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LINE BALANCING OF OPERATIONS IN AN AUTOMOBILE BODY BUILDING SHOP

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Abstract - *The production rate is depending on how well the line is running. Line balancing is not about making people work harder, but working smarter. It is setting up a system for material to flow smoothly through the various manufacturing processes at the speed required to meet the customer demand. Kondody Autocrafts India Private Limited (KAIPL) is facing a problem of delay in delivering the vehicle on the actual planned date. There occurs a deviation in the actual date of delivery from the planned date. This condition is prevailing due to poor line efficiency of the assembly line. It is found that at some stations, inventory pile up more but in some other stations starving is there, which leads to idleness of work. So the project aims to propose a new assembly line with the objective of reducing the delay in delivery of finished goods by meeting the customer demands. This is done with analyzing and application of Assembly Line Balancing methods to the existing assembly line. This aims to minimize workloads and workers on the assembly line while meeting a required output. This study focuses on 222viking model. Ranked positional weight method is selected as a tool for line balancing. Line balancing was done to minimize the idle time and to improve the cycle efficiency by reducing the number of work stations. Thus a new Assembly line is proposed with the help of RPW method and the technical and financial feasibility in implementing the new assembly line in the industry is analyzed.*

Keywords: *Line balancing, Assembly line , Rank Position Weighted (RPW method),Feasibility study*

I. INTRODUCTION

Manufacturing processes can be divided into two basic types, which are processing operations and assembly operations. A processing operation transforms a work material from one state of completion to a more advanced state that is closer to the final desired product. It adds value by changing the geometry, properties, or appearance of the starting material. In general, processing operations are performed on discrete work parts, but some processing operations are also applicable to assembled items. An assembly operation joins two or more components in order to create a new entity, called an assembly, subassembly, or some other term that refer the joining process. Components of new entity are connected either permanently or semi-permanently. Mechanical assembly methods are available to fasten two or more parts together in a joint that can conveniently disassembled. Line balancing problem especially the assembly line balancing plays an important role for the industries to obtain the high quality and lowest cost. Assembly line balancing is a production strategy that sets an intended rate of production to produce a particular product within a particular time frame. Also, the assembly line needs to be designed effectively and tasks needs to be distributed among workers, machines and work stations ensuring that every line segments in the production process can be met within the time frame and available production capacity. Assembly line balancing can also be defined as assigning proper number of workers or machines for each operations of an assembly line so as to meet required production rate with minimum or zero ideal time. The very purpose of line balancing is to assign workloads to each assigned work station in a manner that the every works stations has approximately same amount of work to be done. In manufacturing industry it is always necessary to re-arrange the activities based on individual workstation so that total processing time can be optimized and the effort is well balanced leading to optimum level of production.

1.1 Problem Definition

Planning and scheduling have a lot of importance as they help as a mean of monitoring progress to ensure the project is completed on time and within budget. The project is intended to be conducted at Kondody Autocraft India Pvt. Ltd. (KAIPL). There occurs deviation in the actual date of delivery of the product after completion of work from the planned date of delivery. The duration of each activity depends upon the availability of resources, time required for each activities etc.The actual plan of the company includes producing 1 unit per day which leads to a production of 26 units per month. But they are not able to achieve this target with the normal production hours. It leads to additional production cost to the company as they tries to achieve the target of 26 units by giving overtime hours etc to the labors. This increases the total production cost to the company.

The project aims at identifying the actual production flow process of the company and also to suggest a modification for the work stations being practiced by the industry by identifying the activities , resource limitations etc and thus avoid the delay in production and reduce the production cost to the company.

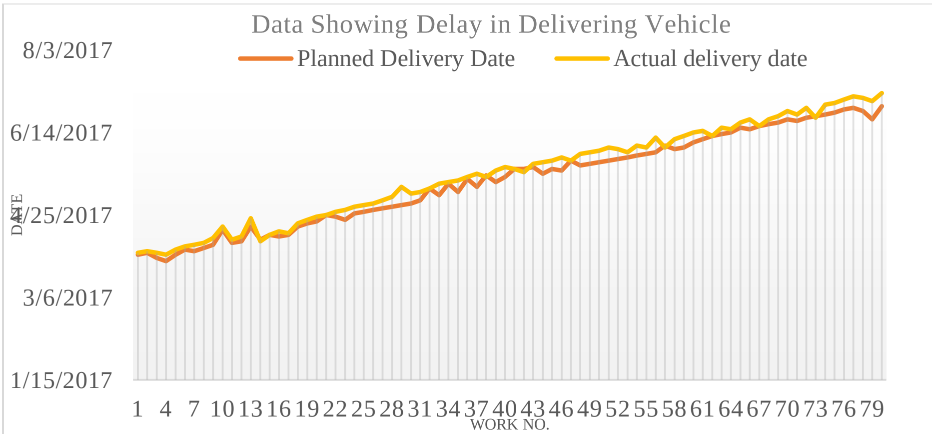

Figure 1 Data showing delay in delivering the vehicle

II. LITERATURE REVIEW

According to Bhattacharjee T. K. (1988), an assembly line consists of a sequence of stations performing a specified set of tasks repeatedly on consecutive product units moving along the line at constant speed. "Assembly Line Balancing (ALB) problem is to determine the allocation of the tasks to an ordered sequence of stations such that each task is assigned to exactly one station, no precedence constraint is violated, and some selected performance measure is optimized like minimize the number of stations"Model, to modeling the production line and the works estimated are used to reduce the line unbalancing causes and relocate the workforce associated to idle time, eliminating the bottleneck and improving the productivity. Improper line balancing causes the poor distribution of workloads, accumulation of inventories, and workers along the assembly line. Company thus faces a problem of irregular production rate.(Joyal George Mathew 2017) Nguyen Thi Lam et al (2016). Focuses on Lean line balancing for an electronics assembly line. In a typical workstation the work is performed manually by human operators using simple tools or by semi-automated machines controlled by those operators. The time required to perform all tasks assigned to a workstation is termed workload. In a paced assembly line each workstation has a predefined amount of time to complete all the tasks assigned to it: the cycle time. When this time is elapsed the sub-assembly must be moved to the next workstation and the workstation receives a new sub-assembly from the previous workstation. Thus, the cycle time determines the production rate of the assembly line.

2.1Types of Simple Assembly Line Balancing

Simple assembly line balancing problems are classified into two types, type I and type II. In type I problems, the required production rate (i.e. cycle time), assembly tasks, tasks times, and precedence requirements is given. The objective of this is to minimize the number of workstations. A line with fewer stations results in lower labor costs and reduced space requirements. Type I problems generally occurs at the time of designing new assembly lines. To achieve the forecast demand the number of workstations should be reduced. For expansion (when demand is increased) type I problems also can be used to minimize the number of extra stations need to install. In type II problems, when the number of workstationsor number of employees is fixed, the objective is to minimize the cycle time. This leads to maximize the production rate. Type II balancing problems generally occurs, when the organization wants to produce the optimum number of items by using a fixed number work stations without expansion. In this type it is necessary to identify precedence, and constraints. While balancing the main line, it is necessary to consider subassembly lines. Type I problems are more common than type II. The exact algorithms available for the same become intractable when the problem size increases.

2.2 Heuristic Methods of Line Balancing

1. Moodie -Young Method
2. Killbridge and Wester Heuristic
3. Ranked Position Weighted Method (RPW)

The RPW solution represents a more efficient way to assign the work elements to station than any other methods mentioned above. In RPW method, one can assign cycle time and then calculate the work stations required for production line or vice versa. This cannot be done in any other method of line balancing. So in the existing problem RPW method is used.

III. METHODOLOGY

The literature review led to the conclusion that the present layout of the KAIPL can be improved using line balancing. Ranked positional weight method can be used as the manual tool for assembly line balancing. For conducting the detailed line balancing several input data are required. They are:

- Selection of product
- Operations required for the product
- Total time taken for production
- Individual time of each operation and work station
- Material flow

3.1 Selection of Product

Selection of the product is the first step in line balancing. The company produces a number of products which comprises of models like 4900 lynx, 210 stag, 210 viking, 222 viking, 210 cheetah etc. Out of the various products 222viking model is taken for study, since only 222 viking model has arrived for body building during the research period . For the study purpose plant 1 is taken into consideration.

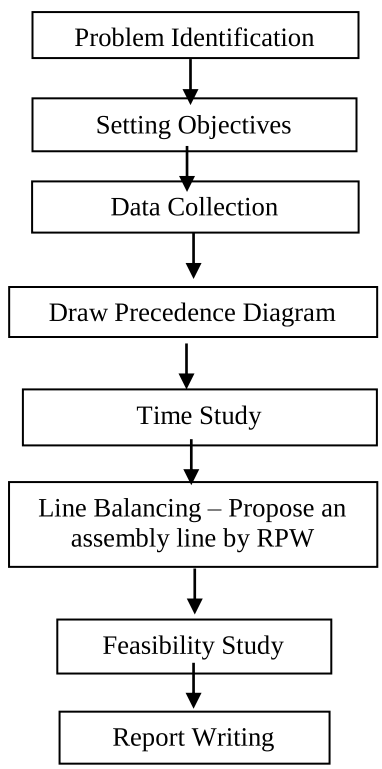

Figure 2.Research Methodology

3.2 Ranked Positional Weighted Method

Steps involved in RPW method-
Step 1: Draw the precedence diagram
Step 2: For each work element, determine the positional weight. It is the total time on the longest path from the beginning of operation to the last operation of the network.
Step 3: Rank the work elements in descending order of ranked positional weight (R.P.W).
Step 4: Assign the work element to a station. Choose the highest RPW element. Then, select the next one. Continue till cycle time is not violated. Follow the precedence constraints also.
Step 5: Repeat step 4 till all operations are allotted to one station.

IV. DATA ANALYSIS

4.1 Precedence diagram

A Precedence Diagramming Method (PDM), which is sometimes also known as the Activity on Node (AON) Diagramming Method, is a graphical representation technique, which shows the inter-dependencies among various project activities. It shows the inter-dependencies among various project activities

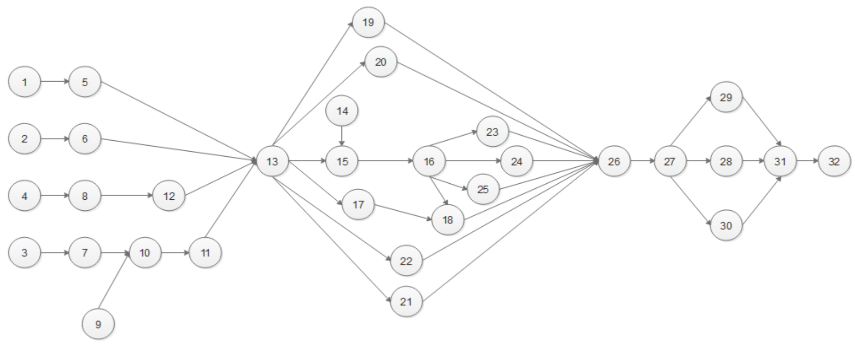

Figure 3. Precedence diagram of 222 viking model

4.2 Current Cycle Efficiency

In order to calculate the cycle efficiency, cycle time of each workstations, takt time, total available time for production, total production time etc is required.

$Line\ efficiency = T \div (n \times C) * 100$

Where , T is the total production time
n is the number of workstations and
C is the cycle time

- Takt time = net available time per day × customer demand per day
- Net available time per day = 11 hrs-1hr (break time)
  = 10 hrs = 600 minutes
- Demand per day = 1 units
- Takt time = 600/1 = 600minutes
- Total time for production = 6714 minutes
- Total no of current work station = 32
- Maximum cycle time = 480 minutes

$Line\ efficiency = T \div (n \times C)$
Current balance efficiency = 6714/(32*480) = 43.71 %
$Idle\ time = n \times c - T$
Current idle time = 32*480-6714 = 8646 minutes
$Theoritical\ number\ of\ stations = T \div t$

- Theoretical number of stations = Total time for production/takt time
  = 6714 / 600 = 11.2 = 12 workstations

Current line efficiency was found to be 43.71%

4.3 Assembly Line By Rpw Method – Line Balancing

Line balancing was done by RPW method. Weightage is given initially to each of the activities based upon the time, required from each activity for the completion of the whole work.

Table 1. Assigning Weightage and ranking tasks

Rank	Job Description	Element	Time (in minutes)	Weightage (in minutes)
1.	Top Structure Jig Settings	3	120	3480
2.	Top Structure Jig Welding	7	180	3360
3.	Platform Structure Jig Settings	4	120	3300
4.	Top Sheet Bending	9	48	3228
5.	Platform Structure Jig Welding	8	150	3180
6.	Top Side Sheet KSRTC	10	180	3180
7.	Co-Driver Side Structure Jig Settings	1	180	3090
8.	Driver Side Structure Jig Settings	2	180	3090
9.	Platform Structure Assembly	12	270	3030
10.	Top Center Sheet KSRTC	11	240	3000
11.	Co-Driver Side Structure Jig Welding	5	150	2910
12.	Driver Side Structure Jig Welding	6	150	2910
13.	Structure Assembly-2 (Raised Platform KSRTC)	13	480	2760
14.	Driver Platform Jig Settings	14	120	2400
15.	Driver Platform Fixing with extreme front door	15	300	2280
16.	Front Assembly with EDC unit at front	16	480	1980
17.	Rear Assembly KSRTC	17	360	1590
18.	Dicky at side	20	360	1530
19.	Battery Door, Dickey Door, Stepney Door, Air filter door fixing	25	330	1500
20.	Driver door Fixing, Emergency Door Fixing	19	270	1440
21.	Front Glass Frame Fit-up and Fixing	23	240	1410
22.	Winch Type Stepney Bracket Fixing	21	150	1320
23.	Seat Angle Fixing	18	60	1230
24.	Inside Mudguard Frame	24	30	1200
25.	Footboard Guard Frame	22	20	1190
26.	Bus Grinding	26	240	1170
27.	Pre-Painting	27	150	930
28.	Escape Hatch Door Fixing, Air Vent Door Fixing	28	480	780
29.	Side Sheet Stretching	29	360	660
30.	Berth Fittings	30	16	316
31.	Platform Sheet Forming	31	240	300
32.	Loading	32	60	60

4.4 Assigning Tasks to Work Stations

Tasks are assigned to workstations based upon the weightage and rank of each activity calculated in the above table (Table 1).

Table 2. Assigning Tasks to Work Stations

Work Station	Work Element	Time (in minutes)	Unsausaged Cycle Time (in minutes)	Ready Task
I	3	120	480	1,2,4,9,7
	4	120	360	1,2,7,8,9
	1	180	180	2,9,8,7,5
	2	180	0	5,6,7,8,9
II	7	180	420	5,6,8,9
	8	150	270	5,6,9,12
	5	150	120	6,9,12
	9	48	72	6,12,10
III	10	180	420	6,11,12
	12	270	150	6,11
IV	11	240	360	6
	6	150	210	13,14
	14	120	90	13
V	13	480	120	15,17,20,21,19,22
	22	20	100	15,17,19,20,21
VI	15	300	300	16,17,19,21,20
	19	270	30	16,20,21,19,17
VII	16	480	120	20,23,25,24,19,21,17
	24	30	90	20,23,25,19,21,17
VIII	17	360	240	18,20,21,23,25
	23	240	0	18,20,21,25
IX	20	360	240	18,21,25
	21	150	90	18,25
	18	60	30	25
X	25	330	270	26
	26	240	30	27
XI	27	150	450	28,29,30
	29	360	90	28,30
	30	16	74	28
XII	28	480	120	31
XIII	31	240	160	32
	32	60	100	-

Thus a new assembly line is developed by RPW method. The new assembly line consists of 13 workstations and the time required at each of the work stations is mentioned clearly in the table.

4.5 Calculation of New Cycle Efficiency

In order to calculate the cycle efficiency, cycle time of each workstations, takt time, total available time for production, total production time etc is required.

$$Line\ efficiency = T \div (n \times C) * 100$$

Where , T is the total production time
n is the number of workstations and
C is the cycle time

Total time, T = 6714 minutes

No. of work stations, n = 13

Maximum cycle time, C	=	600 minutes
Line efficiency	=	(T*100)/ nC
	=	(6714*100) / (13 * 600)
	=	86.10 %
Idle time	=	600*13-6714
	=	1086 minutes

Thus the new line efficiency after balancing is 86.1 %

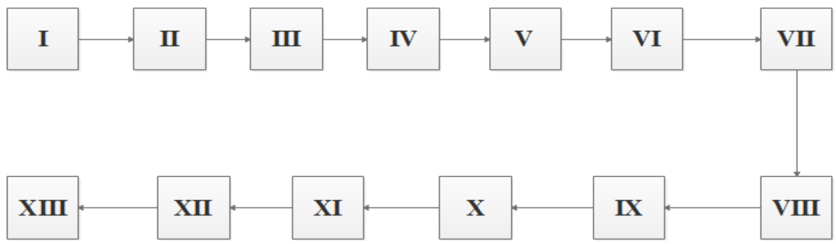

Figure 4. New Workstation

The new work station developed as a result of the assembly line balancing is shown in the above figure. The number of workstations gets decreased from 32 to 13. Also as a result of the line balancing the efficiency gets increased from 43.71 % to 86.1 %. Thus the efficiency gets increased by 42.39%.

4.6 Comparison of Present Assembly Line And New Assembly Line

The assembly line before balancing with 32 workstations and assembly line with 9 workstations is compared.

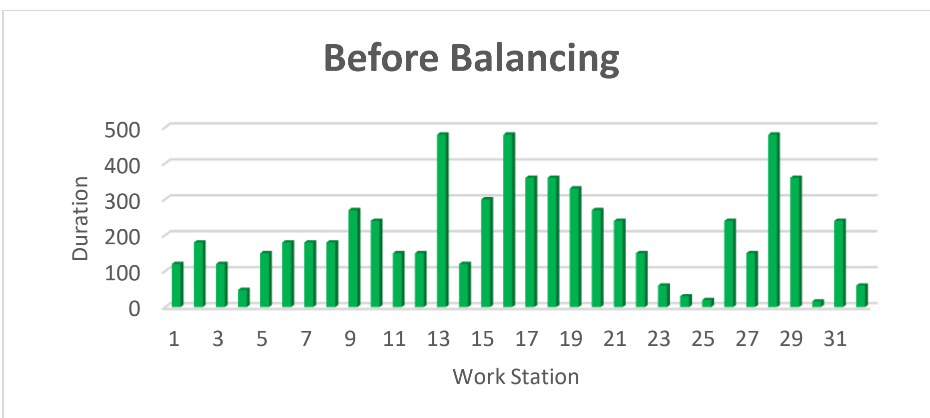

Figure 5. Workstations before balancing

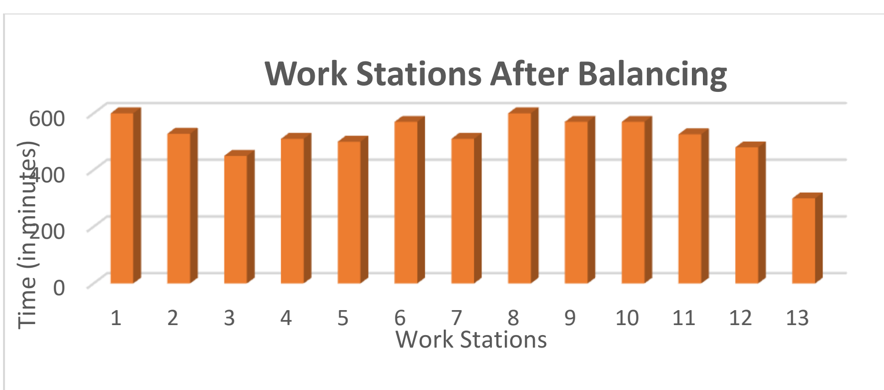

Figure 6. Workstations after balancing

4.7 Feasibility

To check the feasibility of the new work station / assembly line. Technical feasibility and financial feasibility of the new assembly line is checked.

4.7.1 Technical Feasibility

Technical feasibility of the new proposed assembly line is checked. Data is collected regarding the resource requirements in the new assembly line. Also the available resources in the organisation is found out.

Table 3. Resources required for new assembly line

Work Station	Work Element	No. of Labours	Equipments Required	Remarks
I	3, 4, 1, 2	2 Fitters	Hinges , Fixtures	
II	7, 8, 5, 9	2 Welders	1 MIG welding set- up	
III	10, 12	1 Fitter, 1 Welder	1 MIG welding set- up	Both should be experts
IV	11, 6, 14	2 Welders	1 MIG welding set- up, 1 Arc welding set-up	Activity 14 have to be done by welders
V	13, 22	2 Welders	1 MIG welding set- up, 1 Arc welding set-up 1 Over Head Crane	
VI	15, 19	2 Welders	1 MIG welding set- up, 1 Arc welding set-up	
VII	16, 24	2 Welders	1 MIG welding set- up, 1 Arc welding set-up	
VIII	17, 23	2 Welders	1 MIG welding set- up, 1 Arc welding set-up	
IX	20, 21, 18	2 Welders	1 MIG welding set- up, 1 Arc welding set-up	
X	25, 26	2 Welders	1 MIG welding set- up, 1 Arc welding set-up	Grinding have to be done by welders
XI	27, 29, 30	1 Fitter, 1 Welder, 1 Painter	1 MIG welding set- up, 1 Arc welding set-up Compressor	
XII	28	2 Welders	1 MIG welding set- up, 1 Arc welding set-up	
XIII	31, 32	2 Loading people	-	Platform have to be spread in order

Work stations 1 to 4 consists of activities which is a part of the sub assembly. Workstation 5 to 13 includes the activities in the main assembly line.From the above table , table 6.4, the total requirement for the new assembly line is calculated and the current status of resources are obtained in data collection and the result is tabulated.

Table 4.Technical Feasibility

Sl No.	Resource	Requirement (no. of units)	Availability (no. of units)
1.	Labor - fitter	4	12
2.	Labor - welders	20	26
3.	Labor - loading	2	2
4.	Labor – painter	1	1
5.	MIG welding unit	10	13
6.	Arc welding unit	9	15
7.	Over Head Crane	1	2
8.	Compressor	1	1
9.	Bus parking bay	9	8

For the case of bus bay the even though only 9 bays are available currently, the works performed in the plant utilizes about 9 to 11 bays by parking the partially built buses in front of other bays. Thus since all the resources which is required for implementing the new assembly line is available, the new assembly line is technically feasible.

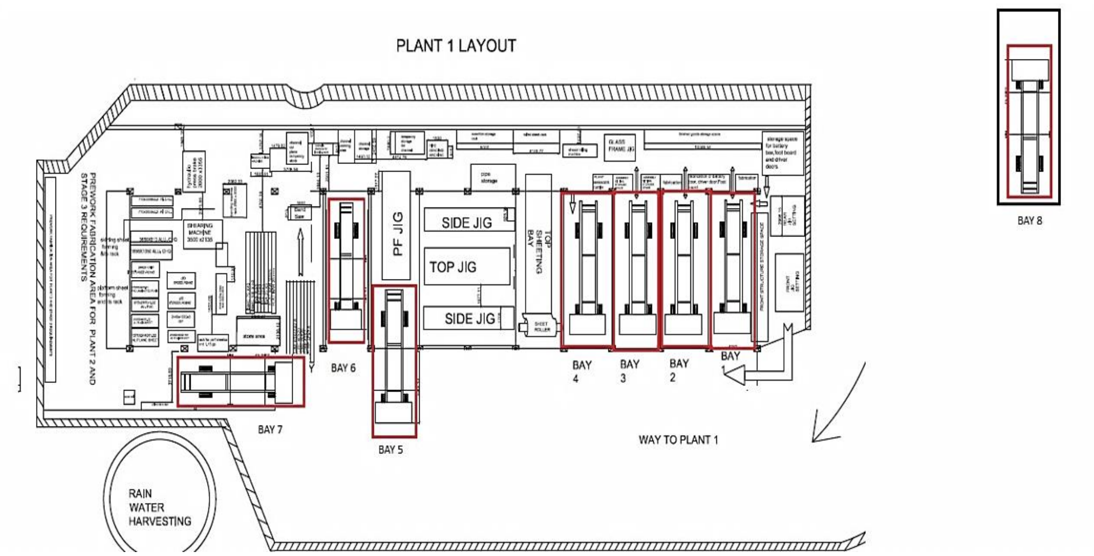

Figure 7. Current Layout with 8 bus bays

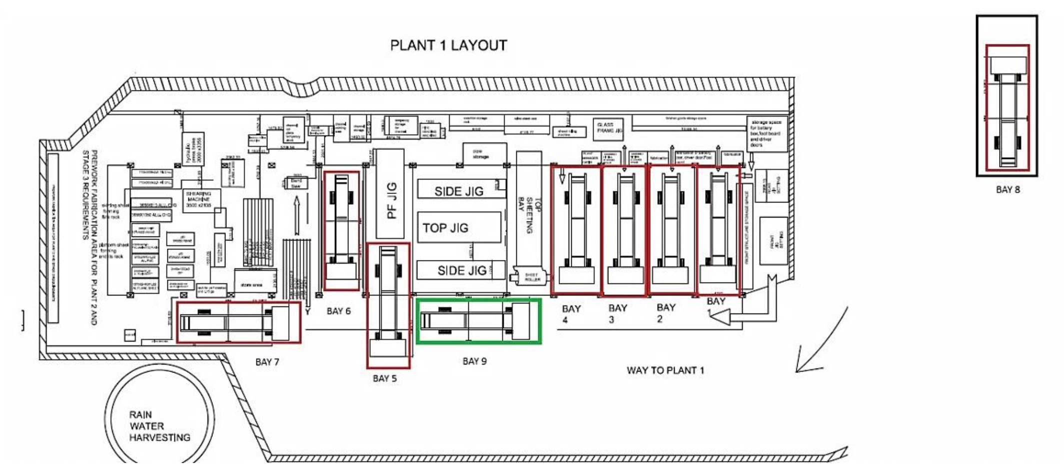

Figure 8. Layout with 9 bus bays

Width required for the bay	=	3 metres
Length required	=	13 metres
Area of space required	=	13*3 = 39 m^2

As shown in the figure 4.5, currently as per the layout , only 8 bays are available for parking buses. The additional bay should be allotted, as per the new assembly line in such a way that, the entry and exit to any of the currently existing bays is not affected. Thus new bay could be allotted as shown in the figure 4.6.Since 39 m^2 area is available at the proposed space as in the layout (Figure 4.6) , investment regarding the same is nil.

4.7.2 Economic Feasibility

Economic feasibility for the new proposed assembly line is checked

Costs

The cost associated with each new implementations have to be identified. Since all the resources required for the new assembly line is already available, no further investment is required and hence the assembly becomes financially feasible.

Benefits

In addition to that since 27 labours are only required to complete the job, as per the new assembly line company could gain the labour cost of additional 18 labours.

Average labour cost per day	=	Rs 600
Current count of labours in plant 1	=	41
Labour cost incurred per day	=	41*600
	=	Rs 24600
Total number of labours required (new Assembly line)	=	27
Labour cost per day (as per the new plan)	=	27*600
	=	Rs 16200
Cost reduced per month	=	24600 – 16200
	=	Rs 8400
Therefore labour cost gained per month	=	Rs 210000
Labour cost gained annually	=	Rs 25,20,000

Thus by implementing this assembly line , the organisation could gain a sum of rupees 25 lakhs annually.

V. RESULTS AND DISCUSSIONS

Currently the workstations being followed by the company is 32 in number. After applying assembly line balancing by Rank Position Weighted method, the number of work stations reduced from 32 to 13. Hence the cycle efficiency gets increased from 43.71% to 86.10%. Thus with the new assembly line, the line efficiency gets increased by 42.39 % and idle time is reduced from 8646 minutes to 1086 minutes. As a result of line balancing a new assembly line with fewer number of work stations is obtained. Taking into consideration the new assembly line and when the feasibility is analyzed, it was found that since all the required resources for the new assembly line is already available in the company, the assembly line is technically feasible. Also the total number of work force in the different stations in the plant 1 gets reduced from 41 to 27 in a day. It will save a lot of money in the production of even a single unit. The company could actually gain a sum of rupees 25 lakhs in terms of labor costs from its plant 1.

VI. CONCLUSION

For a bus body manufacturer, efficiency of assembly line is very important especially for their daily production. Assembly line balancing will help the company solve existing problem with inefficiency of assembly line and thus they will be able to deliver products on time. It was also clear that the overall performance of the company was much affected by the unbalanced production line being practiced by them leading to the necessity for modifying the assembly line. By using the collected data, an analysis is conducted on the present assembly line of the product 222 Viking chasis and using Rank Position Weighted (RPW) method assembly line is balanced. After applying assembly line balancing by Rank Position Weighted method, the number of work stations reduced from 32 to 13. Hence the cycle efficiency gets increased from 43.71% to 86.10%. Thus with the new assembly line, the line efficiency gets increased by 42.39 %.

A new assembly line with fewer number of work stations is obtained as a result of the line balancing done. Taking into consideration the new assembly line and when the feasibility is analyzed, it was found that since all the required resources for the new assembly line is already available in the company, the assembly line is technically feasible. Also the total number of work force in the different stations in the plant 1 gets reduced which will save a lot of money in the . Thus the new proposed assembly line is both technically and financially feasible.

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