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Enhancing Productivity Improvement by Line Balancing Techniques

Radha Halagani[1], Rajesh S M[2], Reena Y A[3]
[1,2,3]Faculty, Department of Industrial Engineering & Management, DSCE, Bangalore, Karnataka, INDIA

ABSTRACT

The Line balancing and Optimizing cycle time methods of value engineering are used to improve the productivity of an assembly line in a XYZ Factory. The main idea starts by optimising the cycle time at all the work stations to increase the productivity. The factory works at 2 shifts, each shift contains 8 hours. To optimize the cycle time, the bottleneck process are found where the cycle time is maximum, affecting the productivity. By analying all the manufacturing processes involved in making of the metro car and found the processes which had the highest cycle time. In particular station reallocateing the workers which helps in reducing the cycle time. The production schedule can be scrutinized and by inducing skilled labours at such situations will help in fastening the process.

The productivity is increased by adding or reducing the number of employees in work stations in favour of bottleneck process and the cycle time is reduced. This is achieved by analysing all processes using QSA software.

Keywords-- Line balancing, Assembly line, Optimising, productivity

I. INTRODUCTION

Line and work cell balancing is an effective tool to improve the assembly lines and work cells while reducing manpower requirements and costs. Assembly Line Balancing, or simply Line Balancing (LB), is the problem of assigning operations to workstations along an assembly line, in such a way that the assignment be optimal in some sense. Ever since Henry Ford's introduction of assembly lines, LB has been an optimization problem of significant industrial importance the efficiency difference between an optimal and a sub-optimal assignment can yield economies (or waste) reaching millions of dollars per year..

Line Balancing is a classic Operations Research (OR) optimization problem, having been tackled by OR over several decades. Many algorithms have been proposed for the problem. Yet despite the practical importance of the problem, and the OR efforts that have been made to tackle it, little commercially available software is available to help industry in optimizing their lines. In fact, according to a recent survey by Becker and Scholl (2004), there appear to be currently just two commercially available packages featuring both a state of the art optimization algorithm and a user-friendly interface for data management. Furthermore, one of those packages appears to handle only the "clean" formulation of the problem (Simple Assembly Line Balancing Problem, or SALBP), which leaves only one package available for industries such as automotive. This situation appears to be paradoxical, or at least unexpected: given the huge economies LB can generate, one would expect several software packages vying to grab a part of those economies.

II. PROBLEM DEFINITION

It is necessary to optimising the cycle time at all the work stations to increase the productivity. The factory works at 2 shifts, each shift contains 8 hours. The company has to increase the productivity of the metro car shell, so that they can meet the desired customer demand (standard amount). With the current production schedule they are able to produce 17 cars per month and it is proposed to increase the production up to 25 cars per month. To optimize the cycle time first we need to find out the bottleneck process where the cycle time is maximum, affecting the productivity, we analyzed all the manufacturing process involved in making of the metro car and found the process which had highest cycle time.

III. MAJOR STAGES IN ASSEMBLY LINE

There are seven major stages in the assembly of the metro car shell.

1) ***Sidewall :*** Side wall is the one of the major component of the metro car body. Each of the side walls constitutes front block, middle block and end block, one front block, one end block and three middle block are required to make one complete one side sidewall. Two sidewalls are required for to produce one metro car shell. This stage only generates the individual blocks in hanger 2 whereas these blocks are taken to the hanger 7 for the integration.

Total integration of side wall in carried out in the hanger 7. The figure shows the workstation and Jig used for the process.

Figure 3.1: Sidewall assembly jig

2) Roof ; The next major stage in the assembly of the metro car shell is the Roof stage. Roof is the top covering for the metro car that prevents the water and other foreign materials entering into the car from the top. There are two types of Roof used in the metro car one is the flat roof and other is the radial roof. The total length of the roof is 22 meters. Each complete roof has two flat roofs and two radial roofs. Flat roofs of size 3 meters and 7 meters along with Radial roof of 3 meters and 9 meters are used to constitute one complete roof. Flat roof is required for accompanying air conditioning system.

The flat roof structure and skinning is carried out in the hanger 2 whereas the radial roof structure and skinning is carried out in the hanger 7. Total integration of the roof structure is done in the hanger 7. Figure shows the jig used for the above processes.

Figure 3.2 : Ceiling frame jig

3) End wall : End wall is the side covering part of the metro car shell. Each car requires two end walls where the passengers can pass through one compartment to another. These processes are carried out in the different Tatra hanger due to in-availability of the space in the hanger 2 and hanger 7. Separate jigs are used for the assembly of the end wall as follows.

Figure 3.3: End wall jigs

4) Car Body Erection: Here the total car body shell is erected and which is critical in the total assembly line. Under frame which is the lower part of the metro shell on which the entire load is mounted is brought to this hanger. The first step is to lock it on with the screw gauge. After placing it in the right position optical levelling instruments are used to level the under frame. In the middle and at the edges slight upper elevation is provided i.e. 15mm elevation in the middle and a 4mm elevation at the edges. The side wall, roof and the end wall are mounted, load is applied. This load will level the under frame and straighten it out. This eruption held up until the full welding is done. Following figure shows Jig used for the purpose.

Figure 3.4: Car body erection jig

5) Indirect Spot Welding

This method of spot welding is implemented since it is not possible to spot weld directly. Indirect spot welding substitutes a contact block for one of the electrodes both top and bottom work pieces contact the electrical elements, electrode and contact block, during direct welding; only one of the work pieces meets the electrode. This welding process promotes good weld appearance. In the actual process this welding joints the sidewall with the under frame firmly. The jig has two spot welding machines on either side of the rail. Figure shows the workstation and jig used.

Figure 3.5 : Indirect spot welding jig

6) Alignment of Brackets

In a car, brackets are aligned for seat arrangement and space allocation. Three major steps are undertaken:

- General alignment of the brackets and top cover installation.
- Installation of long seat and doorway brackets.

Here the installations of brackets are done manually using welding process. This is done after the indirect spot welding process and straightening process are done. The workstation contains no special jig, hence the same workstation is used for the straightening and alignment of brackets processes.

7) Straightening 1 and 2

Straightening is done for the entire shell body. It helps in hardening the whole shell body and also releases the stress and strain that might have accumulated when the load was applied odue to bends occurred while welding process. Specifications: Flame tip is maintainedthrough 13mm Nozzle. Fuel used here Acetylene and Oxygen. Temperature is maintained around 1800□ C. straightening is done before alignment of brackets is called 1st stage straightening and after the alignment of brackets is called 2nd stage straightening. Below figure shows the workstation location where alignment of brackets and straightening is done.

Figure 3.6 : Straightening process workstation

IV. METHODOLOGY

For line balancing and optimizing cycle time the major requirement of data is number of employees working in each work station, time taken and processes that occur in precedence or simultaneously. Cycle time is calculated by dividing the total process time by the number of workers working in respective process.

SIDE WALL					
sl no	activity name	part name and process	total process time(hrs)	no of workers	cycle time(hrs)
1	A1	Middle block structure	177.50	15	11.83
2	E	Middle block skinning	24.00	4	6.00
3	A2	End block structure	22.33	4	5.58
4	E	End block skinning	6.16	2	3.08
5	A3	Front block structure	15.00	2	7.50
6	E	Front block skinning	11.00	2	5.50
7	A4	Cantrail	18.00	2	9.00
8	A5	Door frame	71.33	6	11.89
9	I	Total side wall integration	165.33	14	11.81

Table 4.1: Cycle time calculation for SIDE WALL

ROOF					
sl no	activity name	part name and process	total process time(hrs)	no of workers	cycle time(hrs)
1	B1	Radial structure(9mts)	30.00	3	10.00
2	F	Radial skinning(9mts)	25.16	4	6.29
3	B2	Radial structure(3mts)	7.60	2	3.80
4	F	Radial skinning(3mts)	8.50	4	2.13
5	B3	Vertical end and vertical centre	37.33	4	9.33
6	B4	Flat roof(3mts) structure	3.60	2	1.80
7	G	Skinning and integration of flat roof(3mts)	12.00	4	3.00
8	B5	Flatroof (7mts) structure	8.33	2	4.17
9	G	Skinning and integration of flat roof(7mts)	33.00	4	8.25
10	J	Total roof integration	68.00	10	6.80

Table 4.2: Cycle time calculation for ROOF

END WALL					
sl no	activity name	part name and process	total process time(hrs)	no of workers	cycle time(hrs)
1	C1	End wall structure	112.0	8	14.00
2	K	End wall skinning	39.33	4	9.83

Table 4.3: Cycle time calculation for END WALL

CARBODY INTEGRATION					
sl no	activity name	part name and process	total process time(hrs)	no of workers	cycle time(hrs)
1	R	Carbody erection	216.00	10	21.60
2	S	Indirect spot welding	67.33	4	16.83
3	T	Straightening 1	52.00	12	4.33
4	U	Allignment of bracketories	130.66	10	13.07
5	V	Straightening 2	50.00	12	4.17

Table 4.4: Cycle time calculation for CARBODY INTEGRATION

V. DATA ANALYSIS

By analysing the each work station and found out the cycle time. Cycle time is considered by taking into account the number of hours a single employee might take in each work station. For example Middle block structure takes 177.5 hours and 15 Employees works in that workstation. Hence cycle time 177.5/15=11.83. Its cycle time is 11.83 hours. Later the skinning process is carried out at one workstation only hence middle block skinning, front block skinning and end block skinning cycle time are added up hence its cycle time is 6.00+3.08+5.50=14.58. Likewise all the skinning process are carried out in the same manner and cycle time of each is calculated same as above. According to the work stations and processes precedence diagram is brought about. Through this we can represent processes that can be done parallel with other processes.

The quantitative system analysi (QSA) software which allows to solve mathematical problems like line balancing, linear programming etc. In solving the line balancing problem it uses various method by combining workstations and reducing it to raise the efficiency of the total Process.

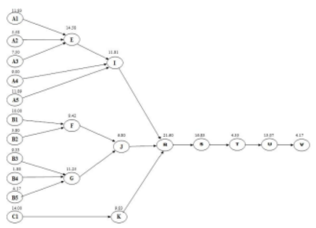


Figure 5.1: Precedence diagram

From the precedence Diagram we observe:

Work element	Precedence	Cycle time (hrs)
A1	-	11.83
A2	-	5.58
A3	-	7.50
A4	-	9.00
A5	-	11.89
B1	-	10.00
B2	-	3.80
B3	-	9.33
B4	-	1.80
B5	-	4.17
C1	-	14.00
E	A1, A2, A3	14.58
F	B1, B2	8.42
G	B3, B4, B5	11.25
I	E, A4, A5	11.81
J	F, G	6.00
K	C1	9.83
R	I, J, K	21.60
S	R	16.83
T	S	4.33
U	T	13.07
V	U	4.17

Table 5.1: Precedence relations and cycle times for present method

The number of hour's employee works per month.
Number of working hours = 7.5
Number of shifts per day = 2
Number of working days per month = 25
Total number of hours per month =7.5×2×25 = 375
From the table we found out that the work element R has the longest cycle time.
Total number of production depends upon the longest cycle time = 21.60.

Using the QSA software and entering the input datas task time, Precedence Relations in the Line Balancing problem, we got the results as

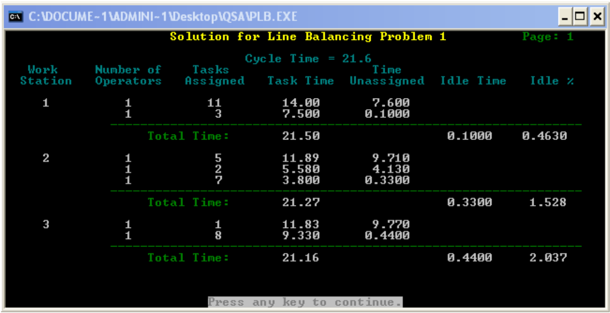


Figure 5.2 solution from line balancing

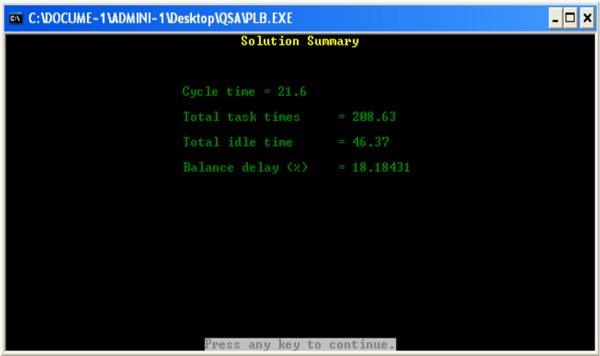


Figure 5.3 Final solution

Balance delay is 18.18%
Even after combining parallel works:
Efficiency = (100- % delay) = 81.82%

Let us try to find the ways in which we can increase the production to the required standard and optimize Cycle Time to increase the Efficiency:

- Division of work station at the Bottleneck point:
- Increase the Number of Employees in the bottleneck point:
- Installation of New Technology or New Methods:
- Reallocate the number of labours in workstation with idle time:
- Employing Multi-skilled workers:
- Simultaneous Installation of two or more processes in a workstation:

The above mentioned new methods are implemented to increase the production and efficiency by optimizing cycle time.

VI. PROPOSED METHODS

6.1 Optimizing Cycle Time

Reallocate the number of workers in workstation where there is lot of idle time:

Optimization takes place only when the cycle time is increased but should not exceed the max cycle time. Consider M, T and V (Radial skinning 3 & 9mts, straightening 1&2). Here multi-skilled workers are assigned for M (Radial skinning 3 & 9mts) and for T+V (straightening 1+ straightening 2). These multi skilled workers are reallocated to tasks R and S (car body erection and indirect spot welding)

Task name	Duration(Hrs.)	Employees	Cycle time(Hrs.)
F	33.66	4	8.42
(reallocate 1employee to S)	33.66	3	11.22
T	52	12	4.33
(reallocate 5employees to R)	52	7	7.43
V	50	12	4.17
(reallocate 5employees to R)	50	7	7.14

Table 6.1: Optimized cycle time

2) Reallocated multi-skilled workers:

Consider R & S (car body erection and indirect spot welding). Let us assign multi-skilled workers in F who can also work in S. Out of 4 employees working in F let us assume there is 1 multi-skilled worker. After their work in F, during their idle time they can work in S. Reallocate the 1 worker to S. Let the 1 multi-skilled worker work in S

Task name	Duration (Hrs.)	Employees	Cycle time(Hrs.)
S	67.33	4	16.83
S (added 1 employee from F)	67.33	4+1(multi)	13.47

Table 6.2: Proposed method resulted cycle time 1

Similarly consider R & S (car body erection and indirect spot welding). Let us assign multiskilled

Workers in T and V who can also work in R. Out of 12 employees working in T and V let us assume there are 5 multi-skilled workers. After their work in T and V, during their idle time they can work in R. Reallocate the 5 workers to R. Let the 5 multi-skilled workers work in R.

Task name	Duratin (Hrs.)	Employees	Cycle time(Hrs.)
R	216.00	10	21.60
R (added 5 employee from T,V)	216.00	10+5(multi)	14.78

Table 6.3: Proposed method resulted cycle time 2

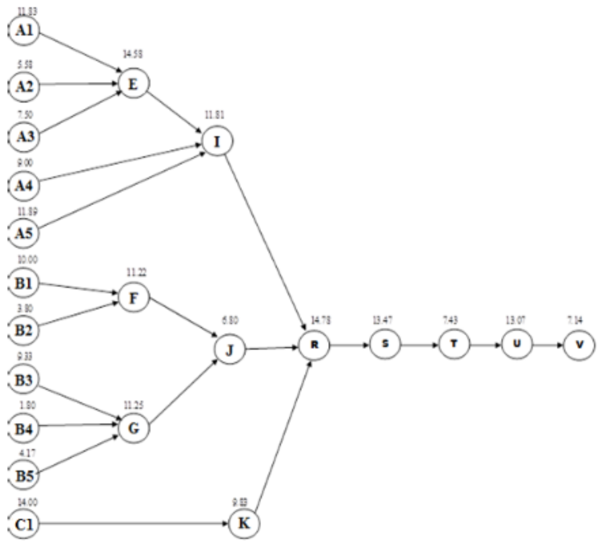


Figure 6.1: Precedence diagram (proposed)

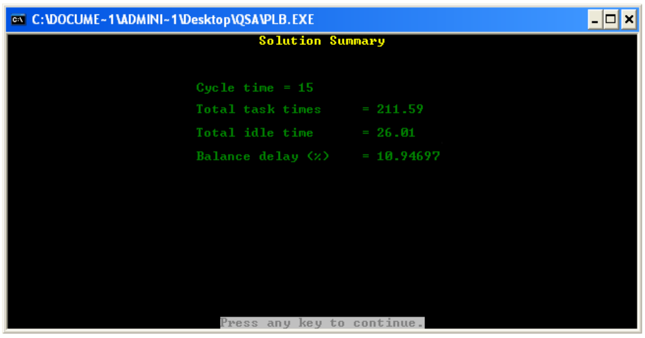
The proposed method resulted in the following Cycle times.

Work element	Precedence	Cycle time (hrs)
A1	-	11.83
A2	-	5.58
A3	-	7.50
A4	-	9.00
A5	-	11.89
B1	-	10.00
B2	-	3.80
B3	-	9.33
B4	-	1.80
B5	-	4.17
C1	-	14.00
E	A1, A2, A3	14.58
F	B1, B2	11.22
G	B3, B4, B5	11.25
I	E, A4, A5	11.81
J	F, G	6.00
K	C1	9.83
R	I, J, K	14.78
S	R	13.47
T	S	7.43
U	T	13.07
V	U	7.14

Table 6.4: Precedence relations and cycle time for propose method

VII. RESULTS

Using the QSA software and entering the input datas task time, Precedence Relations in the Line Balancing problem, we got the results as



From the proposed method the cycle time of work element R has been reduced to 14.78, therefore number of car produced = 375/14.78 =25.37~25 cars/month
From the final solution we found that the total efficiency = 100-10.95=89.05%

Hence finally the total line balancing of the work stations and optimized the total cycle time for the production of 25 metro cars.

Production is increased by 47.06% (8 cars more than the standard)
Efficiency of the total System is brought to 89% which means it has a good layout plan
and good Process.

VIII. CONCLUSION

Proposed method is to optimize the bottleneck process cycle time by introducing multiskilled workers and also assigning proper addition and reduction of workers at right places.

This is achieved by analysing problems in QSA software. We managed to increase production to 25 cars per month. Production rate is increased by 47% (8 coaches more than the standard). We also increased the Efficiency of the total System to 7.23% which means it has a good layout plan and good Process. Capital investment is kept unchanged by swapping employees from the process with high idle time to bottleneck process.

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