PRODUCTIVITY IMPROVEMENT IN BREWERIES THROUGH LINE BALANCING USING HEURISTIC METHOD

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ABSTRACT

This paper presents a heuristic procedure for improving productivity in breweries companies. A case study of Champion brewery Plc, Uyo, Akwa Ibom State was adopted. The aim of this paper is to balance the Production line of Champion lager beer. In the course of line balancing, the idle time and the number of workstations on the production line was minimized so as to maximize the efficiency of the production line. All the required data was measured and the parameters such as elapsed time at each work station, efficiencies, number of workers, time of each of the workstations etc. was calculated from the existing line. A new heuristic approach, the Longest Operation Time (LOT) method was used in designing the new production line. After set up of the new production line, the cost of production and effectiveness of the new line was computed and compared with those of the existing one. The new production line was found to have been increased by a significant amount reducing the overall production cost per unit.

Keywords*:* Assembly Line Balancing (AlB*)*, balancing techniques, idle time, Line Efficiency, Task Time, Cycle Time and Bottleneck.

1. Introduction

Assembly lines are production systems developed to meet the requirements of mankind, which continue to grow day by day. The demand for greater product variability and shorter life cycles has caused traditional production methods to be replaced with assembly lines. The aims of these systems are to manufacture products at production rates in the shortest time, in the most productive way, cheaply and with the quality required. Since assembly line balancing is an NP-hard problem, some heuristic methods are still needed to solve large scale assembly line balancing problems.

An assembly line consists of a number of workstations which are arranged along a conveyor belt, or similar material transportation equipment, in order to obtain a sequence of finished product types. The work pieces are moved from station to station and at each one certain operations are performed in view of some constraints. The first primary constraint is the cycle time. The cycle time is the time interval between finishing two units or the maximum available time for the production of any work piece at any workstation. Assembly line exists when we assemble or handle any device or product in a planned, sequential manner with two or more operators performing tasks of repetitive work at established workstation (Milas, 1990). When the products have many operations and the demand is high the process of balancing the line becomes more difficult. There are two types of optimization problems for the line-balancing problem (Ajenbit, 1998). In Type I, the cycle-time (maximum amount of time units that can be spent at each workstation) is fixed and the objective is to minimize the required number of workstations. The Type II attempts to minimize the maximum cycle-time given a fixed number of workstations. This research paper will adopt the Type I problem. The overall objective of this paper is to improve productivity through line balancing by minimizing both labour and idle times on the production line.

This paper intends to investigate and evaluate the line balancing problem in a production line of Champion lager beer .The paper seeks to:

I. Identify the line balancing problem.
ii. Identify the idle time at each workstations and how it can be reduced.
iii. Asses the workstations on the production lines in order to minimize the number of workstations.

1.1 Terminology Defined:

The Terminology of assembly line analysis are as follows:

1. Work Element (i): The job is divided into its component tasks so that the work may be spread along the line. Work element is a part of the total job content in the line. Let TV be the maximum number of work element, which is obtained by dividing the total work elements into minimum rational work elements. Minimum rational work element is the smallest practical divisible task into which a work can be divided. The time in a-work element, *i* say (TjN), is assumed as constant.

2**. Work Stations (**w**):** It is a location on the assembly line where a combination of few work elements is performed.

3**. Total Work Content (**Twc**):** This is the algebraic sum of time of all the work elements on the line.

4**. Station Time (**Tsi**):** It is the sum of all the work elements (i) on work station (s).

5**. Cycle Time (c):** This is the time between two successive assemblies coming out of a line. Cycle time can be greater than or equal to the maximum of all times. If, c = max {Tsi}, then there will be ideal time at all stations having station time less than the cycle time.

6. **Delay or Idle Time at Station (**Tds): This is the difference between the cycle time of the line and station time.

7. **Precedence Diagram:** This is a diagram in which the work elements are shown as per their sequence relations. Any job cannot be performed unless its predecessor is completed. A graphical representation, containing arrows from predecessor to Predecessor have the successor work element. Every node in the diagram represents a work element.

8. **Balance Delay or Balancing Loss** (d): This is a measure of line-inefficiency. Therefore, the efficient is done to minimize the balance delay. Due to imperfect allocation of work along various stations, there is idle time to station.

9. **Line Efficiency** (LE): It is expressed as the ratio of the total station time to the cycle time, multiplied by the number of work stations.

10. **Target time:** Target cycle time (which must be greater than or equal to the target task) or define the target number of workstations.

2. Method Used

The Longest Operation Time (LOT) procedure is used in this research work. It is the line-balancing heuristic that gives top assignment priority to the task that has the longest operation time. The steps of LOT are:

LOT 1: To assign first the task that takes the most time to the first station.

LOT 2: After assigning a task, to determine how much time the station has left to contribute.

LOT 3: If the station can contribute more time, assign it to a task requiring as much time as possible.

2.1 Data and Results

The following are the work elements that make up the production line of Champion lager beer:

1. Carrying pallets from the store by the forklift to the production line.
   Break Point: Forklift drops the pallet.
2. Depalletizing by depalletizer.
   Break point: Depalletizer drops the last crate.
3. Moving one crate to Decrater
   Break Point: The crate reaches the Decrater
4. Decrating by Decrater.
   Break point: The bottles are dropped on the conveyor
5. The empty crate moves to the crate washer
   Break point: The crate is at the exit of crate washer.
6. The empty bottles moves to the bottle washer.
   Break point: The bottles are at the entrance of the bottle washer.
7. Washing of the bottle by bottle washer.
   Break point: The bottle is at the exit of the bottle washer.
8. Pre-Inspection by Inspector.
   Break point: The bottle is at the exit of the pre-inspection point.
9. The bottle moves to empty bottle inspector.
   Break point: The bottle is at the entrance of the empty bottle inspector.
10. Empty bottle Inspection by Inspector.
    Break point: The bottle is at the entrance of the full inspection light.
11. The bottles moves to the filler and crowner

Break point: The bottle is at the entrance of the filler.

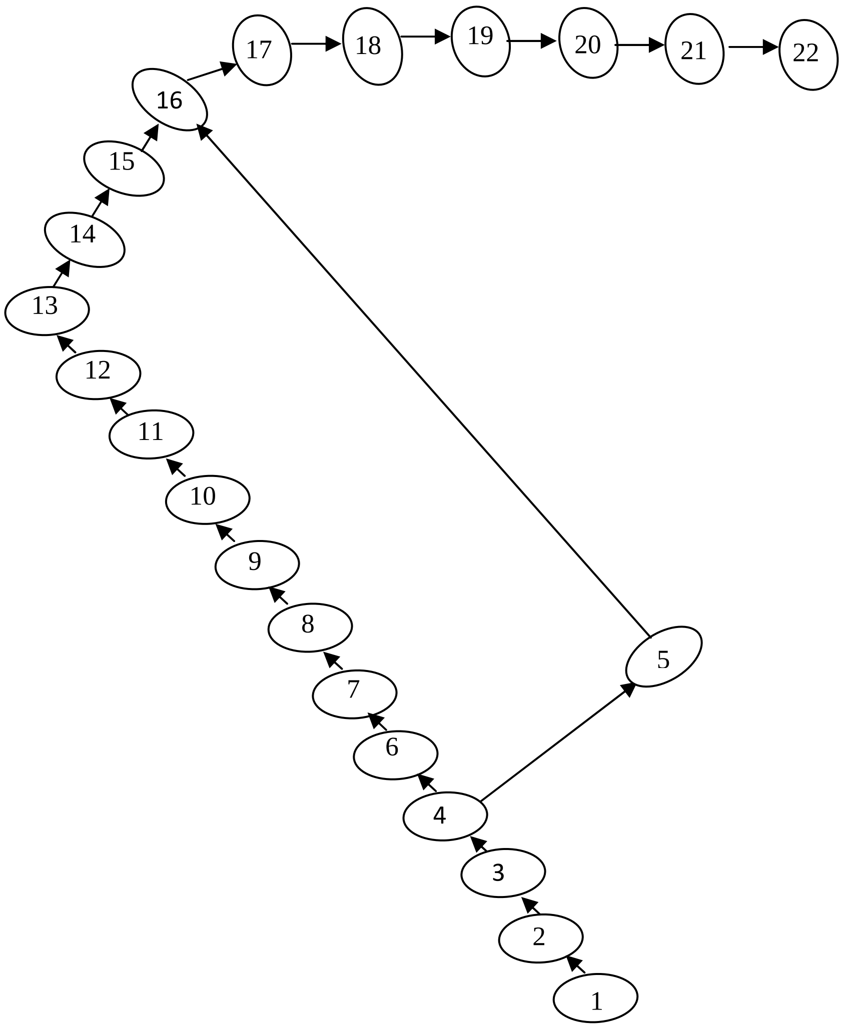
12. Filling of the bottle with the beverage and crowning.
    Break point: The bottle is at the exit of the crowner.
13. The bottle moves to the manual filled bottle inspector.
    Break point: The bottle is at the exit of the manual filled bottle inspector.
14. The bottle moves to pasturizer for treatment.
    Break point: The bottle is at the entrance of pasturizer.
15. Full inspection by pasturizer.
    Break point: The bottle is at the exit of the pasturizer.
16. The bottle moves to the labeler.
    Break point: The bottle is at the entrance of the labeler
17. Labeling the bottle by Labeler
18. The bottle moves to the packing table.
    Break point: The bottle is at the packing table.
19. Packing at the packing table by Packer.
    Break point: A crate of Coca Cola is packed.
20. The crate moves to the palletizer.
    Break point: A crate reaches the palletizer.
21. Palletizing by palletizer.
    Break point: A pallet is packed.
22. Carrying a pallet to the store by forklift.
    Break point: A pallet gets to the store.

The work elements (or tasks) are represented by numbers 1 to 22.

The time study was conducted on one pallet of 60cl bottle of Champion lager beer. One pallet contains 48 crates, which contains 12 bottles each. Therefore, the total number of bottles in one pallet is 576 bottles.

It takes 12856 seconds to produce one pallet of Champion lager beer. This means, a crate, which contains 12 bottles, is produced in 275 seconds. The precedence diagram of Champion lager beer production line starts with carrying the pallets from the store by the forklift and ends with carrying pallet of finished product to the store. Task 12 is the bottleneck operation and its task time is 108 seconds is the cycle time. Thus, cycle time is 108 seconds. Champion lager beer production lines originally have 9 workstations and 15 workers excluding one supervisor. The production line is comprises of machines and workers. The production line is been monitored and operation of the line is analyzed in this research paper.

This figure below shows the Precedence diagram of Champion lager beer production line:



Task number 12, (filling the bottle with the beverage and crowning) has a task time of 108 seconds giving us a production rate of 400 crates per day.

The table below shows the summary sheet for Champion lager beer Production line:

Task or Element	**Basic time (sec)**	**ALLOWANCE (sec)**		**Standard Time per Pallet (sec)**	**Standard Time per Crate (sec)**
		Fatigue (4%)	**Personal Need (6%)**		
1	197	7.88	11.82	217	5
2	262	10.48	15.72	288	6
3	273	10.92	16.31	300	6
4	542	21.68	32.02	596	12
5	217	8.68	13.02	239	5
6	480	19.2	28.8	528	11
7	989	39.56	59.34	1088	23
8	206	8.24	12.36	227	5
9	202	8.08	12.12	222	5
10	559	22.36	33.54	615	13
11	210	8.4	12.6	213	4
12	4700	188	282	5170	108
13	245	9.8	14.7	270	6
14	189	7.56	11.34	208	4
15	613	24.52	36.78	674	14
16	206	8.24	12.36	227	5
17	498	19.92	29.88	548	11
18	218	8.72	13.08	240	5
19	506	20.24	30.36	557	12
20	185	7.4	11.1	204	4
21	250	10	15	275	6
22	208	8.32	12.48	229	5
TOTAL				**12856**	**275**

The production line of Champion lager beer is operational for 12 hours in seconds daily.

$$\text{Maximum daily output} = \frac{\text{Available time per day in seconds}}{\text{Cycle time required per crate}}$$

$$= \frac{3600 \times 12}{108}$$

$$= \frac{43200}{108}$$

$$= 400 \text{ crates/day}$$

The table below shows the assignment of task to workstations for Champion lager beer Production line:

Workstation	Number of workers	work element	Task times (sec)	Time per station (sec)	Idle time Per station (sec)
1	2	1 2 3 4	5 6 6 12	29	79
2	1	5 6	5 11	16	92
3	2	7 8	23 5	28	80
4	2	9 10 11	5 13 4	22	86
5	1	12	108	108	0
6	2	13 14 15	6 4 14	24	84
7	1	16 17	5 11	16	92
8	1	18 19	5 12	17	91
9	2	20 21 22	4 6 5	15	93
TOTAL	**15**			**275**	**697**

2.1.1 Sample Calculation of the existing Production Line:

$$\text{Idle time per day} = \frac{\text{Total idle time per station}}{\text{One hour in seconds}}$$

$$= \frac{697}{3600}$$

$$= 0.2 \text{ hours}$$

$$\text{Line efficiency} = \frac{\text{Total Station time}}{\text{Cycle time x no of workstation}} \times 100\%$$

$$= \frac{275}{108 \times 9} \times 100\%$$

$$= 28.3\%$$

$$\text{Balance Delay (BD)} = \frac{\text{Idle time of all workstations}}{\text{Available working time for all stations}}$$

$$\text{BD} = (100 - \text{LE})$$

$$= (100 - 28.3)\ \%$$

$$= 71.1\%$$

$$\text{Balance Efficiency} = \frac{\text{Theoretical minimum no. of workers}}{\text{Actual no. of workers}}$$

Theoretical minimum no. of worker $= \frac{\Sigma T}{CT}$

Since, Total time, $\Sigma T = W1T1 + W2T2 + W3T3 + \ldots\ldots\ldots + WyTy$
$= 3 \times 29 + 1 \times 16 + 2 \times 28 + 2 \times 22 + 1 \times 108 + 2 \times 24 + 1 \times 16 + 1 \times 17 + 2 \times 15$
= 885 seconds

Theoretical minimum no. of worker $= \frac{885}{108}$

$= 8.2$ no.

Balance Efficiency $= \frac{8.2}{15} \times 100\%$

$= 55\%$

Balancing of Champion lager beer Production line as to minimize the number of work stations. Originally, the production line of Champion brewery has 9 workstations. In an attempt to balance the line, the new number of workstations is calculated as follows:

Theoretical minimum Number of workstation $= \frac{\left(\text{Total work content (Time) per unit}\right)\left(\text{Desire number of units per day}\right)}{\text{Total productive time available per day}}$

$= \frac{\text{(Total time per cycle)(Desire number of unit}}{\text{Available time per day}}$

$= \frac{275 \times 400}{43200}$

$= 2.55$

$=$ 3 stations

To balance the production line, the tasks or elements would be assigned to at least 3 workstations following the precedence relationship of the elements. The performance times assigned to each station cannot exceed 108 seconds cycle time. To minimize idle time, the line should now have 3 workstations and 10 workers, instead of the previous 9 workstations and 15 workers.

The table below shows the new task workstations assignment in Champion lager beer Production line:

Workstation	Number of workers	Task or element	Task time (sec)	Time per station (sec)	Idle time per station (sec)
		1	5		
		2	6		
		3	6		
		4	12		
		5	5		
		6	11		
		7	23		
		8	5		
		9	5		
		10	13		
1	5	11	4	95	13
2	1	12	108	108	0
		13	6		
		14	4		
		15	14		
		16	5		
		17	11		
		18	5		
		19	12		
		20	4		
		21	6		
3	4	22	5	72	36
TOTAL	**10**			**275**	**49**

Sample Calculation of the New Production line:

$$\text{New idle time per day} = \frac{\text{Idle time cycle}}{\text{One hour in seconds}} = \frac{49}{3600} = 0.14 \text{ hours}$$

The new idle time per day is 0.14 hours compared to the former 0.2 hours

$$\text{New Line efficiency} = \frac{\text{Total station time}}{\text{Cycle time x no. of workstation}} \times 100\% = \frac{275}{108 \times 9} \times 100\% = 84.9\%$$

$$\text{New Balance Delay (BD)} = (100 - LE) = (100 - 84.9)\ \% = 15.1\%$$

$$\text{New Balance Efficiency} = \frac{\text{Theoretical minimum no. of workers}}{\text{Reduced no. of workers}} \times 100\% = \frac{8.2}{10} \times 100\% = 82\%$$

3. Cost analysis and comparison

The table below shows the cost analysis and comparison of Champion lager beer Production line:

Station number	No. of workers of the existing production line
01	3
02	1
03	2
05	1
06	2
07	1
08	1
09	2
Total	**15**

New station number	No. of workers of the new production line
01	5
02	1
03	4
Total	**10**

Total no. of reduced workers = 10 Nos.

The company pays at least ₦1500 to every worker for each working day.

The previous design of the production line has 15 workers at the production line. Therefore, the total labour costs for the previous design of production line are:

Daily labour cost = ₦1500 x 15 = ₦22,500.00

Weekly labour cost = ₦22,500 x 6 = ₦135,000.00

Monthly labour cost = ₦22,500 x 26 = ₦585,000.00

Considering one day as holiday, the number of working days in a month = 26

Hence, the previous design of the production line of Champion lager beer shows that the top management spent ₦585,000.00 per month for workers salary.

The new production line of Champion lager beer has 10 workers at the production line. The total labour costs for the new design of the production line are:

Daily labour cost = ₦1,500 x 10 = ₦15,000.00

Weekly labour cost = ₦15,000 x 6 = ₦90,000.00

Monthly labour cost = ₦15,000 x 26 = ₦390,000.00

The modify production line of Coca Cola, reveals that the company spent ₦390,000.00 per month for workers salary.By comparison, the new production line will improve the productivity of the company by minimizing the labour cost in the production line. The difference between the previous and the new production line of the labour cost per month is ₦585,000 – ₦390,000 = ₦195,000.00

Therefore, it would be now easy to realize that, it would be more profitable to choice the modify production line, because it minimizes the labour cost per month of the production line by ₦195,000.00.

In summary, Champion lager beer production line was balanced using longest operational time (LOT). The idle and workstations was minimized to improve productivity. A modify or new production line of 3 workstations and 10 workers was introduced instead of the previous 9 workstations and 15 workers. It was discovered that the worker responsible for task 2 (i.e depalletizing) could also take care of task 3. Also, the worker responsible for task 12 (i.e filling the bottle with beer and crowning) could also take care of task 13 and the worker responsible for task 14, could also take care task 15 and finally, worker responsible for task 20, could also take care of task 21 and 22. This led to the reduction of workers from 15 to 10 workers. As a result of this, the labour utilization or line efficiency increased from 28.3% to 84.9%, the idle time or balance delay reduced from 17.7% to 15.1% and the balance efficiency increased from 55% to 82%. Consequently, daily labour hour idle reduced from 0.2 hours to 0.14 hours and labour cost per month of the production line reduced from ₦585,000.00 to ₦390,000.00.

4. Conclusions

The cycle time used and the precedence diagrams used were based on the result of this study. Normally, it took 12856 seconds for Champion Brewery PLC., Plant to produce one pallet of 60cl bottles of Champion lager beer. The production line runs 12 hours and the maximum daily output is 400 crates (i.e 4800 bottles). The production line consists of 9 workstations and 15 workers including one supervisor. Before the production line was balance, the line was not efficient. The line efficiency was 28.3%, the idle time was 17.7%, the balance efficiency was 56% and the daily idle time was 0.2 hours. As a result of assembly line balancing, the line efficiency increased from 28.3% to 84.9%, the idle time decreased from 17.7% to 15.1%, the balance efficiency increased from 53% to 82%, and the daily idle time reduced from 0.2 hours to 0.14 hours. Through the study of the total costs, it had been shown that ₦195,000.00 could be saved every month. Although the output remains the same but the number of workstations reduced from 9 to 3 workstations and the number of workers reduced from 15 to 10 workers including one supervisor. Hence, the same amount of product (Champion lager beer) is produced at less cost.

4.1 Recommendations and Recommendation for further study

On Champion lager beer production line, task 12 is the bottleneck operation. The company should create an efficient pathways linking pasturizer to the labeler. The empty inspection light should also be replaced with a new one for higher performances. Lastly, the speed of the conveyor belt should be increased for efficient drive. This paper covered extent of activities on the production line, for further studies, work measurement and assembly line balancing should be carried out on other sectors of the industries. The other sectors include placement of orders of raw material before getting to the production line, storage and before and after sale services. Also, other heuristic techniques for production line balancing should also be used for further studies.

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APPENDIX 1

Table below shows the summary result of Champion lager beer Production line:

S/n	Sample Calculation	Before line balancing	After Line Balancing
1	Idle time per day(hours)	0.2	0.04
2	Line efficiency (%)	28.3	84.9
3	Balance delay (%)	71.1	15.1
4	Balance efficiency (%)	55	82
5	Labour cost per month (N)	585,000.00	390,000.00

APPENDIX 2

Time study top sheet for Champion lager beer Production line

	Observed time (sec)										Total time (sec)	Average time (sec)	Ratin g	Basic time (sec)
E	1	2	3	4	5	6	7	8	9	10				
1	180	175	165	185	190	180	195	170	160	190	1790	179	110	197
2	264	250	255	260	270	275	268	258	250	272	2622	262.2	100	262
3	280	270	260	285	274	288	266	275	279	265	2733	273.3	100	273
4	456	465	475	486	495	512	520	450	530	535	4924	492.4	110	542
5	200	192	198	220	215	210	195	185	180	175	1970	197	110	217
6	485	476	478	480	481	480	476	480	481	489	4800	480	100	480
7	900	920	915	850	855	895	885	935	930	910	8995	899.5	110	989
8	204	214	228	230	210	198	195	190	192	200	2061	206.1	100	206
9	195	190	200	215	225	185	180	184	220	230	2024	202.4	100	202
10	553	560	543	565	548	568	570	550	560	568	5585	558.5	100	559
11	200	220	190	210	215	195	220	210	230	200	2100	210	100	210
12	4800	4700	4480	4600	4850	4650	4860	4660	4750	4650	47000	4700	100	4700
13	252	242	230	220	255	260	265	270	235	225	2454	245.4	100	245
14	180	185	189	192	178	186	195	198	200	175	1878	187.8	100	189
15	560	554	550	540	565	560	570	555	545	575	5574	557.4	110	613
16	200	216	220	225	195	198	190	187	215	210	2056	205.6	100	206
17	475	450	445	435	460	455	465	430	445	470	4530	453	110	498
18	220	222	218	215	200	210	230	225	235	205	2180	218	100	218
19	460	456	450	465	455	470	445	440	475	485	4601	460.1	110	506
20	190	180	196	184	186	176	170	180	190	195	1847	184.7	100	185
21	254	250	248	240	235	260	262	248	268	238	2503	250.3	100	250
22	210	215	200	206	196	190	189	225	218	226	2075	207.5	100	207

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