

# Study on the Importance of Employee Performance Assessment and Lost Productive Time Rate Determination in Garment Assembly Lines

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## Abstract

*This study primarily includes theoretical information on the performance and lost productive time of a firm. Furthermore t-shirt sewing operations of a garment firm were analysed and time measurement for each operation was carried out by the time keeping method. By considering the measurements obtained, different performance estimations, the firm's lost productive time rates, and the standard time was calculated within 5 different scenarios. According to each sewing standard time obtained, the assembly line balancing practice was carried out using the Hoffman method. Later on results of the assembly line balancing were compared, and the importance of employee performance assessment and its lost productive time rates for firms were discussed. The aim of the study was to emphasize the value of impeccable determination of the employee performance assessment and lost productive time rates. Consequently garment firms will be more cautious in calculating the standard time and will be able to reach their production target within the accurate measurement they obtain.*

**Key words:** *employee performance, lost productive time, standard time, assembly line balancing, ready-made clothing, hoffman method.*

## ■ Introduction

Today, to manage a firm's operation effectively, time standards are needed. Decisions which are made for the preparation of a production plan, short and long term predictions as well as cost control cannot be expected to be accurate and consistent without basing them on standard time [1]. The operation, production, control and plans which are performed according to the standard time assigned by means of work measurement enable to minimise time loss and increase efficiency [2]. For these reasons, the term of standard time has a place in every firm.

Standard time is the total time for finalizing an operation along with the standard performance [3].

When the formula for standard time calculations is observed, it is concluded that there are 3 main elements forming it: measured time, performance and lost productive time (tolerances).

Measured time represents the time which is provided by an experienced time surveyor observing an employee operation and is mostly measured using a stopwatch.

Performance generally is a concept which specifies what is obtained as a result of an intended and planned activity [4]. According to another definition, perfor-

mance is a product, service or idea which is produced to fulfil a duty or to realise an aim within the framework of a duty by meeting determined standards [5].

Performance assessment is defined as the individual performing a job suitable for his/ her traits and skills within acceptable limits. Thus in order to talk about the performance of an employee, first the person needs to face a defined job. Along with this, the job must be suitable for the traits and skills that the employee possesses, and the standards indicating the duty performance level of the person must be found. While defined standardization reflects the good performance of the person, staying below the standard is accepted as unsuccessful performance [6].

Therefore it is of great importance that the performance presented by the employee is determined accurately by the job surveyor. The performance set higher or lower than it actually is will cause the standard time to be miscalculated, and this will cause the production not to happen as planned.

Lost productive time consists of the total flow periods that emerge additionally during the carrying out of a flow by people in accordance with the plan. It is usually shown as a lost productive time percentage and named as the lost productive (%) time percentage [7]. It is also called as tolerance or share. As in performance

assessment, a lost productive time rate set higher or lower than required causes different results to be found in calculation of the standard time.

The basic data required for the design and balance of a production line are the standard times obtained as a result of detailed method analysis and work measurement. With the help of these data, the best ordering patterns are found within the level that technical limitations allow [8]. Therefore accurate finding of the standard time is extremely important for firms.

Accurate determination of employee performance and/or a firm's lost productive time causes standard time to be miscalculated. Taking the rate of employee performance and operator lost productive time higher or lower than required will cause standard time to be found shorter or longer than it is supposed to be. Thus it will affect the daily production amount, number of workstations and assembly line productivity in a negative way. In this study standard times are calculated by considering different performance values and lost productive time rates. Five different scenarios are predicted within this framework. In these scenarios two different lost productive time rates and three different labour force performances are taken.

Scenario 1. It is accepted that all employees working on the same assembly line

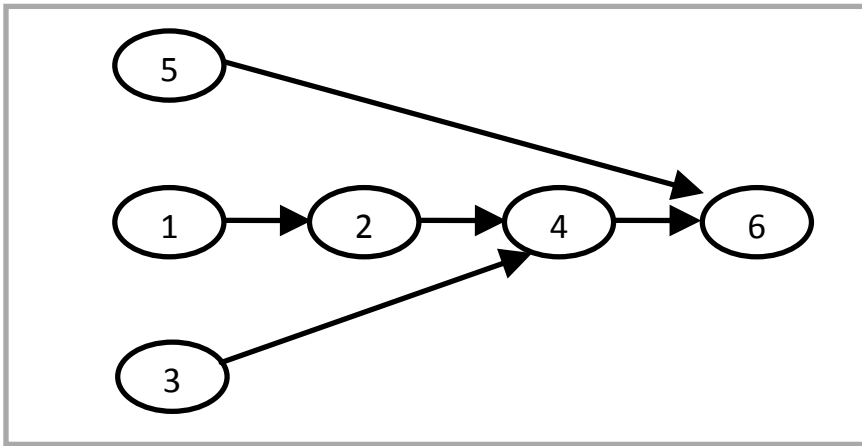


Figure 1. Precedence diagram for the example.



Figure 2. Model of t-shirt.

work with 100% performance and the firm's lost productive time is taken as %15.

Scenario 2. It is accepted that all employees working on the same assembly line work with 100% performance and the firm's lost productive time is taken as %20.

Scenario 3. It is accepted that all employees working on the same assembly line work with 80 % performance and the firm's lost productive time is taken as %15.

Scenario 4. It is accepted that all employees working on the same assembly line work with 80 % performance and the firm's lost productive time is taken as %20.

Scenario 5. Unlike Scenario 1, it is accepted that only the employee performing operation number 4 performs a related operation within 80% performance. In these calculations time measurement is carried out with a timekeeper and

it is assumed that the time measured is obtained accurately. After that, line balancing practices are done by the Hoffman method considering the standard obtained times obtained. The reason why the Hoffman method is chosen in line balancing practices is that it is easily applicable. When studies of assembly line balancing in the ready-to-wear industry are reviewed, it can be seen that in four studies conducted by Kayar and his colleagues, the Hoffman Method was used. [9-12].

The Hoffman method is one of the heuristic line balancing methods, named after the man who founded it. The idea of assembly line balancing by the Hoffman Method was first suggested by Thomas R. Hoffman in his article called "Assembly Line Balancing with a Precedence Matrix" in 1963 [13].

To apply the method, firstly in the case where item 1 precedes item 2, where line 1 and column 2 of the matrix intersect, a value of 1 is assigned, otherwise the priority matrix (Table 1) is enhanced by

assigning 0 for all the rest. In order that the priority item can be used to generate all possible work item permutations, each column of the matrix is summed together to obtain a row matrix called "code numbers". The item number of the code number sequence (row matrix) obtained at first has the same number of work items, where at least one of them is zero. Among the code numbers, the first item zero (0) from left to right is sought and assigned to the first workstation. After each assignment, the rows and columns of the assigned operations are deleted and the operations are continued to be assigned [9].

For example, the 1<sup>st</sup> operation is assigned to 1<sup>st</sup> workstation, the row and column of operation 1 is deleted, and then the 2<sup>nd</sup> matrix is obtained. The 2<sup>nd</sup> and 3<sup>rd</sup> operations are assigned to the 2<sup>nd</sup> workstation, the rows and columns of operations 2 and 3 deleted, and the 3<sup>rd</sup> matrix is obtained (Table 1).

The aim of this study was to research the effects of mistakes made in the determination of performance assessment and the firm's lost productive time rate on the assembly line.

Assembly lines are places where the parts and components of products are pieced together and treated in different ways. The basic aim of an assembly line is to transfer work pieces from one station to another [1]. *Assembly line balancing* or *line balancing* is used to achieve operations required during product formation at assembly stations in a way that the duration of lost time can be reduced. In other words, it is described as allocating work pieces to operation systems [14].

Table 1. Solution matrices for the example.

Priority matrix						
Op.	1	2	3	4	5	6
1	0	1	0	0	0	0
2	0	0	0	1	0	0
3	0	0	0	1	0	0
4	0	0	0	0	0	1
5	0	0	0	0	0	1
6	0	0	0	0	0	0
Code No	0	1	0	2	0	2

Matrix - 2					
Op.	2	3	4	5	6
2	0	0	1	0	0
3	0	0	1	0	0
4	0	0	0	0	1
5	0	0	0	0	1
6	0	0	0	0	0
Code No	0	0	2	0	2

Matrix - 3			
Op.	4	5	6
4	0	0	1
5	0	0	1
6	0	0	0
Code No	0	0	2

In the literature researches made, no source was found about the effect of performance determination nor the lost productive time rate with respect to the standard time. Therefore this study is the first on this subject.

### Experimental

In this research a t-shirt was analysed. A model of the t-shirt used is shown in *Figure 2*.

The t-shirt, which is shown in *Figure 2*, consists of 5 parts including a front, back, sleeve (2) and collar (1). The t-shirt was produced on appropriate machines according to the operation order. *Figure 3* shows the production flow that is necessary for producing the t-shirt.

### Time Study

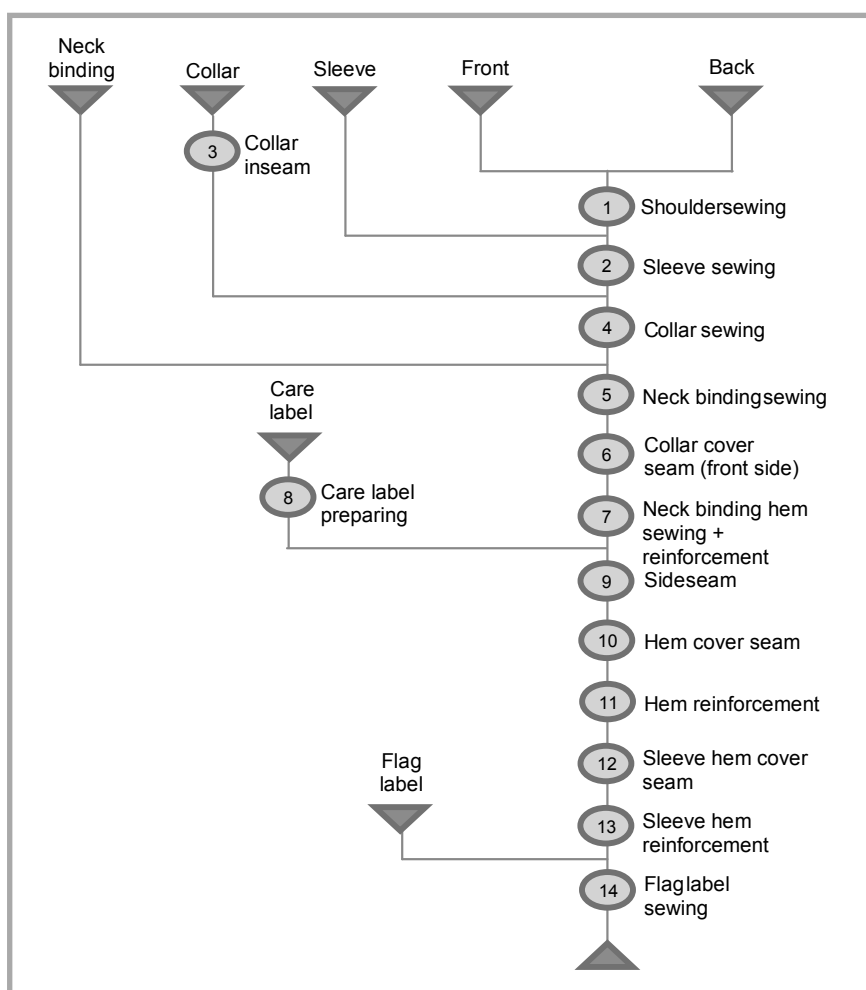
Before constituting a production line for a t-shirt it is necessary to obtain information about the assembly line that will be used. In consequence of the time study, data about the name of the operation, the duration and order of operations, the machines used during the operation, and the operations undertaken by operators are clear.

The time study method most widely used in companies is called the stopwatch technique [15,16]. All operation durations are measured using a stopwatch to determine the standard time of production of t-shirt sewing. Measurements are made in PM (percentage- minute) and are turned into minutes (percentage-minute/60) by calculating their arithmetic means. As these measurements are being done, data on how many measurements are necessary to be made for each operation are provided by means of the formula given below. In this statistical method, several pre-observations ( $n_i$ ) are firstly conducted. Afterwards the formula given below is solved for a 95, 45 security level and  $\pm 5\%$  error margin [3].

$$n = \left( \frac{40 \sqrt{n} \sum x^2 - (\sum x)^2}{\sum x} \right)^2 \quad (1)$$

where,  $n$  is the actual sample size,  $n_1$  number of pre-observations, and  $x$  is the time measured.

Time studies also necessitate unorthodox usage of techniques such as performance assessment to attain the operation speed and link it with the standard operation pace [15]. Performance estimation is



*Figure 3. Operations and flowchart of the operations in t-shirt production.*

a process that really requires being experienced and having vast knowledge [17]. While operation durations are being measured, performance assessment is done for each operation. The normal duration, which is estimated by multiplying the time measured with the distilled per-

formance, needs some additions. Some operations cannot be repeated in every loop due to an unpredictable loss of time, and for such reasons as fatigue requiring increased normal duration with deliberately appointed additions called tolerance (highly forgiving) [16].

*Table 2. Measured time for each operation.*

O.N.	Operations	Machine type	Measured time (MT)	Previous operations
1	Shoulder sewing	4 thread overlock machine	0.217	-
2	Sleeve sewing	4 thread overlock machine	0.339	1
3	Collar inseam	Lock – stitch sewing machine	0.070	-
4	Collar sewing	4 thread overlock machine	0.313	2
5	Neck binding sewing	Binding cover stitch machine	0.157	4
6	Collar cover seam (front side)	Cover stitch machine	0.209	5
7	Neck binding hem sewing + reinforcement	Lock – stitch sewing machine	0.304	6
8	Care label preparing	Lock – stitch sewing machine	0.078	-
9	Side seam	4 thread overlock machine	0.383	7,8
10	Hem cover seam	Blade cover stitch machine	0.217	9
11	Hem reinforcement	Lock – stitch sewing machine	0.043	10
12	Sleeve hem cover seam	Blade cover stitch machine	0.365	11
13	Sleeve hem reinforcement	Lock – stitch sewing machine	0.122	12
14	Flag label sewing	Lock – stitch sewing machine	0.157	13

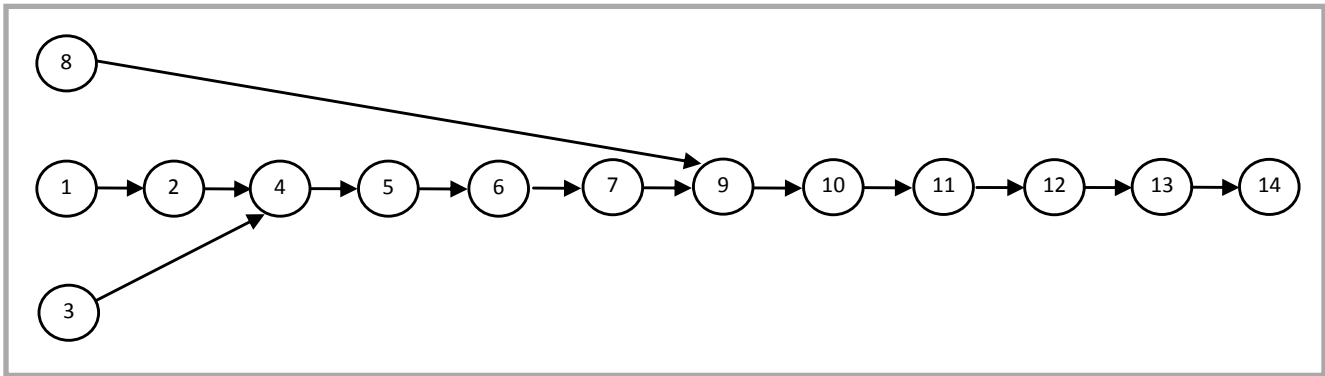


Figure 4. Precedence diagram for t-shirt sewing.

Afterwards the standard time is calculated for each operation using the formula shown below.

$$ST = MT \times R + MT \times R \times t \quad (2)$$

where, *ST* is the standard time, *MT* the measured time, *R* the performance, and *t* the tolerance [18].

The measurement times obtained for each operation as a result of measurements made by using a time keeper are given in **Table 2**.

The times obtained by taking the measurement time given in **Table 1** for each scenario mentioned above are shown in **Table 3**.

The operation times given in **Table 3** are calculated using the standard time calculation formula given above. As an ex-

ample of these calculations, the standard time regarding each scenario for the “collar sewing” operation is shown below.

Scenario 1.

$$ST = MT \times R + MT \times R \times t$$

$$ST = 0.313 \times 1 + 0.313 \times 1 \times 0.15$$

$$= 0.360 \text{ min.}$$

Scenario 2.

$$ST = MT \times R + MT \times R \times t$$

$$ST = 0.313 \times 1 + 0.313 \times 1 \times 0.20$$

$$= 0.376 \text{ min.}$$

Scenario 3.

$$ST = MT \times R + MT \times R \times t$$

$$ST = 0.391 \times 1 + 0.391 \times 1 \times 0.15$$

$$= 0.450 \text{ min.}$$

Scenario 4.

$$ST = MT \times R + MT \times R \times t$$

$$ST = 0.391 \times 1 + 0.391 \times 1 \times 0.20$$

$$= 0.470 \text{ min.}$$

Scenario 5.

Unlike Scenario 1, it is accepted that only the employee performing operation number 4 performs the related operation within 80% performance. The calculation is as shown in scenario 3.

The time measured is taken as 0.391 min. in scenarios 3,4 and 5. Calculation of the time is shown below.

$$MT_1 = 0.313 \text{ min. (with 100% performance)}$$

$$MT_2 = 0.391 \text{ min. (with 80% performance)}$$

$$NZ_1 = 0.313 \times 1 = 0.313 \text{ min.}$$

$$NZ_2 = 0.391 \times 0.80 = 0.313 \text{ min.}$$

#### Assembly line balancing practices

Assembly line balancing studies were carried out for t-shirt production which consists of 14 operations, shown in **Figure 4** with its precedence diagram. The operation time of the t-shirt produc-

Table 3. Operation times for each scenario.

Op. No.	Operations	Machine type	Standard time (ST) – min.				
			Scenario 1 t = 15% R = 100%	Scenario 2 t = 20% R = 100%	Scenario 3 t = 15% R = 80%	Scenario 4 t = 20% R = 80%	Scenario 5 t = 15% R = 80% only for 4th operation
1	Shoulder sewing	4 thread overlock machine	0.250	0.261	0.313	0.326	0.250
2	Sleeve sewing	4 thread overlock machine	0.390	0.407	0.488	0.509	0.390
3	Collar inseam	Lock – stitch sewing machine	0.080	0.083	0.100	0.104	0.080
4	Collar sewing	4 thread overlock machine	0.360	0.376	0.450	0.470	<b>0.450</b>
5	Neck binding sewing	Binding cover stitch machine	0.180	0.188	0.225	0.235	0.180
6	Collar cover seam (front side)	Cover stitch machine	0.240	0.250	0.300	0.313	0.240
7	Neck binding hem sewing + reinforcement	Lock – stitch sewing machine	0.350	0.365	0.438	0.457	0.350
8	Care label preparing	Lock – stitch sewing machine	0.090	0.094	0.113	0.117	0.090
9	Side seam	4 thread overlock machine	0.440	0.459	0.550	0.574	0.440
10	Hem cover seam	Blade cover stitch machine	0.250	0.261	0.313	0.326	0.250
11	Hem reinforcement	Lock – stitch sewing machine	0.050	0.052	0.063	0.065	0.050
12	Sleeve hem cover seam	Blade cover stitch machine	0.420	0.438	0.525	0.548	0.420
13	Sleeve hem reinforcement	Lock – stitch sewing machine	0.140	0.146	0.175	0.183	0.140
14	Flag label sewing	Lock – stitch sewing machine	0.180	0.188	0.225	0.235	0.180
<b>Total time</b>			<b>3.420</b>	<b>3.568</b>	<b>4.178</b>	<b>4.462</b>	<b>3.510</b>

Table 4. Solution matrix 1-3.

a)															b)															c)														
Op.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Op.	2	3	4	5	6	7	8	9	10	11	12	13	14	Op.	3	4	5	6	7	8	9	10	11	12	13	14			
1		1													2			1											3		1													
2				1											3			1											4			1												
3					1										4				1										5				1											
4						1									5					1									6					1										
5							1								6						1								7						1									
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Code No	0	1	0	2	1	1	1	0	2	1	1	1	1	1	Code No	0	0	2	1	1	1	0	2	1	1	1	1	1	Code No	0	1	1	1	1	0	2	1	1	1	1	1	1		

tion and machines used during this operation are shown in Table 2.

In this study, the Daily Total Production Amount (PA) was accepted as 850 unit/day and the Daily Total Production Time (T) as 540 min/day. The cycle time in the assembly line balancing studies was calculated as 0.635 (Equation (5)) minutes. The loss of balance of assembly lines, their efficiency and their daily total production amounts were estimated using the formulas given below.

$$LB = [(nC - \Sigma Co)/nC] 100 \quad (3)$$

$$LE = (1 - LB) 100 \quad (4)$$

$$PA = T/C \quad (5)$$

where, LB is the loss of balance, LE the line efficiency, C the cycle time, n the total number of work stations, ΣCo the average work station time, PA the daily total production amount, and T is the daily total production time [19].

Loss of balance is a measure of how well the distribution of jobs to stations is balanced. In other words, it is an indicator of how much the assembly line deviates from 100%. Line efficiency is the ratio of the sum of the process times to the number of stations and cycle times [9].

**Scenario 1.**

Firstly a priority matrix is designed for the assembly line constituted using the Hoffman Method (Table 4.a). There are 3 operations (1, 3 and 8) which have the rate 0 in the code number array. Operation number 1 is the first one among them assigned to the 1<sup>st</sup> work station. The cycle time is 0.635 minutes. As the time of

Table 5. Line balancing result for scenario 1.

Work-station No.	Op. No.	Machine type	Time, min.	Total time for work station, min. (x)	Remaining time, min. (C-x)
1	1	4 thread overlock machine	0.250	0.610	0.025
	4		0.360		
2	2	4 thread overlock machine	0.390	0.390	0.245
	3		0.080		
3	8	Lock – stitch sewing machine	0.090	0.570	0.065
	7		0.350		
	11		0.050		
	5		0.180		
4	5	Binding cover stitch machine	0.180	0.180	0.455
5	6	Cover stitch machine	0.240	0.240	0.395
6	9	4 thread overlock machine	0.440	0.440	0.195
7	10	Blade cover stitch machine	0.250	0.250	0.385
8	12	Blade cover stitch machine	0.420	0.420	0.215
9	13	Lock – stitch sewing machine	0.140	0.320	0.315
	14		0.180		
<b>Total time</b>			<b>3.420</b>	<b>3.420</b>	<b>2.295</b>

the first operation is 0.250 minutes, the remaining work station time is calculated as C-t<sub>1</sub> = 0.635 – 0.250 = 0.385 minutes. The time of the second operation, which has a rate of 0 ( operation number 3) is 0.080 minutes, which is shorter than the remaining time of the 1<sup>st</sup> work station. However, since it is carried out by a different type of machine, operation number 2 cannot be assigned to the 1<sup>st</sup> work station. The time of the third operation, which has a rate of 0 (operation number 8) is 0.090 minutes, which is shorter than the remaining time of the 1<sup>st</sup> work station. However, since it is conducted by a different machine, operation number 8 cannot be assigned to the 1<sup>st</sup> work station.

To make an assignment to the 2<sup>nd</sup> work station, a new priority matrix is obtained by crossing out the line and column numbered 1 in the priority matrix (Table 4.b). The first rate 0, which is left to right in the code number array, can be seen in op-

eration number 2. The time of operation 2, which has a rate of 0 is 0.390 minutes, which is longer than the remaining time of the 1<sup>st</sup> work station (0.385). As this operation cannot be assigned to the 1<sup>st</sup> work station, it is assigned to the 2<sup>nd</sup> work station. The remaining time of the 2<sup>nd</sup> work station is calculated as C-t<sub>2</sub> = 0.635 – 0.390 = 0.245 minutes. The time of the second operation, which has a rate of 0 (operation number 3) is 0.080 minutes, which is shorter than the remaining time of the 1<sup>st</sup> and 2<sup>nd</sup> work stations. However, since it is conducted by a different machine, operation number 3 cannot be assigned to the 1<sup>st</sup> and 2<sup>nd</sup> work stations. The time of the third operation, which has a rate of 0 (operation number 8), is 0.090 minutes, which is shorter than the remaining time of the 1<sup>st</sup> and 2<sup>nd</sup> work stations. However, since it is conducted by a different machine, operation number 8 cannot be assigned to the 1<sup>st</sup> and 2<sup>nd</sup> work stations.

**Table 6.** Line balancing result for scenario 2.

Work-station No.	Op. No.	Machine type	Time, min.	Total time for work station, min. (x)	Remaining time, min. (C-x)
1	1	4 thread overlock machine	0.261	0.261	0.374
2	2	4 thread overlock machine	0.407	0.407	0.228
3	3 8 7 11	Lock – stitch sewing machine	0.083 0.094 0.365 0.052	0.594	0.041
4	4	4 thread overlock machine	0.376	0.376	0.259
5	5	Binding cover stitch machine	0.188	0.188	0.447
6	6	Cover stitch machine	0.250	0.250	0.385
7	9	4 thread overlock machine	0.459	0.459	0.176
8	10	Blade cover stitch machine	0.261	0.261	0.374
9	12	Blade cover stitch machine	0.438	0.438	0.197
10	13 14	Lock – stitch sewing machine	0.146 0.188	0.334	0.301
<b>Total time</b>			<b>3.568</b>	<b>3.568</b>	<b>2.782</b>

**Table 7.** Line balancing result for scenario 3.

Work-station No.	Op. No.	Machine Type	Time (min.)	Total Time for Work Station (min.) (x)	Remaining Time (min.) (C-x)
1	1	4 thread overlock machine	0.313	0.313	0.322
2	2	4 thread overlock machine	0.488	0.488	0.147
3	3 8 11 13	Lock – stitch sewing machine	0.100 0.113 0.063 0.175	0.451	0.184
4	4	4 thread overlock machine	0.450	0.450	0.185
5	5	Binding cover stitch machine	0.225	0.225	0.410
6	6	Cover stitch machine	0.300	0.300	0.335
7	7	Lock – stitch sewing machine	0.438	0.438	0.197
8	9	4 thread overlock machine	0.450	0.450	0.185
9	10	Blade cover stitch machine	0.313	0.313	0.322
10	12	Blade cover stitch machine	0.525	0.525	0.110
11	14	Lock – stitch sewing machine	0.225	0.225	0.410
<b>Total time</b>			<b>4.178</b>	<b>4.178</b>	<b>2.807</b>

To make an assignment to the 3<sup>rd</sup> work station, a new priority matrix is designed by crossing out the line and column numbered 2 in the priority matrix (Table 4.c). The first rate 0, which is left to right in the code number array can be seen in operation number 3. Operation number 3, which is the first one among them, is assigned to the 3<sup>rd</sup> work station. The cycle time is 0.635 minute. As the time of the third operation is 0.080 minutes, the remaining work station time is calculated as  $C-t_3 = 0.635 - 0.080 = 0.555$  minutes. The time of the second operation which has a rate of 0 (operation number 8) is 0.090 minutes. Since it is shorter than the remaining time of 3<sup>rd</sup> work station and is conducted by the same machine, it is assigned to the 3<sup>rd</sup> work station. The remaining time of the 3<sup>rd</sup> work station is calculated as  $C-t_8 = 0.555 - 0.090 = 0.465$  minutes.

As can be seen in the assignment example which is done for the 1<sup>st</sup>, 2<sup>nd</sup> and 3<sup>rd</sup> work stations, one can achieve a solution. The solution results according to the design of the assembly line using the Hoffman Method are shown in Table 5.

As can be deduced from Table 5, the assembly line is designed for a 0.635 minute cycle time with 9 workstations. The loss of balance and assembly line efficiency of the assembly line designed are shown below.

$$LB = [(9 \times 0.635) - (3.42)] / (9 \times 0.635) \times 100 = 40.16\%$$

$$LE = (1 - 0.4015) \times 100 = 59.84\%$$

**Scenario 2.**

Assembly line results for Scenario 2 after applying the operation steps of Scenario 1 are given in the table below.

As can be deduced from Table 6, the assembly line is designed for a 0.635 minute cycle time with 10 work stations. The loss of balance and assembly line efficiency of the assembly line designed are shown below.

$$LB = [(10 \times 0.635) - (3.568)] / (10 \times 0.635) \times 100 = 43.81\%$$

$$LE = (1 - 0.4381) \times 100 = 56.19\%$$

**Scenario 3.**

Assembly line results for Scenario 3 after applying the operation steps of Scenario 1 are given in the table below.

As can be deduced from Table 7, the assembly line is designed for a 0.635 minute cycle time with 11 workstations. The loss of balance and assembly line efficiency of the assembly line designed are shown below.

$$LB = [(11 \times 0.635) - (4.178)] / (11 \times 0.635) \times 100 = 40.19\%$$

$$LE = (1 - 0.4018) \times 100 = 59.81\%$$

**Scenario 4.**

Assembly line results for Scenario 4 after applying the operation steps of Scenario 1 are given in the table below.

As can be deduced from Table 8, the assembly line is designed for a 0.635 minute cycle time with 11 workstations. The loss of balance and assembly line efficiency of the assembly line designed are shown below.

$$LB = [(11 \times 0.635) - (4.462)] / (11 \times 0.635) \times 100 = 36.12\%$$

$$LE = (1 - 0.3612) \times 100 = 63.88\%$$

**Scenario 5.**

Assembly line results for Scenario 2 after applying the operation steps of Scenario 1 are given in the table below.

As can be deduced from Table 9, the assembly line is designed for a 0.635 minute cycle time with 11 work stations. The loss of balance and assembly line efficiency of the assembly line designed are shown below.

$$LB = [(10 \times 0.635) - (3.51)] / (10 \times 0.635) \times 100 = 44.72\%$$

$$LE = (1 - 0.3612) \times 100 = 55.28\%$$

**Results**

In this study, the assembly line was balanced with the Hoffman method for 5

different scenarios in t-shirt production and the results were analysed. The results of assembly line balancing practices with the Hoffman method for 5 different scenarios in t-shirt production are shown in **Table 10**.

As can be seen in **Table 10**, all scenario results were different for the same day production amount and cycle period. While the S1 line was balanced within 9 workstations, for S2 and S5 it was 10 and for S3 and S4 the number of workstations was 11.

In the light of the results given above, it can be deduced that the change in performance review and lost productive time affect the t-shirt production time, and, consequently, the assembly line regarding both the number of work stations and line productivity.

When results in **Table 10** are analysed in terms of assembly line productivity, it is concluded that the assembly line productivity for each scenario is distinctive. Among these results, the most remarkable is that of S5, showing that a decrease in performance of only an employee affected not only the number of workstations but also line productivity negatively.

## Conclusions

The aim of this study was to show to what extent performance review and lost productive time determination are important for firms. In this context, assembly lines are balanced with the Hoffman Method for 5 different scenarios organised within varied performance and lost productive time rates and their results are evaluated. When the results of the study are analysed, it highlights that the mistakes which are made in the determination of performance assessment and the lost productive time rate, dramatically affect the production time, number of work stations and line productivity. According to the results of the study, performance assessment and tolerance share both have a separate and simultaneous effect on the productive time and number of stations and productivity. When the negative effects of misevaluating only one operator's performance level are considered, it can be pointed out that it is crucial to determine the rate of performance assessment and tolerance share accurately.

In addition to this, the mistakes made in performance assignment and toler-

**Table 8.** Line balancing result for scenario 4.

Work-station No.	Op. No.	Machine type	Time, min.	Total time for work station, min. (x)	Remaining time, min. (C-x)
1	1	4 thread overlock machine	0.326	0.326	0.309
2	2	4 thread overlock machine	0.509	0.509	0.126
3	3 8 11 13	Lock – stitch sewing machine	0.104 0.117 0.065 0.183	0.469	0.166
4	4	4 thread overlock machine	0.470	0.470	0.165
5	5	Binding cover stitch machine	0.235	0.235	0.4
6	6	Cover stitch machine	0.313	0.313	0.322
7	7	Lock – stitch sewing machine	0.457	0.457	0.178
8	9	4 thread overlock machine	0.574	0.574	0.061
9	10	Blade cover stitch machine	0.326	0.326	0.309
10	12	Blade cover stitch machine	0.548	0.548	0.087
11	14	Lock – stitch sewing machine	0.235	0.235	0.4
<b>Total time</b>			<b>4.462</b>	<b>4.462</b>	<b>2.523</b>

**Table 9.** Line balancing result for scenario 5.

Work-station No.	Op. No.	Machine type	Time, min.	Total time for work station, min. (x)	Remaining time, min. (C-x)
1	1	4 thread overlock machine	0.250	0.250	0.385
2	2	4 thread overlock machine	0.390	0.390	0.245
3	3 8 7 11	Lock – stitch sewing machine	0.080 0.090 0.350 0.050	0.570	0.065
4	4	4 thread overlock machine	0.450	0.450	0.185
5	5	Binding cover stitch machine	0.180	0.180	0.455
6	6	Cover stitch machine	0.240	0.240	0.395
7	9	4 thread overlock machine	0.440	0.440	0.195
8	10	Blade cover stitch machine	0.250	0.250	0.385
9	12	Blade cover stitch machine	0.420	0.420	0.215
10	13 14	Lock – stitch sewing machine	0.140 0.180	0.320	0.315
<b>Total time</b>			<b>3.510</b>	<b>3.510</b>	<b>2.840</b>

**Table 10.** Comparison of balancing results.

Scenarios	Daily total production amount, Piece	Cycle time, min	Total time, min	Remaining time, min	Total number of workstation, Piece	Loss of balance, %	Line efficiency, %
S 1	850	0.635	3.420	2.295	9	40.16	59.84
S 2	850	0.635	3.568	2.782	10	43.81	56.19
S 3	850	0.635	4.178	2.807	11	40.19	59.81
S 4	850	0.635	4.462	2.523	11	36.12	63.88
S 5	850	0.635	3.510	2.840	10	44.72	55.28

ance share determination also affect the firm negatively in terms of reaching its production targets, causing the off-time delivery of orders and extra expenses because of this delay.

## References

1. Kayar, M. *Production and Productivity - Basic Principles and Practice*, Ekin Press, ISBN: 978-605-5335-19-9, Bursa, Turkey, 2012.
2. Timur H. *Work Measurement, Work Planning, Productivity*, Public Administration Institute for Turkey and Middle East Publication, No: 207, Ankara, Turkey, 1984.
3. Kanawaty G. *Work Study*, International Labour Office (ILO), 6<sup>th</sup> Edition, National Productivity Center Publications, ILO: 29, pp. 22-23, Ankara, Turkey, 2004.
4. Akal Z. *Performance Measurement and Control in Companies (Versatile Performance in Indicators)*. National Productivity Center Publications 1992; 1, 473, Ankara, Turkey.

5. Pugh D. *Organizational Behaviour*, Prentice Hall International (UK) Ltd., Londra, 1991.
6. Erdoğan I. *Employee Selection and Success Valuation Techniques in Companies*, Graduate School of Business Publication, No: 67, İstanbul, Turkey 1991.
7. Dal V. *Comparative Study of REFA, MTM and GSD Workflow Time Identification Systems with a Sample Application*, Turkish Science – Research Foundation, TÜBAV Science Journal 2010; 3, 3: 224-237.
8. Top A. *Production Systems Analysis, Planning and Control*, Alfa Publications, 3<sup>rd</sup> Edition, pp. 45-54, İstanbul, Turkey, 2001.
9. Kayar M.; “*Study of the Causes of Unproductiveness in Apparel Companies and Fieldwork Analysis for Their Solution*”, PhD Thesis, University of Marmara, İstanbul, Turkey, (2008).
10. Kayar M, Akyalçın ÖC. Applying Different Heuristic Assembly Line Balancing Methods in the Apparel Industry and their Comparison. *Fibres & Textiles in Eastern Europe* 2014; 22, 6(108): 8-19.
11. Kayar M, Akalın M. Comparing Heuristic and Simulation Methods Applied to the Apparel Assembly Line Balancing Problem. *Fibres & Textiles in Eastern Europe* 2016; 24, 2(116): 131-137. DOI: 10.5604/12303666.1191438.
12. Türkmen A, Yeşil Y, Kayar M. *Heuristic Production Line Balancing Problem Solution with MATLAB Software Programming. International Journal of Clothing Science and Technology* 2016; 28(6): 750-779.
13. Hoffman TR. Assembly Line Balancing with a Precedence Matrix. *Management Science* 1963; 9, 4.
14. Erel E, Sabuncuoğlu I, Aksu BA. *Balancing of U-Type, Assembly Systems Using Simulated Annealing. International Journal of Production Research*, Taylor & Francis Ltd., 2001; 39, 13: 3004-3015.
15. Prokopenko J. *Productivity Management: A Practical Handbook*, 2<sup>nd</sup> Edition, International Labour Office, Geneva, Switzerland, 1992.
16. Kobu B. *Production Management*. Expanded and Updated 13<sup>th</sup> Edition, Beta Publishing, pp. 3-5, İstanbul, Turkey, 2006.
17. Mayer R R. *Production and Operations Management*, 3rd Edition, McGraw-Hill, pp. 514-519, New York – London, 1975
18. Ercan MN. *Work and Time Study*, Expanded 3<sup>rd</sup> Edition, Dokuz Eylül University Publications, No: 4, pp. 95-103, İzmir, Turkey, 2004.
19. Kayar M. Comparison of Different Production Technologies’ Productivity in Jean Trousers Sewing by Simulation Technique, MSc. Thesis, University of Marmara, İstanbul, Turkey, 2003.



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