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Optimizing the Material-Product Transformation Processes in the Clothing Manufacturing Line

Mehmet Küçük[1] 0000-0002-0017-5762
Meral İşler[2] 0000-0002-9654-4664
Mücella Güner[1] 0000-0001-8910-7338

[1]Ege University, Engineering Faculty, Textile Engineering Department, İzmir, Türkiye
[2]Selçuk University, Faculty of Architecture and Design, Fashion Design Department, Konya, Türkiye

Corresponding Author: Mehmet Küçük, mehmet.kucuk@ege.edu.tr

ABSTRACT

In current economic conditions, one of the major problems in the textile and apparel industry is unable to determine the unnecessary movements of resources (operators, machines, materials). Especially during the production processes, to adjust and decrease the movements of the resources are more difficult, because the focus is mostly on the workers and materials. “Method Study” has developed for resolving these challenges. The string diagram which is one of the techniques of the method study, helps to provide minimum movements of the resources during manufacturing activities. In this study, the production activities of a clothing company were examined with the help of the string diagram to achieve the objectives of eliminating unnecessary movements of the resources, increasing the working speed, providing better working conditions, balancing the production lines. So in the study, the current status of the production system and the parts to be improved were determined. In this direction, the string diagram and line balancing methods were applied for improvements and generation of a new layout plan. As a result of the research, the journal distance of the pieces before sewing together for obtaining the end product was shortened by 39% and the number of operators working in the line was reduced from 32 to 26.

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1. INTRODUCTION

In a production environment, resources (operators and/or materials and/or machines) have to move between the predetermined stations necessarily or unnecessarily. These unnecessary displacements cause mess, chaos, loss of time and efficiency in the workplace. For this reason, it has always been extremely important for companies to arrange the workplace and the workflow by following the shortest path from the entrance to the exit. A string diagram is a scaled plan or a model to follow and measure the paths of resources along a specific sequence of events. A resource to be evaluated in the string diagram method is monitored as the work moves from one station to another. Each station where the resource moves, and if these movements are long, the arrival and departure times need methodically to be recorded and evaluated. Then, according to these evaluations, the flow and the working areas need to be corrected in order to minimize the movement distance. Since the clothing industry is a labor-intensive sector, the number of employees is relatively high. In addition to this, the materials used in production consist of many large and small parts (for instance, the pieces of a shirt), and the variety of machines used also prevents unnecessary movements in production from being easily seen.

The string diagram is frequently used alone or in combination with other method study applications to detect and eliminate unnecessary movements in many manufacturing and service industries. As a result of the literature reviews on the subject, the following studies were obtained.

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C. R. Duguay, S. Landry and F. Pasin compared the mass production system with the agile production system in a study they conducted in 1997. In this direction, the main differences between the two systems were stated. So, at the end of this study, the importance of the agile system and agile operators were mentioned [1]. In a study conducted by R. Quintana in 1998, they examined the suitability of American companies to lean and agile production systems in order to maintain their competitive advantage [2]. Liu G and Fu Y. investigated the motion of satellites in space using the string diagram in a study that they conducted in 2001. By analyzing these movements in the light of the data obtained, it was proven that the string diagram could be used effectively in different disciplines as well [3]. In a study conducted by Lozier and Gawarkiewicz in 2001, the string diagram was used to examine the movements of boats of different sizes along the bay [4]. Donahue used a string diagram to observe nurses working in a hospital in 2009. The study aimed to reduce the lost time of nurses by detecting and eliminating unnecessary movements. Accordingly, thanks to the method, the way nurses traveled during the day was modeled. This time saved has been allocated to patient care [5]. In 2009, Aakre et al. used the string diagram to determine a flow chart of patients who came to a hospital for bone densitometer measurement. As a result of preparing the hospital's current and improved situation with the help of the string diagram, they enabled patients to complete their treatment with covering less distance [6]. In a study conducted by Bevilacqua et al. in 2015, a lean applications study was carried out on the packaging line of a pharmaceutical company. In this direction, they managed to reduce the total process time by 50% and increase the overall equipment efficiency by 25% using the string diagram [7]. In a study conducted by Ferreira et al. in 2015, new tools have been developed to apply lean manufacturing practices in different sectors over the years. In the research, a roadmap for the application of lean manufacturing methods in industrial settings was proposed [8]. In a study by Gebrehiwet and Odhuno in 2017, various improvement scenarios related to the way of doing business and layout were presented. First of all, an enterprise's current status was examined, and then the current situations were rearranged with line balancing methods. In the new case created due to the study, productivity by 25.74%, performance by 35.5% was increased, and the production per hour was increased from 49 to 68 pieces [9]. In a 2018 study by Chan and Tay, they tried to combine lean manufacturing techniques to increase productivity and achieve defined goals in a printing company. In this direction, between 10-30% productivity raise was achieved in the assembly line of the printing company. As a result of the study, it was suggested to use lean production techniques by combining them [10].

Güngör and Ağaç in 2014 were analysed the small scale companies' assembly lines with line balancing technique. They used COMSOAL which is meta-intuitive algorithm to evaluate the data from the assembly line [20]. Manaye in 2019 aimed on increasing the accuracy of process times and work rearrangements among the operators and wors stations line balancing techniques. At the end of the study, the production capacity was increased from 850 t-shirts to 1768 daily and the line efficiency was improved from 69,8% to 76,4% with the help of the line balancing methods [21]. In 2021, Paredes et al. made an application of the line balancing method in a clothing company. At the end of this study, they proposed a solution model optimize the production process. Results reveal the usefulness of the optimization tools for improving both efficiency and revenue at the company level [22]. Amira and Nejib in 2021 were analysed the parameters that influence the decline in production. After the line balancing implementations, the results showed that, the parameter "Machine failures" had a 34.6% effect on production, and "lack of versatility" 19.7%, while the parameter "heavy launch" had an effect of 17.1%, "lack of supplies" 9%, touch-ups 3%, and "lack of cut parts" 2% [23].

Within the scope of this study, firstly a garment was selected for following each manufacturing step in a clothing company that produces mostly knitted garments. The workflow that the materials went through during the transformation into the final product was determined. Accordingly, shortening the workflow path, rising efficiency, and accelerating the flow as much as possible were aimed.

2. MATERIAL AND METHOD

a. Material

This study was carried out in a clothing company. The product features whose production process was examined in the company are as follows (Table 1).

The model examined has embroidery on the front body and a zipper on the collar. Each product has 1 ornament tag, 1 washing instruction, 1 size tag, and 1 belt tag. The production stages of the model and the machines used are shown in Table 2.

The company where the study was conducted consists of 2 floors. The characteristics of the floors and the number of machines on these floors are shown in the tables below (Table 3).

While the basement was organized in accordance with fabric spreading and cutting processes, the first floor was for sewing, ironing, packaging, and quality control processes. Accordingly, there were 1 foreman and 13 laying and cutting operators in the basement, and 2 foremen and 51 sewing operators on the first floor.

b. Method

The method to be used in examining the selected product was the string diagram. The string diagram is one of the most useful techniques of method study. It is a scaled plan or model made by entangling a thread to track and measure the movement paths of resources along a specific sequence of events [11].

Table 1. Examined product

Product Group: Male Top Group
Product Type: Fleece Sweatshirt
Fabric: 100% PES
Color: Turquoise
Daily Production: 1250 pieces

Table 2. Operation sequence and machines

Operation	Machine
1-Attaching Ornament Tag	Lockstitch Machine
2- Attaching Washing Instructions	Lockstitch Machine
3- Preparation of Fly Tip	Lockstitch Machine
4- Fly Overcast	Overlock Machine
5- Fly and Zipper Seam	Lockstitch Machine
6- Fly Place Marking	Handwork
7- Attaching Fly to the Body Pieces	Lockstitch Machine
8- Shoulders Combining (front-back)	Overlock Machine
9- Shoulder Flatlock	Coverstitch Machine
10- Collar Preparation	Overlock Machine
11- Collar Attaching	Overlock Machine
12- Zipper Attaching	Lockstitch Machine
13- Facing	Lockstitch Machine
14- Collar Foot Stitch	Lockstitch Machine
15- Collar End Stitch	Lockstitch Machine
16- Front Foot Stitch	Lockstitch Machine
17- Sleeves Setting	Overlock Machine
18- Side Seam	Overlock Machine
19- Hemline Flatlock	Coverstitch Machine
20- Sleeve Flatlock	Coverstitch Machine
21- Attaching a Folding Tag	Lockstitch Machine

Table 3. Floors and machines

Basement	250 m^2	Warehouses	1 foreman - 13 operators
		Sorting area	
		1 roll fabric opening machine	
		1 fabric spreading table	
		1 cutting table (cutter)	
		1 fabric control table	
		3 wheeled shelf system	
		1 transport trolley	
		Placing baskets	
First floor	420 m^2	Sorting shelf	2 foreman - 51 operators
		15 lockstitch machines	
		8 overlock machines	
		5 coverstitch machines	
		4 sorting table	
		1 handwork table	
		2 meto label table	
		2 thread cleaning table	
		4 precontrol table	
		2 final control table	
		1 packaging table	
		Transfer baskets	

The string diagram is a scaled diagram that provides to show the movement paths of the resources in their own manufacturing processes. Like the method study schemes, the string diagram is prepared on the basis of the process, showing the entire process without going into details. On a scaled sketch of the workplace, the method tries to determine between which stations and how often the source travels, by counting the threads that a source passed through the stations [12].

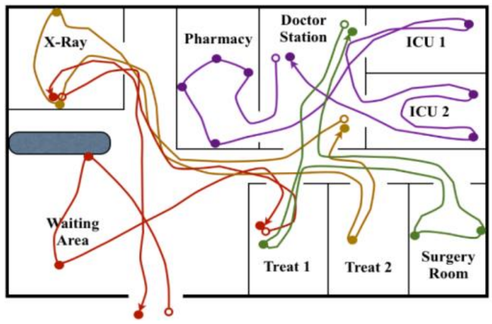

Figure 1. A string diagram example

Preparation of the string diagram starts like other method studies; Firstly, all events related to direct observation are recorded. The work-study expert watches the resource of interest during it moves from one point to another as the work is performed. If the expert gives a sign such as numbers, letters to various machines, warehouses, and other points during the examination, the work will be followed in a simpler way [13].

This recording process continues until the work-study expert is sure about having enough information to show the resource's movements. This period can be a few hours, a day, or longer. Thus, the expert can obtain all the information about all the movements made by the source and how often these movements are repeated relatively. If the expert observes only a part of the sequence of movements made by the source, the study will be insufficient and cause to reach wrong conclusions. Also, during such a study, the source may have used a different path than the standard route. A string diagram can be created, only when the expert believes that he/she has obtained the necessary and enough information and be sure that there is no unobserved movement. Additionally, he/she should check all the gathered information together with someone who observes the manufacturing activities continuously, such as a foreman, to avoid missing something out [13].

Machinery, equipment, warehouses, and all points should be drawn to scale. In addition to these, doors, pillars and partitions that have effects on movement paths should be shown. In the conventional technique, the completed plan should be placed on a soft board and pinned with pins to be put on the "stop" points shown in the plan. The remaining part of the needle should not be less than 1 cm. At the same time, pins should be placed at turning points on the path. Then a measured piece of thread is taken and wrapped around the needle located at the starting point of the movements. The thread is then wrapped around the needles at the other points in the order shown on the study until all the movements are completed. As a result, a complete string diagram can be obtained that shows the resource's all motion paths [14]. Today, some computer software can be used in the drawings to be made in this direction.

In order to eliminate unnecessary movements in the study, the line balancing method was also applied to the production line with the string diagram. The traditional assembly line balancing problem considers the production process in which products are created by assigning tasks sequentially to different workstations. The distribution of tasks among stations depends on the time unit required to complete each task as well as the existing priority constraints between tasks. The product is allowed to stay in each station for a maximum of the cycle time. [15]

There are 2 options in the traditional line balancing problem scenario. One of them is to minimize the required number of stations by fixing the cycle time. The other is the minimization of cycle time in a fixed number of stations [16]. To achieve these objectives, assigning tasks to sequential workstations is called line balancing, with providing the priority relationships are not violated and cycle time is not exceeded. In this study, the required number of stations is minimized by taking the cycle into account.

3. FINDINGS

Following the examinations and follow-up procedures for the production of the selected product, first of all, the current situation of the company was prepared by the string diagram method. With the studies on the current situation and the calculations of the distance traveled by the product, some implementations were made to shorten this distance.

In the basement of the company, the spreading and cutting processes of the fabrics were completed. Afterward, the cut pieces were carried to the 1st floor by elevators after going through the meto labeling processes. On the 1st floor, the cut pieces were shipped to the production line. After sewing, the products were transferred to yarn cleaning, ironing, and packaging processes. Findings of the whole process were given below (Figure 2-3).

As a result of the examinations and studies carried out in the company, no reorganization was required due to the volumetric size of the tables and other immovable materials used in the basement. Also, improvements were made only on the 1st floor. The current and improved situation of the floors were drawn with Microsoft Visio Standard 2019 software. Drawings were created in a 1/100 ratio.

a. The Current Flow

Basement

The way the raw material is spread and cut in the company is as shown below (Figure 2).

The 1st Floor

Similarly, the flow on the 1st floor of the company is as follows. The arrow colors and names used in displaying the flow are also shown in Figure 3.

In the Figure 3, the numbers refer the operation numbers and the letters refer the operators in Table 5. According to this configuration, the operators, operation numbers, processes and machines were indicated in Table 5.

The processes applied to the product at each station on the 1st floor are shown in the table below (Table 6).

Table 5. Current 1st floor – operators, operations and machines

OPERATOR	OPERATION NO	PROCESS	MACHINES
A	16	Attaching Ornament Tag	Lockstitch Machine
B	17	Attaching Washing Instructions	Lockstitch Machine
C	18	Preparation of Fly Tip	Lockstitch Machine
D	19	Fly Overcast	Overlock Machine
E	20	Fly and Zipper Seam	Lockstitch Machine
F	21	Fly Place Marking	Handwork
G	22	Attaching Fly to the Body Pieces	Lockstitch Machine
H	23	Shoulders Combining (front-back)	Overlock Machine
I	24	Shoulder Flatlock	Coverstitch Machine
J	25	Collar Preparation	Overlock Machine
K	26	Collar Attaching	Overlock Machine
L	27	Zipper Attaching	Lockstitch Machine
M	27	Zipper Attaching	Lockstitch Machine
N	28	Facing	Lockstitch Machine
O	29	Sorting	Sorting Table
P	30	Collar Foot Stitch	Lockstitch Machine
R	30	Collar Foot Stitch	Lockstitch Machine
S	31	Collar End Stitch	Lockstitch Machine
T	32	Front Foot Stitch	Lockstitch Machine
U	31	Collar End Stitch	Lockstitch Machine
V	32	Front Foot Stitch	Lockstitch Machine
Y	33	Sorting	Sorting Table
Z	34	Sleeves Setting	Overlock Machine
AA	34	Sleeves Setting	Overlock Machine
AB	35	Sorting	Sorting Table
AC	36	Side Seam	Overlock Machine
AD	36	Side Seam	Overlock Machine
AE	37	Hemline Flatlock	Coverstitch Machine
AF	37	Hemline Flatlock	Coverstitch Machine
AG	38	Sleeves Flatlock	Coverstitch Machine
AH	38	Sleeves Flatlock	Coverstitch Machine
AI	42	Attaching a Folding Tag	Lockstitch Machine

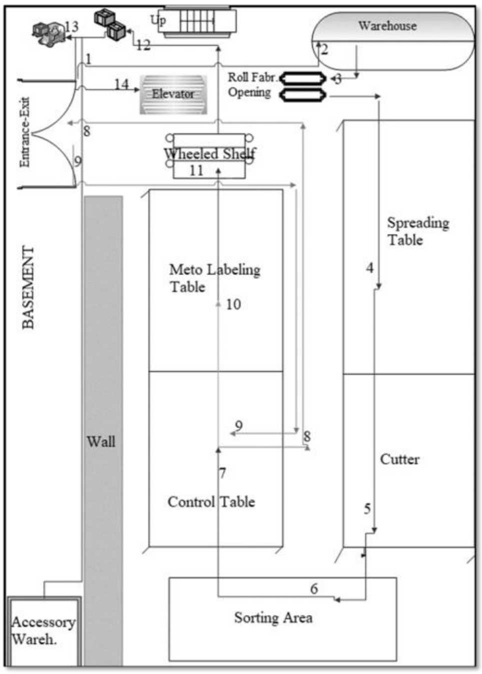

Figure 2. Basement

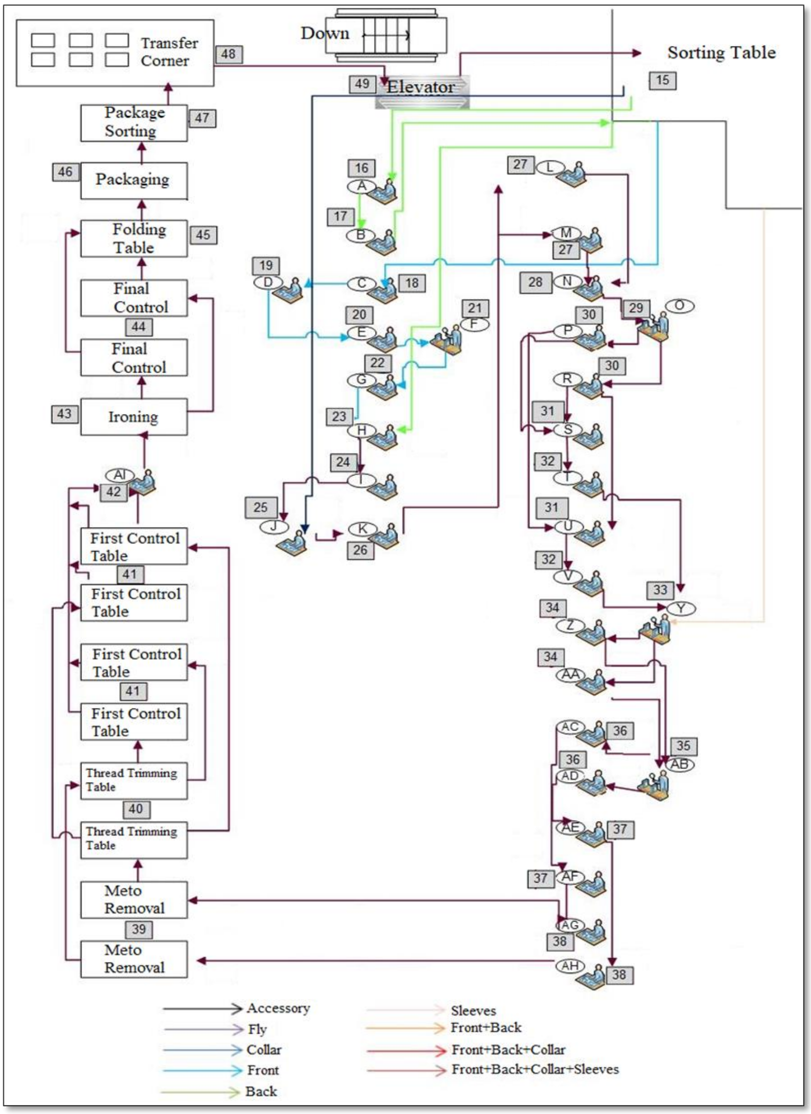

Figure 3. Current 1st floor scheme

Table 4. Basement workflow

Process Numbers	Processes
	The company supplies the fabrics required for production.
(1-2)	Purchased fabrics are transported from the entrance door to the warehouse.
(2-3)	Fabrics are transferred from the warehouse to the roll fabric opening machine.
(3-4)	The rolls are transferred to the spreading table.
(4-5)	After the spreading processes, fabrics are brought to the cutter for cutting.
(5-6)	The cut pieces are kept in the sorting area.
(6-7)	The parts are brought to the control table for checking the cutting process.
(7-8)	The front pieces are sent to the exit for the embroidery process.
(8-9)	Pieces coming from embroidery are brought to the control table.
(9-10)	After the control process is completed, all pieces are transferred to the meto labeling table.
(10-11)	The pieces are placed in a wheeled rack system.
(11-12)	Baskets are placed on the trolley.
(13)	Meanwhile, accessories are brought from the warehouse and placed in the trolley.
(13-14)	In order for the pieces to enter production line, the transport car is brought to the elevator and raised to the 1st floor.

Table 6. The 1st floor - current workflow

OPERATION NO	PROCESSES
(15)	Pieces come from basement are placed to the sorting table
(15-16)	From sorting table to the Operator-A for attaching the ornament tag
(16-17)	Then pieces come to the Operator-B for attaching the washing instructions and send to sorting table back
(15-18)	Front pieces come from the sorting table to Operator-C for preparation of fly tips
(18-19)	The pieces are brought to the Operator-D for fly overcast
(19-20)	The Operator-C gets pieces for the fly and zipper seam
(20-21)	The pieces are brought to the Operator-F for fly place marking (handwork)
(21-22)	After the marking processes, pieces are sent to the Operator-G for attaching fly to the body pieces
(22-23) (15-23)	Front pieces are brought to the Operator-H for shoulders combining process. At the same time, the back pieces that are waiting on the sorting table are brought to the Operator-H as well for the same process
(23-24)	The pieces are sent to the Operator-I for shoulder flatlock stitches
(24-25) (15-25)	Pieces then comes to the Operator-J and at the same time the collar pieces are brought for collar preparation process
(25-26)	After the preparation process, pieces are brought to the Operator-K for collar attaching
(26-27)	The pieces coming out of the Operator-K are divided into two and brought to the Operator-L and Operator-M for zipper attaching
(27-28)	After the zipper attaching processes, the pieces are brought to the Operator-N for facing
(28-29)	Then the pieces come to Operator-O for sorting (handwork)
(29-30)	The pieces are brought to Operator-P and Operator-R from the sorting table for collar foot stitch
(30-31)	The pieces are sent to Operator-S and Operator-U for collar end stitches
(31-32)	The pieces are brought to the Operator-T and Operator-V for front foot stitches
(32-33) (15-33)	The pieces are brought to the Operator-Y for sorting process. At the same time, sleeves also are brought to this sorting table
(33-34)	The pieces after this matching process are brought to the Operator-Z and Operator-AA for sleeves setting processes
(34-35)	Then the pieces come to the Operator-AB for sorting
(35-36)	The pieces are sent to the Operator-AC and Operator-AD for side seam
(36-37)	The pieces are brought to the Operator-AE and Operator-AF for hemline flatlock
(37-38)	The pieces are then brought to the Operator-AG and Operator-AH for sleeves flatlock
(38-39)	After that the pieces are brought to the meto label removing table
(39-40)	Then they are sent to the thread trimming table
(40-41)	The pieces are brought to the first control table for controlling in detail
(41-42)	Then the pieces are sent to Operator-AI for attaching a folding tag process
(42-43)	Then the products are brought to the ironing processes
(43-44)	The products then sent to the final control table
(44-45)	The products are brought to the folding table
(45-46)	The products are brought to the packaging table
(46-47)	The products are brought to the package sorting table
(47-48-49)	The packages are brought to the transfer corner
	The shipping processes.

As a result of the analysis, in the current situation of the 1st floor of the company, a total of 32 operators and 28 machines were employed only on the sewing line (excluding control and packaging processes). It has been observed that the pieces traveled 51m 5cm in the 250 m2 area on the basement and 108m 9cm in the 420 m2 space on the 1st floor until turning into the final product form, starting from the first station of raw material warehouse.

b. 1st Floor New Layout

Within the scope of the study, in order to minimize the distance that materials traveled in the sewing line and to re-establish the band with the optimum number of machines and operators, the line balancing application was also carried out on the line with the string diagram. Firstly, the number of machines allocated for the order in question, the number of operators, the daily working time, and the standard times of each operation were recorded.

Standard times calculation procedures were carried out on each production activity according to the time study method. After that, during the line balancing implementations, the standard times and the daily production numbers were taken into account. Subsequently, the reorganization processes were carried out with the string diagram. As a result of these method implementations and practices, the sewing line's new improved layout was generated. In this direction, the distance traveled by the materials while transforming into the sweatshirt was measured in the latest status of the sewing line, as well.

The new layout obtained as a result of the string diagram and line balancing applications performed for eliminating the unnecessary movements of the materials on the 1st floor current form is as follows (Figure 4).

The operations performed at each station on the new 1st floor were shown in the table below (Table 8). In addition, unlike the current situation, the decisions taken to make the flow more regular were specified in each operation step.

Table 7. New layout 1st floor – operators, operations, machines and times

Operator	Operation No	Process	Machine	Std Time (Sec)	Output (Pcs)	Time Needed (Min)	Time Remaining (Min)
A	**16**	Attaching Ornament Tag	Lockstitch Machine	9.00	1250	188	
A	**17**	Attaching Washing Instructions	Lockstitch Machine	13.00	1250	271	**22**
B	**18**	Preparation of Fly Tip	Lockstitch Machine	22.40	1250	467	**13**
C	**19**	Fly Overcast	Overlock Machine	20.80	1250	433	**47**
D	**20**	Fly and Zipper Seam	Lockstitch Machine	35.70	1250	744	
E	**20**	Fly and Zipper Seam	Lockstitch Machine	35.70	1250	744	
E	**21**	Fly Place Marking	Handwork	9.00	1250	188	**29**
F	**22**	Attaching Fly to the Body Pieces	Lockstitch Machine	21.00	1250	438	**43**
G	**23**	Shoulders Combining (front-back)	Overlock Machine	31.20	1250	650	
H	**24**	Shoulder Flatlock	Coverstitch Machine	22.90	1250	477	**3**
I	**23**	Shoulders Combining (front-back)	Overlock Machine	31.20	1250	650	**-3**
I	**25**	Collar Preparation	Overlock Machine	15.00	1250	313	
J	**26**	Collar Attaching	Overlock Machine	44.20	1250	921	
K	**26**	Collar Attaching	Overlock Machine	44.20	1250	921	**39**
L	**27**	Zipper Attaching	Lockstitch Machine	46.20	1250	963	
M	**27**	Zipper Attaching	Lockstitch Machine	46.20	1250	963	**-3**
N	**28**	Facing	Lockstitch Machine	22.00	1250	458	**22**
O	**29**	Collar Foot Stitch	Lockstitch Machine	23.40	1250	488	**-8**
P	**30**	Collar End Stitch	Lockstitch Machine	45.00	1250	938	
R	**30**	Collar End Stitch	Lockstitch Machine	45.00	1250	938	
R	**31**	Front Foot Stitch	Lockstitch Machine	47.10	1250	981	**1**
S	**31**	Front Foot Stitch	Lockstitch Machine	47.10	1250	981	
T	**31**	Front Foot Stitch	Lockstitch Machine	47.10	1250	981	
U	**32**	Sleeves Setting	Overlock Machine	49.40	1250	1029	
V	**32**	Sleeves Setting	Overlock Machine	49.40	1250	1029	
Y	**33**	Side Seam	Overlock Machine	42.40	1250	883	
Z	**33**	Side Seam	Overlock Machine	42.40	1250	883	**77**
Z	**32**	Sleeves Setting	Overlock Machine	49.40	1250	1029	**7**
AA	**34**	Hemline Flatlock	Coverstitch Machine	23.20	1250	483	**-3**
AB	**35**	Sleeve Flatlock	Coverstitch Machine	23.00	1250	479	**1**
AC	**36**	Attaching a Folding Tag	Lockstitch Machine	20.00	1250	417	**63**
			Total	**668.60 sec**			

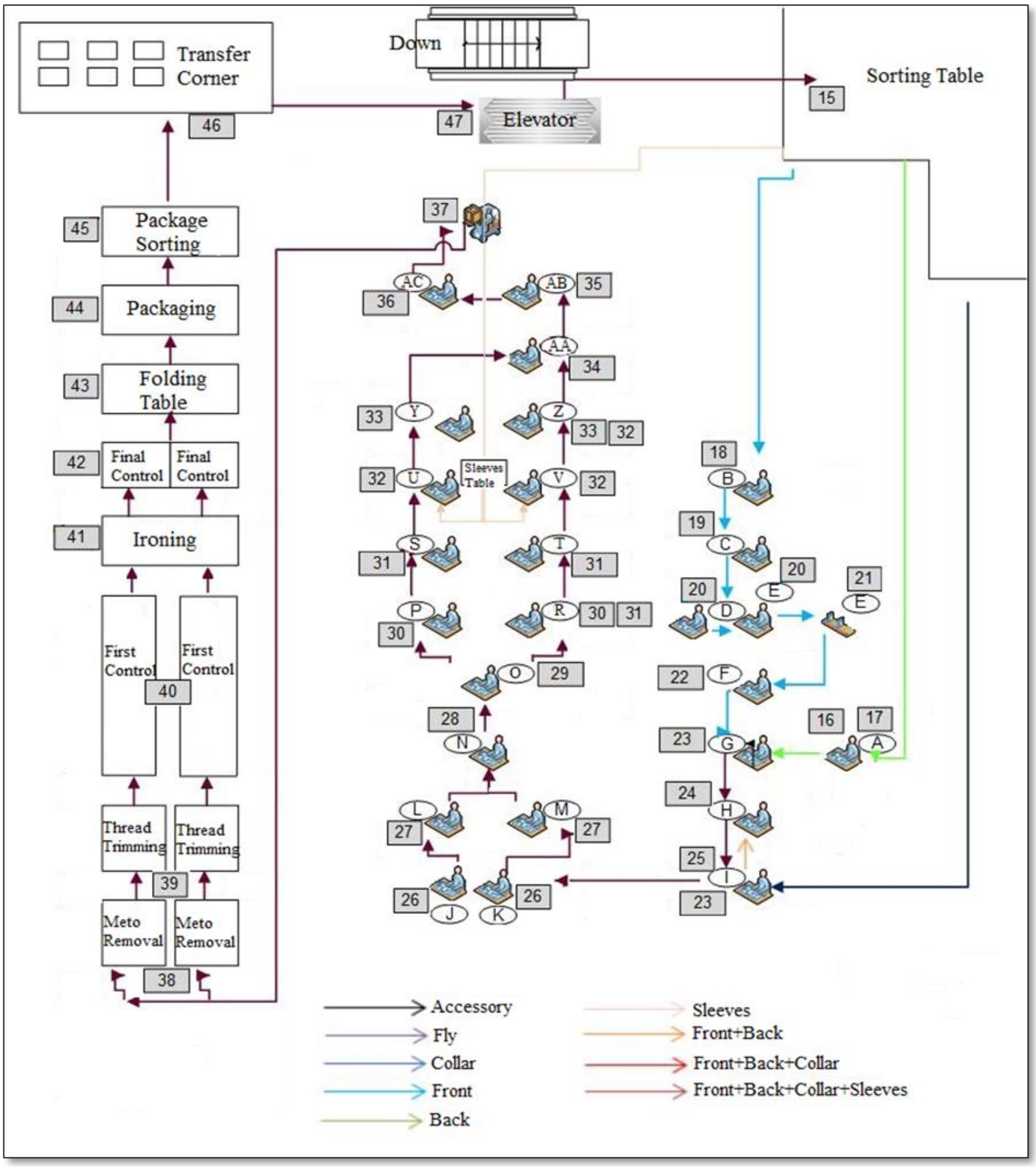

Figure 4. The 1st floor new layout

In the quality-control, ironing and packaging area, the positions of the tables were changed to make the operators move less with the material. In this direction, the tables were mostly placed parallel to each other. Thus, it is thought that this area was relieved by a path between the tables.

As a result of the improvements applied with the string diagram and line balancing technique, 26 operators and 26 machines in total were employed in the production of the sweatshirt only in the sewing line (excluding control and packaging processes) in the new situation pf the 1st floor of the company.

Accordingly, while this transformation to the sweatshirt, the pieces took 108m and 9cm in current situation. This distance was reduced to 66m and 3cm in the new layout. Thus, improvements were made to complete manufacturing steps of the swearshirt with around 39% less traveling of the pieces in the sewing room.

4. RESULTS AND DISCUSSIONS

Method study implementations are among the most frequently used methods to solve problems such as blockages in the work flow, delays, waiting for pieces, idle times or overloading of machines, not being able to use the factory area efficiently and delaying delivery times to the customer and so on, encountered in manufacturing industry. Finding solutions to this kind of problems has become even more important in dynamic sectors such as the clothing sector, where a large number of people work and orders are made with short deadlines. In this study, minimizing the biggest problems experienced in clothing industry, such as excessive accumulation of end products or pieces of them in unnecessary places, ergonomic complaints of the employee in the workplace, unnecessary extension of production time, unnecessary transportations, were aimed to minimize and/or eliminate.

Table 8. The 1st floor – new workflow

OPERATION NO	PROCESSES
(15)	Pieces come from basement are placed to the sorting table
(15-16-17)	The pieces are sent to the Operator-A for the processes of attaching ornament tag and attaching washing instructions
	(Operator-A does these both processes)
(15-18)	Front pieces come from the sorting table to Operator-B for preparation of fly tips
(18-19)	The pieces are brought to the Operator-C for fly overcast
(19-20)	The pieces are sent to Operator-D and Operator-E for the fly and zipper seam
	(The fly and zipper seam processes are done by 2 different operators to provide a more optimum flow)
(20-21)	Operator-E does the fly place marking process his/her own remaining time
	(Operator-E moves to the table for the process number-21 in the remaining time.)
(21-22)	After the marking processes, pieces are sent to the Operator-F for attaching fly to the body pieces
(22-23)	The pieces after the fly processes from Operator-F and washing instruction processes from Operator-A are brought to the Operator-G and Operator-I for the shoulders combining (front and back) processes
	(Operator-I also does the shoulders combining process with the collar preparation process due to available time remaining)
(23-24)	The pieces are sent to the Operator-H for shoulder flatlock stitches
(24-25)	The pieces then comes to the Operator-I and at the same time the collar pieces are brought for collar preparation process
(25-26)	After the preparation process, the pieces are brought to the Operator-J and the Operator-K for collar attaching
	(As a result of the line balancing processes, collar attaching process is done by 2 operators)
(26-27)	The pieces coming out of the Operator-J and Operator-K are brought to the Operator-L and Operator-M for zipper attaching
(27-28)	After the zipper attaching processes, the pieces are brought to the Operator-N for facing
(28-29)	The pieces are brought to Operator-O for collar foot stitch
(29-30)	The pieces are sent to Operator-P and Operator-R for collar end stitches
(30-31)	The pieces are brought to the Operator-S and Operator-T for front foot stitches
	(This process is also done by the Operator-R that has enough remaining time, in order to provide a better flow)
(31-32)	The pieces are brought to the Operator-U, Operator-V and Operator-Z for sleeves setting processes
	(Sleeves pieces wait on the middle table)
(32-33)	The pieces are sent to the Operator-Y and Operator-Z for side seam
	(The Operator-Z also does the sleeves setting process and side seam process due to available time remaining)
(33-34)	The pieces are brought to the Operator-AA for hemline flatlock
	(***As a result of the line balancing processes, hemline flatlock process is done by just 1 operator***)
(34-35)	The pieces are then brought to the Operator-AB for sleeves flatlock
	(***As a result of the line balancing processes, sleeves flatlock process is done by just 1 operator***)
(35-36)	Then the pieces are sent to Operator-AC for attaching a folding tag process
	(It has been decided that there is no need to perform a first control just before attaching a folding tag, for that reason this process is placed at the end of the sewing line)
(36-37)	The products are brought to vehicle
(37-38)	After that the products are brought to the meto label removing table
(38-39)	Then they are sent to the thread trimming table
(39-40)	The pieces are brought to the first control table for controlling in detail
(40-41)	Then the products are brought to the ironing processes
(41-42)	The products then sent to the final control table
(42-43)	The products are brought to the folding table
(43-44)	The products are brought to the packaging table
(44-45)	The products are brought to the package sorting table
(45-46-47)	The packages are brought to the transfer corner
	The shipping processes.

Sewing department is one of the most important departments in textile and apparel industry and an efficient line balancing improves motivation of the workers and benefit of the establishment. The line balancing method is of great importance in apparel manufacturing processes having a large number of employees. As one of the method study techniques, the string diagram provides to measure all the faults in their current situation in the most effective way and allow the numerical values of the improvements to be made as a result of observations [17]. Also in the study, the string diagram was contributed with the line balancing method.

In this study, the whole production process of a sweatshirt was examined. After all the examinations were carried out in the production, the sewing line needed to be reorganised mode urgently throughout the production process. In this direction, it is thought that all unnecessary activities were eliminated, and the most appropriate layout was generated. To obtain a more effective and permanent layout plan, while the string diagram was applied on the sewing line, the standard times of each operation were also calculated for supporting the diagram with line balancing method. Production line balancing is of great importance in apparel manufacturing processes which works a large number of employees [18].

Unnecessary movements in the production line were eliminated owing to the method. In parallel with this, it is thought that by shortening the work flow path, the time of transformation of materials to end product was reduced. In addition, it is thought that the delivery time and the new product processes into production were accelerated, and thus the factory area was used more efficiently.

Since the tables, devices, and shelves on the basement were large in volume, it was caused restrictions in terms of changes in replacement. However, this area was dealt with other lean production techniques such as 5S, Muda-muri-mura and general arrangements were made accordingly. On the 1st floor where mostly sewing machines were located, while 32 operators and 28 sewing machines were used in total in current flow, these numbers were reduced to 26 operators and 26 sewing machines in the new layout plan. Besides, in the new layout plan, the same operation was assigned to more than one operator as well as more than one operation to one operator considering the standard times. Simultaneously, unnecessary processes in the sewing line were also eliminated and the machine layout was changed, allowing the pieces to travel less. Thanks to the string diagram and line balancing techniques, while a product was ready after traveling 108m 9cm in the current situation, this distance was reduced to 66m 3cm in the new layout plan.

By improving the production processes in the sectors like clothing, the lean tools have enough importance on this goal. Analysing the the current situation requires some observation methods. To carry out this analysis an observation plan was used, having the Spaghetti diagram as a reference as well as the line balancing method [19]. It is thought that supporting the string diagram with some other method study techniques like line balancing is a must in today’s competitive environment for manufacturing companies. Thus, by eliminating the problems experienced by these companies in the assembly lines, production activities will be completed in the shortest time and in the most efficient way. In this context, this study is intended to be a useful roadmap, especially for the clothing industry, in theoretical and practical ways.

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