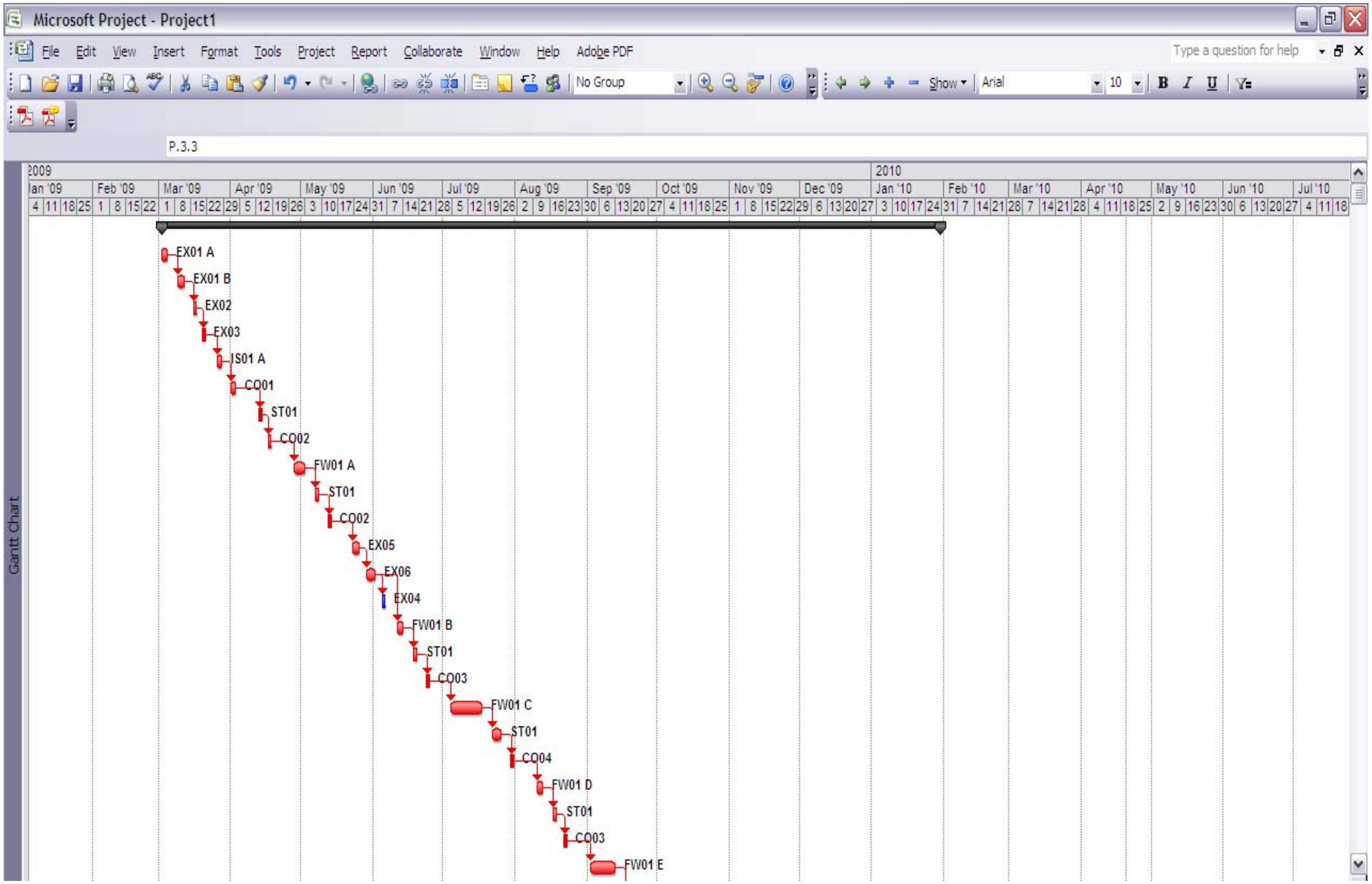
Appendix G: Reports Of Microsoft Project

Table 12: Microsoft Project Work Break Down Structure Table

1 Project1 Sun 3/1/09 Fri 1/29/10

ID	Activity ID	ID	Task Name	Duration	Start	Finish	Predecessors	Resource Names
1	**P**	**1**	**Villa Project**	**287 days**	**Mon 3/2/09**	**Fri 1/29/10**		
2	P.1.1	2	Site Layout, Installation,Marking	3 days	Mon 3/2/09	Wed 3/4/09		EX01 A
3	P.1.2	3	Cleaning and leveling	3 days	Mon 3/9/09	Wed 3/11/09	2FS+3 days	EX01 B
4	P.2.1	4	Excavation footing by hand and excavato	1 day	Mon 3/16/09	Mon 3/16/09	3FS+3 days	EX02
5	P.2.2	5	Laying sand on footing's base	1 day	Fri 3/20/09	Fri 3/20/09	4FS+3 days	EX03
6	P.7.1	6	Foundation insulation	2 days	Thu 3/26/09	Fri 3/27/09	5FS+4 days	IS01 A
7	P.4.1	7	Plain Concrete for footing	2 days	Wed 4/1/09	Thu 4/2/09	6FS+3 days	CO01
8	P.5.1	8	Reinforcement for spread footings	1 day	Mon 4/13/09	Mon 4/13/09	7FS+8 days	ST01
9	P.4.2	9	Concreting for Foundation	1 day	Fri 4/17/09	Fri 4/17/09	8FS+3 days	CO02
10	P.3.1	10	Formwork Ground beam	5 days	Tue 4/28/09	Sat 5/2/09	9FS+8 days	FW01 A
11	P.5.2	11	Reinforcement for Ground beam	2 days	Thu 5/7/09	Fri 5/8/09	10FS+3 days	ST01
12	P.4.3	12	Concreting for Ground beam	1 day	Wed 5/13/09	Wed 5/13/09	11FS+3 days	CO02
13	P.2.3	13	Back filing material	2 days	Sat 5/23/09	Mon 5/25/09	12FS+8 days	EX05
14	P.2.4	14	Compacted soil	3 days	Fri 5/29/09	Mon 6/1/09	13FS+3 days	EX06
15	P.2.5	15	Laying HardCore	1 day	Fri 6/5/09	Fri 6/5/09	14FS+3 days	EX04
16	P.3.2	16	Formwork for ground floor Columns	3 days	Thu 6/11/09	Sat 6/13/09	14FS+8 days	FW01 B
17	P.5.3	17	Reinforcement for ground floor Columns	2 days	Thu 6/18/09	Fri 6/19/09	16FS+3 days	ST01
18	P.4.4	18	Concreting for ground floor columns	1 day	Wed 6/24/09	Wed 6/24/09	17FS+3 days	CO03
19	P.3.3	19	Formwork for ground floor Slab	12 days	Sat 7/4/09	Fri 7/17/09	18FS+8 days	FW01 C
20	P.5.4	20	Reinforcement for ground floor Slab	4 days	Wed 7/22/09	Sat 7/25/09	19FS+3 days	ST01
21	P.4.5	21	Concreting for ground floor slab	1 day	Thu 7/30/09	Thu 7/30/09	20FS+3 days	CO04
22	P.3.4	22	Formwork for 1st floor columns	3 days	Mon 8/10/09	Wed 8/12/09	21FS+8 days	FW01 D
23	P.5.5	23	Reinforcement for 1st floor columns	2 days	Mon 8/17/09	Tue 8/18/09	22FS+3 days	ST01
24	P.4.6	24	Concreting for 1st floor columns	1 day	Sat 8/22/09	Sat 8/22/09	23FS+3 days	CO03
25	P.3.5	25	Formwork for 1st floor slab	10 days	Wed 9/2/09	Sat 9/12/09	24FS+8 days	FW01 E
26	P.5.6	26	Reinforcement for 1st floor Slab	3 days	Thu 9/17/09	Sat 9/19/09	25FS+3 days	ST01
27	P.4.7	27	Concreting for 1st floor slab	1 day	Thu 9/24/09	Thu 9/24/09	26FS+3 days	CO04
28	P.16.1	28	Septic tank	4 days	Mon 10/5/09	Thu 10/8/09	27FS+8 days	SW01 A
29	P.16.2	29	Well construction	7 days	Thu 10/8/09	Thu 10/15/09	28SS+3 days	SW01 B
30	P.16.3	30	Sweage, Mechanical plumbing work	1 day	Tue 10/13/09	Tue 10/13/09	28FS+3 days	ME01 A
31	P.6.1	31	Laying Bricks for ground floor wall constru	11 days	Tue 9/29/09	Sat 10/10/09	27FS+3 days	WA01
32	P.17.1	32	Pumping system,Drainage	2 days	Sat 10/17/09	Mon 10/19/09	30FS+3 days	ME01 B
33	P.17.2	33	Plumbing job for ground floor (Mechanica	4 days	Fri 10/23/09	Tue 10/27/09	32FS+3 days	ME01 C
34	P.15.1	34	Piping work for ground floor (Electrical)	2 days	Fri 10/2/09	Sat 10/3/09	31SS+3 days	EL01
35	P.6.2	35	Laying Bricks for 1st floor wall constructic	8 days	Thu 10/15/09	Fri 10/23/09	31FS+3 days	WA01
36	P.6.3	36	Laying Bricks for roof wall construction	1 day	Wed 10/28/09	Wed 10/28/09	35FS+3 days	WA01
37	P.17.4	37	Plumbing job for 1st floor (Mechanical)	3 days	Sat 10/31/09	Tue 11/3/09	33FS+3 days	ME01 D

38	P.15.4	38		Piping work for 1st floor (Electrical)	1 day	Thu 10/8/09	Thu 10/8/09	34FS+3 days	EL01
39	P.12.1	39		Roof Structure Work	4 days	Wed 10/7/09	Sat 10/10/09	27FS+10 days	WO02
40	P.7.2	40		Wall and toilets,Kitchen insulation for gro	4 days	Mon 10/19/09	Thu 10/22/09	31FS+6 days	IS01 B
41	P.7.3	41		Wall and toilets,Kitchen insulation for 1st	4 days	Sat 10/31/09	Wed 11/4/09	35FS+6 days	IS01 C
42	P.15.2	42		Wiring work for ground floor (Electrical)	2 days	Tue 10/27/09	Wed 10/28/09	40FS+3 days	EL01
43	P.15.5	43		Wiring work for 1st floor (Electrical)	1 day	Mon 11/2/09	Mon 11/2/09	42FS+3 days	EL01
44	P.7.4	44		Roof Insulation	2 days	Mon 11/9/09	Tue 11/10/09	41FS+3 days	IS01 D
45	P.12.2	45		Roof Tile	2 days	Wed 11/18/09	Thu 11/19/09	44FS+6 days	TL01 B
46	P.8.1	46		Plastering for ground floor internal walls,c	4 days	Mon 11/2/09	Thu 11/5/09	42FS+3 days	Pl01 A
47	P.8.2	47		Plastering for 1st floor internal walls,Ceili	4 days	Tue 11/10/09	Fri 11/13/09	46FS+3 days	Pl01 B
48	P.9.1	48		Floor Tiling for ground floor	5 days	Fri 11/13/09	Wed 11/18/09	46FS+6 days	TL01 A
49	P.9.2	49		Wall,toilets,kitchen Tiling for ground floor	8 days	Wed 11/25/09	Thu 12/3/09	48FS+5 days	TL02
50	P.9.3	50		Floor Tiling for 1st floor	5 days	Tue 12/8/09	Sat 12/12/09	49FS+3 days	TL01 A
51	P.9.4	51		Wall,toilets,kitchen Tiling for 1st floor	6 days	Thu 12/17/09	Wed 12/23/09	50FS+3 days	TL02
52	P.13.1	52		Windows (Aluminium)	1 day	Sat 11/21/09	Sat 11/21/09	47FS+6 days	AL01 A
53	P.13.2	53		Doors (Aluminium)	1 day	Mon 11/30/09	Mon 11/30/09	52FS+6 days	AL01 B
54	P.17.6	54		Solar system	1 day	Wed 12/2/09	Wed 12/2/09	45FS+10 days	ME01 G
55	P.8.3	55		External Plastering	4 days	Wed 11/18/09	Sat 11/21/09	47FS+3 days	Pl01 C
56	P.10.1	56		Painting for ground floor internal area	4 days	Fri 12/4/09	Tue 12/8/09	53FS+3 days	PA01
57	P.10.2	57		Painting for 1st floor internal area	4 days	Sat 12/12/09	Wed 12/16/09	56FS+3 days	PA01
58	P.11.1	58		Doors (Carpentry work)	1 day	Thu 12/24/09	Thu 12/24/09	57FS+6 days	WO01 A
59	P.14.1	59		Bathroom(shower,WC) sanitary fitting wo	2 days	Fri 12/25/09	Sat 12/26/09	57FS+7 days	SA01
60	P.14.2	60		Kitchen sanitary fitting work	1 day	Sat 1/2/10	Sat 1/2/10	59FS+5 days	SA01
61	P.15.3	61		Finishing electrical work for ground floor	2 days	Fri 12/18/09	Sat 12/19/09	56FS+8 days	EL01
62	P.15.6	62		Finishing electrical work for 1st floor	1 day	Wed 12/30/09	Wed 12/30/09	61FS+8 days	EL01
63	P.17.3	63		Finishing for ground floor (Mechanical)	2 days	Thu 1/14/10	Fri 1/15/10	60FS+9 days	ME01 E
64	P.11.2	64		Cupboards (Carpentry work)	4 days	Tue 12/29/09	Fri 1/1/10	58FS+3 days	WO01 B
65	P.11.3	65		Wardrobes (Carpentry work)	5 days	Tue 12/29/09	Sat 1/2/10	58FS+3 days	WO01 C
66	P.17.5	66		Finishing for 1st floor (Mechanical)	1 day	Sat 1/23/10	Sat 1/23/10	63FS+6 days	ME01 F
67	P.10.3	67		External Painting	4 days	Fri 12/4/09	Tue 12/8/09	55FS+10 days	PA02
68	P.18	68		Clearing and finishing	2 days	Thu 1/28/10	Fri 1/29/10	66FS+3 days	CL01



Microsoft Project - Project1
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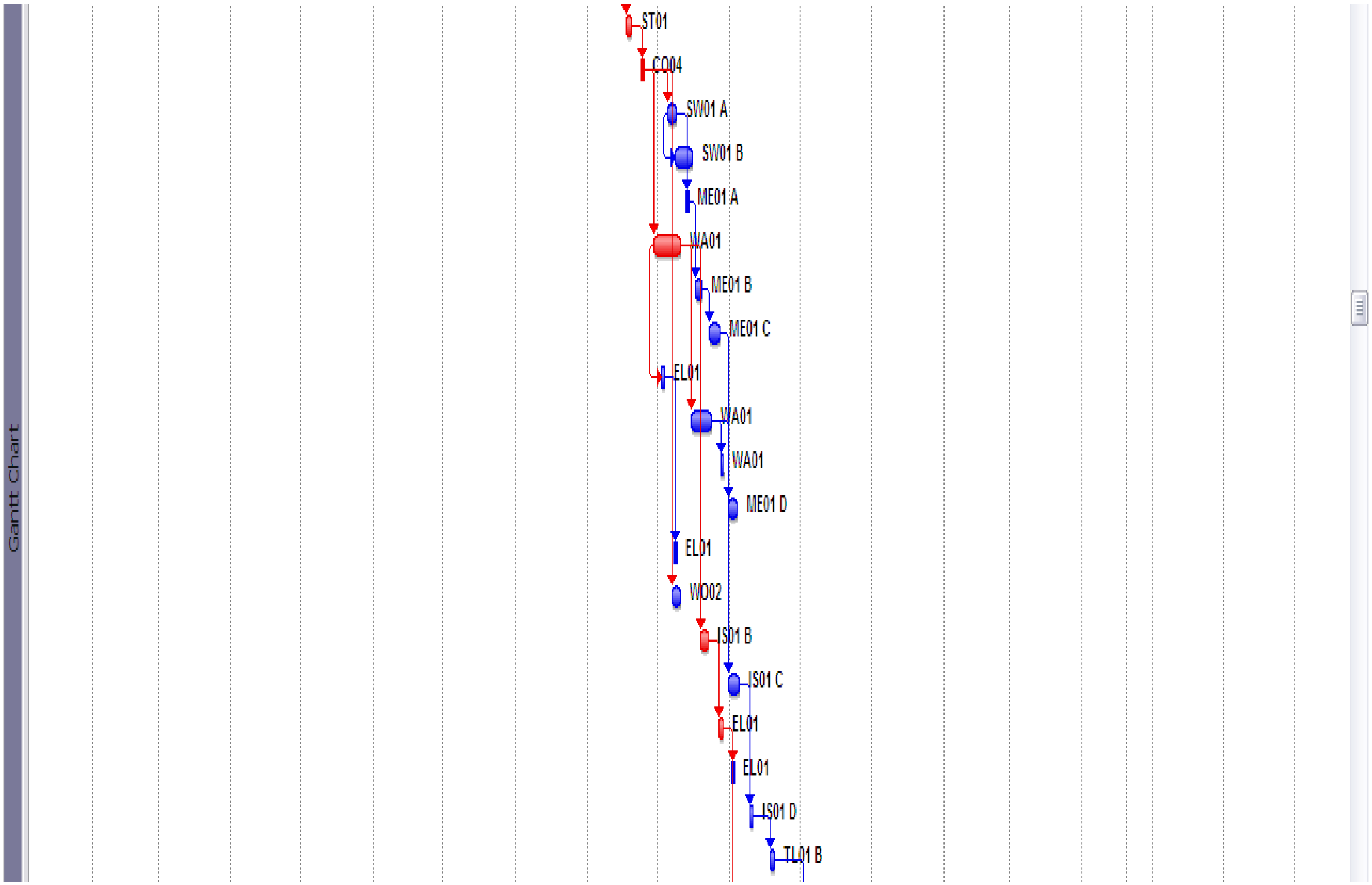
P.3.3
Gantt Chart
2009
Jan '09 Feb '09 Mar '09 Apr '09 May '09 Jun '09 Jul '09 Aug '09 Sep '09 Oct '09 Nov '09 Dec '09
2010
Jan '10 Feb '10 Mar '10 Apr '10 May '10 Jun '10 Jul '10
EX01 A
EX01 B
EX02
EX03
IS01 A
CO01
ST01
CO02
FW01 A
ST01
CO02
EX05
EX06
EX04
FW01 B
ST01
CO03
FW01 C
ST01
CO04
FW01 D
ST01
CO03
FW01 E


Gantt Chart
ST01
CO04
SW01 A
SW01 B
ME01 A
WA01
ME01 B
ME01 C
EL01
WA01
WA01
ME01 D
EL01
WO02
IS01 B
IS01 C
EL01
EL01
IS01 D
TL01 B

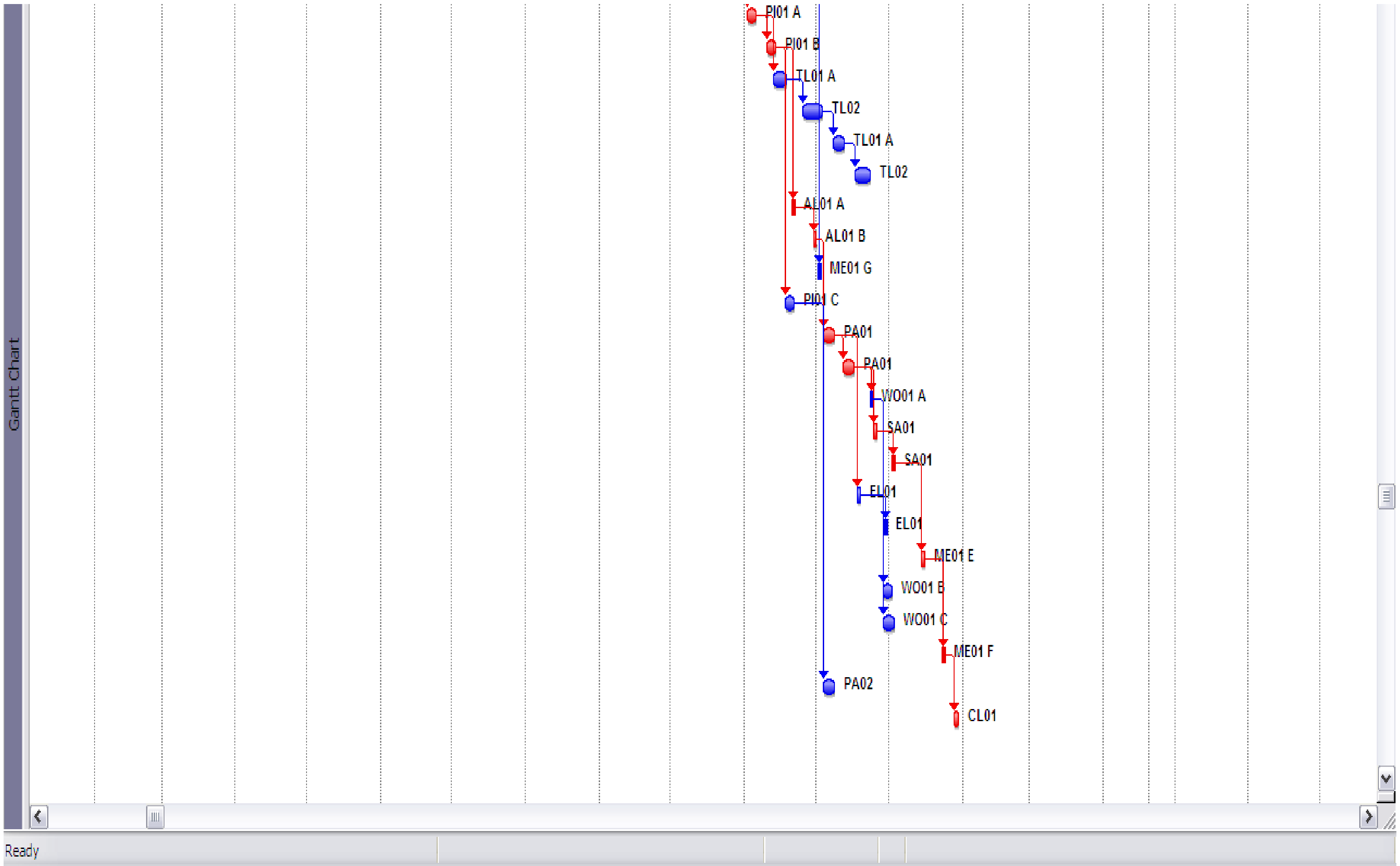


Figure 65: Microsoft Project Bar Chart

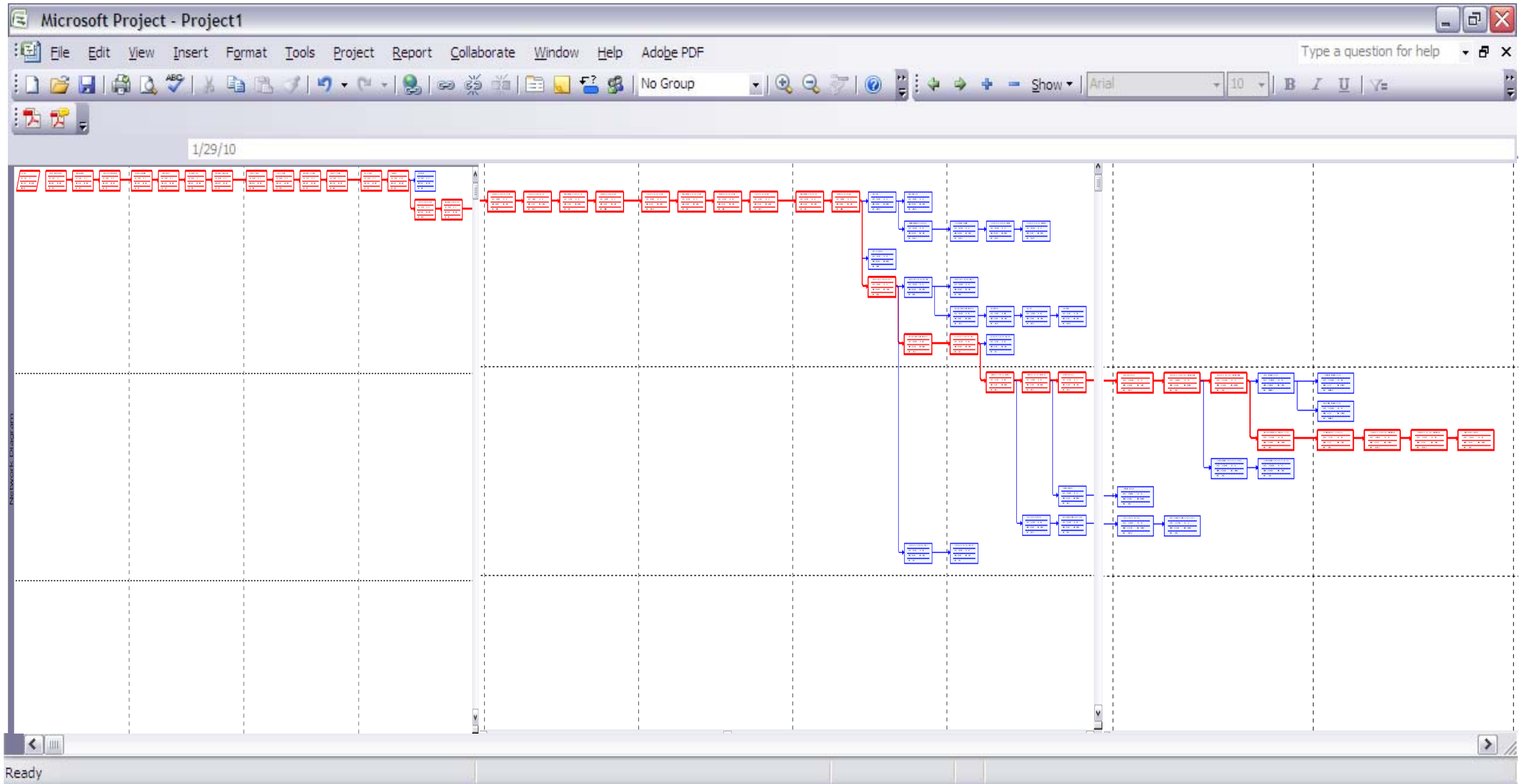


Figure 66: Network Diagram By MS