

# Line Balancing in the Apparel Industry Using Simulation Techniques

Department of Textile Engineering,  
Faculty of Engineering, University of Ege,  
Izmir, Turkey  
E-mail: mucella.guner@ege.edu.tr

## Abstract

Line balancing problems are well-known applications of industrial engineering departments. Different kinds of line balancing algorithms have been applied for many years in the apparel industry. However manual-operations oriented system of this sector makes it impossible to gain certain results with the algorithms currently used, and also makes it difficult to predict upcoming events when the production system is modified. This paper investigates and demonstrates the application of computer simulation for the design of a manufacturing process for t-shirt production in a virtual-reality environment. For this purpose, lots of data are collected from the real system and alternative systems are composed in order to find best one.

**Key words:** line balancing, simulation technique, apparel mills, modular production, productivity.

ferent operations which are done manually, the sewing department has to be under constant control. Consequently, all line balancing processes which determine the speed of an assembly line are done in this department. But it is a big mistake not to consider the relationship of the sewing department with other departments.

In the apparel industry, it is essential to form a new production line for each order, and also the number of workers is changed according to the complexity of the order, the number of operations, throughput etc. The things which should be done during the installation of an assembly line are as follows;

- To define a standard time for each operation,
- To balance the production line for each order,
- To keep the utilisation rate at a maximum for each operator,
- To complete all these steps in one week before production begins.

Therefore, to develop a new system, good observation is needed. However, to observe real manufacturing systems is very expensive and sometimes cumbersome. The rapid rate at which the whole process takes place, the interaction between workers, and the different transition times between workers make it increasingly more difficult for a human being to make correct decisions regard-

ing how fast each operator should work in order to continue the process, while at the same time keeping productivity high and throughput at an acceptable level.

Therefore, a simulation model is an easier way to build up models to represent real life scenarios, to identify bottlenecks, to enhance system performance in terms of productivity, queues, resource utilisation, cycle times, lead times, etc. A re-configurable assembly line can provide flexibility for high mix low volume manufacturing systems, which can meet growing customer demand.

## ■ Description of the problem

In many garment assembly plants, standard push production systems with dozens of workers are being reorganised into straight assembly lines. In sewing departments the Standard time ( $S_t$ ) for each operation is calculated by the sum of the base time ( $B_t$ ), the fatigue allowances ( $F_a$ ) and the idle time ( $I_t$ ). The base time consists of the stopwatch time ( $S_w$ ) and the performance rating ( $P_r$ ). It is calculated as follows;

$$S_t = B_t + F_a + I_t = S_w \times P_r + F_a + I_t$$

The line balancing problem of sewing departments is solved by using  $S_t$ , and it's assumed that all of the same operations are processed equally. However, in real-

## ■ Introduction

Today's business climate for clothing manufacturers requires low inventory and quick response systems that turn out a wide variety of products to meet customer demand. It is especially in the apparel industry that managers are trying to develop their current systems or looking for new production techniques in order to keep pace with the rapid changes in the fashion industry.

In apparel enterprises a raw material is processed in different departments before becoming a garment (Figure 1). There is no doubt that the sewing department is the most important department in the whole firm. Because there are lot of dif-

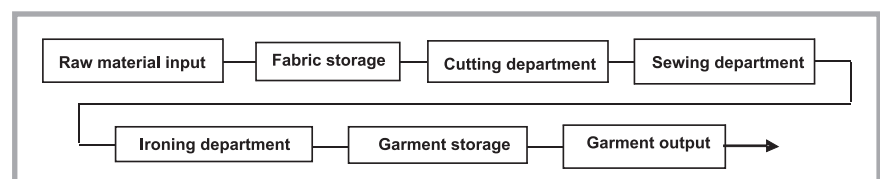
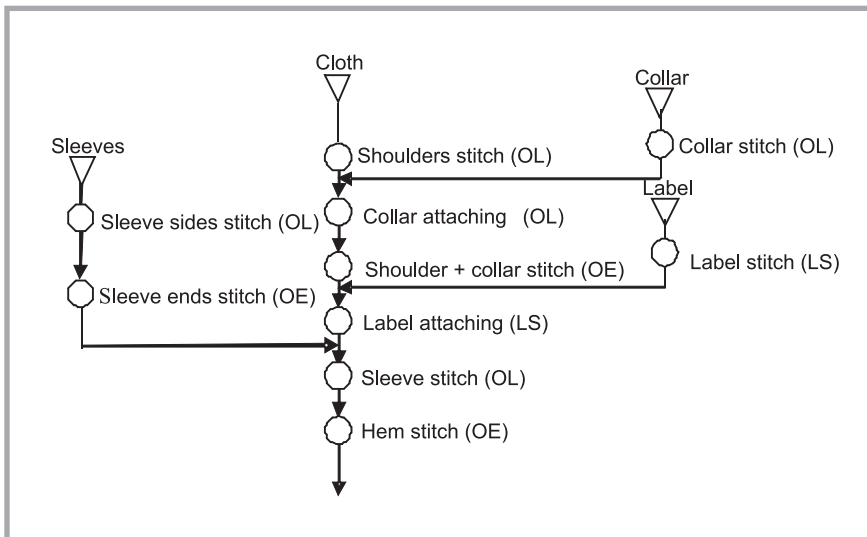


Figure 1. Departments of apparel enterprises.



**Figure 2.** Production diagram of a t-shirt; (OL: Overlock Machine, OE: Overedge Stitch Machine, LS: Lockstitch Machine).

ity, all operations are completed at different times because of their stochastic structure, and the stochasticity of operations makes it almost impossible to follow a fixed time pattern. Therefore, managers are up against unexpected queues and decreasing levels of performance during the sewing process. New calculation methodology which reflects reality better is needed in order to estimate more realistic production quantities and performance.

Also, managers want to change whole production lines to create lean ones in order to immediately respond to changes in demand. But the main difficulty of this is to obtain skilled operators who can use different kinds of sewing machines. Even if operators are found, it is hard to calculate the new line balancing problem with the current work force and those who are skilled.

The simulation modelling research proposed here is based on how to build a reconfigurable simulation model to meet customer requirements as well as improve system performances.

Several researchers have studied assembly line performance by using simulation techniques; Scriber, described a case study for selecting the best probable production system from four proposed production systems using simulation [1]. Azadeh developed an integrated simulation model which generates a set of optimising alternatives for a heavy continuous rolling mill system in a full-scale steel-making factory and generates a set

of optimum production alternatives [2]. Patel et al. discussed the methodology of modelling and studying the Final Process System of the automobile manufacturing process in order to develop an effective and efficient process to ensure the system throughput [3]. Choi et al. discusses initial efforts to implement simulation modelling as a visual management and analysis tool at an automotive foundry plant manufacturing engine blocks [4]. Potoradi et al. described how a large number of products are scheduled by a simulation engine to run in parallel on a pool of wire-bond machines to meet weekly demand [5]. Kibira et al. presents a virtual-reality simulation of a design of a production line for a mechanically assembled product [6]. Altiparmak et al. used simulation metamodels to improve the analysis and understanding of the decision-making processes of an asynchronous assembly system to optimise the buffer sizes in the system [7]. Wiendahl et al. used simulation tools in the field of assembly planning and due to the different objectives of the different efforts, the tools are divided into the four-hierarchy classes of an assembly shop, cell, station and component [8]. Gurkan et al. investigated current problems in an order based weaving mill so as to propose a new system for the aforementioned mill [9].

#### Assembly line description

In this study, the problem under consideration is about the production of a basic t-shirt. The production diagram of a t-shirt consists of 10 different operations (Figure 2).

## Simulation model

The simulation model was built using Arena® version 7.0 simulation software. The construction period of the model is based on a production diagram which was provided by an apparel firm. Sewing machines are organised according to the production diagram, but the number of machines which are used for each operation are determined by the line balancing algorithm. During straight line production each operator uses only one machine, whereas in a lean production system, skilled operators can use different machines.

This study represents discrete-event modelling and the apparel firm works for 540 minutes in a day. At the beginning of each order, the production line begins empty. This start-up condition must also be simulated. Statistics during this part of the simulation may negatively bias the final results since the line takes time to “warm up” and begin operating consistently in a steady state. When an entity arrives at a sewing machine, it waits in a first-in-first-out queue until the resource is available.

The following assumptions are used to define the problem:

- the assembly line is never starved,
- set-up times are not taken into consideration. Because in a real system the setup process is usually accomplished at the end of the working time,
- 540 minutes working time does not include breaks,
- no maintenance process is performed during the working period,
- all process times for sewing operations include ‘insignificant breakdowns’ like the detachment of sewing thread,
- transportation of raw materials is performed by workers who aren’t used for sewing operations.

**Table 1.** Distribution types for each operation; unit, second.

Operations	Distribution Type
Shoulders stitch	8 + LOGN(2.53, 1.24)
Sleeve sides stitch	7 + ERLA(0.893, 2)
Sleeve ends stitch	7 + ERLA(0.973, 4)
Collar attaching	NORM(12.3, 1.42)
Collar stitch	3.6 (Constant)
Shoulder + collar stitch	9 + GAMM(2.17, 1.77)
Label stitch	6 (Constant)
Label attaching	17 + ERLA(1.25, 3)
Sleeve stitch	33 + WEIB(6.96, 1.17)
Hem stitch	8 + LOGN(2.53, 1.24)

### The model input

During the data collection period, between 45 and 70 items of data are obtained for each operation using time study techniques. As has already been mentioned, in assumptions, insignificant breakdowns are also added to the time study data. All data are evaluated by the Arena Input Analyser software in order to determine distribution types for every operation (Table 1).

### Verification/Validation

The following verification efforts were made: The model was coded and debugged step by step. Trace and animation techniques were used to verify that each program path was correct. We made simulation trial runs under a variety of settings of the input parameters, and checked the model output results for appropriacy.

By running the simulation model plenty of times, the interval times of each entity were taken every 5 seconds. It was proved by repetition that using less time for the interarrivals does not change the throughput. It only makes the simulation work more slowly. 5 seconds, which is called the 'critical time', is the most suitable duration to observe queues.

Validation is necessary to show that the proposed model has an acceptable level of confidence in the performances processing assumed. Validation is also associated with whether the proposed model is indeed an accurate representation of the real system. There are several ways to validate the model. Model validation was accomplished through hypothesis tests using a throughput with a 95% confidence interval as follows [10];

The hypotheses are:

$$H_0: \mu_{\text{Filed}} = \mu_{\text{Arena}}$$

$$H_1: \mu_{\text{Filed}} \neq \mu_{\text{Arena}}$$

The test is if  $t_0 < t_{\alpha/2, n_1+n_2-2}$ , we would accept the null hypothesis  $H_0$ , where,

$$t_0 = \frac{\mu_F - \mu_A}{S_p \sqrt{\frac{1}{n_F} + \frac{1}{n_A}}}$$

$$S_p^2 = \frac{(n_F - 1)S_F^2 + (n_A - 1)S_A^2}{n_F + n_A - 2}$$

$\mu_F$  is the mean throughput from the field  
 $\mu_A$  is the mean production rate from the ARENA model  
 $S_p^2$  is the pooled mean variance

Table 2. Number of operators for each alternative; A - alternative models.

No	Operation (machine)	Number of operators					
		Real system model	A1	A2	A3	A4	A5
1	Sleeve sides stitch (OL)	4	9	6	5	5	4
2	Sleeve ends stitch (OE)	5					
3	Collar stitch (OL)	1	3	2	2	2	2
4	Label stitch (LS)	2					
5	Shoulders stitch (OL)	4	9	7	7	6	6
6	Collar attaching (OL)	5					
7	Shoulder + collar stitch (OE)	3	8	7	7	7	7
8	Label attaching (LS)	5					
9	Sleeve stitch (OL)	8	8	8	8	8	8
10	Hem stitch (OE)	3	3	3	3	3	3
Total number of operators		40	40	33	32	31	30
Throughput		6464	6463	6462	6464	6463	6462
Piece per operator		161.6	161.5	195.8	202	208.4	215.4

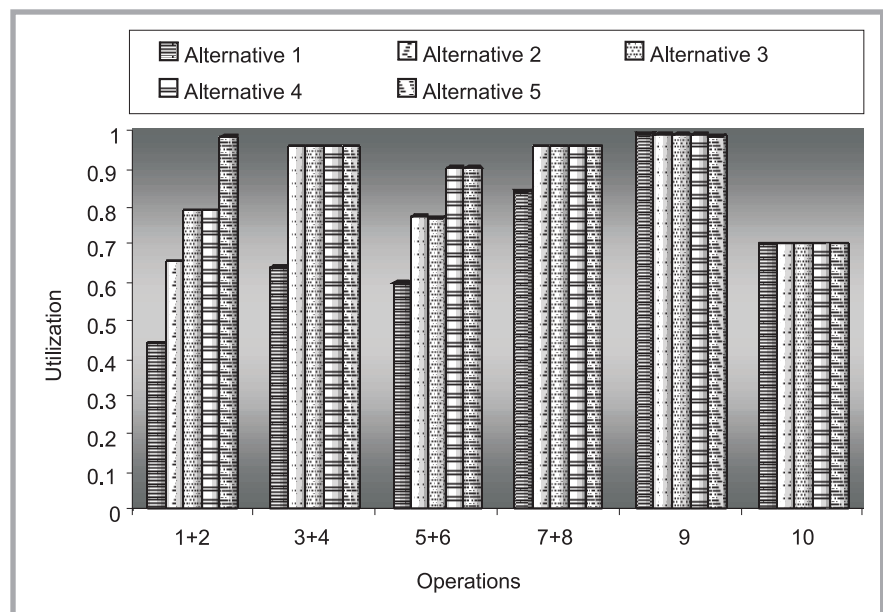


Figure 3. Utilisations for each alternative.

$n_F$  and  $n_A$  the number of field samples and runs of the model, respectively.

The average throughput of 50 items of data ( $n_1 = 50$ ) collected from the field was  $\mu_F = 6463.78$  unit with variance  $S_F^2 = 48.72$ . and that for the ARENA model was  $\mu_A = 6462.58$  with variance  $S_A^2 = 1.56$  after running the model for a total of 50 times ( $n_2=50$ ).

Hence,  $S_p = 5.01$  which makes  $t_0 = 1.19$  and from the 't' table (%95 C.I.)

$$t_{\alpha/2, n_1+n_2-2} = t_{0.025, 98} = 1.96$$

Since,

$$t_0 < t_{\alpha/2, n_1+n_2-2}$$

it implies that there is no significant difference between the means, therefore the simulation model is valid.

### Results

After the validation process was done, different decision options were evaluated for the design or reconfiguration of the assembly line. Skilled operators were added for suitable operations in order to decrease the bottleneck in the assembly line. The queue length and the utilisation of each resource were also observed. Thus, five different alternative models (A1, A2, A3, A4, A5) were developed until the best result was gained (Table 2).

As seen in Table 2, what-if analyses led us to use some skilled operators, for instance the first and second operations in the real system  $t_0$  model was done by four operators who could handle OL and five operators who could handle OE. However, in A1 model 9 operators who can han-

**Table 3.** Simulation results of modular production.

Operations	Modular production	
	Number of operators	Utilization
Sleeve sides stitch (OL)	3	0.9997
Sleeve ends stitch (OE)		
Collar stitch (OL)		
Label stitch (LS)	2	0.9191
Shoulders stitch (OL)		
Collar Attaching (OL)	2	0.9989
Shoulder + collar stitch (OE)	1	0.8802
Label attaching (LS)	1	0.9997
Sleeve stitch (OL)	4	0.9265
Hem stitch (OE)	1	0.9924
Total number of operators	14	
Throughput	3030	
Piece per operator	216.42	

dle OL and also OE is used. In the apparel industry there are two ways of fulfilling this purpose: to employ new workers or to train current workers. In any case, more efficient production is achieved by using alternative models. When we analyse Figure 3, changes in utilisation can easily be seen.

The development of utilisation is undertaken by observing the utilisation of each operator after every repetition of a model. Operations which have insufficient utilisation are reorganised by removing redundant operators. So after developing five different alternatives, the best model is obtained according to the throughput and utilisation rate.

### Designing the assembly line for modular production

Also, a different scenario analysis was done to modify the assembly line to become a modular production line. The main advantage of this production style is as follows;

- increment in production speed,
- ease of control,
- it gives the opportunity to create a competitive atmosphere between operators,
- fewer operators required,
- flexibility.

However, this type of production frequently needs more skilled operators who can perform two or three different jobs at the same time. A new scenario was developed by using these steps;

- The whole production line is divided into two different small groups in

order to change the assembly line's cumbersome structure,

- All operators are allocated suitable jobs according to their utilisations,
- Entity interarrival times were changed every 10 seconds after the 'critical time' is determined in order to rapidly simulate the model.

As is seen in Table 3, the results of one modular production are better than all the alternatives above; especially the production of piece per operator, which has the highest rank.

### Discussion & conclusions

Our proposed simulation approach, developed for the line balancing of t-shirt production, provides the planning manager with a simulation based optimisation tool that can achieve the following objectives: gaining information without disturbing the actual system, improved system performance, testing new systems before implementation, and labour requirement planning.

The base model was a replicate of the existing system without variation. The reconfigured/redesigned models were developed in order to add skilled operators to the current system. However, the application of simulation technology today is not very widespread in the apparel industry; these models can be applied in a real system to analyse the system performance more efficiently and effectively. The modelling environments can easily be used for line balancing and assessing the behaviour of a line. Thus, managers can prevent any unexpected situations by analysing results using the simulation model.

Nowadays, apparel mills, particularly those based upon small lots and orders, must respond rapidly to changes in style. It is essential to know the current situation of a system in order to process orders on time. In order to increase productivity, it is essential to describe the behaviour of a system and to generate alternative systems. For this purpose, by developing a suitable simulation program for an enterprise, the situation of the company in the short-term future can be predicted and productivity can be increased.

### References

1. Scriber T. J. 'An introduction to simulation using GPSS/H' New York: Wiley, 1991.
2. Azadeh, M. A., 'Optimization of a heavy continuous rolling mill system via simulation' *Proceedings of the Seventh International Conference on Industrial Engineering and Engineering Management*, 2000, Guangzhou, China pp. 378-384.
3. Patel, V., J. Ashby, and J. Ma. 2002. *Discrete event simulation in automotive Final Process System*, *Proceedings of the 2002 Winter Simulation Conference*, ed. E. Yücesan, C.-H. Chen, J. L. Snowdon, and J. M. Charnes, pp. 1030-1034, San Diego, California.
4. Choi, S.D., A.R. Kumar, and A. Houshyar., 'A simulation study of an automotive foundry plant manufacturing engine blocks' *Proceedings of the 2002 Winter Simulation Conference*, ed. E. Yücesan, C. H. Chen, J. L. Snowdon, and J. M. Charnes, 2002 San Diego, California, pp.1035-1040.
5. Potoradi, J., O.S. Boon, S.J. Mason, J. W. Fowler, and M. E. Pfund, 'Using simulation-based scheduling to maximize demand fulfillment in a semiconductor assembly facility' *Proceedings of the 2002 Winter Simulation Conference*, ed. E. Yücesan, C.H. Chen, J. L. Snowdon, and J. M. Charnes, 2002, San Diego, California pp.1857-1861.
6. Kibira, D., McLean C., 'Virtual reality simulation of a mechanical assembly production line' *Proceedings of the 2002 Winter Simulation Conference*, ed. E. Yücesan, C. H. Chen, J. L. Snowdon, and J. M. Charnes, 2002, San Diego, California pp. 1130-1137.
7. Altıparmak, F., B. Dengiz, and A. A. Bulgak., 'Optimization of buffer sizes in assembly systems using intelligent techniques.' *Proceedings of the 2002 Winter Simulation Conference*, ed. E. Yücesan, C.H. Chen, J. L. Snowdon, and J.M. Charnes, 2002, San Diego, California pp. 1157-1162.
8. Wiendahl, H., Garlichs R., Zeugtraeger K., 'Modeling and simulation of assembly systems' *CIRP Annals* 1991, 40(2), pp. 577-585.
9. Gurkan P., Taskin C., 'Application of simulation technique in weaving mills' *Fibers & Textiles in Eastern Europe*, 2005, Vol. 13, No.3(51), pp. 8-10.
10. Hines W. W., Montgomery D. C., 'Probability and statistics in engineering and management science'. New York: Wiley, 1989.



Received 21.02.2007

Reviewed 09.03.2008