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Assembly Line Balancing to Improve Productivity using Work Sharing Method in Apparel Industry

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Assembly Line Balancing to Improve Productivity using Work Sharing Method in Apparel Industry

Md. Niaz Morshed [α] & Kazi Saifujjaman Palash [σ]

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I. Introduction

Textile industry is one of the world's major industries and the garment industry is a substantial one within the supply chain of textile industry. The production process of garments is separated into four main phases: designing or clothing pattern generation, fabric cutting, sewing, and ironing or packing. The most critical phase is the sewing phase, as it generally involves a great number of operations.

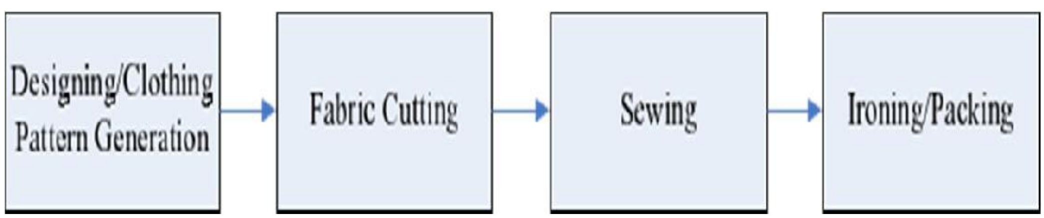
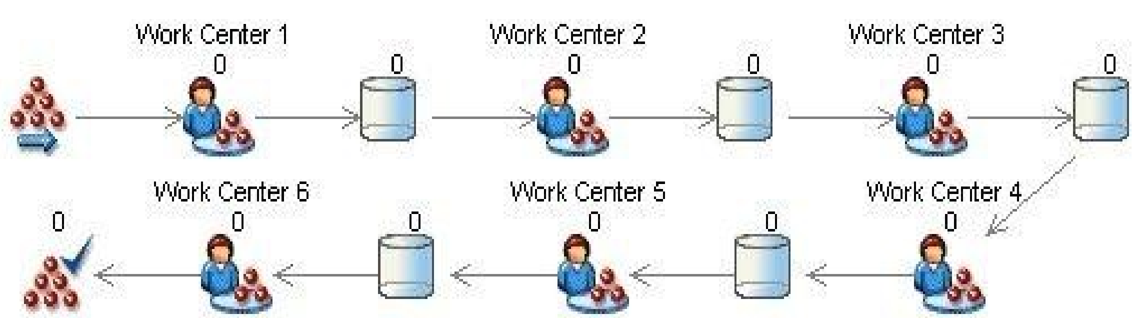


Figure 1 : Garment manufacturing processes

The sewing line consists of a set of workstations in which a specific task in a predefined sequence is processed. In general, one to several tasks is grouped into one workstation. Tasks are assigned to operators depending on the constraints of different labor skill levels. Finally, several workstations in sequence are formed as a sewing line. Shop floor managers are concerned with the balance of the lines by assigning the tasks to workstations as equally as possible. Unequal workload among workstations of a sewing line will lead to the increase of both WIP and waiting time, indicating the increase of both production cycle time and cost. In practice, the sewing line managers or production controllers use their experience to assign tasks to workstations based on the task sequence, labor skill levels and the standard time required to complete each task. As a result, the line balance performance cannot be guaranteed from one manager to another with different assignment preference and/or work experience.



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In garment industry a product is manufactured through a series of operations. Each operation must be performed on a machine (sewing machine) with a specific machine setting, i.e. yarn color, machine attachment. Manufacturing a product always requires different types of sewing machines and different yarn colors, making it difficult to assign a worker to perform operations on just a single machine. There is a maximum number of machines that each worker can use for a particular product. Figure 1, for example, denotes the line configuration of the problem considered in this research of which each worker can use at most three different machines. For the ease of working, identical machines of different settings will be treated as different machines. The worker therefore needs not to adjust the setting every time he/she performs an operation.

The optimization model takes into account workers' skill levels as well as the constraint on the number of machines at each station (worker). Each operation can be classified as a skill type. Each worker in the team is evaluated for all these skills on standardized tests. The ratings based on time required to perform such skill to meet acceptable quality level is given to each worker for each skill. This rating system allows for incompetent workers who cannot perform certain skills as well. The solution approach is divided into two phases. In the first phase, a multi-stage integer programming model is developed to assign operations, corresponding machines and their settings to stations considering standard operation times, station by station. Parallel stations are allowed so as to improve overall line cycle to as well as to use the required number of workers. Then in the second phase, another integer programming model is used to assign workers to stations based on their aptitudes to minimize the overall line cycle time.

II. Literature Review

Assembly line balancing is the problem of assigning various tasks to workstations, while opt-imizing one or more objectives without violating any restrictions imposed on the line. ALBP has been an active field of research over the past decades due to its relevancy to diversified industries such as garment, footwear and electronics. The assembly line balancing problem has received considerable attention in the literature, and many studies have been made on this subject since 1954. 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. The first article was published in 1955 by Salveson. He developed a 0-1 integer programming model to solve the problem. 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. Helgeson ve Birnie [11] developed the "Ranked Positional Weight Technique". In this method, the "Ranked Positional Weight Value" is determined. It is the sum of a specified operation time and the working times of the other operations that can't be assembled without considering the operation finished. While taking into consideration the cycle time and technological precedence matrix, the 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.

Configurations of assembly lines for single and multiple products could be divided by three line types, single-model, mixed-model and multi-model.

Single-model assembles only one product, and mixed-model assembles multiple products, whereas a multi-model produces a sequence of batches with intermediate setup operations. A single-model line balancing problem with real application was solved in this project.

ALBP with various objectives are classified into three types

- ALBP-I: Minimizes the number of workstations, for a given cycle time.
- ALBP-II: Minimizes the cycle time, for a given number of workstations.
- ALBP-III: Maximizes the workload smoothness, for a given number of workstations.

In type I problems, the ALBP of assigning tasks to workstations is formulated with the objective of minimizing the number of workstations used to meet a target cycle time. It can result in low labor costs and reduced space requirements. Type II problems maximize the production rate of an assembly line. Since this objective requires a predetermined number of workstations, it can be seen as the counterpart of the previous one. In general, shop managers are concerned with the workload equity among all workers. The issue of workload smoothing in assembly lines allocates tasks among a given number of workstations, so that the workload is distributed as evenly as possible. This problem is known as Type III problem. Our project was focused on type-1 line balancing problem. Relevant data obtained from an apparel industry was used to formulate the solution. The objective of the project was to balance the cycle time for various operations and minimization of workstations.

III. Methodology

In order to balance a production line in sewing floor a line was chosen and necessary data was accumulated from the line.

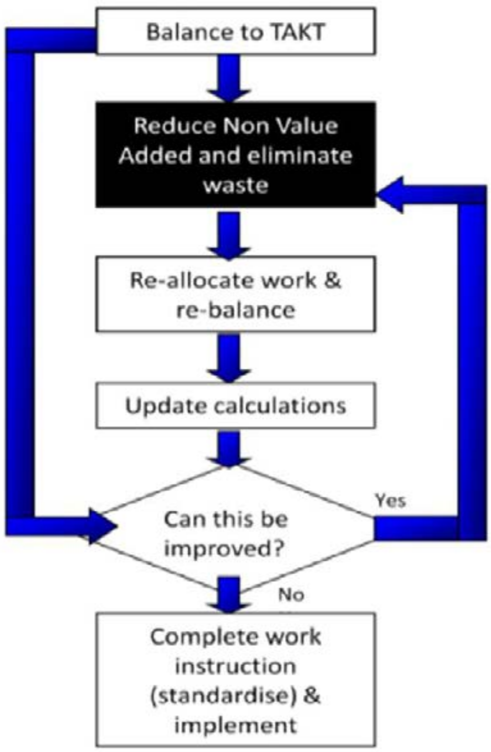

Figure 2 : flowchart for line balancing

A garment order is chosen which was started in that line, knowing total amount of order, style description, fabric type and color. Two important attributes have been considered, one is possible standard method for each process and another is considerable time in between the input has been fed to the time study took to record the actual individual capacity of each worker. We have recorded the time to make each process for each and every worker to find out the number of operator and helper, type of machines and individual capacity. To find out the(standard minute value) S.M.V , process wise capacity has been calculated, in addition to that we have calculated the target, benchmark capacity, actual capacity line graph, labor productivity and line efficiency. After taking necessary data from the line we proposed a suitable line balancing technique for the line. At first we highlighted the bottleneck processes which were our prime concern and then seek solution to minimize the problem. In this project we proposed a method to balance the line by sharing workload among equally adept workers who has experience in both the bottleneck process and balancing process. Line has been balanced considering the bottleneck and balancing process where the balancing process has shared the excess time after the benchmark production in the bottleneck process. After balancing, new manpower has been proposed and final capacity of each worker has been reallocated. We have compared the line graph after balancing the line, labor productivity and line efficiency. Finally a proposed production layout has been modeled with balanced capacity.

IV. Equations

Standard minute value (S.M.V) = (average cycle time * allowance) in minute

$$\text{Takt time}=\frac{\text{Total S.M.V}}{\text{no. of operators}}$$

$$\text{Target}=\frac{\text{Total manpower per line}*\text{total working minutes per day}}{\text{S.M.V}}*100\%$$

$$\text{Theoretical manpower}=\frac{\text{Benchmark target per hour}}{\text{process capacity per hour}}$$

$$\text{Labor productivity}=\frac{\text{Total number of output per day per line}}{\text{number of workers worked}}$$

$$\text{Line efficiency}=\frac{\text{Total output per day per lines}*\text{S.M.V}}{\text{Total manpower per line}*\text{total working minutes per day}}*100\%$$

V. Data Analysis and Calculations

a) *Before balancing the line*

The first step of line balancing is to breakdown the operation into sequential logical order.

The breakdown is done to better understand and implement the sequential order of product processing steps.

Taking cycle time for each operation is done manually and S.M.V is calculated from the average time with suitable allowance. Adding total S.M.V we can obtain target/hour. In this case 80% efficiency is the desired output level per hour.

Before line balancing production scenario is illustrated in table -1

Table 1 : Bench mark Target, Labor productivity and Line Efficiency before balancing line

Total output per day	=	1100
Total manpower	=	27
Working time	=	600
S.M.V	=	6.42
Takt time (min)	=	.238
Target/hour	=	252 (efficiency 100%)
Target/hour	=	201 (efficiency 80%)
	=	151 (efficiency 60%)
Labor productivity		40
Line efficiency		44

Process wise capacity of each work station has been shown in Annexure 1 where Standard minute value (S.M.V) has been calculated by taking average cycle time for each process and considering allowances. Table: 1 shows the target per hour for the line calculating total 27 manpower worked on that line for 6oo minutes with a S.M.V value of 6.42. We have standardized the Bench mark target of 201 pieces of garment at 80% efficiency. Observation before balancing the line has been reflected as labor productivity is 40, line efficiency is 44%.

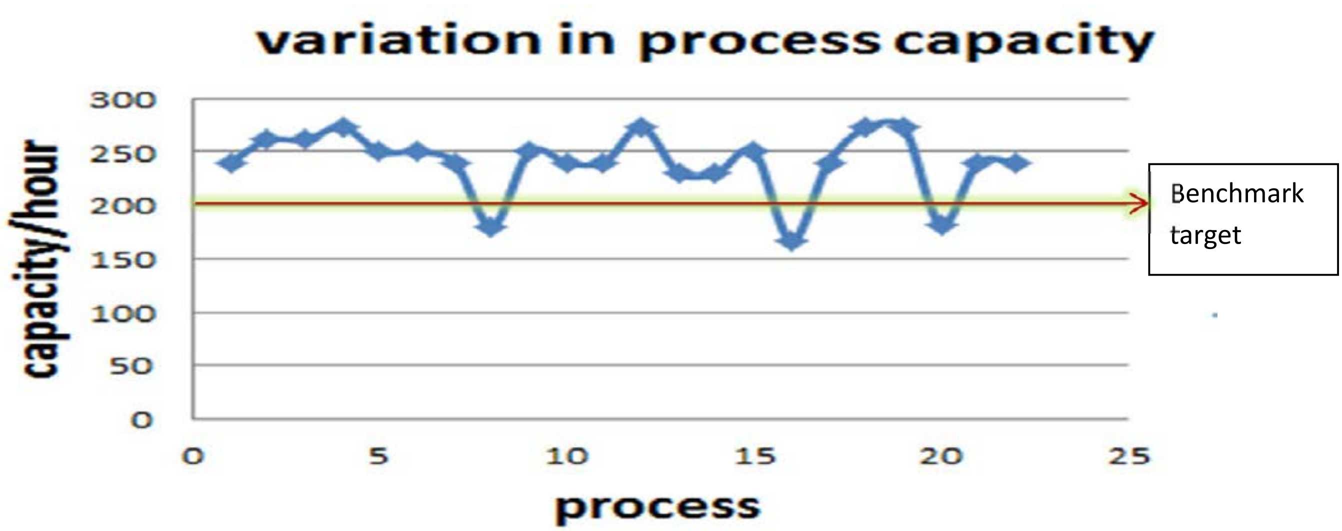

Figure 1 : Variation in each process capacity per hour compare to bench mark target per hour

Plotting process wise capacity in a line graph shows the variation of each process from the bench mark target as the upper capacity is 273 pieces per hour where the lower capacity is only 167 pieces per hour compare to the bench mark target of 201 pieces. This shows the imbalance situation in the line and bottleneck condition throughout the process of the whole garment making as lots of WIP stations in the line.

Table 2 : Balancing Processes to equalize the bottleneck process

Sl no		Bottleneck process				Balancing process		
	Process name	Process no	Capacity /hour	Balanced capacity	Process name	Process no	Capacity /hour	Balanced capacity
1.	Main label attach position mark	8	180	200	Thread cut & fold	7	240	212
	Remarks	Process # 7 can work for 50 min. and share work with process # 8 for last 10 min.						

Sl no		Bottleneck process				Balancing process		
	Process name	Process no	Capacity /hour	Balanced capacity	Process name	Process no	Capacity /hour	Balanced capacity
2.	Side seam	16	167	195	Sleeve join with body	13	230	192
	Remarks	Process # 13 can work for 50 min. and share work with process # 16 for last 10 min.						

Sl no		Bottleneck process				Balancing process		
	Process name	Process no	Capacity /hour	Balanced capacity	Process name	Process no	Capacity /hour	Balanced capacity
3.	Body heam	20	182	212	Sleeve heam	18	273	227
	Remarks	Process # 18 can work for 50 min. and share work with process # 20 for last 10 min.						

b) *Bottleneck processes*

From Figure 1: we have identified some variations in process capacity from the bench mark target and the lower capacity from the bench mark target is the bottleneck process as production flow would stuck on the bottleneck point. Comparing total capacity of each process to the 80% bench mark target, we have identified the bottleneck processes named Main label attach position mark, Side seam with care label attaching, Body heam . Total production has been blocked in these seven work stations and large work in process (WIP) has been stuck in these bottleneck processes.

c) *Balancing Processes*

Balancing method is very essential to make the production flow almost smoother compare to the previous layout. Considering working distance, type of machines and efficiency, workers who have extra time to work after completing their works, have been shared their work to complete the bottleneck processes. Previously identified three bottleneck processes have been plotted in the left side of the Table 2. Side seam and Sleeve join with body both have been made by overlock machine and these have been shared by two overlock machine processes.

Operator who work in Process no. 13 Sleeve join with body, have been worked for 50 minutes per hour in her first process, capacity 192 pieces and then have been worked in the process no. 16 Side seam for last 10 minutes to make additional 28 pieces for overall capacity of 195 pieces on process no. 16.

d) Proposed Layout

Balanced Capacity/hr	Previous capacity	S.M.V	Process name	Process No.	M/C		M/C	Process No.	Process name	S.M.V	Previous capacity	Balanced Capacity/hr
120	120	.25	Back and Front matching	1. a	ML		ML	1. b	Back and Front matching	.25	120	120
261	261	.23	Shoulder join	2	O/L		ML	4	Neck rib measure & cut	.22	273	273
261	261	.23	Thread cut & fold	3	ML		SN	5	Neck rib make	.24	250	250
250	250	.24	Neck rib join with body	6	o/L							
212	240	.25	Trim & fold	7	ML		ML	8	Main label attach positioning mark	.33	180	200
240	240	.25	Back tape	10	F/L		SN	9	Main label attach with body	.24	250	250
240	240	.25	Thread cut & fold	11	ML							
273	273	.22	Sleeve match with body	12	ML		O/L	13	Sleeve join with body	.26	230	192
						WIP	ML	14	Thread cut & fold	.26	230	230
250	250	.24	Care label make	15	SN		O/L	16	Side seam with care label	.36	167	195
							ML	17	Thread cut & fold	.25	240	240
227	273	.22	Sleeve heam	18	F/L		F/L	20	Body heam	.33	182	212
273	273	.22	Thread cut & fold	19	ML		ML	21	Thread cut & fold	.25	240	240
120	120	.5	Quality inspectio n	22. a	ML		ML	22.b	Quality inspection	.5	120	120

Figure 2 : Work in Process in different table in a sewing section in a garments industry

First column on both side of center table shows the machine type and then followed by process no. process name, S.M.V value, previous capacity and after balance capacity. After first process front and back match, bundle of garments have been come to process no. 2 shoulder joint, then the bundle have been passed to process no. 6 Neck rib join with body and in between the processes, 3 helper has been worked in process no. 3,4,5. The working bundle then has been passed to process no. 7 and so on. In the proposed balancing process machines of the same type are used for line balancing. Process no 7 and 8 are both manual operations, process 13 and 16 are done by overlock machine, process 18 and 20 are done by flatlock machine .So workers operating on the same machines are accustomed to the various operations done by the same machine. As a result they can share their work.

VI. Result and Findings

Changing from traditional layout to balanced layout model, there are considerable improvements have moved toward us. Among the three operators who were replaced to another line, have been used in the overlock and flatlock machines and the total worker of 24 instead of 27, labor productivity has been increased from 40 to 50.

In a day we have boost up the production up to 1190 and with manpower of 24, line efficiency has been improved from 43% to 53% which is shown in Table 3. In an improved layout, target has been decreased at each efficiency level. At 80% efficiency, target is now 180 pieces per hour which has been considered as new bench mark target.

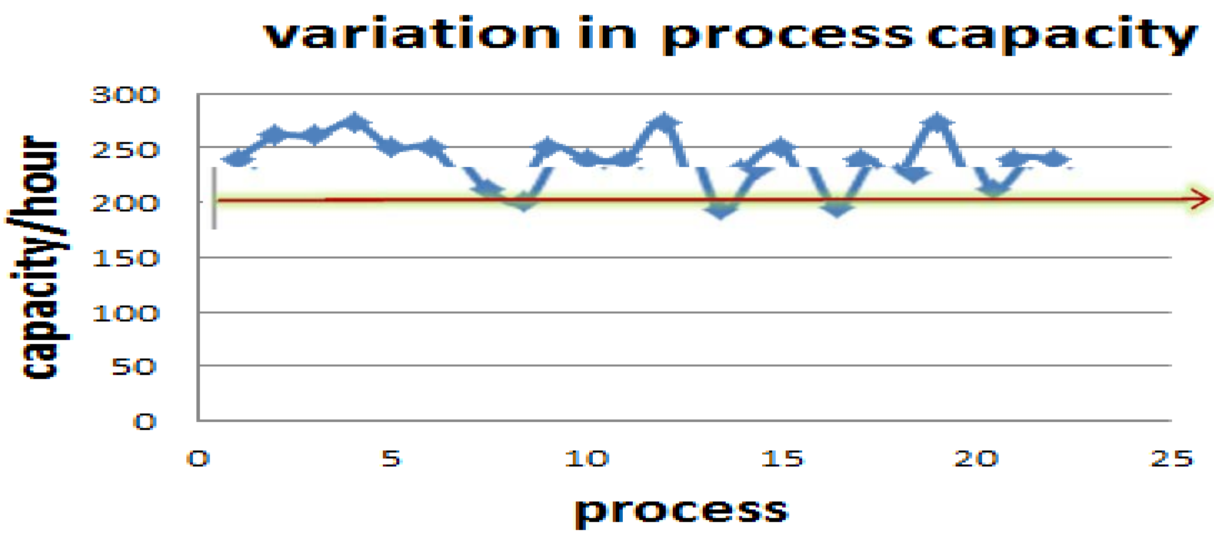

Figure 3 : Variation in each process capacity per hour compare to bench mark target per hour

Figure 3: Variation in each process capacity per hour compare to bench mark target per hour Figure -3 illustrates the distribution of target capacity after implementing proposed balancing method. Here we can see all the target capacity for each operations are above or very close to the benchmark capacity/hour .So the effect of bottleneck operation has been minimized by this balancing method.

Table 3 : Process wise revised capacity and optimized manpower distribution

Serial no	process	S.M.V	Total capacity	Total capacity (revised)	Target (80%)	Actual manpower	Proposed manpower
1	Back and Front matching	.25	240	240	201	2	2
2	Shoulder join	.23	261	261	201	1	1
3	Thread cut & fold	.23	261	261	201	1	1
4	Neck rib measure & cut	.22	273	273	201	1	1
5	Neck rib make	.24	250	250	201	1	1
6	Neck rib join with body	.24	240	240	201	1	1
7	Trim & fold	.25	240	212	201	1	1
8	Main label attach positioning	.33	180	200	201	2	1
9	Main label attach with body	.24	250	250	201	1	1
10	Back tape	.25	240	240	201	1	1
11	Thread cut & fold	.25	240	240	201	1	1

12	Sleeve match with body	.22	273	273	201	1	1
13	Sleeve join with body	.26	230	192	201	1	1
14	Thread cut & fold	.26	230	230	201	1	1
15	Care label make	.24	250	250	201	1	1
16	Side seam with care label	.36	167	195	201	2	1
17	Thread cut & fold	.25	240	240	201	1	1
18	Sleeve heam	.22	273	227	201	1	1
19	Thread cut & fold	.22	273	273	201	1	1
20	Body heam	.33	182	212	201	2	1
21	Thread cut & fold	.25	240	240	201	1	1
22	Quality inspection	.50	240	240	201	2	2
					total	27	24

(Blue cells signifies capacity changing cells and orange cells shows change of manpower)

As a result of the balancing process total output per day has been increased and manpower requirement has been reduced which ultimately leads to increased labor productivity and line efficiency. Revised takt time is estimated to be .2675.

Table 3 : Bench mark Target, Labor and machine productivity and Line Efficiency after line balancing

Total output per day	=	1190
Total manpower	=	24
Working time	=	600
S.M.V	=	6.42
Takt time (min)		.2675
Target/hour	=	224 (efficiency 100%)
Target/hour	=	180 (efficiency 80%)
	=	134 (efficiency 60%)
Labor productivity		50
Line efficiency		53

VII. Improvement

Further improvements in the productivity can be achieved by considering large amount of order minimum 10000pieces. Table 2 shows the new bench mark target which can be the further chance of improvements to balance the line with this new bench mark target. Proposed layout model has been followed the logic of modular system (one worker works more than two processes who is skilled on all processes and these combination of skilled workers finish their work in piece flow production) and traditional system (one worker works in one process and all the workers who may be skilled or not finish their work in bundle flow production) both together where only modular production system can be applicable with a series of skilled workers to achieve more productivity. On this occasion, skilled workers are eligible for the production processes and proper training and supervision is essential to achieve the optimum improvements on productivity and efficiency.

Maximum outputs have been increased to 1190 pieces a day which was previously recorded to 1100 pieces a day. Before balancing the line 7700 pieces of garments have been produced for 7 days where 7140 pieces have been produced for 6 days after balancing the line. We have saved one day lead time for that style of 9000 pieces and almost 600 minutes of labor work value time. We have replaced 2 operators and 1 helpers into different lines and relatively saved 3 workers work time of 1800 minutes from that line.

VIII. Conclusion

Result would have been more effective if we would have taken some large quantity order and balancing the process is highly related to the type of machines as machine utilized in bottleneck and balancing process should be similar. Further improvements in the productivity can be achieved by considering large amount of order minimum. Proposed layout model has been followed the logic of modular system (one worker works more than two processes who is skilled on all processes and these combination of skilled workers finish their work in piece flow production) and traditional system (one worker works in one process and all the workers who may be skilled or not finish their work in bundle flow production) both together where only modular production system can be applicable with a series of skilled workers to achieve more productivity. On this occasion, skilled workers are eligible for the production processes and proper training and supervision is essential to achieve the optimum improvements on productivity and efficiency.

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