

Assembly Line Balancing in Garment Production by Simulation

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1. Introduction

Construction of a quality garment requires a great deal of know-how, a lot of coordination and schedule management. Clothing manufacturing consists of a variety of product categories, materials and styling. Dealing with constantly changing styles and consumer demands is so difficult. Furthermore, to adapt automation for the clothing system is also so hard because, beside the complex structure also it is labor intensive. Therefore, garment production needs properly rationalized manufacturing technology, management and planning (Glock et. al, 1995; Caputo, et. al., 2005).

In garment production, until garment components are gathered into a finished garment, they are assembled through a sub-assembly process. The production process includes a set of workstations, 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 styles simultaneously (Chan et al, 1998). The joining together of components, known as the sewing process which is the most labor intensive part of garment manufacturing, makes the structure complex as the some works has a priority before being assembled (Cooklin, 1991). Furthermore, since sewing process is labor intensive; apart from material costs, the cost structure of the sewing process is also important. Therefore, this process is of critical importance and needs to be planned more carefully (Tyler, 1991). As a consequence, good line balancing with small stocks in the sewing line has to be drawn up to increase the efficiency and quality of production (Cooklin, 1991; Tyler, 1991; Chuter, 1988).

An assembly line is defined as a set of distinct tasks which is assigned to a set of workstations linked together by a transport mechanism under detailed assembling sequences specifying how the assembling process flows from one station to another (Tyler, 1991). In assembly line balancing, allocation of jobs to machines is based on the objective of minimizing the workflow among the operators, reducing the throughput time as well as the work in progress and thus increasing the productivity. Sharing a job of work between several people is called division of labor. Division of labor should be balanced equally by ensuring the time spent at each station approximately the same. Each individual step in the assembly of product has to be analyzed carefully, and allocated to stations in a balanced way over the available workstations. Each operator then carries out operations properly and the work flow is synchronized. In a detailed work flow, synchronized line includes short distances between stations, low volume of work in process, precise of planning of production times, and predictable production quantity (Eberle et al, 2004).

Overall, the important criteria in garment production is whether assembly work will be finished on time for delivery, how machines and employees are being utilized, whether any station in the assembly line is lagging behind the schedule and how the assembly line is doing overall (Glock & Kutz, 1995; Hui & Ng, 1999). To achieve this approach, work-time study, assembly line balancing and simulation can be applied to apparel production line to find alternative solutions to increase the efficiency of the sewing line (Kursun & Kalaoglu, 2009).

This chapter deals with assembly line balancing in garment production by simulation. In this chapter, to analyze the structure of garment assembly, a sewing line will be focused on. Firstly, work flow of sewing line and the chronological sequence of assembly operations needed to transform raw materials into finished garment will be described in detail. Then, a detailed work and time study along the sewing line will be summarized considering the precedence constraints. After time study, real-data taken from factory floor will be discussed for distribution fit and goodness of fit. The chapter goes on creation of model of the sewing line by simulation. To set-up the model, all fitted data and allocation of operations to the operators will be transferred to simulation model. Model will be verified by comparing the actual system. Chapter then addresses how simulation model can be used to analyze assembly line's problems such as bottlenecks. Simulation model will be compared with the ones of the actual system according to model statistics; number of current and average content in workstations in the system, cycle time, server utilization percentage, average staying time of jobs, average output, throughput values of workstations.. etc., Hence, this chapter concludes balancing of assembly line model in garment production by suggesting possible scenarios that eliminate the bottlenecks along the line by various what-if analyses using simulation technique. Throughout this chapter how assembly line balancing in garment production can be done by using simulation will be understood.

2. Experimental

In the production of garment, at first garment model is designed. Then, according to model requirements, a sort of fabrics are cut as well as classified due to their sewing sequences. Then, cut fabrics are sewn and assembled in order to form garment. After the sewing and pressing process, garment is controlled for eliminating sewing faults, and finally it is sent to package and expedition.

In this chapter, to analyze the structure of garment assembly processes, a trousers sewing line was considered. The first step performed in this study was to understand trousers sewing processes' components and sewing line problems. The objective was to have a clear idea on how a trousers production-sewing process line flows and then, how the line can be balanced as well as the performance of production line can be increased.

2.1 Sewing line flow

The whole trousers manufacturing cycle includes a sequence of different phases of assembly operations. In Fig. 1, a set of assembly operations to transform raw materials (cut fabrics-accessories) into finished product of trousers is shown.

In the production of trousers, there are mainly four sequence of phases namely (i) pre-preparation of pockets, fly and labels, (ii) production of back of trousers, (iii) production of front of trousers, and (iv) assembling of fabric parts. As seen in Fig.1., at first pockets, fly and labels are prepared in order to be ready for insertion to fabric parts. Then, both back

and front pockets are inserted to back and front fabric of the trousers, respectively. Fly is sewn on the front fabric. Front and back fabrics of trousers are prepared individually. Then all fabric parts are assembled in order to form trousers sequentially: Back and front fabrics are assembled. Zipper is attached and, belt and waistband are attached and sewn as well. Finally, hems, pockets, belt loop bartack seams are done and, by this way the sewing process of trousers is finished.

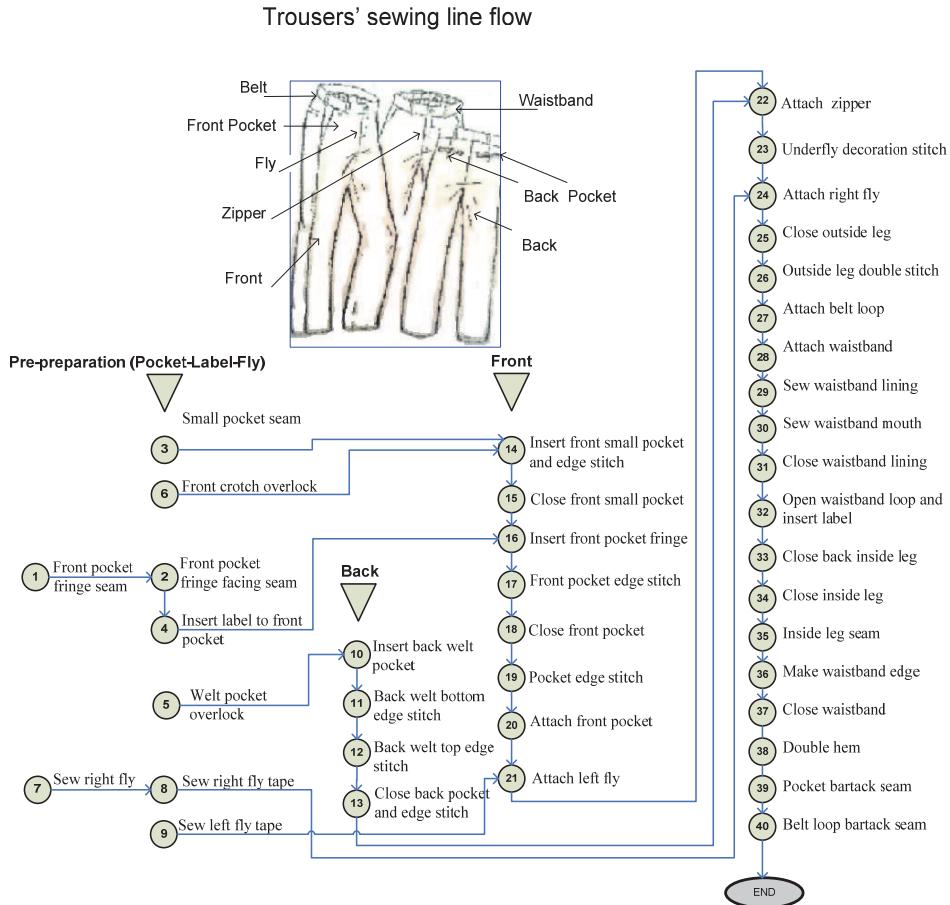


Fig. 1. Trouzers' sewing line flow

2.2 Time study

In order to balance the sewing line as well as to increase the efficiency of the line, at first a detailed work and time study was carried out to find the task durations (Niebel, 1976). However, the time required to complete a task depends on a lot of factors such as the task, the operator, the properties of fabric and sub materials, working environment, quality level of the product, the hour of the day, psychology of the operator etc. (Fozzard et al, 1996).

Therefore to calculate the approximate real process time of a task, 20 measurements were taken for each task and operator working on the line. Time study was performed along the line by chronometer. Each operation was measured in seconds and recorded. Then the data gathered from job floor was tested for firstly independency. It should be noted here that data taken from job floor should be independent. Then gathered data was tested for distribution fit and goodness of fit.

2.3 Distribution fit and goodness of fit

To estimate the relevant distribution fit of the data gathered, histogram of each process was obtained firstly. For instance; histograms of process 1-front pocket fringe seam, process 3-small pocket seam, process 18-close front pocket, process 19-pocket edge stitch are shown in Fig. 2. The estimated distributions for the processes mentioned above were obtained as *Logistic* (42.20,3.47), *Weibull* (23.95,7.10), *Uniform* (43.76,60.24), *Lognormal* (36.1.17,0.972), respectively. The red lines in the figures show the estimated distributions. Similarly, the distributions estimated for all tasks were calculated.

After the estimation of the fit distribution, to validate the goodness of fit Chi Squared test, Kolmogorov Smirnov test and Anderson Darling test can be applied. While the Chi Squared test is asymptotic, which is valid only as the number of data points gets larger, it might not be appropriate for this study as 20 measurements were taken for each operator. Since the Kolmogorov Smirnov test is not a limited distribution, being appropriate for any sample size, it was chosen to test the goodness of fit. In order to do the tests, an SPSS program was used. The level of significance was set at 0.05 (95% confidence interval) for the Kolmogorov Smirnov test (Law & Kelton, 2000; Brunk, 1960) and, consequently all the goodness of fit distributions estimated were validated. Table 1 summarizes the estimated fit distributions for all processes.

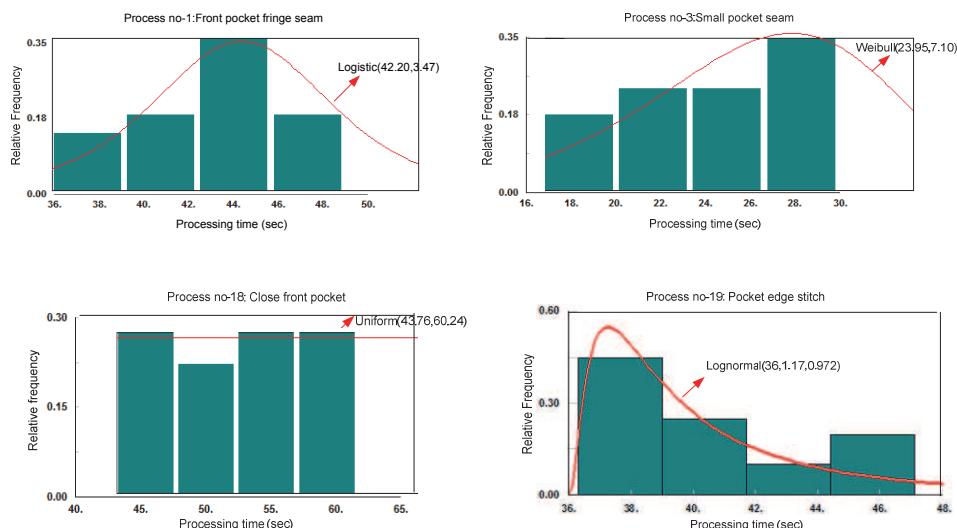


Fig. 2. Examples of estimated distributions for some processes

No:	Process Name	Fit Distribution (sec)	No:	Process Name	Fit Distribution (sec)
1	Front pocket fringe seam	Logistic (42.20,3.47)	21	Attach left fly	Uniform (31.34,46.86)
2	Front pocket fringe facing seam	Uniform (34.15,49.15)	22	Attach zipper	Uniform (48.88,73.62)
3	Small pocket seam	Weibull (23.95,7.10)	23	Underfly decoration stitch	Uniform (45.28,63.22)
4	Insert label to front pocket	Uniform (23.74,36.86)	24	Attach right fly	Normal (11.68,2.02)
5	Welt pocket overlock	Uniform (2.68,6.12)	25	Close outside leg	Normal (77.23,4.37)
6	Front crotch overlock	Uniform (17.92,28.28)	26	Outside leg double stitch	Normal (53.28,4.95)
7	Sew right fly	Lognormal (6,1.34,0.775)	27	Attach belt loop	Uniform (47.78,61.72)
8	Sew right fly tape	Uniform (2.56,4.64)	28	Attach waistband	Lognormal (93.2,0.7,0.972)
9	Sew left fly tape	Lognormal (2,0.034,0.81)	29	Sew waistband lining	Normal (44.88,3.96)
10	Insert back welt pocket	Normal (57.29,5.66)	30	Sew waistband mouth	Uniform (71.06,89.54)
11	Back welt bottom edge stitch	Normal (31.50,2.48)	31	Close waistband lining	Normal (64.96,3.43)
12	Back welt top edge stitch	Uniform (13.43,25.67)	32	Open waistband loop and insert label	Logistic (28.10,4.23)
13	Close back pocket and edge stitch	Uniform (51.78,70.22)	33	Close back inside leg	Uniform (34.36,51.24)
14	Insert front small pocket and edge stitch	Lognormal (37,1.22,0.98)	34	Close inside leg	Normal (45.80,4.79)
15	Close front small pocket	Uniform (30.53,48.27)	35	Inside leg seam	Uniform (13.00,22.90)
16	Insert front pocket fringe	Normal (52.42,4.14)	36	Make waistband edge	Logistic (61.80,3.79)
17	Front pocket edge stitch	Logistic (42.10,3.54)	37	Close waistband	Uniform (79.27,95.53)
18	Close front pocket	Uniform (43.76,60.24)	38	Double hem	Uniform (34.11,47.49)
19	Pocket edge stitch	Lognormal (36,1.17,0.972)	39	Pocket bartack seam	Uniform (54.39,72.31)
20	Attach front pocket	Uniform (65.26,80.54)	40	Belt loop bartack seam	Normal (64.46,4.53)

Table 1. Estimated distributions for processes

For instance; as seen in Table 1, the estimated distribution for the processes 10, 11, 16, 24, 25, 26, 29, 31, 34, 40 were found as *normal* distribution. In order to test if *normal* distribution is appropriate for the input data or not, Kolmogorov Smirnov test results were evaluated. With reference to Table 2 results, it was confirmed that the estimated *normal* distributions for these processes are appropriate for the input data. As seen in Table 2, the asymptote significant (2-tailed) values of the mentioned processes were found to be greater than the

level of significance (0.05) for the Kolmogorov Smirnov test. Thus, these results can permit us to state that *normal* distributions for the processes mentioned above are appropriate and herewith, the distribution fit was validated. Similarly, each estimated distribution for each process was validated for goodness of fit by Kolmogorov-Smirnov test and it was found that all estimated distributions are appropriate for the input data so that they are ready to be transformed in simulation model of sewing line.

One-Sample Kolmogorov-Smirnov Test											
		Processes (No)									
		10	11	16	24	25	26	29	31	34	40
N		20	20	20	20	20	20	20	20	20	20
Normal Parameters ^a	Mean	57.29	31.50	52.42	11.68	77.23	53.28	44.88	64.96	45.80	65.46
	Std. Deviation	5.66	2.48	4.14	2.020	4.371	4.95	3.96	3.43	4.79	4.53
Most Extreme Differences	Absolute	0.182	0.112	0.125	0.189	0.097	0.150	0.159	0.134	0.126	0.089
	Positive	0.163	0.093	0.125	0.108	0.084	0.150	0.159	0.122	0.075	0.071
	Negative	-0.182	-0.112	-0.079	-0.189	-0.097	-0.116	-0.112	-0.134	-0.126	-0.089
Kolmogorov-Smirnov Z		0.814	0.500	0.559	0.846	0.434	0.673	0.709	0.599	0.563	0.398
Asymp. Sig. (2-tailed)		0.522	0.964	0.913	0.471	0.992	0.756	0.696	0.865	0.909	0.997

a. Test distribution is Normal.

Table 2. Kolmogorov-Simirnov test results

2.4 Setting up the simulation model

Simulation is a technique to model a real-life or hypothetical situation on a computer so that it can be used for analyzing the behavior of system. By changing variables predictions can be made on system behavior. It provides predictions on the performance of an existing system. Moreover, by suggesting possible scenarios on system alternative solutions can be compared. Therefore, it is a very useful engineering technique to suggest investment strategies to companies for a particular design problems.

If the operations in the system are based on chronological sequence of events, then it is called as discrete-event simulation. Since our sewing line consists of a sequence of different phases of assembly operations, it is an example of discrete-event simulation. Therefore, to set up the model, ENTERPRISE DYNAMICS ® simulation program (Student Version) from Incontrol Simulations Solutions, which is a software program for discrete event simulation, was used (Incontrol Simulation Solutions, 2003).

Before setting up model of sewing line, it is necessary to identify the components of model. With reference to sewing line flow seen in Fig. 1, 40 processes were considered to be assigned to 40 operators, and these operators with their machines including queues, materials, assembly operations with precedence constraints were determined as components of model.

2.4.1 Model building basics

In the creation of a model, the decision of right atom at a right place is critical issue. An atom can be a machine, a counter, a queue or a product etc. To create our sewing line

model, mainly six different types of atoms were used as shown in Fig. 3. The explanations of atoms that were used in our model are as follows:

- Product: This atom represents the products/customers/raw materials that comes into an atom through an input channel and leave the atom through an output channel
- Source: The function of this atom is to produce products into the model
- Queue: This atom represents the waiting area for customers or products.
- Server: This atom corresponds to a machine or a counter. Atoms coming to a server undergo a process and stay in this atom for a certain time (the process time).
- Assembler: The atom which is used for assembly operation
- Sink: The products or customers leave the model through this atom and finishes the schedule (Incontrol Simulation Solutions, 2003).

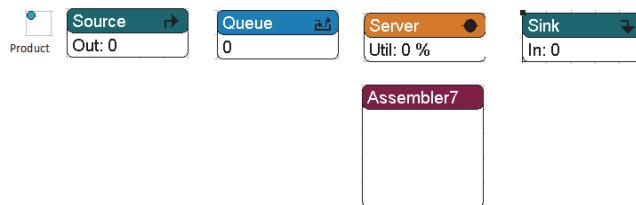


Fig. 3. Type of atoms used in our simulation model

By using these atoms, the model of sewing line was formed as shown in Fig. 4.

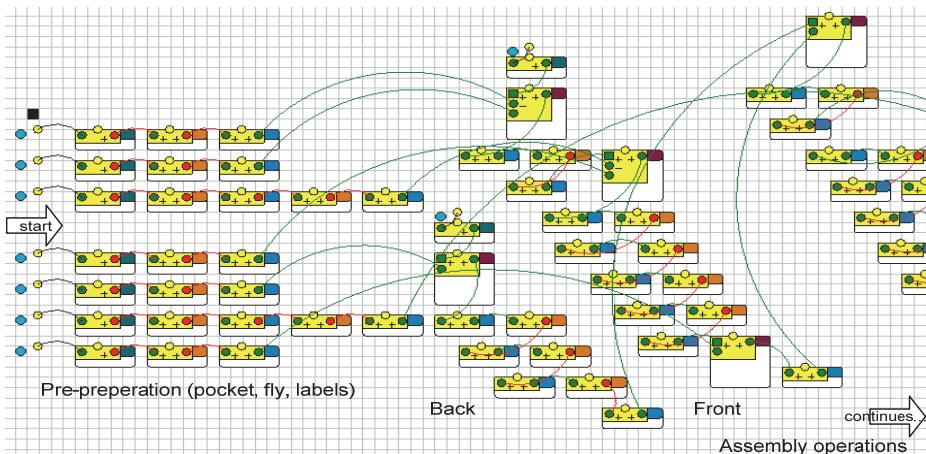


Fig. 4. Simulation model preview of sewing line

Arrows in the figure show the connections as well as the relations between atoms. Before and after server and assembly atoms or in other words before and after sewing processes, products always wait in queues for being processed like real system. Here, the data for model were entered by considering precedence constraints. Data in Table 1, as explained in the proceeding section, was transformed into simulation model for each operation individually. Also, the interval arrival time of raw material feeding in the

system was obtained as an exponential distribution and directly transformed into the model as well.

Unfortunately, to analyze the real system and create the model, some conjectures were considered:

- The 8 hour working day of the system.
- Only one worker is at each machine.
- Allowances are not taken into consideration.
- Delay times (machine breakdowns, changing apparatus) are not taken into consideration.
- There is no energy problem in the system.
- Fabric loss is not taken into consideration.
- Raw material is unlimited.
- The supervisor's job on the line was ignored.

2.5 Model verification and validation

By considering the conjectures, simulation model was run. Verification of model was done step by step comparing with actual system. The model statistics; number of current and average content in atoms in the system, cycle time, server utilization percentage, waiting time of jobs, average output, throughput values of atoms.. etc., were compared with those of the actual system, and in all cases there were no significant differences between the model and the actual system.

3. Results

To analyze the results of the system, three performance measures were considered:

- average staying times of jobs in queues,
- average content of jobs in machines,
- quantity of the average daily output

Since our system is an example of a nonterminating simulation, it was evaluated in two stages to consider the effect of the warm-up period . Firstly, to find the warm-up period, the simulation model was run for 800 hours (5 months as a working day) at a 95% confidence level. Nevertheless, with these results, the average output quantity of the system for a day cannot be evaluated. To find the quantity of the average daily output, the system was run 100 times, each run consisting of 8 hours of simulated time, taking into account the warm-up period (Law & Kelton, 2000).

3.1 Results based on reference layout model

Results of the reference layout model are summarized in Table 3 according to the performance measures. As seen in Table 3, it can be observed that the average number of finished trousers in a day is 295, the average content of jobs in machines is 28 and the average staying time of jobs in queues is 260 sec. The state diagrams of the performance measures for 100 observations (5 months) are shown in Fig. 5-7. When these results were compared with those of the actual system, it was also found that the actual system and the reference model results were alike.

To increase the efficiency of the line, firstly bottlenecks were determined, and then possible scenarios were tried by what-if analysis. As a result four scenarios were developed for the production of trousers.

Performance measures	Average	St. Deviation	L-bound (95%)	U-bound (95%)	Min.	Max.
Average content of jobs in machines	28.34	0.04	28.33	28.35	28.26	28.42
Average staying of jobs in queues	260.66	1.07	260.45	260.87	258.10	264.03
Average daily output	295.12	0.48	295.03	295.21	294.00	296.00

Table 3. Results based on reference layout model

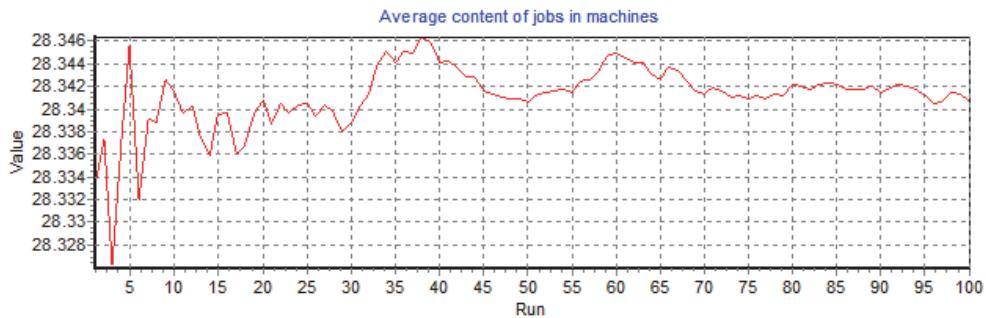


Fig. 5. Reference layout model: Average content of jobs in machines for 100 observations (5 months)

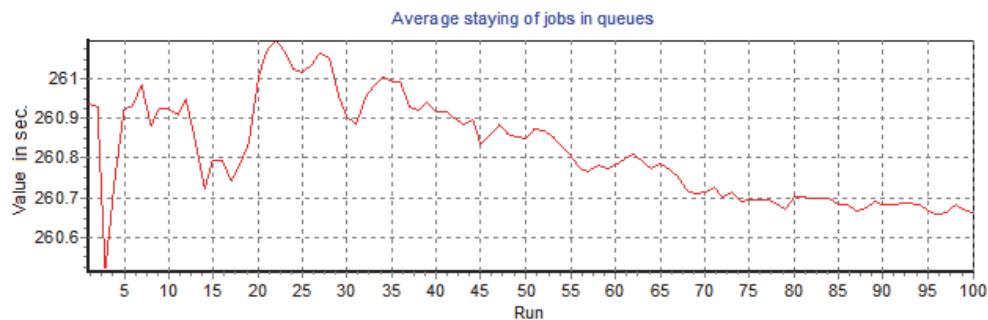


Fig. 6. Reference layout model: Average staying of jobs in queues for 100 observations (5 months)

In order to determine bottlenecks in the reference layout model; number of current and average content in atoms in the system, cycle time, server utilization percentage, waiting time of jobs, average output, throughput values of atoms.. etc. were taken into account. It was observed that process 28: Attach waistband with a higher processing time blocks the system. The server utilization status of process 28 is shown in fig. 8. As seen in the figure, machine is busy with 97.7 percentage of total time. Therefore, in reference layout model, process 28 was identified as bottleneck. By this way, the first scenario was developed by adding one extra machine to the system in order to overcome process 28's bottleneck problem.

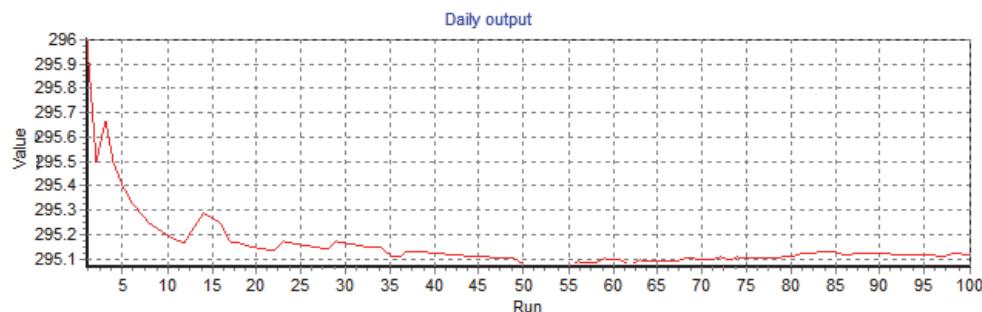


Fig. 7. Reference layout model: Average daily output for 100 observations (5 months)

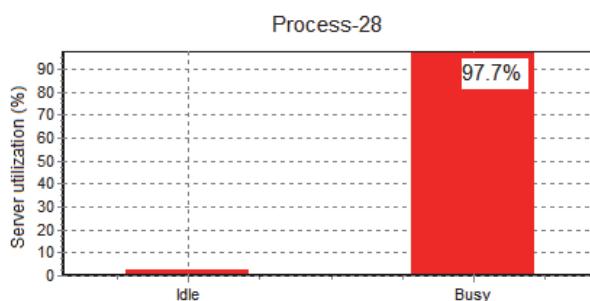


Fig. 8. Overview of the different statuses of process 28 as a percentage of total time

3.2 Results based on scenario 1

With only adding extra one machine with an operator to the reference system, the average daily output of the system increased up to 312. That means if one machine with one operator is added to the system, then around 312 trousers will be able to be produced in a day. Moreover, when other performance measures were considered, it was also observed that average content of jobs in machines increased, besides average staying of jobs in queues decreased.

Table 4 summarizes results based on scenario 1, when only one extra machine with one operator added to reference model. Fig. 9 shows the average daily output of the system according to scenario 1.

Performance measures	Average	St. Deviation	L-bound (95%)	U-bound (95%)	Min.	Max.
Average content of jobs in machines	30.22	0.06	30.21	30.23	30.07	30.38
Average staying of jobs in queues	230.97	1.28	230.72	231.22	227.24	233.64
Average daily output	312.13	0.80	311.97	312.29	311.00	315.00

Table 4. Results based on scenario 1

With scenario 1, it was found that the utility percentage of server 28 decreased to 62.6% (busy). However, despite the decrease in server utility of process 28, this time new

bottleneck was appeared in other machine. The server 37 was identified as second bottleneck along the line after one extra machine was added. Fig. 10 shows its usage percentage due to total working time.

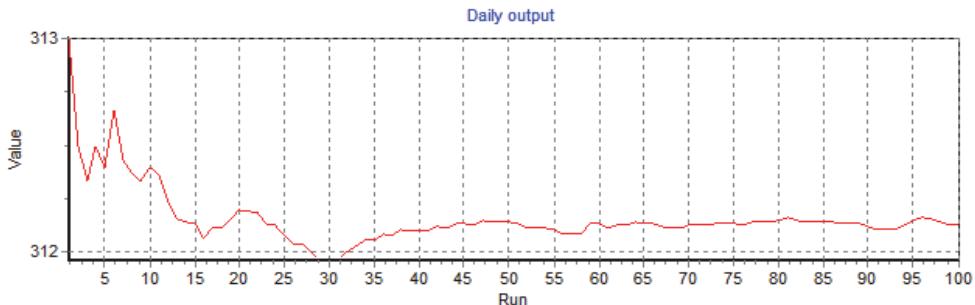


Fig. 9. Scenario 1: Average daily output for 100 observations (5 months)

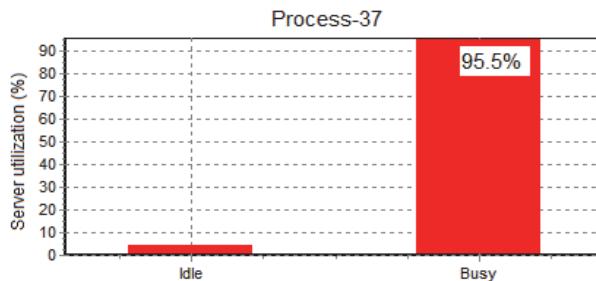


Fig. 10. Overview of the different statuses of process 37 as a percentage of total time

Therefore, as a second scenario it was decided to add one more extra machine with one more operator to the system to overcome server 37's work load. Indeed, the aim of adding new machine is to increase efficiency of sewing line.

3.3 Results based on scenario 2

By adding one more extra machine with one more operator to the system, the bottleneck problem in server 37 was also solved. By this way, the average daily output of the system increased from 312 (according to scenario 1) up to 322 as seen in Fig. 11. Moreover, average staying of jobs in queues decreased from 230 to 221 as seen in Table 5 and the work load of server 37 decreased from 95.5% to 60.30%.

Performance measures	Average	St. Deviation	L-bound (95%)	U-bound (95%)	Min.	Max.
Average content of jobs in machines	30.31	0.06	30.30	30.32	30.17	30.46
Average staying of jobs in queues	221.29	0.83	221.12	221.45	219.48	224.36
Average daily output	322.25	1.20	322.01	322.49	319.00	325.00

Table 5. Results based on scenario 2

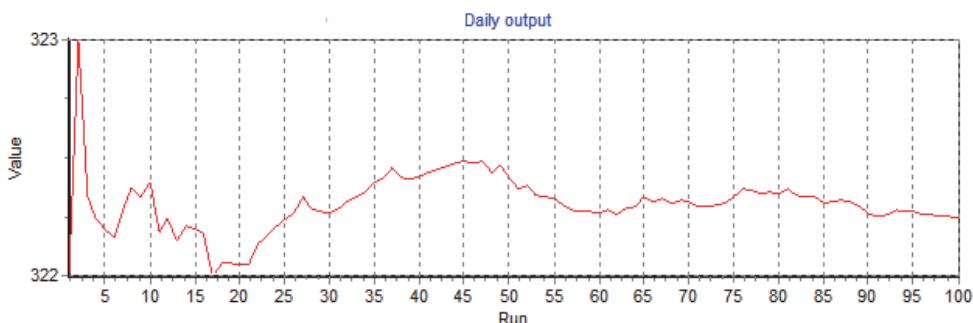


Fig. 11. Scenario 2: Average daily output for 100 observations (5 months)

However, despite the better performance measures, adding additional machine to the system brought new bottlenecks. This time, bottlenecks occurred in server 1, server 2 (see Fig. 12) and server 16.

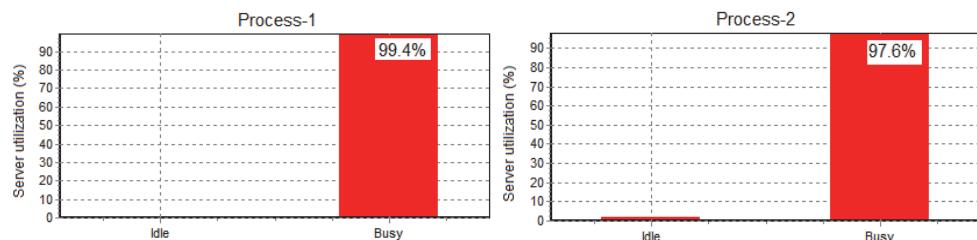


Fig. 12. Overview of the different statuses of process 1 and process 2 as a percentage of total time

Therefore, as a new strategy three machines with three operators were added to the system in order to decrease server 1, server 2 and server 16's workloads and increase the efficiency of the line as well.

3.4 Results based on scenario 3

As seen in Table 6, the daily production of trousers is increased to 340 with scenario 3. Also, with the same scenario the average content of jobs in machines was higher than the scenario 2, but the average staying times of jobs in queues was found to be slightly higher (Fig. 13) than the reference layout. Moreover with scenario 3, the workloads of server 1 and server 2 decreased to 65.7% and 64.8%, respectively. As far as performance measures are concerned, the first important thing for production is the daily output, which is directly related to the line efficiency; therefore results such as the average staying of jobs in queues can be ignored for this reason, but only when they are within acceptable limits.

However, the balance of sewing line can be increased by adding new servers to the system. Therefore, as a final scenario to increase the line efficiency more, four additional servers were added to system for recently overloaded servers; server 30 (96.8% busy), server 25 (97.9% busy), server 20 (98.8% busy), and server 14 (61.1% busy and 37% distributing).

Performance measures	Average	St. Deviation	L-bound (95%)	U-bound (95%)	Min.	Max.
Average content of jobs in machines	36.26	0.05	36.25	36.27	36.13	36.38
Average staying of jobs in queues	291.35	1.59	291.04	291.66	286.52	295.27
Average daily output	339.95	1.27	339.70	340.20	337.00	343.00

Table 6. Results based on scenario 3

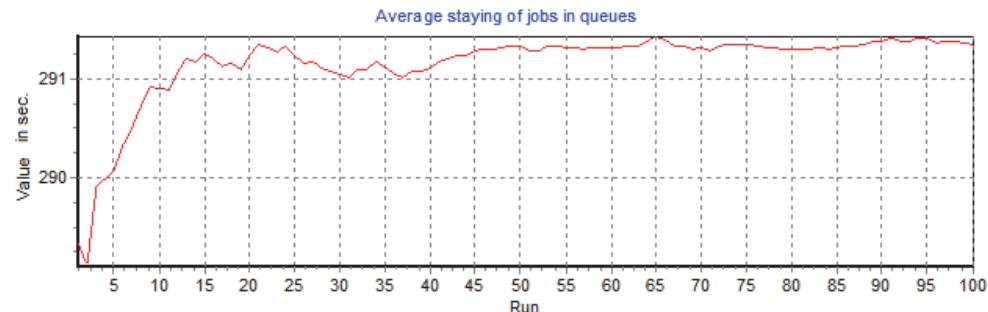


Fig. 13. Scenario 3: Average staying of jobs in queues for 100 observations (5 months)

3.5 Results based on scenario 4

With final scenario, the best performance results were obtained as summarized in Table 7. The average daily output of the system increased from 295 (according to reference layout) up to 419. Average staying of jobs in queues decreased from 260 (according to reference layout) to 186. Additionally, average content of jobs in machines increased from 28 (according to reference layout) up to 39.56. With reference to this scenario, it can be said that the balancing of sewing line seems appropriate for all performance measures.

Performance measures	Average	St. Deviation	L-bound (95%)	U-bound (95%)	Min.	Max.
Average content of jobs in machines	39.56	0.11	39.54	39.58	39.32	39.78
Average staying of jobs in queues	186.82	2.39	186.35	187.29	181.40	191.63
Average daily output	419.21	1.30	418.96	419.46	415.00	422.00

Table 7. Results based on scenario 3

Furthermore, the results of scenario 4 shows that the system became nearly balanced after 30 working days by running it for 8 hours at a 95% confidence level (Fig. 14).

Moreover, workloads of the server 30, server 25, server 20 and server 14 decreased to 62.5%, 63.9 %, 68.6 % (Fig.15), and 55.1%, respectively. As it can be understood from above also when the workloads of the all servers became around 60 % (busy), it was observed that system got nearly balanced.

As a summary, considering precedence constraints four scenarios were developed according to determined bottlenecks in the models. Table 8 summarizes the total changes that were suggested in each scenario. Scenario 1 includes one new operator with one

machine, scenario 2 includes two new operators with two machines. Scenario 3 consists of five new operators with five machines and scenario 4 consists of nine operators with nine machines.

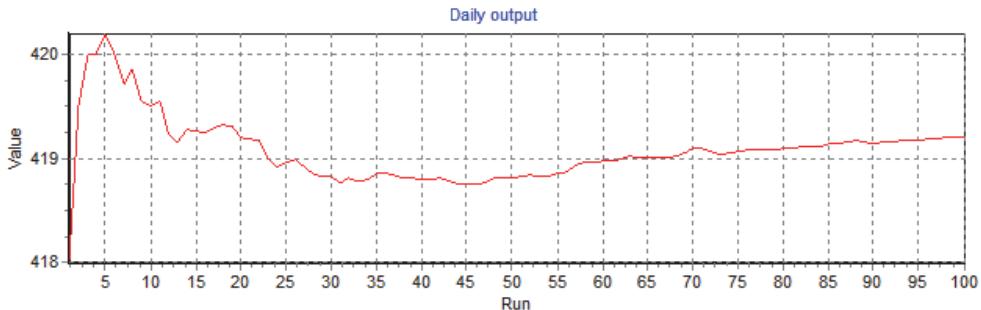


Fig. 14. Scenario 4: Average daily output for 100 observations (5 months)

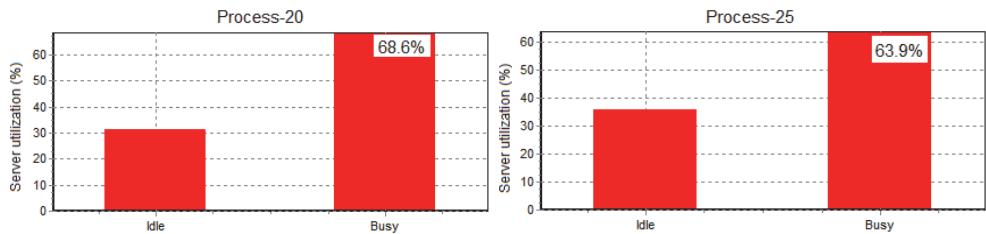


Fig. 15. Overview of the different statuses of process 20 and process 25 as a percentage of total time

	Determined bottlenecks in the model	Suggested solution for consecutive scenario	Total changes in the line according to reference layout
Reference Layout	Server 28	Add one new operator with one machine	-
Scenario 1	Server 37	Add one new operator with one machine	One new operator with one machine was added
Scenario 2	Server 1,2, 16	Add three new operators with three machines	Two new operators with two machines were added
Scenario 3	Server 30, 25, 20, 14	Add four new operators with four machines	Five new operators with five machines were added
Scenario 4	-	-	Nine new operators with nine machines were added

Table 8. Summary of suggested scenarios

As mentioned above in detail, with the suggested scenarios trousers' sewing line was tried to be balanced. It is apparent from the Fig. 16 that the best results are obtained with scenario 4. The number of averaged finished trousers per day is increased by 42% with scenario 4. The averaged content of jobs increased by 40 % whereas the average staying of

jobs is decreased by 28 %. As seen from the figure; the daily output of the system is increased to 312 with scenario 1, 322 with scenario 2, 340 with scenario 3, and 419 with scenario 4. To sum up, with the suggested scenarios the efficiency of the line was increased, and the line was balanced.

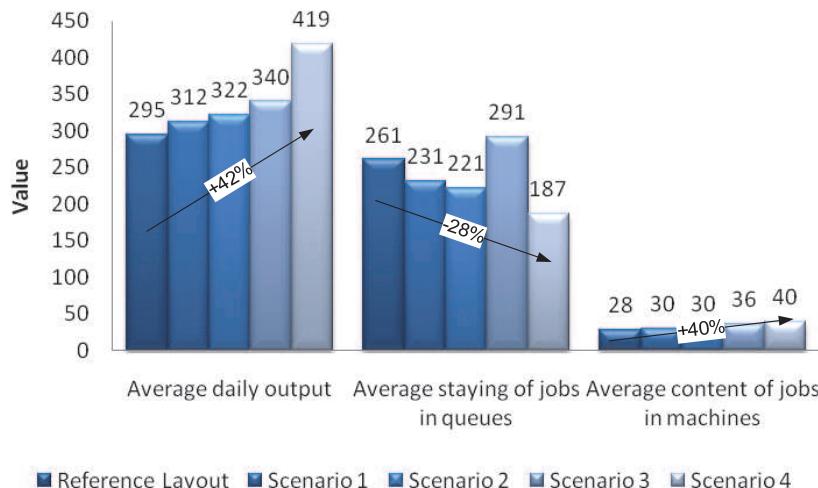


Fig. 16. Total results of suggested scenarios according to performance measures

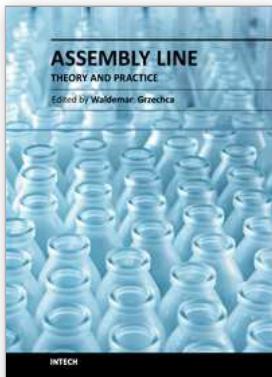
4. Summary

In this chapter, the structure of garment assembly line was analyzed by simulation. A trousers sewing line was considered for simulation model. Firstly, the work flow of the line as well as the chronological sequence of assembly operations needed to transform raw materials into finished trousers were described in detail. Then, a detailed work and time studies were performed along the line. Secondly, real-data gathered from factory floor was tested for distribution fit, and a Kolmogorov-Smirnov test was carried out for the goodness of fit. Afterwards, the creation of model was explained. To set-up the model, all fitted data and allocation of operations to the operators with machines considering precedence constraints were transferred to simulation model. Model verification was done by comparing the results of the model with the ones of the actual system. Then, bottlenecks in the line were determined. In order to eliminate bottlenecks in the line and to balance line, the model statistics; number of current and average content in workstations in the system, cycle time, server utilization percentage, average staying time of jobs in queues, average output, throughput values of workstations.. etc. were taken into account. Due to model statistics, possible scenarios were formed by various what-if analyses in order to balance line as well as increase its efficiency. These scenarios can provide investment decision alternatives to company administrators. Moreover, in order to present more comprehensive decision alternatives, study can be enhanced by a cost analysis of the possible scenarios.

To conclude, this chapter has demonstrated the use of simulation technique to solve assembly line balancing problem in a garment production.

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An assembly line is a manufacturing process in which parts are added to a product in a sequential manner using optimally planned logistics to create a finished product in the fastest possible way. It is a flow-oriented production system where the productive units performing the operations, referred to as stations, are aligned in a serial manner. The present edited book is a collection of 12 chapters written by experts and well-known professionals of the field. The volume is organized in three parts according to the last research works in assembly line subject. The first part of the book is devoted to the assembly line balancing problem. It includes chapters dealing with different problems of ALBP. In the second part of the book some optimization problems in assembly line structure are considered. In many situations there are several contradictory goals that have to be satisfied simultaneously. The third part of the book deals with testing problems in assembly line. This section gives an overview on new trends, techniques and methodologies for testing the quality of a product at the end of the assembling line.

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