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Productivity Improvement of a Flow Line Layout Using Line Balancing Techniques

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Abstract

Effective Line Balancing forms the core of every successful organization as strive to increase productivity without incurring unnecessary costs. This thesis paper addresses the performance analysis and productivity improvement of a flow line layout of a selected sewing line by applying line balancing techniques. The core idea behind the thesis work was to analyze the line performance and reducing the number of workstations by line balancing techniques as well as reducing idle time in order to improve the productivity of a flow line. If workstation can be reduced, the idle time of each workstation can be reduced to a remarkable label. The existing line was analyzed and improvement has been done by line balancing techniques. Finally, line balancing technique is proposed to the management that will be used for productivity improvement of the existing flow line as well as the increase of daily output of the sewing section.

Keywords: *Assembly line balancing (ALB), balancing techniques, idle time, line efficiency, labor productivity, Cycle time*

1. Introduction

Productivity is an average measure of the efficiency of production. It can be expressed as the ratio of output to inputs used in the production process. Productivity is an economic measure of output per unit of input. Inputs include labor and capital, while output is typically measured in revenues and other gross domestic product (GDP) components such as business inventories. Productivity measures enhance an organization's strategic planning .Not only does it provide a gauge for ascertaining whether strategic objectives have been achieved or not (and to what extend) but it also relates these measure to productivity performance. As a diagnostic took, the behavior of productivity ratios over a period of time will reveal problematic areas that require immediate attention and will focus on these high priority areas for improvement. The concept of productivity analysis in garment sectors may give misleading results, if not used carefully. Productivity analysis refers to the process of differentiating the actual data over the estimated data of output and input measurement and presentation. Productivity Analysis is conducted to identify areas for potential productivity improvement projects based on statistical data collected during the analysis. The analysis also pinpoints areas of delays and interruptions that cause loss of productivity. The first step in any productivity improvement initiative is to understand the current state of the operation. Productivity analysis provides baseline indicators that will also yield data which will be used to determine possible productivity improvement objectives and potential cost savings. Productivity improvement means that workers are putting out products more quickly or completing services at a more rapid rate than before. In most businesses, the more products that workers produce or services they complete, the more money comes in to the business, priority of improving productivity is high for many business owners. In a flow-line the workstations are arranged in a liner path. Flow line layout is used to manufacture high volumes of products with high production rates and low costs. Separate dedicated flow line is created for each product. Dedicated machines are used to manufacture the products at high production rates. These machines are generally expensive. A large volume of the products must be produced in order to justify the cost of such expensive machines. Flow line layout is most suitable to manufacture high volumes of products continuously. Flow line layout is used in such industries where raw materials are fed at one end and finished products are produced continuously at the other end. Thus flow line layout is utilized in mass production industries. A flow-line may have a better flow by balancing it. Line balancing techniques can be used to make a better flow of a flow-line. Line Balancing means balancing the production line, or any assembly line. The main objective of line balancing is to distribute the task evenly over the work station so that idle time of man and machine can be minimized. Line balancing aims at grouping the facilities or workers in an efficient pattern in order to obtain an optimum or most efficient balance of the capacities and flows of the production or assembly processes. Assembly Line Balancing (ALB) is the term commonly used to refer to the decision process of assigning tasks to workstations in a serial production system. The task consists of elemental operations required to convert raw material in to finished goods.

2. Literature Review

2.1 Introduction: Productivity is essentially the efficiency in which a company or economy can transform resources into goods, potentially creating more from less. The gains in productivity are one of the major weapons to achieve cost and quality advantages for competition.
2.2 Necessary equations of line balancing: The equation needed to solve line balancing problems are as follows:

1. Line Efficiency = Total SMV /Process Cycle Time * no. of workstation * 100%
2. Balance Delay = (100-Line Efficiency) %
3. Balance Efficiency = Theoretical minimum no. of workers /Actual no. of workers
4. Theoretical Minimum no. of worker = Total Time in all workstations /Process Cycle Time
5. Theoretical Minimum no. of workstation = Total SMV" /"Process Cycle Time
6. Daily Output = (No. of workers * working hours per day * 60 * line efficiency %) /Total SMV
7. Productivity = Actual Line Output /Line Capacity × 100%

8. Normal Time = Average work element Cycle Time * Performance Rating

9. Standard Minute Value, SMV = Normal Time + (Normal Time × Allowance)

10. Workstation Idle Time = Process cycle Time – Total SMV in workstation
11. Labor Productivity = Actual Production per day /No. of workers
12. Machine Productivity= Actual Production per day /No. of machines

3. Method Used

The following methods are used in this research work.
1. Largest candidate rule (LCR)
2. Killbridge and wester method (KWR)
3. Ranked positional Method (RPW)
4. Least predecessor rule (LPR)

4. Data Analysis

Work element no.	Work element name	Expected observed time in sec	No of worker	machine		predecessors
				Type	No.	
1	care label writing and attach	14.43	1	S/N (auto)	1	-
2	front rise scissoring and sticker remove	13.64	1	O/L	1	1
3	back rise and scissoring	16.93	1	O/L	1	2
4	back and front part matching sticker remove	12.55	1	Manual	-	2,3
5	in seam	15.96	1	O/L	1	4
6	side seam	26.26	2	O/L	2	5
7	in seam point bartack	11.73	1	Bartack	1	5
8	measure cut elastic tack, mark	14.69	1	Needle (Auto)	1	7
9	Elastic joint	17.44	1	O/L	1	8
10	four tack	13.34	1	S/N (auto)	1	9
11	wrest belt top seam	16.94	1	Kansai	1	10
12	thread seaming	44.13	2	Manual	-	11
13	leg hem	27.66	2	REC	2	6,12
14	thread seaming	32.37	2	Manual	2	13
			Σ =18	Σ=15		

Figure 1: The Collected Data of The Selected Line

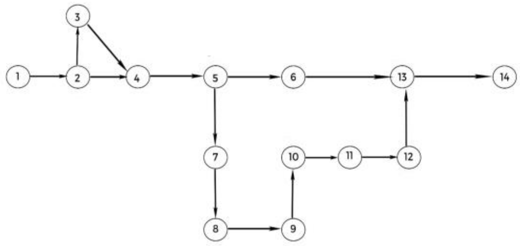

Figure 2: Precedence Diagram for The Assembly Line

The time study was conducted on the sewing line and detailed time study is given below

Work element no. (A)	Observed time in sec (E)	Rating of worker % (F)	Normal time (G)=E*F	Allowances (20%) (H)	Standard time, sec(I) = G+E*H	SMV (J) = I/60,min
1	14.43	90%	12.99	20%	15.58	0.260
2	13.64	90%	12.28	20%	14.73	0.246
3	16.93	90%	15.24	20%	18.28	0.305
4	12.55	90%	11.30	20%	13.55	0.226
5	15.96	90%	14.36	20%	17.24	0.287
6	26.26	90%	23.63	20%	28.36	0.473
7	11.73	90%	10.56	20%	12.67	0.211
8	14.69	90%	13.22	20%	15.87	0.264
9	17.44	90%	15.70	20%	18.84	0.314
10	13.34	90%	12.01	20%	14.41	0.240
11	16.94	90%	15.25	20%	18.30	0.305
12	44.13	90%	39.72	20%	47.66	0.794
13	27.66	90%	24.89	20%	29.87	0.498
14	32.37	90%	29.13	20%	34.96	0.583

Figure 3: Time Study Sheet for The Flow Line

workstation no	Assigned work element	No. of workers	SMV, min	Idle time .min
A	1	1	0.26	0.620
B	2	1	0.246	0.634
C	3	1	0.305	0.575
D	4	1	0.226	0.654
E	5	1	0.287	0.593
F	6	2	0.473	0.407
G	7	1	0.211	0.669
H	8	1	0.264	0.616
I	9	1	0.314	0.566
J	10	1	0.24	0.64
K	11	1	0.305	0.575
L	12	2	0.794	0.086
M	13	2	0.498	0.382
N	14	2	0.583	0.297
Total w/s= 14		Total=18	Σ= 5.005	7.314

Figure 4: Existing allocation of workstation

The demand for the existing line is 4088 units per week.
So the Daily desired output is = desired output in units ÷ no of working days per week
= 4088.462 ÷ 6
= 681.333 ≈681 units per day

Theoretical calculation

1. Process cycle time = $\frac{\text{working hour per day*60}}{\text{daily target output}} = \frac{10*60}{681}$ = 0.88 minutes per unit

2. Total allocated time = productive time + idle time
= 5.005 + 7.314 = 12.319 minutes per cycle

3. Line Efficiency = $\frac{\text{Total SMV}}{\text{process cycle time * no. of workstation}} * 100\% = \frac{5.005}{.88 * 14} * 100\%$ = 40.625%

4. Balance Delay = (100-line efficiency) % = (100-40.625) % = 59.375%

5. Labor productivity = $\frac{\text{Target production per day}}{\text{no. of worker}} = \frac{681}{18}$ = 37 units per worker

Applying LCR method

Work element	SMV	Immediate predecessors
12	0.794	11
14	0.583	13
13	0.498	6,12
6	0.473	5
9	0.314	8
11	0.305	10
3	0.305	2
5	0.287	4
8	0.264	7
1	0.260	-
2	0.246	1
10	0.240	4
4	0.226	2,3
7	0.211	5

Figure 5: List all elements in descending order of work element time

workstation	Assigned work element no	SMV	sum of SMV of element in min	Idle time in min
A	1	0.260	0.26	0.62
B	2	0.246	0.550	0.33
	3	0.305		
C	4	0.226	0.226	0.654
D	5	0.287	0.760	0.118
	6	0.473		
E	7	0.211	0.211	0.669
F	8	0.264	0.578	0.302
	9	0.314		
G	10	0.240	0.545	0.335
	11	0.305		
H	12	0.794	0.794	0.086
I	13	0.498	0.498	0.382
J	14	0.583	0.583	0..297
No of w/s = 10			Σ= 5.005	Σ= 3.793

Figure 6: Assignment of workstation

Calculation

1. Actual no of workstation = 10
2. Total smv: 5.5005 min
3. Line Efficiency = $\frac{\text{Total SMV}}{\text{process cycle time} \times \text{no. of workstation}}$×100% = $\frac{5.005}{.88\times10}$×100% = 56.875%
4. Balance Delay = (100-line efficiency)% = (100-56.875) % = 43.125%
5. Labor productivity = $\frac{\text{actual production per day}}{\text{no. of worker}}$ = $\frac{681}{10}$ = 68 units per worker
6. **Applying KWR Method**

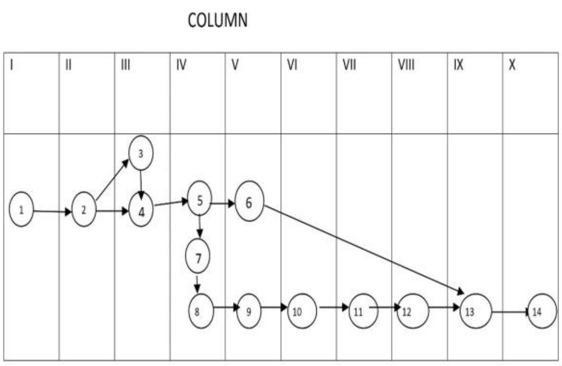

Figure 7: assigning work elements into column

Work element	Column	SMV	Sum of column SMV
1	I	0.26	`
2	II	0.246	0.551
3	II	0.305	
4	III	0.226	0.226
5	IV	0.287	0.762
6	IV	0.473	
7	IV	0.211	
8	V	0.264	0.787
9	V	0.314	
10	VI	0.240	0.240
11	VII	0.305	0.305
12	VIII	0.794	0.794
13	IX	0.498	0.498
14	X	0.583	0.583

Figure 8: arranging work elements according to Their column value

workstation	work elements	SMV	total SMV at each workstation	Idle time at each workstation
A	1	0.26	0.506	0.374
	2	0.246		
B	3	0.305	0.531	0.349
	4	0.226		
C	5	0.287	0.762	0.118
	7	0.211		
	8	0.264		
D	6	0.473	0.787	0.093
	9	0.314		
E	10	0.24	0.545	0.585
	11	0.305		
F	12	0.794	0.794	0.086
G	13	0.498	0.498	0.382
H	14	0.583	0.583	0.297
Total no of w/s = 8			Σ= 5.005	Σ= 2.284

Figure 9: Assignment of workstation

Calculation

1. Actual no of workstation = 8
2. Total smv: 5.5005 min
3. Line Efficiency = $\frac{\text{Total SMV}}{\text{process cycle time} \times \text{no. of workstation}} \times 100\%$

$= \frac{5.005}{.88 \times 8} \times 100\% = 71.09\%$

4. Balance Delay = (100-line efficiency)%

= (100-71.09) % = 28.91%

5. Labor productivity $= \frac{\text{target production per day}}{\text{no. of worker}}$

$= \frac{681}{8}$

$= 85.125 \approx 85$units per worker

Applying RPW method

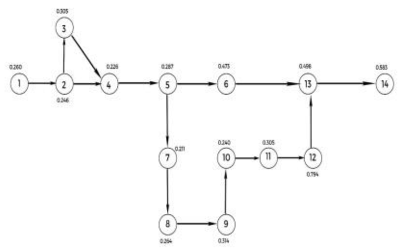

Figure 10: precedence diagram with SMV

Workstation	Work elements	SMV, min	Sum of SMV	Idle time per workstation
A	1	0.26	0.811	0.069
	2	0.246		
	3	0.305		
B	4	0.226	0.724	0.156
	5	0.287		
	7	0.211		
C	8	0.264	0.818	0.062
	9	0.314		
	10	0.24		
D	11	0.305	0.778	0.102
	6	0.473		
E	12	0.794	0.794	0.086
F	13	0.498	0.498	0.382
G	14	0.583	0.583	0.297
Total No of w/s = 7			∑ = 5.005	∑ = 1.154

Figure 11: Assignment of workstation

Calculation:

1. Actual no of workstation = 7
2. Total smv: 5.5005 min
3. Line Efficiency = $\frac{\text{Total SMV}}{\text{process cycle time} \times \text{no. of workstation}} \times 100\% = \frac{5.005}{.88 \times 7} \times 100\% = 81.25\%$
4. Balance Delay = (100-line efficiency)% = (100-81.25) % = 18.75%
5. Labor productivity $= \frac{\text{target production per day}}{\text{no. of worker}} = \frac{681}{7} =$ 97 units per worker

Applying LPR method

Work element	SMV	Immediate predecessors
12	0.794	11
14	0.583	13
13	0.498	6,12
6	0.473	5
9	0.314	8
11	0.305	10
3	0.305	2
5	0.287	4
8	0.264	7
1	0.260	-
2	0.246	1
10	0.240	4
4	0.226	2,3
7	0.211	5

Figure 12: arranging work elements according to the number of predecessor

Workstation	Work element	SMV	∑SMV at workstation	Idle time
A	w-1	0.26	0.506	0.374
	w-2	0.246		
B	w-3	0.305	0.531	0.617
	w-4	0.226		
C	w-5	0.287	0.551	0.329
	w-7	0.264		
D	w-6	0.473	0.473	0.407
E	w-8	0.264	0.787	0.093
	w-9	0.314		
F	w-10	0.24	0.545	0.335
	w-11	0.305		
G	w-12	0.794	0.794	0.086
H	w-13	0.498	0.498	0.382
I	w-14	0.583	0.583	0.297
Total No of w/s = 9			∑ = 5.005	∑ = 2.84

Figure:13 Assignment of workstation

1. Actual no of workstation = 9
2. Total smv: 5.5005 min

3. Line Efficiency = $\frac{\text{Total SMV}}{\text{process cycle time} \times \text{no. of workstation}} \times 100\% = \frac{5.005}{.88 \times 9} \times 100\% = 63.19\%$
4. Balance Delay = (100-line efficiency)% = (100-63.19) % = 36.81%

Labor productivity = $\frac{\text{target production per day}}{\text{no. of worker}} = \frac{681}{9}$ = 75 units per worker

All the four methods of line balancing are applied in the flow line are based on heuristic approach. The result of all the methods are not optimum but closed to the optimum. The calculation of all the methods are compared to each other and the best one is suggested to the production manager of the flow line. The following table shows the comparison and summary of the calculation of the line balancing methods.

Cycle time in minutes	Method	Actual no of workstation	Allocated time in minutes	Idle time in minutes	daily output in units	Line efficiency	Labor productivity per worker in units
0.88	Largest candidate rule	10	8.8	3.795	681	56.875%	68
	Kilbridge and wester method	8	7.04	2.035		71.09%	85
	RPW method	7	6.16	1.156		81.25%	97
	Least predecessor rule	9	7.92	2.915		63.19%	75

Figure 14**:** Comparison and Summary of The Calculation of the Line Balancing Methods.

Conclusion

The main purpose of the research paper is to represent the improvement of a flow line layout using heuristic line balancing techniques. Among all the methods the Ranked positional weight (RPW) methods has better line efficiency and labor productivity than other methods used in this research. In RPW method the no of workstation is reduced to 7 from 14. As a result the labor productivity is increased. Because of reducing idle time the line efficiency is also increased. So it is recommended to the production manager of the flow line to implement line selected methods for the selected sewing line.

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