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. Bar charts and 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 has been evolved which uses Location Based Scheduling (LBS) in the form of flow line scheduling, which is a combination of CPM and Linear Scheduling Method (LSM) which can be used for planning and scheduling of small, medium and big projects. This study uses 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, were 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/Bar chart scheduling method.

Keywords: *Time Management, Line of Balance, Location Based Scheduling, Linear Scheduling Method.*

Introductıon

In recent years, most of the construction industry focused on the use of CPM/Bar chart to schedule and plan construction projects, and the usage of LSM or LOB mainly focused on the linear or repetitive process construction. However, it has not gained popularity because of the commercial use of software programs for CPM/Bar charts, and it was believed that LOB or LSM 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 CPM does, rather than focusing on the productivity and resource constraints that LSM or LOB does.

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 CPM and linear scheduling, and shows the activities in a flow line graph.

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In Finland in late 1980's, a group of researchers started to modify the LBS 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 [1].

The main scope of this study is to use the Location Based Scheduling in the scheduling of small, non-repetitive, and nonlinear construction project, and to compare the results with the traditional use of CPM/Bar charts. A 3 floor steel structure villa with a swimming pool was used as a case study in this research.

The other objective is to conduct a questionnaire survey on the use of both LBS and CPM/Bar charts and to discuss the results of the respondents.

LITERATURE REVIEW

Many authors have discussed theory of Line of Balance and 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 [2];

- 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 [3].

Bar Chart (Gantt Chart) was introduced originally by Henry L. Gantt in 1917 [3]. 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 [3,4]. A bar chart represents time scaled activities in a horizontal bar graphic way of tasks, these tasks represent project information activities. Bar charts are simple, universal, understandable, and easy to be produced [5]. 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 [3]. Bar charts' most disadvantageous characteristic is the lack of linkage representations of longest path and float calculation, which CPM has [4]. 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 [5].

Network diagrams can be defined as the linkage or logical representation of activities; it could be arrow or node diagrams. The arrow diagrams were popular between 1960s and 1970s, then after this time of era the node diagrams became choice for network diagrams [3]. One of the most commonly used network diagrams is the Critical Path Method (CPM) [4,6,7,8,9]. Planners in construction normally use both CPM and bar charts to schedule their projects [10], and they are used widely in construction industry [6,10,11,12,13,14]. 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 [4]. 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 [3]. 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) [5,6,8,15,14], because of different production rate, and there is no indication of production rate in CPM [5], and do not show interrelationships between activities for high rise buildings [8].

Line of Balance (LOB) was originated in 1940's by the Good year company [7]. 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 [7,16]. Later it was developed in UK for repetitive housing projects by National building agency [16].

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 [4,6,7], 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 [6].

Line of Balance (LOB) is a deviation of Linear Scheduling Method (LSM) [4,5,7,17,18,19], same as other LSM scheduling like Vertical Production Method (VPM), Time Versus Distance, and others [4,7,19]. 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 [20]. The main advantage of LOB is that it calculates productivity along with time in an easy graphical representation [7]. 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 [5]. LOB has the ability to balance activity operations in a way that each activity is being continuously achieved in different location though project [9]. For repetitive construction process projects, LOB can lead a crucial important schedule and planning by reducing time, cost overruns, and clashes [15]. Seppänen & Aalto [1] 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 [14] 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.

Beside its advantageous features, LOB development is quite slow and its acceptance through construction industry is low [6]. The most disadvantageous principle that LOB or

LSM has is the lack of critical path [6,11]. The critical path determines the smallest duration of the project, and determines which activity will lengthen the project time if they are delayed [6]. 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 [5]. 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 [5,18]. Mendes, Fernando & Heineck [14] and Lutz & Hijazi [7] 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 [1] and Lutz & Hijazi [7] 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.

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 [21]. 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 [21].

The objective of this study 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.

Methodology Of Lbs Wıth A Case Study

This section presents the basic theory and method of planning and scheduling by Location Based Scheduling, and its comparison to CPM/bar chart. 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/Bar chart and LBS.

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 introduces 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 "flowline" diagram, which is LBS method graph. In flowline 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".

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 (Figure 1).

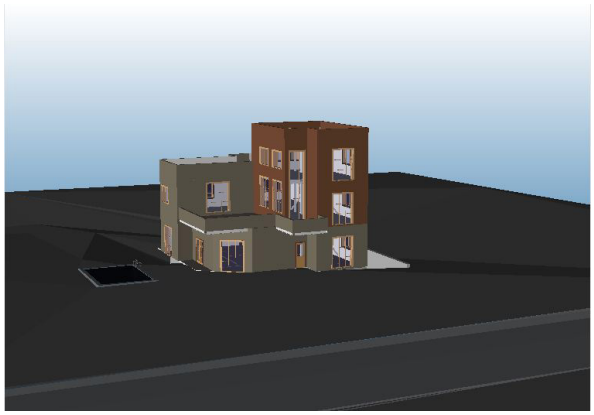

Figure 1: *3D CAD BIM model of a 3 floor steel structure villa [22]*

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.

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. 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). Figure 2 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.

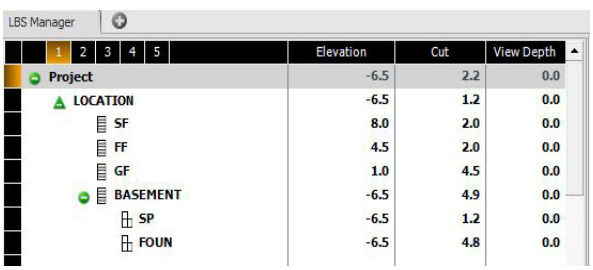

Figure 2: *Hierarchical location of 3 floor villa using Vico LBS manger software.*

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. 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.

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.

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 3).

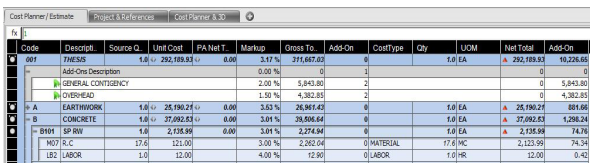

Figure 3: *Concrete component with subcomponent SP RW; Vico cost planner*

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

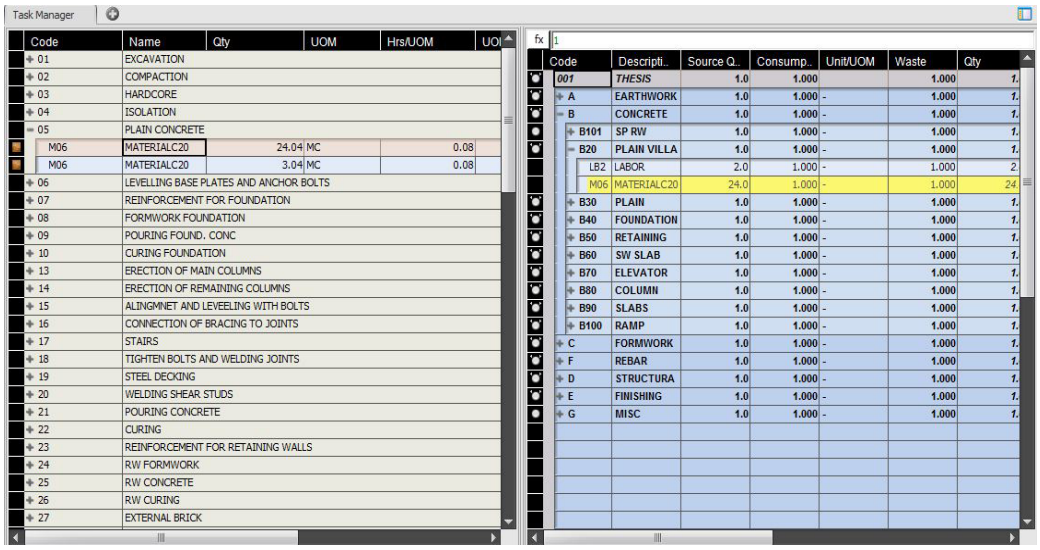

Figure 4: *Managing tasks with consumption rate; Vico task manager*

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 4).

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 [21].

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

$$\text{Crew hour}=\frac{\text{Manhour}}{\text{crew size}} \quad \text{Eq.2}$$

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 man hour/MS, to find man hour 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). 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 [23] in the analysis of construction labors in Turkey.

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. 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). In the case study, FS logic activities are assigned to all tasks, because the succeeding task cannot start until the predecessor task finishes.

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 [24].

Scheduling Visualization

Since the study objective is to perform a comparison between LBS and CPM/Bar charts, 4 types of scheduling have been prepared. One of them is the traditional CPM/Bar charts schedule and the other two are Continuous LBS and Discontinuous LBS. the discontinuous LBS schedule has been transferred from traditional CPM/Bar charts 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/Bar charts.

LBS shows the scheduling visualization through flow line concept, which is a graphical representation that shows the work and movement of resources through locations [21].

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 5).

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 [25].

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.

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

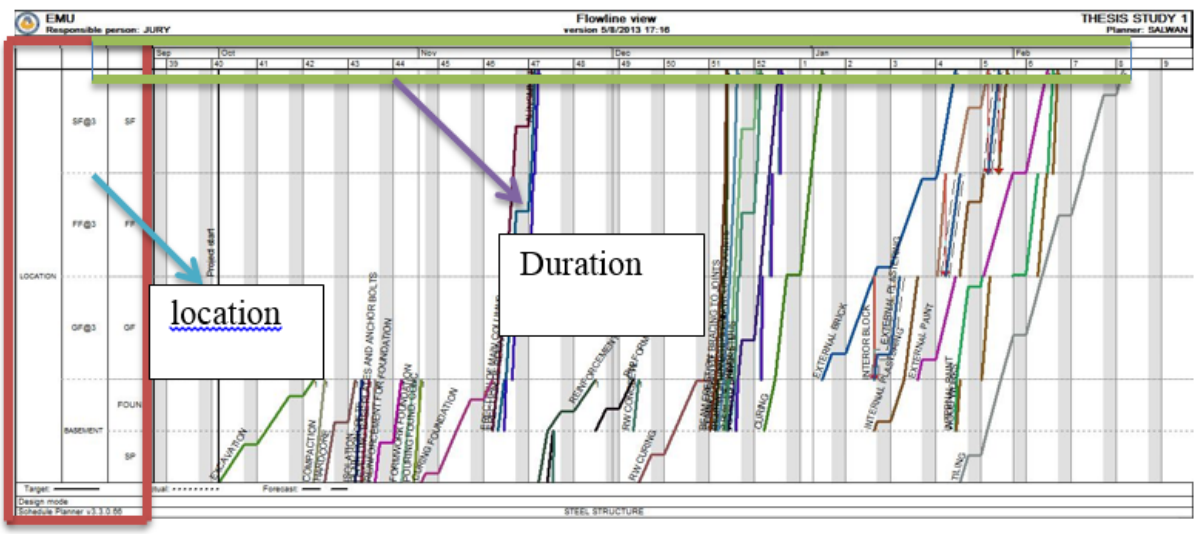

Figure 5: *Flow line View; Vico schedule planner*

The continuous production defines the work of a task continuously from location to location [21].

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:

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 levels were 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 were 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.

After risks have been defined, a Monte Carlo risk simulation was 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 was done to both continuous flow and discontinuous flow, with the same risk levels defined in both type of production flow.

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 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. 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.

Results and Dıscussıons

The comparison is huge between the two scheduling plans. The two scheduling plans CPM/Bar charts and LBS can be compared in two categories; one as a general and another one as results. Table 1 shows the general comparison between CPM/Bar charts and LBS:

Table 1: *General summary*

General characteristics	CPM/Bar charts	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/Bar charts 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/Bar charts 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/Bar charts can only be done by changing the duration, or logics in CPM.	Optimization can be done by changing productivity of resources without increasing risk.

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/Bar charts discontinuous and continuous flow.

As a summary from Table 2, the cost of the project using both scheduling tools LBS and CPM/Bar charts has a small difference about 726TL. For the duration of the project, CPM/Bar charts 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

Table 2: *Results summary*

Results	CPM/Bar charts	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

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/Bar charts .

Conclusıon

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/ Bar charts 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/ Bar charts 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/Bar charts do to those projects which do not have a continuous, linear, or repetitive process of activities.

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.

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