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Application Of Project Management Tools To Optimize The Assembly Time Of Lead-Acid Battery Machine

Shreyas S Kari[1], A. Balakrishna[2]

[1]P.G Student, Department of IEM, M S Ramaiah Institute of Technology, Bangalore, India
[2]Associate professor, Department of IEM, M S Ramaiah Institute of Technology, Bangalore, India

Abstract- *The present dissertation work was carried in a XYZ industry. In order to reduce the assembly time of Lead-Acid battery machine (Special Purpose Machine). The machine seals the cathode and anode plate with polyethylene cover along with glass mate cover. Earlier the XYZ industry used to take 40 days to get the materials from the vendors and the time taken to assemble the machine was about 30-45 days. Machine consists of 6 sub-assemblies and the time required to assemble the machine was 3394.5 min. It was observed that there was a single workstation to assemble the machine and the line efficiency was 27.199% and the balance delay was 72.800% and it required 7 days to assemble the machine. In order to optimize the assembly time, industrial engineering techniques such as Work Breakdown Structure, Outline process chart, Critical Path Method, Program Evaluation Review Technique and Ranked Positional Weight Method are used. Thereby increasing the line efficiency to 95.40% and reducing the balance delay to 4.59% and it required 4 days to assemble the machine.*

Keywords- *Lead-Acid battery machine (special purpose machine), Work Breakdown Structure, Outline process Chart, Critical Path Method, Program Evaluation and Review Technique and Ranked Positional Weight Method.*

I. INTRODUCTION

The aim of the paper is to reduce the assembly time of lead-Acid battery machine by eliminating the non-value added activities. This is done by using the industrial engineering techniques such as,

1. Critical Path Method (CPM).
2. Program Evaluation and Review Technique (PERT).
3. Ranked Positional Weight (RPW).

1. Critical Path Method and Program Evaluation and Review Technique.
   CPM and PERT are network based methods to assist in the planning, scheduling and control of projects. A project is defined as a collection of interrelated activities with each activity consuming time and resources. Both the methods are basically time oriented methods in the sense that they both lead to the determination of a time schedule for a project. The important difference is that CPM uses time estimates that are deterministic while PERT uses probabilistic time estimates[12]

Network representation
Rule 1- Each activity is represented by one and only one arc.
Rule 2- Each activity must be defined by two distinct end nodes.
Rule 3- Maintain the correct precedence relationships.

2. Ranked Positional Weight Method (RPW)

   The assembly line balancing problem is considered as one of the classical industrial engineering problems. An assembly line is a sequence of workstations connected together by the material handling systems. It is used to assemble components or tasks into a final product.[12]

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II. PROBLEM STATEMENT

Problem identified is to optimize the assembly time of Lead-Acid battery machine. Earlier the XYZ industry used to take 40 days to get the materials from the vendors and the time taken to assemble the machine was about 30-45 days. This 30-45 days was because of-

- Not performing the assembly activities in parallel.

- Material delay while doing the assembly activities.
- Using the same resources (people) to carry out the other sub-assemblies.

Figure 1. Lead-acid battery machine

III. LITERATURE REVIEW

There are many literatures available on optimizing the assembly time. I have used these literatures to tackle the real life problem to optimize the assembly time of Lead-Acid battery machine.

[1] Title- Balancing of Parallel Assembly lines

Author- Hadi Gokcen, Kursad Afgak.

Content

This paper tells about the productivity improvement in the assembly line because it increases the capacity and reduces the cost. If the capacity of the line is insufficient, one possible way to increase the capacity is to construct the parallel lines. This paper taught me about the U-type assembly lines, problems of assembly lines, line balancing, task time and cycle time. Total task time should be less than or equal to the cycle time. [3]

[2] Title- Project Analysis through CPM

Author- Peter Stelth Professor Guy Le Roy

Content

CPM, a technique for analyzing projects by determining the longest sequence of tasks (or the sequence of task with the least slack) through a project network. The CPM and the CCPM (Critical chain project management) are both valuable tools that any organization can use successfully to manage their projects. “Scope management, cost management, and time management” are important variables for projects.

Concepts like network diagram (PERT and CPM), learnt how to draw the CPM network, precedence diagram and management engineering were more useful in my project. [6]

[3] Implementation of CPM and PERT In Assembly Line

Author- Ali Goksu, Selma Catovic.

Content

Ali Goksu, Selma Catovic done their work on Implementation of Critical Path Method and Project Evaluation and Review techniques. They carry their study in Furniture industry, where the activities will be high. This paper will help to all managers in furniture industry to implement CPM and PERT to their projects, and by doing that, they will improve effectiveness and efficiency of their organizations.

This paper gave me the clear view of how PERT and CPM can be helpful to improve the efficiency and effectiveness in the industry. [7]

IV. PROJECT PLAN

To carry out the dissertation work in a XYZ industry observation was done in the plant to identify the problem statement. Problem statement was identified as “To reduce the assembly time of Lead-Acid battery machine”. Then literature review was done to solve the current real life problem. Assembly process of the complete machine was studied thoroughly to understand value added activities and non-value added activities. So in order to reduce the assembly time non-value added activities should be eliminated. Then data collection of time for completing each assembly and activities undergoing in the particular assembly was collected. After data collection Industrial Engineering concepts such as Ranked positional Weight Method, Critical Path Method and Program Evaluation and Review Technique were used to solve the problem. After using these concepts results were obtained and problem was solved.

V. PROJECT OBJECTIVES

- Parallely performing the assembly activities.
- Increase line efficiency.
- Decrease balance delay.
- Decrease in material delay.
- Reduction of days to assemble the machine.

VI. PROBLEM ANALYSIS AND RESULTS

6.1 Ranked positional weight method

Procedure is given below-

- Draw the precedence diagram of the activities performed.
- For each work element, determine the positional weight. It is the total time on the longest path from beginning of operation to the last operation of the network.
- Rank the work elements in descending order of the ranked positional weight.
- Assign the work element to the station. Choose the highest RPW element then select next one. Continue till cycle time is not violated. Follow the precedence constraints also.
- Repeat step 4 till all operations are allocated to one station.

6.1.1 Current method

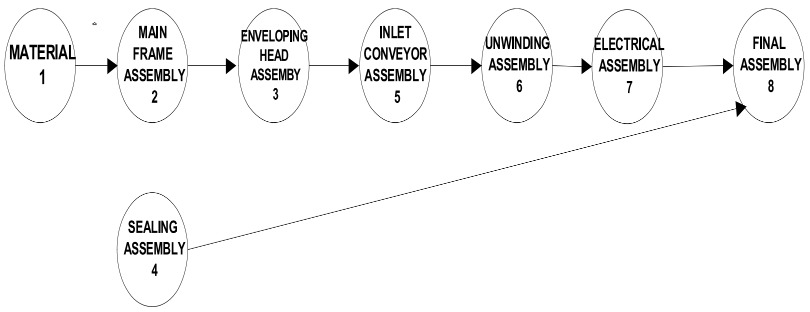

Figure 2. Current assembly procedure

Table 1.Total task time of each assembly

Assembly Name	Total Task Time (min)
Main frame assembly	531
Enveloping head assembly	132.5
Sealing assembly	46
Inlet conveyor assembly	840
Unwinding assembly	306
Electrical assembly	1539

Yearly demand – 9
Monthly demand- 9/12=0.75 (1)
Daily working hours- 9 hours
Allowance (tea+snacks+lunch) – 1 hour
So daily available working hours- 8 hours
Monthly available days – 26
Cycle time= number of available time / demand
Cycle time = 26*8*60 / 1
Cycle time = **12480 minutes**
Total task time – **3394.5 minutes**
Number of workstations – **1**
Line efficiency = sum of task times / (number of workstations* cycle time)

Line efficiency = 3394.5 / (1*12480)
Line efficiency = 27.199 %
Balance delay = (no. of workstations* cycle time) – task time / (no. of workstations* cycle time)
Balance delay = (1*12480) – 3394.5/ (1*12480)
Balance delay = 72.800 %

6.1.2 Proposed method

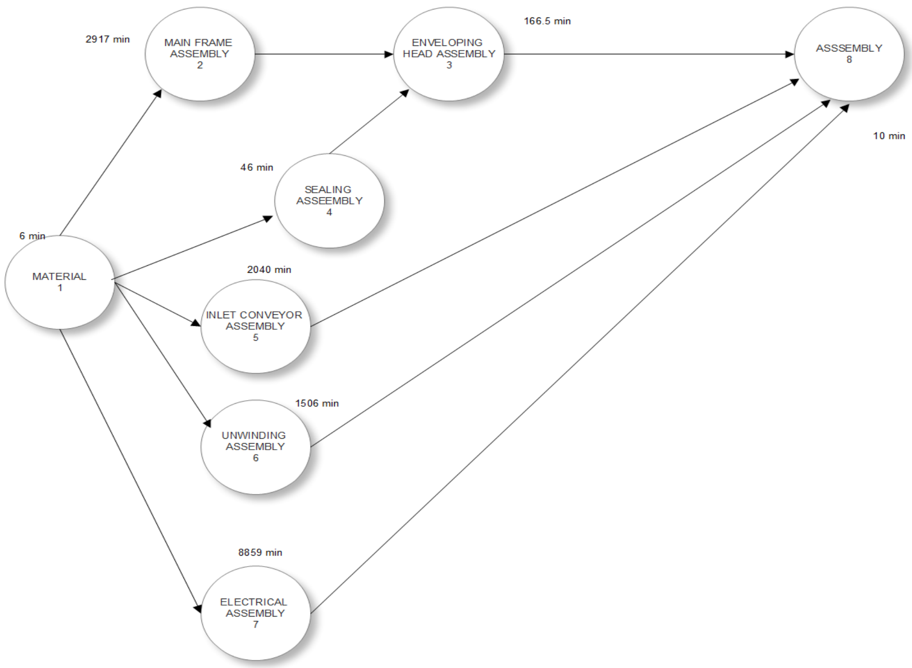

Figure 3. Proposed assembly procedure

Table 2.Precedence table

Element	RPW	Precedence
1	3410.5	-
2	719.5	1
3	142.5	2,4
4	719.5	1
5	850	1
6	316	1
7	1549	1

Table 3.Assigning RPW in descending order

Rank	Element	RPW	Precedence
1st	1	3410.5	-
2nd	7	1549	1
3rd	5	850	1
4th	4	719.5	1
5th	2	719.5	1
6th	6	316	1
7th	3	142.5	2,4

Grouping of workstations
Station 1 – main frame assembly, inlet conveyor assembly, unwinding assembly.
Station 2 **–** enveloping head assembly, sealing assembly, electrical assembly.
From the CPM network highest time from critical path is **1779 min.**
So cycle time will be **1779 min.**
Station 1 total task time – 531+840+306= **1677 min<1779 min.**
Station 2 total task time – 132.5+46+1539= **1717.5 min < 1779 min.**
Minimum number of workstations = total task time / cycle time
Minimum number of workstations= 3394.5 /1779
Minimum number of workstations= **1.90 i.e. 2 workstations.**
Line efficiency of station 1 = sum of task times / (number of workstations* cycle time)
Line efficiency of station 1 = 1677 / 1779
Line efficiency of station 1 = 94.26 %
Line efficiency of station 2 = sum of task times / (number of workstations* cycle time)
Line efficiency of station 2 = 1717.5 / 1779
Line efficiency of station 2 = 96.54 %
Over all line efficiency = sum of task times / (number of workstations* cycle time)
Over all line efficiency = 3394.5/ (2*1779)
Over all line efficiency = 95.40 %
Balance delay = (no. of workstations* cycle time) – task time / (no. of workstations* cycle time)
Balance delay = (2*1779)-3394.5/ (2*1779)
Balance delay = 4.59 %

From both the current and proposed methods it is observed that line efficiency has been increased from **27.199 % to 95.40 %** and balance delay has been decreased from **72.800 % to 4.59 %.**

Figure 4. Grouping of Workstations

The above graph shows the results of RPW method where work elements- 2, 5, and 6 are grouped in 1st workstation which has task time of 1677 min. In the 2nd workstation work elements- 3, 4, and 7 are grouped which has task time of 1717.5 min. The cycle time of assembly line is 1779 min.

6.2 Critical path method (proposed method of assembly)

6.2.1 Main frame assembly

Table 4.Precedence table for enveloping head assembly (CPM)

Activity	Immediate predecessor	Duration(min)
A-Motor mounting plate	-	20
B-Motor Supporting plate	-	10
C-Fixing plate for crank	-	10

D-Mounting of crank on plate	C	2
E-Drilling activity for main drive	D	8
F-Doing threading for drilled holes	E	11
G-Fixing the main drive plate	F	20
H-Mounting the main drive	G	41
I-Adjusting the dummy splitter	H	57
J-Installing the main splitter with supporting plate	I	10
K-Installing the main motor on to the main frame	A,B,H	240
L-Conveyor attachment	K	80
M-Shuttle base plate fixing	L	2
N-Painting	M	240

6.2.2 Enveloping head assembly

Table 5. Precedence table for enveloping head assembly (CPM)

Activity	Immediate predecessor	Duration(min)
O-Side plate fixing on both the sides	M	6
P-Attaching the guide roller on side plate	O	0.5
Q-Fixing of rollers and knurling nob	O	5
R-Attaching of sealing house on side plate	O	2
S-Attaching of vertical plate for the top roller	O	2
T-Attaching of bearing on the vertical plate on both the side	O	7
U-Fixing of bearing block on the bearing to hold	T	6
V-Fixing of knurling nob to the bearing block for grip	U	7
W-Fixing of GM bearing	V	10
X-Fixing of cutter shaft	U	11
Y-Fixing of speeding roller	R	5
Z-Fixing of square tube	A	20
A1-Fixing of 4 plumber block on both side	M	17

B1-Fixing of drive shaft on both the sides with pulley into it for belt drive	A1	8
C1-Fixing of roller to the bearing block with attaching with knurling nob	U	10
D1-Gear box	O	6
E1-Mounting of motor	Z	5
F1-Mounting of chain	B1	5

6.2.3 Sealing assembly (parallel)

Table 6. Precedence table for sealing assembly (CPM)

Activity	Immediate predecessor	Duration (min)
G1-Base plate	-	1
H1-Sealing side plate	G1	5
I1-Bearing block	H1	10
J1-Drive and driven shaft	I1	12
K1-Rubber roller	J1	8
L1-Sealing wheel	K1	6
M1-Sealing wheel clamp	L1	0.5
N1-Spur gear	J1	2
O1-Handle	H1	0.5
P1-Spring	J1	0.5
Q1-Stud	P1	0.5

6.2.4 Inlet conveyor assembly (parallel)

Table 7- Precedence table for inlet conveyor assembly (CPM)

Activity	Immediate predecessor	Duration(min)
R1-Painting of mainframe and conveyor	-	240
S1-Chain roller and spoket	R1	120
T1-Chain cutting and fixing	S1	240
U1-Joining	T1	240

6.2.5 Unwinding assembly (parallel)

Table 8. Precedence table for unwinding assembly (CPM)

Activity	Immediate predecessor	Duration(min)
V1-Cutting according to measurement	-	20
W1-Welding	V1	15
X1-painting	W1	240
Y1-Motor mounting	X1	10
Z1-Disc	Y1	7
A2-Fixing of 4 shaft to hold the roll of polyethylene	Z1	8
B2-Fixing of main shaft	A2	6

6.2.6 Electrical assembly (parallel)

Table 9.Precedence table for electrical assembly (CPM)

Activity	Immediate predecessor	Duration(min)
C2-Dendrile fixing	-	30
D2-MCB fixing	C2	30
E2-TB fixing	D2	5
F2-MPCB and contactor fixing	E2	8
G2-Relays fixing	F2	6
H2-Delta ISP software	G2	120
I2-Drives fixing	H2	10
J2-Attaching wires to all mechanical parts	I2	840
K2-Transformer fixing	J2	10
L2-MOP assembly	K2	480

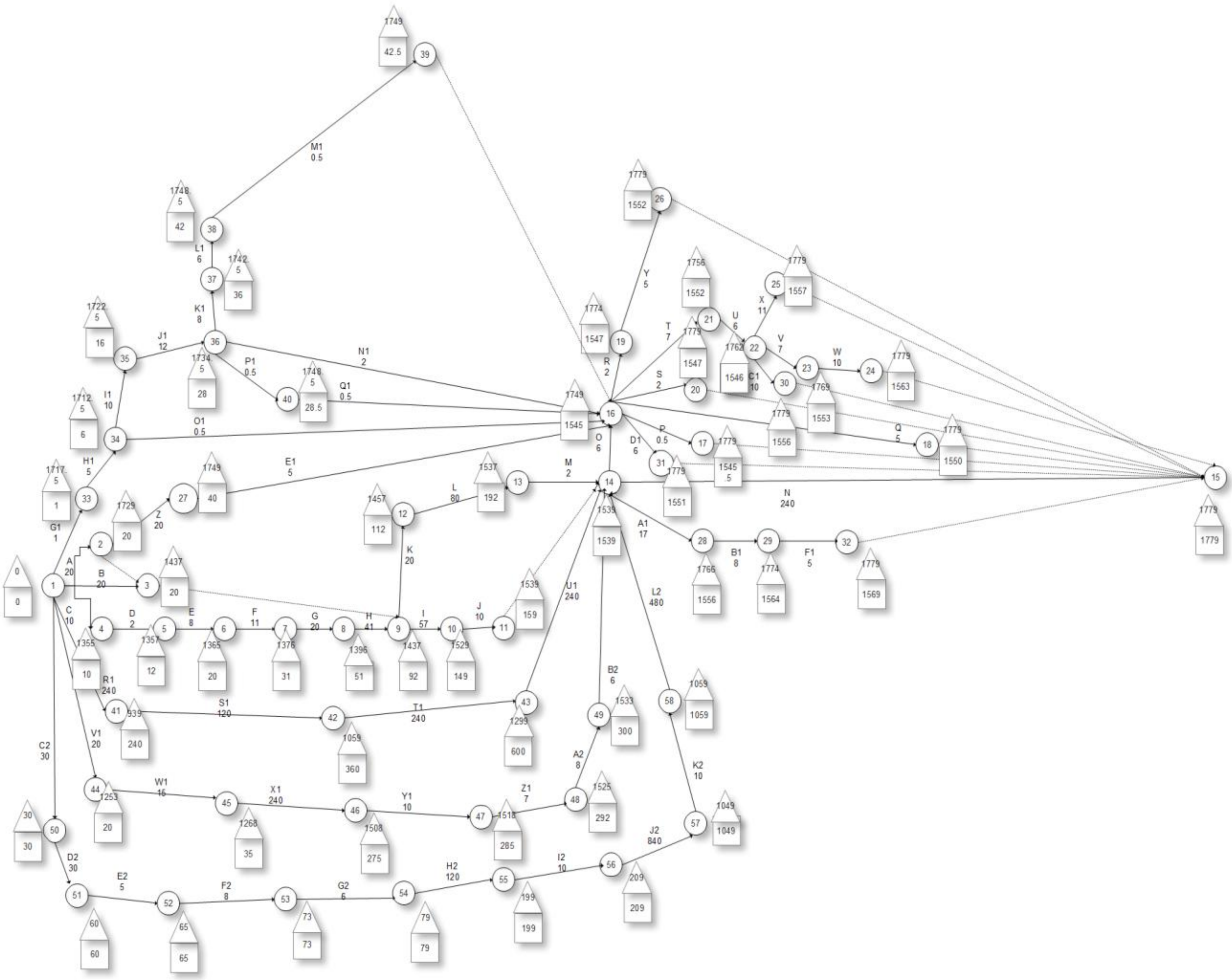

Figure 5. CPM network diagram

Network diagram

The network diagram is the proposed method given to the company in which some sub-assemblies have to be done parallel as shown in the diagram. Currently the assembly of entire machine is done in 7 days. By following the new network

diagram the assembly of entire machine can be done in 4 days. Therefore saving the valuable 3 days (24 hours) of working.
Unit- minutes

Critical Path

1-50-51-52-53-54-55-56-57-58-14-15

30+30+5+8+6+120+10+840+10+480+240=**1779min**

Working hours=8 hours

1779minutes=29.65hours

So, therefore 29.65hours/8=3.70days = 4 working days

So the machine assembly can be completed in 4 working days according to CPM network.

6.3 Program evaluation and review technique (proposed method of assembly)

Table 10. Precedence activities (PERT)

Node No.	Activity	Predecessor	t_o	t_m	t_p	t_e	σ^2
1	Motor mounting plate	0	15	20	25	20	2.7777778
2	Motor Supporting plate	0	5	10	15	10	2.7777778
3	Fixing plate for crank	0	5	10	15	10	2.7777778
4	Mounting of crank on plate	3	1	2	3	2	0.1111111
5	Drilling activity for main drive	4	4	8	12	8	1.7777778
6	Doing threading for drilled holes	5	7	11	15	11	1.7777778
7	Fixing the main drive plate	6	10	20	30	20	11.111111
8	Mounting the main drive	7	25	41	51	40	18.777778
9	Adjusting the dummy splitter	8	45	57	69	57	16
10	Installing the main splitter with supporting plate	9	6	10	20	11	5.4444444
11	Installing the main motor on to the main frame	1.2.8	17	20	35	22	9

12	Conveyor attachment	11	50	80	98	78	64
13	Shuttle base plate fixing	12	1	2	15	4	5.4444444
14	Painting	13	180	240	300	240	400
15	Side plate fixing on both the sides	13	4	6	14	7	2.7777778
16	Attaching the guide roller on side plate	15	0.3	0.5	1	0.55	0.0136111
17	Fixing of rollers and knurling nob	15	2	5	8	5	1
18	Attaching of sealing house on side plate	15	1	2	3	2	0.1111111
19	Attaching of vertical plate for the top roller	15	1	2	3	2	0.1111111
20	Attaching of bearing on the vertical plate on both the side	15	4	7	10	7	1
21	Fixing of bearing block on the bearing to hold	20	3	6	15	7	4

22	Fixing of knurling nob to the bearing block for grip	21	4	7	10	7	1
23	Fixing of GM bearing	22	8	10	12	10	0.4444444
24	Fixing of cutter shaft	21	7	11	15	11	1.7777778
25	Fixing of speeding roller	18	2	5	8	5	1
26	Fixing of square tube	1	13	20	27	20	5.4444444
27	Fixing of 4 plumber block on both side	15	10	17	24	17	5.4444444
28	Fixing of drive shaft on both the sides with pulley into it for belt drive	27	6	8	16	9	2.7777778
29	Fixing of roller to the bearing block with attaching with knurling nob	21	6	10	20	11	5.4444444
30	Gear box	15	3	6	15	7	4
31	Mounting of motor	26	3	5	13	6	2.7777778

32	Mounting of chain	28	3	5	7	5	0.4444444
33	Base plate	0	0.5	1	1.5	1	0.0277778
34	Sealing side plate	33	2	5	8	5	1
35	Bearing block	34	6	10	14	10	1.7777778
36	Drive and driven shaft	35	9	12	15	12	1
37	Rubber roller	36	7	8	21	10	5.4444444
38	Sealing wheel	37	4	6	8	6	0.4444444
39	Sealing wheel clamp	38	0.3	0.5	1	0.55	0.0136111
40	Spur gear	36	1	2	3	2	0.1111111
41	Handle	34	0.3	0.5	1	0.55	0.0136111

42	Spring	36	0.3	0.5	1	0.55	0.0136111
43	Stud	42	0.3	0.5	1	0.55	0.0136111
44	Painting of mainframe and conveyor	0	180	240	300	240	400
45	Chain roller and spoket	44	110	120	160	125	69.444444
46	Chain cutting and fixing	45	200	240	280	240	177.77778
47	Joining	46	200	240	280	240	177.77778
48	Cutting according to measurement	0	10	20	30	20	11.111111
49	Welding	48	10	15	20	15	2.7777778
50	painting	49	180	240	300	240	400
51	Motor mounting	50	6	10	20	11	5.4444444

52	Disc	51	5	7	15	8	2.7777778
53	Fixing of 4 shaft to hold the roll of polyethylene	52	6	8	16	9	2.7777778
54	Fixing of main shaft	53	4	6	14	7	2.7777778
55	Dendrile fixing	0	20	30	40	30	11.111111
56	MCB fixing	55	20	30	40	30	11.111111
57	TB fixing	56	4	5	12	6	1.7777778
58	MPCB and contactor fixing	57	5	8	17	9	4
59	Relays fixing	58	4	6	14	7	2.7777778
60	Delta ISP software	59	90	120	180	125	225
61	Drives fixing	60	5	10	15	10	2.7777778

62	Attaching wires to all mechanical parts	61	600	840	960	820	3600
63	Transformer fixing	62	5	10	15	10	2.7777777
64	MOP assembly	63	360	480	600	480	1600

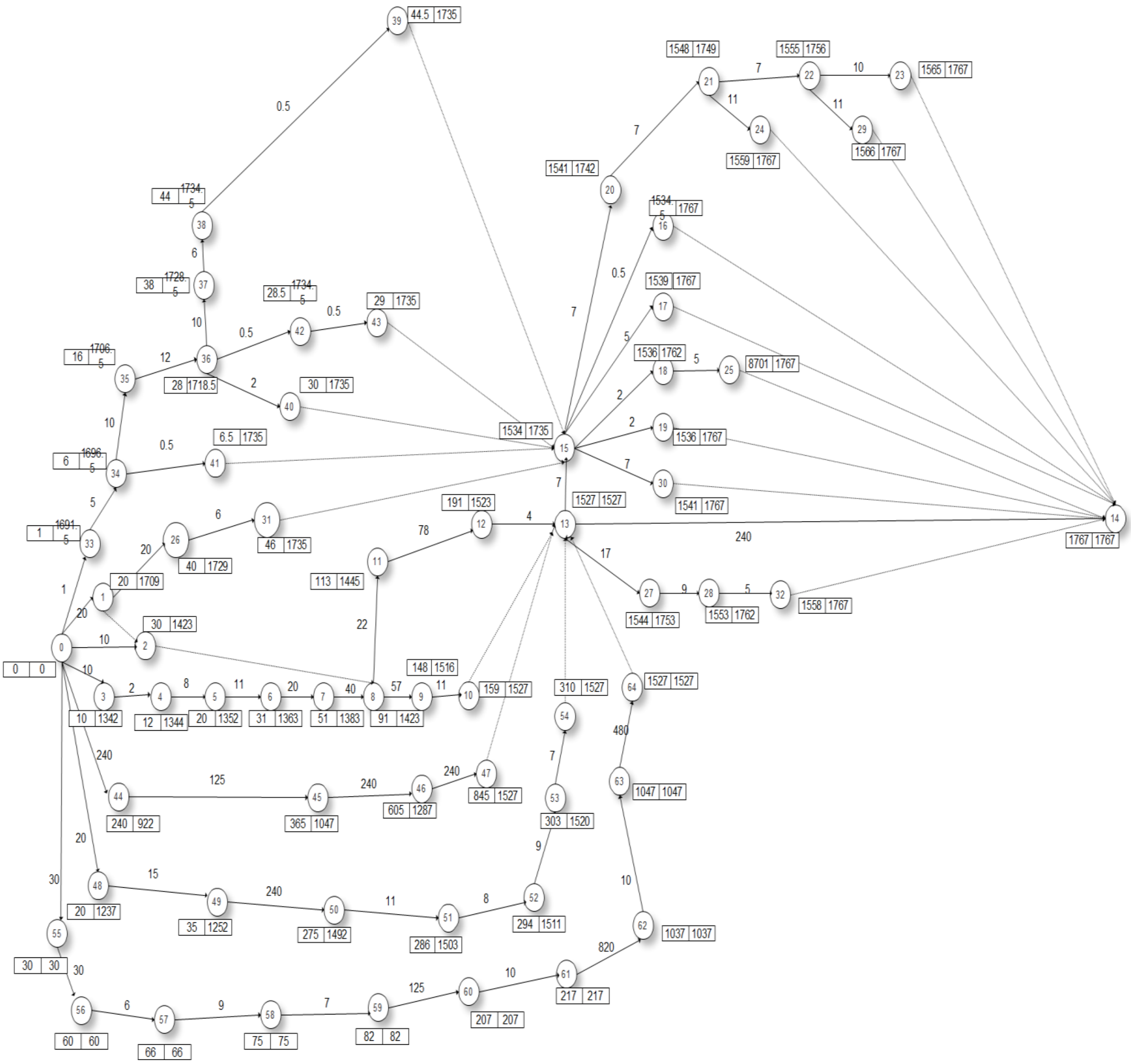

Figure 6. PERT network diagrm

Network diagram

The network diagram is the proposed method given to the company in which some sub-assemblies have to be done parallel as shown in the diagram. Currently the assembly of entire machine is done in 7 days. By following the new network diagram the assembly of entire machine can be done in 4 days. Therefore saving the valuable 3 days (24 hours) of working.

From both CPM and PERT it is observed that machine can be assembled in 4 working days.

PERT calculation

Critical path

0-55-56-57-58-59-60-61-62-63-64-13-14

0+30+30+6+9+7+125+10+820+10+480+240= **1767min**

Working hours = 8 hours

1767=29.45 hours

29.45/8= 3.68 (4 days) working days

σ^2 value from critical path is

11.1111111+11.1111111+1.77777778+4+2.7777778+225+2.7777778+3600+2.7777778+1600+5.4444444+400

σ^2 = 5866.7777 **σ = 76.5948**

1. Considering only the time required for assembling the machine is 30days (project completion time).
2. Considering over all time i.e. parts procurement + assembly time is 70 days (project completion time).

$Z= t_s - t_e / \sigma$

1. Z= 30-4 / 76.5948
   Z= 0.33
   From the normal distribution table z value is **0.629**
   62.9 %
   62.9 % chance of completing the project.

2. Z= 70-4 / 76.5948
   Z= 0.86
   From the normal distribution table z value is 0.8051
   80.51 %

80.51 chance of completing the project.

VII. CONCLUSION

The aim of this project was to suggest changes that could be made that would decrease the assembly time of lead-Acid battery machine, by using various Industrial Engineering concepts.

In the current method the assembly of the machine is done in 3394.5 min i.e. 7 working days. Critical Path Method is the proposed method to carry out the assembly operations in parallel way so that the assembly of the complete machine can be completed in 4 days. Therefore saving 3 working days for the company.

In order to validate the CPM result PERT analysis was done and it also showed the same result i.e. complete machine assembly can be done in 4 working days.

Initially due to 1 work station the work load was not evenly distributed and parallely performing the assembly operations was not done, due to which workers have to wait for the sub-assembly to complete and then start with another sub-assembly. Due to which line efficiency was 27.199% and balance delay was 72.800%.
Therefore Ranked Positional Weight method was suggested by increasing the workstations to 2 so that assembly can done in a parallel way there by increasing the line efficiency to 95.40% and reducing the balance delay to 4.59%.

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