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Creating an Alternative Production Line by Using a Simulation Technique in Duvet Cover Production

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Abstract
In this study, the discrete-event system simulation technique was used in order to create smooth work flow on a duvet cover production line. In accordance with this purpose, a model of the work flow of a duvet cover was created, and input data was collected by means of a time study in order to determine the statistical distribution of all operations using Stat-fit for Simul8 software. The model translation phase was executed in Simul8 Software. Then for the purpose of the verification and validation process, actual system data and simulation model outputs were compared statistically using the normality test and Mann-Whitney non-parametric test in Minitab Software. Once the simulation model of the actual system was properly validated, an alternative model considering fewer operators was generated in order to acquire more output and have a smoother line balance. The alternative model was compared with main one by considering the output rate per operator.

Key words: *apparel industry, simulation technique, productivity, line balancing.*

Introduction

Simulation is an important tool for the modeling of a complex system. It is used to represent manufacturing, transportation, and service systems in a computer program for the purpose of performing experiments. Representation of the system via a computer program enables the testing of engineering design changes without disruption to the system being modeled [1].

In recent years, especially in the field of clothing, studies related to simulation have been concerned with issues such as computing the shape descriptors in fabric [2, 3] and garment [4] drape as well as determining the impact of body posture and shape on garment fit and design [5, 6]. However, the research topic herein is production simulation, of which there are two distinct types of: discrete and continuous. In discrete simulation, observations are gathered only at points in time when changes occur in the system. On the contrary, continuous simulation requires that observations be collected continuously at every point in time. Although continuous simulation has important applications, most attention has been directed toward discrete simulation [7]. Since a textile and apparel production line consists of a sequence of different phases of assembly operations, it is an example of discrete-event simulation.

In any assembly line, time-synchronisation of operations is the most important factor because the flow of work cannot be synchronised if there are considerable variations in the task times allowed for all the operations performed on the line [8]. In most apparel enterprises, estimation of the production time for each task is by reference to the Standard Minute Value (SMV).

The assembly line balancing problem, which considers the (task time) standard unit time, in apparel industry has been worked on for different purposes such as applying different heuristic algorithms [9], solving the problem of multi-model assembly line balancing [10], developing a new module for production monitoring software [11], investigating the results of method study [12], and comparing the efficiency of different balancing algorithms [13].

The characteristic of SMV is deterministic in nature, derived from the method of work study. However, it cannot reflect the real production environment factors in the clothing industry that may cause variations in task time, which, in turn, lead to the assembly line balancing problem becoming more complicated [14]. In order to cope with this stochastic nature of the production process, a simulation technique is used in this study.

The simulation technique has been used in many studies, such as evaluating alternative line configurations in apparel industry by considering line balancing [15-19], meeting order due dates, maximising loom utilisation [20], exploring the impacts of lot size and order complexity and their interaction effect on the performance of apparel production systems [21], explaining the production flow and distribution logic of bobbins for the rewinding process in a yarn dyeing factory, comparing the different scenarios of production (manual and automatic) [22], and researching the effects of using automation in assembly lines on production volume and efficiency [23].

This study deals with creating an alternative production line in Simul8 software (Boston, USA) by considering the output rate per operator using simulation. As managers aim to increase operators' productivity, the study was carried out in a well-known bed linen and curtain production firm which has more than 1200 employees in Turkey. In order to analyse the structure of a production line and demonstrate the benefits of the simulation technique, a simple duvet cover production line was focused on intentionally. Because the production system becomes more complicated, simulation application can be used more effectively. Firstly the work flow of the production line was described in detail. Then a detailed work and time study along the sewing line was performed in order to determine the statistical distribution of all operations using Stat-fit for Simul8 software (Boston, USA). The study went on to create a model of the sewing line by simulation. To set up the model, all fitted data and allocation of operations to the operators

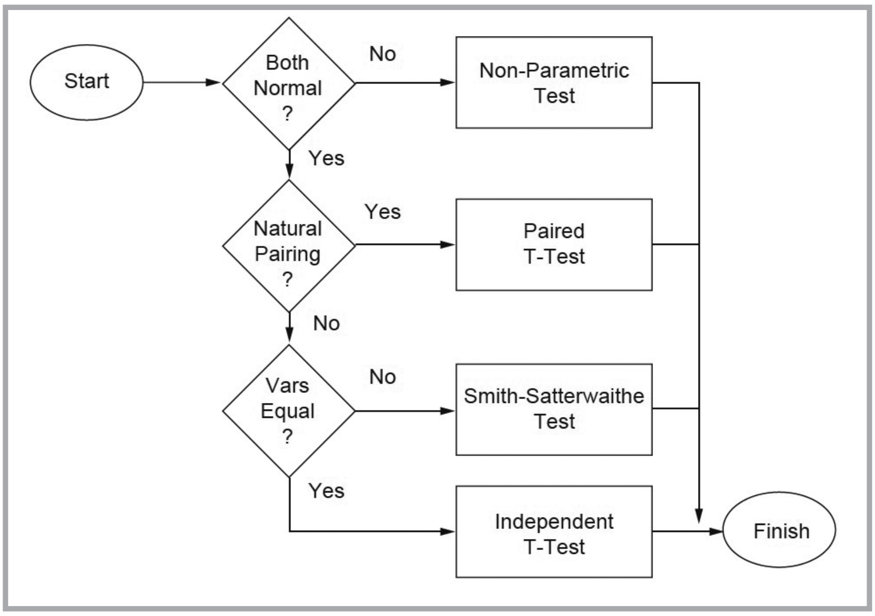

Figure 1. *Hypothesis test flow chart [25].*

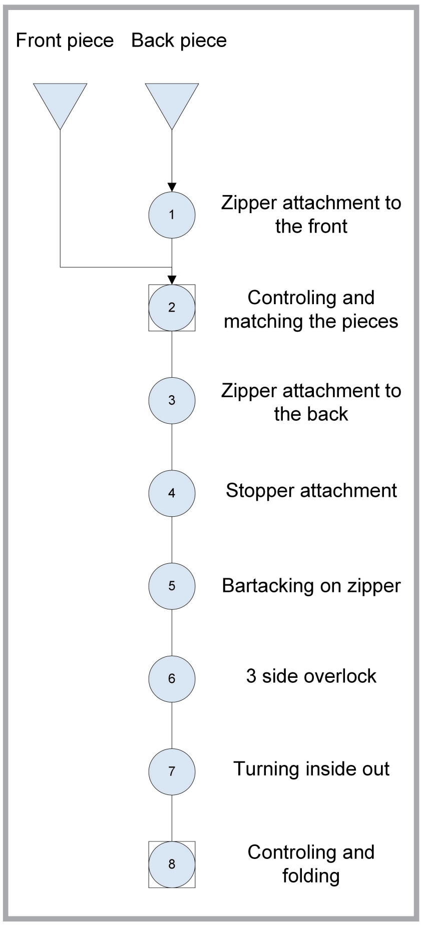

Figure 2. *Work flow of duvet cover production.*

were transferred to the simulation model. The model is validated by comparing the actual system statistically. This study concludes by creating an alternative production line in duvet cover production by considering the output rate per operator.

Materials and methods

To perform a simulation study properly, the following steps are required to be taken;

Step 1 – Understand the system: The first step is to understand the system to perform the simulation study.

Step 2 – Set the goals: The performance measures are also defined, that is, the parameters and way to measure performance are defined.

Step 3 – Collect the data: Relevant input data are collected which may reveal the nature or the inherent distribution of the data. After collecting the data, they may be analysed for establishing a probability distribution that suits the data most.

Step 4 – Decide on the model representation: The design of the model is developed. The software to be used for the purpose of modeling is chosen. After choosing the software, the model elements are identified.

Step 5 – Develop the model: The actual simulation model is developed and a test run is performed. Various execution-related parameters, such as the number of runs and the trace elements, are decided.

Step 6 – Verify the model developed: The model developed is verified by checking whether it actually represents the system to be simulated and whether the model produces the desired results.

Step 7 – Validate the model: Validation checks whether the results of the system actually match those of the real system statistically. There are a total of four different types of hypothesis tests. Selection of an appropriate comparison test is dependent on whether or not the data are normally distributed, paired, or independently generated and similar or not in variance (***Figure 1***).

Step 8 – Design the experiments: The questions asked in this step include, for example, "What are the what-if scenarios?" The number of factors or levels is also identified in this step.

Step 9 – Run and analyse the simulation model: The simulation model is run based on the parameter set in steps [24].

Results and discussion

In order to obtain a fundamental understanding of the duvet cover production system, a flow chart was developed (***Figure 2***). Then input data were collected manually in real time with an electronic stopwatch for each operation (in the range of 30-50 observations). To employ a probability distribution in order to represent operation times in the simulation model, data were analyzed in Stat-fit for Simul8 software (***Table 1***). As is seen in ***Table 1***, the number of operators assigned to operations varies due to the company's

Table 1. *Distribution type of operations.*

No	Operations	Distributions	Number of operators
1	Zipper attachment to the front	Pearson 6 (0,17, 0,0335, 5,49, 3,01)	R1
2	Controlling and matching the pieces	Pearson 5 (0,102, 1,82, 0,0454)	R2-R3
3	Zipper attachment to the back	Pearson 6 (0,2, 0,0945, 3,46, 5,41)	R4
4	Stopper attachment	Pearson 5 (0,087, 11,8, 1,83)	R5
5	Bartacking on zipper	Weibull (0,166, 1,72, 0,11)	R6
6	3 side overlock	Pearson 6 (0,81, 0,0483, 4,55, 2,16)	R7-R8-R9
7	Turning inside out	Beta (0,183, 0,361, 4,27, 4,68)	R10
8	Controlling and folding	Pearson 6 (0,27, 0,0622, 18,7, 11,2)	R11-R12-R13-R14

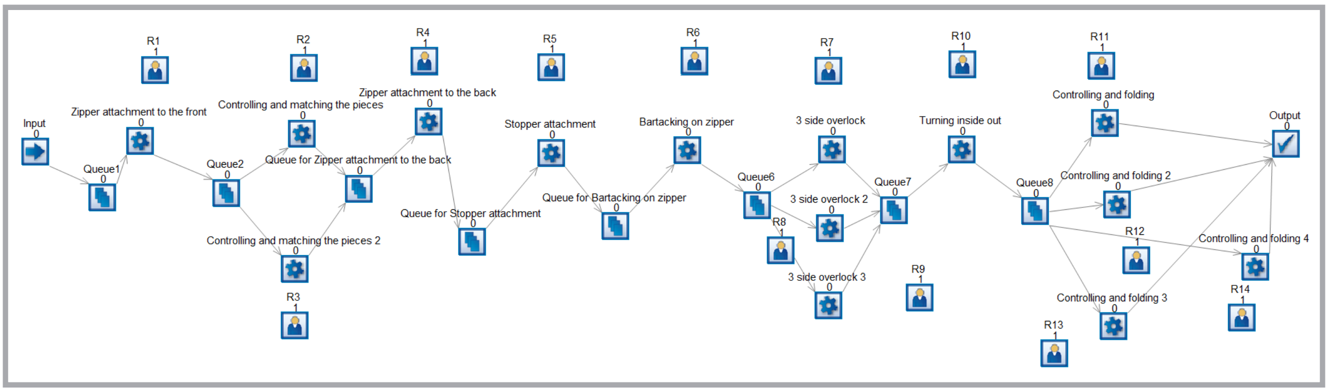

Figure 3. *Simul8 model of duvet cover production.*

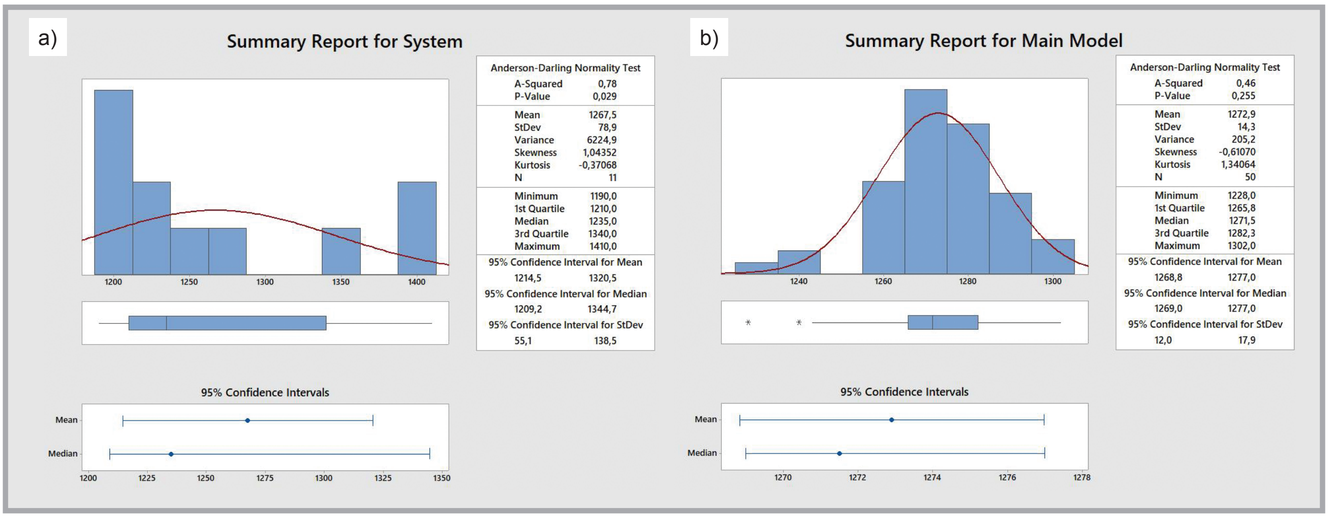

Figure 4. *Normality test results for system (a) and main model (b).*

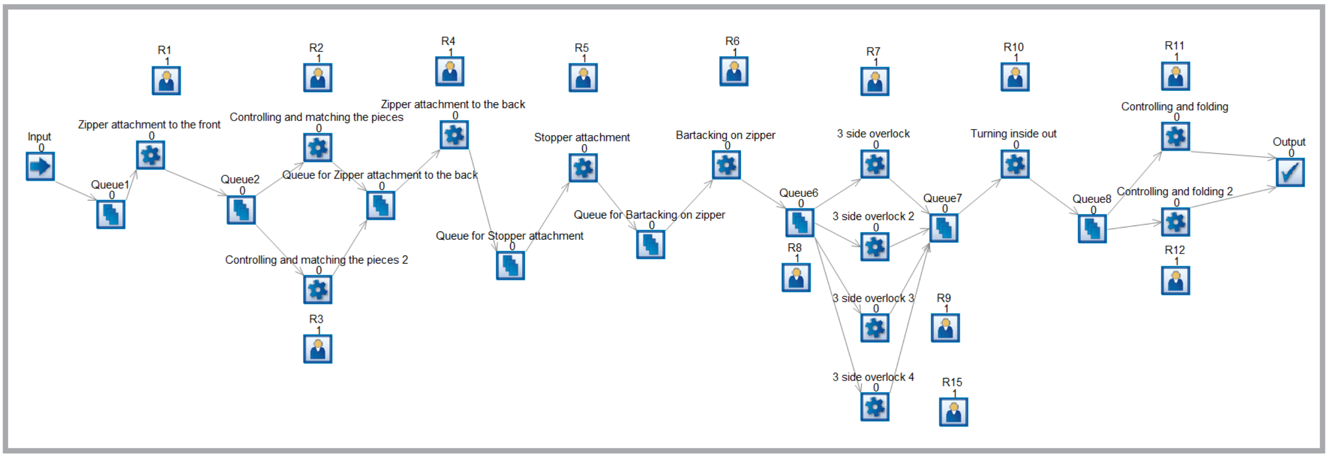

Figure 5. *Simul8 model of main model alternative.*

line balancing and some operators being engaged in more than one operation.

The assumptions of the simulation model of the duvet cover production line are defined as follows:

- The queuing discipline is First-In-First-Out (FIFO),
- Operators are multi-skilled.
- Raw materials are always available,
- Set-up times are ignored,
- Transfer times among the workstations are included in operation times,
- Machine downtime has no impact on production system performance,
- The production system works nine hours a day.

After collecting the data, the design of the model is developed using Simul8 software and named the 'Main Model' (***Figure 3***). In Simul8, models are created by drawing the flow of work with the computer mouse, using icons and arrows to represent the resources and queues in the system. Default values are provided for all properties of the icons so that the animation can be viewed very early in the modeling process. Drilling down in property boxes opens up progressively more detailed properties [26].

The verification process of the main model is done by examining the model output for reasonableness under a variety of settings of the input parameters and verifying that what is seen in the animation imitates the actual system.

Validation of the main model is performed using the different types of hypothesis tests in ***Figure 1***. First both main model and production line outputs are tested for normality using 'Minitab 17' software. If the "p-value" of these test is less than the α-level chosen, the null hypothesis can be rejected and we can conclude that the population is not normally distributed. As is seen in ***Figure 4***, even though the null hypothesis cannot be rejected for the main model (p_{model} = 0.255), it is rejected for the system (p_{system} = 0.029) p-value, which is less than the α-level (0.05). Thus the system is not normally distributed (***Figure 4***).

The second step of the validation process is to check the main model and production line outputs for the Mann-Whitney non-parametric test. For this purpose, sample medians of the system and main model data are calculated as 1235 and 1271.5. The 95% confidence interval for the difference in population medians (System – Main Model) is [-58 to 2]. Test statistic W = 241 has a p-value of 0.0620 or 0.0619 when adjusted for ties. Since the p-value is not less than the chosen level of 0.05, it is concluded that there is insufficient evidence to reject H_0, where, H_0: $\eta_1 = \eta_2$ versus H_1: $\eta_1 \neq \eta_2$, where η is the population median.

Therefore the data do not support the hypothesis that there is a difference between the population medians.

Once the simulation model of the actual system has been properly validated, what-if scenarios are investigated considering bottleneck operations. The new model, named the 'main model alternative', is created in accordance with this purpose (***Figure 5***). With a small change in the number of operators (by increasing the number of operators in a "3 side overlock" operation and decreasing the number of operators in the "controlling and folding" operation) and line balancing, the production rate per operator increased (from 90.92 to 118.47) by 30.3% after a total of 50 replications were performed for each model by Simul8 software (***Table 2***).

Table 2. *Comparison of main model and alternative model.*

No	Operations	Operators of main model	Operators of main model alternative
1	Zipper attachment to the front	R1	R1
2	Controlling and matching the pieces	R2-R3	R2-R3
3	Zipper attachment to the back	R4	R4
4	Stopper attachment	R5	R5
5	Bartacking on zipper	R6	R6
6	3 side overlock	R7-R8-R9	R7-R8-R9-R15
7	Turning inside out	R10	R10
8	Controlling and folding	R11-R12-R13-R14	R11-R12
Total number of operators		14	13
Average production		1272,9	1540,12
Production rate per operator		90,92	118,47

Conslusions

The use of simulation modeling and analysis techniques enabled examination of a duvet cover production line of a bed linen and curtain production factory. This process consisted of data collection, data fitting, model building, verification, validation, experimental design and statistical analysis. With proper execution of these steps, an insight was gained concerning an effective alternative model. Because simulation is the only effective analytic technique that can be used to examine the operation of a production system without disruption or compromise of efficiency requirements, it can be used in any production optimisation study.

In this study, a discrete event simulation model of the duvet cover production line is developed. To achieve this purpose, time studies were performed along the production line. Then data gathered were tested for distribution fit using Stat-fit for Simul8 software. As the data are transformed into Simul8 software, the simulation model of the duvet cover production line is validated by comparing the model with output results of the real system. And by considering the bottlenecks in the line, the production rate of the alternative model is investigated. Experimental results indicate that even though the alternative model proposed contains fewer operators, it can maintain a better production rate.

For future studies, it is proposed that more detailed scenarios (such as considering cost analysis, absenteeism and maintenance periods) can be used in the simulation model.

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