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Research Article

Efficiency Improvement and Capacity Enhancement using Line Balancing Technique

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Abstract

Maximise the utilization of the resources by optimizing the working conditions and elimination of the waste is the ultimate goal of the lean manufacturing. In order to achieve this we have various tools which can be used as per the need of the project. In this paper we are going to optimize the use of resources by increasing the line efficiency by applying line balancing technique and achieving continuous flow. Increase in demand has set a new takt time which has given us an opportunity to redefine the flow of line and increase the line efficiency from 60.44% to 83.44%. We have used the results of method study to get modified times presented in the table, which helped to get balanced line with improved efficiency.

Keywords: *Line Balancing, line efficiency, takt time.*

Introduction

The study is conducted in an organization, which is a pioneer in control valves manufacturing since decades. Increasing market share of the organization has resulted to increase in demand of an assembly line by around 45%. Management has target to modify the assembly line to get 50% increase in output with the same available resources and to achieve the demand of an assembly line of 15600 valves per year.

For a given product there are two parallel lines namely Line-A and Line-B, working with identical capacities and setup with four major assembly stations having total 17 task distributed across and two subassembly stations having one task each. Line has total six operators distributed over eight assembly stations; with first operator working half time on each station-1, one operator each on station-2 and station-3 on each line and sixth operator again half a time on each station-4 of Line-A and Line-B. In present scenario to manage the half time operator at station-1 works half day for Line-A and half day for Line-B which has developed a batching pattern which is followed in every station till station-4.

Here in assembly line the organization have a demand of average 35 valves from the group hence 17.5 valves/day from Line-A and Line-B respectively. Based on this, the organization has started making a batch of 18 jobs on each station including sub-assembly stations. This has piled up the work in progress inventory and increased handling and searching time on each station. Also, station time for each station varies from 7.5 min for station 4 to 24 min for station 3 in minimum to maximum range. This results in excess load on higher cycle time station operator at station-4 and more relaxed time for station-3 operator. This resulted in poor utilization of the operator-1,2,4 and operator-3 was always overloaded.

Methodology

Line balancing is the apportionment of sequential work activities into workstations in order to get higher utilization of labour and equipment so as to minimize the idle time. In order to achieve the line balanced, we need to study the following terminologies:

- Workstation: It is a location where given amount of work is completed.
- Task: Smallest group of work activities that is assigned to workstation.
- Predecessor task: A task that must be performed before the next task.

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- Task Time: Time to perform the element task.
- Station time (T_S): Total standard work content of specific workstation.

Also, we will make use of following formulae:

- $Takt\ Time(T_C) = \frac{Available\ Time\ for\ Production}{Required\ units\ of\ production}$ (1)
- $Line\ Efficiency\ (\eta_L) = \frac{Total\ Station\ Time}{Takt\ Time\ x\ number\ of\ workstations}\ x\ 100$ (2)
- $Balance\ Delay(BD) = \frac{Total\ idle\ time\ for\ all\ workstation}{Takt\ Time\ x\ number\ of\ workstations}\ x\ 100 = [1 - \eta_L]x100$ (3)

The production capacity is calculated on the basis of working time available and the time of the bottleneck station, can be given as follows:

- $Production\ capacity = \frac{Availabletimein\ period\ p}{Timeof\ thebottleck\ station}$ (4)

Data Analysis and Results

Before Scenario

As already mentioned in the introduction, assembly line has two identical set-up. Here we have a flow of product elaborated as below:

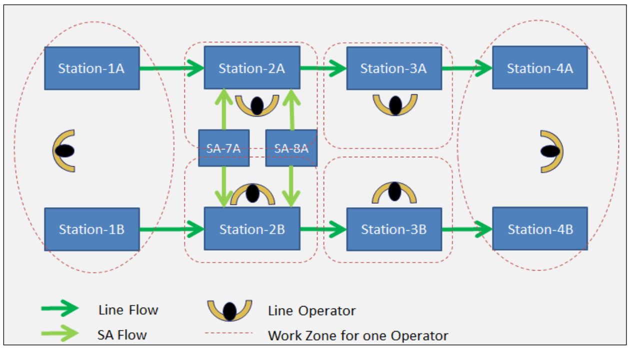

Fig-1: Flow Diagram of assembly line – before

In this flow Stations were having available manpower, available times and station time as follows:

Table-1: Details of assembly line

Station	Station-1	Station-2	Station-3	Station-4
Available manpower	0.5	1	1	0.5
Daily Available Time (min)	255	510	510	255
Station Time (Ts)	8.0	17.6	22.7	6.1

Bottleneck station is a station having maximum station time, here in above table station-3 is the bottleneck station. Now we can calculate the capacity of the line using equation (4) as follows:

$$Daily\ Production\ capacity = \frac{Daily\ Available\ time}{Timeof\ thebottleck\ station}$$
$$= \frac{510}{22.7} = 22.46 \frac{Valves}{day}$$

Here capacity available is equal to 22.5 valves considering station-3 as bottleneck station. Total capacity of the line combining part A & Part B is 45valves/day. This capacity was not suitable to meet the demand of the line hence need to work on improvements.

To ensure the optimum utilization of the line, we need to calculate the line efficiency and balance delay using equation (2) & equation (3) respectively. The line efficiency & balance delay was very low calculated as follows:

$$Line\ Efficiency\ (\eta_L) = \frac{Total\ Station\ Time}{Bottleneck\ station\ time\ x\ number\ of\ workstations}\ x\ 100$$

$$= \frac{8.0+17.6+22.7+6.1}{22.5\ x\ 4}\ x\ 100 = \frac{54.4}{90}\ x\ 100 = 60.44\%$$

Balance Delay (BD) = [1-0.6044]x100= 39.56%.

Precedence diagram of current scenario

An assembly line was having station times and work distribution of activities as follows:

Table-2: Precedence Table

S.No	Element	Notations	Cycle time in min	Immediate predecessor
1	Subassembly-1	A	1.4	-
2	Subassembly-2	B	0.8	-
3	Subassembly-3	C	1.7	-
4	Subassembly-4	D	2.4	A,b,c
5	Testing-1	E	0.6	D
6	Assembly step-1	F	1.1	E
7	Subassembly-5	G	2.0	-
8	Subassembly-6	H	1.6	G
9	Subassembly-7	I	2.0	G,h
10	Subassembly-8	J	2.8	F,i
11	Subassembly-9	K	2.0	J
12	Assembly-2	L	2.3	-
13	Testing step-2	M	8.5	-
14	Subassembly-10	N	1.3	M
15	Subassembly-11	O	3.3	-
16	Subassembly-12	P	1.3	L,n,o
17	Assembly step-3	Q	4.8	P
18	Testing-3	R	12.0	-
19	Subassembly-13	S	2.5	R,q

This results in formation of precedence diagram as follows:

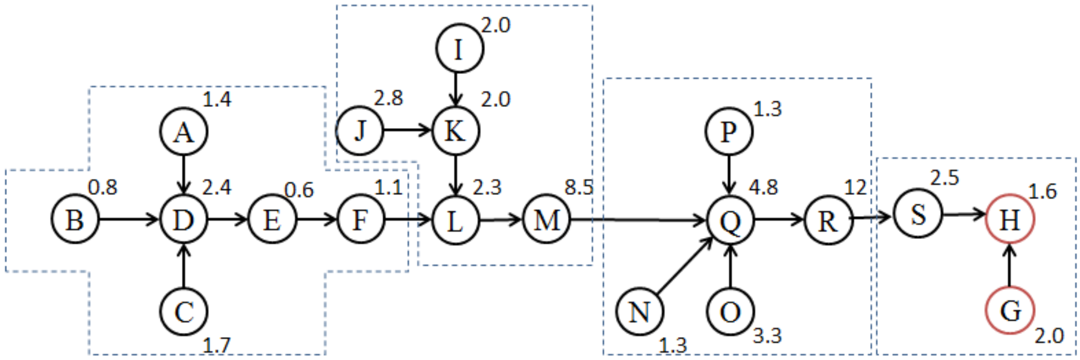

Fig-2: Precedence diagram for before state

Improvement

It can be seen from the results in section 3.1 that, there is need of line balancing in order to increase the efficiency and capacity improvement. Considering current flow, there are eight stations available and six manpower managing with station-1 & station-4 shared resource in each line. It is required to study the flow of process in detail and try to get an ideal situation of three stations and three operators on both the side with improved flow and utilization.

Expected demand for the line is 7800 valves from each part A & B. Hence it comes 30.6 units per day considering 255 working days per annum (as per input from the organization). Using equation (1)takt time with demand of 30.6 units per day and 510 minutes available can be calculated as follows:

$$Takt\ Time(T_C) = \frac{Available\ Time\ for\ Production}{Required\ units\ of\ production} = \frac{510}{30.6} = 16.7\ min$$

We can see the following chart for station time and takt time comparison of the projected demand with current state scenario.

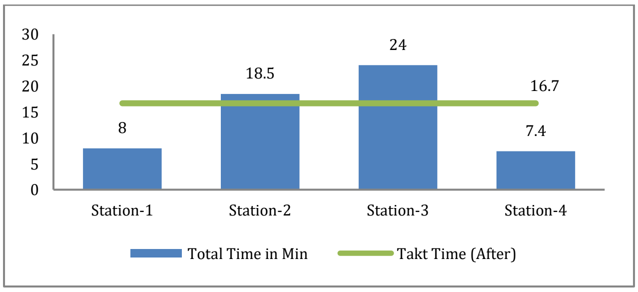

Fig-3: Takt time and station time chart for line - before

It can be seen from above charts that station-2 and station-3 times need to get below takt time level and also, station-1 & station-4 times are much lower than takt time hence can be loaded with extra activities.

Before working on modification, a method study (method study and its improvements are not taken under the scope of the paper) was done and times were modified with the details as follows:

Table-3: Improvements after method study

Task description	Task time (before)	Task time (after)	Time saving	Actions taken
Subassembly-1	1.3	1.2	0.1	Clean parts, ready to use
Subassembly-2	0.8	0.6	0.2	Clean parts, ready to use
Subassembly-3	1.7	1.4	0.3	Quick clamping vice
Subassembly-4	2.5	2.3	0.2	Auto-shut off straight tool
Testing-1	0.6	0.6	0.0	
Assembly step-1	1.1	1.1	0.0	
Subassembly-5	2.0	2.0	0.0	Change in assembly sequence-1
Subassembly-6	1.6	1.6	0.0	Change in assembly sequence-2
Subassembly-7	2.0	1.1	0.9	
Subassembly-8	2.8	1.1	1.8	
Subassembly-9	2.0	2.0	0.0	
Assembly-2	2.3	2.3	0.0	
Testing step-2	8.5	8.5	0.0	
Subassembly-10	1.3	1.3	0.0	
Subassembly-11	3.3	0.0	3.3	From other part of assembly section
Subassembly-12	1.3	0.0	1.3	Outsourced
Assembly step-3	4.8	2.3	2.5	Material handling improvement
Testing-3	12.0	10.0	2.0	Modification in assembly set-up
Subassembly-13	2.5	2.5	0.0	Change in assembly sequence-2
Total time in min	54.4	41.8	12.6	

Also, as per our discussion to achieve the idea condition of three stations and three resources each line, we modified the precedence diagram with combining some activities on station-1 & station-4. It was made with modification in precedence of activity H which was defined to be done after activity F on station-1 instead of activity S on station-4 which was also possible in technical point of view and also shifting one activity to station-3 from station-4 to get a modified precedence diagram as follows:

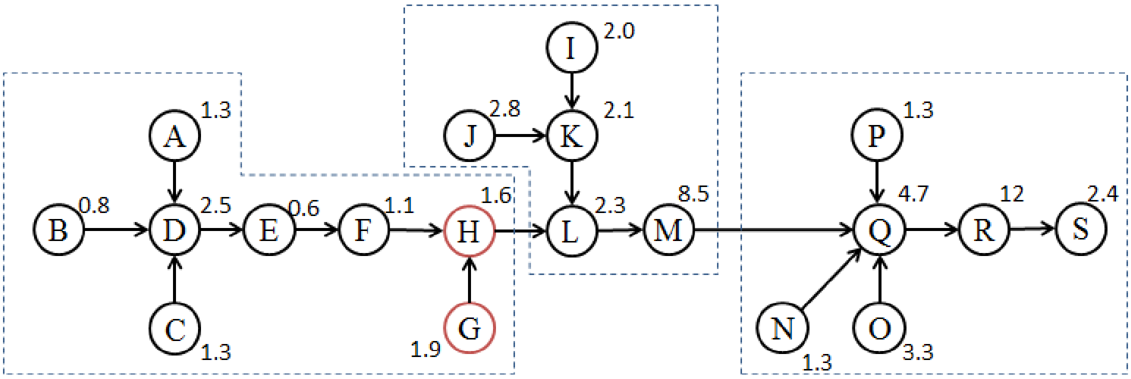

Fig-4: Precedence diagram for after state

Along with modification of precedence diagram and combining stations, station for sub-assembly-7 was made additional to provide it for individual operator. Sub-assembly-8 task was combined with station-2 as a part of improvement. The revised flow diagram of the line can be shown by below diagram:

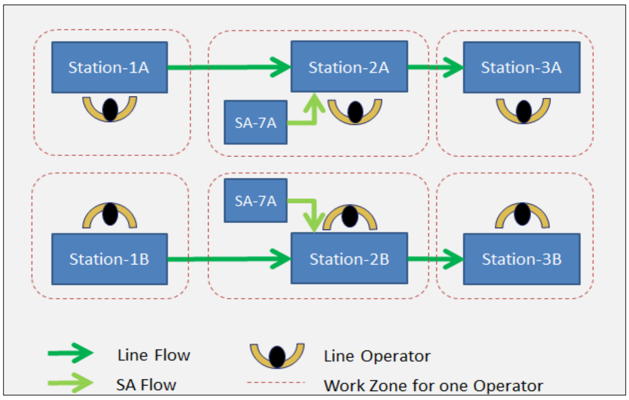

Fig-5: Flow Diagram of assembly line – before

As a result for which we got a revised station times as follows:

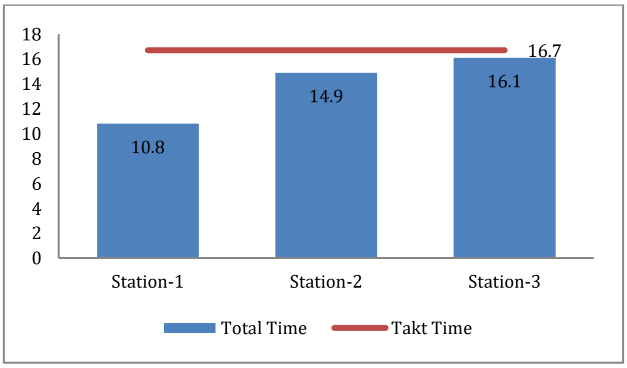

Fig-5: Takt time and station time chart for line-After

After Scenario

Now, we can calculate the same values we did in section 3.1 to see if benefits are achieved.

$$Daily\ Production\ capacity = \frac{Daily\ Available\ time}{Time of\ the bottleck\ station}$$

$$= \frac{510}{16.5} = 30.9 \frac{Valves}{day}$$

Here capacity available is equal to 30.9 valves per day considering station-3 as bottleneck station. Total capacity of the line combining part A & Part B is 61.8 valves per day.

$$Line\ Efficiency\ (\eta_L) = \frac{Total\ Station\ Time}{Takt\ time\ x\ number\ of\ workstations}\ x\ 100$$

$$= \frac{10.8+14.9+16.1}{16.7\ x\ 3}\ x\ 100 = \frac{41.8}{50.1}\ x\ 100 = 83.44\%$$

Balance Delay (BD) = [1-0.8343]x100= 16.56%.

Conclusion

We were able to get the expected demand and increase in line efficiency with more tangible outputs as follows:

Table-4: Tangible benefits of improvement

Sr. No.	Parameter of Comparison	Before	After
1	Capacity of Line (per day)	45	61.8
2	Line Efficiency	60.44	83.44
3	Balance Delay	39.56	16.56
4	Numbers of stations	8	6

The prime objective of achieving a continuous flow was possible using balanced line using modified material handling system which is not in the scope of the paper.

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