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Line Balancing Techniques to Improve Productivity Using Work-Sharing Method in Footwear Industry

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ABSTRACT

The expanding economy of Bangladesh encourages the expansion of the leather industry. This environment leads to severe competition in the leather products industry, notably in the footwear industry, allowing businesses to develop high-quality items to meet customer demands. To reach the demand, companies must push themselves toward high Productivity. Due to different existing and hidden problems, sometimes, they face challenges in meeting the target capacity. The assembly lines on the production floor should be well-designed and efficiently utilized to solve the problems. Line balancing techniques are very popular in increasing Productivity. Line balancing is an efficient way to enhance assembly line production while lowering cycle time and bottlenecks. Line balancing is the problem of allocating tasks to workstations along an assembly line in the most efficient manner. The primary purpose of this project is to raise the overall Productivity of a single-model assembly line by decreasing bottleneck events, cycle time, and workload distribution at each workstation through line balancing, utilizing line-balancing techniques and the work-sharing approach. Work sharing is an employment arrangement in which two or more persons are engaged on a part-time or reduced-time basis to execute a job that a single full-time employee generally performs. The major purpose of this study is to raise the overall efficiency of a single-model assembly line by reducing non-value-added tasks, cycle time, and workload allocation at each workstation. To increase overall Productivity, the technique chosen involves evaluating the cycle time of the process, identifying non-value-added activities, estimating the total workload on the station, and balancing the workload on each workstation through line balancing.

Keywords: Line balancing, Line efficiency, Labor productivity, Work-sharing method, Productivity.

1. Introduction

The footwear industry is an important part of the world's supply chain and one of its largest industries. The footwear manufacturing process consists of different distinct phases [1]. The stitching process is typically the most difficult since it requires many operations. The sewing line is composed of a sequence of workstations where a certain task is executed in a specified order. One too many tasks are often given to a single workstation. Operators are assigned jobs according to the limitations imposed by differing labor skill levels. In conclusion, multiple workstations are arranged sequentially to create a sewing line [2]. Shop floor managers are concerned with maintaining line balance by distributing duties to workstations as equitably as possible. Uneven workload throughout a sewing line's workstations will increase work-in-process and waiting time, indicating a rise in production cycle time and cost [3]. In practice, sewing line managers or production controllers use their experience to assign tasks to workstations based on the task order, worker skill levels, and average time required to complete each activity [4]. Due to variances in assignment selection and work experience, it is impossible to guarantee the performance of the line balance from one manager to the next. In the footwear business, the production of a product involves going through several different steps. Each stage must be performed on a machine with specific settings, such as the color of the yarn or the machine attachment. Since the creation of a product typically involves various types of sewing machines and different colors of yarn, it is

unsuitable for assigning a single machine to individual responsibility. There is a limited number of machines that each employee is allowed to utilize in the production of a certain item. For instance, it depicts the line configuration of the problem that was taken into consideration for this research. The optimization model considers both the skill levels of the employees and the limitation placed on the number of machines that may be located at each station (worker).

2. Methodology

A production line on the operation floor was selected, and then the necessary data was gathered from that line to achieve balance in the production line. Two crucial factors have been considered: first, a feasible standard method for each procedure, and second, a substantial amount of time, which serves as an input for a time study and is used to record the actual individual capacity of each worker [5]. Both aspects are important. The amount of time it takes to complete each procedure for every single worker is timed and recorded so that the number of operators and helpers, types of machines, and individual capacities may be determined. To determine (the standard minute value), process-wise capacity, the actual capacity line graph, labor productivity, and line efficiency, the following steps must be followed [6].

- To determine the cycle time of every operation.
- To determine the capacity of each station.
- To calculate the S.M.V. (Standard Minute Value).
- To identify the station of a bottleneck.

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- To Balance cycle time by adjusting the workforce.
- To apply U-shaped single model line balancing design and increase the number of available stations.
- To eliminate bottlenecks by work sharing.
- To update the calculation.
- To complete work instruction and implement.

3. Working-Sharing Method

Work-sharing is a common understanding in which two or more persons are retained on a part-time or reduced-time basis to execute a job that is generally performed by a single full-time employee [7]. An order that had been initiated in that line is picked, with the total amount of the order, the style description, the kind of leather, and the color being known. The first is the presence of a prospective standard procedure for each process, and the second is the considerable amount of time that elapsed between the input and the time required by the study to record each worker's actual individual capacity. We have kept a record of the amount of time it takes for each and every worker to complete each procedure. This allows us to determine the number of operators and helpers needed, as well as the types of equipment and individual capacities. In order to determine the S.M.V., the process-wise capacity has been computed. Using code blocks, we also determined the target capacity, the benchmark capacity, the actual capacity line graph, worker productivity, and line efficiency [7]. After gathering all pertinent information about the line, we proposed a method of line balancing that would be suitable for the line. First, we identified the processes that were causing the bottlenecks that were our primary concern, and then we sought solutions to reduce the severity of the problem. In the framework of this project, we presented an approach for balancing the line that included splitting the workload among individuals with comparable abilities and past experience in both the bottleneck and balancing processes. The line has been balanced, taking into account both the bottleneck and the balancing process, with the balancing process consuming a portion of the additional time remaining after the benchmark goods were produced in the bottleneck process [8].

4. Experimental setup/Numerical modeling

- Average Required Time = Total Cycle Time ÷ Number of Cycle Time
- Normal time = Average required time × Performance Rating
- Standard Minute Value (SMV) = Normal Time + Allowance (10% of Normal Time)
- Dedicated Cycle Time = S.M.V. ÷ Number of Operators Worked
- Capacity = 60 ÷ Dedicated Cycle Time
- Labor Productivity = Labor hours per day ÷ Unit produced per day (hours/unit)
- Line efficiency = Total output per day per line
 $\times \text{Total SMV} / \text{Total manpower per line} \times \text{Total}$

working minutes per day

- Takt time = Total SMV / Number of operators
- Target/hour = Total number of Operators
 $\times \text{Total working minute per day} / \text{Total SMV}$ [6].

5. Data Analysis and Calculation

Table 1 S.M.V. and Capacity of each station

Work station number	Work	Average Required Time (sec)	Manpower	SMV(N+Allowance) sec	Round hourly capacity
1	Charging	41	1	33.005	109
2	Marking	42	1	43.47	83
3	Tape attaching	60	1	62.1	58
4	Charter and lining joining	40	2	32.2	112
5	Stitching that join	40	1	36.8	98
6	Joining two	40	1	41.4	87
7	Quarter zigzag and counter	62	1	64.17	56
8	Tape attaching on the stitching	63	1	43.47	83
9	Attaching batch	34	1	31.28	115
10	Folding vamp/quarter	98	1	67.62	53
11	Attaching tape on elastic	48	1	33.12	109
12	Attaching back strip and quarter	71	1	48.99	73
13	Stitching that join	62	2	49.91	72
14	Joining vamp and quarter with glue	97	1	66.93	54
15	Stitching the joint of vamp and quarter	87	1	90.045	40
16	Adding adhesive to elastic	93	2	64.17	56

17	Elastic by adhesive	52	1	53.82	67
18	Back cement	44	2	35.42	102
19	Vaccine	87	1	70.035	51
20	Stitching backstrip	40	2	41.4	87
21	Addin g glue of white paper	50	1	46	78
22	Adding black paper	57	1	45.885	78
23	Stitching on the mark	41	2	42.435	85
24	Removing that white part	41	1	33.005	109
25	Stitching on another part	56	1	38.64	93
26	Addin g glue to elastic	27	2	24.84	145
27	Inserting contour in upper	26	2	17.94	201
28	Marking	59	1	61.065	59
29	Attachin g white tap strip in	58	1	53.36	67
30	Elastic joint with upper 1	81	1	65.205	55
31	Elastic joint with upper 2	87	1	60.03	60
32	Hammering	42	1	38.64	93
33	Adding toe puff	49	1	50.715	71
34	Adding glue to lining	25	1	23	157
35	Adding glue to upper	71	1	57.155	63
36	Lining setting	86	1	89.01	40
37	Top lining sewing 1	96	2	88.32	41
38	Top lining sewing 2	84	1	77.28	47
39	Hand trimming	74	2	68.08	53
40	Pesting	55	1	56.925	63

6. Benchmark Capacity

The theoretical capacity is 77.23 units/hour. We decided to take 60% of that capacity as a benchmark, which is 46 units/hour.

Table 2 Line Efficiency and Productivity of the line before line balancing

Before balancing line		
Total output per day	330	unit
Total manpower	50	
Working Time	600	minutes
SMV	38.84	minutes
Takt time	0.7768	minutes
Target/hour	77.23(100%)	
Target/hour	61.78(80%)	
Target/hour	46.38(60%)	Benchmark 60%
Labour Productivity	0.03030303	hours/unit
Line Efficiency	42%	

7. Proposed Algorithm

The name of the mathematician Al-Khwarizmi, which literally translates to "a procedure or a technique," is where the word "algorithm" comes from. The planning and problem-solving processes typically involve the usage of an algorithm by software engineers. An algorithm is a series of stages that can be followed to solve a specific problem. Another definition of an algorithm is "an ordered set of unambiguous actions that produce a result and finish in a finite amount of time

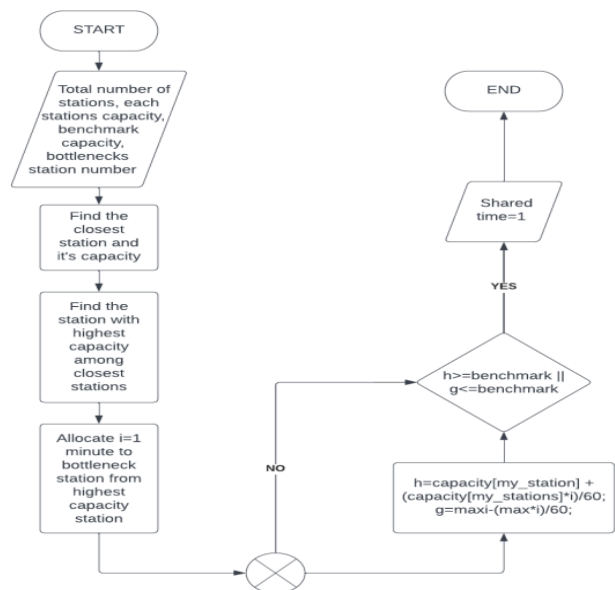


Fig.1 Flowchart for the algorithm

8. Result

8.1 Result for Bottleneck Stations

Table 3 Capacities of each station, including bottleneck stations capacity

station	capacity	capacity	station
1	100	74	40
2	78	55	39
3	55	49	38
4	91	43	37
5	82	42	36
6	82	46	35
7	53	145	34
8	52	83	33
9	96	87	32
10	33	38	31
11	85	51	30
12	51	63	29
13	66	55	28
14	34	140	27
15	38	152	26
16	44	65	25
17	79	89	24
18	83	89	23
19	47	72	22
20	102	73	21

Bottleneck Station 10

For bottleneck station number 10, the surrounding stations given by the algorithm are 9,10,31,30,32. Station number 9 has the highest capacity, 96 units/hour, among the surrounding station. The bottleneck station's increased capacity reached 46 units/hour from 33 units/hour. And the capacity of the surrounding station with the highest capacity decreased to 58 units/hour from 96 units/hour. The shared time for station number 9 is 24 minutes, which means the worker from station 9 will work for 36 minutes and will share work with station 10 for 24 minutes.

```

Enter the number of station : 40
Enter the capacity for each station: 100 78 55 91 82 82 53 52
Enter the benchmark capacity : 46
Enter your station : 10
Nearest station are:
9 11 31 30 32
the maximum capacity of the station index is :9
the capacity is :96
my station capacity is : 33
New bottleneck station's capacity: 46
New capacity of shared surround station: 58
Number of minutes have to share: 24

Enter your station :
    
```

Fig.2 Result for bottleneck station 10

Bottleneck Station 14

For bottleneck station number 14, the surrounding stations given by the algorithm are 13,15,26,27,28. Station number 26 has the highest capacity, 152 units/hour, among the surrounding station. The bottleneck station's increased capacity reached 46 units/hour from 34 units/hour. And the capacity of the surrounding station with the highest capacity decreased to 97 units/hour from 152 units/hour. The shared time for station number 26 is 22 minutes, meaning the worker from station 26 will work for 38 minutes and share work with station 14 for 22 minutes.

```

Enter your station : 14
Nearest station are:
13 15 27 26 28
the maximum capacity of the station index is :26
the capacity is :152
my station capacity is : 34
New bottleneck station's capacity: 46
New capacity of shared surround station: 97
Number of minutes have to share: 22

Enter your station :
    
```

Fig.3 Result for bottleneck station 14

Bottleneck Station 15

For bottleneck station number 15, the surrounding stations given by the algorithm are 14,16,25,26,27. Station number 26 has the highest capacity, 152 units/hour, among the surrounding station. The bottleneck station's increased capacity reached 46 units/hour from 38 units/hour. And the capacity of the surrounding station with the highest capacity decreased to 120 units/hour from 152 units/hour. The shared time for station number 26 is 13 minutes, which means the worker from station 26 will work for 47 minutes and will share work with station 15 for 13 minutes.

```

Enter your station : 15
Nearest station are:
14 16 26 25 27
the maximum capacity of the station index is :26
the capacity is :152
my station capacity is : 38
New bottleneck station's capacity: 46
New capacity of shared surround station: 120
Number of minutes have to share: 13

Enter your station :
    
```

Fig.4 Result for bottleneck station 15

Bottleneck Station 16

For bottleneck station number 16, the surrounding stations given by the algorithm are 15,17,24,25,26. Station number 26 has the highest capacity, 152 units/hour, among the surrounding station. The bottleneck station's increased capacity reached 46

units/hour from 44 units/hour. And the capacity of the surrounding station with the highest capacity decreased to 145 units/hour from 152 units/hour. The shared time for station number 26 is 3 minutes, meaning the worker from station 26 will work for 57 minutes and share work with station 16 for 3 minutes.

```

Enter your station : 16
Nearest station are:
15 17 25 24 26
the maximum capacity of the station index is :26
the capacity is :152
my station capacity is : 44
New bottleneck station's capacity: 46
New capacity of shared surround station: 145
Number of minutes have to share: 3
    
```

Fig.5 Result for bottleneck station 16

Bottleneck Station 31

For bottleneck station number 31, the surrounding stations given by the algorithm are 9,10,11,30,32. Station number 9 has the highest capacity, 96 units/hour, among the surrounding station. The bottleneck station's increased capacity reached 46 units/hour from 38 units/hour. And the capacity of the surrounding station with the highest capacity decreased to 76 units/hour from 96 units/hour. The shared time for station number 9 is 13 minutes, meaning the worker from station 9 will work for 47 minutes and share work with station 31 for 13 minutes.

```

Enter your station : 31
Nearest station are:
30 32 10 9 11
the maximum capacity of the station index is :9
the capacity is :96
my station capacity is : 38
New bottleneck station's capacity: 46
New capacity of shared surround station: 76
Number of minutes have to share: 13
    
```

Fig.6 Result for bottleneck station 31

In the same way we can calculate the sharing time for station 36 and 37.

8.2 Elimination of Bottleneck

The bottlenecks are identified and eliminated with the help of the algorithm. The orange line from the figure indicates the benchmark capacity.

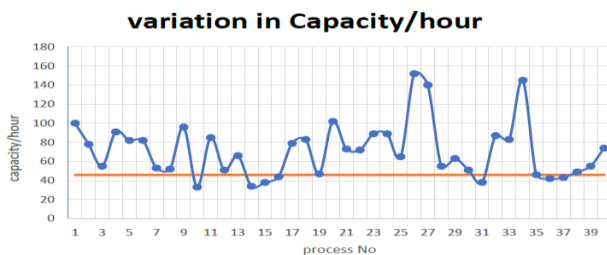


Fig.9 Bottleneck capacity of stations before line balancing

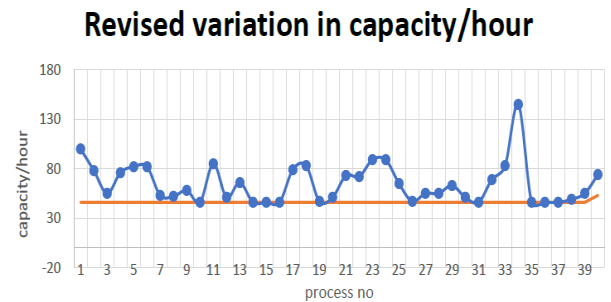


Fig.10 Bottleneck capacity of stations after line balancing

8.3 Increased Line Efficiency

The Productivity is increased from 330 units/hour to 460 units/hour. And the line efficiency is increased to 63% from 42%.

Table 4 Line Efficiency and Productivity of the line before applying line balancing

Before balancing line		
Total output per day	330	unit
Total manpower	50	
Working Time	600	minutes
SMV	38.84	minutes
Takt time	0.7768	minutes
Target/hour	77.23(100%)	
Target/hour	61.78(80%)	
Target/hour	46.38(60%)	
Labor Productivity	0.0303	hours/unit
Line Efficiency	42%	

Table 5 Line efficiency and Productivity of the line after applying line balancing

After balancing line		
Total output per day	460	unit
Total manpower	47	
Working time	600	minutes
SMV	38.84	minutes
Takt time	0.826382979	minutes
Target/hour	72.6(100%)	
Target/hour	58.08(80%)	
Target/hour	43.58(60%)	
Labor Productivity	0.0217	hours/unit
Line Efficiency	63%	

9. Conclusion

Though line balancing is a popular concept, method. Very few studies have been done on the work-sharing For single-model line balancing, the work-sharing method can be very effective. The method needs some correction for its effectiveness. One of the

Our contribution to this study is to develop a proper system or algorithm to determine the work share

time. This will make the method more specific. Some constraints need to be fit into the method to make the method more effective. Future work can be done by identifying each constraint and a way to deal with it.

If we had taken some orders for large quantities, our results would have been more effective. Additionally, balancing the process is highly related to the types of machines that are used, as the machines that are used in the bottleneck and those that are used in the balancing process should be similar. Taking into consideration a large number of orders minimum as a minimum might result in further improvements in Productivity.

- The station worker with the highest capacity, chosen by the algorithm, may not be skilled with the same working skills required for a bottleneck station. A developed algorithm should deal with the problem.

- As some workers will share work in a single workstation, two types of different work will be done. So, the setup cost will be high. Finding the optimal setup cost will be important.

- Only skilled people are permitted to participate in manufacturing processes, and sufficient training and supervision are required to achieve maximum productivity gains. Certain limits must be considered to create a suitable system.

- This method is not effective for small production volumes and assembly lines running below their designed capacity. Work is to make the algorithm suitable for every production line.

If we had taken some orders for large quantities, our results would have been more effective. In addition, the machines that are used in the bottleneck and those that are used in the balancing process should be comparable in order for the process to be considered balanced. This is because the machines that are used in the bottleneck and those that are used in the balancing process should have similar functions. The consideration of huge quantities of orders, with a minimum of ten thousand pieces, enables further increases in Productivity to be realized.

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