Location Based Scheduling in the Form of Flow Line and its Comparison to CPM/Bar Chart Scheduling

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ABSTRACT

Time Management is a process of planning, scheduling and control over the amount of time spent in specific activities, especially to increase effectiveness, efficiency, or productivity.

Planning of construction projects differ in size, type, and nature. Bar charts are generally popular, easy and good for small projects; network diagrams like Critical Path Method (CPM) are used for medium to large size projects, while the line of balance technique is used for big linear projects and repetitive actions.

Location based scheduling is a deviation of line of balance technique, which is graphical line showing the movement of crew's productivity and continuity of two dimensional coordinate system using the location and time. A modified method have been evolved with the use of computer software called Vico office which uses Location Based Scheduling (LBS) in the form of flow line scheduling, which is a combination of CPM and Linear Scheduling Method(LSM) with which, one can deal with small, medium and big projects in planning and scheduling.

Every type of planning has advantages and disadvantages.CPM algorithm is designed for optimizing project duration rather than dealing the balancing of resource constraints to ensure easy productivity of crews from unit to unit as the LSM does.

This study will use the modified LBS method for a case study of 3 floor villa which represents as a small project. Both scheduling tools, CPM/Bar chart and LBS, will be used to schedule the villa and a comparison between the two methods with their

limitations and advantages will be discussed. The results of the LBS scheduling through the case study showed that the LBS scheduling can work on small projects, can be easily planned, and it gave some advantageous results than the traditional CPM/Barchart scheduling method.

Keywords: Time Management, Line of Balance, Location Based Scheduling, Critical Path Method, Bar Charts

ÖZ

Time management belirli aktivitelerde planlama, zamanlama ve harcanılan zaman miktarını kontrol eden bir aşamadır, özellikle geçerliliği, verimi veya üretkenliği artırır.

İnşaat projelerinin planlanması boyutuna, çeşidine ve yapısına göre farklıdır. Genelde Bar chart'lar popülerdir, küçük projeler için kullanımı kolay ve daha iyidir; Network diagram'larda Critical Path Method (CPM)'dun orta ve büyük boyutlu projelerde kulanıldığı gibi, aynı zamanda Line of Balance tekniklerinin büyük çizgisel projelerde ve tekrarlı çalışmalarda kullanılmasıdır.

Location based scheduling line of balancei teknik çizgisinin bir sapmasıdır, grafiksel çizgi crew's productivity 'nin hareketini ve iki boyutlu koordinat sisteminin sürekliliğini ve zaman'ı kullanarak göstermektedir. Vico Office olarak adlandırılan bilgisayar programı kullanarak modifiye edilmiş bir method geliştirildi. Bu method esas konum çizelgesini (LBS) akış hat çizelgesi formunda kullanmakta, bu da Critical Path Method ve Linear scheduling method (LSM) ile hangi küçük, orta veya büyük projelerin ele alına bileceğinin planlamada ve çizelgede birleşimidir.

Her çeşit planlamanın avantajları ve dezavantajları vardır. CPM algorithm proje süresini iyileştirmeden ziyade sınırlı kaynakların dengelenmede ve crews' in kolay üretkenliğini LSM' de olduğu gibi birimden birime sağlamakla ilişkilidir.

Bu çalışmada modifiye edilmiş LBS method ile küçük bir projeyi temsil eden 3 katlı bir villa örnek olarak kullanılacaktır. Her iki çizelge aletleri, CPM/Bar chart ve LBS,

villa'nın programlanmasında kullanılcak ve aynı zamanda iki method'un limitleri ve avantajları karşılaştırılıp tartışılacaktır. LBS çizelgesinin sonuçları örnek villa ile küçük projelerde çalışılabileceğini gösterdi, kolayca planlana bilmektedir, ve traditional CPM/Bar chart çizelgesi method'undan daha fazla avantaj sağlamaktadır.

Anahtar Kelimeler: Time Management, Line of Balance, Location Based Scheduling, Critical Path Method, Bar Charts

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This dessertation is dedicated to my lovely mother, and my passed away father, may his soul rest in peace inshala.

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LIST OF ABBREVIATIONS

CPM:……………………………………………………………… Critical Path Method

EF:…………………………………………………………………Earliest Finish

ES:………………………………………………………………..Earliest Start

FF: …………………………………………………………….Finish to Finish

F.F:…………………………………………………...…..……………..First Floor

FF:………………………………………………………………...Free Float

FOUN:……………………………………………………..………...Foundation

FS:……………………………………………………………...Finish to Start

G.F: …...…………………………………………………………...Ground Floor

KG: ………………………………………………………………...Kilo Gram

LBS:…………………………………………………...Location Based Scheduling

LF: ……………………………………………………………Latest Finish

LOB:……………………………………………………………. Line of Balance

LS:…………………………………………………………Latest Start

LSM:……………………………………………………..Liner Scheduling Method

M:……………………………………………………………………… Meter

MC:……………………………………………………………Meter Cubic

MS:………………………………………………………………Meter square

MS Project:……………………………………………………....Micro Soft project

PERT: …………………………………………….Program Evaluation Review Technique

RC:………………………………………………………………Reinforced Concrete

RW:………………………………………………………………Retaining Wall

SF:………………………………………………………………....Start to Finish

S.F:……………………..…………………………………………..Second Floor

SP:………………………………………………………………….Swimming Pool

SS:………………………………………………………………..Start to Start

SW:………………………………………………………………Skilled Worker

TF:………………………………………………………………Total Float

TON:………………………………………………………………Tonnage

UW:………………………………………………………………Unskilled Worker

Chapter 1

INTRODUCTION

1.1 Overview

Locations based scheduling is a deviation of line of balance and linear scheduling method, it uses location break down structure to schedule the activities in a combined Critical Path Method (CPM) and linear scheduling, and shows the activities in a flow line graph. The first documentation usage of LBS was used in the Empire State building in 1929 (Figure 1).
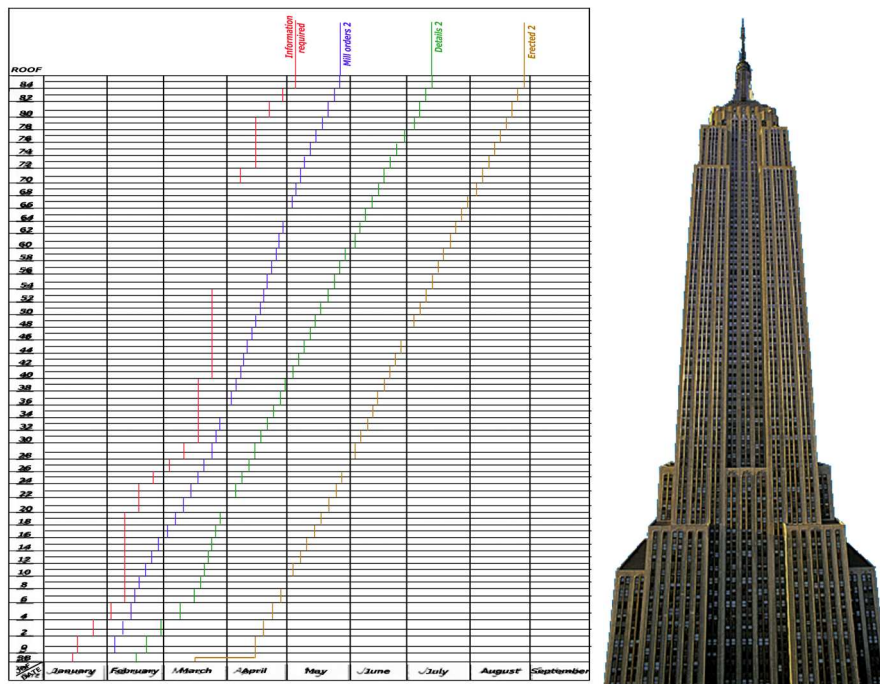
Figure 1: The Use of LBS in Empire State; Source (Gagne, 2012)

In recent years, most of the construction industry focused on the use of Critical Path Method (CPM) and Bar chart to schedule and plan construction projects, and the

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usage of Linear Scheduling Method (LSM) mainly focused on the linear or repetitive process construction. Beside that Line of Balance has many disadvantages while used in scheduling of small projects, even though most of contractors and engineers are not familiar to use or communicate Line of Balance technique in their work. In Finland in late 1980's, a group of researchers started to modify line of balance tool in Helsinki University. They modified a software tool called Dyna project through their research studies in 2003.After some years the software became commercial and started to be used in construction companies named as VICO office (Seppänen & Aalto, 2005).

However, it has not gained popularity because of the commercial use of software programs for Critical Path Method (CPM) and Bar charts, and it was believed that Linear Scheduling Methods are not suitable for nonlinear or non-repetitive projects with large amount of activities. Beside of this, civil engineers focus to minimize the duration of projects like Critical Path Method (CPM) does, rather than focusing on the productivity and resource constraints that Linear Scheduling Method (LSM) does.

The objective of this study is to use Line of Balance technique on small building of a 3 floor villa, with commercial software and compare the results of CPM/Barcharts with Line of Balance technique. At the same time collecting answers of questionnaires about the usage of scheduling tools from academic and industrial engineers so as to find their point of view about the Line of Balance technique.

Using the Vico software for the case study has been useful; the CPM/Barcharts has been transferred into Line of Balance technique, and resulted with the same data.

After that risk levels were define, it showed that using CPM/Barcharts are more risky than the continuous flow of Line of Balance, with use of optimization of the continuous flow line, the time duration has been decreased. Moreover the visualization of line of balance were better than the CPM/Barchrts, because it showed the locations of the structure more better than the bar charts, and controlling flow and movements of crews can be easily controlled through line of balance technique.

1.2 Objective of the Study

The main objective of this study is to use the Location Based Scheduling in the scheduling and to see if it has the same or better results with CPM/Barcharts, the objectives of this thesis are:

1. To collect a literature review survey about the different scheduling tools used in the construction industry with their advantages and limitations.

2. Using Line of Balance technique for a small, non-repetitive, and nonlinear construction project, since the most disadvantages of the line of balance technique is that not suitable to be used in small construction projects, and to compare the results with the traditional use of CPM/Barcharts. A small 3 floor villa has been selected as a case study.

3. To collect answers for a question surveys distributed via email for different construction sectors, academic and industrial, so as to find their different point of views about the usage of scheduling tools in their construction project.

1.3 Works Done

In order to achieve the main objectives of this study as mentioned in section 1.2, the following works has been done:

1. Collection of literature review from journals, books, conferences, and blogs, for the three types of scheduling tools, critical path method, bar charts and line of balance technique.

2. Vico software is used to schedule the case study (3 floor villa) with line of balance technique and CPM/Barcharts.

3. Survey questions were distributed among academic and industrial civil engineers for different industrial civil sectors.

1.4 Achievements

The following achievements of the study are summarized as below:

1. A detailed literature review is provided in Chapter 2 of this thesis, for the three types of scheduling tools, bar charts, critical path method and line of balance, with their limitation and advantages. It showed that from the literature review CPM is the most widely used scheduling tools, but it not suitable to be used in linear or repetitive process construction. While line of balance is not widely used in construction industry, especially for small and large amount of activities, but its suitable for linear and repetitive process construction projects.

2. Results were obtained from line of balance and CPM/Barcharts scheduling technique. It showed the same results while transferring CPM/Barcharts into LOB technique for a small construction villa, but while defining risk levels it showed that the LOB has better results than the CPM/Barcharts as time duration, visualizing of activities, and low risk of time completion.

3. 83 respondents were collected through collecting their answers from a question survey, for different countries, different construction industrial sectors, and different civil engineering academic sectors.

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1.5 Limitations of the Study

This research has some limitations. The scheduling of the case study has been only done to construction quantities; electrical and mechanical has not been considered since the model itself did not have any data about them. Another limitation is the update, control, and forecasting of the schedule which is not included. This is because the building was constructed before the research study has been started, and there is no history data about the construction.

1.6 Thesis Outline

This thesis is structured as follows:

Chapter 1 is the general introduction about the location based scheduling tool (LBS), and other traditional scheduling tools.

Chapter 2 is the literature review; theories, research studies papers about the comparison of linear scheduling, bar chart and critical path method has been collected.

Chapter 3 is the methodology of the study. It contains the procedure of how CPM/Barchart and LBS schedule by using a case study.

Chapter 4 is the questionnaire survey which describes how questionnaire survey was prepared and how respondents were chosen.

Chapter 5 is the results and discussion of the data obtained from the scheduling of both LBS and CPM/Barchart. It also contains results and discussion of the surveyed questions.

Chapter 6 is the conclusion of the study, and future recommendations of the study.

This chapter is followed by the bibliography of the thesis.

Chapter 2

LITERATURE REVIEW

2.1 Introduction

Many authors have discussed theory of Line of Balance and Critical Path Method CPM with their comparison to each other. It can be seen from the literature review that different types of scheduling are used for different project type, nature and size, which they vary depending on how they analyze and how their logical representations are shown. There are different kinds and varieties of scheduling tools like (Yamin & Harmelink, 2001);

-Network diagram scheduling (CPM)

-Bar/Gantt chart.

-Linear Scheduling method (LOB)

Since construction projects differ in nature, size, and type, bar charts are used for small projects and small amount of activities, CPM is used for medium to large size projects with large amount of activities, while linear scheduling method is used for repetitive or linear continuous activities that have small amount of activities with large quantities (Mubarak, 2010).

2.2 Bar Chart (Gantt Chart)

It was introduced originally by Henry L. Gantt in 1917 (Mubarak, 2010). Bar charts have faced many changes and modifications to date. It is the most commonly used technique among others, because of its easy usage and understanding(Mubarak,

2010) and (Uher, 2003).

A bar chart represents time scaled activities in a horizontal bar graphic way of tasks, these tasks represent project information activities. As a graphical representation, bar charts use x-axis as time in columns, it could be months, weeks, days or even hours, and y-axis represents the individual activities into different rows (Mubarak, 2010) and (Uher, 2003) (see Figure 2).

Activity ID	Activity Description	Orig Dur	FEB
			,10 ,17 ,24 ,3
1000	Excavate	4	Excavate
1010	Form Footings	6	Form Footings
1020	Place Rebar	4	Place Rebar
1030	Place Concrete	6	Place Concrete
1040	Strip Forms	4	Strip Forms
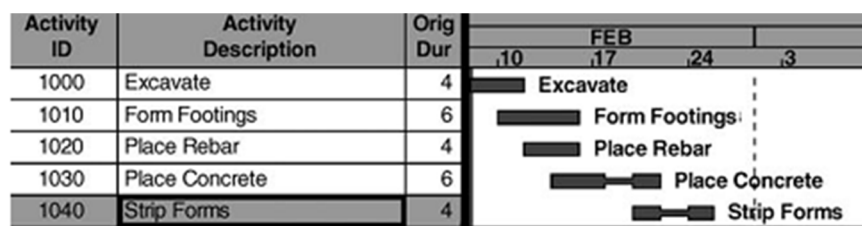
Figure 2: Bar Chart; source (Mubarak, 2010)

2.2.1 Advantages

Galloway (2006) made a survey and stated that most construction owner companies prefer bar charts for small projects, because of its easiness to understand and that it does not impose cost as much as CPM does.

Bar charts are simple, universal, understandable, and easy to be produced (Arditi, Tokdemir, & Suh, 2002).

Bar charts are easy to use, good presenting project duration, and more information can be loaded from it like man hours, and cash flow diagram (Mubarak, 2010).

2.2.2 Disadvantage and Limitations

Bar charts' most disadvantageous characteristic is the lack of linkage representations of longest path and float calculation, which CPM has (Uher, 2003).Without linkage representation, it may cause problems in updating and modifying activities or if some

activities are modified, it will not affect or change other related activities (Arditi, Tokdemir, & Suh, Challeneges in Line-of-Balance Scheduling, 2002), and (Arditi, Sikangwan, & Tokdemir, 2002).

But with the aid of computer software, CPM (Critical Path Method) and PERT evolved in the bar chart system which made it most powerful tool to be used in construction projects (Mubarak, 2010).

Bar charts are not still perfect in linear scheduling with the evolvement of other scheduling tools like CPM, which may cause inappropriate and missing information in linear or repetitive projects (Arditi, Tokdemir, & Suh, 2002).

2.3 Critical Path Method

Network diagrams can be defined as the linkage or logical representation of activities; it could be arrow or node diagrams. Every type of network is classified into different methods as shown in Figure 3(Koirala, 2008).
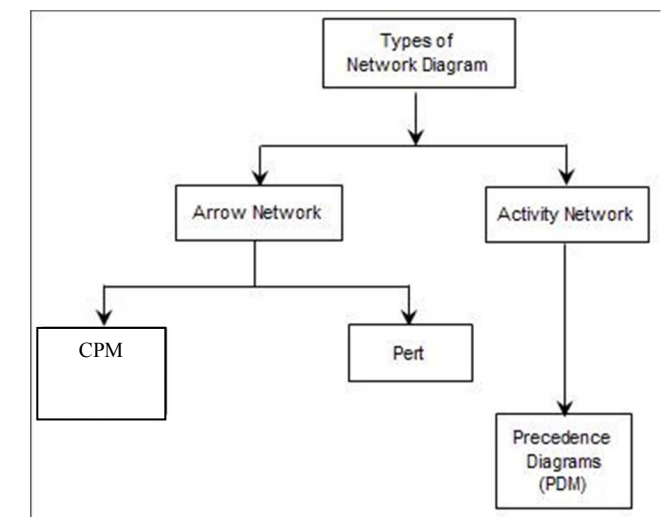
Figure 3: Types of Network Diagram; source (Koirala, 2008)

The arrow diagrams were popular between 1960s and 1970s, then after this time of era the node diagrams became choice for network diagrams (Mubarak, 2010).

One of the most commonly used network diagrams is the Critical Path Method (CPM) (Uher, 2003), (Mattila & Park, 2003), (Lutz & Hijazi, 1993), and (Arditi, Sikangwan, & Tokdemir, 2002),and(Jongeling & Olofsson, 2006).Planners in construction normally use both CPM and bar charts to schedule their projects (Koo & Fischer, 2000),and they are used widely in construction industry (Harmelink, 2001), (Mattila & Park, 2003),(Lu & Li, 2003), (Galloway, 2006), (Koo & Fischer, 2000), and (Mendes, Fernando, & Heineck, 1998). They represent the task in an arrow diagram by linking the activities in a shape of map into work break down structure (WBS), with each task related to each other in a logical order and dependency (Figure 4) (Uher, 2003).
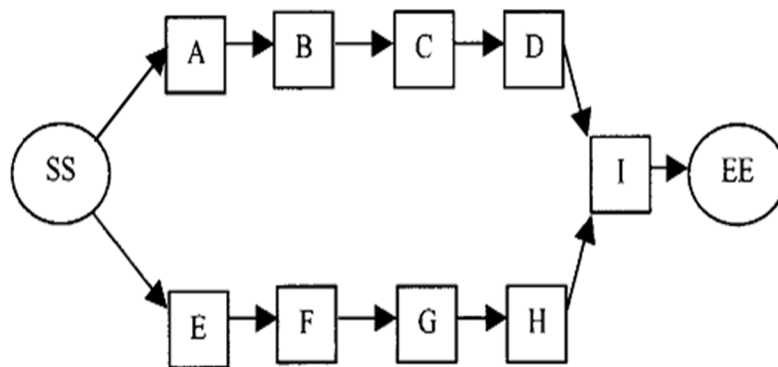
Figure 4: CPM Network Diagram; source (Lu & Li, 2003)

2.3.1) Advantages

Network diagrams, unlike bar charts, show logical representations, which gives relationship between activities, and from these logical activities, a critical path is calculated which can predict the completion date of the project, and they are good to represent large or complicated construction projects (Mubarak, 2010).

Harmelink (2001) stated that while scheduling construction projects, activities that are planned to complete in longest duration are called critical and these critical activities have zero floats that are flexible in time completion. He also stated that these floats can be useful to determine the delay of activities before it affect the project duration.

The critical path method (CPM) of scheduling is widely accepted and utilized by the building construction industry. It determines which activities are on the critical path and which are not (Harmelink, 2001).

Lowe, D'Onofrio, Fisk, & Seppänen, (2012) stated that 90% of construction projects in USA use CPM to manage and plan their projects; while Galloway (2006) made a survey on usage of CPM and she found that 47.6% of the projects owners always rely on CPM tool. She also stated many contracts force contractors or subcontractors to use CPM which is about 72.5%.

According to software programs which use CPM, Galloway (2006) stated that about 64% use Primavera in their scheduling and planning of construction projects, while 20% use MS project, other 16% use other types of scheduling software.

The software's most advantageous feature is that they show CPM schedules as a graphical representation of bar charts with other additional features like tabular data, PERT, and others (Figure 5)(Lowe, D'Onofrio, Fisk, & Seppänen, 2012), and (Mubarak, 2010).
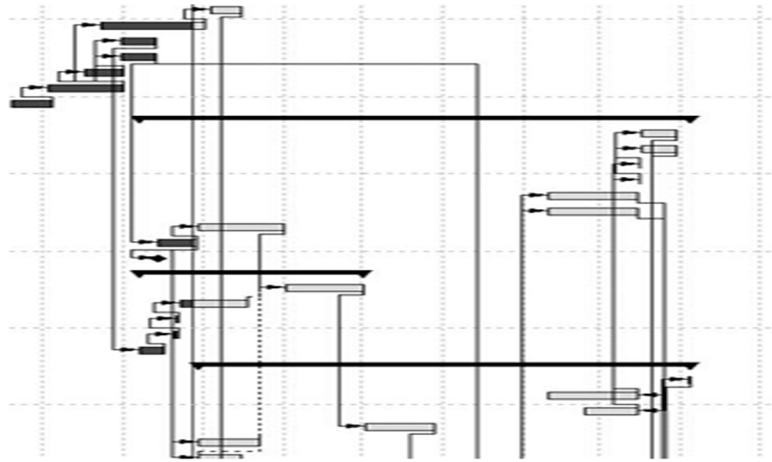
Figure 5: Linked (Time scaled) Bar Chart; source (Mubarak, 2010)

2.3.2) Disadvantages and Limitations

Despite CPM has been proven the powerful scheduling and control tool, but one of the most disadvantageous characteristics in CPM is that they are not suitable to be used or manipulate in linear scheduling (like highways, pipe lines and tunnels), and repetitive projects (high rise buildings, and multi housing unit complex), (Arditi, Tokdemir, & Suh, 2002), (Arditi, Sikangwan, & Tokdemir, 2002) (Mattila & Park, 2003),(Vanhoucke, 2006), and (Mendes, Fernando, & Heineck, 1998), because of different production rate, and there is no indication of production rate in CPM (Arditi, Tokdemir, & Suh, 2002), and do not show interrelationships between activities for high rise buildings (Arditi, Sikangwan, & Tokdemir, 2002).

Arditi, Sikangwan, & Tokdemir (2002) stated that CPM deals mostly with minimizing the duration rather than dealing with resource and productivity factors, at the same time for repetitive projects like high rise buildings the linkage of the activities will be too much and big size, which will cause difficulties in communication.

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Mattila & Park (2003) stated that CPM does not have the ability to schedule the resource in continuous way, especially in repetitive or linear continuous projects, which rate of activities are not indicated and does not reflect the actual condition. They also stated that CPM does not give any further information of project task or activities where exactly the work is done.

Harris & Ioannou (1998) stated that CPM can schedule repetitive process projects, but the control and operation of resources cannot be guaranteed, because the resource constraints cannot be represented in CPM schedule.

Lu & Li (2003) described that CPM and other related network diagrams (PERT, and Precedence diagram) does not focus or coordinate activity and resource planning, it assumes limitless availability of crews, with no critical resource.

Lu & Li (2003) also stated that CPM has not succeeded to clarify the critical resource, this is because some critical activities may be noncritical for resource, and these non-critical resource may delay the project duration time if they fail to load the sufficient resource required by their critical activities.

Lu & Li(2003) and Vanhoucke (2006) stated two main points that CPM gives insufficient scheduling in repetitive and linear projects:

1) The CPM if used in repetitive or linear projects will use a large amount of tasks to represent the activities, and it will be difficult to evaluate and hard to read them. Vanhoucke (2006) stated that if network scheduling in repetitive projects will be like

a complicated ladder like shape, and the number of nodes and links will be very large for the whole construction project.

2) The second point which they stated is the balance of resource or continuity of resource which CPM does not take into consideration while scheduling.

Matilla & Abraham (1998) and Vanhoucke (2006) stated an extra point that when applying CPM to repetitive or linear activities, it may lead difficulty while assigning extra resource or modification in resource, which will result in exchanging of time/cost activity profile, and crashing of productivity between similar activities at different units.Arditi, Tokdemir & Suh (2002) had same conclusion with both authors that since CPM does not take into account the production rate, it will never be predictable or detected by the scheduler during development of the project or activity within a project.

Koo & Fischer (2000) and Jongeling & Olofsson (2006) discussed more about the look and visualizing of CPM/bar chart in the scheduling;

Koo & Fischer (2000) stated that construction schedulers find it difficult to view all activities related to the project, it will be difficult to determine the schedule of all activities complete by viewing them as a CPM schedule, especially when assigning activities taken from 2D drawings, however when he viewed the activities in a 4D model he could find the missing activities which were not included in the CPM schedule.

They also stated that, the breakdown structure of activities will be difficult to identify them when they are out of sequence link in CPM, this is because some tasks have same dependency, which may be located in different zones of the schedule.Such a problem is important for users to understand the linkage of the project;on the other hand,Jongeling & Olofsson (2006) discussed that a very detailed CPM schedule is difficult and hard to update. They also discussed about spatial design of a project while using CPM.

Koo & Fischer (2000) and Jongeling & Olofsson (2006) expressed that CPM does not show or provide further information of an activity specially its location.

At the end, the usage of CPM/Bar charts in repetitive or continuous project is still used despite its limitations and disadvantages (Yamin & Harmelink, 2001).

2.4 Line of Balance (LOB)

It was originated in 1940's by the Good year company (Lutz & Hijazi, 1993).LOB was introduced in the planning and controlling of the manufacturing industrial process. Then in 1942 it was developed in US navy to control and program repetitive process projects (Lutz & Hijazi, 1993), and (Suhail & Neale, 1994).Later it was developed in UK for repetitive housing projects by National building agency (Suhail & Neale, 1994).

LOB is a graphical method of diagonal lines with slopes representing the productivity of resource or activity, plotted on X-Y graph, the X (horizontal axis) represents time, while Y (vertical axis) represents location or quantities (Uher, 2003), (Lutz & Hijazi, 1993),and (Mattila & Park, 2003), or opposite depending on which type of project you are dealing with, like for buildings Y axis represents the location,

and for highway projects X axis represents the location or stations (Figures 6 and 7)

(Mattila & Park, 2003).
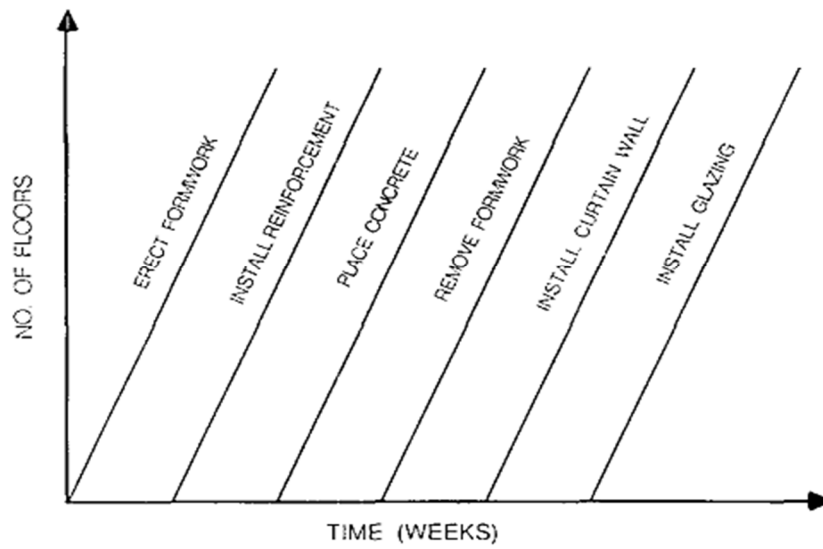
Figure 6: Location vs. Time LOB; source (Lutz & Hijazi, 1993)
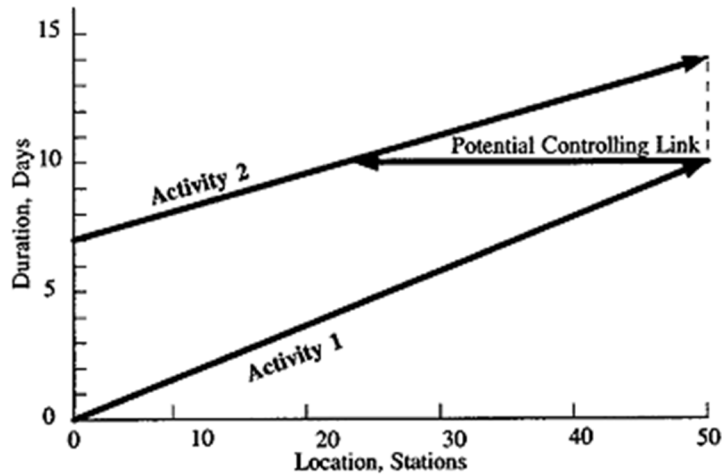
Figure 7: Time vs. Location LOB; source (Mattila & Park, 2003)

Line of Balance (LOB) is a deviation of Linear Scheduling Method (LSM) (Arditi, Tokdemir, & Suh, 2002), (Björnfot & Jongeling, 2007), (Uher, 2003), (Arditi & Albulak, 1986), (Lutz & Hijazi, 1993), and (Harris & Ioannou, 1998), same as other LSM scheduling like Vertical Production Method (VPM), Time Versus Distance, and others (Harris & Ioannou, 1998), (Lutz & Hijazi, 1993), and (Uher, 2003).

The difference between linear scheduling method and line of balance is that, LOB is used to record or schedule the cumulative repetitive events of the work done, while LSM plans the recorded progress on multiple activities that are moving continuously linear along the length of the project. The LSM origin is not clear and it may have different deviations according to countries. But they have same logic that they depend on the resource orientation and productivity (Arditi, Tokdemir, & Suh, 2001).

Arditi & Albulak (1986) made a research by using line of balance in linear construction projects like highway and was generally successful with some lacks like presentation of lines and overlapping with each other.

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2.4.1 Advantages

Linear projects like highway, pipelines and tunnels and repetitive action projects like high-rise buildings, multi-unit complex houses, and precast concrete production are all suitable for LOB and LSM schedules(Arditi, Tokdemir, & Suh, 2002), (Harmelink, 2001), (Harris & Ioannou, 1998), (Matilla & Abraham, 1998), (Mendes, Fernando, & Heineck, 1998), (Seppänen & Aalto, 2005), (Mubarak, 2010), (Vanhoucke, 2006), (Uher, 2003), (Yamin & Harmelink, 2001), (Hamerlink & Rowings, 1998), (Suhail & Neale, 1994), and (Mattila & Park, 2003).

The main advantage of LOB is that it calculates productivity along with time in an easy graphical representation (Lutz & Hijazi, 1993).

Despite its specialization of LOB and LSM usage for linear and repetitive projects, Matilla & Abraham (1998), Yamin & Harmelink (2001) and Uher (2003) stated that CPM can also be used for these linear or repetitive process projects, but they are not appropriate.

Repetitive activity process allows construction to continue in a continuous repetitive manner, which allows cost and time to be efficient by balancing the resource crews (Arditi, Tokdemir, & Suh, 2002).

Line of balance graph shows the project situation graphically that what is wrong with activity, and can find potential future jams. It also has the possibility to adjust the productivity of resource to allow smooth and efficient flow. At the same time in the creation of LOB, it will take less time and effort than other scheduling techniques (Lutz & Hijazi, 1993), and (Arditi, Tokdemir, & Suh, 2002).

Mendes, Fernando, & Heineck (1998) and Harmelink (2001) also stated about the graphical representation of LOB, that it is easy to read, understandable, and sets the goal of the planning.

LOB has the ability to balance activity operations in a way that each activity is being continuously achieved in different location though project (Jongeling & Olofsson, 2006).

For repetitive construction process projects, LOB can lead a crucial important schedule and planning by reducing time, cost overruns, and clashes (Vanhoucke, 2006).

Vanhoucke (2006) also stated that scheduling of repetitive process projects can be improved by three main points:

1) Work of crew in continuous way

2) Schedule optimization and resource operation to optimize the project duration

3) Integration of discrete and non-discrete schedules.

Seppänen & Aalto (2005) stated in their research that LOB has low risk schedule for contractors, since their subcontractors are forced continuously to be kept on site, and at the same time their crews have low risk to interfere with each other and minimize the clash or resource.

Mendes, Fernando, & Heineck (1998) stated that LOB can balance the resource in continuous work over construction locations, crews will work with periodic productivity and no wastes will be introduced in the schedule.

Lowe, D'Onofrio, Fisk, & Seppänen (2012) and Arditi, Tokdemir, & Suh (2002) stated that another main feature of LOB is the ability to optimize the schedule time by increasing crew size which will lead to soften the slope and make it similar to its predecessor task.

2.4.2 Disadvantages and Limitation

Beside its advantageous features, LOB development is quite slow and its acceptance through construction industry is low (Mattila & Park, 2003).

The most disadvantageous principle that LOB or LSM has is the lack of critical path, (Harmelink, 2001), and (Mattila & Park, 2003). The critical path determines the smallest duration of the project, and determines which activity will lengthen the project time if they are delayed (Mattila & Park, 2003).

Hamerlink & Rowings (1998) developed a Control Activity Path (CAP) for LSM, as an activity path, but unlike CPM it determines the control and non-control path through linear projects only.

Arditi, Tokdemir, & Suh (2002) found some conclusion from the criticality of both CPM and LSM, the production rate is the major parameter for criticality in LSM and activity duration in CPM, but they stated that the LOB does not define this difference, and does not define float and criticality in LOB terms.

At the same time, they stated that critical path in LOB may be non-critical in CPM when the production rate of the crews adjusted. Furthermore they stated that the critical path is important parameter to shorten the project duration as like CPM does,

unlike LOB which depends on continuous work of crews through activities in order to achieve performance.

Another limitation of LOB is in its basic feature which is the productivity assumptions are constant over specific time of an activity. At the same time LOB can reduce the duration of project but with no regard to reduce cost like other scheduling methods (Lutz & Hijazi, 1993).

Yamin & Harmelink (2001) and Mattila & Park (2003) stated that LSM cannot be used for discontinuous or discrete projects, while CPM can do complex discrete projects, like culverts or bridge structure in linear projects.

LOB is complicated especially for projects which have large number of activities that are related to each other or bounded to be linked with time dependency. Such a time dependency like in highway projects prime coat should be followed by base course, which is more related to dependency than production or resource (Arditi, Tokdemir, & Suh, 2002).

Plotting LOB must be carefully evaluated, otherwise if too many activities are plotted in the schedule, the diagram will be a jungle of tilted lines, and they may also cross each other. Another major difficulty in plotting LOB is for the activities that have same productivity and may overlapping each other; it will not be easy to separate them unless they are drawn with different color. The scale of the lines should be appropriate so that it will be better understandable, and information can be readable easily. (Arditi, Tokdemir, & Suh, 2002), and (Arditi & Albulak, 1986).

Mendes, Fernando, & Heineck (1998) and Lutz & Hijazi (1993) described that the unpopularity of LOB in the construction industry was mainly due to popularity of CPM commercial software that made hard for LOB beat CPM in the construction industry.

Seppänen & Aalto (2005) and Lutz & Hijazi (1993) also stated about the usage of LOB, despite of its strong tool but it did not gain popularity in the worldwide construction industry mainly due to lack of using easy software to implement them.

Beside its lack of software usage, some commercial companies or university researches tried to design a software tool for the LOB technique, some of these software tools are as below:

1) Vico Control (Graphisoft Control/Dyna project at Helsinki University of Technology) by Vico Software in Finland.

2) Tilos by Asta Development in Germany.

3) Spider Project PM system by Spider Management Technologies in Russia.

4) PlaNet by Artemis International solution in Finland.

5) UNaLSS (university of Naples linear scheduling software) in 2005 as a research.

6) FLSP (Florida Linear Scheduling Program) in 1999 as a research.

7) Location based Management System (Swinburne University of Australia) in 2006 as a research.

8) Cash Flow Diagramming in Line of Balance Technique by Using Matlab. (Eastern Mediterranean University) 2010 as a research.

Between 1989 and 2003, Helsinki University in Finland started to develop the location based scheduling as an academic research. The new research improved scheduling skills and used software to design a planning and control tool. LBS is a combination of Linear scheduling and CPM, the schedule was represented a graphical method called the flow line, the same basic of line used in the LOB (Lowe, D'Onofrio, Fisk, & Seppänen, 2012).

The concept of the planning is to use location breakdown instead of working breakdown structure, and the activities can be either continuous work or discontinuous work (Lowe, D'Onofrio, Fisk, & Seppänen, 2012).

This thesis objective is to use LSB which is a deviation of LOB with some modification for a small villa project, to see if it is an appropriate scheduling method to be used in small, nonlinear, and non-repetitive projects.

Chapter 3

METHODOLOGY OF LBS WITH A CASE STUDY

3.1. Introduction

The following section presents the basic theory and method of planning and scheduling by Location Based Scheduling, and its comparison to CPM/barchart. To compare both methods, a case study of a 3 floor villa has been taken as an example. The case study of a 3 floor villa has been planned and scheduled by both methods CPM/Barchart and LBS.

3.2 Planning Principle by LBS

Planning principle by LBS looks basically like the traditional CPM based planning. The general idea is:

- The plan must ensure that the project objectives can be achieved within the time, resource and quality framework that is applicable to the project.

- The plan serves as a map of the project showing the intended path from start to target.

- The plan serves as a basis for analysis and decisions choice of production methods, materials and equipment and other resources.

- The plan serves as a communication instrument that delivers production in race build up, what to do at each particular time, what resources to be used, and in what order the work to be performed.

All these planning requirements are the same regardless of the selected planning method, but the way to meeting the requirements are different.

Both LBS and CPM based have the same basic planning elements and activities, resources and linkages between activities. LBS also uses the time analysis (network analysis) that the CPM methodology uses it in the calculation of the critical path and activities free and total slack. But these typical CPM concepts lose their function in the LBS method, and instead, LBS introduce concepts of locality critical latitude zone, location based activity bonds, resource flow and other specific planning concepts.

The fundamental difference between the traditional CPM method and LBS is that the CPM method is based on the activities and their logical linkages to each other, while LBS method is increasingly based on resources and their "flow" through the project. The CPM method activities are considered distinct elements which can be linked and analyzed in a logical network. The CPM method focuses on activities as categorized method as an "activity based planning method".

LBS as compared to the CPM is a "resource oriented planning approach" where resources flow through the project is a key part of planning. An efficient flow means resources of the individual activities flowing smoothly to the project's various parts, or various project sites. Thus one geographical location of the project activities, is achieved an identification of where and when activities will take place, and it becomes possible to record LBS method typical as a "time / place diagram", or "flow line" diagram, which is LBS method graph. In flow line chart, the vertical axis location divided into project physical locations, and the horizontal axis indicates the

project timing. The activities and their conduct described in this way as oblique slopes, indicates the labor productivity of activities carried out, and the distance between activity bars show the distance between activities respectively the time and space called "flexibility zones".

3.2 Case Study "A 3 Floor Steel Structure Villa with a Swimming Pool"

A 3 floor steel structure villa in North Cyprus is taken as a case study. This case study has been used before for a capstone project named as "Building Information Modeling (BIM) and integration with Off-site Construction" submitted by Asst.Prof. Dr. Murude Celikag's Capstone project group, in 23rdJanuray, 2012 (Figure 8).

Figure 8: 3D CAD BIM Model of a 3floor Steel Structure Villa; source (Celikag, Qaymari, Manoucheri, Dzafic, & Sehwail, 2012).

The steel structure villa location is in Karpaz route, Gazimagusa, North Cyprus. The villa area is about 240 meter square with a swimming pool of 30 meter square, with structures consisting of both reinforced concrete and steel.

This case study has been chosen due to following reasons:

1) The structure has been modeled and drawn by Revit, which is a 3D BIM modeling tool.

2) The case study is real and has been constructed, and it was easy to find some missing data, like rebar quantities, and stairs.

3) It is a small building structure, which can satisfy one of the main objectives of the thesis.

The case study of 3 floor villa steel structure has some limitations in the quantities, like the MEP, such as mechanical and electrical quantities are not considered in the scheduling and planning. But most of the construction materials are included. At the same time the model is not as built drawing, it may consist of some missing quantities after the villa has been constructed. So the model was considered before the construction. Rebar bars, stairs and other miscellaneous steel structures are manually added to the 3D model.

3.4 Identification of Location/Floors– Workspaces (The Project Location Structure)

Identification of project floors or workspaces is not a mandatory part of the traditional CPM/Bar chart activity planning, but is a key element in LBS method. In LBS plan appears project hierarchical localities (e.g. building - floor - zones - room), and each activity has an efficiency in the schedule planned from a location. Each

location is connected to other location in an order; each activity in a location has linkages between different activities. This implies a great difference in comparison to the traditional CPM scheduling, which exclusively handles the logical interconnection locational. The structure also affects the way the schedule presented at the graphical representation of the activities of a LBS schedule. A more detailed discussion with figures can be found in chapter 4 with a case study of 3 floor steel structure villa. Since the case study is 3 floor villa with a swimming pool, the structure of the building is divided into four location floors, Basement, Ground Floor (G.F), First Floor (F.F), and Second Floor (S.F). If the project was large and big, or different resources would work on different zones of the floor, it could be divided into zones as well, like the basement location is divided into two zones, swimming pool zone (SP) and Foundation (Foun). Figure9 shows a hierarchical locating quality structure that is divided into floors of a 3 floor villa project that is taken from Revit 3D CAD and then exported to Vico Office. See appendix A1 for different location views of floor.

						Elevation	Cut	View Depth
	1	2	3	4	5			
Project						-6.5	2.2	0.0
LOCATION						-6.5	1.2	0.0
SF						8.0	2.0	0.0
FF						4.5	2.0	0.0
GF						1.0	4.5	0.0
BASEMENT						-6.5	4.9	0.0
SP						-6.5	1.2	0.0
FOUN						-6.5	4.8	0.0

Figure 9: Hierarchical Location of 3 Floor Villa Using Vico LBS Manger Software.

After location is defined in the Vico office LBS management, the Vico schedule planner will automatically upload the locations in the flow line view of the vertical

axis (Figure 10).The project's physical parts and geographical areas, and the work to be performed are divided into different locations. The project floors are organized in a hierarchy structure, called the Location Breakdown Structure (LBS). This hierarchical structure is same as Work Breakdown Structure (WBS) that is used for the structuring of the project in traditional CPM/Bar charts or activity-based planning (Figure 11).

Figure 10: Hierarchal View of Location

	Hierarchy	Code	Name	Dura
1	+1	01	EXCAVATION	1
3	+2	02	COMPACTION	
5	+3	03	HARDCORE	
7	+4	04	ISOLATION	
9	+5	05	PLAIN CONCRETE	
11	+6	06	LEVELLING BASE PLA	
13	+7	07	REINFORCEMENT FOR	
15	+8	08	FORMWORK FOUNDAT	
17	+9	09	POURING FOUND. CON	
19	+10	10	CURING FOUNDATION	
21	+11	13	ERECTION OF MAIN CC	
26	+12	14	ERECTION OF REMAINI	
31	+13	15	ALINGMNET AND LEVE	
36	+14	23	REINFORCEMENT FOR	
38	+15	24	RW FORMWORK	
40	+16	25	RW CONCRETE	
42	+17	26	RW CURING	
44	+18	35	BEAM ERECTION	
49	+19	16	CONNECTION OF BRAC	
54	+20	36	ALIGNMENT AND LEVE	
59	+21	17	STAIRS	
64	+22	18	TIGHTEN BOLTS AND \	
69	+23	19	STEEL DECKING	
74	+24	20	WELDING SHEAR STUL	

Figure 11: WBS View Barcharts

3.5 Managing the Takeoff Item and Quantity Unit Cost

LBS defines the task as a group of activities within a specific location, the activities are driven LBS management tool, can easily identify the quantity of materials used in the building by identifying them according to their location, and where exactly this amount of material is used.

For example the concrete foundation used in the 3 floor villa is shown only in the hierarchy level of basement, and it shows zero amounts in the other floor levels. This is because the foundation is used only in the basement hierarchy level (Figure12). See appendix A2 for all quantities within location.

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Figure 12: Quantities with Location;Vico Takeoff Manager

The component is cost line item in cost planner, and every component may consist of
subcomponents. After components have been added, a source quantity can be derived
from the quantity take off item manager from the 3D BIM drawings with their unit
cost, by using formula (Figure 13).
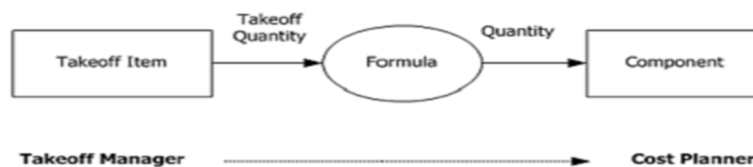
Figure 13: Components Driven from Takeoff Item; source (Tutorials, 2009)

After quantities have been taken off from the model, the LBS management tool has
the ability to plan the cost which is called cost planner. The tool consists of
components, source quantity, markup value, unit cost, gross total, net total, add on,
and others can be added if required by the planner (Figure 14).

For example the reinforced concrete is added as a component in the cost planner with
a subcomponent of structures which uses the reinforced concrete such as retaining

wall of swimming pool. Then other sub components are added for the retaining wall of swimming pool which are materials and labors .Other subcomponents may be added to the component like subcontractor or machinery use like mixer (Figure 14). See appendix A3 for all components of the building with their unit prices.

	Code	Descripti..	Source Q..	Unit Cost	PA Net T..	Markup	Gross To..	Add-On	CostType	Qty	UOM	Net Total	Add-On
	001	THESIS	1.0	292,189.93	0.00	3.17 %	311,667.03	0		1.0	EA	292,189.93	10,226.65
		Add-Ons Description				0.00 %	0	1				0	0
		GENERAL CONTIGENCY				2.00 %	5,843.80	2				0	5,843.80
		OVERHEAD				1.50 %	4,382.85	2				0	4,382.85
	A	EARTHWORK	1.0	25,190.21	0.00	3.53 %	26,961.43	0		1.0	EA	25,190.21	881.66
	B	CONCRETE	1.0	37,092.53	0.00	3.01 %	39,506.64	0		1.0	EA	37,092.53	1,298.24
	B101	SP RW	1.0	2,135.99	0.00	3.01 %	2,274.94	0		1.0	EA	2,135.99	74.76
	M07	R.C	17.6	121.00		3.00 %	2,262.04	0	MATERIAL	17.6	MC	2,123.99	74.34
	LB2	LABOR	1.0	12.00		4.00 %	12.90	0	LABOR	1.0	HR	12.00	0.42

Figure 14: Concrete Component with Subcomponent SP RW;Vico Cost Planner

3.6 Managing Tasks for Schedule Planner

After components have been prepared in the LBS Management tool, the tasks should be defined and derived in the manage tasks tool in cost planner. The tasks are the activities of the structure which will be scheduled and planned according to their logic and location. After tasks have been defined, they can be easily managed by dropping the components of the cost planner. For example after defining the pouring of plain concrete activity in the task manager, the quantity of this task would be taken from the cost planner of quantity source, then productivity will be defined for that task to calculate the duration of task it will take to accomplish the work (Figure 15).

Figure 15: Managing Tasks with Consumption Rate; Vico Task Manager

The duration of the tasks can be calculated through the productivity of resource and their size by multiplying them to quantities. Equation 1 and equation 2 show how the crew hour and man hour are calculated (Lowe, D'Onofrio, Fisk, & Seppänen, 2012).

$$Manhours = Quantity per location(unit) \times consumption rate \left(\frac{manhour}{unit}\right) \quad \text{Eq.1}$$

$$Crewhour = \frac{Manhour}{crewsize} \quad \text{Eq.2}$$

For example to find how much hour is needed to finish "Tiling" work for the 3 floor steel structure villa, with a quantity of 687 meter square, the quantity is multiplied by a consumption rate of 0.13 manhour/MS, to find manhour then divided by the crew size, which one crew is used, the crew consist of 2 tilers, 1 unskilled worker (UW), and one helper (HP).See appendix A4 for all tasks duration consumption rate and resources. Consumption rates or productivity has been assumed for the resources, some of them assumed by experience others were taken from research done by Kazaz & Ulubeyli (2003) in the analysis of construction labors in Turkey.

3.7 Locations with Dependency (Logical Representation)

LBS method uses dependency links or linkages as CPM method. The logical constraint specifies the order of activities, or how activities relate to each other. A logical binding specifies, for example, an activity must start when another is completed. With LBS method location based dependency developed the use of the logical linkages according to locations which activities are included.

3.7.1 The Traditional Logical Activity

The four logical activity links also used in the CPM method which are: Finish - Start (FS), Finish - Finish (FF), Start-Start (SS) and Start - Finish (SF) (Figure 16).
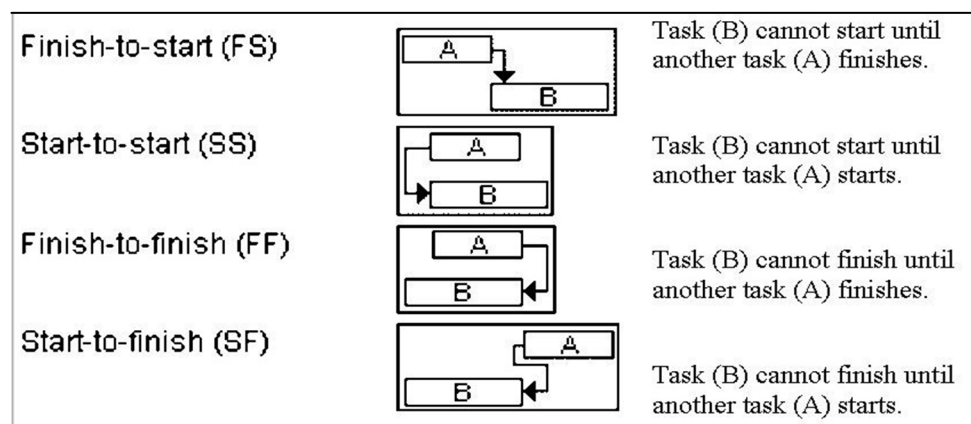
Figure 16: CPM Logic; source (Glen, 2012)

In the case study, FS logic activities are assigned to all tasks, because the succeeding task cannot start until the predecessor task finishes. Figure 17 shows the work of Earthwork with bar charts, and network diagram (CPM). See appendix A5 for the CPM/Bar chart logic.
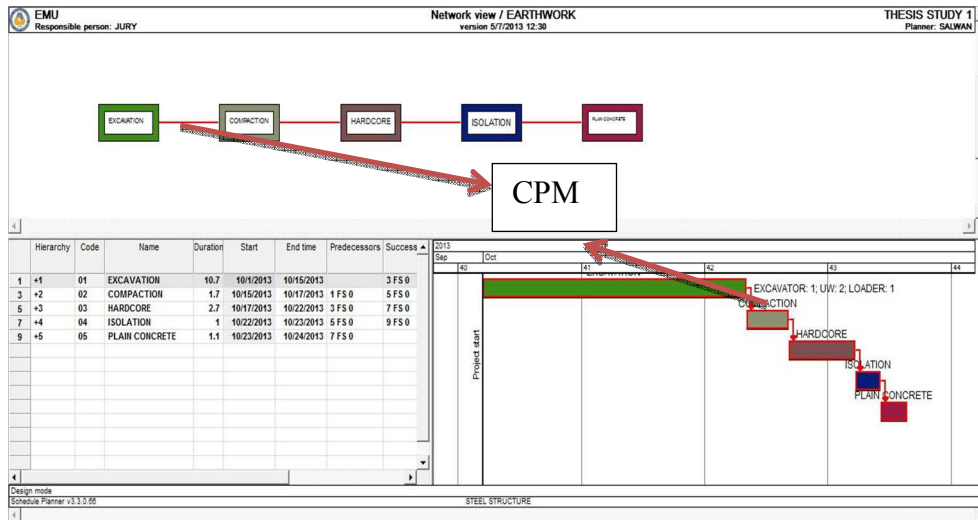
Figure 17: Network and Linked Barchart View of CPM; Vico Schedule Palnner

3.7.2 Location-Based Logical Activity

LBS method uses all the traditional logical activity linkages, but adds additional constraints related to activities locations. There are five different types or levels of location based logic activities, which CPM does not support them. These layers interact with CPM logic which forms a powerful location based logic or layered logic (Tutorials, 2009).

Layer 1: External Logic

External logic is a linkage or logic between activities within same location. A dependency between two succeeding activities at layer 1 regulates the relationship between activities in the same location level. The example in Figure 18 shows that activity "Erection of main columns" is tied to succeeding activity "Erection of remaining columns" on location level GF. This implies that activity "Erection of remaining columns" cannot start in location GF before work in activity "Erection of main columns" is completed in this location.
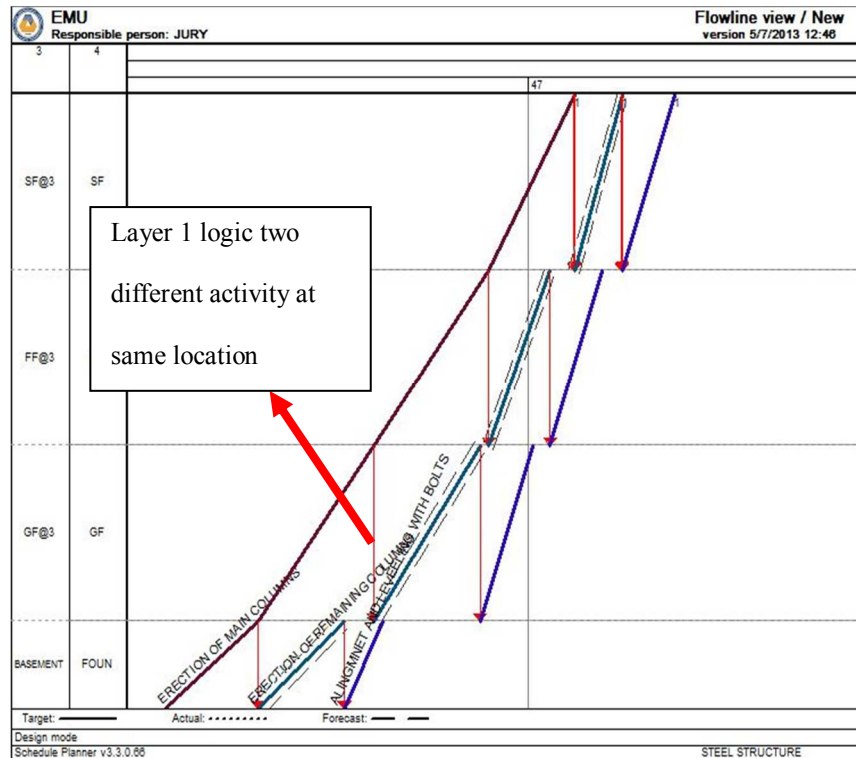
Figure 18: Layer 1 logic; Vico Schedule Planner

Layer 2: External Higher Layer Logic

External high layer is a linkage or logic between activities within same location. A dependency between two subsequent activities regulates the relationship between activities in different location levels. As an example in Figure 19,theactivity "Wood works" planned at site level (Foun), while activity "Tiling" has localities at (SP) level. This will therefore result in the entire activity "Wood works" must be completed at the (Foun) before work with activity "Tiling" can be started in the (SP) location.
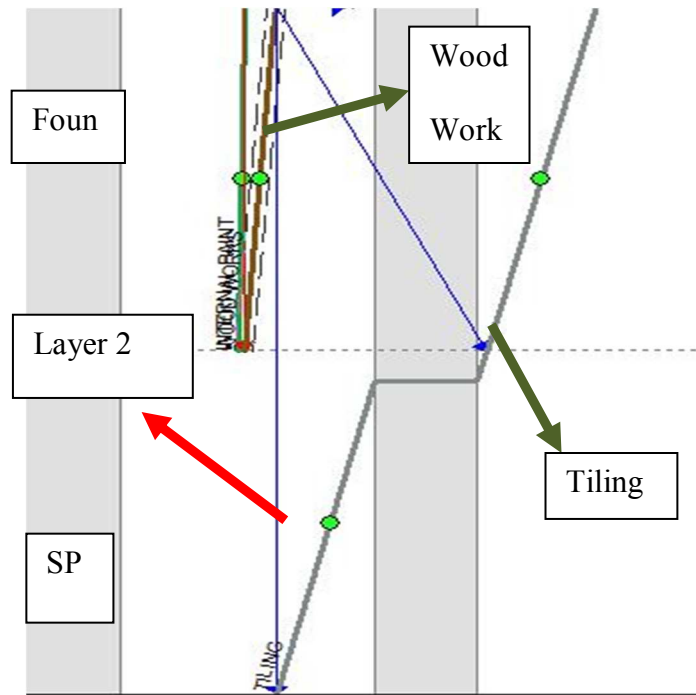
Figure 19: Layer 2 logic; Vico Schedule Planner

Layer 3: Internal Logic

Internal logic is a logical relationship between two activities within the same task.For

example, activity "External plastering" in(G.F) location has an external logic to

activity "Internal plastering" in (F.F)(Figure 20).The internal logic has a

characteristic to make the tasks of an activity to be continuous flow (Tutorials, 2009).
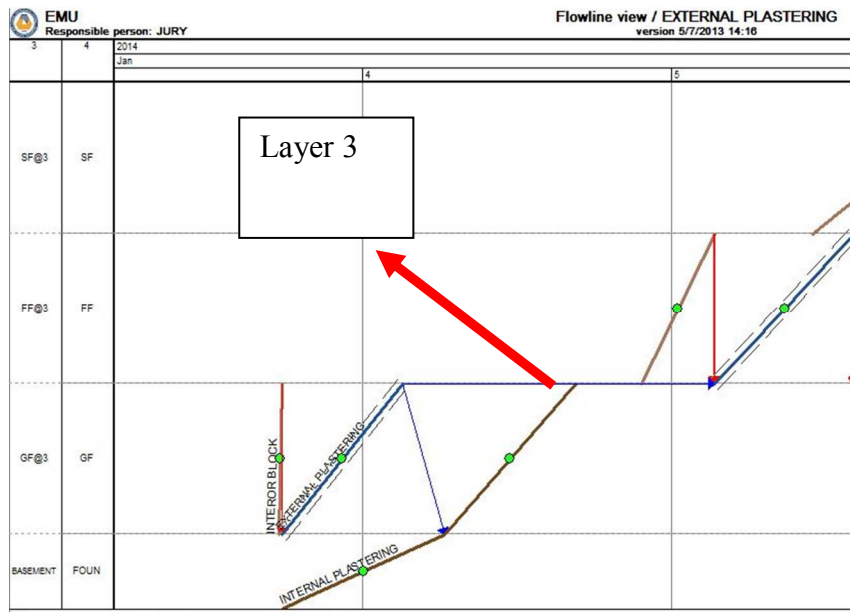
Figure 20: Layer 3 Logic; Vico Schedule Planner

Layer 4: Phase Hybrid Layer

Phase hybrid layer is a logic relationship which represents between task in related locations. This logic dependency is typically used to describe the relationship between the various activities involved in the execution of a given structure in a building, just like time lag in CPM as shown in Figure 21, the lag in LBS will be defined as location lag. For example the "Curing of slabs" activity in all locations (G.F),(F.F), and (S.F) has a location delay of -2used in LBS, for the predecessor task of "External brick" activity (Figure21).
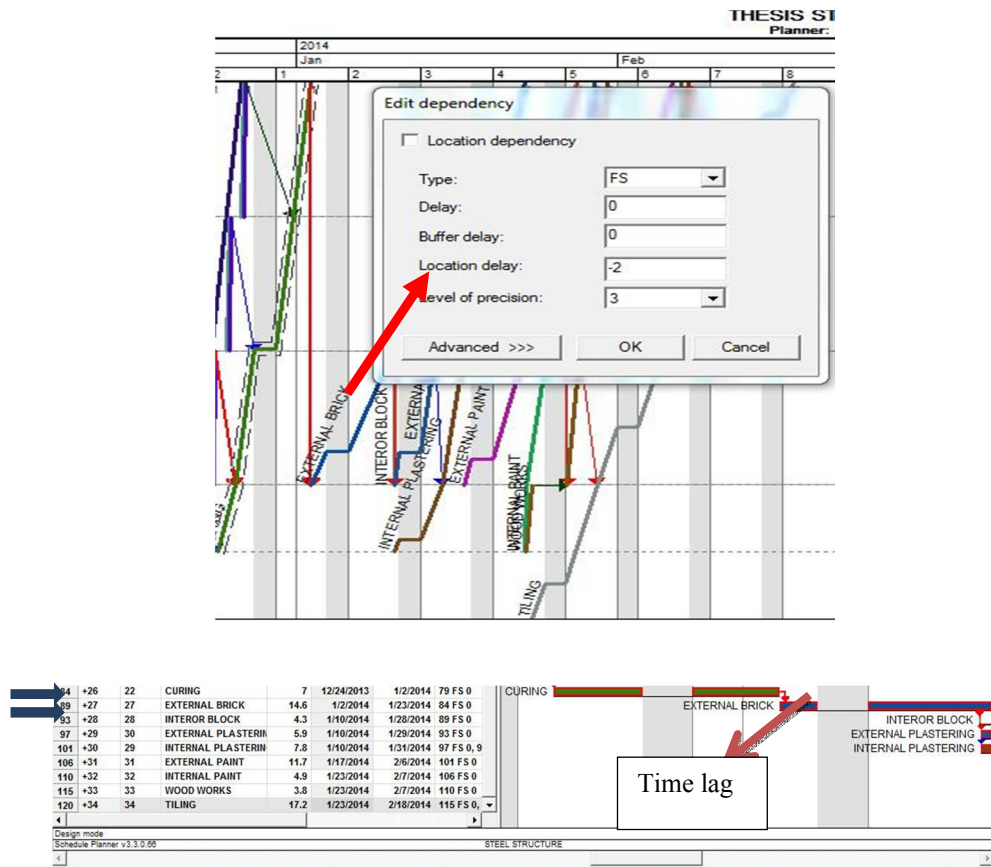
Figure 21: Layer 4 Logic; Vico Schedule Planner

Layer 5: Standard CPM Logic

CPM logic relationship between any task within any location in LBS.Same as the combination of bar charts and CPM, same characteristics can be done within flow line method but according to location breakdown structure rather than WBS.

The use of location based scheduling layering allows the project to be planned in a way that reduces the duration of the project, without resource consumption increases. See appendix A6 for the layered logic in LBS.

3.8 Scheduling Visualization

Since the study objective is to perform a comparison between LBS and CPM/Barcharts, 4 types of scheduling have been prepared. One of them is the traditional CPM/Barcharts schedule and the other two are Continuous LBS and

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Discontinuous LBS. the discontinuous LBS schedule has been transferred from traditional CPM/Barcharts into LBS without continuity force of the resources or crews, while the continuous LBS forces the crews to be continuous while performing their jobs, and it is also transferred to CPM/Barcharts.

3.8.1 LOB Flow Line Visualization and Formulation

LBS shows the scheduling visualization through flow line concept, which is a graphical representation that shows the work and movement of resources through locations (Lowe, D'Onofrio, Fisk, & Seppänen, 2012).

In flow line view of scheduling, the vertical axis represents the location, zones, or units, while the horizontal view represents the duration, which could be days, weeks, or months (Figure 22).
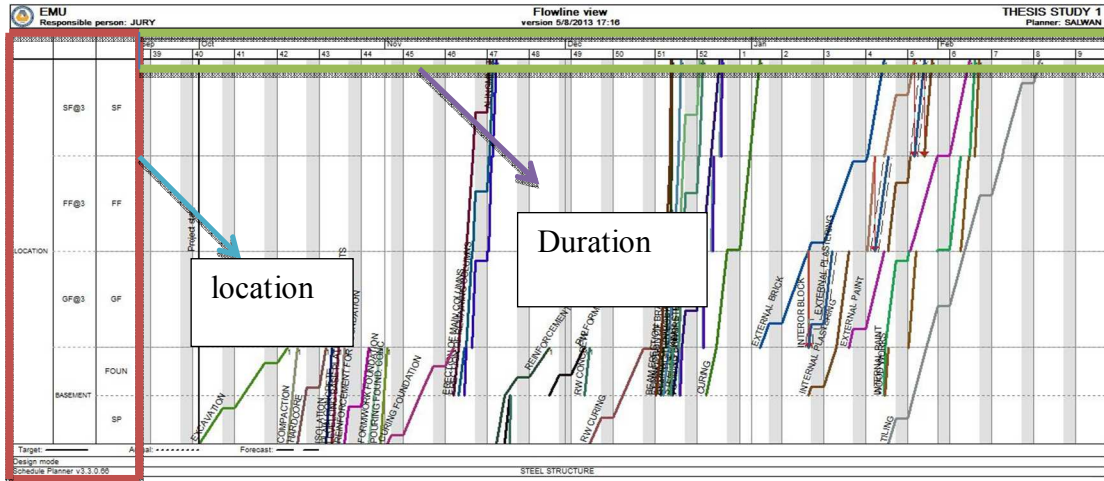
Figure 22: Flow line View; Vico Schedule Planner

The flow line view can show more characteristics about the visual aspect, like steeper slope line reflects to high productivity, while a flatter slope line reflects to a low productivity.

The main objective of line of balance in location based scheduling is to schedule a balanced resource by using suitable crew size and number of resources, which can be done (Elbeltagi, 2013):

1) The locations or units should be delivered in a rate that meets the specified finish of task.

2) The CPM should be taken into account for every task.

3) The continuity of work should be maintained.

In order to meet these three objectives, the LOB diagram formulation should be drawn according to these formulations:

3.8.1.1 Crew Synchronization

The relationship between crews and duration can be derived from the following equation below, see Equation 3 and Figure 23 (Elbeltagi, 2013):

$$R = 1 / (D / C) \qquad\qquad\qquad \text{Eq.3}$$

Where:

R: Slope of progress rate

C: Number of crews

D: Time
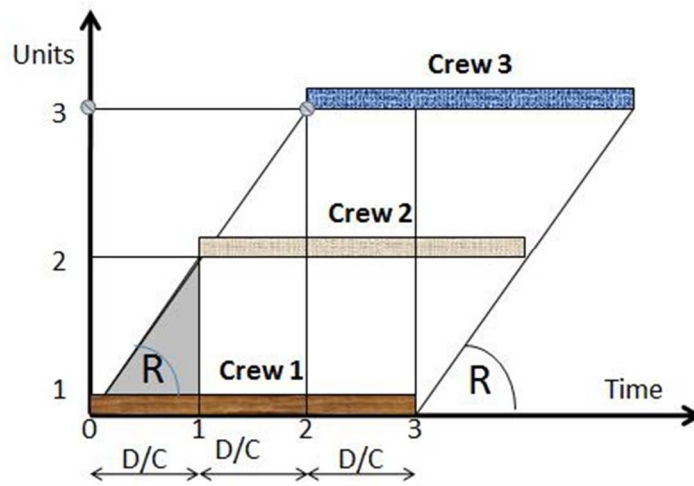
Figure 23: Crew synchronization; source (Elbeltagi, 2013)

3.8.1.2 CPM with Deadline Duration

The slope of flow line (LBS) according to CPM calculation can be drawn according to formulation in Equation 4 and Figure 24 (Elbeltagi, 2013); the calculation should meet the deadline of the finishing number of locations or units.

$$R_d = (n - 1)/(T_1 - T_L) \qquad \text{Eq.4}$$

Where

R_d: Minimum desired rate of delivery

n-1: Number of units or locations

T_1: CPM duration of unit or location

T_L: Project or task deadline duration
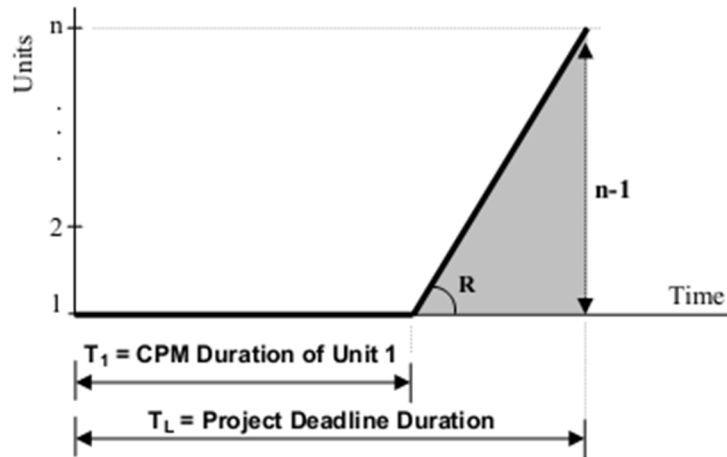
Figure 24: Minimum Desired Rate; source (Elbeltagi, 2013)

3.8.1.3 Resource Need Calculation

In order to complete a required job in a specific time, within a minimum delivery rate (R_d), number of resources should be calculated. Since it is related to CPM network, it will be calculated on longest path which is the critical path.At the same time,non critical activities are included by adding their total float, so the desired rate can be calculated according to Equation 5, Equation 6, and Figure 25 (Elbeltagi, 2013):

$$R_i = (n - 1) / (T_L - T_1) + TF_i \qquad \text{Eq.5}$$

$$C_i = D_i \; x \; R_i \qquad \text{Eq.6}$$

Where:

R_i: Desired rate for any repetitive task i

n: Number of units or locations

T_1: CPM duration of unit or location

T_L: Project or task deadline duration

TF: Total float for repetitive task i

As an example shown in Figure25, critical activities A, B, and C each have durations of 5 days, while noncritical activity D has duration of 2 days, within a total float of 3 days.
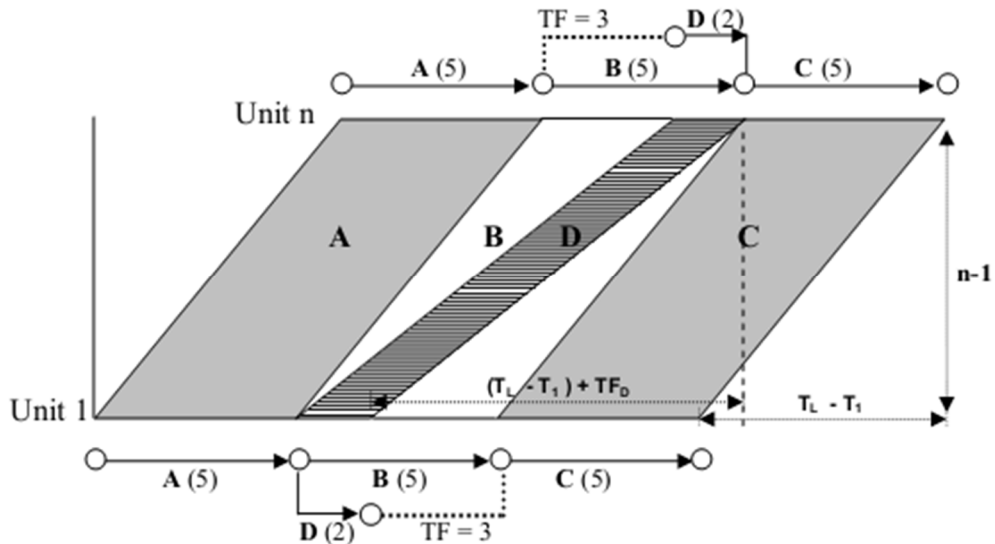
Figure 25: Resource Need Calculation; source (Elbeltagi, 2013)

In such cases since an integer number should be used for crew size, the number of crews should be rounded up, and an adjustment should be done to calculate the actual progress rate (Rai), this can be done by using the Equation7 and Equation 8(Elbeltagi, 2013):

$$Rai = Cai / Di \hspace{6cm} Eq.7$$

$$Cai = Round\ Up\ (Ci) \hspace{5cm} Eq.8$$

3.8.2 CPM and Bar Chart Visualization

Bar charts do not have any related calculation to view their visual aspects, but their visual representations depend on the time and tasks only. The vertical axis represents the task of activities within rows, while the duration is represented within horizontal axis, can be either days, weeks, or months. On the other hand, CPM is a different visual representation that shows activity within a network diagram map (Figure26).

CPM calculates the free float and total float. Total float is the total duration that an activity can be delayed without delaying the whole project duration. Free float is the duration that an activity within a project can be delayed without delaying the early start of successor activity. The critical path can be found from the float calculations. The zero floats represent the critical path of the project (Equation 9 and Equation10).

TF= (LS – ES) or (LF – EF)   Eq.9

FF= ES of successor activity – EF   Eq.10

Where:

TF: Total Float

FF: Free Float

LS: Latest Finish

ES: Earliest Finish

LF: Latest Finish

EF: Earliest Finish

See appendix A5 for all activities total float and free float.

By combination of both scheduling tools, CPM/Barcharts, a better visual representation can be maintained, like showing the critical path of the whole project (Figure26).Appendix A5 includes the whole project tasks.
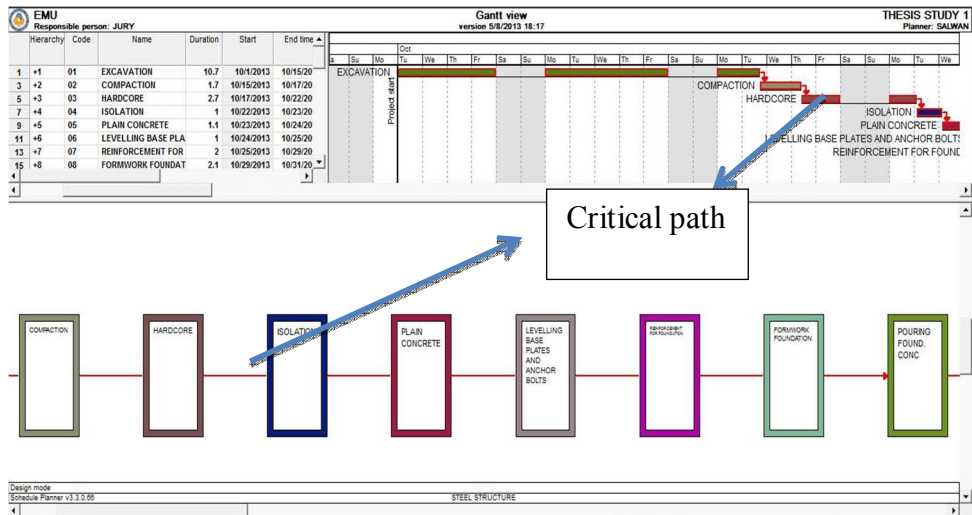
Figure 26: CPM/Barchart Visualization; Vico Schedule Planner

3.9 Production Flow

Construction projects typically consist of repetitive activities of the same resources in various locations of the project. A work or production flow is defined in the LBS context as activities and resources through movement of the project and its locations. Figure27 shows a continuous flow of tasks of steel structures through all floors.
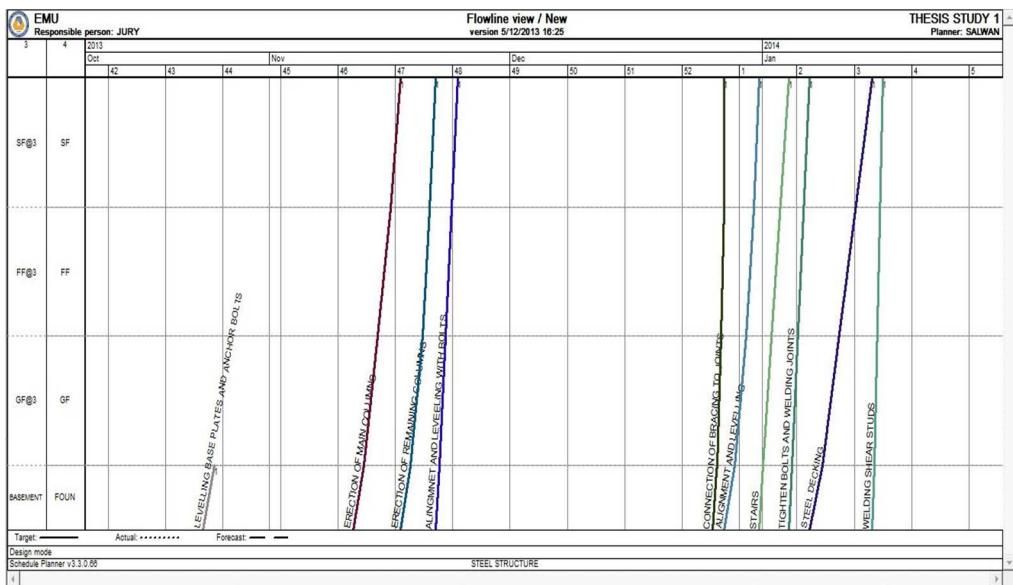
Figure 27: Continuous Flow of Steel Structures; Vico Schedule Planner

LBS have the ability to schedule projects in continuous flow, which forces the crew to work in a continuity way without interruption. The continuous production defines

the work of a task continuously from location to location (Lowe, D'Onofrio, Fisk, &Seppänen, 2012). As mentioned before, the difference between CPM and LBS is that LBS schedules the project in a continuous way of balancing resources, which may delay the start of a task so that work can be achieved in a continuous way.

LBS does not schedule tasks as late as possible. The objective is to schedule the continuity of work through crews without interruption, which may lead to low risk and high productivity of resources, because the labors will not leave the locations specified to them until they finish (Lowe, D'Onofrio, Fisk, & Seppänen, 2012).

For discontinuous flow, the concept is opposite to continuous production, which the work is not scheduled according to location. It is scheduled according to the predecessor work, which the work in a location cannot start until the predecessor work in the same location is finished (Figure 28) for the 3 floor steel building for the steel structural tasks.
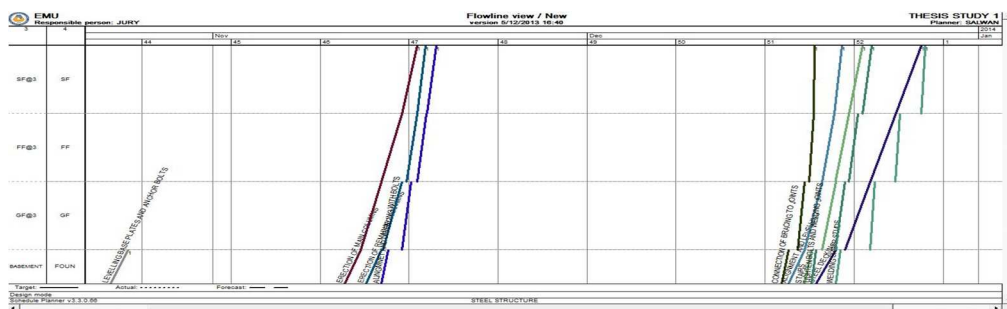
Figure 28: Discontinuous Work Flow of Steel Structure Tasks; Vico Schedule Planner

The discontinuous flow is same with the CPM/Barchart scheduling which uses as soon as possible to finish the task when the predecessor task finishes.

Appendices A5 and A6 show the continuous flow production of both LBS vs. CPM/Barcharts and the discontinuous flow production between LBS vs. CPM/Bar charts. It can be shown that the duration in continuous flow is greater than the duration of discontinuous flow due to a reason described before that the line of balance schedules the project according to resource continuity rather than shortening the project duration that CPM does(Seppänen, Ballard, & Pesonen, 2010).

3.10 Defining Risk Levels and Monte Carlo Simulation

Vico schedule planner has the ability to add risk categories with their levels, and assess them in Monte Carlo risk simulation which can mitigate the location based scheduling. There are five categories of risk that can be used in LBS (Fridays with Vico, 2009):

1) Starting risk: the risk or likelihood that task will begin on time.

2) Duration risk: risk or variability of a duration linked to individual location.

3) Resource beginning risk: risk or variability tied to getting resource to mobilize when needed to begin in a task.

4) Resource come back delay: delay associated with a crew's return if it forced to demobilize.

5) Production factor risk: risk or variability to production factor (i.e. skill level of crews).

The risk management is another topic, but it should be included in the scheduling and planning of the projects. Risk management includes planning continuous work, with using buffers is a special characteristics of line of balance, which will be described in next part of this chapter.

The risk levels are entered for every task, some tasks are more risky than others, some may have no risk at all, which depends on the contractor, subcontractor, or the crews themselves. The risks are entered according to logic of the work of crews, by experience of the planner, or by entering history agendas of the construction company. In this case study, the risk levels are entered theoretically and based on practical experience. For example the risk entry level for excavation can be different than the plain concrete. It can be seen that the risk category of starting the project in excavation is low, while for plain concrete is high. This is because of the experience that sometimes the mixer of concrete can be delayed (Figure 29). See appendix A7 for risk levels and schedule task risks.

Hierarchy	Name	Start of schedule task		Schedule task duration (%)		Beginning risk		Come-back delay		Production factor distribution	Dependencies
-1	EXCAVATION	Low	-2/0/5	Zero	100/100/100	Zero	0/0/0	Zero	0/0/0	(0.1-0.4)/(0.1-0.4)/1.1	
-1.1	EXCAVATION	Low	-2/0/5	Zero	100/100/100	Zero	0/0/0	Zero	0/0/0	(0.1-0.4)/(0.1-0.4)/1.1	
1.1.1	BASEMENT	Low	-2/0/5	Zero	100/100/100	Zero	0/0/0	Zero	0/0/0	(0.1-0.4)/(0.1-0.4)/1.1	
-2	COMPACTION	Low	-2/0/5	Zero	100/100/100	Low	0/0/20	Zero	0/0/0	(0.1-0.6)/(0.1-0.7)/1.1	- (FS)
+2.1	COMPACTION	Low	-2/0/5	Zero	100/100/100	Low	0/0/20	Zero	0/0/0	(0.1-0.6)/(0.1-0.7)/1.1	
-3	HARDCORE	Low	-2/0/5	Zero	100/100/100	Low	0/0/20	Zero	0/0/0	(0.1-0.6)/(0.1-0.7)/1.1	- (FS)
+3.1	HARDCORE	Low	-2/0/5	Zero	100/100/100	Low	0/0/20	Zero	0/0/0	(0.1-0.6)/(0.1-0.7)/1.1	
-4	ISOLATION	Low	-2/0/5	Zero	100/100/100	Low	0/0/20	Zero	0/0/0	(0.1-0.6)/(0.1-0.7)/1.1	- (FS)
-4.1	ISOLATION	Low	-2/0/5	Zero	100/100/100	Low	0/0/20	Zero	0/0/0	(0.1-0.6)/(0.1-0.7)/1.1	
4.1.1	BASEMENT	Low	-2/0/5	Zero	100/100/100	Low	0/0/20	Zero	0/0/0	(0.1-0.6)/(0.1-0.7)/1.1	
-5	PLAIN CONCRETE	High	-10/0/15	Zero	100/100/100	Low	0/0/20	Zero	0/0/0	(0.1-0.6)/(0.1-0.7)/1.1	- (FS)
+5.1	PLAIN CONCRETE	High	-10/0/15	Zero	100/100/100	Low	0/0/20	Zero	0/0/0	(0.1-0.6)/(0.1-0.7)/1.1	

Figure 29: Entering Risk Levels for LBS for Monte Carlo Risk Simulation; Vico

Schedule Planner

After risks have been defined, a Monte Carlo risk simulation is done. The Monte Carlo risk simulation is a tool used to model and identify the problem in the schedule. The results from the simulation can alert the planner to make proactive decisions. The process is like a throw dice or probability calculation to access each of the different 5 risk categories that has been defined in the task of the 3 floor villa

steel building. A Monte Carlo risk simulation is done to both continuous flow and discontinuous flow, with the same risk levels defined in both type of production flow. The red dot represents high risk, yellow represents intermediate while green represents that the tasks are in low risk level (Figures30 and 31).
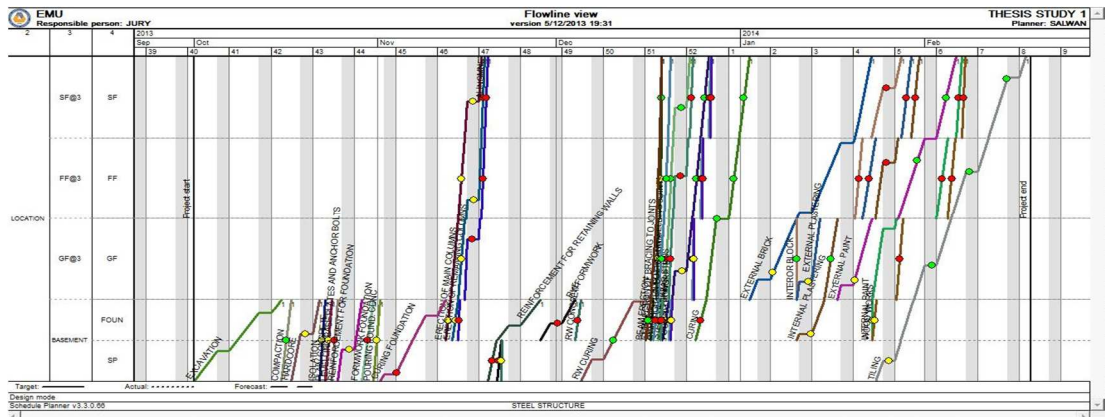
Figure 30: Monte Carlo Risk Simulation for Discontinuous Flow; Vico Schedule
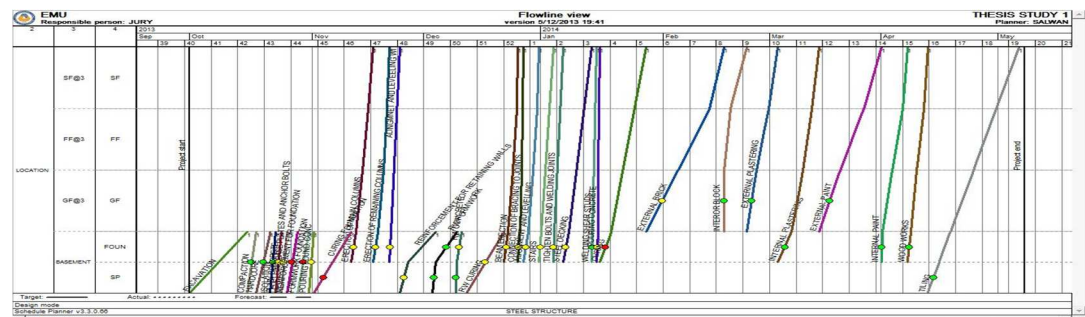
Planner

Figure 31: Monte Carlo Risk Simulation for Continuous Flow; Vico Schedule

Planner

3.11 Buffers

The buffers are used to absorb delays occurred in the project schedule and to protect the continuous flow. They are same as float but the difference is that in the base line schedule the buffer acts as a lag (Lowe, D'Onofrio, Fisk, & Seppänen, 2012).

LBS consumes an extensive amount of float while scheduling in a continuous flow and it extends the project duration. As a result, a buffer is added to the task in order to perform a contingency schedule and reduce the risk. A buffer is also used to optimize durations and shorten the whole project duration when optimization is done to the tasks that have floats.

3.12 Optimization of LBS Task

The process of continuous flow of scheduling in LBS is different than the CPM. It extends the project duration and consumes float. Buffers are used to absorb delay as mentioned before. The continuous flow produces time spaces between tasks (Figure 32) as an example for the 3 floor steel structure building. This time spaces can be optimized by changing the flow line slopes and make them parallel to the predecessor tasks, which will result in shortening the project duration (Figure 33). The slope of the flow line can be optimized by either changing the crew productivity or adding resource number. This method of controlling flow line can also be useful in the construction stage of the project while the resources can be controlled according to their daily, weekly or monthly work, unlike CPM it updates the schedule during the construction of the project.
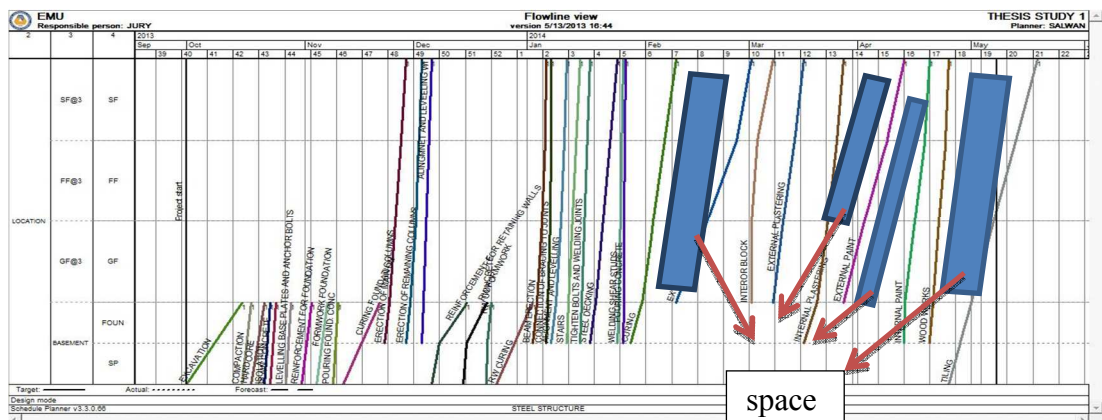
Figure 32: Time Space Between Activities; Vico Schedule Planner
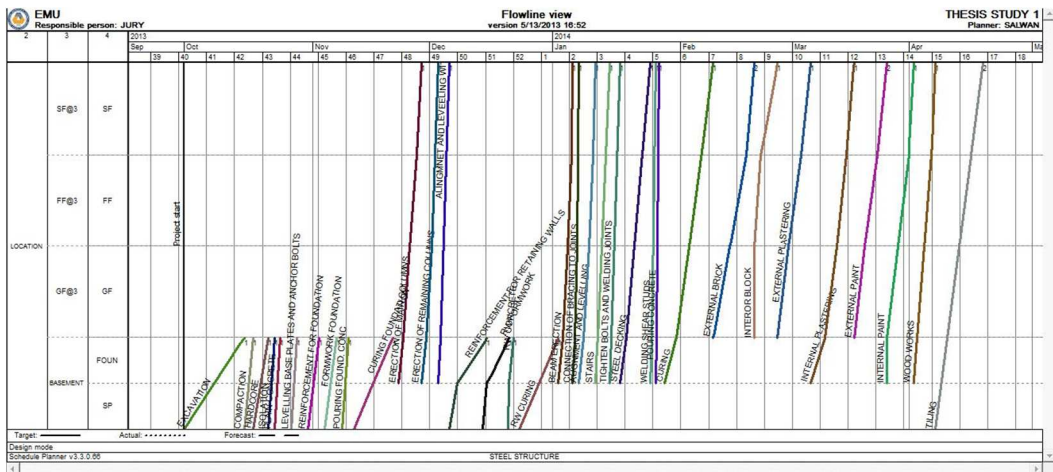
Figure 33: Optimization of Activities; Vico Schedule Planner

Chapter 4

QUESTIONNAIRE SURVEY ON LOB AND CPM/BARCHARTS

4.1 Introduction

The first time of documentation of LBS usage was in the Empire State building project in 1929 (Lowe, D'Onofrio, Fisk, & Seppänen, 2012), but its application in construction industry has not received 100% acceptance or usage. In recent years, many researchers have developed the LOB scheduling tool by modifying them or using software tool to implement them. Some undeveloped countries may even do not know what is line of balance and their family of LSM. This is because main usage of scheduling tool in their projects was CPM/Barcharts.

In order to examine the views of construction industry in LOB applicability and usage, a survey was conducted among different civil engineers in construction companies and academic staff for civil engineering and construction management schools. The questions were among different universities and construction companies like USA, UK, Australia, Canada, Turkey, Iraq, Iran and North Cyprus.

The questions were simple and limited. It may consist of some lacks like the respondents nationality, and this is because it costs more to develop a professional research survey. But at the end, it can be used to evaluate the civil engineers and academic staff views. The questionnaire survey was prepared to establish the following points:

1) Establish the viewpoints from both academic and construction engineers in the use or knowledge of line of balance.

2) To establish which scheduling tool is mostly used in construction projects, in different size of projects.

3) To get idea about what is the reason for not using line of balance in some projects.

4) To find out which scheduling tool has been used mostly and why.

4.2 Preparing Questionnaire

Preparing questionnaire is not an easy method and it needs time and money.In order to establish a good survey, the questionnaire should provide easy and understandable questions for the respondents. It should prepare them into logic and order. The software which was used for the questionnaire survey was free of use, but it has some limitations. These limitations are number of respondents, number of questions, and while submitting the questionnaire survey, it just asks about name, gender, and birth, and does not ask about the nationality. At the same time, the questions are uploaded online for a specific short time.

Most of the questions were prepared as closed ended questions with multiple answers. The multiple answer gives the flexibility to respondent to check more than one answer, while only one answer forces the respondent to check only one answer that he is satisfied with it. In order to simplify the answer to the respondent, an extra choice is added like "other" with an open answer beside it to specify their answer with another option which was not listed in the questions (Figures34 and 35). See Appendix B1 for all survey questions.

Questionaries

1.

Which type of organization do you represent?[*]

- Private owner
- Contractor
- Government
- Engineer
- Project Manager
- Academic Professor
- Research Assistant
- Graduate student
- Other (Please Specify)

Figure 34: A Sample of Survey Question Closed Ended with One Answer; thesis tool

website

9.

What are the benefits obtained from using Line of balance? (Check all that apply)

- Improved scheduling
- Improved estimating/bidding
- Increase control over risk and uncertainty
- Faster response to problems
- Improve planning before work starts
- Improved project control and forecasting after project start
- Balance between different activities achieved to reach objective duration
- Resource balance
- Work continuity for effective performance
- Easy understanding of the graphic schedule
- Other (please Specify)

Figure 35: A Sample of Survey Question Closed Ended with Multiple Answer; thesis

tool website

In order to receive a desirable amount of respondents, it was easy to use the internet to get emails of academic staff and construction companies from their official construction company or university website. Figure 36 shows the sending email to different respondent emails that were collected from their construction companies or universities.
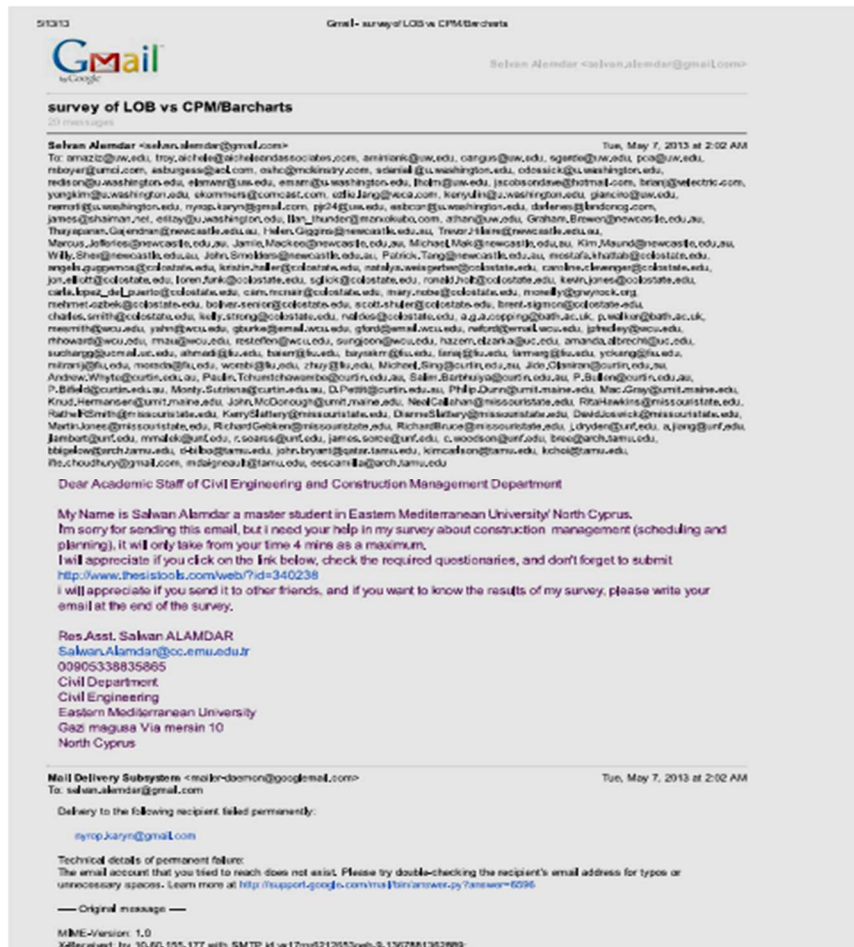
Figure 36: Sending Emails to Different Respondents with the Link of the Question

Survey; Gmail Website

4.3 Evaluating Respondents Answers

The process of calculation of respondents' answers was the aim of survey. The thesis tool website collects data itself and construct the answer of the respondents into two formats, Microsoft excel and charts.

The total of respondents divided by their answer, and multiplied by 100 to get the percentage of the respondents answered for specific question from the survey.

Chapter 5

RESULTS AND DISCUSSIONS

5.1 Introduction

As mentioned before, a case study of 3 floor steel structure was used on both LBS and CPM/Barcharts. The CPM/Barcharts scheduling were transferred into LBS scheduling method which was resulted into discontinuous flow. After that the discontinuous flow were transferred into continuous flow and data were collected from both scheduling tools. The important factor for the planner is to find the quantity, cost, time, resource allocation and distribution, and the risk of the project.

This section will explain the results obtained from CPM/Barcharts and the continuous and discontinuous flow of LBS. The results were collected by using LOB schedule with the use of Vico office software. The Vico office can schedule projects with both CPM/Barchart and LBS, so it was no need to use other software scheduling tool like Primavera or MS project.

This section will also discuss about the results obtained from the questionnaire survey which was distributed electronically by emails among civil engineers and academic staff of civil department for a specific construction companies and universities.

5.2 Scheduling the 3 Floor Steel Structure with CPM/Barcharts and Transferring them to LBS Discontinuous

After defining the tasks with their logical representations, the first result obtained from the case study was the CPM with combination of barcharts. The scheduling was prepared according to author's site experience, construction management courses, and some advices from academic staff of civil engineering department.

A review of the plans showed that they are generally characterized by:

- The activities were broken down by WBS (Work Breakdown Structure).

- Dependencies between activities were normally occurring.

- Resources were limited to labor, and machinery / equipment.

- The starting time of the project was 10/1/2013 and end of the project was 2/18/2014, considering the working hours of 8 hours/day, and the weekends were Saturday and Sunday, no holidays were included in the project (Figure 37). Appendix C1 shows all activities durations, quantities, costs, resources, and dependencies. The visual representation of bar chart in the software does not show all of the activities and all bars, scrolling down should be used when viewing the results in computer.
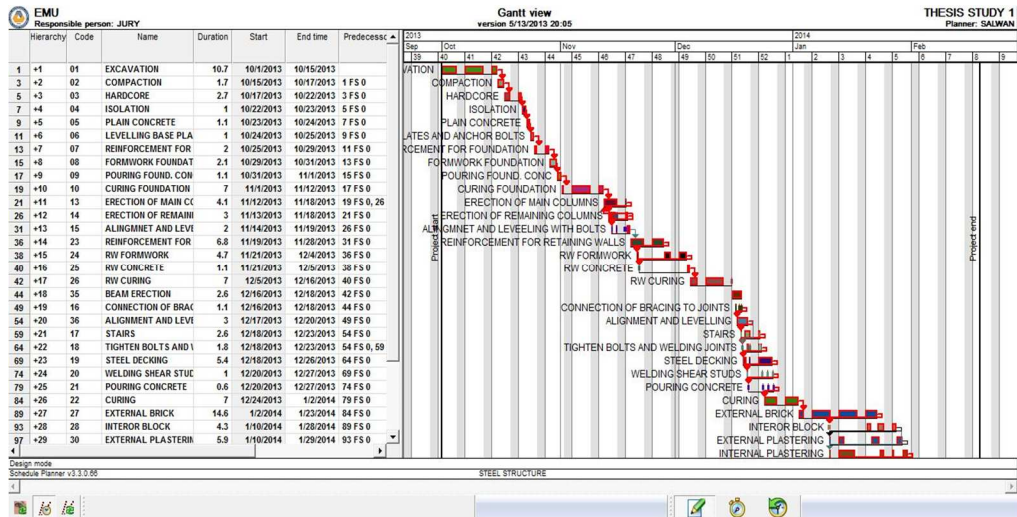
Figure 37: Barchart View with Critical Path; Vico Schedule Planner

After the schedule was prepared into CPM/Barcharts, it was transferred into LBS schedule. The data were all the same since the software itself can show both CPM/Barcharts and LBS in one window. Figure 38 shows the combined view of CPM/Barchart and LBS.
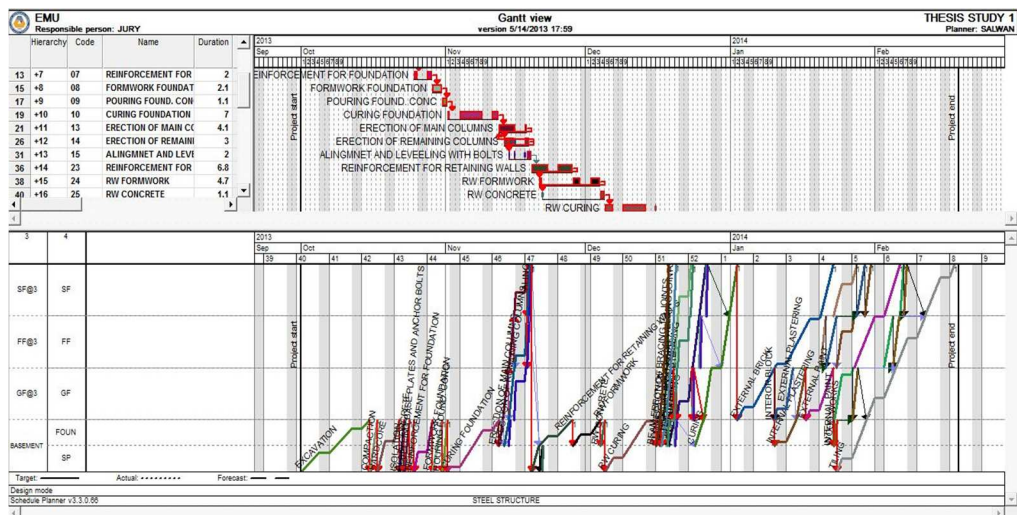
Figure 38: Combined View of CPM/Barcharts and LBS

As shown in Figure 38, the representation of visualization of tasks in LBS is better than the visualization in bar charts. Al the activities in LBS can be shown for the whole project duration unlike bar charts.

The resource graph can be readable and it can be seen how the resources are characterized in by showing their work hours in vertical axis and the days which they work in horizontal axis (Figure 39).
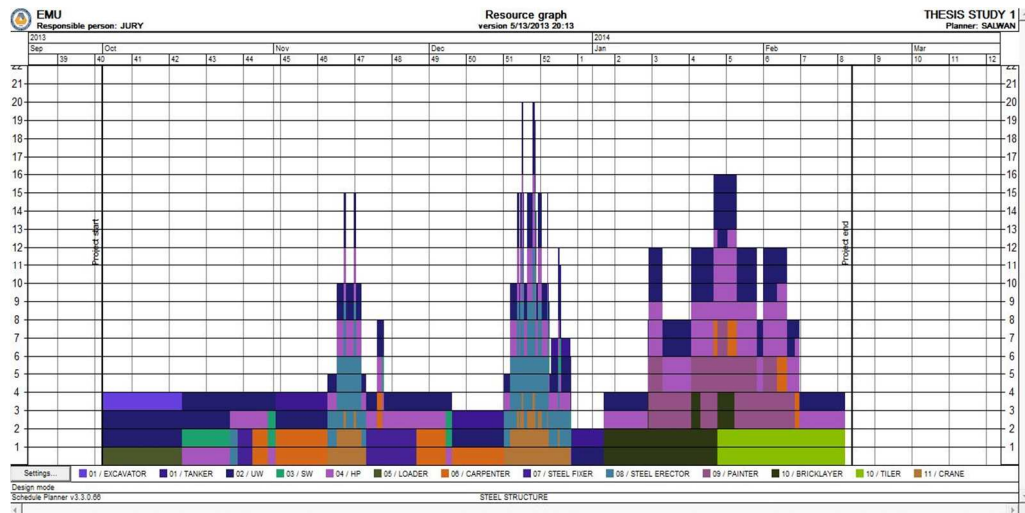
Figure 39: Resource Graph for all Activities; Vico Schedule Planner

A summary graph can be shown in resource histogram (Figure 40) which seems non homogenous work done while doing the schedule in a discontinuous work, the total maximum hour can be shown in 4th week of January which is 4978.7 hours consumed (Appendix C1). But in order to know which activity exactly worked maximum hour, we have to check date in bar chart view. Unlike LBS, within every flow line there is representation of resource histograms (Figure 41).
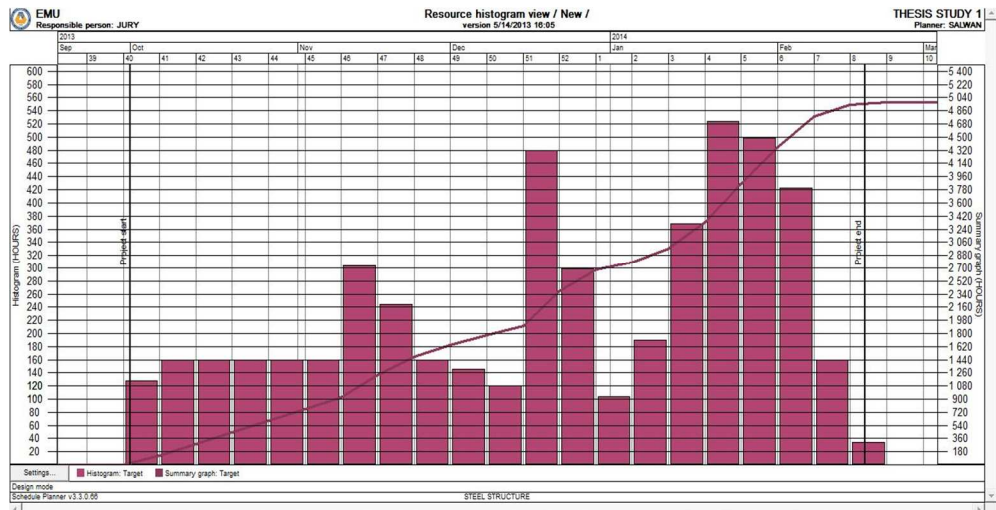
Figure 40: Resource Histogram for Discontinuous Flow; Vico Schedule Planner
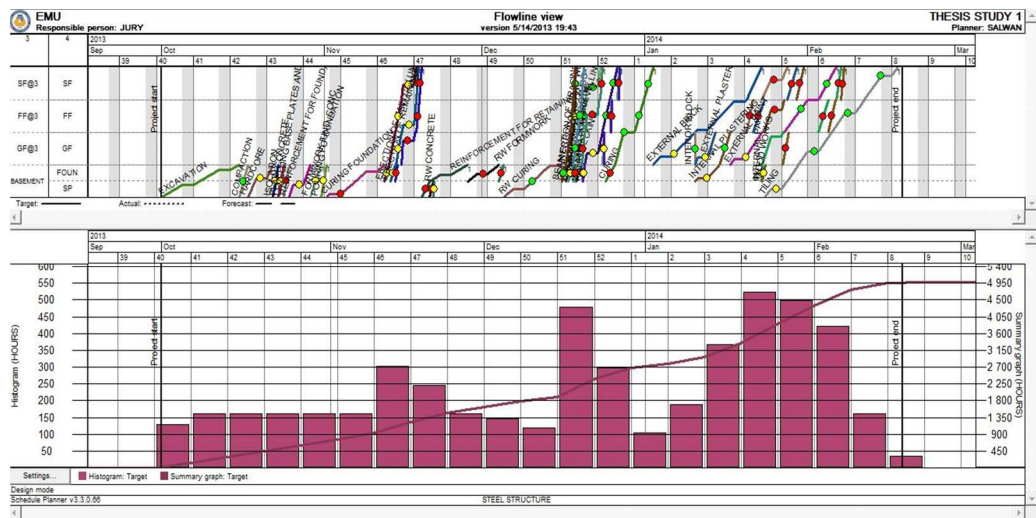
Figure 41: Combined View of LBS and Resource Histogram

Risk and certainty has been defined in the schedule of discontinuous flow. It can be shown that the project is risky with some activities. After that, a Monte Carlo simulation risk has been run with a 1000 iterations in the schedule. It can be seen that some task are dotted with red (high risk), yellow (medium risk), and green (low risk) (Figure 42) for the LBS schedule after defining risks.
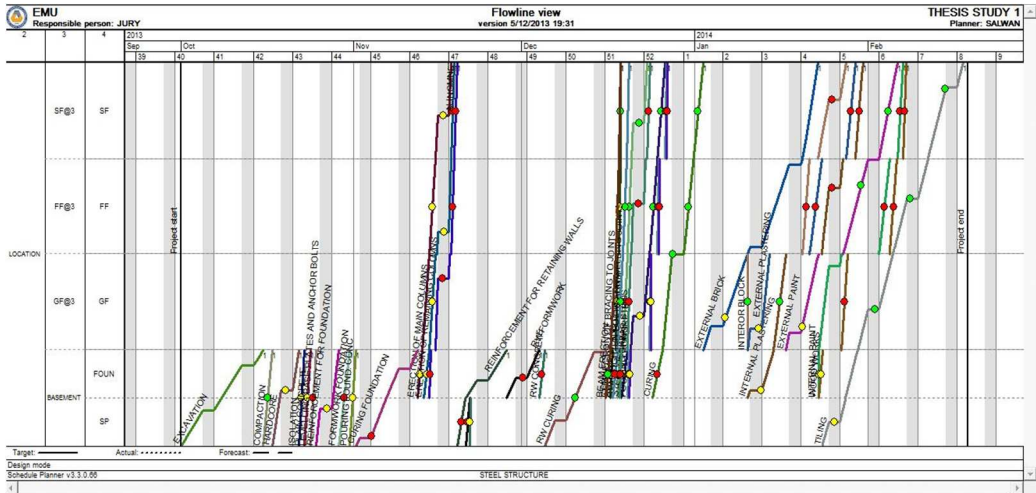
Figure 42: LBS with Risk Dotted Representation

For example, activity "External brick" shows 93.7% risky in the second floor location as shown in Figure 43.
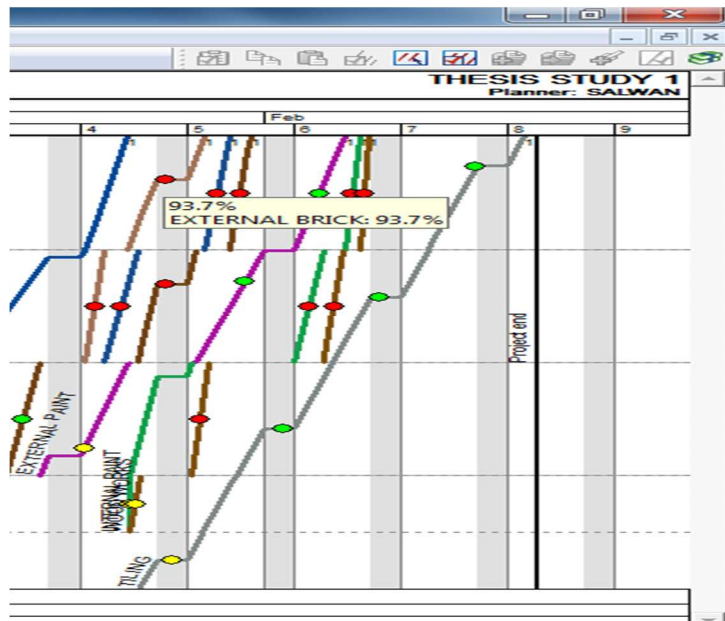
Figure 43: External Brick Activity with Red Doted Risk; Vico Schedule Planner

The total cost of the project is 251,915 TL as a BOQ method cost, crew cost is 101,844 TL, with a total cost of 353,759 TL (Appendix C1).

In order to remove the risk within activities, buffer is added. The buffer as described before is to absorb delays occurred in the project schedule and to protect the continuous flow. Figure 44 shows the risk levels for activities after buffer addition.
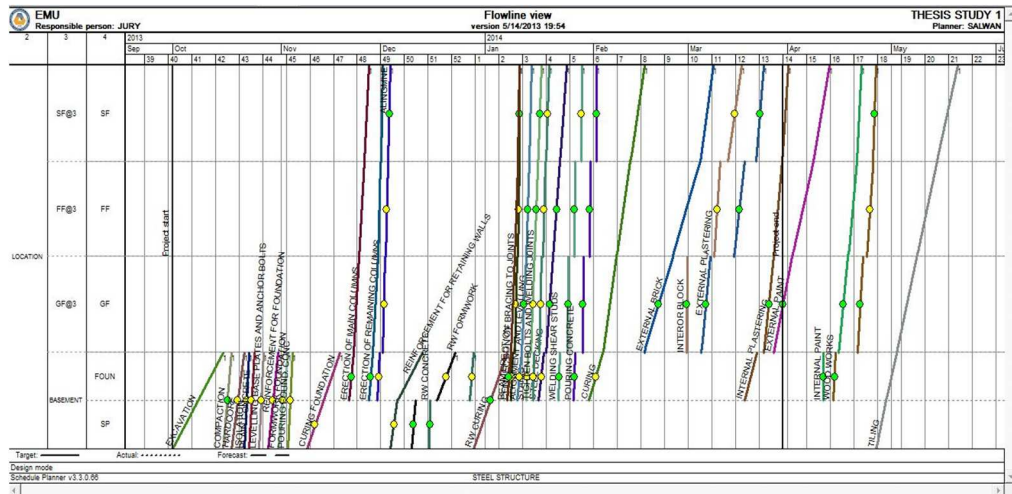
Figure 44: Risk Levels after Buffer Addition; Vico Schedule Planner

After buffer addition, the resource histogram has been changed from 4978.7 hours to 5053 hours and the finish of the project was shifted to 2/05/2013. With a BOQ method cost 251,915TL, resource cost 104,517TL, and total scheduled cost was 356,432TL.Appendix C1includes the BOQ, cost, duration, resource, and dependencies. This change is normal since risks are involved in the schedule.

5.3 Transferring Discontinuous Flow of LBS into Continuous Flow

The first objective of the thesis was achieved by transferring the CPM/Barcharts of a 3 floor steel structure villa into a LBS method. The project is considered as small, discontinuous flow, and with non-repetitive activities.

If we consider that every activity is repeated with same resource in different locations, we can schedule the project with a continuous flow of resources. For example, if we consider the "paintings of walls", the activities within this task are the

same except that the location is different. Since from beginning we defined the location of all activities within their tasks, it is possible to make all tasks forced to be continuous flow.

Figure 45 shows the new schedule of continuous flow of activities with resource histogram when transferred into continuous flow and running Monte Carlo risk simulation on it. There are still risky activities with red dotted risk but with low quantity if compared to discontinuous flow.
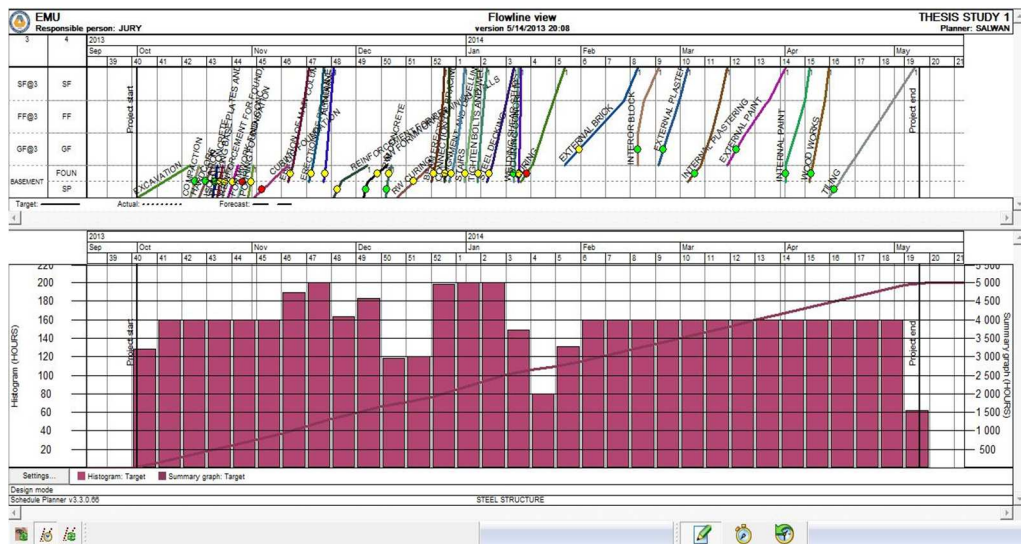
Figure 45: LBS With Risk and Resource Histogram; Vico Schedule Planner

As shown in Figure 45, the resource histogram is different than the discontinuous flow; the manhours in project became 5002.9 hours, starting day 10/01/2013 and project finish day 02/05/2014. BOQ method cost 251,915TL, resource cost 102,570TL, and total cost is 354,485TL.See Appendix C2 for BOQ, durations, costs, quantities, resource, and dependencies.

Buffers are added to some quantities to reduce the risky levels, and since it is a continuous flow and spaces are presented in the schedule, there is a great chance to

optimize the schedule by changing the slopes of activities and make them parallel to each other. This is one of the characteristics of flow line in LBS; the optimization can be done either by changing consumption rates or adding crew size. An addition of crew size will be considered to optimize the schedule (Figure 46).
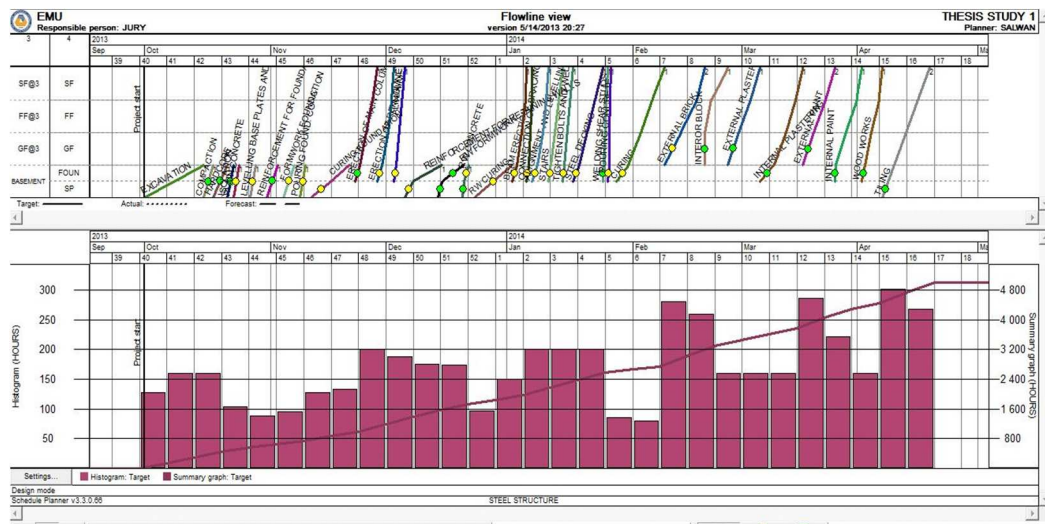
Figure 46: Optimization of Flow Line and Resource Histogram; Vico Schedule Planner

As can be seen in Figure 46,the resource histogram has been the same as 5002.9 hours, and the project finish day became 17/04/2014, which is shortened the duration, with same cost as a total of 354,485TL. See Appendix C4 for BOQ, durations, resources, quantities and dependencies. The temporal distribution of the optimized schedule shows that the project will finish on time in about 98%, which is a good result (Figure 47).
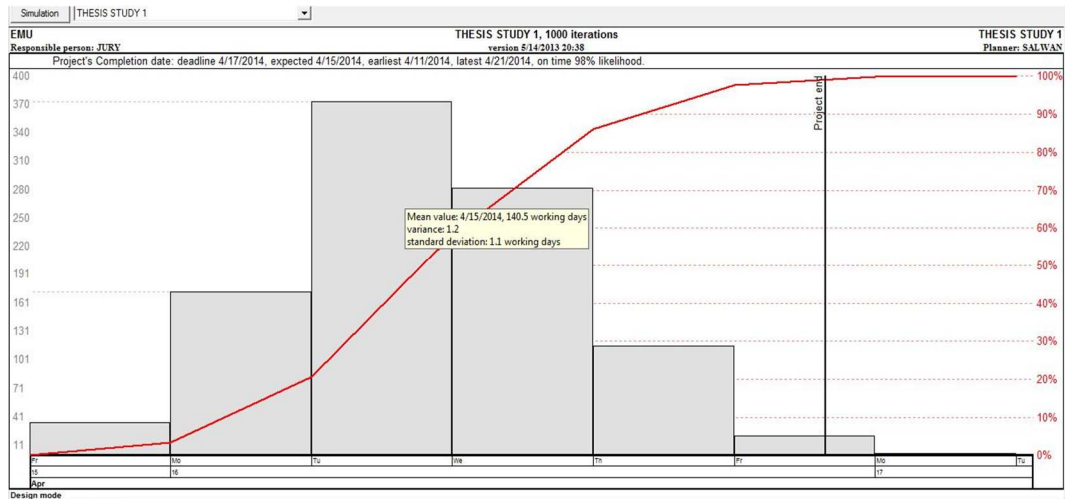
Figure 47: Temporal Distribution by Monte Carlo Risk Simulation; Vico Schedule

Planner

5.4 Summary of the Results and Discussion

The comparison is huge between the two scheduling plans. The two scheduling plans CPM/Barcharts and LBS can be compared in two categories; one as a general and another one as results.

5.4.1 General summary

Table 1 shows the general comparison between CPM/Barcharts and LBS:

Table 1: General Summary

General characteristics	CPM/Barcharts	LBS
Visualization of the schedule	Bar charts are easy to read and most of the engineers can communicate with it, but if so many activities are entered it will be hard to follow.	Flow line view has a better visual especially when it is colored, but it is not suitable to use for so many discrete activities in different locations.
Location	CPM/Barcharts use WBS, which is not suitable for linear or repetitive process.	LBS uses location break down structure, which means it will be easier to show tasks within locations.
Time representation	WBS is represented in horizontal axis as duration.	Locations can be represented either vertical or horizontal axis as a time.
Buffer	CPM uses float.	LBS uses float and buffer.
Production rate	CPM/Barcharts can use the productivity to estimate duration but they do not depend on it.	LBS uses the production rate to identify the flow of resources, and the line is drawn according to

		productivity rate.
Risk levels	CPM uses PERT for durations.	Uncertainty and risk probability is used on the resource time work and their production, rather than the time itself.
Optimization	Optimization of task in CPM/Barcharts can only be done by changing the duration, or logics in CPM.	Optimization can be done by changing productivity of resources without increasing risk.

5.4.2 Case study results summary

A case study has been used to collect the data and results. One of the objectives is to see that can LBS schedule a small 3 floor villa, and is it possible to make it continuous flow. Table 2 shows the results of CPM/Barcharts discontinuous and continuous flow:

Table 2: Results Summary

Results	CPM/Barcharts	LBS Discontinuous	LBS Continuous
Duration with risk without buffer	Start 10/01/2013 End 18/02/2014	Start 10/1/2013 End 18/02/2014	Start 10/01/2013 End 07/05/2014
Duration with low risk and buffer	Start 10/1/2013 End 28/03/2014	Start 10/1/2013 End 28/03/2014	Start 10/01/2013 Finish 19/05/2014
Duration with low risk optimized			Start10/01/2013 Finish17/04/2014
Total cost without buffer	353,759 TL	353,759 TL	354,485TL
Total cost with buffer	356,432TL	356,432TL	354,485TL
Total cost with optimization			354,485TL

As a summary from table 2, the cost of the project using both scheduling tools LBS and CPM/Barcharts has a small difference about 726TL. For the duration of the project, CPM/Barcharts has more advantageous than the LBS method, this is because the critical path shortens the time, but at the same time the project to finish on time is risky. Adding buffer will decrease the risk and lengthens the project duration, the buffer gives the continuous flow of LBS ability to optimize the flow lines, this will result into shortening time of the whole project, so when risk and buffer are considered in the scheduling, the LBS has more advantageous feature of time shortening than the CPM/Barcharts .

5.4.3 Achievements

As an achievement from the thesis study:

1. The project has been scheduled using both types of scheduling tool LOB and CPM/Barcharts, as it was described before by some authors that the LOB is not suitable for small projects, but same results has been found with different visualization of project schedule plan.

2. When risk levels has been defined it was shown that CPM/Barcharts was more risky than the continuous flow of LBS, this is because the continuous flow represents the resource productivity, and by making them balanced in different location the project will less risky, but time will lengthen.

3. Optimization of the flow line has been done in LBS, as a result it shortened the duration time, with a quite less change in cost.

5.4.4 Advantages

While using LBS, some main advantages has been obtianed from scheduling of the case study as follow:

1. Location representations in LBS are more accurate and easily can be read in the schedule plan, it can show you in which location, floor, or zones the work has been started or finished, since they use location break down structure, in CPM or bar charts the location can be only be shown by sentences, but for LBS locations are shown in a way of building floor like starting from ground floor to the final floor.

2. As a productivity the flow line in LBS can show the productivity of resources, the slopes of line represents the productivity of resources, the steeper slope means high productivity, the non steeper slople represents low

productivity, from the visualization of the flow lines in LBS, the planner can control the resources or the flow line by changing their productivity or adding more crew size to overcome the lengthen duration of the whole project.

3. Movement of crews can easily shown in the flow line of LBS, this help the planner to find the clashes of different activities, at the same time distributing them in a balanced way that it will not affect different resources in different locations.

4. Many task with same activity can be shown in one flow line, for example the painting of ground floor, first floor, and second floor can be shown in three different network or Bar chart, while LBS can only shown them in one flow line, this helps the schedule not to be crowded and gives a better visualization of the whole project schedule.

5. Optimization of the flow lines in LBS is one of the main feature, after finishing the schedule with using buffers, the planner have the ability to shorten the project duration, by optimization of the flow lines if there will be any spaces between the lines.

5.4.5 Disadvantages

Some disadvantages can be obtained from the study as follow:

1. Beside buffer are used to consume the delay of the schedule and minimize the risk, but they in updating they have a disadvantages feature, LBS they don't update the schedule instead they control the schedule daily or weekly (Lowe, D'Onofrio, Fisk, & Seppänen, 2012), at the same time this will make the schedule to work slowly and make the tasks to be as late as possible, so as to perform a continuous flow, not like CPM which the aim is to finish the task a soon as possible.

2. The other disadvantages are the cash flow diagram, but with aid of computer software it could overcome the problem.

3. For small building with large amount of discrete activities and different location LBS, will be hard to manipulate theses activities into tasks.

4. The communication will be hard for engineers to use the schedule in the site with each other, since they are not used to work on LBS, or track their work on it, as they used to do in Bar charts.

5.5 Questionnaire Survey Results

83 respondents replied in two weeks. The respondents answered to a specific question related to which organization they work, what is their primary industry, and usage of scheduling tool with their software. The results were convincing for this study; however, more survey can be done on this subject. But since it costs time and money, the results and questions were moderately satisfied for this research.

5.5.1 Question 1: Organization Type

The first question was to see which respondents are included in the survey. Since the academic life of civil is different than the site life,it is important to see different perspective views (Figure 48).

Which type of organization do you represent?

Private owner	5 (6.02 %)
Contractor	4 (4.82 %)
Government	6 (7.23 %)
Engineer	22 (26.51 %)
Project Manager	8 (9.64 %)
Academic Professor	18 (21.69 %)
Research Assistant	10 (12.05 %)
Graduate student	10 (12.05 %)
Other (Please Specify)	0 (0 %)
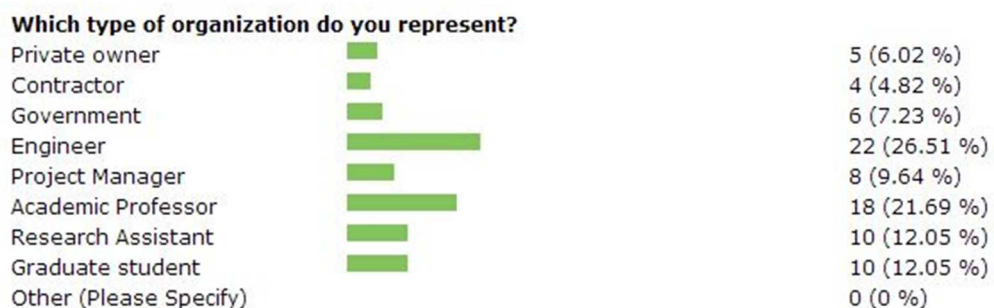
Figure 48: Type of Organizations

Most of the respondents were engineers (26.51%), followed by academic professors (21.69%). The least percentage was contractors (4%). This is a good result that most of the respondents were site engineers and academic professors, which can give results on which scheduling tool they prefer.

5.5.2 Question 2: Primary Industry

The second question was the primary industry of the respondents, which is another important factor to know that which industry type we are dealing with. The highest percent was the building construction with 67.47% followed by 10.84% others; which most of their answers was geotechnical survey, and education (Figure 49).

What is your primary industry?		
Building Construction		56 (67.47 %)
Transportation		5 (6.02 %)
Hydraulics		5 (6.02 %)
Oil and Gas		4 (4.82 %)
Power		2 (2.41 %)
Process		2 (2.41 %)
Other (Please specify)		9 (10.84 %)

Figure 49: Primary Industry of the Respondents

5.5.3 Question 3,4, and 5:Scheduling Tool

The most important question was asking the respondents about the best scheduling they prefer in the construction projects. The questions were divided into 3 questions with different questions and same multiple answers. Unfortunately, when respondent came to these questions, some of them left the survey without answering the question which dropped into 80 respondents, this may be because the respondent was bored from the first couple questions, or did not have any idea to answer.

For small construction projects, most of respondents answered bar chart schedule, while for medium construction projects the answer was distributed between CPM and Barcharts. For big projects, linear and repetitive process construction projects,

the answers were divided between the 3 scheduling tools, CPM, Barcharts, and LOB (Figure 50).

Which type of scheduling tool you think is appropriate to use on small size...

Network Diagram (eg. CPM)	15 (18.52 %)
Bar Chart (Gantt Chart)	51 (62.96 %)
Line of Balance	11 (13.58 %)
Other (Please specify)	4 (4.94 %)

n = 81
# 81

Which type of scheduling tool you think is appropriate to use on Medium siz...

Network Diagram (eg. CPM)	32 (40 %)
Bar Chart (Gantt Chart)	36 (45 %)
Line of Balance	8 (10 %)
Other (please specify)	4 (5 %)

n = 80
# 80

Which type of scheduling tool you think is appropriate to use on Mega,linea...

Network Diagram(eg. CPM)	29 (36.71 %)
Bar Chart (Gantt Chart)	20 (25.32 %)
Line Of Balance	23 (29.11 %)
Other (Please specify)	7 (8.86 %)

n = 79
# 79

Figure 50: Survey Answer to Different Scheduling to Different Construction Project Size

As a result it seems most of civil engineers prefer CPM/Barcharts, this may have many reasons and conclusions, one of the reasons could be that most of civil engineers don't have any idea about the linear scheduling or line of balance scheduling, this can be discussed in section 5.5.5 of this chapter. The other reason may be because of the availability of software, weak communication between engineers because the visualization of LOB is different than CPM/Barcharts.

5.5.4 Considering Risk Levels and Uncertainty in Construction Projects

Another question was asked to respondents about the consideration of risk levels or uncertainty in scheduling projects. Most of answers were yes with 80.49%.The aim of the question was in order to know if planners use risk or uncertainty or PERT

while scheduling and planning their projects(Figure 51). Considering risk is one of the important parts in construction management, especially while planning or scheduling a construction project, MS project and Primavera use the PERT technique to define the optimistic and pessimistic of durations, LBS also use PERT as risk levels for resource since the resource themselves control duration of project by their productivity and use Monte Carlo risk simulation to run the results in a 1000 iterations. The case study has been defined the risk levels in both scheduling tools CPM. Barcharts and LBS in order to see the difference between them.
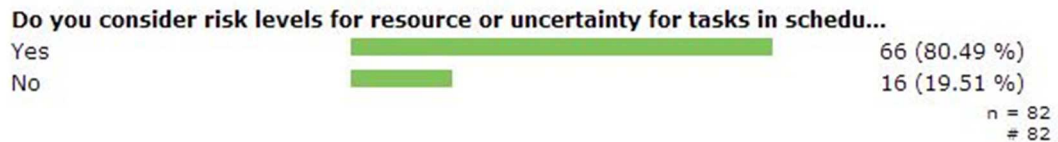
Figure 51: Risk Level Consideration in Projects

5.5.5 Information about LOB

This is the most important question in the survey. Some engineers or construction companies might not have any idea about the line of balance scheduling. This question was asked to know how many percent of the respondents know about line of balance or other linear deviation. The survey was prepared in a way that if the respondent said "YES", a group of questions will appear to him ;and if said "NO", the question survey will stop. This is because there is no benefit for survey to take place if the respondent does not know anything about line of balance. At the same time, this means that this amount of percent do not use line of balance. The respondents who said "NO" were 37.8%, which means they never used line of balance or heard of it (Figure 52).

This question realizes that there still some engineers haven't heard of LSM or any other deviations. 31 out of 82 respondents were unfamiliar with the scheduling tools, even so for different country it has other meanings like LOB, LSM, LBS, VPM, Time distance graph and others. In the question we mentioned the most famous ones, it may occur to respondent that he heard of LSM, but he never heard of LBS or vice versa, but most of them were mentioned in the question since they have the same characteristics.

Do you have any idea about Line of Balance, Flow line, Linear Scheduling or...

Yes	51 (62.2 %)
No	31 (37.8 %)
	n = 82
	# 82
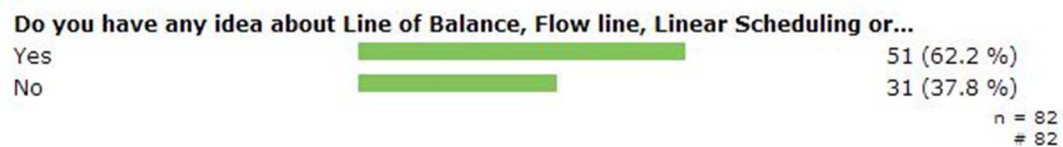
Figure 52: Survey Question about Knowledge of LOB and its Deviations

5.5.6 Usage of LOB in Construction Industry

A new page would appear for the respondents who answered "YES" in previous question about how much percent do they use LOB. The highest percent of answer was 36% who said "NO", and then followed by28% who claimed between 25-50 % they use line of balance.

For respondents who answered the last two choices "NO", and (25-50%) would be guided to another page asking about what is the reason of their response. Other respondents who answered the other 3 multiple answers like "always", "on 75 or more", or "over 50%", would be guided to a different page of survey on why they use LOB scheduling. The highest percent was 36%, of those who have knowledge about LOB, but they never use it; followed by 28% for those who use about 25%-50% in their construction project. Figure 53 shows the details of the answers.

Do you use Line of Balance (Flow Line) scheduling on your construction proj...

Yes, always	6 (12 %)
On 75% or more of projects	7 (14 %)
On over 50% of projects	5 (10 %)
50-25% of time	14 (28 %)
No	18 (36 %)

n = 50
# 50
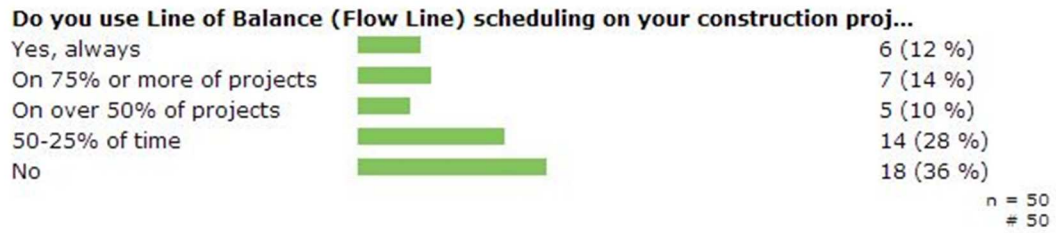
Figure 53: Usage of LOB

As seen in Figure 53, the respondents dropped from 81 to 50 respondents, this is because the pervious question was linked to it, in case respondents answered YES. It can be seen from the results even though civil engineers know or familiar with LOB, but they don't use them, the sections 5.5.7 and 5.5.8 discuss the results of benefits and disadvantageous usage of LOB of only 50 respondents out of 80.

5.5.7 Respondents Who Always or More Than 50% Of Their Projects Use LOB

Respondents who answered "always" or "more than 50%" of their construction project use LOB scheduling, were guided to a new page about benefits of using LOB. This part is important to know the respondents point of view for using LOB in their projects. The highest percent was 57% that the LOB benefit of using was "improving the schedule" followed by42% as "an increase control over risk" (Figure 54). Since there was no need to ask respondents about the other scheduling tools if they always use LOB or more than 50% use in their project, the survey question will end for them.

What are the benefits obtained from using Line of balance? (Check all that ...

Improved scheduling	8 (57.14 %)
Improved estimating/bidding	4 (28.57 %)
Increase control over risk and uncertainty	6 (42.86 %)
Faster response to problems	5 (35.71 %)
Improve planning before work starts	3 (21.43 %)
Improved project control and forecasting after project start	5 (35.71 %)
Balance between different activities achieved to reach objective duration	6 (42.86 %)
Resource balance	5 (35.71 %)
Work continuity for effective performance	4 (28.57 %)
Easy understanding of the graphic schedule	5 (35.71 %)
Other (please Specify)	1 (7.14 %)

n = 14
≠ 52

Figure 54: Benefits of LOB

As it can be seen that out of 50 respondents only 14 said YES, still it's a small number from a random sample, but still it seems that most of civil engineers don't use the LOB technique, to find out why they don't prefer it, a special question was prepared for the remaining respondents who answered NO, in section 5.5.8.

5.5.8 Respondents who Answered "NO" Or "25%-50%" of Their Project Use LOB

Respondents who answered "NO" or "25%-50%" of their projects use LOB, would be guided to a different page of survey.

The first question was "why they do not use LOB in their construction projects", followed by another question about "which scheduling tool you prefer other than LOB".

Respondents who did not use LOB in their construction projects, mostly answered that the reason was lack of wide application and unavailability of software with both

78

having a percent of answer as 42%. Other answered that it is only used for repetitive

and linear projects with 27% (Figure 55).

Why you do not use Line of Balance on Construction scheduling? (Check all t...

It is not widely used	14 (42.42 %)
It is a complicated scheduling tool	5 (15.15 %)
Unavailability of software	14 (42.42 %)
Does not give any beneficial results	2 (6.06 %)
It is used only for repetitive action and mega projects	9 (27.27 %)
It does not have CPM or lack dependency	6 (18.18 %)
Hard to read or manipulate the scheduling graphs	2 (6.06 %)
Lack of risk and uncertainty	2 (6.06 %)
Limited capability in improving production	2 (6.06 %)
Hard calculation of time	3 (9.09 %)
Cost more money	2 (6.06 %)
Delay in time	7 (21.21 %)
other (please specify)	6 (18.18 %)

n = 33
# 74

Figure 55: Reason for not Using LOB

It can be shown that, if the availability of software, or if it was widely used as

CPM/Barcharts, the respondents will use the LOB scheduling tool.

5.5.9 Respondents who Prefer Other Scheduling Tools Over LOB

This question asked about which scheduling tool the respondent prefers over LOB.

The highest answer was Barcharts with 48% percent followed by CPM with 39%

(Figure 56). Another question was followed for those who answered "CPM" and

Barcharts asking them which the benefits obtained from using CPM and Barcharts,

and which scheduling tool software is preferred to be used.

Which other scheduling techniques do you mostly prefer on your work?

Bar charts		16 (48.48 %)
CPM		13 (39.39 %)
4D planning		4 (12.12 %)
Other (Please specify)		0 (0 %)

n = 33
# 33
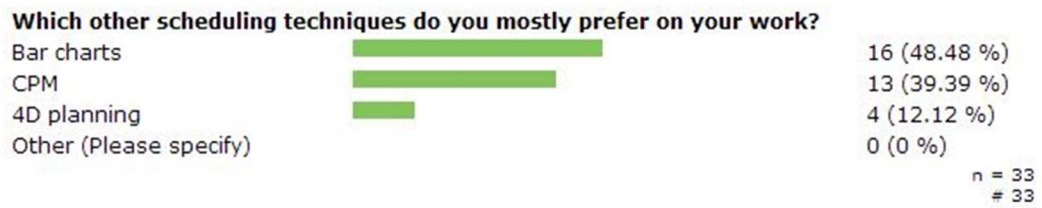
Figure 56: Question Survey of Using Other Scheduling Tool than LOB

5.5.10 Benefits Obtained From Using CPM/Barcharts

Respondents who rarely or never used LOB and preferred other scheduling tools, were asked about the benefits obtained using CPM/Barcharts.The highest percentage of answer was "time" saving with 57% followed by 53% as it "improves scheduling" (Figure 57).

What are the benefits obtained from using Bar charts or CPM than other sche...

Improved scheduling		15 (53.57 %)
Improved estimating/bidding		5 (17.86 %)
Reduce delays		8 (28.57 %)
Time savings		16 (57.14 %)
Increase control of risk and uncertainty		4 (14.29 %)
Faster response to problems		7 (25 %)
Cost savings		7 (25 %)
Improved understanding of the project		14 (50 %)
Improved planning before work starts		11 (39.29 %)
Improved project control after work starts		12 (42.86 %)
Crucial to keep project in critical path		7 (25 %)
Other (please specify)		0 (0 %)

n = 28
# 106

Figure 57: Benefits of CPM/Barcharts

Respondents answered that CPM/Barcharts has benefits in shortening time, improving and understanding of the project, but does it mean that LOB does not have this characteristics, from the case study of 3 floor steel structure building it showed that the LBS improved the scheduling and shortened duration by optimizing the flow

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lines, although for those who always use LOB in their projects as described in sections 5.5.7, also answered that the reason of using LOB in their project is improve the schedule.

5.5.11 Software Use in CPM/Barcharts

This question was related to the software use of the CPM/Barcharts. Most of the respondents answered that they use primavera and MS project in their planning and scheduling projects, other software were not checked (Figure 58).

For those who answered Primavera or MS project, another page was opened as the final page of the survey with submit option.The last question was that what was the reason for choosing Primavera or MS project.

What computer software do you mostly specify or use on scheduling of constr...

Ms Project		14 (50 %)
Primavera		14 (50 %)
Vico control		0 (0 %)
Suretrak		0 (0 %)
Artemis		0 (0 %)
Other (please specify)		0 (0 %)

n = 28
# 28
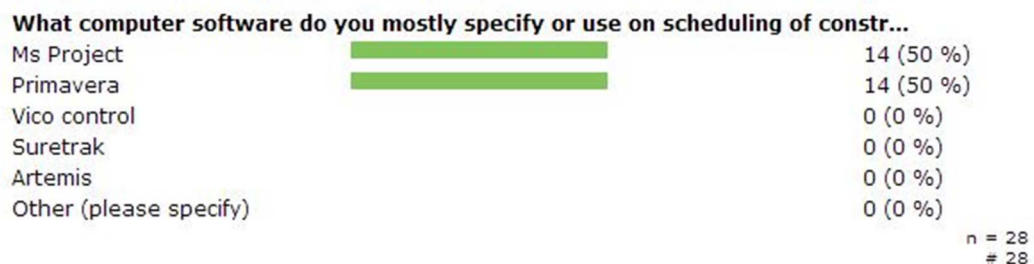
Figure 58: Question Survey about Usage of Scheduling Software

5.5.12 Reason for Choosing Primavera or MS Project in Construction Planning and Scheduling

This question is most related about what are the reasons of using the Primavera or MS project. Most of the answers were "easy of usage for MS project", and 66% answered that the reason for using primavera was because its widely used for Primavera (Figures 59 and 60).

Why do you prefer using Primavera software on you scheduling projects? (Che...

Easy of usage	6 (40 %)
Widely used	10 (66.67 %)
It schedules combined Bar chart and CPM	6 (40 %)
It is forced by contractor to use	3 (20 %)
It has more feature than other softwares	6 (40 %)
Other (Please Specify)	2 (13.33 %)

n = 15
# 33
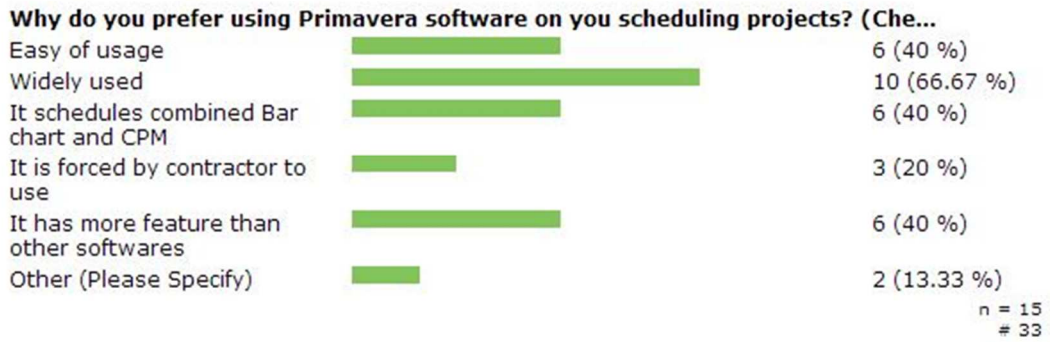
Figure 59: Primavera Software Survey Question

Why do you prefer using MS project software on you scheduling projects? (Ch...

It is easy of usage	11 (84.62 %)
It is widely used	10 (76.92 %)
It schedules combined Bar chart and CPM	7 (53.85 %)
It is forced by contractor to use	1 (7.69 %)
It has more feature than other softwares	0 (0 %)
Other (Please Specify)	1 (7.69 %)

n = 13
# 30
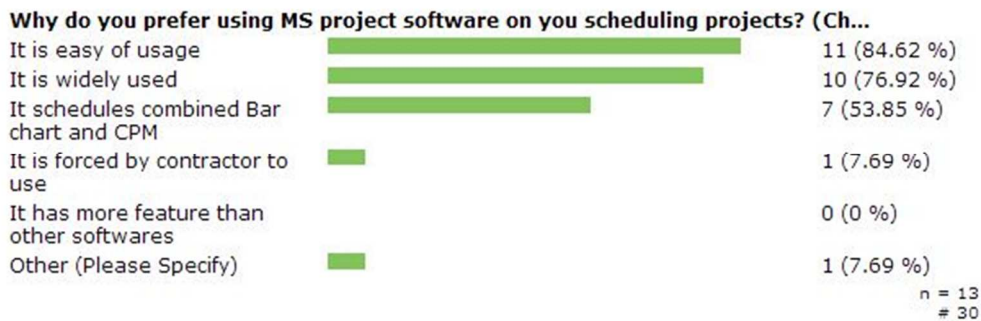
Figure 60: Question Survey about MS Project Software

5.5.13 Summary

Most of the respondents preferred CPM/Barcharts while scheduling their projects which is because of availability of software and it's widely use unlike LOB. At the same time, there is a plenty of engineers who do not have any information about LOB. This might be because it never appeared for them in construction site. Many theories can be driven from this questionnaire survey; but at the end, more survey and interview should be done about using these scheduling tools. As was stated before, it takes time and money to make a professional survey about the use of LOB or other scheduling tools.

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Chapter 6

CONCLUSION

6.1 Summary

Construction industry is growing widely; mega, linear, strategic and high rise building projects are constructed. With these kinds of projects, construction companies seek an effective, control and achievable planning and scheduling tool to plan their projects. Although the popular used scheduling tools, like CPM/Barcharts are used widely in construction industry, whether it was big, medium, or small sized construction projects, but at the same time most authors of construction management field criticized that CPM/Barcharts while used or applied on linear, repetitive projects. The linear scheduling tools and their deviations like LOB, VPM, LBS, and others give beneficial results in representing productivity of resource, project progress, location correspondent and optimization of the schedule.However, most of studies of LSM or LOB focused on the linear and repetitive projects rather than small projects, this is because it was believed that the LOB and LSM do not provide any beneficial results like CPM/Barcharts do to those projects which do not have a continuous, linear, or repetitive process of activities.

6.2 Conclusion of the Study

The trial of LBS which is a deviation of linear scheduling and LOB method on a small construction projects have shown that LBS brings benefits for construction management planning and scheduling of construction projects.

Construction management highlights four main areas where there are significant advantages over the previously used scheduling based on CPM scheduling and Bar charts:

First, LBS improved an overview over the project schedule via the flow-line diagram. It is possible to schedule a better understanding to the timing versus location. It also provides a better basis for communication with subcontractors and other parties involved in the project.

Second, LBS supports planning a continuous working flow of resources at work, at the same time avoiding duplication of work in the same location and unused work spaces.

Third, LBS can be improved by adding risk levels to each activity, and optimization of them can be easily done while buffers are added to minimize the risk.

Fourth, with the use of BIM, the LBS can integrate a better view of 5D BIM. This is because LBS deals with location rather than activities, and it makes easier for BIM integration of a 4D CAD integration.

6.3 Recommendations for Future and Further Study

As it was mentioned before, one of the limitations of this study is the control, forecasting, progress, and updating the schedule during implementation or construction stage of the project. LBS do not update the project plan like barcharts; it plots the actual progress, and takes a control action to modify the productivity in order to achieve the original plan (Lowe, D'Onofrio, Fisk, & Seppänen, 2012).The controlling and updating methodology in LBS is different than the bar charts

visualization; it uses forecasting which is based on the actual movements of the crews production rate. This feature can help the planner to take action of a late activity by giving warning alarms due to production interference.

The future study could be in the combination of BIM and time management with cost which results a 5D BIM model. The 5D BIM model resulted from the combination of 3D CAD BIM with time as 4D and cost as 5Dcan be modified more for example adding logistics, supply chains or suppliers of the materials.

Another dimension can be added to integrate a new CAD BIM, like adding risks, safety, or quality management. Vico Office Company integrated a new 6D BIM, the 6th dimension CAD was including the details of rooms in a building.

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APPENDİCES

Appendix A1
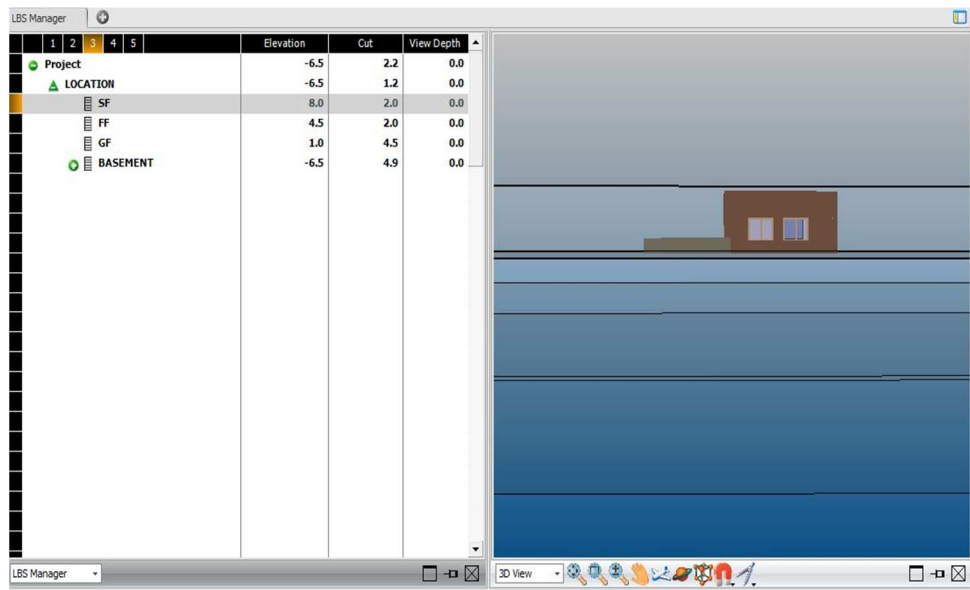
Figure 61: Second Floor; Vico LBS Manager
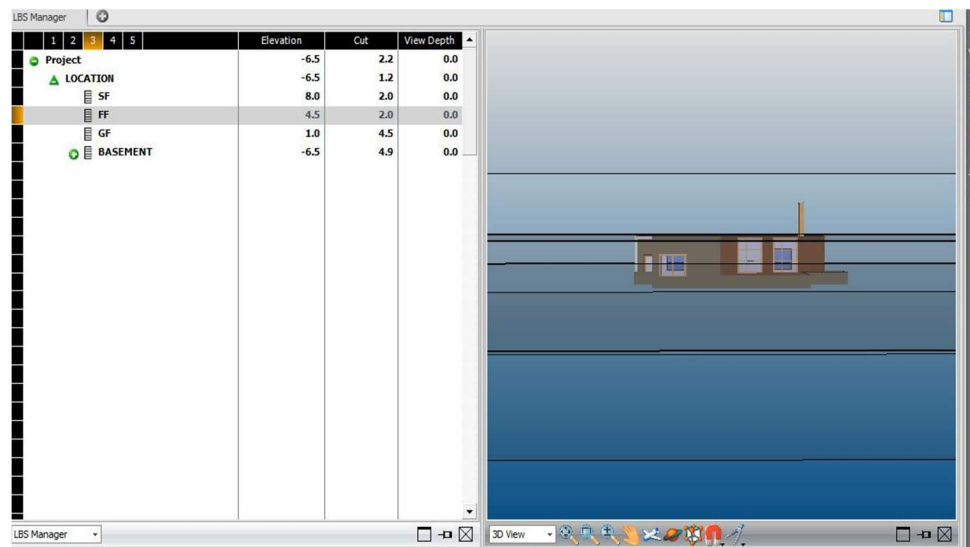
Figure 62: First Floor; Vico LBS Manager
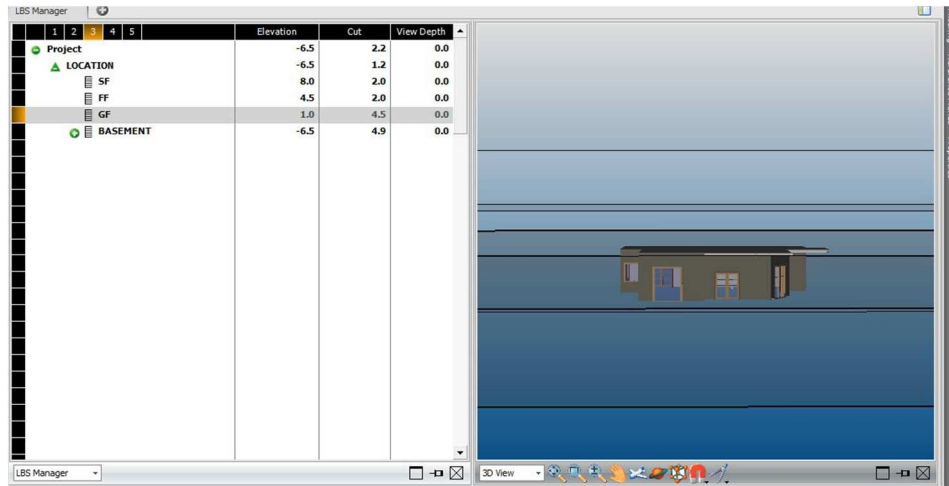
Figure 63: Ground Floor; Vico LBS Manager
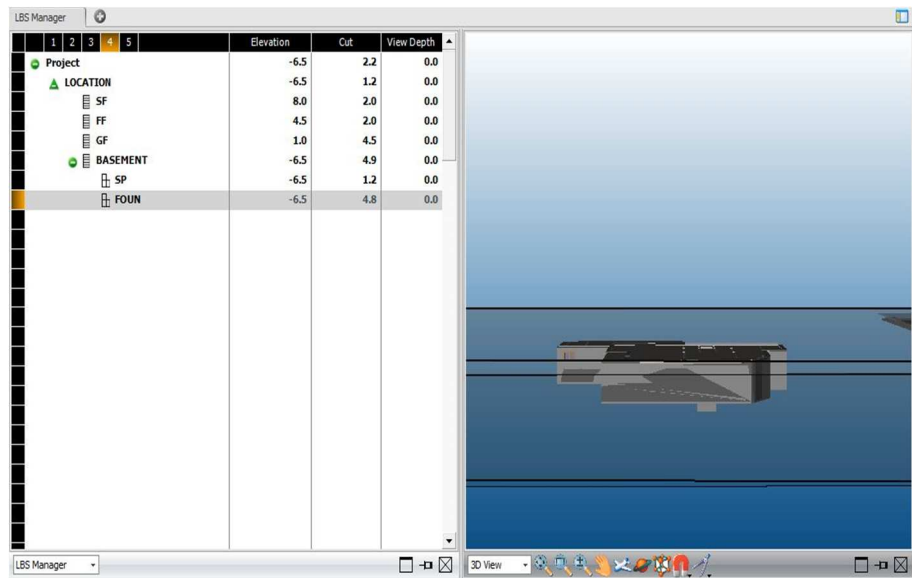
Figure 64: Basement Foundation; Vico LBS Manager
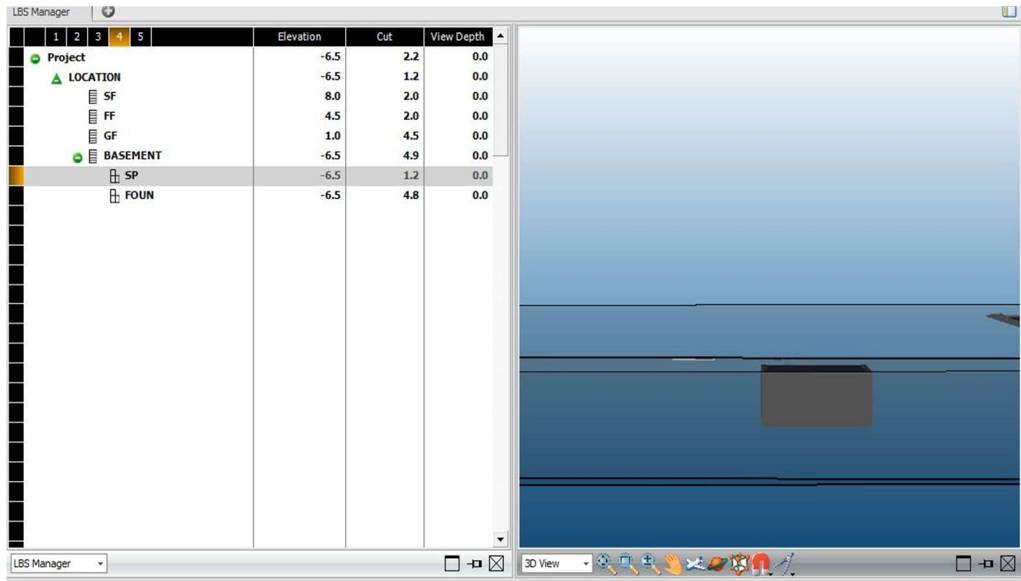
Figure 65: Swimming Pool; Vico LBS Manager

Appendix A2

Table 3: Quantity Take Off With Location; Vico Take Off Manager

Project Code	001	Length Unit	meter	
Project Name	THESIS STUDY 1	Area Unit	square meter	
Project Address	Famagusta Northen Cyprus Karpaz Route	Volume Unit	cubic meter	
		Report Date	Wednesday, May 15, 2013	

Foundation - 300mm Concrete

	Project	LOCATION	BASEMENT	SP	FOUN	GF	FF	SF
Count	26	26	26	null	26	null	null	null
Length	79.48	79.48	79.48	0.00	79.48	0.00	0.00	0.00
Net Reference Side Surface Area	192.82	192.82	192.82	0.00	192.82	0.00	0.00	0.00
Net Opposite Reference Side Surface Area	196.93	196.93	196.93	0.00	196.93	0.00	0.00	0.00
Top Surface Area	24.65	24.65	24.65	0.00	24.65	0.00	0.00	0.00
Bottom Surface Area	24.65	24.65	24.65	0.00	24.65	0.00	0.00	0.00
Ends Surface Area	40.07	40.07	40.07	0.00	40.07	0.00	0.00	0.00
Reference Side Opening Surface Area	5.85	5.85	5.85	0.00	5.85	0.00	0.00	0.00
Opposite Reference Side Opening Surface Area	5.85	5.85	5.85	0.00	5.85	0.00	0.00	0.00
Net Volume	58.46	58.46	58.46	0.00	58.46	0.00	0.00	0.00
Gross Volume	60.22	60.22	60.22	0.00	60.22	0.00	0.00	0.00
Piece Count	26	26	26	null	26	null	null	null

Piece Length	79.48	79.48	79.48	0.00	79.48	0.00	0.00	0.00

CW 102-85-250p 2							
	Project	LOCATION	BASEMENT	SP	FOUN	GF	FF	SF
Count	29	29	12	null	12	11	6	null
Length	141.73	141.73	57.89	0.00	57.89	54.83	29.02	0.00
Net Reference Side Surface Area	389.38	389.38	7.62	0.00	7.62	156.57	152.93	72.26
Net Opposite Reference Side Surface Area	383.91	383.91	7.55	0.14	7.40	151.17	152.93	72.26
Top Surface Area	49.08	49.08	1.28	0.00	1.28	18.70	19.02	10.07
Bottom Surface Area	43.69	43.69	15.68	0.36	15.32	18.71	9.30	0.00
Ends Surface Area	73.65	73.65	2.34	0.01	2.32	29.36	28.84	13.12
Reference Side Opening Surface Area	92.63	91.98	4.82	0.00	4.82	34.73	33.27	19.15
Opposite Reference Side Opening Surface Area	92.63	91.98	4.82	0.00	4.82	34.73	33.27	19.15
Net Volume	134.17	134.17	2.63	0.02	2.61	53.39	53.07	25.07
Gross Volume	166.31	166.08	4.31	0.02	4.29	65.45	64.61	31.72
Joint Horizontal Surface Area	0.00	86.51	15.25	0.36	14.88	33.95	28.01	9.30
Joint Vertical Surface Area	0.00	0.28	0.28	0.14	0.14	0.00	0.00	0.00
Piece Count	29	58	13	1	12	22	17	6
Piece Length	141.73	283.92	62.35	4.46	57.89	108.71	83.85	29.02

Interior - Blockwork 140							
	Project	LOCATION	BASEMENT	SP	FOUN	GF	FF	SF
Count	21	21	null	null	null	7	8	6
Length	86.19	86.19	0.00	0.00	0.00	23.88	32.55	29.75

Net Reference Side Surface Area	85.24	85.24	0.00	0.00	0.00	1.17	23.80	60.27
Net Opposite Reference Side Surface Area	85.24	85.24	0.00	0.00	0.00	1.17	23.80	60.27
Top Surface Area	13.98	13.98	0.00	0.00	0.00	0.00	3.83	10.15
Bottom Surface Area	13.98	13.98	0.00	0.00	0.00	3.83	5.27	4.88
Ends Surface Area	6.89	6.89	0.00	0.00	0.00	0.11	2.31	4.46
Net Volume	13.98	13.98	0.00	0.00	0.00	0.19	3.90	9.88
Gross Volume	13.98	13.98	0.00	0.00	0.00	0.19	3.90	9.88
Joint Horizontal Surface Area	0.00	18.20	0.00	0.00	0.00	3.83	9.10	5.27
Piece Count	21	36	null	null	null	7	15	14
Piece Length	86.19	142.62	0.00	0.00	0.00	23.88	56.44	62.31

Retaining - 300mm Concrete								
	Project	LOCATION	BASEMENT	SP	FOUN	GF	FF	SF
Count	4	4	4	4	null	null	null	null
Length	21.20	21.20	21.20	21.20	0.00	0.00	0.00	0.00
Net Reference Side Surface Area	58.51	58.51	58.51	58.51	0.00	0.00	0.00	0.00
Net Opposite Reference Side Surface Area	58.51	58.51	58.51	58.51	0.00	0.00	0.00	0.00
Top Surface Area	6.36	6.36	6.36	6.36	0.00	0.00	0.00	0.00
Bottom Surface Area	6.36	6.36	6.36	6.36	0.00	0.00	0.00	0.00
Ends Surface Area	6.62	6.62	6.62	6.62	0.00	0.00	0.00	0.00
Net	17.55	17.55	17.55	17.55	0.00	0.00	0.00	0.00

Volume								
Gross Volume	17.55	17.55	17.55	17.55	0.00	0.00	0.00	0.00
Piece Count	4	4	4	4				
Piece Length	21.20	21.20	21.20	21.20	0.00	0.00	0.00	0.00

80mm Concrete With 40mm Metal Deck

	Project	LOCATION	BASEMENT	SP	FOUN	GF	FF	SF
Count	4	4	1		1	1	1	1
Edge Perimeter	124.58	124.58	70.35	0.00	70.35	9.86	15.35	29.02
Hole Count	3.00	3.00	1.00	0.00	1.00	0.00	1.00	1.00
Hole Perimeter	13.23	13.23	4.41	0.00	4.41	4.41	4.41	0.00
Net Bottom Surface Area	540.12	540.12	209.24	0.14	209.10	168.57	114.50	47.81
Net Top Surface Area	540.12	540.12	209.24	0.14	209.10	0.00	168.57	162.31
Edge Surface Area	25.47	25.47	8.44	0.35	8.09	2.90	6.80	7.32
Hole Surface Area	3.62	3.62	1.21	0.00	1.21	0.00	1.21	1.21
Net Volume	64.81	64.81	25.11	0.02	25.09	8.43	17.52	13.75
Gross Volume	65.25	65.25	25.25	0.02	25.24	8.49	17.67	13.84
Joint Horizontal Surface Area	0.00	566.14	0.00	0.00	0.00	168.57	283.07	114.50
Joint Vertical Surface Area	0.00	0.68	0.68	0.34	0.34	0.00	0.00	0.00
Piece Count	4	7	2	1	1	1	2	2
Edge Length	124.58	237.44	70.35	2.95	67.41	58.03	64.69	44.37
Joint Length	0.00	5.70	5.70	2.85	2.85	0.00	0.00	0.00
Hole Edge Length	13.23	22.05	4.41	0.00	4.41	4.41	8.82	4.41

150mm Foundation Slab (Elevator)

	Project	LOCATION	BASEMENT	SP	FOUN	GF	FF	SF
Count	1	1	1	0	1.00	0	0	0
Edge Perimeter	6.81	6.81	6.81	0.00	6.81	0.00	0.00	0.00
Net	2.89	2.89	2.89	0.00	2.89	0.00	0.00	0.00

Bottom Surface Area							
Net Top Surface Area	2.89	2.89	2.89	0.00	2.89	0.00	0.00	0.00
Edge Surface Area	1.02	1.02	1.02	0.00	1.02	0.00	0.00	0.00
Net Volume	0.43	0.43	0.43	0.00	0.43	0.00	0.00	0.00
Gross Volume	0.43	0.43	0.43	0.00	0.43	0.00	0.00	0.00
Piece Count	1	1	1	0	1	0	0	0
Edge Length	6.81	6.81	6.81	0.00	6.81	0.00	0.00	0.00

300mm Foundation Slab (SP)

	Project	LOCATION	BASEMENT	SP	FOUN	GF	FF	SF
Count	1.00	1.00	1.00	1.00				
Edge Perimeter	22.40	22.40	22.40	22.40	0.00	0.00	0.00	0.00
Net Bottom Surface Area	30.36	30.36	30.36	30.36	0.00	0.00	0.00	0.00
Net Top Surface Area	30.36	30.36	30.36	30.36	0.00	0.00	0.00	0.00
Edge Surface Area	6.72	6.72	6.72	6.72	0.00	0.00	0.00	0.00
Net Volume	9.11	9.11	9.11	9.11	0.00	0.00	0.00	0.00
Gross Volume	9.11	9.11	9.11	9.11	0.00	0.00	0.00	0.00
Piece Count	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00
Edge Length	22.40	22.40	22.40	22.40	0.00	0.00	0.00	0.00

HE180B

	Project	LOCATION	BASEMENT	SP	FOUN	GF	FF	SF
Count	7.00	7.00	7.00		7.00			
Height	68.92	68.92	68.92	0.00	68.92	0.00	0.00	0.00
Vertical Surface Area	73.26	73.26	20.91	0.00	20.91	25.88	14.83	11.64
Top Surface Area	0.04	0.04	0.00	0.00	0.00	0.02	0.01	0.02
Bottom Surface Area	0.04	0.04	0.04	0.00	0.04	0.00	0.00	0.00

Hole Surface Area	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Net Volume	0.44	0.44	0.12	0.00	0.12	0.15	0.09	0.07
Gross Volume	0.44	0.44	0.12	0.00	0.12	0.15	0.09	0.07
Joint Horizontal Surface Area	0.00	0.18	0.04	0.00	0.04	0.07	0.04	0.02
Piece Count	7.00	21.00	7.00		7.00	7.00	4.00	3.00
Piece Height	68.92	68.92	19.67	0.00	19.67	24.35	13.95	10.95

HE200B								
	Project	LOCATION	BASEMENT	SP	FOUN	GF	FF	SF
Count	10.00	10.00	10.00	null	10.00	null	null	null
Height	119.30	119.30	119.30	0.00	119.30	0.00	0.00	0.00
Vertical Surface Area	141.01	141.01	33.21	0.00	33.21	41.37	41.13	25.29
Top Surface Area	0.08	0.08	0.00	0.00	0.00	0.00	0.03	0.05
Bottom Surface Area	0.08	0.08	0.08	0.00	0.08	0.00	0.00	0.00
Net Volume	0.90	0.90	0.21	0.00	0.21	0.26	0.26	0.16
Gross Volume	0.90	0.90	0.21	0.00	0.21	0.26	0.26	0.16
Joint Horizontal Surface Area	0.00	0.39	0.08	0.00	0.08	0.15	0.12	0.05
Piece Count	10.00	36.00	10.00	null	10.00	10.00	10.00	6.00
Piece Height	119.30	119.30	28.10	0.00	28.10	35.00	34.80	21.40

HE160B								
	Project	LOCATION	BASEMENT	SP	FOUN	GF	FF	SF
Count	6	6	6		6			
Height	80.76	80.76	80.76	0.00	80.76	0.00	0.00	0.00
Vertical Surface Area	76.24	76.24	15.92	0.00	15.92	19.82	19.82	20.67
Top	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.03

Surface Area								
Bottom Surface Area	0.03	0.03	0.03	0.00	0.03	0.00	0.00	0.00
Net Volume	0.42	0.42	0.09	0.00	0.09	0.11	0.11	0.11
Gross Volume	0.42	0.42	0.09	0.00	0.09	0.11	0.11	0.11
Joint Horizontal Surface Area	0.00	0.19	0.03	0.00	0.03	0.06	0.06	0.03
Piece Count	6	24	6		6	6	6	6
Piece Height	80.76	80.76	16.86	0.00	16.86	21.00	21.00	21.90

300 x 300mm								
	Project	LOCATION	BASEMENT	SP	FOUN	GF	FF	SF
Count	1.	1	1	null	1	null	null	null
Height	2.76	2.76	2.76	0.00	2.76	0.00	0.00	0.00
Vertical Surface Area	3.27	3.27	3.27	0.00	3.27	0.00	0.00	0.00
Top Surface Area	0.09	0.09	0.09	0.00	0.09	0.00	0.00	0.00
Bottom Surface Area	0.09	0.09	0.09	0.00	0.09	0.00	0.00	0.00
Net Volume	0.24	0.24	0.24	0.00	0.24	0.00	0.00	0.00
Gross Volume	0.24	0.24	0.24	0.00	0.24	0.00	0.00	0.00
Piece Count	1	1	1		1			
Piece Height	2.76	2.76	2.76	0.00	2.76	0.00	0.00	0.00

IPE200								
	Project	LOCATION	BASEMENT	SP	FOUN	GF	FF	SF
Count	64	64	14	null	14	24	14	12
Length	194.46	194.46	46.25	0.00	46.25	71.71	42.65	33.85
Bottom Surface Area	35.32	35.32	8.36	0.00	8.36	13.10	7.77	6.10
Top Surface Area	35.32	35.32	8.36	0.00	8.36	13.10	7.77	6.10

Reference Side Surface Area	33.25	33.25	7.87	0.00	7.87	12.33	7.32	5.74
Opposite Reference Side Surface Area	1.54	1.54	0.37	0.00	0.37	0.57	0.34	0.27
Ends Surface Area	0.35	0.35	0.08	0.00	0.08	0.13	0.08	0.07
Net Volume	0.50	0.50	0.12	0.00	0.12	0.18	0.11	0.09
Gross Volume	0.50	0.50	0.12	0.00	0.12	0.18	0.11	0.09
Piece Count	64	64	14	null	14	24	14	12
Piece Length	194.46	194.46	46.25	0.00	46.25	71.71	42.65	33.85

IPE240

	Project	LOCATION	BASEMENT	SP	FOUN	GF	FF	SF
Count	23	23	6	0	6	10	5	2
Length	90.55	90.55	25.37	0.00	25.37	35.79	21.37	8.02
Bottom Surface Area	20.05	20.05	5.65	0.00	5.65	7.88	4.74	1.77
Top Surface Area	20.05	20.05	5.65	0.00	5.65	7.88	4.74	1.77
Reference Side Surface Area	18.90	18.90	5.33	0.00	5.33	7.43	4.47	1.67
Opposite Reference Side Surface Area	0.84	0.84	0.24	0.00	0.24	0.33	0.20	0.07
Ends Surface Area	0.17	0.17	0.04	0.00	0.04	0.07	0.04	0.01
Net Volume	0.32	0.32	0.09	0.00	0.09	0.13	0.08	0.03
Gross Volume	0.32	0.32	0.09	0.00	0.09	0.13	0.08	0.03
Piece Count	23	23	6	0	6	10	5	2
Piece Length	90.55	90.55	25.37	0.00	25.37	35.79	21.37	8.02

IPE160

	Project	LOCATION	BASEMENT	SP	FOUN	GF	FF	SF
Count	53	53	24	null	24	10	10	9
Length	117.78	117.78	64.93	0.00	64.93	18.27	18.27	16.31
Bottom Surface	17.15	17.15	9.61	0.00	9.61	2.60	2.60	2.33

Area								
Top Surface Area	17.15	17.15	9.61	0.00	9.61	2.60	2.60	2.33
Reference Side Surface Area	15.66	15.66	8.78	0.00	8.78	2.38	2.38	2.13
Opposite Reference Side Surface Area	0.80	0.80	0.45	0.00	0.45	0.12	0.12	0.11
Ends Surface Area	0.21	0.21	0.09	0.00	0.09	0.04	0.04	0.03
Net Volume	0.21	0.21	0.12	0.00	0.12	0.03	0.03	0.03
Gross Volume	0.21	0.21	0.12	0.00	0.12	0.03	0.03	0.03
Piece Count	53	53	24	null	24	10	10	9
Piece Length	117.78	117.78	64.93	0.00	64.93	18.27	18.27	16.31

IPE300

	Project	LOCATION	BASEMENT	SP	FOUN	GF	FF	SF
Count	16	16	5	null	5	6	null	null
Length	92.83	92.83	28.66	0.00	28.66	34.81	29.36	0.00
Bottom Surface Area	26.14	26.14	8.05	0.00	8.05	9.81	8.28	0.00
Top Surface Area	26.14	26.14	8.05	0.00	8.05	9.81	8.28	0.00
Reference Side Surface Area	24.87	24.87	7.66	0.00	7.66	9.33	7.87	0.00
Opposite Reference Side Surface Area	0.96	0.96	0.29	0.00	0.29	0.36	0.30	0.00
Ends Surface Area	0.17	0.17	0.05	0.00	0.05	0.06	0.05	0.00
Net Volume	0.46	0.46	0.14	0.00	0.14	0.17	0.15	0.00
Gross Volume	0.46	0.46	0.14	0.00	0.14	0.17	0.15	0.00
Piece Count	16.00	16.00	5.00	0.00	5.00	6.00	5.00	0.00
Piece Length	92.83	92.83	28.66	0.00	28.66	34.81	29.36	0.00

120x80RHS

	Project	LOCATION	BASEMENT	SP	FOUN	GF	FF	SF

Count	17	17	8		8.00	6	3	
Length	68.92	68.92	34.06	0.00	34.06	21.86	13.01	0.00
Bottom Surface Area	5.28	5.28	1.20	0.00	1.20	1.77	1.37	0.94
Top Surface Area	5.05	5.05	1.18	0.00	1.18	1.53	1.38	0.96
Reference Side Surface Area	6.78	6.78	1.34	0.00	1.34	2.18	2.05	1.20
Opposite Reference Side Surface Area	7.32	7.32	1.78	0.00	1.78	2.06	2.06	1.43
Ends Surface Area	0.51	0.51	0.03	0.00	0.03	0.02	0.45	0.01
Hole Surface Area	19.62	19.62	4.98	0.00	4.98	5.59	5.31	3.75
Net Volume	0.19	0.19	0.04	0.00	0.04	0.06	0.05	0.04
Gross Volume	0.62	0.63	0.14	0.00	0.14	0.19	0.17	0.13
Joint Horizontal Surface Area	0.00	0.07	0.01	0.00	0.01	0.02	0.02	0.01
Piece Count	17	28	8	0	8	10	7	3
Piece Length	68.92	118.42	34.06	0.00	34.06	40.10	31.25	13.01
IPE330								
	Project	LOCATION	BASEMENT	SP	FOUN	GF	FF	SF
Count	5	5	0	0	0	3	2	
Length	6.46	6.46	0.00	0.00	0.00	3.86	2.60	0.00
Bottom Surface Area	1.58	1.58	0.00	0.00	0.00	0.96	0.63	0.00
Top Surface Area	1.58	1.58	0.00	0.00	0.00	0.96	0.63	0.00
Reference Side Surface Area	1.55	1.55	0.00	0.00	0.00	0.94	0.61	0.00
Opposite Reference Side Surface Area	0.06	0.06	0.00	0.00	0.00	0.04	0.02	0.00
Ends Surface Area	0.06	0.06	0.00	0.00	0.00	0.04	0.02	0.00

Net Volume	0.03	0.03	0.00	0.00	0.00	0.02	0.01	0.00
Gross Volume	0.03	0.03	0.00	0.00	0.00	0.02	0.01	0.00
Piece Count	5	5				3		
Piece Length	6.46	6.46	0.00	0.00	0.00	3.86	2.60	0.00

1830 x 1981mm

	Project	LOCATION	BASEMENT	SP	FOUN	GF	FF	SF
Count	1	1	null	null	null	1	null	null
Width	1.83	1.83	0.00	0.00	0.00	1.83	0.00	0.00
Height	2.50	2.50	0.00	0.00	0.00	2.50	0.00	0.00
Perimeter	8.66	8.66	0.00	0.00	0.00	8.66	0.00	0.00

0915 x 2134mm

	Project	LOCATION	BASEMENT	SP	FOUN	GF	FF	SF
Count	2	2	null	null	null	null	1	1.00
Width	1.83	1.83	0.00	0.00	0.00	0.00	0.92	0.92
Height	4.27	4.27	0.00	0.00	0.00	0.00	2.13	2.13
Perimeter	12.20	12.20	0.00	0.00	0.00	0.00	6.10	6.10

1830 x 2134mm

	Project	LOCATION	BASEMENT	SP	FOUN	GF	FF	SF
Count	1	1	null	null	null	1	null	null
Width	1.83	1.83	0.00	0.00	0.00	1.83	0.00	0.00
Height	2.13	2.13	0.00	0.00	0.00	2.13	0.00	0.00
Perimeter	7.93	7.93	0.00	0.00	0.00	7.93	0.00	0.00

2435 x 1981mm

	Project	LOCATION	BASEMENT	SP	FOUN	GF	FF	SF
Count	1	1	1	null	1	null	null	null
Width	2.44	2.44	2.44	0.00	2.44	0.00	0.00	0.00
Height	1.98	1.98	1.98	0.00	1.98	0.00	0.00	0.00
Perimeter	8.83	8.83	8.83	0.00	8.83	0.00	0.00	0.00

0762 x 2032mm

	Project	LOCATION	BASEMENT	SP	FOUN	GF	FF	SF
Count	1	1	null	null	null	1	null	null
Width	0.76	0.76	0.00	0.00	0.00	0.76	0.00	0.00
Height	2.03	2.03	0.00	0.00	0.00	2.03	0.00	0.00
Perimeter	5.59	5.59	0.00	0.00	0.00	5.59	0.00	0.00

1730 x 2032mm

	Project	LOCATION	BASEMENT	SP	FOUN	GF	FF	SF
Count	1	1	null	null	null	1	null	null
Width	1.73	1.73	0.00	0.00	0.00	1.73	0.00	0.00
Height	2.03	2.03	0.00	0.00	0.00	2.03	0.00	0.00
Perimeter	7.52	7.52	0.00	0.00	0.00	7.52	0.00	0.00

180x250

	Project	LOCATION	BASEMENT	SP	FOUN	GF	FF	SF
Count	6	6	null	null	null	2	3	1
Width	10.80	10.80	0.00	0.00	0.00	3.60	5.40	1.80
Height	15.00	15.00	0.00	0.00	0.00	5.00	7.50	2.50
Perimeter	51.60	51.60	0.00	0.00	0.00	17.20	25.80	8.60

150*150

	Project	LOCATION	BASEMENT	SP	FOUN	GF	FF	SF
Count	5	5	null	null	null	2	2	1
Width	7.50	7.50	0.00	0.00	0.00	3.00	3.00	1.50
Height	7.50	7.50	0.00	0.00	0.00	3.00	3.00	1.50
Perimeter	30.00	30.00	0.00	0.00	0.00	12.00	12.00	6.00

100*80

	Project	LOCATION	BASEMENT	SP	FOUN	GF	FF	SF
Count	5	5	null	null	null	1	1	3
Width	4.00	4.00	0.00	0.00	0.00	0.80	0.80	2.40
Height	5.00	5.00	0.00	0.00	0.00	1.00	1.00	3.00
Perimeter	18.00	18.00	0.00	0.00	0.00	3.60	3.60	10.80

200x250

	Project	LOCATION	BASEMENT	SP	FOUN	GF	FF	SF
Count	2	2	null	null	null	1	1	null
Width	4.00	4.00	0.00	0.00	0.00	2.00	2.00	0.00
Height	5.00	5.00	0.00	0.00	0.00	2.50	2.50	0.00
Perimeter	18.00	18.00	0.00	0.00	0.00	9.00	9.00	0.00

180x140

	Project	LOCATION	BASEMENT	SP	FOUN	GF	FF	SF
Count	6	6	null	null	null	1	3	2
Width	10.80	10.80	0.00	0.00	0.00	1.80	5.40	3.60
Height	8.40	8.40	0.00	0.00	0.00	1.40	4.20	2.80
Perimeter	38.40	38.40	0.00	0.00	0.00	6.40	19.20	12.80

160x570

	Project	LOCATION	BASEMENT	SP	FOUN	GF	FF	SF
Count	1	1	null	null	null	null	1	null
Width	1.30	1.30	0.00	0.00	0.00	0.00	1.30	0.00
Height	5.70	5.70	0.00	0.00	0.00	0.00	5.70	0.00
Perimeter	14.00	14.00	0.00	0.00	0.00	0.00	14.00	0.00

75x290

	Project	LOCATION	BASEMENT	SP	FOUN	GF	FF	SF
Count	3	3	3	null	3	null	null	null
Width	8.70	8.70	8.70	0.00	8.70	0.00	0.00	0.00
Height	2.25	2.25	2.25	0.00	2.25	0.00	0.00	0.00
Perimeter	21.90	21.90	21.90	0.00	21.90	0.00	0.00	0.00

75 x 90

	Project	LOCATION	BASEMENT	SP	FOUN	GF	FF	SF
Count	3	3	3	null	3.00	null	null	null
Width	3.00	3.00	3.00	0.00	3.00	0.00	0.00	0.00
Height	2.25	2.25	2.25	0.00	2.25	0.00	0.00	0.00
Perimeter	10.50	10.50	10.50	0.00	10.50	0.00	0.00	0.00

Ramp 1

	Project	LOCATION	BASEMENT	SP	FOUN	GF	FF	SF
Count	1	1	1	null	1.00	null	null	null
Perimeter	25.40	25.40	25.40	0.00	25.40	0.00	0.00	0.00
Top Surface	34.80	34.80	34.80	0.00	34.80	0.00	0.00	0.00

Area								
Edge Surface Area	22.64	22.64	22.64	0.00	22.64	0.00	0.00	0.00
Net Volume	30.81	30.81	30.81	0.00	30.81	0.00	0.00	0.00
Bottom Surface Area	34.04	34.04	34.04	0.00	34.04	0.00	0.00	0.00
Piece Count	1	1	1	null	1	null	0	0
Edge Length	25.40	25.40	25.40	0.00	25.40	0.00	0.00	0.00
Joint Length	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

mat foundation slab								
	Project	LOCATION	BASEMENT	SP	FOUN	GF	FF	SF
Count	1	1	1	null	1	null	null	null
Edge Perimeter	69.56	69.56	69.56	0.00	69.56	0.00	0.00	0.00
Net Bottom Surface Area	240.44	240.44	240.44	0.00	240.44	0.00	0.00	0.00
Edge Surface Area	239.83	239.83	239.83	0.00	239.83	0.00	0.00	0.00
Piece Count	1.00	1.00	1.00	0.00	1.00	0.00	0.00	0.00
Edge Length	69.56	69.56	69.56	0.00	69.56	0.00	0.00	0.00

Appendix A3

Table 4: Quantity with Unit Cost; Vico Cost Planner

Code	Descripti..	Source Q..	Unit Cost	Markup	Markup V..	Gross To..	Add-On	CostType	Qty		Net Total	Add-On
001	THESIS	1.0	271,656.46	3.18 %	8,634.44	289,798.88	0		1.0 ▲		271,656.46	9,507.98
	Add-Ons Description			0.00 %	0	0	1				0	0
	GENERAL CONTIGENCY			2.00 %	5,433.13	5,433.13	2				0	5,433.13
	OVERHEAD			1.50 %	4,074.85	4,074.85	2				0	4,074.85
A	EARTHWORK	1.0	16,293.98	3.82 %	622.67	17,486.94	0		1.0 ▲		16,293.98	570.29
A10	EXCAVATION	1.0	12,738.95	3.96 %	503.87	13,688.68	0		1.0 ▲		12,738.95	445.86
A11	EXCAVATION	1.0	10,224.00	4.00 %	408.96	10,990.80	0		1.0 ▲		10,224.00	357.84
LB	LABOUR	72.0	12.00	4.00 %	34.56	928.80	0	LABOR	72.0		864.00	30.24
E	LOADER	72.0	50.00	4.00 %	144.00	3,870.00	0	EQUIPMENT	72.0		3,600.00	126.00
E	EXCAVATOR	72.0	80.00	4.00 %	230.40	6,192.00	0	EQUIPMENT	72.0		5,760.00	201.60
M	MATERIAL	480.9	0.00	0.00 %	0.00	0.00	0		480.9		0.00	0.00
A12	EXCAVATION	1.0	2,514.95	3.77 %	94.91	2,697.88	0		1.0 ▲		2,514.95	88.02
E	LOADER	13.8	50.00	4.00 %	27.54	740.14	0	EQUIPMENT	13.8		688.50	24.10
E	EXCAVATOR	13.7	80.00	4.00 %	43.71	1,174.76	0	EQUIPMENT	13.7		1,092.80	38.25
LB	LABOUR	13.7	12.00	4.00 %	6.58	176.73	0	LABOR	13.7		164.40	5.75
M	MATERIAL	91.1	6.25	3.00 %	17.08	606.25	0	MATERIAL	91.1		569.25	19.92
A20	COMPACTED	1.0	627.72	3.90 %	24.50	674.19	0		1.0 ▲		627.72	21.97
A21	COMPACTED	1.0	504.00	4.00 %	20.16	541.80	0		1.0 ▲		504.00	17.64
E	COMPACTOR	12.0	30.00	4.00 %	14.40	387.00	0	EQUIPMENT	12.0		360.00	12.60
M	MATERIAL	0.0	20.00	3.00 %	0.00	0.00	0	MATERIAL	0.0		0.00	0.00
LB	LABOUR	12.0	12.00	4.00 %	5.76	154.80	0	LABOR	12.0		144.00	5.04
A22	COMPACTED	1.0	123.72	3.51 %	4.34	132.39	0		1.0 ▲		123.72	4.33
E	COMPACTOR	1.5	30.00	4.00 %	1.80	48.38	0	EQUIPMENT	1.5		45.00	1.58
M	MATERIAL	3.0	20.00	3.00 %	1.82	64.67	0	MATERIAL	3.0		60.72	2.13
LB	LABOUR	1.5	12.00	4.00 %	0.72	19.35	0	LABOR	1.5		18.00	0.63
A30	HARDCORE	1.0	1,710.60	3.34 %	57.08	1,827.55	0		1.0 ▲		1,710.60	59.87
A32	HARDCORE	1.0	1,134.60	3.00 %	34.04	1,208.35	0		1.0 ▲		1,134.60	39.71
M	MATERIAL	30.4	35.00	3.00 %	31.88	1,131.67	0	MATERIAL	30.4		1,062.60	37.19
LB	LABOUR	6.0	12.00	3.00 %	2.16	76.68	0	MATERIAL	6.0		72.00	2.52
A31	HARDCORE	1.0	576.00	4.00 %	23.04	619.20	0		1.0 ▲		576.00	20.16
M	MATERIAL	0.0	35.00	3.00 %	0.00	0.00	0	MATERIAL	0.0		0.00	0.00
LB	LABOUR	48.0	12.00	4.00 %	23.04	619.20	0	LABOR	48.0		576.00	20.16
A40	ISOLATION	1.0	1,216.71	3.06 %	37.23	1,296.52	0		1.0 ▲		1,216.71	42.58
A42	ISOLATION	1.0	107.28	3.06 %	3.28	114.32	0		1.0 ▲		107.28	3.75
M	MATERIAL	6.7	15.00	3.00 %	3.02	107.35	0	MATERIAL	6.7		100.80	3.53
LB	LABOUR	0.5	12.00	4.00 %	0.26	6.97	0	LABOR	0.5		6.48	0.23
A51	ISOLATION	1.0	1,109.43	3.06 %	33.94	1,182.20	0		1.0 ▲		1,109.43	38.83
M	MATERIAL	69.6	15.00	3.00 %	31.30	1,111.25	0	MATERIAL	69.6		1,043.43	36.52
LB	LABOUR	5.5	12.00	4.00 %	2.64	70.95	0	LABOR	5.5		66.00	2.31
B	CONCRETE	1.0	25,455.29	3.01 %	766.76	27,112.99	0		1.0 ▲		25,455.29	890.94
B101	SP RW	1.0	2,135.99	3.01 %	64.20	2,274.94	0		1.0 ▲		2,135.99	74.76
M07	R.C	17.6	121.00	3.00 %	63.72	2,262.04	0	MATERIAL	17.6		2,123.99	74.34
LB2	LABOR	1.0	12.00	4.00 %	0.48	12.90	0	LABOR	1.0		12.00	0.42
B20	PLAIN VILLA	1.0	2,861.18	3.01 %	86.08	3,047.39	0		1.0 ▲		2,861.18	100.14
LB2	LABOR	2.0	12.00	4.00 %	0.96	25.80	0	LABOR	2.0		24.00	0.84
M06	MATERIALC20	24.0	118.00	3.00 %	85.12	3,021.59	0	MATERIAL	24.0		2,837.18	99.30
B30	PLAIN	1.0	364.25	3.02 %	10.99	387.98	0		1.0 ▲		364.25	12.75
LB2	LABOR	0.5	12.00	4.00 %	0.24	6.45	0	LABOR	0.5		6.00	0.21
M06	MATERIALC20	3.0	118.00	3.00 %	10.75	381.53	0	MATERIAL	3.0		358.25	12.54

Code	Description	Source Q..	Unit Cost	Markup	Markup V..	Gross To..	Add-On	CostType	Qty	Net Total	Add-On
C20	MAT VILLA	1.0	10,023.80	3.03 %	303.51	10,678.15	0		1.0 ▲	10,023.80	350.83
LB3	CARPENTER	20.0	14.00	4.00 %	11.20	301.00	0	LABOR	20.0	280.00	9.80
M08	PLYWOD	389.8	25.00	3.00 %	292.31	10,377.15	0	MATERIAL	389.8	9,743.80	341.03
C30	SP FOUND	1.0	214.20	3.22 %	6.89	228.59	0		1.0 ▲	214.20	7.50
LB3	CARPENTER	3.3	14.00	4.00 %	1.85	49.67	0	LABOR	3.3	46.20	1.62
M08	PLYWOD	6.7	25.00	3.00 %	5.04	178.92	0	MATERIAL	6.7	168.00	5.88
C40	SP RW	1.0	3,009.60	3.03 %	91.13	3,206.06	0		1.0 ▲	3,009.60	105.34
LB3	CARPENTER	6.0	14.00	4.00 %	3.36	90.30	0	LABOR	6.0	84.00	2.94
M08	PLYWOD	117.0	25.00	3.00 %	87.77	3,115.76	0	MATERIAL	117.0	2,925.60	102.40
C50	SLABS	1.0	32.54	3.22 %	1.05	34.72	0		1.0 ▲	32.54	1.14
+ C 52	150 MM	1.0	32.54	3.22 %	1.05	34.72	0		1.0 ▲	32.54	1.14
C60	COLUMN	1.0	83.13	3.02 %	2.51	88.55	0		1.0 ▲	83.13	2.91
M08	PLYWOD	3.3	25.00	3.00 %	2.45	87.05	0	MATERIAL	3.3	81.73	2.86
LB3	CARPENTER	0.1	14.00	4.00 %	0.06	1.51	0	LABOR	0.1	1.40	0.05
C70	RAMP	1.0	580.08	3.02 %	17.54	617.92	0		1.0 ▲	580.08	20.30
LB3	CARPENTER	1.0	14.00	4.00 %	0.56	15.05	0	LABOR	1.0	14.00	0.49
M08	PLYWOD	22.6	25.00	3.00 %	16.98	602.87	0	MATERIAL	22.6	566.08	19.81
F	REBAR	1.0	24,936.10	3.03 %	754.68	26,563.55	0		1.0 ▲	24,936.10	872.76
F60	DEFORMED	1.0	2,310.00	3.00 %	69.30	2,460.15	0		1.0 ▲	2,310.00	80.85
M11	REBAR	50.0	45.00	3.00 %	67.50	2,396.25	0	MATERIAL	50.0	2,250.00	78.75
LB8	REBAR FIXER	4.0	15.00	3.00 %	1.80	63.90	0	MATERIAL	4.0	60.00	2.10
F10	#8	1.0	2,575.00	3.03 %	78.00	2,743.13	0		1.0 ▲	2,575.00	90.13
M16	REBAR	5.0	500.00	3.00 %	75.00	2,662.50	0	MATERIAL	5.0	2,500.00	87.50
LB8	REBAR FIXER	5.0	15.00	4.00 %	3.00	80.63	0	LABOR	5.0	75.00	2.63
F20	#10	1.0	5,665.00	3.03 %	171.60	6,034.88	0		1.0 ▲	5,665.00	198.28
M16	REBAR	11.0	500.00	3.00 %	165.00	5,857.50	0	MATERIAL	11.0	5,500.00	192.50
LB8	REBAR FIXER	11.0	15.00	4.00 %	6.60	177.38	0	LABOR	11.0	165.00	5.78
F30	#12	1.0	4,120.00	3.03 %	124.80	4,389.00	0		1.0 ▲	4,120.00	144.20
M16	REBAR	8.0	500.00	3.00 %	120.00	4,260.00	0	MATERIAL	8.0	4,000.00	140.00
LB8	REBAR FIXER	8.0	15.00	4.00 %	4.80	129.00	0	LABOR	8.0	120.00	4.20
F40	#14	1.0	6,180.00	3.03 %	187.20	6,583.50	0		1.0 ▲	6,180.00	216.30
M16	REBAR	12.0	500.00	3.00 %	180.00	6,390.00	0	MATERIAL	12.0	6,000.00	210.00
LB8	REBAR FIXER	12.0	15.00	4.00 %	7.20	193.50	0	LABOR	12.0	180.00	6.30
F50	#16	1.0	4,086.10	3.03 %	123.78	4,352.90	0		1.0 ▲	4,086.10	143.01
LB8	REBAR FIXER	8.0	15.00	4.00 %	4.80	129.00	0	LABOR	8.0	120.00	4.20
M16	REBAR	7.9	500.00	3.00 %	118.98	4,223.90	0	MATERIAL	7.9	3,966.10	138.81
D	STRUCTURA	1.0	91,385.28	3.15 %	2,875.51	97,459.27	0		1.0 ▲	91,385.28	3,198.48
D10	COLUMNS	1.0	23,867.97	3.13 %	746.20	25,449.55	0		1.0 ▲	23,867.97	835.38
D 11	HE 180 B	1.0	5,879.94	3.12 %	183.68	6,269.38	0		1.0 ▲	5,879.91	205.80
E	CRANE	7.0	90.00	4.00 %	25.20	677.25	0	EQUIPMENT	7.0	630.00	22.05
LB	STEELMAN	7.0	14.00	4.00 %	3.92	105.35	0	LABOR	7.0	98.00	3.43
M	STEEL	3,528.7	1.46	3.00 %	154.56	5,486.78	0	MATERIAL	3,528.7	5,151.91	180.32
D12	HE 200 B	1.0	12,237.11	3.13 %	382.71	13,048.12	0		1.0 ▲	12,237.11	428.30
E	CRANE	15.0	90.00	4.00 %	54.00	1,451.25	0	EQUIPMENT	15.0	1,350.00	47.25
LB	STEELMAN	15.0	14.00	4.00 %	8.40	225.75	0	LABOR	15.0	210.00	7.35
M	STEEL	7,313.1	1.46	3.00 %	320.31	11,371.12	0	MATERIAL	7,313.1	10,677.11	373.70
D 13	HE 160 B	1.0	5,750.95	3.13 %	179.81	6,132.04	0		1.0 ▲	5,750.95	201.28
E	CRANE	7.0	90.00	4.00 %	25.20	677.25	0	EQUIPMENT	7.0	630.00	22.05
LB	STEELMAN	7.0	14.00	4.00 %	3.92	105.35	0	LABOR	7.0	98.00	3.43
M	STEEL	3,440.4	1.46	3.00 %	150.69	5,349.44	0	MATERIAL	3,440.4	5,022.95	175.80

Code	Descripti..	Source Q..	Unit Cost	Markup	Markup V..	Gross To..	Add-On	CostType	Qty	Net Total	Add-On
B40	FOUNDATION	1.0	91.20	4.00 %	3.65	98.04	0		1.0 ▲	91.20	3.19
LB2	LABOR	7.6	12.00	4.00 %	3.65	98.04	0	LABOR	7.6	91.20	3.19
M07	R.C	0.0	121.00	3.00 %	0.00	0.00	0	MATERIAL	0.0	0.00	0.00
B50	RETAINING	1.0	7,122.00	3.01 %	214.14	7,585.41	0		1.0 ▲	7,122.00	249.27
LB2	LABOR	4.0	12.00	4.00 %	1.92	51.60	0	LABOR	4.0	48.00	1.68
M07	R.C	58.5	121.00	3.00 %	212.22	7,533.81	0	MATERIAL	58.5	7,074.00	247.59
B60	SW SLAB	1.0	1,110.47	3.01 %	33.40	1,182.73	0		1.0 ▲	1,110.47	38.87
LB2	LABOR	0.7	12.00	4.00 %	0.34	9.03	0	LABOR	0.7	8.40	0.29
M07	R.C	9.1	121.00	3.00 %	33.06	1,173.70	0	MATERIAL	9.1	1,102.07	38.57
B70	ELEVATOR	1.0	52.80	3.01 %	1.59	56.23	0		1.0 ▲	52.80	1.85
LB2	LABOR	0.0	12.00	4.00 %	0.01	0.39	0	LABOR	0.0	0.36	0.01
M07	R.C	0.4	121.00	3.00 %	1.57	55.84	0	MATERIAL	0.4	52.44	1.84
B80	COLUMN	1.0	29.31	3.00 %	0.88	31.21	0		1.0 ▲	29.31	1.03
LB2	LABOR	0.0	12.00	4.00 %	0.00	0.03	0	LABOR	0.0	0.02	0.00
M07	R.C	0.2	121.00	3.00 %	0.88	31.18	0	MATERIAL	0.2	29.28	1.02
B90	SLABS	1.0	7,936.56	3.01 %	239.06	8,453.40	0		1.0 ▲	7,936.56	277.78
LB2	LABOR	8.0	12.00	4.00 %	3.84	103.20	0	LABOR	8.0	96.00	3.36
M07	R.C	64.8	121.00	3.00 %	235.22	8,350.20	0	MATERIAL	64.8	7,840.56	274.42
B100	RAMP	1.0	3,751.55	3.01 %	112.79	3,995.64	0		1.0 ▲	3,751.55	131.30
LB2	LABOR	2.0	12.00	4.00 %	0.96	25.80	0	LABOR	2.0	24.00	0.84
M07	R.C	30.8	121.00	3.00 %	111.83	3,969.84	0	MATERIAL	30.8	3,727.55	130.46
C	FORMWORK	1.0	14,767.14	3.04 %	449.16	15,733.15	0		1.0 ▲	14,767.14	516.85
C10	FOUNDATION	1.0	823.79	3.22 %	26.53	879.16	0		1.0 ▲	823.79	28.83
LB3	CARPENTER	13.0	14.00	4.00 %	7.28	195.65	0	LABOR	13.0	182.00	6.37
M08	PLYWOD	25.7	25.00	3.00 %	19.25	683.51	0	MATERIAL	25.7	641.79	22.46

Code	Descripti..	Source Q..	Unit Cost	Markup	Markup V..	Gross To..	Add-On	CostType	Qty	Net Total	Add-On
D 20	BEAMS	1.0	24,856.18	3.21 %	798.22	26,524.36	0		1.0	24,856.18	869.97
D27	PL12*140	1.0	1,439.04	3.87 %	55.65	1,545.06	0		1.0	1,439.04	50.37
E	CRANE	12.0	90.00	4.00 %	43.20	1,161.00	0	EQUIPMENT	12.0	1,080.00	37.80
LB	STEELMAN	12.0	14.00	4.00 %	6.72	180.60	0	LABOR	12.0	168.00	5.88
M	STEEL	261.7	1.46	3.00 %	5.73	203.46	0	MATERIAL	130.9	191.04	6.69
D28	RHS100*100*	1.0	2,489.49	3.15 %	78.33	2,654.95	0		1.0	2,489.49	87.13
E	CRANE	3.5	90.00	4.00 %	12.64	339.59	0	EQUIPMENT	3.5	315.90	11.06
LB	STEELMAN	3.5	14.00	4.00 %	1.97	52.83	0	LABOR	3.5	49.14	1.72
M	STEEL	1,455.1	1.46	3.00 %	63.73	2,262.53	0	MATERIAL	1,455.1	2,124.45	74.36
D 21	IPE 200	1.0	4,219.84	3.25 %	137.00	4,504.53	0		1.0	4,219.84	147.69
E	CRANE	10.0	90.00	4.00 %	36.00	967.50	0	EQUIPMENT	10.0	900.00	31.50
LB	STEELMAN	10.0	14.00	4.00 %	5.60	150.50	0	LABOR	10.0	140.00	4.90
M	STEEL	4,355.9	1.46	3.00 %	95.40	3,386.53	0	MATERIAL	2,178.0	3,179.84	111.29
D22	IPE 240	1.0	4,890.63	3.17 %	155.04	5,216.84	0		1.0	4,890.63	171.17
E	CRANE	8.0	90.00	4.00 %	28.80	774.00	0	EQUIPMENT	8.0	720.00	25.20
LB	STEELMAN	8.0	14.00	4.00 %	4.48	120.40	0	LABOR	8.0	112.00	3.92
M	STEEL	2,779.9	1.46	3.00 %	121.76	4,322.44	0	MATERIAL	2,779.9	4,058.63	142.05
D 23	IPE 160	1.0	2,496.69	3.17 %	79.06	2,663.13	0		1.0	2,496.69	87.38
E	CRANE	4.0	90.00	4.00 %	14.40	387.00	0	EQUIPMENT	4.0	360.00	12.60
LB	STEELMAN	4.0	14.00	4.00 %	2.24	60.20	0	LABOR	4.0	56.00	1.96
M	STEEL	1,425.1	1.46	3.00 %	62.42	2,215.93	0	MATERIAL	1,425.1	2,080.69	72.82
D 24	IPE 300	1.0	5,778.91	3.14 %	181.69	6,162.86	0		1.0	5,778.91	202.26
E	CRANE	8.0	90.00	4.00 %	28.80	774.00	0	EQUIPMENT	8.0	720.00	25.20
LB	STEELMAN	8.0	14.00	4.00 %	4.48	120.40	0	LABOR	8.0	112.00	3.92
M	STEEL	3,388.3	1.46	3.00 %	148.41	5,268.46	0	MATERIAL	3,388.3	4,946.91	173.14
D 25	120*80 RHS	1.0	2,870.78	3.11 %	89.24	3,060.50	0		1.0	2,870.78	100.48
E	CRANE	3.0	90.00	4.00 %	10.80	290.25	0	EQUIPMENT	3.0	270.00	9.45
LB	STEELMAN	3.0	14.00	4.00 %	1.68	45.15	0	LABOR	3.0	42.00	1.47
M	STEEL	1,752.6	1.46	3.00 %	76.76	2,725.10	0	MATERIAL	1,752.6	2,558.78	89.56
D 26	IPE 330	1.0	670.80	3.31 %	22.20	716.49	0		1.0	670.80	23.48
E	CRANE	2.0	90.00	4.00 %	7.20	193.50	0	EQUIPMENT	2.0	180.00	6.30
LB	STEELMAN	2.0	14.00	4.00 %	1.12	30.10	0	LABOR	2.0	28.00	0.98
M	STEEL	317.0	1.46	3.00 %	13.88	492.89	0	MATERIAL	317.0	462.80	16.20
D30	STAIRS	1.0	15,555.22	3.02 %	469.74	16,569.39	0		1.0	15,555.22	544.43
D31	PL 50*1200	1.0	1,365.16	3.02 %	41.23	1,454.17	0		1.0	1,365.16	47.78
LB	STEELMAN	2.0	14.00	4.00 %	1.12	30.10	0	LABOR	2.0	28.00	0.98
M	STEEL	915.9	1.46	3.00 %	40.11	1,424.07	0	MATERIAL	915.9	1,337.16	46.80
D 32	PL 50*1175	1.0	4,116.30	3.02 %	124.32	4,384.70	0		1.0	4,116.30	144.07
LB	STEELMAN	6.0	14.00	4.00 %	3.36	90.30	0	LABOR	6.0	84.00	2.94
M	STEEL	2,761.9	1.46	3.00 %	120.97	4,294.40	0	MATERIAL	2,761.9	4,032.30	141.13
D33	PL 50*350	1.0	10,073.76	3.02 %	304.17	10,730.51	0		1.0	10,073.76	352.58
LB	STEELMAN	14.0	14.00	4.00 %	7.84	210.70	0	LABOR	14.0	196.00	6.86
M	STEEL	6,765.6	1.46	3.00 %	296.33	10,519.81	0	MATERIAL	6,765.6	9,877.76	345.72
D40	ACCESORRIE	1.0	9,048.67	3.07 %	277.48	9,642.85	0		1.0	9,048.67	316.70
D43	FORMWORK	1.0	2,438.90	3.11 %	75.97	2,600.23	0		1.0	2,438.90	85.36
LB	STEELMAN	20.0	14.00	4.00 %	11.20	301.00	0	LABOR	20.0	280.00	9.80
M	STEEL	1,478.7	1.46	3.00 %	64.77	2,299.23	0	MATERIAL	1,478.7	2,158.90	75.56
D41	CONN AND	1.0	6,235.09	3.02 %	188.17	6,641.50	0		1.0	6,235.09	218.23
LB	STEELMAN	8.0	14.00	4.00 %	4.48	120.40	0	LABOR	8.0	112.00	3.92
M	STEEL	4,193.9	1.46	3.00 %	183.69	6,521.10	0	MATERIAL	4,193.9	6,123.09	214.31
D42	ANCHOR	1.0	374.67	3.56 %	13.34	401.12	0		1.0	374.67	13.11
LB	STEELMAN	15.0	14.00	4.00 %	8.40	225.75	0	LABOR	15.0	210.00	7.35
M	STEEL	112.8	1.46	3.00 %	4.94	175.37	0	MATERIAL	112.8	164.67	5.76
D50	DECKING	1.0	18,057.25	3.23 %	583.88	19,273.13	0		1.0	18,057.25	632.00
D51	RIDECK 1ST	1.0	6,870.25	3.24 %	222.57	7,333.46	0		1.0	6,870.25	240.46
E	CRANE	16.0	90.00	4.00 %	57.60	1,548.00	0	EQUIPMENT	16.0	1,440.00	50.40
LB	STEELMAN	16.0	14.00	4.00 %	8.96	240.80	0	LABOR	16.0	224.00	7.84
M	DECK	208.3	25.00	3.00 %	156.19	5,544.66	0	MATERIAL	208.3	5,206.25	182.22
D52	RIDECK 2ND	1.0	5,681.00	3.26 %	184.99	6,064.83	0		1.0	5,681.00	198.84
E	CRANE	14.0	90.00	4.00 %	50.40	1,354.50	0	EQUIPMENT	14.0	1,260.00	44.10
LB	STEELMAN	14.0	14.00	4.00 %	7.84	210.70	0	LABOR	14.0	196.00	6.86
M	DECK	169.0	25.00	3.00 %	126.75	4,499.63	0	MATERIAL	169.0	4,225.00	147.88
D53	RIDECK 3RD	1.0	3,890.00	3.27 %	127.10	4,153.25	0		1.0	3,890.00	136.15
E	CRANE	10.0	90.00	4.00 %	36.00	967.50	0	EQUIPMENT	10.0	900.00	31.50
LB	STEELMAN	10.0	14.00	4.00 %	5.60	150.50	0	LABOR	10.0	140.00	4.90
M	DECK	114.0	25.00	3.00 %	85.50	3,035.25	0	MATERIAL	114.0	2,850.00	99.75
D54	RIDECK ROOF	1.0	1,616.00	3.03 %	49.04	1,721.60	0		1.0	1,616.00	56.56
E	CRANE	4.0	90.00	3.00 %	10.80	383.40	0	MATERIAL	4.0	360.00	12.60
LB	STEELMAN	4.0	14.00	4.00 %	2.24	60.20	0	LABOR	4.0	56.00	1.96
M	DECK	48.0	25.00	3.00 %	36.00	1,278.00	0	MATERIAL	48.0	1,200.00	42.00
E	FINISHING	1.0	84,298.67	3.07 %	2,584.86	89,833.99	0		1.0	84,298.67	2,950.45
E 10	BRICK WORK	1.0	6,412.59	3.27 %	209.78	6,846.80	0		1.0	6,412.59	224.44
M10	BRICKS	389.4	12.00	3.00 %	140.18	4,976.30	0	MATERIAL	389.4	4,672.59	163.54
LB5	BRICKLAYER	116.0	15.00	4.00 %	69.60	1,870.50	0	LABOR	116.0	1,740.00	60.90
E 20	INTERIOR	1.0	1,362.39	3.00 %	40.87	1,450.94	0		1.0	1,362.39	47.68
M12	BLOCK	85.2	10.00	3.00 %	25.57	907.79	0	MATERIAL	85.2	852.39	29.83
LB5	BRICKLAYER	34.0	15.00	3.00 %	15.30	543.15	0	MATERIAL	34.0	510.00	17.85

Code	Descripti..	Source Q..	Unit Cost	Markup	Markup V..	Gross To..	Add-On	CostType	Qty	Net Total	Add-On
E 30	INTERNAL	1.0	16,253.96	3.04 %	493.82	17,316.67	0		1.0	16,253.96	568.89
M13	PLASTERING	625.4	25.00	3.00 %	469.02	16,650.17	0	MATERIAL	625.4	15,633.96	547.19
LB6	PAINTER	62.0	10.00	4.00 %	24.80	666.50	0	LABOR	62.0	620.00	21.70
E 40	PLASTERING	1.0	9,842.97	3.00 %	295.29	10,482.76	0		1.0	9,842.97	344.50
E 41	PLASTRING	469.1	20.00	3.00 %	281.49	9,992.86	0	MATERIAL	469.1	9,382.97	328.40
LB6	PAINTER	46.0	10.00	3.00 %	13.80	489.90	0	MATERIAL	46.0	460.00	16.10
E 50	TILES	1.0	32,402.00	3.02 %	980.06	34,516.13	0		1.0	32,402.00	1,134.07
E 51	80 MM SLAB	687.0	46.00	3.00 %	948.06	33,656.13	0	MATERIAL	687.0	31,602.00	1,106.07
LB7	TILEMAN	80.0	10.00	4.00 %	32.00	860.00	0	LABOR	80.0	800.00	28.00
E 60	PAINTING	1.0	12,612.22	3.16 %	399.17	13,452.81	0		1.0	12,612.22	441.43
E 61	INTERNAL	389.4	15.00	3.00 %	175.22	6,220.38	0	MATERIAL	389.4	5,840.73	204.43
LB6	PAINTER	76.0	10.00	4.00 %	30.40	817.00	0	LABOR	76.0	760.00	26.60
E 62	EXTERNAL	383.9	10.00	3.00 %	115.17	4,088.64	0	MATERIAL	383.9	3,839.10	134.37
LB6	PAINTER	115.0	10.00	4.00 %	46.00	1,236.25	0	LABOR	115.0	1,150.00	40.25
E 63	EXTERNAL	85.2	10.00	3.00 %	25.57	907.79	0	MATERIAL	85.2	852.39	29.83
LB6	PAINTER	17.0	10.00	4.00 %	6.80	182.75	0	LABOR	17.0	170.00	5.95
E 70	WOOD	1.0	5,412.56	3.06 %	165.88	5,767.88	0		1.0	5,412.56	189.44
E71	DOORS	1.0	1,014.56	3.00 %	30.44	1,080.51	0		1.0	1,014.56	35.51
E	0915*2134mm	12.2	20.00	3.00 %	7.32	259.77	0	MATERIAL	12.2	243.92	8.54
E	1830*1981	8.7	20.00	3.00 %	5.20	184.46	0	MATERIAL	8.7	173.20	6.06
E	1830*2134	7.9	20.00	3.00 %	4.76	168.87	0	MATERIAL	7.9	158.56	5.55
E	GARAGE	8.8	20.00	3.00 %	5.30	188.12	0	MATERIAL	8.8	176.64	6.18
E	KITCHEN	5.6	20.00	3.00 %	3.35	119.02	0	MATERIAL	5.6	111.76	3.91
E	1730*2032	7.5	20.00	3.00 %	4.51	160.26	0	MATERIAL	7.5	150.48	5.27
LB9	CARPENTER	10.0	15.00	4.00 %	6.00	161.25	0	LABOR	10.0	150.00	5.25
E 72	WINDOWS	1.0	4,048.00	3.00 %	121.44	4,311.12	0		1.0	4,048.00	141.68
E	180*250 mm	51.6	20.00	3.00 %	30.96	1,099.08	0	MATERIAL	51.6	1,032.00	36.12
E	150*150 mm	30.0	20.00	3.00 %	18.00	639.00	0	MATERIAL	30.0	600.00	21.00
E	100*80 mm	18.0	20.00	3.00 %	10.80	383.40	0	MATERIAL	18.0	360.00	12.60
E	200*250 mm	18.0	20.00	3.00 %	10.80	383.40	0	MATERIAL	18.0	360.00	12.60
E	180*140 mm	38.4	20.00	3.00 %	23.04	817.92	0	MATERIAL	38.4	768.00	26.88
E	160*570 mm	14.0	20.00	3.00 %	8.40	298.20	0	MATERIAL	14.0	280.00	9.80
E	75*290 mm	21.9	20.00	3.00 %	13.14	466.47	0	MATERIAL	21.9	438.00	15.33
E	75*90 mm	10.5	20.00	3.00 %	6.30	223.65	0	MATERIAL	10.5	210.00	7.35
LB10	CARPENTER	10.0	20.00	4.00 %	8.00	215.00	0	LABOR	10.0	200.00	7.00
G	MISC	1.0	7,576.00	4.00 %	303.04	8,144.20	0		1.0	7,576.00	265.16
G30	CURING SB	1.0	3,472.00	4.00 %	138.88	3,732.40	0		1.0	3,472.00	121.52
E12	TANKER	56.0	50.00	4.00 %	112.00	3,010.00	0	EQUIPMENT	56.0	2,800.00	98.00
LB1	LABOUR	56.0	12.00	4.00 %	26.88	722.40	0	LABOR	56.0	672.00	23.52
G40	CURING	1.0	248.00	4.00 %	9.92	266.60	0		1.0	248.00	8.68
LB1	LABOUR	4.0	12.00	4.00 %	1.92	51.60	0	LABOR	4.0	48.00	1.68
E12	TANKER	4.0	50.00	4.00 %	8.00	215.00	0	EQUIPMENT	4.0	200.00	7.00
G50	CURINGRW	1.0	3,472.00	4.00 %	138.88	3,732.40	0		1.0	3,472.00	121.52
LB1	LABOUR	56.0	12.00	4.00 %	26.88	722.40	0	LABOR	56.0	672.00	23.52
E12	TANKER	56.0	50.00	4.00 %	112.00	3,010.00	0	EQUIPMENT	56.0	2,800.00	98.00
G60	STRUCTURE	1.0	384.00	4.00 %	15.36	412.80	0		1.0	384.00	13.44
G61	LEVELLING	8.0	12.00	4.00 %	3.84	103.20	0	LABOR	8.0	96.00	3.36
G26	LEVELLING	24.0	12.00	4.00 %	11.52	309.60	0	LABOR	24.0	288.00	10.08

Appendix A4

Table 5: Task with Quantity, Resource, Man Hours, Cost and Consumption; Vico Schedule Planner

Hiera rchy	Name	Quan tity	U ni t	Consu mption	Prod uctio n rate	Resourc es	Work grou p count	Dur atio n	MAN HOU RS	Cos ts
1	EXCAVATI ON	572	M C	0.6	53.3	EXCAV ATOR: 1; LOADE R: 1; UW: 2	1	10.7	343. 2	210 76.6
2	COMPACT ION	27.1	M S	2	16	HP: 1; SW: 1; UW: 2	1	1.7	54.2	119 1.5
3	HARDCOR E	270. 8	M S	0.32	100	HP: 1; SW: 1; UW: 2	1	2.7	86.7	105 17.8
4	ISOLATIO N	76.3	M S	0.43	75	HP: 1; SW: 1; UW: 2	1	1	32.5	153 4.8
5	PLAIN CONCRET E	27.1	M C	1.28	25	HP: 1; SW: 1; UW: 2	1	1.1	34.7	361 1.4
6	LEVELLIN G BASE PLATES AND ANCHOR BOLTS	8	H R	4	8	HP: 1; STEEL ERECT OR: 2; UW: 1	1	1	32	512
7	REINFOR CEMENT FOR FOUNDATI ON	16	T O N	4	8	HP: 1; STEEL FIXER: 2; UW: 1	1	2	64	880 0
8	FORMWO RK FOUNDATI ON	33.4	M S	2	16	CARPE NTER: 2; HP: 1; UW: 1	1	2.1	66.8	167 0.7
9	POURING FOUND. CONC	105. 7	M C	0.32	100	HP: 1; SW: 2; UW: 1	1	1.1	33.8	132 14.6
10	ERECTION OF MAIN COLUMNS	107 54	K G	0.02	2625	CRANE: 1; HP: 1; STEEL ERECT OR: 2; UW: 1	1	4.1	163. 9	206 81.5
11	ERECTION OF REMAININ G COLUMNS	352 9	K G	0.03	1167	CRANE: 1; HP: 1; STEEL ERECT OR: 2; UW: 1	1	3	121	882 9.8

12	ALINGMNET AND LEVEELING WITH BOLTS	4194	KG	0.02	2133	CRANE: 1; HP: 1; STEEL ERECTOR: 2; UW: 1	1	2	78.6	8513.6
13	CONNECTION OF BRACING TO JOINTS	3208	KG	0.01	3046	CRANE: 1; HP: 1; STEEL ERECTOR: 2; UW: 1	1	1.1	42.1	5963.9
14	STAIRS	10443	KG	0.01	4000	CRANE: 1; HP: 1; STEEL ERECTOR: 2; UW: 1	1	2.6	104.4	18421.9
15	STEEL DECKING	539.3	MS	0.4	100	CRANE: 1; HP: 1; STEEL ERECTOR: 2; UW: 1	1	5.4	215.7	20038.5
16	WELDING SHEAR STUDS	50	EA	0.8	50.3	CRANE: 1; HP: 1; STEEL ERECTOR: 2; UW: 1	1	1	39.8	5618.5
17	POURING CONCRETE	64.8	MC	0.32	100	HP: 1; SW: 2; UW: 1	1	0.6	20.7	8099.8
18	CURING	56	HR	2.01	8	TANKER: 1; UW: 1	1	7	112.4	6846.5
19	REINFORCEMENT FOR RETAINING WALLS	27.9	TON	7.8	4.1	HP: 1; STEEL FIXER: 2; UW: 1	1	6.8	217.9	16690.4
20	RW FORMWORK	532.7	MS	0.28	114.5	CARPENTER: 2; HP: 1; UW: 1	1	4.7	148.9	15178.3
21	RW CONCRETE	107.1	MC	0.32	100	HP: 1; SW: 2; UW: 1	1	1.1	34.3	13383.1
22	RW CURING	56	HR	3	8	CARPENTER: 1; TANKER: 1; UW: 1	1	7	168	5488
23	EXTERNAL BRICK	389.4	MS	1.2	26.7	BRICKLAYER: 2; HP: 1; UW: 1	1	14.6	467.3	10046.1
24	INTEROR BLOCK	85.2	MS	1.6	20	BRICKLAYER: 2; HP: 1; UW: 1	1	4.3	136.4	2420.8

25	INTERNAL PLASTERING	625.4	MS	0.4	80	HP: 1; PAINTER: 2; UW: 1	1	7.8	250.1	18760.8
26	EXTERNAL PLASTERING	469.1	MS	0.4	80	HP: 1; PAINTER: 2; UW: 1	1	5.9	187.7	11728.7
27	EXTERNAL PAINT	469.1	MS	0.8	40	HP: 1; PAINTER: 2; UW: 1	1	11.7	375.3	9383
28	INTERNAL PAINT	389.4	MS	0.4	80	HP: 1; PAINTER: 2; UW: 1	1	4.9	155.8	7787.7
29	WOOD WORKS	253.1	M	0.48	66.7	CARPENTER: 2; HP: 2	1	3.8	121.5	6520.6
30	TILING	687	MS	0.8	40	HP: 1; TILER: 2; UW: 1	1	17.2	549.6	38472
31	CURING FOUNDATION	56	HR	4	8	CARPENTER: 2; TANKER: 1; UW: 1	1	7	224	8400
32	ALIGNMENT AND LEVELLING	24	HR	5	8	CRANE: 1; HP: 1; STEEL ERECTOR: 2; UW: 1	1	3	120	3936
33	TIGHTEN BOLTS AND WELDING JOINTS	112.8	KG	0.65	61.5	CRANE: 1; HP: 1; STEEL ERECTOR: 2; UW: 1	1	1.8	73.3	2393.3
34	BEAM ERECTION	10219	KG	0.01	4000	CRANE: 1; HP: 1; STEEL ERECTOR: 2; UW: 1	1	2.6	102.2	18026.5

Appendix A5

Table 6: Free and Total Float; Vico Schedule Planner

Hierarchy	Task	Free float (Workshifts) Planned last task	Total float (Workshifts) Planned last task	Free float (Workshifts) Planned deadline	Total float (Workshifts) Planned deadline
-1	EXCAVATION	0	0	0	0
1.1	BASEMENT	0	0	0	0.9
-2	COMPACTION	0	0	0	0
2.1	BASEMENT	0	0	0	0.9
-3	HARDCORE	0	0	0	0
3.1	BASEMENT	0	0	0	0.9
-4	ISOLATION	0	0	0	0
4.1	BASEMENT	0	0	0	0.9
-5	PLAIN CONCRETE	0	0	0	0
5.1	BASEMENT	0	0	0	0.9
-6	LEVELLING BASE PLATES AND ANCHOR BOLTS	0	0	0	0
6.1	BASEMENT	0	0	0	0.9
-7	REINFORCEMENT FOR FOUNDATION	0	0	0	0
7.1	BASEMENT	0	0	0	0.9
-8	FORMWORK FOUNDATION	0	0	0	0
8.1	BASEMENT	0	0	0	0.9
-9	POURING FOUND. CONC	0	0	0	0
9.1	BASEMENT	0	0	0	0.9
-10	ERECTION OF MAIN COLUMNS	0	0	0	0
10.1	BASEMENT->FOUN	0.3	0	0.3	0.9
10.2	G.F@3->GF	0.1	0	0.1	0.9
10.3	F.F@3->FF	0.2	0	0.2	0.9
10.4	S.F@3->SF	0	0	0	0.9
-11	ERECTION OF REMAINING COLUMNS	0	0	0	0
11.1	BASEMENT->FOUN	0	0	0	0.9
11.2	G.F@3->GF	0	0	0	0.9
11.3	F.F@3->FF	0	0	0	0.9
11.4	S.F@3->SF	0	0	0	0.9
-12	ALINGMNET AND LEVEELING WITH BOLTS	0	0	0	0
12.1	BASEMENT->FOUN	67.2	1.1	68.1	2
12.2	G.F@3->GF	65.9	0.3	66.9	1.3
12.3	F.F@3->FF	2	0	2	0.9
12.4	S.F@3->SF	0	0	0	0.9
-13	CONNECTION OF	0	0	0	0

	BRACING TO JOINTS				
13.1	BASEMENT->FOUN	0	0	0	0.9
13.2	G.F@3->GF	0	0	0	1
13.3	F.F@3->FF	0.5	1.5	0.5	2.4
13.4	S.F@3->SF	1.1	3.6	1.1	4.6
-14	STAIRS	0	0	0	0
14.1	BASEMENT->FOUN	0	0.5	0	1.4
14.2	G.F@3->GF	0	0	0	0.9
14.3	F.F@3->FF	0	0.9	0	1.8
14.4	S.F@3->SF	0	2.1	0	3
-15	STEEL DECKING	0	0	0	0
15.1	BASEMENT->FOUN	0	0.5	0	1.4
15.2	G.F@3->GF	0	0	0	0.9
15.3	F.F@3->FF	0	0.2	0	1.2
15.4	S.F@3->SF	0	0.8	0	1.7
-16	WELDING SHEAR STUDS	0	0	0	0
16.1	BASEMENT->FOUN	0	0.5	0	1.4
16.2	G.F@3->GF	0	0	0	0.9
16.3	F.F@3->FF	0	0.2	0	1.2
16.4	S.F@3->SF	0	0.8	0	1.7
-17	POURING CONCRETE	1	0	1	0
17.1	BASEMENT->FOUN	1.5	0.5	1.5	1.4
17.2	G.F@3->GF	1	0	1	0.9
17.3	F.F@3->FF	1.2	0.2	1.2	1.2
17.4	S.F@3->SF	1.8	0.8	1.8	1.7
-18	CURING	0	0	0	0
18.1	BASEMENT->FOUN	37.8	0	38.7	0.9
18.2	G.F@3->GF	36.1	0	37	0.9
18.3	F.F@3->FF	34.3	0	35.2	0.9
18.4	S.F@3->SF	0	0	0	0.9
-19	REINFORCEMENT FOR RETAINING WALLS	0	0	0	0
19.1	BASEMENT->SP	0	0	0	0.9
19.2	BASEMENT->FOUN	0	0	0	0.9
-20	RW FORMWORK	0	0	0	0
20.1	BASEMENT->SP	0	4.6	0	5.5
20.2	BASEMENT->FOUN	0	0	0	0.9
-21	RW CONCRETE	0	0	0	0
21.1	BASEMENT->SP	62.2	8.3	63.1	9.2
21.2	BASEMENT->FOUN	0	0	0	0.9
-22	RW CURING	0	0	0	0
22.1	BASEMENT	0	0	0	0.9
-23	EXTERNAL BRICK	0	0	0	0
23.1	G.F@3	0	0	0	0.9
23.2	F.F@3	0	0.6	0	1.5

23.3	S.F@3	0	2.7	0	3.6
-24	INTEROR BLOCK	0	0	0	0
24.1	G.F@3	0	0	0	0.9
24.2	F.F@3	0	0.6	0	1.5
24.3	S.F@3	0	2.7	0	3.6
-25	INTERNAL PLASTERING	0	0	0	0
25.1	BASEMENT->FOUN	23.9	0	24.8	0.9
25.2	G.F@3->GF	0	0	0	0.9
25.3	F.F@3->FF	0	0.6	0	1.5
25.4	S.F@3->SF	0.8	2.7	0.8	3.6
-26	EXTERNAL PLASTERING	0	0.6	0	0.6
26.1	G.F@3	0.7	0.7	0.7	1.6
26.2	F.F@3	0	0.6	0	1.5
26.3	S.F@3	0	2.7	0	3.6
-27	EXTERNAL PAINT	0	0	0	0
27.1	G.F@3	0	0	0	0.9
27.2	F.F@3	0	0.6	0	1.5
27.3	S.F@3	0	1.8	0	2.8
-28	INTERNAL PAINT	0	0	0	0
28.1	BASEMENT->FOUN	0	0	0	0.9
28.2	G.F@3->GF	0	1.8	0	2.7
28.3	F.F@3->FF	0	0.6	0	1.5
28.4	S.F@3->SF	0	1.8	0	2.8
-29	WOOD WORKS	0	0	0	0
29.1	BASEMENT->FOUN	0	0	0	0.9
29.2	G.F@3->GF	1.8	1.8	1.8	2.7
29.3	F.F@3->FF	3.5	2.8	3.5	3.8
29.4	S.F@3->SF	1.8	1.8	1.8	2.8
-30	TILING	0	0	0	0
30.1	BASEMENT->SP	15	0	15.9	0.9
30.2	BASEMENT->FOUN	12.9	0	13.8	0.9
30.3	G.F@3->GF	8.6	0	9.5	0.9
30.4	F.F@3->FF	4.3	0	5.2	0.9
30.5	S.F@3->SF	0	0	0.9	0.9
-31	CURING FOUNDATION	0	0	0	0
31.1	BASEMENT->SP	73.2	0	74.1	0.9
31.2	BASEMENT->FOUN	0	0	0	0.9
-32	ALIGNMENT AND LEVELLING	0	0	0	0
32.1	BASEMENT->FOUN	0	0	0	0.9
32.2	G.F@3->GF	0	0	0	0.9
32.3	F.F@3->FF	0.1	1	0.1	1.9
32.4	S.F@3->SF	0.4	2.5	0.4	3.4
-33	TIGHTEN BOLTS AND WELDING JOINTS	0	0	0	0
33.1	BASEMENT->FOUN	0	0.5	0	1.4
33.2	G.F@3->GF	0	0	0	0.9

33.3	F.F@3->FF	0.7	0.9	0.7	1.8
33.4	S.F@3->SF	1.4	2.1	1.4	3
-34	BEAM ERECTION	0	0	0	0
34.1	BASEMENT->FOUN	0	0	0	0.9
34.2	G.F@3->GF	0	0	0	1
34.3	F.F@3->FF	0	1.5	0	2.4
34.4	S.F@3->SF	0	3.7	0	4.6

79	-25	21	POURING CONCRETE	0.6	12/20/2013	12/27/2013	74 FS 0
80	25.1		BASEMENT	0.3	12/20/2013	12/20/2013	
81	25.2		GF@3	0.1	12/24/2013	12/24/2013	
82	25.3		FF@3	0.2	12/25/2013	12/25/2013	
83	25.4		SF@3	0.1	12/27/2013	12/27/2013	
84	-26	22	CURING	7	12/24/2013	1/2/2014	79 FS 0
85	26.1		BASEMENT	1.8	12/24/2013	12/26/2013	
86	26.2		GF@3	1.8	12/26/2013	12/30/2013	
87	26.3		FF@3	1.8	12/30/2013	12/31/2013	
88	26.4		SF@3	1.8	12/31/2013	1/2/2014	
89	-27	27	EXTERNAL BRICK	14.6	1/2/2014	1/23/2014	84 FS 0
90	27.1		GF@3	6	1/2/2014	1/10/2014	
91	27.2		FF@3	5.8	1/10/2014	1/20/2014	
92	27.3		SF@3	2.8	1/20/2014	1/23/2014	
93	-28	28	INTEROR BLOCK	4.3	1/10/2014	1/28/2014	89 FS 0
94	28.1		SF@3	3	1/23/2014	1/28/2014	
95	28.2		GF@3	0.1	1/10/2014	1/10/2014	
96	28.3		FF@3	1.2	1/20/2014	1/21/2014	
97	-29	30	EXTERNAL PLASTERING	5.9	1/10/2014	1/29/2014	93 FS 0
98	29.1		GF@3	1.9	1/10/2014	1/14/2014	95 FS 0
99	29.2		FF@3	2.2	1/21/2014	1/23/2014	
100	29.3		SF@3	1.7	1/28/2014	1/29/2014	
101	-30	29	INTERNAL PLASTERING	7.8	1/10/2014	1/31/2014	97 FS 0, 9!
102	30.1		BASEMENT	2.6	1/10/2014	1/15/2014	
103	30.2		GF@3	2.1	1/15/2014	1/17/2014	
104	30.3		FF@3	1.7	1/23/2014	1/27/2014	
105	30.4		SF@3	1.4	1/29/2014	1/31/2014	
106	-31	31	EXTERNAL PAINT	11.7	1/17/2014	2/6/2014	101 FS 0
107	31.1		GF@3	3.9	1/17/2014	1/23/2014	
108	31.2		FF@3	4.5	1/27/2014	2/3/2014	
109	31.3		SF@3	3.3	2/3/2014	2/6/2014	
110	-32	32	INTERNAL PAINT	4.9	1/23/2014	2/7/2014	106 FS 0
111	32.1		BASEMENT	0.1	1/23/2014	1/23/2014	
112	32.2		GF@3	2	1/23/2014	1/27/2014	
113	32.3		FF@3	1.9	2/3/2014	2/4/2014	
114	32.4		SF@3	0.9	2/6/2014	2/7/2014	
115	-33	33	WOOD WORKS	3.8	1/23/2014	2/7/2014	110 FS 0
116	33.1		BASEMENT	0.6	1/23/2014	1/23/2014	
117	33.2		GF@3	1.2	1/27/2014	1/28/2014	
118	33.3		FF@3	1.3	2/4/2014	2/6/2014	
119	33.4		SF@3	0.7	2/7/2014	2/7/2014	
120	-34	34	TILING	17.2	1/23/2014	2/18/2014	115 FS 0, '
121	34.1		BASEMENT	4.3	1/23/2014	1/30/2014	
122	34.2		GF@3	4.3	1/30/2014	2/5/2014	
123	34.3		FF@3	4.3	2/5/2014	2/11/2014	
124	34.4		SF@3	4.3	2/11/2014	2/18/2014	

Design mode
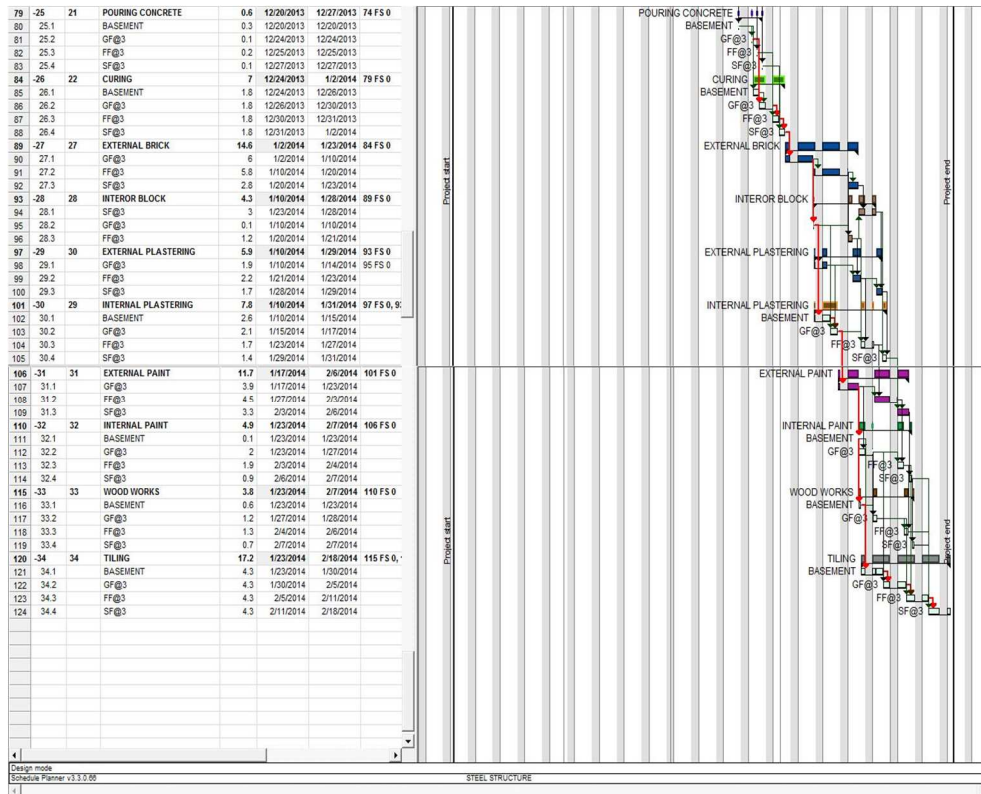Schedule Planner v3.3.0.66 STEEL STRUCTURE

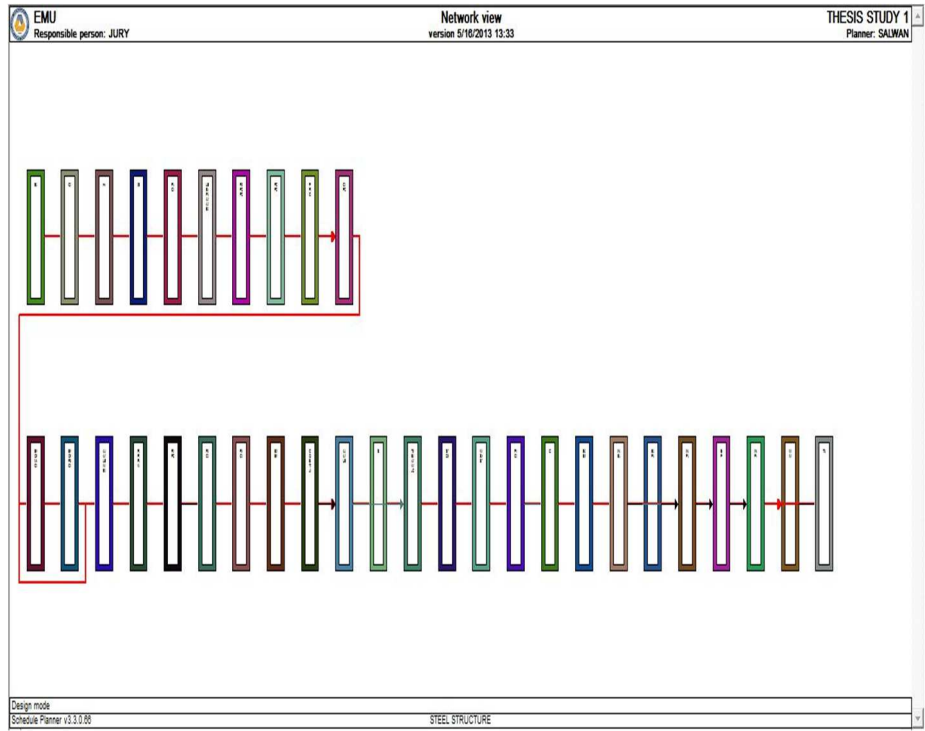Figure 66: Bar Charts; Vico Schedule Planner

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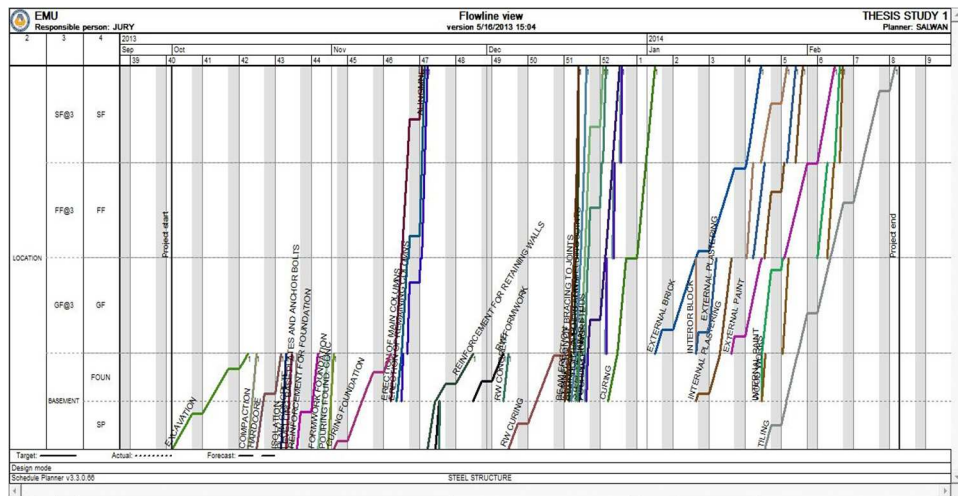Figure 67: Network Diagram; Vico Schedule Planner

Appendix A6

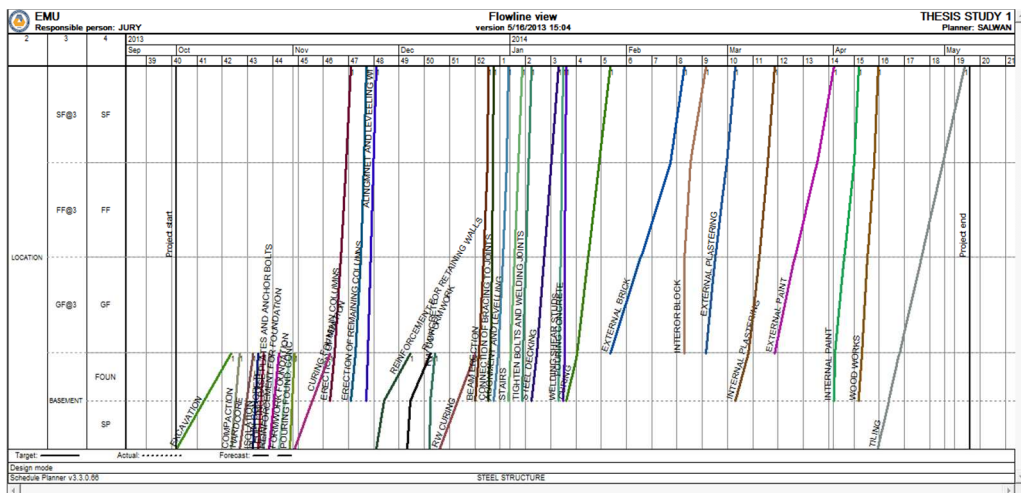Figure 68: LBS Discontinuous Flow; Vico Schedule Planner

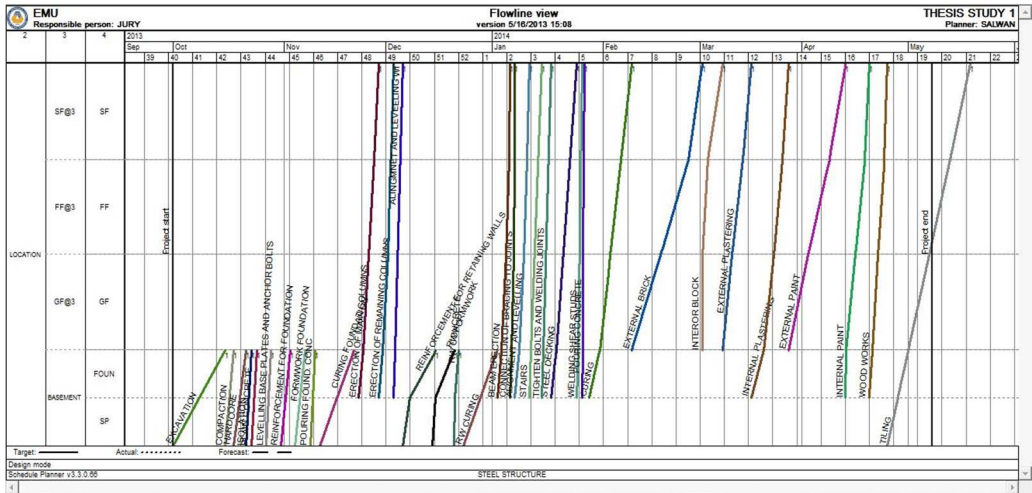Figure 69: LBS Continuous Flow; Vico Schedule Planner

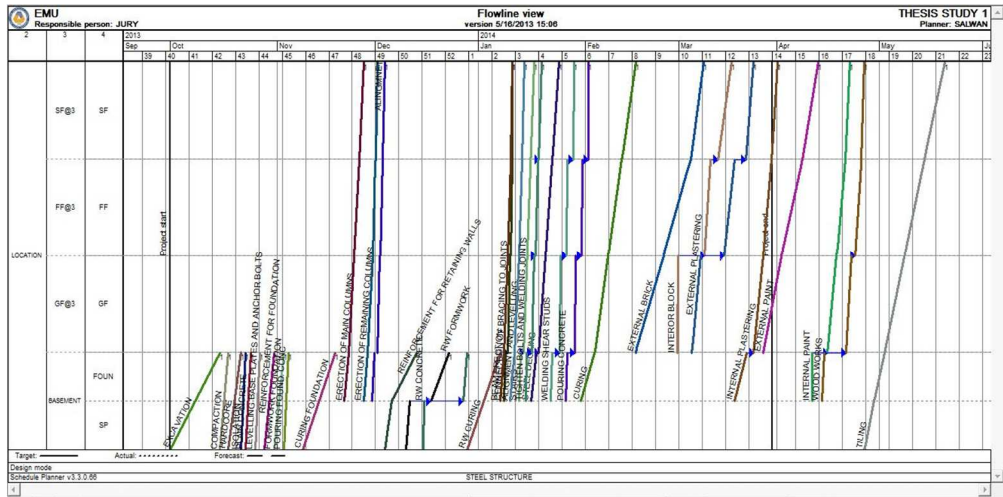Figure 70: Continuous Flow with Buffer; Vico Schedule Planner

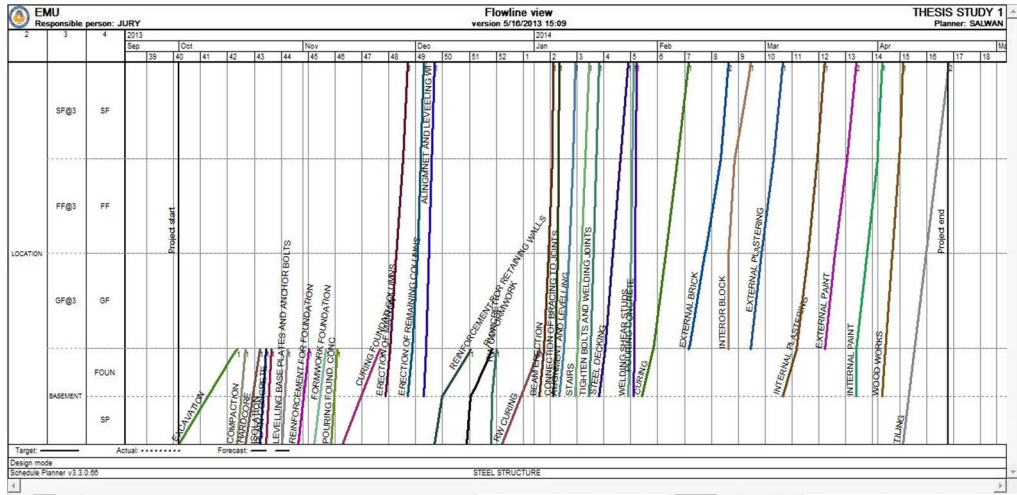Figure 71: LBS Discontinuous Flow with Buffer; Vico Schedule Planner

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Figure 72: Continuous Flow with Optimization; Vico Schedule Planner

Appendix A7

Hierarchy	Name	Start of schedule task		Schedule task duration (%)	Beginning risk		Come-back delay		Production factor distribution	Dependencies
+1	EXCAVATION	Low	-2/0/2	Zero	100/100/100	Zero	0/0/0	Zero	0/0/0	(0.1-0.4)/(0.1-0.4)/1.1	
+2	COMPACTION	Low	-2/0/2	Zero	100/100/100	Low	0/0/20	Zero	0/0/0	(0.1-0.6)/(0.1-0.7)/1.1	- (FS)
+3	HARDCORE	Low	-2/0/2	Zero	100/100/100	Low	0/0/20	Zero	0/0/0	(0.1-0.6)/(0.1-0.7)/1.1	- (FS)
+4	ISOLATION	Low	-2/0/2	Zero	100/100/100	Low	0/0/20	Zero	0/0/0	(0.1-0.6)/(0.1-0.7)/1.1	- (FS)
+5	PLAIN CONCRETE	High	-15/0/15	Zero	100/100/100	Low	0/0/20	Zero	0/0/0	(0.1-0.6)/(0.1-0.7)/1.1	- (FS)
+6	LEVELLING BASE PLATES	Low	-2/0/2	Zero	100/100/100	Low	0/0/20	Zero	0/0/0	(0.1-0.4)/(0.1-0.4)/1.1	- (FS)
+7	REINFORCEMENT FOR FOUI	Intermed	-5/0/5	Low	90/100/120	Low	0/0/20	Zero	0/0/0	(0.1-0.4)/(0.1-0.4)/1.1	- (FS)
+8	FORMWORK FOUNDATION	Intermed	-5/0/5	Low	90/100/120	Low	0/0/20	Zero	0/0/0	(0.1-0.4)/(0.1-0.4)/1.1	- (FS)
+9	POURING FOUND. CONC	High	-15/0/15	Low	90/100/120	Low	0/0/20	Zero	0/0/0	(0.1-0.4)/(0.1-0.4)/1.1	- (FS)
+10	CURING FOUNDATION	Zero	0/0/0	Zero	100/100/100	Zero	0/0/0	Zero	0/0/0	(0.2-0.4)/(0.2-0.4)/1	- (FS)
+11	ERECTION OF MAIN COLUI	Intermed	-5/0/5	Low	90/100/120	Low	0/0/20	Zero	0/0/0	(0.1-0.4)/(0.1-0.4)/1.1	- (FS) - (FS) - (FS)
+12	ERECTION OF REMAINING (	Intermed	-5/0/5	Low	90/100/120	Low	0/0/20	Zero	0/0/0	(0.1-0.4)/(0.1-0.4)/1.1	+ (FS) + (FS) + (FS)
+13	ALINGMNET AND LEVEELII	Low	-2/0/2	Low	90/100/120	Low	0/0/20	Zero	0/0/0	(0.1-0.4)/(0.1-0.4)/1.1	- (FS) - (FS) - (FS)
+14	CONNECTION OF BRACING	Intermed	-5/0/5	Low	90/100/120	Low	0/0/20	Zero	0/0/0	(0.1-0.4)/(0.1-0.4)/1.1	
+15	STAIRS	Low	-2/0/2	Low	90/100/120	Low	0/0/20	Zero	0/0/0	(0.1-0.4)/(0.1-0.4)/1	
+16	TIGHTEN BOLTS AND WELI	Low	-2/0/2	Low	90/100/120	Low	0/0/20	Zero	0/0/0	(0.1-0.4)/(0.1-0.4)/1.1	+ (FS) + (FS)
+17	STEEL DECKING	Intermed	-5/0/5	Low	90/100/120	Low	0/0/20	Zero	0/0/0	(0.1-0.4)/(0.1-0.4)/1.1	+ (FS) + (FS)
+18	WELDING SHEAR STUDS	Low	-2/0/2	Low	90/100/120	Low	0/0/20	Zero	0/0/0	(0.1-0.4)/(0.1-0.4)/1.1	+ (FS) + (FS)
+19	POURING CONCRETE	High	-15/0/15	Zero	100/100/100	Low	0/0/20	Zero	0/0/0	(0.2-0.4)/(0.2-0.4)/1.1	+ (FS) + (FS)
+20	CURING	Zero	0/0/0	Zero	100/100/100	Zero	0/0/0	Zero	0/0/0	(0.1-0.7)/(0.1-0.7)/1	+ (FS)
+21	REINFORCEMENT FOR RET/	Intermed	-5/0/5	Low	90/100/120	Low	0/0/20	Zero	0/0/0	(0.1-0.4)/(0.1-0.4)/1.1	+ (FS) + (FS) + (FS) + (FS) + (
+22	RW FORMWORK	Intermed	-5/0/5	Low	90/100/120	Low	0/0/20	Zero	0/0/0	(0.1-0.4)/(0.1-0.4)/1.1	+ (FS)
+23	RW CONCRETE	High	-15/0/15	Zero	100/100/100	Low	0/0/20	Zero	0/0/0	(0.1-0.4)/(0.1-0.4)/1.1	+ (FS) + (FS)
+24	RW CURING	Zero	0/0/0	Zero	100/100/100	Zero	0/0/0	Zero	0/0/0	(0.2-0.4)/(0.2-0.4)/1	+ (FS)
+25	EXTERNAL BRICK	Low	-2/0/2	Low	90/100/120	Low	0/0/20	Zero	0/0/0	(0.1-0.4)/(0.1-0.4)/1.1	+ (FS) + (FS)
+26	INTEROR BLOCK	Low	-2/0/2	Low	90/100/120	Low	0/0/20	Zero	0/0/0	(0.1-0.4)/(0.1-0.4)/1.1	+ (FS) + (FS)
+27	INTERNAL PLASTERING	Low	-2/0/2	Low	90/100/120	Low	0/0/20	Zero	0/0/0	(0.1-0.4)/(0.1-0.4)/1.1	
+28	EXTERNAL PLASTERING	Low	-2/0/2	Low	90/100/120	Low	0/0/20	Zero	0/0/0	(0.1-0.4)/(0.1-0.4)/1.1	+ (FS) + (FS)
+29	EXTERNAL PAINT	Low	-2/0/2	Low	90/100/120	Low	0/0/20	Zero	0/0/0	(0.1-0.4)/(0.1-0.4)/1.1	+ (FS) + (FS)
+30	INTERNAL PAINT	Low	-2/0/2	Low	90/100/120	Low	0/0/20	Zero	0/0/0	(0.1-0.4)/(0.1-0.4)/1.1	+ (FS) + (FS) + (FS)
+31	WOOD WORKS	Low	-2/0/2	Low	90/100/120	Low	0/0/20	Zero	0/0/0	(0.1-0.4)/(0.1-0.4)/1.1	+ (FS) + (FS)
+32	TILING	Low	-2/0/2	Low	90/100/120	Low	0/0/20	Zero	0/0/0	(0.1-0.4)/(0.1-0.4)/1.1	+ (FS) + (FS) + (FS)
+33	BEAM ERECTION	Intermed	-5/0/5	Low	90/100/120	Low	0/0/20	Zero	0/0/0	(0.1-0.4)/(0.1-0.4)/1.1	+ (FS)
+34	ALIGNMENT AND LEVELLII	Low	-2/0/2	Low	90/100/120	Low	0/0/20	Zero	0/0/0	(0.1-0.4)/(0.1-0.4)/1.1	+ (FS) + (FS)

Figure 73: Risk Levels; Vico Schedule Planner

Hierarchy	Name	Start (Shifts)			Duration (As a percentage)			Dependencies
		Soonest	Expected	At latest	At least	Expected	At most	
-1	EXCAVATION							
+1.1	EXCAVATION	-2	0	2	100	100	100	
-2	COMPACTION							- (FS)
+2.1	COMPACTION	-2	0	2	100	100	100	
-3	HARDCORE							(FS)
+3.1	HARDCORE	-2	0	2	100	100	100	
-4	ISOLATION							(FS)
+4.1	ISOLATION	-2	0	2	100	100	100	
-5	PLAIN CONCRETE							(FS)
+5.1	PLAIN CONCRETE	-15	0	15	100	100	100	
-6	LEVELLING BASE PLATES AND ANCHOR BOLTS							(FS)
+6.1	LEVELLING BASE PLATES AND ANCHOR BOLTS	-2	0	2	100	100	100	
-7	REINFORCEMENT FOR FOUNDATION							(FS)
+7.1	REINFORCEMENT FOR FOUNDATION	-5	0	5	90	100	120	
-8	FORMWORK FOUNDATION							(FS)
+8.1	FORMWORK FOUNDATION	-5	0	5	90	100	120	
-9	POURING FOUND. CONC							(FS)
+9.1	POURING FOUND. CONC	-15	0	15	90	100	120	
-10	CURING FOUNDATION							(FS)
+10.1	CURING FOUNDATION	0	0	0	100	100	100	
-11	ERECTION OF MAIN COLUMNS							(FS) (FS) (FS)
+11.1	ERECTION OF MAIN COLUMNS	-5	0	5	90	100	120	
-12	ERECTION OF REMAINING COLUMNS							(FS) (FS) (FS)
+12.1	ERECTION OF REMAINING COLUMNS	-5	0	5	90	100	120	
-13	ALINGMNET AND LEVEELING WITH BOLTS							(FS) (FS) (FS)
+13.1	ALINGMNET AND LEVEELING WITH BOLTS	-2	0	2	90	100	120	
-14	CONNECTION OF BRACING TO JOINTS							(FS) (FS)
+14.1	CONNECTION OF BRACING TO JOINTS	-5	0	5	90	100	120	
-15	STAIRS							(FS) (FS)
+15.1	STAIRS	-2	0	2	90	100	120	
-16	TIGHTEN BOLTS AND WELDING JOINTS							(FS) (FS)
+16.1	TIGHTEN BOLTS AND WELDING JOINTS	-2	0	2	90	100	120	
-17	STEEL DECKING							(FS) (FS)
+17.1	STEEL DECKING	-5	0	5	90	100	120	
-18	WELDING SHEAR STUDS							(FS) (FS)
+18.1	WELDING SHEAR STUDS	-2	0	2	90	100	120	
-19	POURING CONCRETE							(FS) (FS)
+19.1	POURING CONCRETE	-15	0	15	100	100	100	
-20	CURING							(FS)
+20.1	CURING	0	0	0	100	100	100	
-21	REINFORCEMENT FOR RETAINING WALLS							(FS) (FS) (FS) (FS) (FS)
+21.1	REINFORCEMENT FOR RETAINING WALLS	-5	0	5	90	100	120	
-22	RW FORMWORK							(FS)
-22.1	RW FORMWORK	-5	0	5	90	100	120	
22.1.1	BASEMENT->SP				90	100	120	
22.1.2	BASEMENT->FOUN				90	100	120	
-23	RW CONCRETE							(FS) (FS)
+23.1	RW CONCRETE	-15	0	15	100	100	100	
-24	RW CURING							(FS)
+24.1	RW CURING	0	0	0	100	100	100	
-25	EXTERNAL BRICK							(FS) (FS)
+25.1	EXTERNAL BRICK	-2	0	2	90	100	120	
-26	INTEROR BLOCK							(FS) (FS)
+26.1	INTEROR BLOCK	-2	0	2	90	100	120	
-27	INTERNAL PLASTERING							(FS) (FS) (FS)
+27.1	INTERNAL PLASTERING	-2	0	2	90	100	120	
-28	EXTERNAL PLASTERING							(FS) (FS)
+28.1	EXTERNAL PLASTERING	-2	0	2	90	100	120	
-29	EXTERNAL PAINT							(FS) (FS)
+29.1	EXTERNAL PAINT	-2	0	2	90	100	120	
-30	INTERNAL PAINT							(FS) (FS) (FS)
+30.1	INTERNAL PAINT	-2	0	2	90	100	120	
-31	WOOD WORKS							(FS) (FS)
+31.1	WOOD WORKS	-2	0	2	90	100	120	
-32	TILING							(FS) (FS) (FS)
+32.1	TILING	-2	0	2	90	100	120	
-33	BEAM ERECTION							(FS)
+33.1	BEAM ERECTION	-5	0	5	90	100	120	
-34	ALIGNMENT AND LEVELLING							(FS) (FS)
+34.1	ALIGNMENT AND LEVELLING	-2	0	2	90	100	120	

Figure 74: Schedule Task Risk; Vico Schedule Planner

Appendix B1

Figure 75: Type of Organization Question; Thesis Tools

Figure 76: Primary Industry Question; Thesis Tools

Figure 77: Type of Scheduling Used In Small Project; Thesis Tools

Figure 78: Type of Scheduling Used In Medium Sized Projects; Thesis Tools

Figure 79: Type of Scheduling Used In Big Sized Projects; Thesis Tools

Figure 80: Risk Level Question; Thesis Tools

Figure 81: Line Of Balance Question; Thesis Tools

Figure 82: Usage of Line Of Balance; Thesis Tools

9.

What are the benefits obtained from using Line of balance? (Check all that apply)

☐ Improved scheduling
☐ Improved estimating/bidding
☐ Increase control over risk and uncertainty
☐ Faster response to problems
☐ Improve planning before work starts
☐ Improved project control and forecasting after project start
☐ Balance between different activities achieved to reach objective duration
☐ Resource balance
☐ Work continuity for effective performance
☐ Easy understanding of the graphic schedule
☐ Other (please Specify) [   ]

Figure 83: Benefits of Line Of Balance Question; Thesis Tools

10.

Why you do not use Line of Balance on Construction scheduling? (Check all that apply)

☐ It is not widely used
☐ It is a complicated scheduling tool
☐ Unavailability of software
☐ Does not give any beneficial results
☐ It is used only for repetitive action and mega projects
☐ It does not have CPM or lack dependency
☐ Hard to read or manipulate the scheduling graphs
☐ Lack of risk and uncertainty
☐ Limited capability in improving production
☐ Hard calculation of time
☐ Cost more money
☐ Delay in time
☐ other (please specify) [   ]

Figure 84: Non-Usage of Line Balance Question; Thesis Tools

11.

Which other scheduling techniques do you mostly prefer on your work?

○ Bar charts
○ CPM
○ 4D planning
○ Other (Please specify) [   ]

Figure 85: Other Scheduling Tools Preferring Question; Thesis Tools

12.

What are the benefits obtained from using Bar charts or CPM than other scheduling tools? (Check all that apply)

☐ Improved scheduling
☐ Improved estimating/bidding
☐ Reduce delays
☐ Time savings
☐ Increase control of risk and uncertainty
☐ Faster response to problems
☐ Cost savings
☐ Improved understanding of the project
☐ Improved planning before work starts
☐ Improved project control after work starts
☐ Crucial to keep project in critical path
☐ Other (please specify)

Figure 86: Benefits Obtained From Using CPM/Barcharts Question; Thesis Tools

13.

What computer software do you mostly specify or use on scheduling of construction projects?*

○ Ms Project
○ Primavera
○ Vico control
○ Suretrak
○ Artemis
○ Other (please specify) [   ]

Figure 87: Computer Software Question; Thesis Tools

14.

Why do you prefer using Primavera software on you scheduling projects? (Check all that apply)

☐ Easy of usage
☐ Widely used
☐ It schedules combined Bar chart and CPM
☐ It is forced by contractor to use
☐ It has more feature than other softwares
☐ Other (Please Specify) [   ]

Figure 88: Primavera Software Question; Thesis Tools

15.

Why do you prefer using MS project software on you scheduling projects? (Check all that apply)

☐ It is easy of usage
☐ It is widely used
☐ It schedules combined Bar chart and CPM
☐ It is forced by contractor to use
☐ It has more feature than other softwares
☐ Other (Please Specify) [   ]

Figure 89: MS Project software question; Thesis tools

Thank you so much for the taking the time out of your busy schedule to help with this thesis.
If you would like to learn the results of my research, please leave your email. while submitting your answer.

www.thesistools.com

Figure 90: Thank you message; Thesis tools

Appendix C1

Table 7: Discontinuous Flow Project Report; Vico Schedule Planner

Project report			

Project name		Responsible person	
THESIS STUDY 1		JURY	

Date	5/21/2013		
Start	10/1/2013		
End	2/18/2014	BoQ Method Costs	251914.6
		User Entered Crew Costs	101843.9
		Schedule Cost	353758.5

Number of tasks			
34		Schedule Cost	353758.5
		Free costs	0
Man hours in project		Total costs	353758.5
4978.7			

Schedule cost / man hours	50.6

Table 8: Discontinuous with Buffer Project Report; Vico Schedule Planner

Project report			

Project name		Responsible person	
THESIS STUDY 1		JURY	

Date	5/21/2013		
Start	10/1/2013		
End	3/28/2014	BoQ Method Costs	251914.6
		User Entered Crew Costs	104517.4
		Schedule Cost	356432

Number of tasks			
34		Schedule Cost	356432
		Free costs	0
Man hours in project		Total costs	356432
5053			

Schedule cost / man hours	49.9

Appendix C2

Table 9: Continuous Flow Project Report; Vico Schedule Planner

Project report

Project name		Responsible person	
THESIS STUDY 1		JURY	

Date	5/21/2013

Start	10/1/2013
End	5/7/2014

BoQ Method Costs	251914.6
User Entered Crew Costs	102570.2
Schedule Cost	354484.8

Number of tasks	
34	

Schedule Cost	354484.8
Free costs	0
Total costs	354484.8

Man hours in project	
5002.9	

Schedule cost / man hours	50.4
Schedule cost / forecasted man hours	0

Table 10: Continuous flow with buffer project report; Vico schedule planner

Project report

Project name		Responsible person	
THESIS STUDY 1		JURY	

Date	5/21/2013

Start	10/1/2013
End	5/7/2014

BoQ Method Costs	251914.6
User Entered Crew Costs	102570.2
Schedule Cost	354484.8

Number of tasks	
34	

Schedule Cost	354484.8
Free costs	0
Total costs	354484.8

Man hours in project	
5002.9	

Schedule cost / man hours	50.4
Schedule cost / forecasted man hours	0

Table 11: Continuous flow with optimization project report; Vico schedule planner

Project report				

Project name		Responsible person		
THESIS STUDY 1		JURY		

Date	5/21/2013			

Start	10/1/2013			
End	4/17/2014	BoQ Method Costs	251914.6
		User Entered Crew Costs	102570.2
Number of tasks		Schedule Cost	354484.9
34			
		Schedule Cost	354484.9
Man hours in project		Free costs	0
5002.9		Total costs	354484.9

Schedule cost / man hours	50.4		
Schedule cost / forecasted man hours	0		