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Assessment of CPM and LoB Scheduling Method in Real-Time Construction Projects

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ABSTRACT: In construction management, scheduling is a process where resources such as men, material, money, and machinery are planned to fit for a timely scale. Critical path method has limitations when used in construction projects i.e. when the number of activity increases, there is difficulty in the management of project network. To surpass the constraint, other scheduling methods like LoB for repetitive projects, are applied and checked for obtaining preferable results. Numerous authors have specialized their research-work on LoB, CPM; but none have compared merits of LoB and CPM with real time projects. This research deals with two real time construction projects, railway track laying and residential building, where scheduling with LoB and CPM is implemented to compare and obtain results. The practical merits of both scheduling methods are discussed. Resource leveling problem is solved with both scheduling method to identify the better scheduling method. A genetic algorithm based optimization is used to perform resource leveling.

KEYWORDS: Line of Balance (LoB); Critical path method (CPM); Repetitive construction; Resource leveling; Project Scheduling.

I. INTRODUCTION

Civil engineering is one of the oldest disciplines and an important aspect since the beginning of human existence. In construction project management, scheduling plays a major role in monitoring, utilizing and allocating the timely usage of resources required for a construction. It is usually with intended start and finish dates for a whole project. CPM is a scheduling technique used in project management for impeding time-frame problems and processing snags in critical and non-critical tasks. It is preferably used for projects that comprise of several activities interrelating in abstruse manner with minor repetitions. CPM provides the criticality, start, and finish date of the activities in a construction project.

Initially, usage of CPM for repetitive projects turned out to be very difficult and cluttered to furnish the necessary project information [5]. Numerous methods were formulated ever since the development of repetitive projects in 1970, like the productive control of resources in repetitive projects by using two scheduling tools namely, LoB and LSM [1]. Typical projects containing repetitive work activities like roadways, pipelines, a management process called Line of Balance controls railway, high-rise buildings and tunnels. It gathers, evaluates and bestows information associated with the time, cost and completion and suggests it against a specific plan. The rate of production of a project is shown easily through a graphical representation. The traditional CPM does not complement CPM scheduling for repetitive projects; hence, the benefits of CPM and LoB are combined. This model can be, effortlessly understood by non-graphical manner [6][13]. Production line diagram, a graphical format developed to present the rate of production and total project duration easily, is a major advantage of LoB [7][4]. It determines the number of men per gang required for each activity along with their arrangement in repetitive projects. LoB cannot be performed without the estimated worker hours for a section or a typical unit, their optimum crew size and daily working hours [3]. When working in a repetitive scheduling method (LoB), a single crew spends some duration on one unit before moving to the next similar one, where as in CPM the precedence relationship is used between activities throughout the project, but in both the scheduling cases the activity duration is assumed to be constant [2][8]. GA bestows diverse alternatives to its stakeholders and decision makers to make changes in resources. Cost control and simplified resource requirements is the concerned goal of resource levelling [11] [14]. GA offers eccentric alternative results that give stakeholders and planners flexibility in project planning, apart from tackling large search space of a complex problem [12][15]. Activities that should be slowed to conclude resource over allocations under time and

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cost restraints are attempted to be identified. A near optimal solution can be achieved by running this process numerous times [9] [10].

The principle focus of this research is to describe the process of scheduling horizontal and vertical repetitive construction projects through CPM and LoB. To support this study, two real time construction projects are taken into consideration, railway track laying and residential building (G+2). They are scheduled and their results are obtained. Further, it is compared and subjected to optimization of labour productivity which is done through resource levelling using a genetic algorithm (GA) for both the construction projects.

II. Methodology

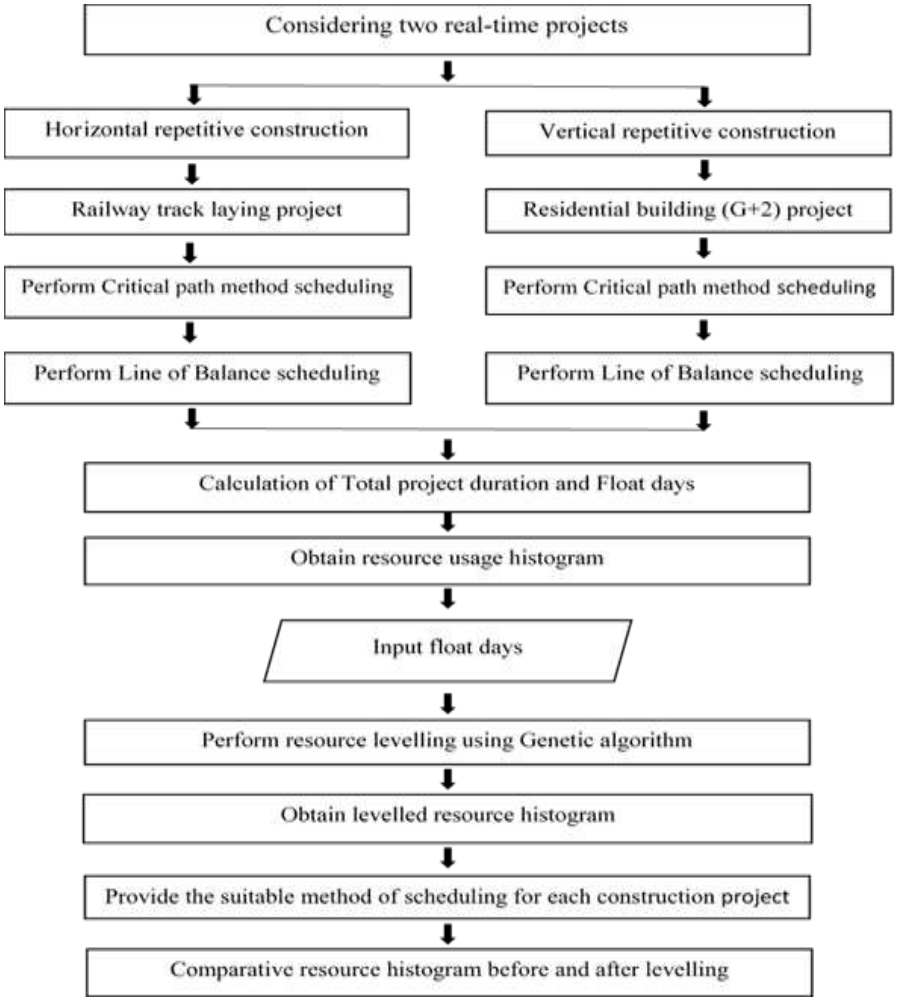

Figure 1. Project methodology

The work is done as per the *Figure 1*. A Network of activities with the precedence relationship of finish-start is considered for both the scheduling method LoB and CPM. Manpower is considered as a resource in terms of several men per gang. Generally, construction activities occur in repetitive form. Since the sequence of activities occurs in linear repetitive structures to improve the computational speed LoB concept is considered. LoB data is used to acquire resource usage from which resource profile is generated; Microsoft Project helps to obtain the float values for all the activities. Using float values of non-critical activity, the levelled resource profile is generated using a Genetic algorithm (GA). In GA, the optimum resource profile is obtained by performing selection, crossover, and mutation with the initial resource profile. MATLAB is considered to perform GA. The resource profile obtained using LoB and the levelled resource profile obtained after the application of GA are further discussed.

III. Results and Discussion

The *Table 1* and*Table 2* gives us the calculation of output rate for both the construction projects using LoB method schedule for repetitive construction project. The LoB calculation is achieved by using the available data

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such as the total number of sections, target unit per week, working hours per day, No. of working days in a week, top and bottom buffer, and the start and finish duration of an activity. This tabulation along with the production line diagram is derived in MS Excel using simple mathematical calculations. The advantage of using MS Excel is that when the number of activities are more, it is easier and simpler to make changes whereas in MS Project it will be difficult with the generation of a lot of network diagrams. Hence the production line diagram and the tabulation for railway track laying and the residential project is obtained using the simple mathematical template in MS Excel. Then the float values from MSP is used to carryout resource levelling and obtain a histogram for both the construction project.

Activity	Man hours per unit	Men per gang	Theoretical gang size at chosen output (G)	Actual gang size (Ga)	Actual output rate (Ra)
Excavation	1440	36	36.00	36	1.00
Pier erection	5880	49	147.00	147	1.00
Pier cap	6944	31	173.60	186	1.07
Trestle beam	4840	55	121.00	110	0.91
Girder (cast in-situ)	7480	55	187.00	165	0.88
Girder transfer	5760	60	144.00	120	0.83

Table 1. LoB Calculation of theOutput Rate for Railway Track Laying

Table 2. LoB Calculation of theOutput Rate for Residential Building

Activity	Man hours per unit	Men per gang	Theoretical gang size at chosen output (G)	Actual gang size (Ga)	Actual output rate (Ra)
Column lifting	2880	24	14.1	24	5.00
Roofing	7400	37	37	37	3.00
Brick work	720	9	3.60	9	7.50
Carpentry	384	8	1.92	8	12.50
Plumbing	384	4	1.92	4	6.25
Plastering	360	9	1.8	9	15.00
Electrical work	192	6	0.96	6	18.75
Flooring	240	6	1.2	6	15.00
Painting	168	7	0.84	7	25.00

Using the data from *Table 1* and *Table 2*, further LoB calculation is done as shown in *Table 3* and *Table*4; it gives us the required duration for each activity, which is calculated, from its first section to n^{th} section. In this case it is 10 sections for railway track laying and 3 sections for residential building.

Table 3. LoBDuration Calculation for Railway Track Laying

Activity duration for one unit (days)	Time from start of first unit to start of last unit (days)	Min Buffer (days)	Top or bottom buffer	First unit		Last unit	
				Start Date	End Date	Start Date	End Date
5.0	45.00	2		0.00	5.00	45.00	50.00
15.0	45.00	2	0	7.00	22.00	52.00	67.00
28.0	42.00	2	0	27.00	55.00	69.00	97.00
11.0	49.50	2	1	57.00	68.00	117.50	128.50
17.0	51.00	2	1	70.00	87.00	138.00	155.00
12.0	54.00	2	1	89.00	101.00	155.00	167.00

Table 4. LoBDuration Calculation for Residential Building

Activity	Time from start	Min	Top or	First unit	Last unit

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				Start Date	End Date	Start Date	End Date
20.00	2.00	1		0.00	20.00	2.00	22.00
25.00	3.33	1	1	21.00	46.00	49.33	74.33
15.00	1.33	1	0	74.00	89.00	75.33	90.33
21.00	0.80	1	0	90.53	111.53	91.33	112.33
15.00	1.60	1	1	112.53	127.53	129.13	144.13
28.00	0.67	1	0	144.47	172.47	145.13	173.13
39.00	0.53	1	0	173.60	212.60	174.13	213.13
15.00	0.67	1	1	213.60	228.60	229.27	244.27
20.00	0.40	1	0	244.87	264.87	245.27	265.27

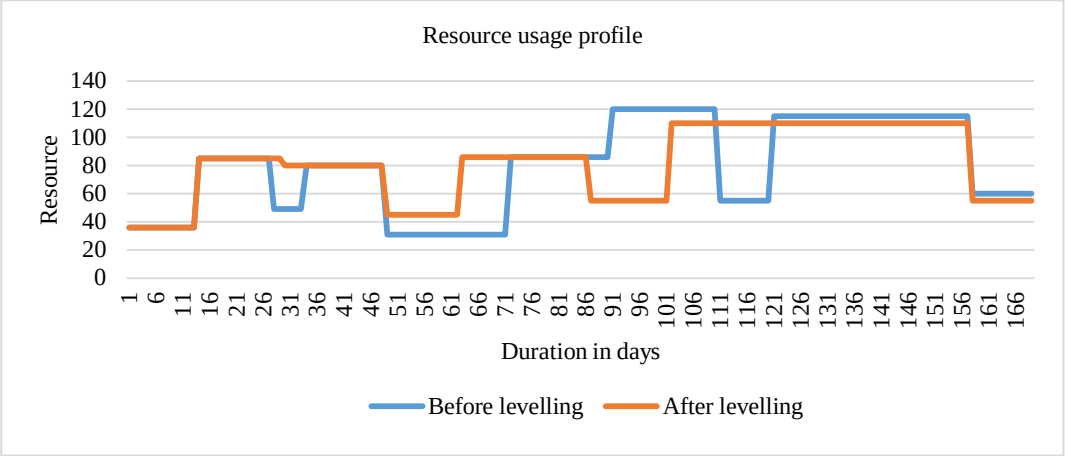

Fig 2. Comparative Resource histogram for Railway track laying

A comparison of the resource profile attained using LoB is performed. LoB helps to improve the computation speed and including the resource leveling concept provides a resource profile with better accuracy. From the *Figure2* and *Figure 3* shows the comparative view of before leveling and after leveling resource profile for both the construction projects

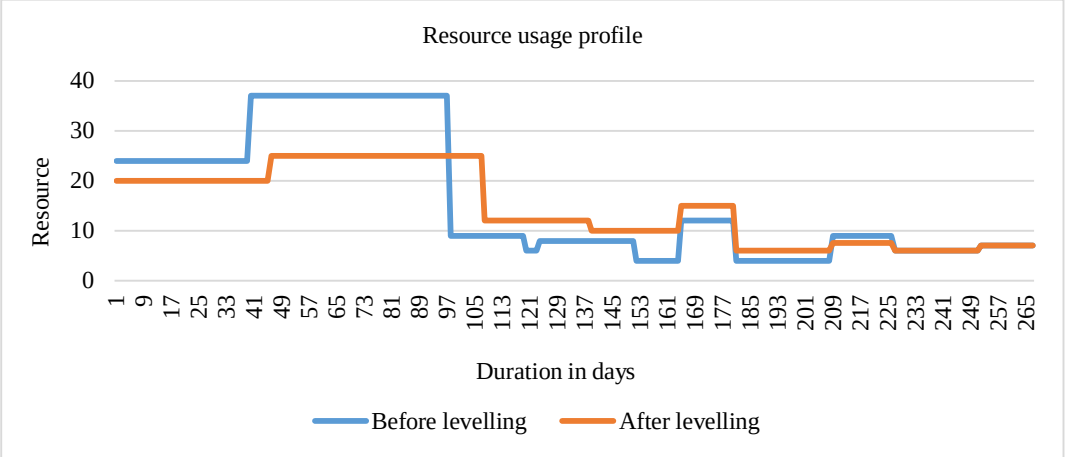

Fig 2. Comparative Resource histogram for Residential Building

The total duration of the network is considered in days. Float values of noncritical activity is considered for leveling resource usage. The non-critical activity float value is considered for an optimum schedule. The peak resource usage for railway track laying and residential building project is 120 and 37, after levelling it is reduced to 108 and 25. This results in resource fluctuation in resource usage is reduced. The major drop in the resource profile for railway track laying and residential building occurs at 92 days and 41 days. After levelling, it is noticed that the resource deviation is reduced and a levelled resource profile is obtained.

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IV. Conclusion

The MS-Excel based mathematical template is made to perform LoB based calculation of scheduling for different LCP's or different construction projects with repetitive nature. Through this research which deals with the scheduling of two real time construction projects, residential building and the railway track laying, it is analyzed that the labour productivity in LoB schedule can be easily studied with the project duration. This can be understood more clearly through LoB than in CPM method of scheduling because the former has a greater impact on efficient resource usage, user-friendly and provides easy understanding.

The merits of LoB include 1) reduction in computation time, 2) ease in the calculation of data, 3) increased accuracy, 4) any error can be easily notified and 5) flexible application based on the purpose. This study can be developed by considering a non-Finish-Start precedence relationship

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