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Line Balancing for Improving Apparel Production by Operator Skill Matrix

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Abstract: In this modern world, fashion & styles are changing frequently. The emergence of fast changes in fashion has given rise to shorten production cycle time in the garment industry. To meet the dynamic customer demands of momentous quantities in shorten lead time, assembly line production systems are used, where the garment components are assembled into a finished garment through a sub-assembly process. So in the era of product customization, the optimal usage of resources especially the available facilities & operators who are adding the value of product is important. Therefore the assembly line has to be planned in much more flexible way. This paper deals with the maximum utilization of manpower in labor intensive assembly lines. The objective is to accurately delegate workers to the various operations required to complete the product based on their skill & experience so as to achieve the highest level of productivity and delivery as per planned target. The experimental result showed meaningful improvement in productivity as compared to the existing system.

Keywords: Line Balancing, Skill Matrix, Assembly Line, Apparel Production

1. Introduction

As a supply chain of textile industry, garment industry is one of the major industries of the world. The production process of garments is separated into four main phases: designing/ clothing pattern generation, fabric spreading & cutting, sewing and ironing & packing. The most critical phase is sewing phase [1]. As the sewing is the heart of apparel industry, we have to design the sewing line properly so as to achieve the best output at maximum efficiency. Apparel is a mass production system. Assembly line production systems are developed to meet the requirements of mankind, which continue to grow day by day [2]. The demand for greater product variability and shorter life cycles has caused traditional production methods to be replaced with assembly lines [3]. Assembly line is an industrial arrangement of machines, equipments and workers for continuous flow of work pieces in mass production operation. Manufacturing a product in an assembly line requires partitioning the total amount of work into a set of elementary operations called tasks [4]. Tasks are assigned to operators depending on constrains of different labor skill levels. Finally, several workstations in sequence are formed as a sewing line [5]. The sewing process includes a set of work stations, at each of which a specific task is carried out in a restricted sequence, with hundreds of employees and thousands of bundles of sub-assemblies producing different style simultaneously [6]. Therefore this process is of critical importance and needs to be planned more carefully [7]. As a consequence, good line balancing with small stocks in the sewing line has to be drawn up to increase the efficiency and quality [7-9]. So the aim of assembly line balancing in sewing line is to assign tasks to the workstations, so that the machines of the workstation can perform the assigned task with a balanced loading with different labor skill levels [5].

2. Literature Review

A line is defined as a group of operators under the control of one production supervisor [10]. Balancing is the technique of maintaining the same level of inventory at each and every

operation at any point of time to meet the production target and to produce garments of acceptable quality [10]. Assembly line balancing (ALB) is a managerial technique and can be applied to balance production flow lines [11-12]. Line balancing is the distribution of work on the line in such a way that everyone gets the same amount of work in terms of time [13]. In practice, a perfect balance could not be achieved but we can improve the situation by using proper technique.

The assembly line balancing problem was first introduced by Bryton in his graduate thesis. In his study, he accepted the amount of workstations as constant, the workstation times as equal for all stations and work tasks as moving among the workstations [14]. The first article was published in 1955 by Salveson [15]. He developed a 0-1 integer programming model to solve the problem. This heuristic method was developed by Helgeson and Birnie of the General Electric Company in 1961 COMSOAL (Computer Method of Sequencing Operations for Assembly Lines) was first used by Arcus in 1966 as a solution approach to the assembly line balancing problem [16,17]. Bartholdi (1993) was the first to address the Two-sided Assembly Line Balancing Problem with the objective of minimizing the number of stations by applying a simple assignment rule. Liu & Chen (2002) presented a Genetic Algorithm approach for assembly planning involving various objectives, such as minimizing cycle time, maximizing workload smoothness, minimizing the frequency of tool change, minimizing the number of tools and machines used and minimizing the complexity of assembly sequences [18-19]. Helgeson ve Birnie (1961) developed the "Ranked Positional Weight Technique" in which operation having the largest ranged weight is assigned to the first workstation, and other operations are assigned to workstations in accordance with their ranked positional weight value [16]. Abdolmajid Yolmeh et al. (2012) proposed a hybrid genetic algorithm to solve the assembly line balancing problem [20].

Operator's Skill Inventory is the database which maintains the record of each operator, who can do what type of operation and at what rating. It is very important to keep this database updated as over the time, operator acquire skills for most of the new operations as well as improve performance in existing operations [21].With the use of skill matrix an engineer's or line supervisors needs very list time to find out and select most efficient operator for a particular operation from the pull of operation. It helps the line supervisor for balancing the line with particular skilled operators according to the work content [21].

There are so many researches going on in the field of assembly line balancing. Various methods are used for balancing sewing lines which are discussed in the above section. We use operator skill matrix for better allocation of operator throughout the sewing line to get maximum output.

3. Materials and Methodology

In this experiment, 100% cotton Jacket was considered. Total 30 sewing machines were used where number of plain, over lock and flat lock machines was 13, 11, and 6 respectively.

In order to balance a production line in sewing floor a line was chosen & necessary data was accumulated from the line. First the garment was analyzed and operational bulletin or breakdown was created with process sequence, operational description & machine requirements (Table 1). Then workers were placed to different work stations based on operation & machine types and a standard minute for each job was given to the operators (allocated SMV) (Table 1). After one day we calculate the output & found that we didn't get the desired output. To found out the problem, we calculated individual workers performed SMV by work study. After that workers individual efficiency & output at individual efficiency was calculated and then saw that efficiencies varies dramatically due to unplanned layout (Table 1). So to balance the line we have to rearrange the operators within the line. To do this, first machine-wise breakdown (Table 2 to Table 7) was done and workers are reallocated based on two assumptions: a) operators are only be allocated depending on the machine type that he/she can operate; b) allocation is also depend on operation type that he/she can perform. After fulfilling above two conditions we rearranged operators based on SMV. Higher the SMV, higher should be the efficiency % as we know where the workload is high, we need higher efficient worker. After total rearrangement, we again calculated the output (Table 8). We observed that productivity is increased but not up to the theoretical productivity. In some process, huge bottleneck was appeared. So to improve productivity we introduced another worker to the bottleneck operation by dividing the workload between two workers (Table 9). Finally we got satisfactory productivity.

4. Experimental Data

Operational Bulletin of Jacket before and after arrangement, Breakdown of different machines before and after rearrangement along with comparison of productions are shown below in different tables.

Table 1. *Operational Bulletin of Jacket before arrangement.*

SL	Process Name	Name	M/c Type	Performed SMV	Allocated SMV	Output @ 100% eff	Efficiency %	Output @ performed efficiency %
1	Back part panel join	Jarna	O/L	0.64	0.62	96.77	96	93.26
2	Back panel ts tc	Naher	F/L	0.35	0.3	200.00	87	173.08
3	Left and right panel join	Hasina	O/L	1.72	0.62	96.77	36	34.95
4	Left and right panel join	Eima	O/L	1.28	0.62	96.77	48	46.88
5	Left and right panel ts and tc	Mena	F/L	0.62	0.55	109.09	89	97.30

SL	Process Name	Name	M/c Type	Performed SMV	Allocated SMV	Output @ 100% eff	Efficiency %	Output @ performed efficiency %
6	Front part panel join & tc	Ronju	O/L	0.78	0.5	120.00	64	76.60
7	Front part panel ts & tc	Monzilla	L/S	0.53	0.3	200.00	57	113.92
8	Left & right panel join	Amina	O/L	0.82	0.62	96.77	76	73.47
9	Left and right panel join	Sahina	O/L	0.79	0.62	96.77	78	75.95
10	Left and right panel ts & tc	Nurbanu	F/L	0.53	0.55	109.09	103	112.50
11	Shoulder panel join	Lima	O/L	0.94	0.43	139.53	46	63.60
12	Shoulder panel ts	Alima	F/L	0.88	0.42	142.86	48	68.18
13	Shoulder join	Rojina	O/L	0.92	0.59	101.69	64	65.45
14	Sleeve panel make	Morina	O/L	0.64	0.45	133.33	70	93.26
15	Sleeve panel top stitch & tc	Sokina	F/L	0.47	0.49	122.45	104	126.76
16	Sleeve hem	Momina	F/L	0.42	0.3	200.00	71	141.73
17	Collar make	Pervin	L/S	0.79	0.63	95.24	80	75.95
18	Collar twill tape attach	Rebeka	L/S	0.26	0.22	272.73	85	230.77
19	Collar serving	Roksana	O/L	0.43	0.39	153.85	90	138.46
20	Zipper twill tape make	Sabina	L/S	0.88	0.42	142.86	48	68.44
21	Zipper twill tape attach	Rojina	L/S	0.87	0.5	120.00	57	68.97
22	Zipper holding tuck	Bobita	L/S	0.66	0.3	200.00	45	90.91
23	Zipper patch attach at bottom	Shahanara	L/S	0.45	0.57	105.26	127	133.33
24	Collar join	Sabina	L/S	1.77	0.78	76.92	44	33.90
25	Collar join	Shahila	L/S	1.99	0.78	76.92	39	30.15
26	Zipper tuck with body	Naher	L/S	0.36	0.42	142.86	118	168.22
27	Zipper join with left side	Halima	L/S	0.58	0.5	120.00	86	103.45
28	Zipper join right side	Orchona	L/S	0.76	0.69	86.96	90	78.60
29	Zipper facing join	Beauty	L/S	0.66	0.5	120.00	76	90.91
30	Zipper facing o/l	Sharmin	O/L	0.36	0.3	200.00	83	165.14
				Max Theoretical output		76.92	practical output	30 pcs

Table 2. Breakdown of Plain machines before rearrangement.

SL	Process Name	Name	M/c Type	Performed SMV	Efficiency
7	Front part panel ts & tc	Monzilla	L/S	0.53	57%
17	Collar make	Pervin	L/S	0.79	80%
18	Collar twill tape attach	Rebeka	L/S	0.26	85%
20	Zipper twill tape make	Sabina	L/S	0.88	48%
21	Zipper twill ta[e attach	Rojina	L/S	0.87	57%
22	Zipper holding tuck	Bobita	L/S	0.66	45%
23	Zipper patch attach at bottom	Shahanara	L/S	0.45	127%
24	Collar join	Sabina	L/S	1.77	44%
25	Collar join	Shahila	L/S	1.99	39%
26	Zipper tuck with body	Naher	L/S	0.36	118%
27	Zipper join with left side	Halima	L/S	0.58	86%
28	Zipper join right side	Orchona	L/S	0.76	90%
29	Zipper facing join	Beauty	L/S	0.66	76%

Table 3. Breakdown of Plain machines after rearrangement.

SL	Process Name	Name	M/c Type	Performed SMV	Efficiency
18	Collar twill tape attach	Shahila	L/S	0.26	39%
26	Zipper tuck with body	Sabina	L/S	0.36	44%
23	Zipper patch attach at bottom	Bobita	L/S	0.45	45%
7	Front part panel ts & tc	Sabina	L/S	0.53	48%
27	Zipper join with left side	Monzilla	L/S	0.58	57%
22	Zipper holding tuck	Rojina	L/S	0.66	57%
29	Zipper facing join	Beauty	L/S	0.66	76%
28	Zipper join right side	Pervin	L/S	0.76	80%
17	Collar make	Rebeka	L/S	0.79	85%
21	Zipper twill tape attach	Halima	L/S	0.87	86%
20	Zipper twill tape make	Orchona	L/S	0.88	90%
24	Collar join	Naher	L/S	1.77	118%
25	Collar join	Shahanara	L/S	1.99	127%

Table 4. *Breakdown of Overlock machines before rearrangement.*

SN	Process Name	Name	M/c Type	Performed SMV	Efficiency
1	Back part panel join	Jarna	O/L	0.64	96%
3	Left and right panel join	Hasina	O/L	1.72	36%
4	Left and right panel join	Eima	O/L	1.28	48%
6	Front part panel join & tc	Ronju	O/L	0.78	64%
8	Left & right panel join	Amina	O/L	0.82	76%
9	Left and right panel join	Sahina	O/L	0.79	78%
11	Shoulder panel join	Lima	O/L	0.94	46%
13	Shoulder join	Rojina	O/L	0.92	64%
14	Sleeve panel make	Morina	O/L	0.64	70%
19	Collar serving	Roksana	O/L	0.43	90%
30	Zipper facing o/l	Sharmin	O/L	0.36	83%

Table 5. *Breakdown of Overlock machines after rearrangement.*

SN	Process Name	Name	M/c Type	Performed SMV	Efficiency
30	Zipper facing o/l	Hasina	O/L	0.36	36%
19	Collar serving	Lima	O/L	0.43	46%
14	Sleeve panel make	Eima	O/L	0.64	48%
1	Back part panel join	Ronju	O/L	0.64	64%
6	Front part panel join & tc	Rojina	O/L	0.78	64%
9	Left and right panel join	Morina	O/L	0.79	70%
8	Left & right panel join	Amina	O/L	0.82	76%
13	Shoulder join	Sahina	O/L	0.92	78%
11	Shoulder panel join	Sharmin	O/L	0.94	83%
4	Left and right panel join	Roksana	O/L	1.28	90%
3	Left and right panel join	Jarna	O/L	1.72	96%

Table 6. *Breakdown of Flat lock machines before rearrangement.*

SN	Process Name	Name	M/c Type	Performed SMV	Efficiency
2	Back panel ts tc	Naher	F/L	0.35	87%
5	Left and right panel ts and tc	Mena	F/L	0.62	89%
10	Left and right panel ts & tc	Nurbanu	F/L	0.53	103%
12	Shoulder panel ts	Alima	F/L	0.88	48%
15	Sleeve panel top stitch & tc	Sokina	F/L	0.47	104%
16	Sleeve hem	Momina	F/L	0.42	71%

Table 7. *Breakdown of Flat lock machines after rearrangement.*

SN	Process Name	Name	m/c	Performed SMV	Efficiency
2	Back panel ts tc	Alima	F/L	0.35	48%
16	Sleeve hem	Momina	F/L	0.42	71%
15	Sleeve panel top stitch & tc	Naher	F/L	0.47	87%
10	Left and right panel ts & tc	Mena	F/L	0.53	89%
5	Left and right panel ts and tc	Nurbanu	F/L	0.62	103%
12	Shoulder panel ts	Sokina	F/L	0.88	104%

Table 8. *Operational Bulletin of Jacket after rearrangement.*

SN	Process Name	Name	M/c Type	Performed SMV	Efficiency %	Output @ performed efficiency
1	Back part panel join	Ronju	O/L	0.64	48	46.45
2	Back panel ts tc	Alima	F/L	0.35	48	96.00
3	Left and right panel join	Jarna	O/L	1.72	96	92.90
4	Left and right panel join	Roksana	O/L	1.28	90	87.10
5	Left and right panel ts and tc	Nurbanu	F/L	0.62	71	77.45
6	Front part panel join & tc	Rojina	O/L	0.78	64	76.80
7	Front part panel ts & tc	Sabina	L/S	0.53	44	88.00
8	Left & right panel join	Amina	O/L	0.82	76	73.55
9	Left and right panel join	Morina	O/L	0.79	70	67.74
10	Left and right panel ts & tc	Mena	F/L	0.53	87	94.91
11	Shoulder panel join	Sharmin	O/L	0.94	83	115.81

SN	Process Name	Name	M/c Type	Performed SMV	Efficiency %	Output @ performed efficiency
12	Shoulder panel ts	Sokina	F/L	0.88	89	127.14
13	Shoulder join	Sahina	O/L	0.92	78	79.32
14	Sleeve panel make	Eima	O/L	0.64	64	85.33
15	Sleeve panel top stitch & tc	Naher	F/L	0.47	103	126.12
16	Sleeve hem	Momina	F/L	0.42	104	208.00
17	Collar make	Rebeka	L/S	0.79	86	81.90
18	Collar twill tape attach	Shahila	L/S	0.26	39	106.36
19	Collar serving	Lima	O/L	0.43	46	70.77
20	Zipper twill tape make	Orchona	L/S	0.88	48	68.57
21	Zipper twill tape attach	Halima	L/S	0.87	57	68.40
22	Zipper holding tuck	Rojina	L/S	0.66	45	90.00
23	Zipper patch attach at bottom	Bobita	L/S	0.45	85	89.47
24	Collar join	Naher	L/S	1.77	118	90.77
25	Collar join	Shahanara	L/S	1.99	127	97.69
26	Zipper tuck with body	Sabina	L/S	0.36	57	81.43
27	Zipper join with left side	Monzilla	L/S	0.58	76	91.20
28	Zipper join right side	Pervin	L/S	0.76	90	78.26
29	Zipper facing join	Beauty	L/S	0.66	80	96.00
30	Zipper facing o/l	Hasina	O/L	0.36	36	72.00

Practical output after rearrangement

Table 9. Final Practical output after sharing of work.

SN	Process Name	Name	M/c Type	Performed SMV	Efficiency %	Output @ performed efficiency
1	Back part panel join	Raju	O/L	0.64	48	46.45
1	Back part panel join	Ronju	O/L	0.64	48	46.45
2	Back panel ts tc	Alima	F/L	0.35	48	96.00
3	Left and right panel join	Jarna	O/L	1.72	96	92.90
4	Left and right panel join	Roksana	O/L	1.28	90	87.10
5	Left and right panel ts and tc	Nurbanu	F/L	0.62	71	77.45
6	Front part panel join & tc	Rojina	O/L	0.78	64	76.80
7	Front part panel ts & tc	Sabina	L/S	0.53	44	88.00
8	Left & right panel join	Amina	O/L	0.82	76	73.55
9	Left and right panel join	Morina	O/L	0.79	70	67.74
10	Left and right panel ts & tc	Mena	F/L	0.53	87	94.91
11	Shoulder panel join	Sharmin	O/L	0.94	83	115.81
12	Shoulder panel ts	Sokina	F/L	0.88	89	127.14
13	Shoulder join	Sahina	O/L	0.92	78	79.32
14	Sleeve panel make	Eima	O/L	0.64	64	85.33
15	Sleeve panel top stitch & tc	Naher	F/L	0.47	103	126.12
16	Sleeve hem	Momina	F/L	0.42	104	208.00
17	Collar make	Rebeka	L/S	0.79	86	81.90
18	Collar twill tape attach	Shahila	L/S	0.26	39	106.36
19	Collar serving	Lima	O/L	0.43	46	70.77
20	Zipper twill tape make	Orchona	L/S	0.88	48	68.57
21	Zipper twill tape attach	Halima	L/S	0.87	57	68.40
22	Zipper holding tuck	Rojina	L/S	0.66	45	90.00
23	Zipper patch attach at bottom	Bobita	L/S	0.45	85	89.47
24	Collar join	Naher	L/S	1.77	118	90.77
25	Collar join	Shahanara	L/S	1.99	127	97.69
26	Zipper tuck with body	Sabina	L/S	0.36	57	81.43
27	Zipper join with left side	Monzilla	L/S	0.58	76	91.20
28	Zipper join right side	Pervin	L/S	0.76	90	78.26
29	Zipper facing join	Beauty	L/S	0.66	80	96.00
30	Zipper facing o/l	Hasina	O/L	0.36	36	72.00

Final Practical output (after sharing of work)

Table 10. Comparison of production before & after study.

Parameter	Before Rearrangement	After Rearrangement	After sharing of work
No of m/c	30	30	31
No of manpower	30	30	31
Output per hr	30	46	68

5. Results & Discussion

Changing from traditional layout to balanced layout model by proper allocation of workers, there are considerable improvements have moved towards us. With final scenario, the best performance results were obtained as summarized in table 10. The average hourly output of the system increased from 30 to 68 pieces. With reference to scenario, it can be said that the balance of sewing line seems appropriate for all performance measures.

6. Conclusion

Skill matrix helps in allocating right person for the right job which helps in achieving desired performance level. It keeps record of all operations an operator had done in the past and efficiency level in each operation. Engineers / line supervisors need minimum time to find and select most efficient operators for an operation from the pull of operators. For line balancing, operators can be selected according to work content. When someone is absent, supervisor can easily find suitable person from the skill matrix table and replace. To analyses the skill availability and distribution throughout the factory. This can be compared with the skill requirement for a particular time period and shortage/excess skill availability to achieve at the training requirement. So productivity can be achieved by allocating skill & semi-skilled workers to the right place and unskilled operator should be trained properly.

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