ASSEMBLY LINE BALANCING

Dr. V. Basavachari
Professor, MBA Department, AMC College, Bengaluru.

Abstract
Line balancing is a production strategy that establishes an intended rate of production to produce a desired product within a particular time frame. Assembly line is so designed so that there is an even flow of production from one work station to the next station. This is carried out by employing mechanized assembly technique, manual, semi-automatic or fully automatic assembling process in hi-tech industry.

Typically, line balancing operations are carried out on conveyor belt, turntable etc. Conveyor may be designed in U-shape or straight line conveyor. The configuration of workstations designed and set up along the assembly line and then assigning tasks (work elements) to each work station.The predominant objective being to achieve optimum efficiency of line balancing with minimum or zero idle time.

Introduction
Assembly line balancing is arranging a production line so that there is an even flow of production from one work station to the next station. A production line is said to be in balance when every worker's task takes the same amount of time. Line-balancing is a manufacturing function in which whole collection of production time tasks are divided into equal portions, well balanced times avoids labour idleness and improves productivity. It is a production strategy that sets an intended rate of production to produce a particular product within a particular time frame and available production capacity.

If work contents are not properly balanced in terms of operational time at each station, in other words, not optimized or not synchronized, this would leave the next work with idle time or delay. Line balancing reveals the concept of mass production system. This is typically employed to make-to-stock products that are generally high-volume consumer goods such as telephones, automobiles, wrist watches and many such FMCG products. The various operations pertaining to each work station are carried out at work centre called production shop (flow shop). The flowshop consists of a set of facilities through which work flows in a serial fashion. The same operations are carried out repeatedly in every work station. Value addition takes place at each stage of semi-finished product.

Literature Review
The very purpose of Assembly line balancing is to assign jobs to each work station in a manner that every work station has approximately same amount of work to be done.

Definition: Line balancing is defined as "the apportionment of sequential work activities into work stations keeping in view operational constraints and precedence.

Benefits of Assembly line Balancing in Organization

- Improved process efficiency
- Increased production rate
- Reduced total processing time
- Minimum or zero idle time.
- Potential in profits and decrease in costs

Theoretical background of the Research Study
The term used in L.B.Technique.
Cycle Time (CT): CT is the time interval at which completed products leave the production line.
Tasks: Elements of work or activity.
Task Precedence: Indicates the sequence in which tasks must be performed – except the beginning task, all other tasks have preceding tasks.
Task Times: The amount of time required for an automatic machine or a well-trained worker to perform a task.
Work Station: Physical location where a particular set of tasks is performed giving a shape to semi-finished product at subsequent station work station could be either a machine or equipment operated by a worker or an automatic machine or a machine operated by a robot.
Work Centre: A physical location (Hanger) where two or more identical work station are located in order to provide the needed production capacity.

Research Design

This research Article developed based on empirical study that has been carried out in M/s Schneider Electric India Pvt. Ltd. An MNC, located in Hosur Road, Bengaluru. The company started in the year 2009. There are 50 executives and 180 workers in all. It manufactures industrial electronic products and caters to the requirement of both domestic and export markets.

Product Range: L.V.Capacitors, M.V. Capacitors, Control panels and allied products. The company engages in the manufacture of both software and hardware products.

Objectives

1. To design a production line so that there is an even flow of production from one work station to the next;
2. To ensure that there are no delays at any work station that will leave the next work station with idle time;
3. To achieve high productivity and line efficiency;
4. To achieve optimum utilization of resources that is, manpower and infrastructure.
5. To achieve high level of labour productivity;
6. To motivate operation to earn more through group incentive scheme;
7. The specific objective of A.L.B. is to sub-divide the total assembly operation, assign into work station set up along the production line taking into account task precedence;
8. To achieve high revenue turnover leading to high rate on investment.

Statement of the Problem

The finished good also called asend product is composed of many sub-Assembly products. Such sub-assembly products are to be further processed progressively and subsequently following assembly precedence/constraints, to bring them into final product (finished good). Sub-Assembly products are broken down into elemental tasks. These are grouped into several sub-assemblies and then assigned to work stations along the production line such that there is even flow of job between work stations with minimum or zero idle time.

Mathematical Aspects of A.L.B

$$\text{Cycle Time (CT)} = \frac{\text{Available time}}{\text{Output required}}$$

Theoretical minimum number of workstations

The least number of workstations that can provide the required production, calculated as under:

$$N = \frac{\text{Sum of all task times}}{\text{Cycle Time (CT)}}$$

$$\text{Line balancing efficiency} = \frac{\text{Minimum no. of workstations}}{\text{Actual no. of workstations}}$$

$$= \frac{\sum t}{CT \times N}$$

Tej: j is used to identify the element out of the n_e elements that make up the total work.
TWC = Total work content
TWC is the aggregate of all the work elements to be done on the line.

$$TWC = \sum_{j=1}^{ne} Tej$$

Tsi = indicate the process time at station "i" of an 'n' stations line.

$$\sum_{i=1}^{n} Tsi = \sum_{j=1}^{ne} Tej$$

The minimum possible value of T_c is established by the bottleneck station, the one with the largest value of T_s.

$$T_c \geq \max T_{si}$$

$$T_c \geq T_{ej}$$

Balance delay (Balancing inefficiency) ‘d’

Balance delay is a measure of the line inefficiency which results from idle time due to imperfect allocation of work among stations.

$$d = \frac{nT_c - T_{wc}}{nT_c} = \frac{\text{Total idle time}}{\text{Total available working time of all stations}} \times 100$$

Where d = Balance delay – measure of line inefficiency due to imbalance in station times.

$$\text{Line efficiency } (L_e) = \frac{\text{Total station time}}{\text{Cycle Time} \times \text{No.of Work stations}} \text{ X } 100$$

Hypothesis

The empirical study allows for formulating hypothesis as follows:
Null hypothesis (H_o) : Line balancing efficiency is not achievable more than 85%.
Alternate hypothesis (H_a): Line balancing efficiency is achievable more than 85%.

Empirical Study

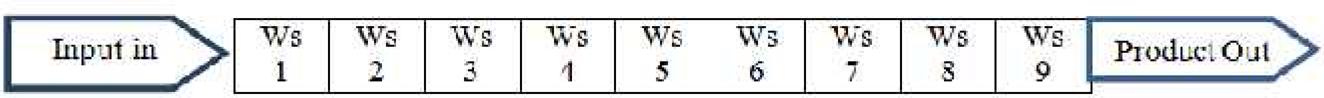
The company manufactures several types of capacitors and control panels. The Researcher selected ‘Clamptite Can Type Capacitor’ for study that is being assembled on the conveyor line-U-type. Both manual and semi-automatic operationare employed. Fixed type solid conveyor has been set up. The Fixed Conveyor Consists of multiple work-situations in which assembly work is accomplished as the product (sub-assembly) is passed from station to station. The parts are passed on from station to station by hand.

At each work station, operator performs a portion of the total assembly work, on the product by adding one or more components to the semi-finished product when it arrives to his station.

The flow (movement) of work is usually uneven. This results in variation of process time at a particular work station. In most practical situations, it is very difficult to achieve perfect balance among the stations along the conveyor line. When work station times are unequal the slowest station determines the overall production rate of the assembly line.

Particulars of Existing Assembly Line

(For manufacture of 3-elements Clamptite ‘can’ Type Capacitor)
Below drawn is an assembly line showing list of 9 tasks that needs to be accomplished to produce a product mentioned above. The time, as established by the company against each task or activity is indicated in addition, type of operations are also indicated.



Symbol	Task (activity)	Time in Secs	Type of Operation
A	Soldering process Station 1	49	Manual
B	Soldering process station 2	49	Manual
C	Can Assembly	37	Manual
D	|Capacitor Value Testing	31	Semi-automatic
E	Resin Filler	23	Semi-automatic
F	Pressing	08	Manual
G	Holder groove forming	12	Semi-automatic
H	Seeming operation	27	Semi-automatic
I	Terminal Soldering	35	Manual

Shift Time : 7.15 hour
Desired output as per Company : 529 parts

Table 1: Tasks allotted to work stations

Work Station	WS 1	WS 2	WS 3	WS 4	WS 5	WS 6	WS 7	WS 8	WS 9
Task	A	B	C	D	E	F	G	H	I
Task Time in sec.	49	49	37	31	23	08	12	27	35

No.of Work Stations - 9
Total processing Time: 49 + 49+37 + 37+ 31+ 23+ 08+12+27+35 = 271 seconds

Cycle Time of Assembly Line
CT is the maximum Time of individual Workstation
∴ CT = Maximum of 49,49,37,31,23,08,12,27,35
∴ CT = 49 Seconds

It is conspicuous and clear that stations 5,6 & 7 can be merged into single station since total task time of these three stations works out to: 23 + 08 + 12 = 43 seconds that is less than 49 secs being the cycle time. Now total number of stations is 7 instead of 9.

Calculation of Line efficiency consequent to rearrangement for better balance

Revised number of workstations 7
Total processing time 271 seconds

$$\text{Line balancing efficiency} = \frac{\Sigma t}{CT \times No.of\ Stations}$$

$$= \frac{271}{49 \times 7} = \frac{271}{343} = 79\%$$

Then, balancing delay = 100% - 79% = 21%

The Researcher has worked out the line efficiency taking the secondary data from past Record maintained by the company except for rearrangement of stations for better balance, that is, 7 stations instead of 9, as explained above.

This article is based on the empirical study that demands primary data. Hence, the Researcher attempted to conduct Time Study against each operation from 1 to 9.

The time Study conducted by the Researcher is exhibited below

Table 2

Operation No.	Cycle 1 In secs.	Cycle 2 In secs.	Cycle 3 In secs.	Cycle 4 In secs.	Average Time	Observed Rating
A	48	49	50	51	49.50	85%
B	49	48	51	50	49.50	80%
C	29	3o	31	32.31	30.58	90%
D	30	31	32	32.24	31.31	80%
E	23	24	24	21.93	23.23	85%
F	07	08	07	07.08	07.27	90%
G	10	11	12.64	10	10.90	90%
H	28	27	28	26.12	27.28	85%
I	32	33	32	30.28	31.82	90%

Table 3 : Calculation of Standard Time

Operation No	Average Time (insecs.)	Observed Rating (in %)	Standard Rating (in %)	Normal Time (in secs)	Standard Time* =Normal Time + 10% allowance
A	49.50	85	100	42.075	47.0
B	49.50	80	100	39.60	44.0
C	30.58		100	27.52	31.0

D	31.31	80	100	25.05	28.0
E	23.23	85	100	19.75	22.0
F	07.27	80	100	05.82	07.0
G	10.90	90	100	09.81	11.0
H	27.28	85	100	23.12	26.0
I	31.82	90	100	28.64	32.0

Rounded off to nearest second

Formulae used to compute Standard Time for each operation

Normal Basic Time = Observed time x Rating factor

$$= \text{observed Time} \times \frac{\text{Observed rating}}{\text{Standard rating}}$$

Observed Time x Observed Rating x Basic or Normal Time x Standard Rating

Standard rating is assumed to be 100%

$$\text{Normal time per unit of operation} = \frac{\text{ObservedTime/Unit} \times \text{Observed Rating}}{\text{Standard Rating}}$$

Standard Time/Unit of operation = Normal Time + Allowance Per unit

Allowance adopted usually 10% of Normal Time)
**** Average Time**

Table 4: Task, Precedence and Task Time as per Time study conducted

Task	A	B	C	D	E	F	G	H	I
Immediate Predecessor	Nil	A	B	C	D	E	F	G	H
Task time	47	44	31	28	11	7	11	26	32
Work station	1	2	3	4	5	6	7	8	9

CT = Maximum of (47,44,31,28,22,7,11,26,32)
∴CT = 47 seconds.

Stations namely 5, 6 and 7 can be merged since their task times 22 + 7 + 11 = 40 seconds < 47 cycle time. Hence, seven stations to be reckoned for calculating line efficiency.

Total Task Time = 47 + 44 +31 + 28 + 22 + 7 + 11 +26 + 32
= 248 seconds.

No. of work stations: $\frac{248}{47} = 5.27 \approx 6$

$$\text{Revised Line Balancing efficient} = \frac{\sum_{i=1}^{n} t}{\text{CT} \times \text{No.of Stations}}$$

$$= \frac{248}{47 \times 6} = \frac{248}{282} = 0.879 \text{ OR } 87.9\%$$

Balancing delay'd' = (100 – 87.9)

= 12.1%≈ 12%

Revised Line balancing efficient = 87.9%

As per secondary data Line balancing efficiency = $\frac{79.0\%}{8.9\%}$

∴ Increase in productivity efficiency = 9%

Conclusion

Assembly line balancing is a significant phase in manufacturing industry. There are a few techniques such as manual, mechanised, semi-automatic, robotic for handling components turntable all are employed for line balancing process. It is a production strategy that sets an intended rate of production to produce a particular product within a specified time frame. Also, the assembly time for each segment of operations needs to be balanced effectively for efficient production; the tasks need to be distributed among workers, machines and workstations ensuring that every operational to meet each segment in the production process can be met within the time frame and available production capacity. The overall goal of line balancing is to minimise idle time between work stations or achieve zero idle time (rarely possible) which would ensure uninterrupted product flow.

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