(REFEREED RESEARCH)

MODELING OF TEXTILE DYEING-FINISHING MILL PRODUCTION COST AND TIME UNDER VARIABLE DEMAND CONDITIONS WITH SIMULATION

TEKSTİL BOYA TERBİYE İŞLETMESİNDE ÜRETİM MALİYETİ VE SÜRESİNİN DEĞİŞKEN TALEP ALTINDA SİMÜLASYONLA MODELLENMESİ

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ABSTRACT

In this study, production cost and production time of a selected dyeing-finishing textile mill is modeled for the type of fabric under variable demand at short and medium term planning period. In the model using real data, production cost and production time could be calculated and also the operator needs have been determined. It is demonstrated that production cost and time of dying-finishing mills are modeled by simulation technique and the model can be solved.

Keywords: Dyeing-Finishing, Production time, Production Cost, Variable Demand, Modelling, Simulation.

ÖZET

Bu çalışmada seçilmiş bir boya terbiye işletmesinin üretim maliyeti ve süresi değişken talebe dayalı olarak orta ve kısa dönemli planlama için simülasyon yöntemiyle kumaş türlerine modellenmiştir. Modele ilişkin gerçek veriler kullanılarak boya terbiyede üretim maliyeti, üretim süresi hesaplanabilmiş ve üretim için gerekli operatör ihtiyacı belirlenebilmiştir. Boya terbiye işletmelerinin üretimin maliyet ve süreye dayalı olarak simülasyon tekniği ile modellenebileceği ve modelin çözülebileceği ortaya konulmuştur.

Anahtar Sözcükler: Boya-Terbiye, Üretim Süresi, Üretim Maliyeti, Değişken Talep, Modelleme, Simülasyon.

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1. INTRODUCTION

Textile industry includes diverse constituents such as raw material, yarn, weaving, dyeing and finishing. Fundamental production steps in an integrated textile mill, from raw material to end product, are shown in Figure 1.

Dyeing & finishing mill is the last processing section for textile products. Here, various processes are being applied in order to enhance the features of textile goods, for instance appearance related ones such as dyeing, printing, polishing; handling related ones such as softening, hardening; usage properties related ones such as easy to iron, flame retardant and shrink-proof finishes. These sections of integrated textile mills are the ones which need the utmost attention hence they accommodate complex processes and contain various operations which are hard to recover and which entail high costs in case of any error. The complexity of the production imposes to employ the techniques that enable to facilitate the decision making mechanism. In textile mills, the optimization techniques and especially simulation are widely used for being able to achieve optimization and improvement (2). Simulation is the separation of the model setting operation in to small parts and recomposing them in way that enables to show their mutual interactions and in their natural order. Simulation is an experimental study which is carried out to complete the process operations of the procedure, to execute the trials and to forecast the error times of the procedures, on purpose of designing the model of the real system and operating the system with this model. (3). There are numerous studies, for example, work-time scheduling for production planning under variable demand (3-12), customer satisfaction (13), reducing the number of stops, elimination of the bottlenecks (14-17), shortening the length of deadlines, cost minimization (18-22) etc.

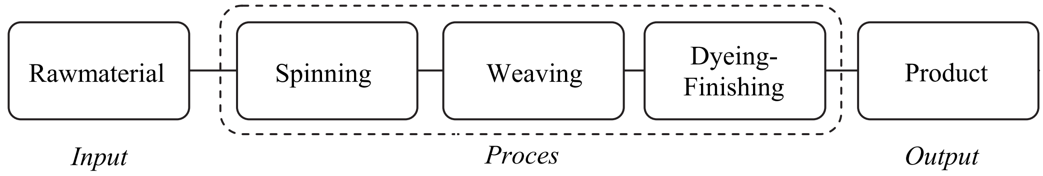

Figure 1. Process Flow in Integrated Textile Production (1)

In textile and apparel industry, it is possible to model the production system with simulation technique as reflecting the real system. By this way, it is possible to detect vast number of problems which are hard to differentiate during the production and to make production related important decisions beforehand. Kurşun and Kalaoğlu modeled the line balancing problem in a sewing line with simulation. They compared the model with the real system and achieved sound results (23). Guner and Unal employed simulation techniques for line balancing in a waving mill (24). Greasley modeled the layout planning of a textile mill and predicted the storing areas. In the study it was also acquired numerical outcomes which could be used as data for the problem of queuing in work flow (25). Ferraris and Morini used simulation technique in production planning and production optimization (26). Dong and Leung proposed a simulation based model for coordination between supplier and producer (27). Bevilacqua and et al. developed a simulation model which aimed to reduce the number of reproductions in the sewing department of a fashion industry affiliated apparel company. They managed to achieve results which enabled to reduce the work flow time and increase the production capacity (28). Ait-Alla and et al., developed a robust production planning model under variable and uncertain demand for fashion oriented fabric producers. The model was also capable of including the risks that were under variable conditions (29). Lee and et al., developed a model to optimize the production plan in an apparel factory having two production lines. The model was effective for optimization of the factory's production times (30).

Demand input is the major basic input parameter for preparing the production plans and control of the stocks. For that reason, as the realist demand forecasts will ensure the validation of the plans, it is necessary to pay due attention to this issue. Hence textile mills mostly follow the strategies to protect the potential customers, they know about their customers and realize their demands leaning against the forecasting methods based on experience and intuition or they make their forecasting, taking in to account the sales volume of a defined product group within an appropriate period (3 months/annual) in accordance with average demand approach. In fact, the demand in textile sector is not constant, therefore, regarding the factors such as seasonal influences and trend would be a more reliable approach. The most important aspect in demand forecasting which is essential to reckon with is the tendency of demands in relation with fashion (trend) and seasonal changes. Therefore, the prime element in textile sector is to accept that the demand is not constant. Dyeing mill is a division at which it is not possible to accept the demand as being constant in between incoming parties. In this study, the variability of the demand was accepted as main variable. Sabır and Batuk (2010) propounded that the time series analysis methods were convenient for demand forecasting at dyeing and finishing mill for fiber dyed goods with Trend Corrected Exponential Smoothing Methods and for tops dyed fabrics with Full Winter's Methods. It was observed that fiber and tops dyed order distribution were not convenient for Simple Exponential Smoothing Method. The fiber dyed fabrics mostly has a polyester-viscose based composition, it is easy to procure these raw materials for every season and variation depends only to the trend. Tops dyed fabrics are mostly cotton based and the existence of variations related to the seasonal effects was observed (1). Dyeing & finishing department is the last processing section for textile products. Here, various processes are being applied in order to enhance the features of textile goods, for instance appearance related ones such as dyeing, printing, polishing; handling related ones such as softening, hardening and lubricating; usage properties related ones such as easy to iron, flame retardant and shrink-proof finishes. In this study, the production amount, time intervals between operations and the cost of production were determined with simulation technique in a selected textile dyeing and finishing mill under variable demand conditions. In the study, the samples were selected from the product groups in which the collected orders by the mill were being concentrated upon. The model was analyzed by the help of ARENA 8.0 software.

2. MATERIAL and METHOD

2.1. Material

For this study, a textile mill consisting of dyeing and finishing processes and having a high production capacity was selected. It was aimed that the system to be modeled would generate valid results for other dyeing and finishing mills too. In the selected dyeing and finishing mill, fiber and roll (tops) dyed fabrics were mostly being used. Hence, 10 different product types out of the mostly ordered (70%) and regularly produced articles were selected. The other 30% part of mill's order range was of short yardage special orders. As it would not have been economic to execute modeling for this type of orders, in this study, the 70% part having continuity was used. The analyzed composition of each sample while in product state is given in Table 1.

Table 1. Selected Samples and Their Compositions (2)

Sample type	Sample code	Sample composition			
		PES (%)	VIS (%)	CO (%)	Elastane (Lycra) (%)
Fiber dyed	N1*	49	47		4
	N2	47.5	47.5		5
	N3	63	33		4
	N4	62	33		5
	N5	62	33		5
Roll dyed	N6	52		43	5
	N7			98	2
	N8			98	2
	N9			98	2
	N10			95	5

**N1:Sample 1*

The samples accompanied with detailed product information were the ones which were subjected to the variable processes in the mill. Table 2 displays the collective work flow for each sample. There were total 17 processes which had been used for the selected products in the mill. There were few more processes in the mill which were excluded from this list. Actually, the processes that were contained in the table were the ones which were being applied continuously in the mill. The applied process was indicated by (+) signs for each process.

2.2. Method

For the study, first of all, a comprehensive cost analysis was carried out for the selected mill. During the cost analysis, standard and production costs were calculated by employing a detailed cost analysis for each sample. Standard costs were defined as consumables including raw material and chemical dyeing agents. Production costs were including direct labor, direct electricity, direct natural gas, indirect labor, depreciation and general manufacturing costs. Table 3 was prepared with the aid of these calculations. The table reveals that the costs tops dyed fabrics are generally much higher than the costs of fiber dyed fabrics. Because, the number of tops dyed fabric production processes higher than the number of fiber dyed fabric production processes, and their reprocess (reversing of the process) rates are also higher.

Inspecting the costs between themselves reveals that the highest ones were the raw material costs. The operational efficiency of the process was also determined. The required process time for being able to meet the demand was also able to be calculated. For instance, lot preparation machine was running with the speed of 50 m/min. On the other hand, when reprocessing and efficiency were also added in to the account, average running speed was reduced to 35m/min. The machine was running continually 22 h 30 min at 1 day. Supposing 1 hour=60 minutes and 1 month =30 days, the monthly production capacity of #1 process would be calculated as 35m/min*22,5h/day*60 min/1h*30 day/1 month=1417500 m/month. Table 4 indicates also the forecasted labor (operator) for each process. The subcontractor production cost of the related process is displayed in the last column.

Table 2. Work Flow for the Selected Samples in the Selected Mill (2)

Processes		***Samples***									
		Fiber dyed					***Roll (Tops) Dyed***				
Process Number	**Process Name**	**N1**	**N2**	**N3**	**N4**	**N5**	**N6**	**N7**	**N8**	**N9**	**N10**
1	Lot preparation	+	+	+	+	+	+	+	+	+	+
2	Singeing	+	+	+		+	+	+	+	+	+
3	Desizing						+		+	+	+
4	Washing	+	+	+	+	+		+			
5	RAM G1-G2-G3	+	+	+	+	+	+	+	+	+	+
6	Calender								+		
7	Bleaching						+	+	+	+	+
8	Mercerizaiton								+	+	+
9	Sanforization							+	+	+	+
10	Pad-Dry						+				
11	Pad Batch Fulard							+	+	+	+
12	Airobin							+			
13	Super Finish							+		+	
14	Stabilo				+		+				
15	Raising				+						

Table 3. Unit Costs of Dyed Fabrics (TL/m) (2)

Sample type	Sample code	***Standard Costs (TL/m)***		***Production Costs(TL/m)***						***Total Cost (TL/m)***
		Material		***Direct costs***			***Indirect costs***			
		Raw material	Supplies (dye-chemical) Cost	Labor	Electric energy	Natural gas energy	Labor	Amortization	Others	
Fiber dyed	N1	4.10	0.03	0.09	0.09	0.37	0.09	0.34	0.14	5.29
	N2	5.01	0.16	0.08	0.08	0.32	0.08	0.29	0.11	6.13
	N3	4.35	0.03	0.08	0.06	0.22	0.07	0.06	0.09	5.15
	N4	6.03	0.29	0.24	0.10	0.20	0.18	0.21	0.16	7.41
	N5	4.63	0.05	0.05	0.04	0.12	0.05	0.15	0.06	5.15
	Total	**24.12**	**0.56**	**0.54**	**0.37**	**1.23**	**0.47**	**1.05**	**0.56**	**29.13**
Tops dyed	N6	4.94	0.19	0.18	0.14	0.64	0.18	0.46	0.18	6.91
	N7	1.75	0.25	0.15	0.08	0.25	0.12	0.21	0.10	2.91
	N8	2.64	0.08	0.11	0.08	0.46	0.11	0.22	0.09	3.79
	N9	0.65	0.07	0.13	0.07	0.48	0.12	0.17	0.07	1.74
	N10	2.80	0.15	0.09	0.06	0.43	0.08	0.15	0.07	3.85
	Total	**12.78**	**0.74**	**0.66**	**0.43**	**2.26**	**0.61**	**1.21**	**0.51**	**19.2**

The first phase during setting up the model was calculating the cost of each selected sample by multiplying its unit sale price by its optimum production output (id est. turnover). By this way, the amount of profit would be calculated. The computed sale prices of the samples are given in Table 5. If there was the risk of failing to catch a deadline or there were any resources related bottle-necks, subcontractor production was a widely employed solution. Regarding the production order, it was an important factor to ensure if the product to be produced existed in the stocks. It was necessary to add these factors to the mathematical model. In this study, the stock policy of the mill was investigated and found that a certain amount of products which were demanded by the major and the regular customers had been kept ready in stock, and this is indicated in Table 5. Time and costs according to selected fabric type, in a textile dyeing & finishing mill operating under variable demand conditions, were managed to be calculated via simulation approach.

3.RESULTS AND DISCUSSION

3.1. Setting up the Simulation Model

In the designed simulation model, demand was accepted as variable and firstly, it was determined that which distribution would have been compatible for variability of demand. Then, by defining the deadline time, considering that the deadline times were between 20 — 40 days and the investigated production planning time was 1 month (30 days), the assignments were carried out. By this way, the fabrics which were within the investigated deadline time (1 month) were included in to the simulation model, and the exceeding ones were excluded. All of the processes, to which the fabrics were subjected in the dyeing & finishing mill, within the model were indicated respectively. By designating all of the machine speed and operator requirements which were needed to fulfill these processes, the time and the resource calculation of the model was managed to be achieved. In the investigated mill, it was being carried out two types of fabric production, id est. fiber dyed and tops dyed. These fabric types were allocated as Rota in the simulation model. Rota 1 demonstrated the fiber dyed fabrics and Rota 2 demonstrated the tops dyed fabrics. Besides, the cost of each process was processed in the system and both Rota based and total based cost calculations were managed to be achieved. The prepared simulation model is given the form which is rearranged from the original ARENA Software print in Figure 3.

It was appropriate to select Exponential distribution for the demand of time between incomings. The application areas of exponential distribution were defined as the times between the customers' incoming that were accessing the system with a constant speed. In the selected mill, it was observed over the customers that average time for each demand incoming was 6 hours. According to the selected distribution, the time of demands between incomings was defined as Expo 0.25 day (6 h) in Create module of ARENA software.

Table 4. Processes and Working Times and Operator Requirements in Dyeing&Finishing Mill (2)

Process Number	The Process Name	Production (%)	Machine speed (m/min)	Reprocess Rate (%)	Maximum working capacity of the machine in the process (m/month)	Operator needs (person)	Unit Fason Costs (TL/m)
1	Lot preparation	70	50	0	1417500	2	3.00
2	Singeing	55	120	1	2646270	1	5.00
3	Desizing	55	45	5	1211970	1	6.00
4	Washing	70	50	3	2646270	2	7.00
5	RAM G1-G2-G3	85	30	5	1096530	2	7.00 (drying)- 10.00 (finishing)
6	Calender	80	20	5	641520	1	2.00
7	Bleaching	65	20	3	510720	2	7.00
8	Mercerizaiton	65	35	1	912180	1	7.00
9	Sanforization	85	50	5	1635180	1	3.00
10	Pad-Dry	45	20	3	810000	2	10.00
11	Pad Batch Fulard	40	30	3	1215000	2	10.00
12	Airobin	75	10	1	405000	1	3.00
13	Super Finish	75	25	1	751770	1	2.00
14	Stabilo	75	25	10	1012500	1	2.00
15	Raising	75	10	1	8748000	1	7.00
16	Scissor	75	7,5	5	303750	1	5.00
17	Quality Control	100	12	1	481140	1	2.00

Table 5. Unit Sale Prices and Stock Conditions of Samples (2)

Sample code	Unit Sale Price (TL/m)	*Stock (m/month)* Starting	Finishing
N1	6.60	0	0
N2	8.00	10000	5000
N3	7.00	5000	3000
N4	9.20	0	0
N5	6.20	0	0
N6	9.00	0	0
N7	4.6.	0	0
N8	8.00	0	0
N9	6.80	0	0
N10	5.20	0	0

It was carried out assignments in the selected module of ARENA Software both for demand size and deadline time. The demand size distribution was compatible with Poisson distribution (2). Poisson distribution is a distribution type having application areas such as number of occurrences of an event which occurs in a certain time interval with constant speed; the number of items in a random sized lot; and demand amount. In this study, by also help of the previous data, the average variation of the demand amount was found as being around 50 m. Therefore, Poisson (50) distribution was assigned to demand. The deadline was compatible with normal distribution within the range of 20 —40 days in compliance with the demands of the customers. Therefore, Uniform (20.40) distribution was assigned to deadline.

It was attained the decision phase in the Decide module of the software. It was defined in Dispose module that the products having a deadline within a month (30 days) were enabled to be produced whereas the others were not.

Products having a deadline within a month were accepted to the production line and subjected to the related processes in accordance with the work flow. Lot preparation and singeing processes were the common ones for the fabrics which were selected for this study. These processes were applied with priority both for fiber dyed fabrics and tops dyed fabrics.

The lot preparation process was carried out with the speed of 50 m/min (Table 4). The process time was found via dividing the incoming demand by 50 m. The lot preparation process was carried out by two operators (Table 2). Therefore, two resources were assigned to this process. The entry of this information to the software was used for "lot preparation process" in "Process" module. The singeing process as being the following common process was carried out with the speed of 120 m/min (Table 4). It was recorded as "Singeing" process in "Process" module. The singeing process was carried out by 1 operator. Therefore, 1 resource was assigned to this process. The information for the other processes was entered similarly.

Cost assignment was made with the model. The first cost calculation was about the amount of the cost without differentiating the fabric type for each fabric that was subjected to the lot preparation and singeing processes. As the lot preparation cost was 3 TL/m and the singeing process cost was 5TL/m, the assignment made by the software to the cost1 designated data was displayed as 3*demand+5*demand.

According to the work flow (Table 2) in the dyeing mill, fabric type was required to be defined in the next point after these two common processes. Because the processes to be followed would have been different as per whether the fabric was fiber dyed or not. At this stage, 2 Rota assignments were carried out and the costs were calculated in accordance with fabric type. 60% of the incoming demands were fiber dyed and the rest was tops dyed in the selected mill. "Is it fiber dyed" designated module was requested to be assigned as Rota 1 if it was fiber dyed or as Rota 2 if it was tops dyed, with "Decide" module of the Software. 1. In Rota, the entry was made as being 60% of the demand (percent true:60%).

After this phase, a model similar to the model in Figure 3 was to be operated according to the processes given in table 2. Similar to the #1 and #2 processes shown in Figure 3, operator resource entry, time and cost calculations were to be entered to the software correspondingly. Cost1 would be displayed as being the total cost upon completion of all the processes or the tops dyed fabrics.

Cost 2 calculation was carried out at the section in which the fiber dyed fabrics were subjected to the dyeing process. All of the costs belonging to this type of fabrics were added up to the Cost1, just like the Cost2.

If the investigated fabric type was fiber dyed, it was directly to be subjected to the washing, drying and finishing processes. Whereas the tops dyed fabrics were to be continued with the same processes (washing, drying and finishing) after being subjected to the defined preparation processes. The color appropriateness of the fabrics was inspected in the mill, upon completion of the finishing. If the color was regarded as being yellowish, it was required to apply washing and drying once again. The observations revealed that the color appropriateness was met by 90%. This intermediate process was also added to the model. A "Decide" module designated as "Is color appropriate" was formed and its correctness was entered as 90% (percent true(0-100): 90%). If the color was rated as being inappropriate, the fabric was to be subjected to 2 processes once again.

Meeting the desired handling characteristics has great importance in point of customer satisfaction. This request was met by 95% in the mill. A "Decide" module designated as "Is handling satisfactory" was added to the model. In case of a fabric was insufficient for meeting the required handling properties, that fabric was needed to be subjected to the finishing process, then sent to the folding process. This orientation in the work flow was added as "finishing process" to the Model. Data belonging to this process, operator resource, time and cost were entered with "Process" module.

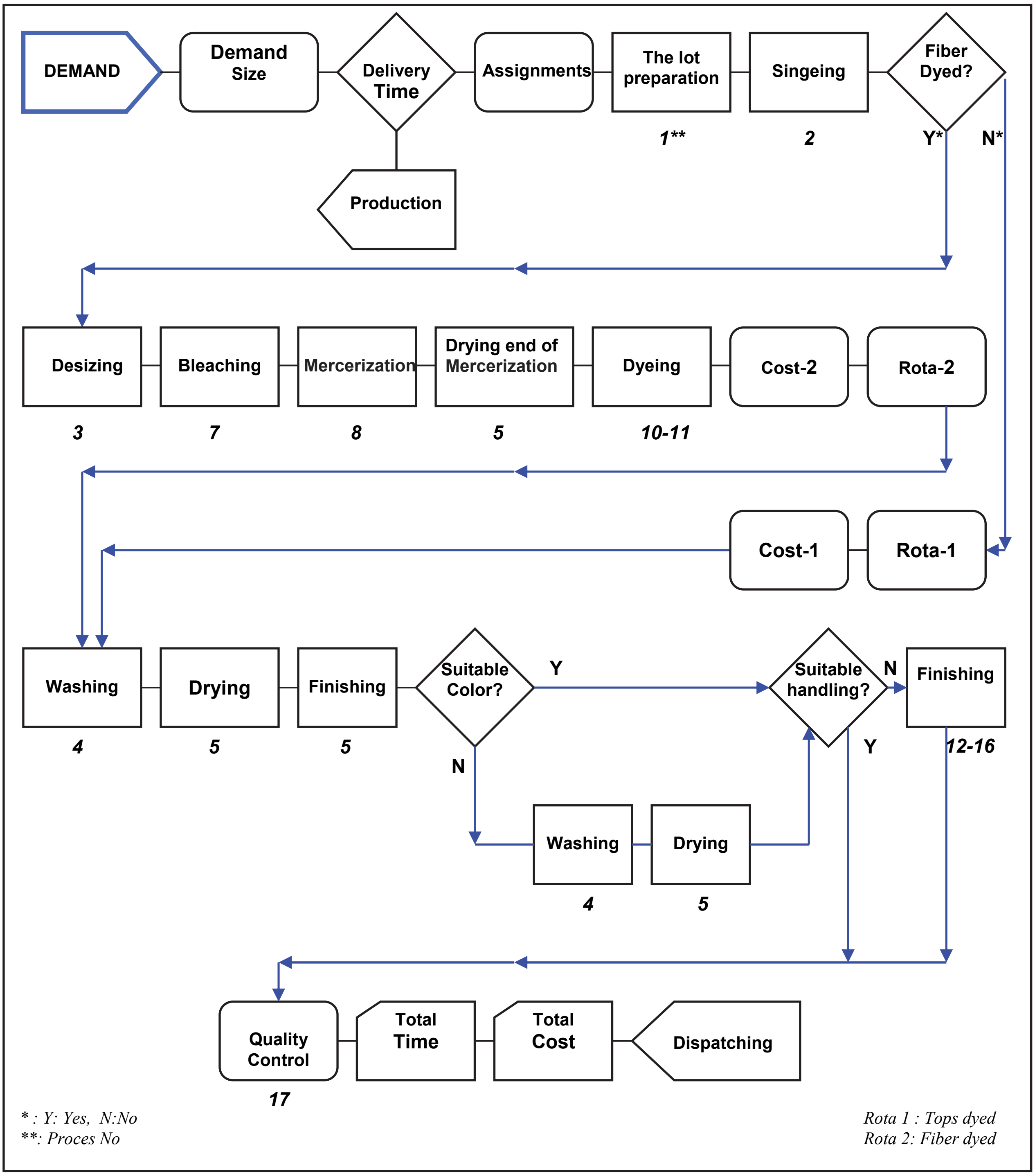

Figure 3. Arranged form of Simulation Model of Dyeing and Finishing Mill

Finally, the calculation of cost and times were added to the model according to both fabric type and Rota. This data was entered via "Record" module of the software. Here were used four "record" modules as being "total time", "Rota", "fabric type related cost" and "total cost".

The simulation model was finalized by the "Dispatching" process which was entered to the "Dispose" module.

3.2. Results of Simulation Model

Demand: From the set up simulation model; the correctness of the model was tested according to the demand variable and findings such as the waiting times (findings about if the processes were running without any problem) of the processes within the model, findings belonging to the operator (working personnel) that were entered in to the model as being the resource information, were obtained. Figure 4 displays correctness and necessary average value of demand in the form of original output. Inspection of the results of the model revealed that the replication was 52. 654 hours. Here the statement (entity1) defined as entry (variable = demand) was "demand value". It was observed that the deviation in demand values as being 0.1230. As this value was smaller than 0.5, this revealed that the simulation results were correct, according to the alternative value hypothesis rule. The average value of the demand was found as 86 m. These numerical values were indicated on the figure by marking. The replication number shown in Figure 4 denotes that how many times the simulation model was tried and ran. In this model, a few more replication trials were carried out, however, as these trials revealed similar values, they were excluded from the assessment. Providing that the simulation hour was set as "0", id est. the starting time was defined as "0", the system was able to complete its running cycle in 654.52 hours.

Waiting times: Analysis of the main processes and waiting times in the Model revealed that there was not any waiting time occurrence. This situation was interpreted as there was no bottle-neck in the mill.

Operator requirement: In the model, number of operators for each machine was entered to the system and they were classified as resource. By running the model for producing the selected 10 pieces of sample fabrics, it was discerned that 30 operators were needed and 1 more operator were needed for each 10 hours. The situation of the resources is also demonstrated in Figure 5.

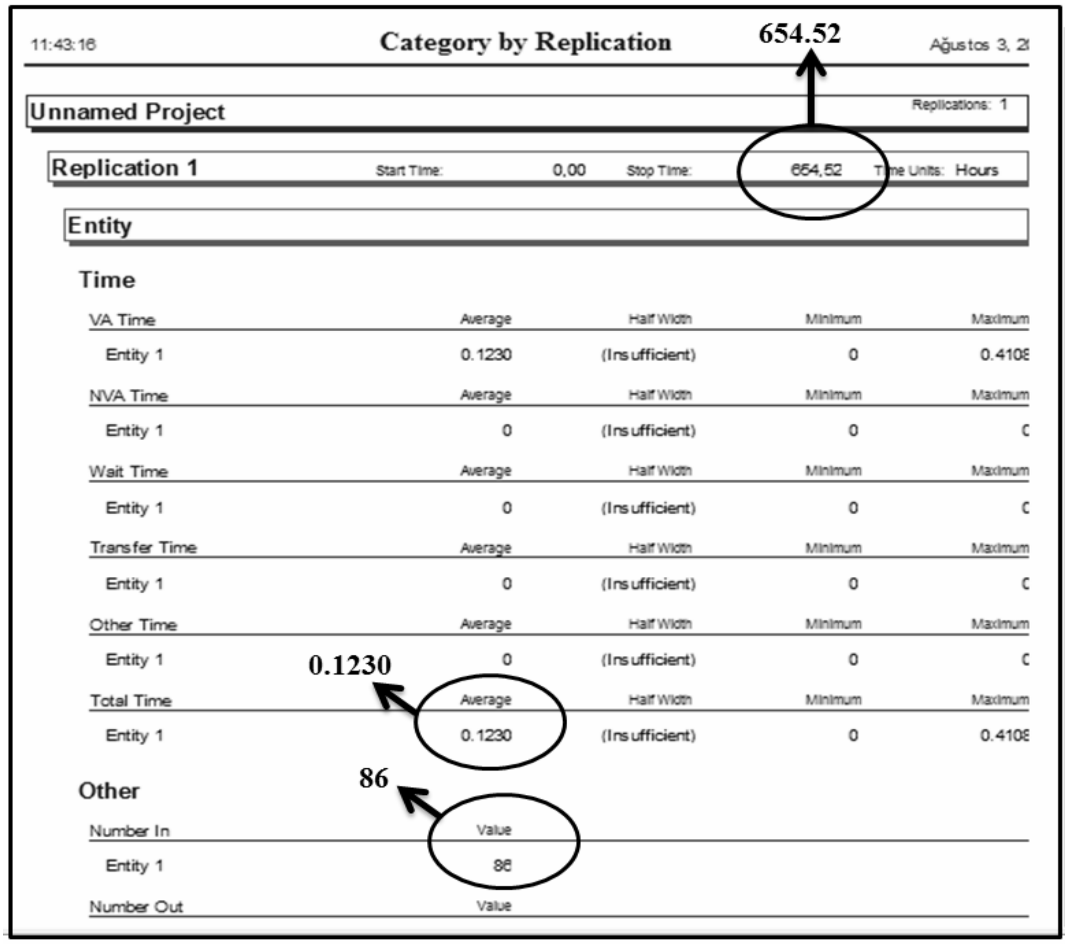

Figure 4. Entity (Demand) Simulation Result

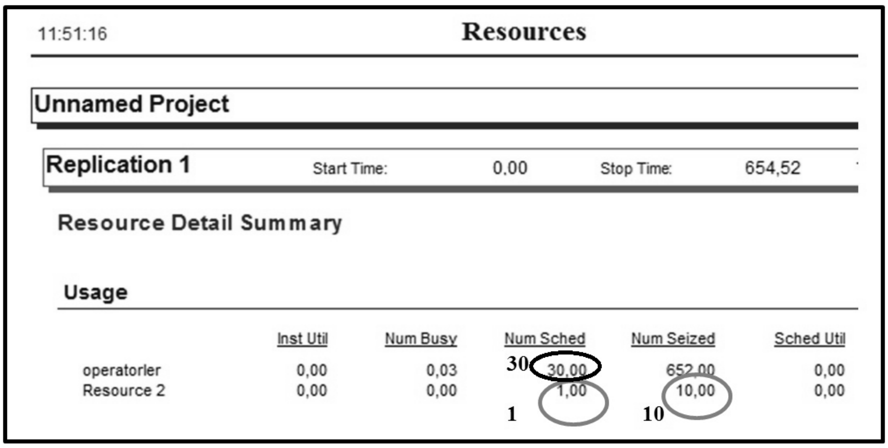

Figure 5. Simulation Results of Resources Used in Model (2)

Figure 6 displays the production (flow) time and costs that are realized according to the fabric type and the defined routes in the simulation model. Rota 1 demonstrates the tops dyed fabrics and Rota 2 demonstrates the fiber dyed fabrics. Fiber dyed production time was found as 0.1695 and tops dyed production time was found as 0.3071. As seen in the figure, with regards to variable demand, tops dyed fabric production cost was 2,579 million TL whereas fiber dyed fabric production cost was 946 million TL. These outputs revealed that the cost of tops dyed production was approximately 2.5 times higher than the cost of fiber dyed production

Calculation of Costs ve Time		
1. Replication	Starting time (h):0.00	Finishing Time (h): 654.52
Fiber dyed	0.2251	
Cost of Fiber dyed (TL)	1.606	
Rota -1 Flow Time (h)	0.3071	
Rota -1 Cost (TL)	2.579	
Rota -2 Flow Time (h)	0.1695	
Rota -2 Cost (TL)	964.14	

Figure 6. Simulation Results of Cost and Time (2)

4. CONCLUSION

The dyeing and finishing sections of mills are the ones which need the utmost attention hence they accommodate the most complex processes and contain various operations which are hard to recover and which entail high costs in case of any error. In such mills, the complexity of the production planning imposed to set up a planning model. It was detected that demand sizes were compatible with Poisson distribution for all of the samples. The variability of the demand was incorporated with simulation application. In the simulation, both production lines for fiber dyed and tops dyed fabric types were separately inspected and modeled. Time and cost results were obtained for both types. It was propounded that the tops dyed production was approximately 2.5 times more expensive than the fiber dyed production. The number of replications within the simulation part of the study was increased and the model was repeated once again, nevertheless, it was observed that the changes in the results were negligible. In this study, it was achieved to demonstrate that determining the monthly production time and costs via employing simulation technique in a dyeing and finishing mill under variable demand conditions by defining the weighted product profile was possible. The study encompassed a one month production. The scope of the study may be enlarged by increasing the length of planning period or rearranging the annual production planning data. It might be possible to take appropriate course of action for being able to reduce the costs considering that the cost of tops dyed goods were rather high under variable demand conditions.

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