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Planning and Scheduling of Low Income Housing Scheme Project by Line of Balancing Method

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Abstract:- Construction projects comes across various milestones, resulting into delay in execution of project, hence there is need to improve techniques in planning so that project is carried out within stipulated time. The LOBST (Line Of Balance Scheduling Technique) is a scheduling method which makes the operations to be carried out effectively and allows activity can be performed continuously and efficiently in each consecutive unit. Line Of Balance Scheduling Technique is a significant technique that plays important role in repetitive construction project. Lack of awareness of proper method and techniques increases cost and project completion time. It becomes very important to adopt proper methodology while doing the housing project for low income group. This paper aims to evaluate the real application of line of balance in low income housing scheme. Case study of low-income housing project by MHADA at Talegaon-Dabhade,Pune. Also supports the method developed in the paper. The findings point out significant controlling benefits of LOB is comparing with GANNT CHART Method in the project and addresses limitations showing the efficient use of LOB. VICO CONTROL software is used to schedule the project by line of balance technique. It is observed that this method increases line efficiency and minimizes smoothness index.

Keywords:- *Repetitive Scheduling Method (RSM), Line Of Balance (LOB),Cycle Time(CT),Line Efficiency(LE),Work Station(WS).*

I. INTRODUCTION

Urban housing shortage in India is prominent across the economically weaker sections (EWS) and low-income groups (LIG) which together constitute over 95 percent of the total housing shortage. There is need to provide housing facilities to EWS and LIG section but due to rapid growth in population and inappropriate planning it can be seen that there is huge gap between demand and supply. Delays in construction project results in collapse of management techniques and results in cost overrun. Hence, proper planning and scheduling of construction project is required to meet the demand.

A. Problem statement

Determining delay in execution of project and comparing Line Efficiency and Smoothness Index with actual project duration and planned duration using Line of Balance technique and the flow lines are plotted in VICO CONTROL software.

B. Objectives

- To study and implement the LINE OF BALANCE method. As LOB method is implemented in repetitive scheduling projects. This method is used to plan activities and act as important method in project management.
- Study of VICO CONTROL software and its implementation for scheduling of project. Flow lines are plotted in this software.
- Determining non-utilized zones with help of VICO CONTROL software. The non utilized zones represents that activities are not carried out during that period of time.
- To compare planned activities and its actual implementation with planned line balancing.
- To estimate amount of delay in the project.

C. Scope

Line of Balance method has various advantages over other planning methods. Use of this method allows us to reschedule the project even if it is affected with delays. Implementation of this method can be useful for housing development authority to provide affordable housing schemes without delay to LIG and EWS section.

II. LITERATURE REVIEW

Lim Chuan Pei (2002) This paper aimed at implementing Line Balancing to improve the productivity. A case study conducted at a manufacturing company. Line balancing method is used to determine productivity rate and assembly line balancing is carried out to achieve high productivity rate.

Olli Seppänen and Erno Aalto (2005) This paper represented the importance of the Line of Balance (LOB) scheduling method and showed how this method can be useful to achieve the practice by using location-based production controlling tools. The case study consisted of Business Park with area of 14,500 m^2. Its design includes 2 sections casted, independently of each other and of parking below the main building. And scheduling of activities was

carried out using Line of Balance method.

Caroline P. Valente, Germano A. Montenegro (2014) This paper, through a case study at a Brazilian construction company aims to put forth the guidelines for developing a LOB for common areas. The results shows that the Line Of Balance in provided transparency to employees and engineers for planning. This was achieved even with decreased crew size. The control over project's total term was achieved.

Ms. Harsha Talodhikar, Mrs. Smita V. Pataskar (2015) This paper includes application of applying Line of Balance method to multi storey buildings and draw the graph of repetitive activities, as applying LOB facilitates the continuous monitoring of the project, at each stage. The production rate of activities is determined and cost is compared with actual and delay project. The rate of flow of activities is determined by plotting the graph of activities after crashing and also rate of flow of activities is determined. The number of crew required is also determined.

III. METHODOLOGY

Case study of MHADA (Maharashtra Housing and Area Development Authority) project located at Talegaon Dabhade, Pune, India is considered.Authority planned/scheduled the project by using gannt chart method. Scheduled project is analyzed by finding line efficiency and Smoothness index. Project rescheduled by line of balance method by using VICO control software and flow lines are plotted.

A. Data Collection

The data of the project was collected from the authority which includes a planned Gantt chart. The below figure shows the planned Gantt chart which was proposed by the authority, and its failure of implementation resulted into delay in the construction project work. The planning of total 26 activities was made by using Gantt.

The table represents the start of project on 4th May,2010 and its completion on 12th September,2011.It can be seen that total planned number of days for execution of project is 496 days.

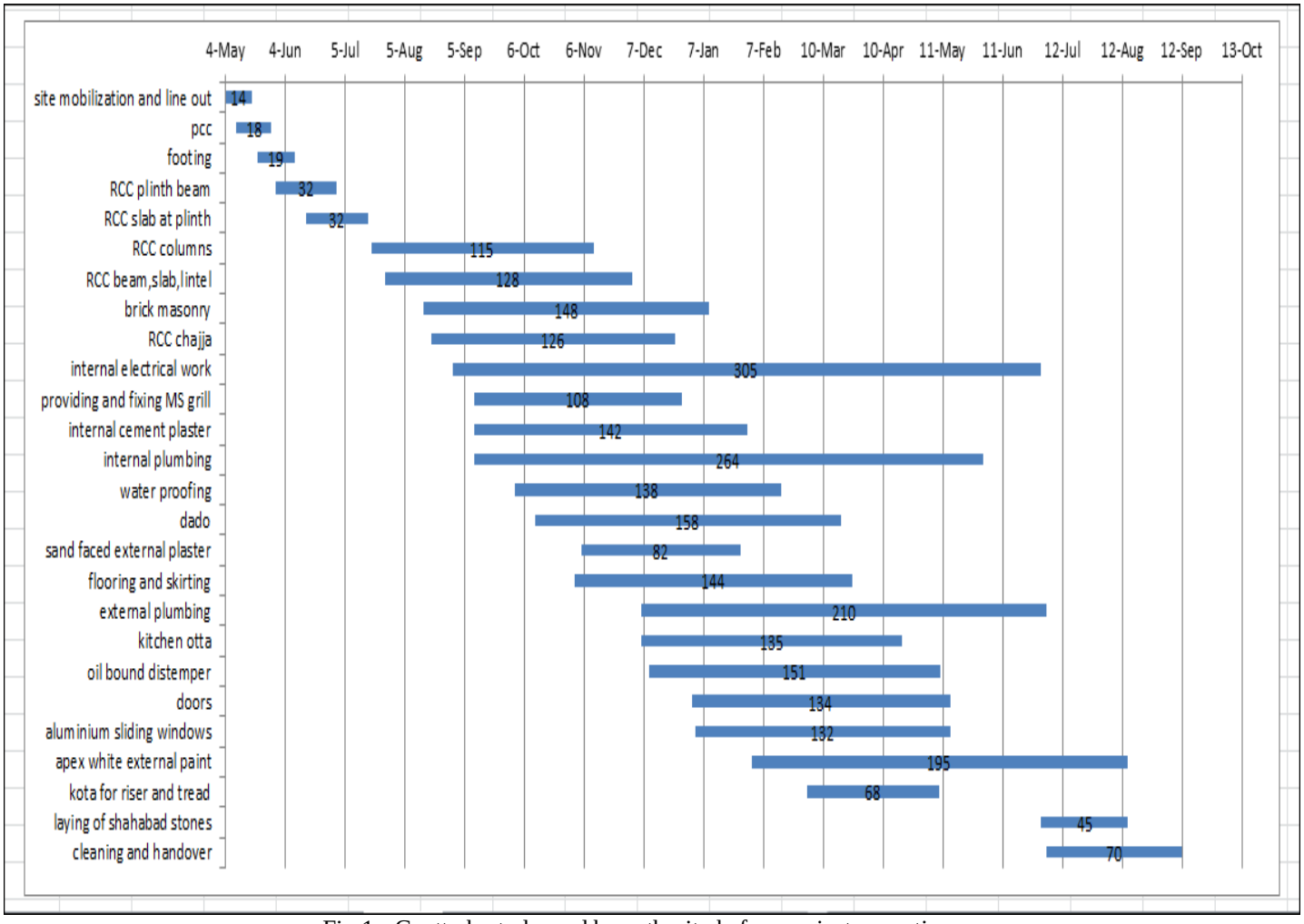

Fig 1:- Gantt-chart planned by authority before project execution

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Activity	Start date	End date	duration in days
site mobilization and line out	04/05/2010	18/05/2010	14
pcc	10/05/2010	28/05/2010	18
footing	21/05/2010	09/06/2010	19
RCC plinth beam	30/05/2010	01/07/2010	32
RCC slab at plinth	15/06/2010	17/07/2010	32
RCC columns	19/07/2010	11/11/2010	115
RCC beam,slab,lintel	26/07/2010	01/12/2010	128
brick masonry	15/08/2010	10/01/2011	148
RCC chajja	19/08/2010	23/12/2010	126
internal electrical work	30/08/2010	01/07/2011	305
providing and fixing MS grill	10/09/2010	27/12/2010	108
internal cement plaster	10/09/2010	30/01/2011	142
internal plumbing	10/09/2010	01/06/2011	264
water proofing	01/10/2010	16/02/2011	138
dado	12/10/2010	19/03/2011	158
sand faced external plaster	05/11/2010	26/01/2011	82
flooring and skirting	01/11/2010	25/03/2011	144
external plumbing	06/12/2010	04/07/2011	210
kitchen otta	06/12/2010	20/04/2011	135
oil bound distemper	10/12/2010	10/05/2011	151
doors	01/01/2011	15/05/2011	134
aluminium sliding windows	03/01/2011	15/05/2011	132
apex white external paint	01/02/2011	15/08/2011	195
kota for riser and tread	02/03/2011	09/05/2011	68
laying of shahabad stones	01/07/2011	15/08/2011	45
cleaning and handover	04/07/2011	12/09/2011	70
PLANNED NUMBER OF DAYS FOR COMPLETION = 496 DAYS			

Table 1:- Planned number of Days for each activity

The above figure shows the planned duration, start date and end date of the activities. From obtained Gantt Chart the following table is prepared and duration of each activities can be easily determined. So, planned duration of project consists of 496 days.

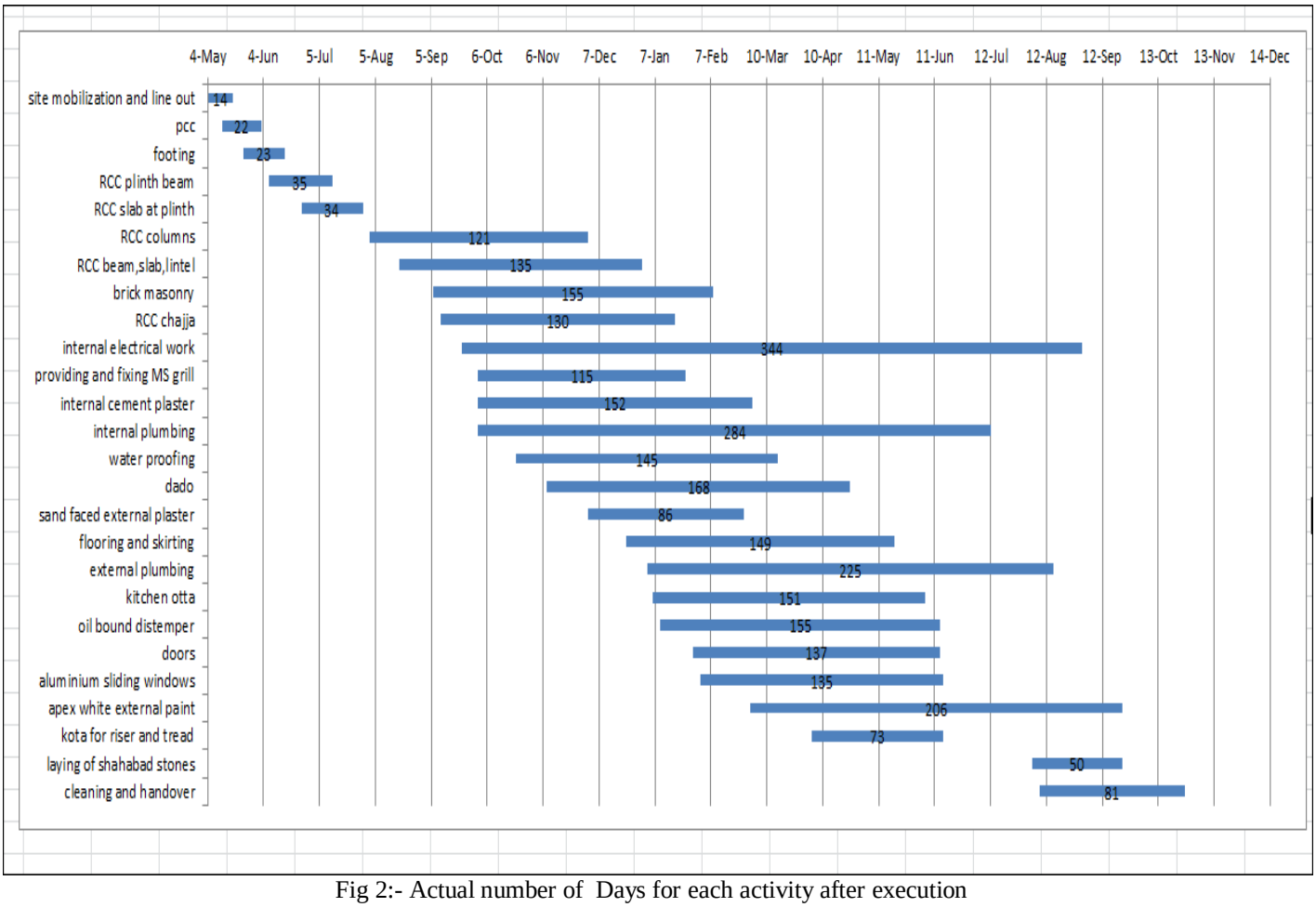

Fig 2:- Actual number of Days for each activity after execution

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The above table obtained from the authority, shows the actual number of days required for the completion of each activity. It can be seen that the project was completed on 28th October,2011 which was scheduled to finish on 12th sepetember,2011.Hence it can be seen that the project required additional 46 days to complete than the planned duration. This shows that there is delay in execution of project.

Activity	Start date	End date	duration in days
site mobilization and line out	04/05/2010	18/05/2010	14
pcc	12/05/2010	03/06/2010	22
footing	24/05/2010	16/06/2010	23
RCC plinth beam	07/06/2010	12/07/2010	35
RCC slab at plinth	25/06/2010	29/07/2010	34
RCC columns	02/08/2010	01/12/2010	121
RCC beam,slab,lintel	18/08/2010	31/12/2010	135
brick masonry	06/09/2010	08/02/2011	155
RCC chajja	10/09/2010	18/01/2011	130
internal electrical work	22/09/2010	01/09/2011	344
providing and fixing MS grill	01/10/2010	24/01/2011	115
internal cement plaster	01/10/2010	02/03/2011	152
internal plumbing	01/10/2010	12/07/2011	284
water proofing	22/10/2010	16/03/2011	145
dado	08/11/2010	25/04/2011	168
sand faced external plaster	01/12/2010	25/02/2011	86
flooring and skirting	22/12/2010	20/05/2011	149
external plumbing	03/01/2011	16/08/2011	225
kitchen otta	06/01/2011	06/06/2011	151
oil bound distemper	10/01/2011	14/06/2011	155
doors	28/01/2011	14/06/2011	137
aluminium sliding windows	01/02/2011	16/06/2011	135
apex white external paint	01/03/2011	23/09/2011	206
kota for riser and tread	04/04/2011	16/06/2011	73
laying of shahabad stones	04/08/2011	23/09/2011	50
cleaning and handover	08/08/2011	28/10/2011	81
ACTUAL NUMBER OF DAYS FOR COMPLETION = 542 DAYS.			

Table 2:- Actual Durations required to complete project

The above figure shows the actual duration required to execute each activity. This indicates that the activities are completed on 28th October,2011 rather than 12th September,2011.

B. Methodology

The following figure shows plotting of flow lines in VICO CONTROL software. This software is used for determining the nature and productivity rates of the activities. When activity is plotted for different floors these flow lines are combined to summary task which gives the nature of the work that has been carried out and also gives productivity rates.

In the figure below depicts the clashing of the activities which means that one activity has higher production rate than the other which implies that the activity with higher production rate has to wait or stand idle until completion of the other activity with lower production rate takes place. This causes delay in construction project work. So basic aim to avoid the crossing of the activities so that none of the activity depends upon other for its completion and does not have to wait idle to decrease the efficiency.

The below figure shows that the Brick Masonry and Chajja these both activities clash each other the productivity rate of chajja is more than the brick masonry work and according to precedence relationship chajja cannot be constructed before the brick masonry work is completed so, here it is necessary to avoid the clashing of the activities. This technique is Line of Balance technique and by this method delay can be avoided. This avoidance of clashing of activities can be done by allotting the buffer.

Another point of clashing takes place between internal plaster, providing and fixing mild steel grill, internal plumbing where the clashing of activities need to be avoided.

Also the area where there are no flow lines which indicates the region where no proper utilization of time has taken place. This areas need to be avoided for increasing the line balancing which is our ultimate goal.

As per the graph drawn using VICO software, construction of “RCC columns” was started on 2 august, 2010. It took 121 days for completion of all units. Then its successor activity is construction of “RCC slab, beams, and lintels”. It means that this activity is purely depends upon first activity for its completion i.e. we cannot construct RCC slab, beams, lintels until the construction of columns have done. Therefore, as shown in the graph, these two activities are not clashing with each other. but the second activity took 135 days for its completion.

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Now, after the construction of beam, slab, lintels have started, the construction of "Brick masonry" can be started as shown in the graph. After this, construction of "RCC chajjas" is the successor activity of the Brick masonry. It means that the RCC chajjas for one unit cannot be constructed until its brick work have done. But from the graph , it is seen that , these two activities are clashing with each other. These is happened because production rate for "RCC chajjas" is greater than that of "Brick masonry" work. Brick masonry is taking 155 days for its completion while that of RCC chajjas are taking only 130 days. Therefore, in planning, we can delay the "RCC chajja " work so that it will finished just after the completion of brick masonry work.

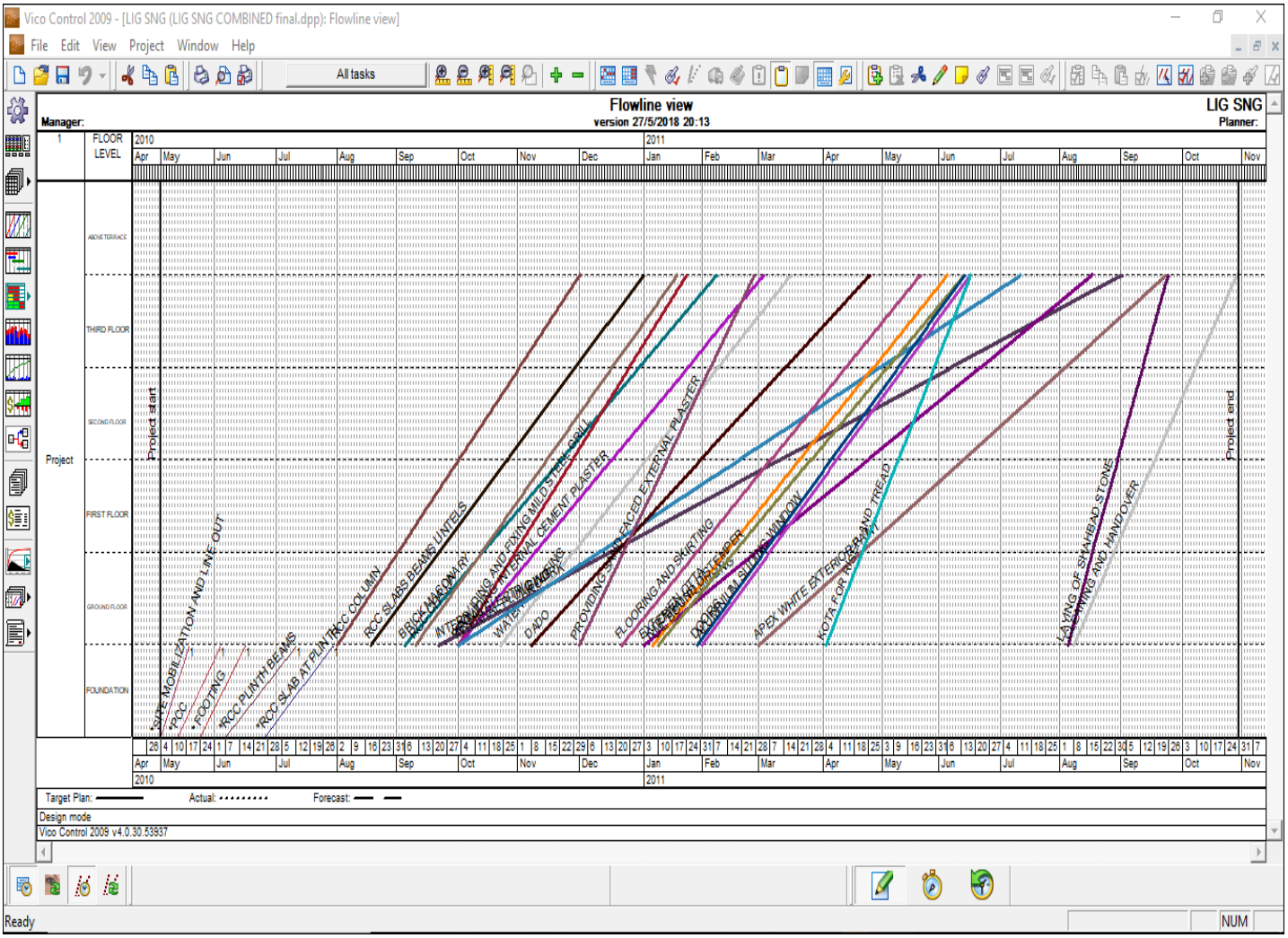

Fig 3:- Flowlines plotted in VICO CONTROL software of actual duration of project

After the RCC chajjas work had been started, work for " providing and fixing MS grills" can be started as per shown in the graph. It is also depends upon the brick masonry work and RCC chajjas work i.e. it cannot be started until the RCC chajjas work for one unit had been done. Here also, as per in the graph, the production rate for "providing and fixing MS grills" is greater .so , it should be adjusted in such a way that it will finish just after the construction of RCC chajjas.

After the "providing and fixing MS grills" work had been started, work for "internal cement plaster" can be started as per shown in the graph. It is also depends upon completion of its previous work. Internal cement plastering work can be finished after MS grills have been provided.

Here ,as shown in the actual schedule, the "Internal plumbing" work is started on the day when internal cement plastering was started. But , the rate of internal plumbing work ,as per the actual schedule, is too slow that it is carrying out even after the internal plastering have been done. It is clashing with so many activities. After that, the water proofing work and dado works are done .As per shown in the graph, these two activities have almost same production rates. but the "dado" work is successor activity of water proofing work. It cannot be completed until the water proofing has done.

The "flooring and skirting" work and work for "kitchen otta" are started after the dado work for one unit has been done. As per in the graph, they both have the same production rates. "Oil bound distemper" can be started applying after the completion of "flooring and skirting" and "kitchen otta " work.

"Fixing doors" and fixing aluminum sliding windows" are the successor activities of the "oil bound distemper" work. These two activities cannot be finished until the oil bound distemper work have been done.

Then, after that, as per the actual schedule, they had started a work of "applying apex white external paint" after the doors and windows fixing. As per the schedule, the "applying sand faced external plaster" and "external plumbing" had already done earlier that had clashed with so many activities. And after completion of external painting," laying of Shahabad stones " had been done. At the end, the "cleaning and handover" work had been done. Overall, actual schedule concludes that it took total "542 days" for completion of project. The project can be managed and planned in such a way that it will take less number of days for its completion. To achieve this, we are going to use a Line of Balancing (LOB) technique for scheduling of activities.

C. Calculation of Line Efficiency on actual duration of project:

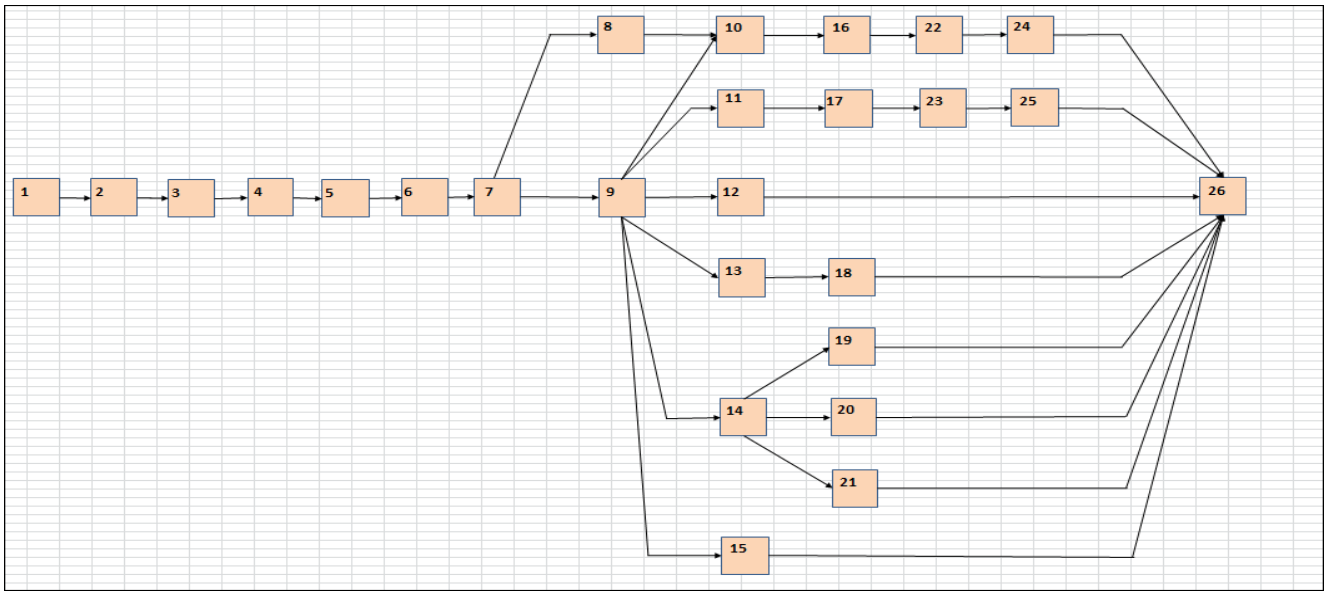

Fig 4:- Precedence relationship between activities

For scheduling of project through line of balance technique it is necessary to know the precedence relationship. The above figure depicts the relationship between the activities based on precedence network diagram. As the relation between the activities is Finish to Finish relationship (FF) relationship i.e. second activity (successor)cannot be finished unless first activity (preceding) does not finish. Like for example, internal cement plaster cannot finish unless and until its successor brick masonry is completed. This is finish to finish relationship between the activities.

The above figure shows various dependency of the activities. The following figure depicts the symbol used for various activities and their dependency with other activity can be determined by the above precedence diagram. For example in the above figure activity with symbol 9 is brick masonry, activity 12 is internal electric work,13 is providing and fixing ms grill,14 is internal cement plaster,15 is internal plumbing now according to the precedence relationship activity 12,13,14 and 15 cannot start until activity 9 (brick work) is completed. This precedence relation shows which activities depends upon the others for their completion. This precedence relationship is required for the scheduling of the project by using line of balance technique.

Based on the precedence network in above figure the activities are symbolized by numeral digits in the following figure the activities with symbols and its duration is shown.

D. Precedence relationship

The figure below shows the summary of the precedence network diagram. Various activities with its preceding activity is summarized from the precedence network diagram.

The precedence relationship is used to solve line balancing problem. In this project Longest Candidate Rule is used to determine line efficiency. For this method it is necessary to know the precedence relationship between the activities. It just simply mean that we should know the logical relationship between the activities.

SR NO	ACTIVITY SYMBOL	ACTIVITY NAME	DURATION IN DAYS
1	1	Site mobilization and line out	14
2	2	PCC	22
3	3	Footing	23
4	4	RCC plinth beam	35
5	5	RCC slab at plinth	34
6	6	RCC columns	121
7	7	RCC beam,slab,lintel	135
8	8	Water proofing	145
9	9	Brick masonry	155
10	10	Flooring and skirting	149
11	11	RCC Chajja	130
12	12	Internal electric work	344
13	13	Providing MS grill	115
14	14	Internal cement plaster	152
15	15	Internal plumbing	284
16	16	Doors	137
17	17	External plaster	86
18	18	Aluminium sliding windows	135
19	19	Oil bound distemper	155
20	20	Dado	168
21	21	Kitchen Otta	151
22	22	kota for riser and tread	73
23	23	External plumbing	225
24	24	Laying of shahabad stones	50
25	25	Apex white external paint	206
26	26	Cleaning and handover	81

Table 3:- Activities with symbols for precedence relation

ACTIVITY	PRECEDENCE	TIME	TIME FOR EACH UNIT
1	_	14	0.378
2	1	22	0.59
3	2	23	0.62
4	3	35	0.94
5	4	34	0.92
6	5	121	3.27
7	6	135	3.64
8	7	145	3.92
9	7	155	4.18
10	8,9	149	4.02
11	9	130	3.51
12	9	344	9.29
13	9	115	3.18
14	9	152	4.1
15	9	284	7.67
16	10	137	3.7
17	11	86	2.32
18	13	135	3.64
19	14	155	4.18
20	14	168	4.54
21	14	151	4.08
22	16	73	1.97
23	17	225	6.08
24	22	50	1.35
25	23	206	5.56
26	12,15,18,19,20,21,24,25	81	2.18
	TOTAL DURATION = 542 DAYS		

Table 4:- Precedence relationship and time required for each unit

The above figure shows that total time duration is 542 days for 37 units. **For 1 unit total task time accounts for 89.82 days.** The total task time for each unit is calculated by dividing the total duration of each activity by number of units (37) and adding the duration required for each activity for 1 unit. This total accounts for 89.82 which is sum of task times for per unit production. It is essential to calculate the minimum number of work stations required for the production.

E. Determination of Cycle Time:

$$\text{Cycle Time (CT)} = \frac{\text{Total time available}}{\text{Desired output}}$$

$$= \frac{542}{37}$$

$$= 14.64 \text{ days}$$

F. Determination of Minimum Number of Work Stations:

$$\text{Minimum number of Work Stations} = \frac{\text{(Total task time for unit production)}}{\text{(Cycle Time)}}$$

$$= \frac{89.82}{14.64}$$

$$= 6.13$$

$$= 7 \text{ stations (number of stations to be rounded off)}$$

Minimum number of work stations =7

G. Longest Candidate Rule:

Procedure:

Step 1. List all elements in descending order of Te value, largest Te at the top of the list.

Step 2. To assign elements to the first workstation, start at the top of the list and work done, selecting the first feasible element for placement at the station. A feasible element is one that satisfies the precedence requirements and does not cause the sum of the Tej value at station to exceed the cycle time Tc.

Step 3. Repeat step 2.

WORK STATION	ACTIVITIES ELIGIBLE	ACTIVITIES ASSIGNED	TASK TIME	CUMULATIVE TIME	IDLE TIME
1	1	1	0.378	0.378	14.262
	2	2	0.59	0.968	13.672
	3	3	0.62	1.58	13.06
	4	4	0.94	2.52	12.12
	5	5	0.92	3.44	11.2
	6	6	3.27	6.72	7.92
	7,8	8	3.92	10.64	4
	7	7	3.64	14.3	0.34
2	9	9	4.18	4.18	10.46
	10,11,12,13,14,15	12	9.29	13.47	1.17
3	10,11,13,14,15	15	7.67	7.67	6.97
	10,11,13,14	14	4.1	11.77	2.87
4	10,11,13,19,20,21	20	4.54	4.54	10.1
	10,11,13,19,21	19	4.18	8.72	5.92
	10,11,13,21	21	4.08	12.8	1.84
5	10,11,13	10	4.02	4.02	10.62
	11,13,16	16	3.7	7.72	6.92
	11,13,22	11	3.51	11.23	3.41
	13,17,22	13	3.18	14.4	0.24
6	17,18,22	18	3.64	3.64	11
	17,22	17	2.32	5.96	8.68
	22,23	23	6.08	12.04	2.6
7	22,25	25	5.56	5.56	9.08
	22	22	1.97	7.53	7.11
	24	24	1.35	8.88	5.76
	26	26	2.18	11.06	3.58

Table 5:- Calculation using Largest candidate rule for actual duration of project

The above figure shows the use of longest candidate rule which is based on the precedence diagram.The idle time is calculated from the formula given below:

Idle time (total unproductive time for all stations)
$= \{ nc - \Sigma t \}$ [min] where,n = number of stations

H. Determination of Line Efficiency:

$$\text{Line Efficiency} = \frac{\text{sum of task times for each unit}}{\text{Number of workstations x cycle time}} \times 100$$

$$= \frac{89.820}{7 \times 14.64} \times 100$$

$$= 87.26\ \%$$

Thus, line efficiency is 87.26%

Larger the Line Efficiency value, more efficient the line.

I. Calculation of Smoothness Index :

Smoothness Index = SI = $\{(S_{max} - S_j)^2\}^{0.5}$ Where, S_{max} = Cycle Time
S_j = Cumulative Time at ecah station

= $\{(14.64\text{-}14.3)^2 + (14.64\text{-}13.47)^2 + (14.64\text{-}11.77)^2 + (14.64\text{-}12.8)^2 + (14.64\text{-}14.4)^2 + (14.64\text{-}12.04)^2 + (14.64\text{-}11.06)^2\}^{0.5}$

= $\{(0.34)^2 + (1.17)^2 + (2.87)^2 + (1.84)^2 + (0.24)^2 + (2.6)^2 + (3.58)^2\}^{0.5}$
= $\{32.74\}^{0.5}$
= 5.72

Smaller the Smoothness Index better it is for Line. Ideally it should be zero.

J. Scheduling of Project by Line of Balance method

Now, at first stage, we are finding out the number of days taken for construction of each activities. Then ,we found out the rate in days required/unit for each activity.

As per tha plan, we have total 37 units. So, if we divide the duration required for completion of each activity by 37, we will get the number of days required for completion of one unit.

We can take it as a rate in days/unit. As per the above table, it is seen that the rate in days/unit is different for different activities. In this, we are going to take the same durations as required during actual construction. Thus, the productivity rate in days/unit for each activity will not change. We are taking a same rate as taken during actual construction.

In this stage of planning, we are only going to give a suitable “buffer” for activities so that no activities will clash with each other . For achieving this, first we are required to know that whether should we have to give a suitable buffer for the activities. As per the table, for the first 8 activities, there is no need to give a buffer because among these first 8 activities, no activity is clashing with any of the activity.

Now, as per the actual schedule graph, ”RCC chajja” activity is intersects with “brick masonry”. The rate of “RCC chajja” activity is greater than that of “brick masonry” activity. Therefore, we have to give a suitable buffer at the end of brick masonry activity, so that after that buffer, means at that time, the activity RCC chajja can be completed without clashing with the previous activity.

In this way, buffer can be provided at the end if the rate of succeeding activity is greater than the previous one. And, it can be provided at the beginning when the rate of succeeding activity is slower than previous activity rate.

We are providing a minimum 5 days buffer. Consider a another activity example, the rate of “water proofing “ activity is grater than “dado” working activity. but the “dado” activity is its successor activity. So ,we are providing a 5 days buffer at the start of “dado” activity so that there will be not a clashing of these two activities.

In these way, we have provided a suitable buffers for activities and have drawn a graph using VICO software. It has duration on its X-axis and number of units i.e.37 units on Y-axis. The main objective is to find out whether providing buffers only is feasible or not so as to make a project well planned and managed. After plotting a graph, we found out that duration for completion of project have been increased to 595 days though the activities are not clashing and well planned.

Now, our main objective is that, to decrease the duration for completion of overall project, we have to increase a productivity rate of each activity so that the duration required for completion of that activity will automatically decreases and hence the overall project duration can be reduced.

LOB graph for planning via increasing the rate of productivity of each activity by decreasing the duration required to complete one unit in each activity and assuming desired rate for activities.

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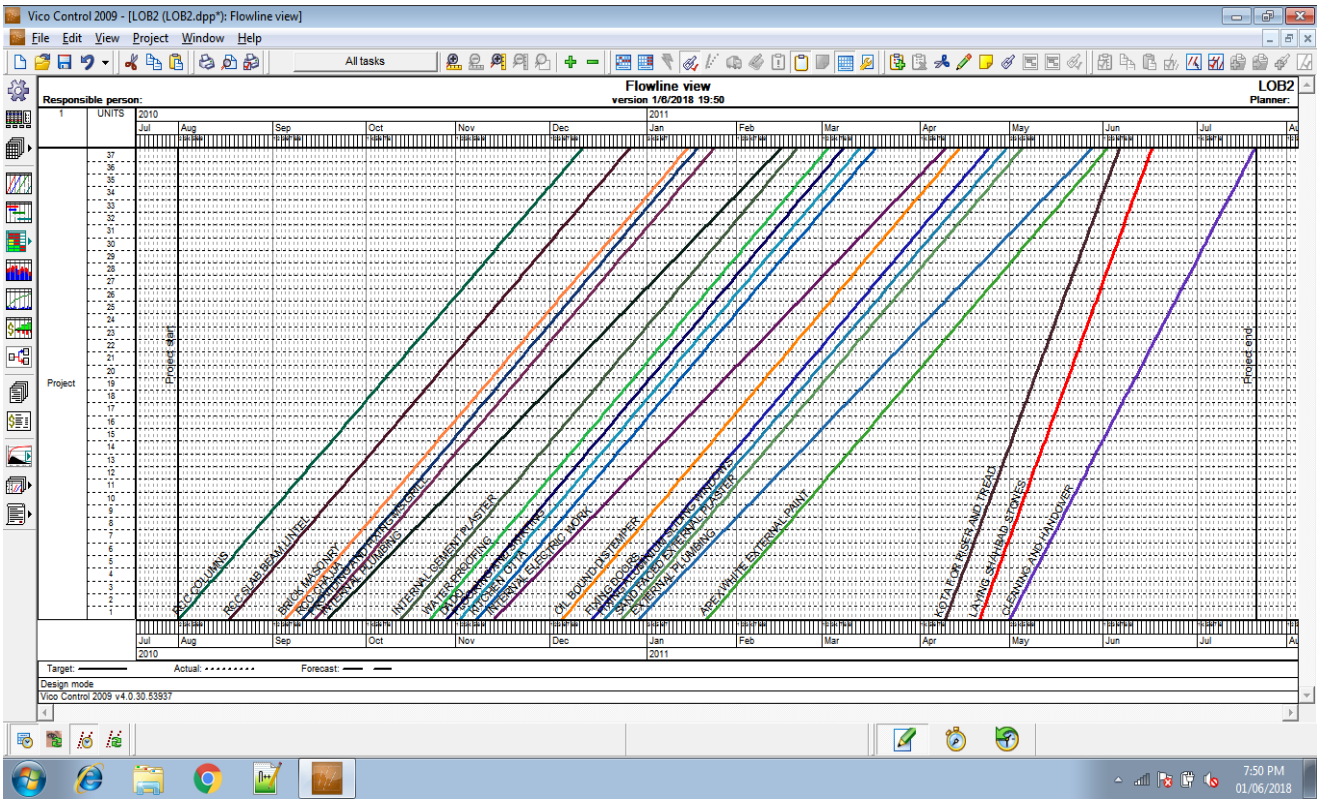

Fig 5:- Plotting of flowline in VICO CONTROL software after giving required buffer and implementing Line of Balance method

Activity	Start date	End date	duration in days	rate(days per unit)	buffer in days
site mobilization and line out	04/05/2010	18/05/2010	14	_	_
pcc	12/05/2010	03/06/2010	22	_	_
footing	24/05/2010	16/06/2010	23	_	_
RCC plinth beam	07/06/2010	12/07/2010	35	_	_
RCC slab at plinth	25/06/2010	29/07/2010	34	_	_
RCC columns	02/08/2010	10/12/2010	130	3.5	_
RCC beam,slab,lintel	18/08/2010	26/12/2010	130	3.5	_
brick masonry	06/09/2010	14/01/2011	130	3.5	_
RCC chajja	10/09/2010	18/01/2011	130	3.5	_
providing and fixing MS grill	15/09/2010	23/01/2011	130	3.5	_
internal plumbing	20/09/2010	15/02/2011	148	4	5
internal cement plaster	13/10/2010	20/02/2011	130	3.5	10
water proofing	23/10/2010	02/03/2011	130	3.5	5
dado	28/10/2010	07/03/2011	130	3.5	5
flooring and skirting	02/11/2010	12/03/2011	130	3.5	5
kitchen otta	07/11/2010	17/03/2011	130	3.5	5
internal electric work	12/11/2010	09/04/2011	148	4	5
oil bound distemper	05/12/2010	14/04/2011	130	3.5	10
fixing doors	15/12/2010	24/04/2011	130	3.5	5
fixing aluminium sliding window	20/12/2010	29/04/2011	130	3.5	5
sand faced external plaster	25/12/2010	04/05/2011	130	3.5	5
external plumbing	30/12/2010	27/05/2011	148	4	5
apex white wxternal paint	22/01/2011	01/06/2011	130	3.5	5
kota for riser and tread	11/04/2011	06/06/2011	56	1.5	10
laying shahbad stones	21/04/2011	16/06/2011	56	1.5	_
cleaning and handover	01/05/2011	20/07/2011	80	0	_
NUMBER OF DAYS FOR COMPLETION = 442 DAYS					

Table 6:- Activity duration and production rate along with buffer after scheduling by Line of Balance method

In this stage, we are going to plot a LOB graph by taking the desired production rate for all the activities so that there will not be any clashes between any of the activity. As we already provided a buffers in last plotted graph, we are just going to change the rate for each activity and keeping the same desired rate.

Now, here, from observing a last plotted graph and actual rates in days/unit, we can fix what desired rate we can take so that most of the activities can be done according to that desired rate taken. After analyzing all the actual rates, we are going to take “3.5 days/unit” as our desired rate for all the activities.

➢ *Let us consider a example*:

Total actual numbers of days required for completion of "brick masonry" work are 155 days for 37 units. So, the no of days required to complete one unit = 155/37 =4.18 days/unit.Here, 4.18 days/unit is the actual rate for completion of brickwork.

So, if we taken a desired rate as 3.5days/unit for brickwork, total no of days for completion of brickwork would be = 3.5*37 =129.5 days= 130 days.

So, with this, we can complete the brickwork 25 days earlier the date it had actually finished. For this, we will have to increase the labors working per day. It will depends upon the quantity of the brickwork which is to be done per day and labor working rate per day.

➢ *Let us consider another example:*

Total actual number of days required for completion of "providing and fixing MS grills" work is 115 days for 37 units.

So, the no of days required to complete one unit = 115/37 =3.10 days/unit.

Here, 3.10 days/unit is the actual rate for completion of fixing MS grills.

So, if we taken a desired rate as 3.5days/unit for providing and fixing MS grills , total no of days for completion of providing and fixing MS grills would be = 3.5*37 =129.5 days= 130 days.

Here, one can say that the duration for the completion is increased. But, as the "providing and fixing MS grills" work is successor activity of brick masonry, it should not be finished until brickwork has done. so ,as the actual rate for "providing and fixing MS grills" is greater than brickwork, it should be reduced to avoid clashes between these two adjacent activities.

In case of "internal plumbing", " internal electric work", "external plumbing", the desired rate is taken as 4days/unit because these activities are actually taking too much time for its completion. Therefore, instead of 3.5days/unit, we are taking a 4 days/unit.In case of "laying of kota for riser and tread" and "laying of Shahabad stones", the actual rate is 1.97days/unit and 1.35 days/unit respectively. Therefore, instead of taking 3.5days/unit which may took longer period for completion, we have taken a rate of 1.5days/unit so that the activities will not intersect with each others avoiding the clashes.

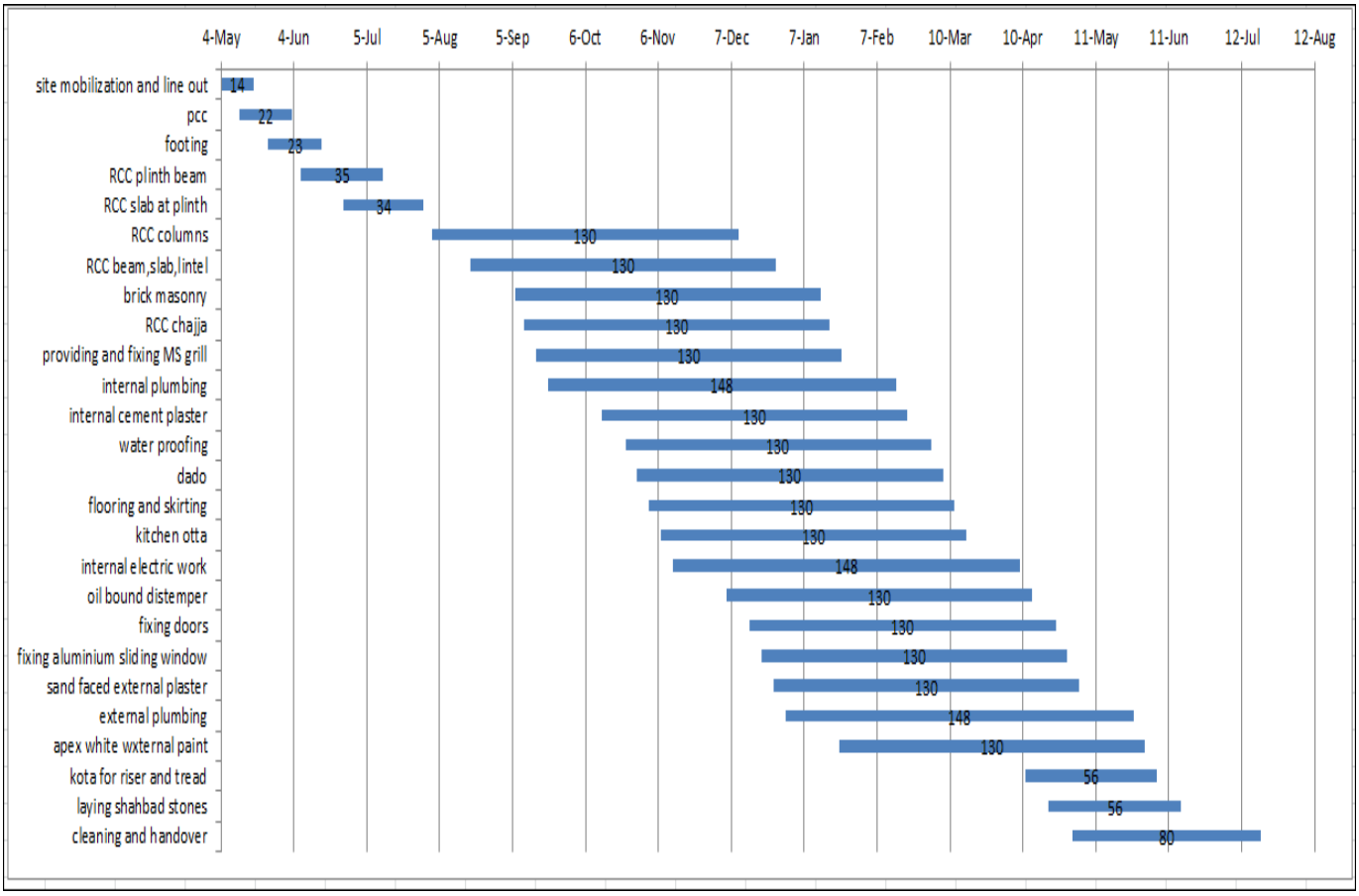

Fig 6:- Gantt chart after scheduling by Line of Balance with desired output

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ACTIVITY	PRECEDENCE	TIME	TIME FOR EACH UNIT
1	_	14	0.378
2	1	22	0.595
3	2	23	0.622
4	3	35	0.946
5	4	34	0.919
6	5	130	3.514
7	6	130	3.514
8	7	130	3.514
9	7	130	3.514
10	8,9	130	3.514
11	9	148	4.000
12	9	130	3.514
13	9	130	3.514
14	9	130	3.514
15	9	130	3.514
16	10	130	3.514
17	11	148	4.000
18	13	130	3.514
19	14	130	3.514
20	14	130	3.514
21	14	130	3.514
22	16	148	4.000
23	17	130	3.514
24	22	56	1.514
25	23	56	1.514
26	12,15,18,19,20,21,24,25	80	2.162
	TOTAL DURATION = 442 DAYS		

Table 7:- Time For Each Unit After Lob scheduling and using precedence relationship

Here we have scheduled the project by using Line of Balance technique by adjusting the production rate.The above table is prepared by using Line of Balance Method.

K. Determination of Cycle Time:

$$\text{Cycle Time (Ct)} = \frac{\text{Total Time Available}}{\text{Desired Output}}$$

$$= \frac{442}{37}$$

$$= 11.94 \text{ days}$$

L. Determination of Minimum Number of Work Stations:

$$\text{Minimum Number of Work Stations} = \frac{\text{(Total Task Time For unit Production)}}{\text{(Cycle Time)}}$$

$$= \frac{75.31}{11.94}$$

$$= 6.13$$

= 7 Stations (Number of stations to be rounded off)

Minimum Number of Work Stations =7

WORK STATION	ACTIVITIES ELIGIBLE	ACTIVITIES ASSIGNED	TASK TIME	CUMULATIVE TIME
1	1	1	0.38	0.38
	2	2	0.6	0.98
	3	3	0.6	1.58
	4	4	1	2.58
	5	5	0.9	3.48
	6	6	3.55	7.03
	7	7	3.55	10.58
2	8,9	8	3.55	3.55
	9	9	3.55	7.02
	10,11,12,13,14,15	11	4	11.02
3	10,12,13,14,15,17	17	4	4
	10,12,13,14,15,23	10	3.55	7.5
	12,13,14,15,16,23	12	3.55	11.02
4	13,14,15,16,23	13	3.55	3.55
	14,15,16,18,23	14	3.55	7.02
	15,16,18,19,20,21,23	15	3.55	10.6
5	16,18,19,20,21,23	16	3.55	3.55
	18,19,20,21,22,23	22	4	7.51
	18,19,20,21,23,24	18	3.55	11.02
6	19,20,21,23,24	19	3.55	3.55
	20,21,23,24	20	3.55	7.02
	21,23,24	21	3.55	10.54
7	23,24	23	3.55	3.55
	24,25	24	1.55	5.028
	25	25	1.54	6.6
	26	26	2.16	8.7

FIG :LONGEST PATH RULE AFTER IMPLEMENTING LINE OF BALANCE

Table 8:- Calculation using Largest candidate rule after scheduling of project through Line of Balance method

M. Determination of Line Efficiency:

$$\text{Line Efficiency} = \frac{\text{sum of task times for each unit}}{\text{Number of workstations x cycle time}} X100$$

$$= \frac{75.31}{7 \times 11.94} \times 100$$

$$= 90.1\ \%$$

Thus, line efficiency is 90.1%

Larger the Line Efficiency, value more efficient the line.

N. Calculation of Smoothness Index :

Smoothness Index = SI=

$$= \{(11.94-10.48)^2 + (11.94-11.02)^2 + (11.94-11.02)^2 + (11.94-10.53)^2 + (11.94-11.02)^2 + (11.94-10.54)^2 + (11.94-8.7)^2\}^{0.5}$$

$$= \{(1.46)^2 + (0.92)^2 + (0.92)^2 + (1.41)^2 + (0.92)^2 + (1.4)^2 + (3.24)^2\}^{0.5}$$

$= \{19.116\}^{0.5}$
$= 4.3$

Smaller the smoothness index better it is for line. Ideally it should be zero.

Activity	Quantity	Actual Duration	Actual Production rate/day	Planned duration	Planned production rate/day
site mobilization and line out	1402.25 cum	14	100.16	14	100.16
pcc	93.60 cum	22	4.25	22	4.25
footing	147.42 cum	23	6.4	23	6.4
RCC plinth beam	35.15 cum	35	1.004	35	1.004
RCC slab at plinth	34.15 cum	34	1.004	34	1.004
RCC columns	164.61 cum	121	1.36	130	1.266
RCC beam,slab,lintel	512.03 cum	135	3.79	130	3.93
brick masonry	3495.9 sqm	155	22.55	130	26.89
RCC chajja	5.99 sqm	130	0.046	130	0.046
providing and fixing MS grill	390.07 sqm	115	3.39	130	3
internal plumbing		284	_	148	_
internal cement plaster	8219.9 sqm	152	54.07	130	1.169
water proofing	1730.81 sqm	145	11.93	130	13.31
dado	805.42 sqm	168	4.79	130	6.19
flooring and skirting	1811.95 sqm	149	12.16	130	13.93
kitchen otta	64.66 sqm	151	0.428	130	0.497
internal electric work		344	_	148	_
oil bound distemper	5576.97 sqm	155	35.98	130	42.89
fixing doors	386.4 sqm	137	2.82	130	2.97
fixing aluminium sliding window	313.02 sqm	135	2.31	130	2.4
sand faced external plaster	5304.54 sqm	86	61.68	130	40.8
external plumbing		225	_	148	_
apex white wxternal paint	5304.54 sqm	206	25.75	130	40.8
kota for riser and tread	112.32 sqm	73	1.53	56	2
laying shahbad stones	121.68 sqm	50	2.43	56	2.17
cleaning and handover		81	_	80	_

Table 9:- Quantity of work and associated production rates for actual and planned duration respectively

IV. RESULTS

- The above table shows the actual quantities of various activities and actual duration required for completion of each of the activity.The result in above shows how the production rate is to be carried out for efficient project implementation.From this data,we found out the productivity rate of each activity in "quantity/day".As ,we have planned the durations and we have actual durations,we can found out what productivity rate should be taken for completion of each activity in that planned duration.
- The above table shows the production rates that is needed to be adjusted for getting parallel flow lines so that there is no clashing of activities.

Consider activity Brick Masonary the obtained quantity is 3495.9 sqm from the authority the actual production rate which is implemented was 22.55 sqm/day we planned the duration using LOB and its duration was reduced to 130 days and so for its completion within duration production rate of 26.89 sqm/day must be followed.

- By using VICO CONTROL software it is possible to schedule the project by line of balance technique.The actual duration was 542 days and after scheduling with line of balance technique it is possible to complete the project in 442 days which is less than the actual duration taken to complete the project.The project can be worked out before 100 days of actual duration required thus line of balance method is quite efficient.

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	BASED ON ACTUAL PROJECT DURATION	BASED ON SCHEDULING BY LINE OF BALANCE METHOD
LINE EFFICIENCY	87.26%	90.10%
SMOOTHNESS INDEX	5.72	4.3

Table 10:- Summary of line efficiency and smoothness index

V. CONCLUSION

In multi storey high rise buildings, same activities are repeated on each floor. In order to trace which activity is going on particular floor, Line of Balance method can be used.

- It is a graphical representation of repetitive activities where project manager can compare the planned and actual rate of production and if the project is lagging behind the planned schedule, the project manager can take suitable action. LOB and CPM method can be integrate for scheduling repetitive activities, since to crash the activity, critical activity should be known therefore CPM can be used in Line of Balance method.
- Since the activities are crashed to reduce the duration of the project, but the cost of the project will increase since the resources have to increase for the project to be completed in stipulated time. Therefore total cost of the project will increase by some amount. The study is limited to the projects where activities are repeated in linear way or non-linear way
- By using VICO CONTROL software it is possible to schedule the project by line of balance technique. The actual duration was 542 days and after scheduling with line of balance technique it is possible to complete the project in 442 days which is less than the actual duration taken to complete the project.
- The project can be worked out before 100 days of actual duration required thus line of balance method is quite efficient.
- Line efficiency is increased and there is decrease in smoothness index.

REFERENCES

[1]. W.Y. Thabet and Y.J. Beliveau," HVLS: Horizontal and Vertical Logic Scheduling for Multistory Projects," J. Constr. Eng. and Mgmt., ASCE, Vol. 120 (4), pp. 875-892 ,1994.

[2]. Kartam, S., Ballard G., and Ibbs, C.W. "Introducing a new concept and approach to modeling construction." J. Constr. Engrg. and Mgmt., 123 (1), Mar, 89-97. 1997.

[3]. Robert B. Harris1, Fellow, ASCE, and Photios G. Ioannou2 , Member, ASCE, "Scheduling Project with Repetitive Activities", Journal of Construction Engineering and Management, vol. 124, No.4, July/August 1998

[4]. Yamin, R. &Harmelink, D. Comparison of Linear Scheduling Method (LSM) and Critical Path Method (CPM).Journal of Construction Engineering and Management, 127. 2001.

[5]. David Arditi, M.ASCE1 ;Onur B. Tokdemir2 and Kangsuk Suh3, "Challenges in Line of-Balance Scheduling", Journal of Construction Engineering and Management, vol. 128, No.6, 2002.

[6]. Gregory A. Duffy, Garold D. Oberlender; and David HyungSeok Jeong, " Linear Scheduling Model with Varying Production Rates", "Journal of Construction Engineering and Management" , The Journal of Construction and Management, Vol.I, pp (254-266)2011.