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Productivity Improvement of BOB T-Shirt Through Line Balancing Using Control Limit Analysis and Discrete Event Simulation, Case Study: MAA Garment and Textile Factory

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Abstract

This study deals with line balancing of BOB T-shirt model with the help of control limit analysis and discrete event simulation of the assembly lines. In this study control limit analysis is used to measure the performance of the assembly line and used to show the bottleneck operations of the assembly line and line balancing technique improves the productivity of the sewing line of the model. BOB T-shirt model has 16 main operations and each operation's time is analyzed as standard minute value (SMV). The main bottleneck operations are analyzed using the control limit analysis and simulation modeling. Based on the SMV of each operation, those operations which are out of lower control limit and upper control limit is called us bottlenecks of the sewing lines of the garment section and the 1st bottleneck operation is tread trimming operation. When we apply control limit analysis and discrete event simulation technique for the line balancing; the daily output has been increased from 1032 pieces to 1289 pieces. And labor productivity and machine productivity are increased from 46.9 and 54.32 to 58.59 and 71.61 respectively. And then finally, the profit that the line generated also increased from 22704 to 28358birr.

Keywords: *C*ontrol limit; bottleneck, SMV; productivity, Line balancing; Simulation modeling.

1. Introduction

Line balancing is the commonly technique to solve problems occurred in assembly line process. It is a technique to minimize unbalance between the workers and workloads to achieve required run rate. This can be done by equalizing the amount of work in each station and assign the smallest number of workers in the particular workstation *(azizul, 2007)*. But the major obstacle to attaining a perfectly balanced line is the difficulty of forming task bundles that have the same duration. Here the job is divided into small part called job element. The aim job element is to keep up production at equal rate. Line that is perfectly balanced will have a smooth flow of work as activities along the lines are synchronized to achieve maximum utilization of labor and equipment. On the basis of time taken of each operation the reason for line balance is that; Maximum output, avoid any bottleneck, Smooth flow of work (production), less supervision and effort. The main objective of this study is to improve productivity. Improve Productivity by the reduction in wastage of resources such as labor, machines, materials, power, space, time, capital, and by initiating operators and offer incentives to produce more and more with less and less inputs of resources. It leads for the development of an attitude of mind and a constant urge to find better performance of operators and their leaders. Aims at the maximum utilization of resources for yielding as many goods and services as possible, of the kinds most wanted by consumers at lowest possible cost. Provide improvements in the layout of lines and work, better working conditions and simplification of work *(yemane, serajul, & ivan, 2017)*

1.1. Problem statement

The problem in line balance is one of the burning issues that hinder its efficiency, speed and effectiveness of the company in one and another way. The difference between planned and real outputs BOB T-shirt on sewing line have a huge amount of variation from day-to-day. the amount of variation between these outputs vary day to day it caused by imbalance of machine, workload and man labor because of this they do not meet their daily target that highly affects the overall productivity of the company and its competitiveness, and delivery time of the company shift from the normal due date (delay on production process). This was the reason to conduct a survey and project on sewing section.

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1.2. Objective of the study

1.2.1. General objective

The general objective of this study is to improve the productivity of the sewing section through line balancing method using control limit analysis and simulation modelling.

1.2.2. Specific objectives: -

- To analyze the standard minute value of each activity and the BOB model t-shirt.
- To identify the bottleneck operations of the BOB model t-shirt.
- To analyze the standard performance of each operation.
- To recommend a remedial actions or solutions for the sewing section

2. Related Literature Review

2.1 Productivity

Ethiopian clothing industries face many problems that have not become competitive globally. These problems include; the poor performance of products in the export market, poor quality and inadequate supply of raw materials, low productivity and poor resource utilization. Because of those, most of the country's textile companies are not lucrative and most are in great loss *(Matebu, 2006)*. Bottlenecks in the production regime involve long queues, long waiting times, poor performance and overall inefficiency of the system, such a system should work under capacity. To maximize resource capacity and the efficiency level of operations it is desirable to have appropriately programmed workstations and disposition in available space structures, with an optimal allocation of available resources.

Work-time study, balancing the assembly line and simulation can be applied to the production line to find alternative solutions to increase sewing line efficiency. A good layout design could increase the productivity by correctly balancing the assembly line *(Mominul, mehidi, & h.m, 2014)*. Some researchers said the simulation model is used to identify bottlenecks in the production line and evaluate a number of suggested solutions using the arena software *(Hailemariam, 2009)* and *(aregawi, serajul, & ivan, Bottleneck Identification Using Time Study and Simulation Modeling of Apparel Industries, 2017)*. In addition to that the productivity of the company will be improved while the company diffuses the appropriate time study of the products to be mounted on the production line, the minimum queue length on the machines, the minimum production cost and high-quality products to set up an improved clothing industry Increase the productivity of the specific model.

Work-time study, Assembly line balancing can be applied to apparel or clothing production line to find alternative solutions to increase the efficiency of the sewing line of the garment section. In this paper, they try to show how a good layout can be designed and productivity can be increased by appropriate assembly line balancing *(Mominul, mehidi, & h.m, 2014)*. Some of the optimization layout design studies from balancing lines using simulation models and different approaches will be studied in this type of problem discussed in the literature. The line balancing is the assignment process of tasks or workstations so that the workstations have roughly the same time requirements. This results in minimizing stop times along the line and high use of labor and equipment and minimizing the cycle time of the production line. Cycle time is the maximum time allowed for each workstation in the production of clothing items, clothing components or parts are collected in a finished output which is the final product of the subassemblies processes. And the process has a different number of workstations, operators, and installation components. Therefore, a good balance line increases the efficiency of the sewing section production line *(Mominul, mehidi, & h.m, 2014)*. In the production of clothing, responsible would have been able to check whether the assembly work will be completed in time for delivery, how machines and man or operators are used, if any station on the line assembly line is late it is global. To achieve this approach, the study of working time is the duration for each part to be mounted on production lines *(Mominul, mehidi, & h.m, 2014)* and *(hapaz & hazmil, 2008)* activities. The assembly lines are generating production systems to meet the humanity needs that have been growing day by day. The goals of these systems produce products that have high production rates in the shortest time, in a more productive, economical and quality manner. The purpose of the case study was to design the assembly chain to achieve maximum line efficiency using the optimum machine working time for constant cycle time *(ashkan, hamid, & hesam, 2014)*. Line Balancing is commonly used to solve problems that have occurred in the assembly line. Line balancing is a technique to minimize the distance between workers and workload to achieve the desired flow rate *(asmelash, 2008)*. This can be done by equating the amount of work at each station and assigning the least number of workers to the particular workstation. A line balancing can be classified into three categories according to the numbers Mounted on the line and in accordance with the rhythm of line *(gorema & mulugeta, 2014)* and *(asmelash, 2008)* are models;

Productivity is nothing but the reduction in wastage of resources such as labor, machines, material, power, space, capital etc. Generally, Productivity defined as the ratio of outputs (goods and services) divided by inputs (resources such as labor and capital).

$$Productivity = \frac{\text{units produced}}{\text{input used}} \quad (1)$$

Industrial productivity is at the heart of cost control and product marketability and productivity can be defined in many ways although it is most commonly associated with labor effectiveness *(Zandin, 2001)*.

Productivity can also be defined in many ways same of them are follows;

Productivity can also be defined as human effort to produce more and more with less and less inputs resources so that products can be purchased by a large number of people at affordable price.

Productivity processes more efficient works involving less fatigue to workers due to improvement in the layout of plant and work, better working condition and simplification of work *(Roy, 2005)*.

Productivity can be express in different ways such as in terms of labor, machine, material and total productivity.

Labor productivity: - total production (output pieces of line) and total labor involved in producing those pieces.

Machine productivity: - total production (output pieces of line) and total machine involved in producing those pieces.

Material productivity: - total production (output pieces of line) and total material involved in producing those pieces.

Total productivity: - total production (output pieces of line) and total labor, total material, total machine and others that involved in producing those pieces *(lamming, Steve, & Richard, 2014)*.

2.1.1productivity improvement techniques

Technology based: - based on computer aided manufacturing and computer integrated manufacturing system refers to design of products, process of system with help of computers.

Employee based: - based on employee promotion, job design, job enlargement, job enrichment and job rotation.

Material based: - based on material and planning control, material storage and retrieval, waste elimination.

Process based: - based on value analysis and value engineering, reliability engineering, standardization and simplification *(Suresh, 2008)*.

2.2 Line balancing

A line is defined as a group of operators under the control of our production supervisor. Assembly line balancing is a managerial technique and can be applied to balance production flow lines. Line balancing is the distribution of work on the line in such a way that everyone gets the same amount of work in term of time. In practice a perfect balancing could not be achieved but we can improve using proper technique *(Babu, 2011)*.

The assembly line balancing problem was first introduced by bryton in his graduate thesis. In his, study he accepted the amount of workstation as constant, the workstation time as equal for all station and work tasks as moving among workstation *(Bryton, 1954)*.

2.2.1 Steps of line balancing

- ❖ Identify problem: - Identify where the bottleneck was found.
- ❖ Prepare to collect data: - collect significant data on the bottleneck area.
- ❖ Select production line: - select a line that has high bottleneck area.
- ❖ Time study calculates the standard minute value (SMV) and Calculating of SMV involve different activities and has the following steps.

1. defined task: - select task that going to be study
2.Estimate the required number observation
3. Record the time and rating performance
4.Average observes time

$$= \frac{C1+C2+C3+\cdots cn}{n} \tag{2}$$

c_i is cycle time for n type of observation.

5. Normal time Normal time=observing time

$$*\frac{\text{OBSERVING RATE}}{\text{STANDARD RATE}} \tag{3}$$

6. Allowance= Normal time* $\frac{allowance}{100}$ (4)

7. Standard time=normal time+ personal need allowance and machine allowance (5)

Eliminate the bottleneck area:-eliminate the operation that has high SMV value by calculating theoretical man labor (theoretical man labor is the exact labor required for that operation) *(hasanshumon, zaman, & azizur, 2010)*.

2.2.2 Objectives of line balancing

- ❖ To obtain task groupings that represent approximately equal time requirements.
- ❖ To balance the work loads of men and machines along a line.
- ❖ To give nearly equal distribution or assignment to all.
- ❖ To distribute tasks evenly over the work stations to minimize the idle time of men and machines.
- ❖ To reduce production cost

- To identify the location of bottlenecks *(hapazl, 2008)*

2.3. Allowance

The normal time for an operation does not contain any allowances for the worker. It is impossible to work throughout the day even though the most practical, effective method has been developed. Allowances are categorized as: Relaxation allowance, Interference allowance, and Contingency allowance.

A. Relaxation Allowance

Relaxation allowances are calculated to allow the worker to recover from fatigue.

B. Interference Allowance

This allowance is applicable for machine or process controlled jobs. Interference allowance varies in proportion to number of machines assigned to the operator. The interference of the machine increases the work content.

C. Contingency Allowance

A contingency allowance is a small allowance of time which may be included in a standard time to meet legitimate and expected items of work or delays. Contingency allowance should not exceed 5% *(Suresh, 2008)*

2.4 Time Study

Time study is a method of measuring work for recording the times of performing a certain specific task or its elements carried out under specified conditions. An operator does same operation (task) throughout the day. Time study help to define how much time is necessary for an operator to carry out the task at a defined rate of performance. It is evaluation of a task in terms of the time that should be allowed by an average worker to perform the task, Focus on human work, Standard time (allowed time), and Includes allowance *(Suresh, 2008)*.

2.5 Bottlenck area analysis process

variation in process from bench mark target and the lower capacity from bench mark target is the bottleneck area. the variation may be in standard minute value or capacity of each operation per hour.bottle neck area can be identified through construction of contol limit. Operation that are out of the control limit are bottleneck area. these bottleneck area should be eliminated to have smooth production flow, increment in output and increment in productivity. The following calculations are necessary to analyse the problems.

$$\text{Pitch time (PT)}=\frac{\text{SMV}}{\text{NO OF MAN POWER}} \quad (1)$$

Upper Control Limit (UCL)

$$=\frac{\text{PITCH TIME}}{\text{Starget organizational efficiency at 70\%}} \quad (7)$$

$$\text{Lower control Limit} = 2*PT-UC\ L \quad (8)$$

$$\text{Theoretical man labor (TML)} = \frac{\text{BENCH MARK TARGET PER HR LINE}}{\text{process capacity per hr individual}} \quad (2)$$

(hasanshumon, zaman, & azizur, 2010).

3. Methodology

3.1 Data collocation

3.1.1 Primary data collection

- Visual observations; Conducted to know where the bottleneck was and Observing overall of the company specifically on sewing section.
- Interview; conducted to know a detailed know how on garment section specifically in sewing area by doing interview with production manager, planning manager, time study and line balance man, line supervisors and workers of the company.
- Direct recording of data; conducted to know standard minute value (SMV) for each operation.

3.1.2 Secondary data collection

The secondary data sources that used for conducting this study are recorded planning activities, Daily reports, Official documents and Referring to some books.

3.2 Data analysis

This project is analyzed by reviewing of the existing time study and line balancing for Identification of bottle necks area and Applying different line balancing techniques and calculations such as labor productivity, machine productivity, output per day, theoretical man labor and profit for comparison of existing line before and after line balanced. In addition, in this study Excel software was used for constructing bar diagram that is used to show the bottleneck area and control limit chart used to show the bottleneck area.

4. Result and Discussion

4.1. Existing data of BOB T-shirt

Table 1
Operations sheet

Style: BOB	*ITEM: T-SHERT*					
Buyer: H&M	*LINE NO: 7*					
NO	*Operation (tasks)*	*m/n type*	*No of m\n*	*No of labor*	*SMV*	*daily capacity*
1	*Shoulder attach one side*	*4T OL*	*1*	*1*	*0.349917*	*1391*
2	*Neck piping attaching*	*4T OL*	*1*	*1*	*0.364*	*1318*
3	*Self-fabric attaches to shoulder*	*SNL*	*1*	*1*	*0.286*	*1678*
4	*V tack at front neck*	*SNL*	*1*	*1*	*0.325*	*1477*
5	*Front cover stitching*	*2T FL*	*1*	*1*	*0.364*	*1319*
6	*Shoulder joining 2nd side*	*4T OL*	*1*	*1*	*0.338*	*1420*
7	*Sleeve attaching*	*4T OL*	*2*	*2*	*0.663*	*1448*
8	*Back neck binding*	*SNL*	*1*	*1*	*0.325*	*1477*
9	*Trimming lable marking*	*------*		*1*	*0.325*	*1476*
10	*Piping end tacking at back neck*	*SNL*	*1*	*1*	*0.299*	*2096*
11	*Back neck out line with lable*	*SNL*	*2*	*2*	*0.663*	*1448*
12	*Sleeve hemming*	*3T FL*	*2*	*2*	*0.676*	*1420*
13	*Side seam*	*4T FL*	*2*	*2*	*0.715*	*1343*
14	*Bottom hemming*	*3T FL*	*1*	*1*	*0.325*	*1477*
15	*Arm hole and neck tacking*	*SNL*	*2*	*2*	*0.494*	*1944*
16	*Thread trimming with stickers removing*	*------*		*2*	*0.91*	*1054*
	Total		*19*	*22*	*7.42*	

4.2. line Balancig process

Time study is combination of several different activities as follows: -

Step 1. defined task: - select task that going to be study Considering Shoulder attach one side

Step 2. estimate the required number of observations. in this study there are 12 observations selected to each operation (C1, C2 and C3 up to C12).

Step 3. record the time and rating performance. the recorded time is 15, 16, 17, 16.4, 15, 17.2, 16.6, 15.1, 16.9, 17.3, 14.8 and 16.5.

Step 4. average observation time: - this is calculated using equation 2.

Average observed time or cycle time (Ci)

$$= \frac{(C1+C2+C3+\cdots C12)}{12} =$$

$$\frac{(15+16+17+16.4+15+17.2+16.6+15.1+16.9+17.3+14.8+16.5)}{12}$$

=16.15 sec change in to minute =0.269minute

Then Observing time is 0.27min

Step 5. Normal time is calculated using equation 3.

Normal time=observing time $*\frac{(\,observing\ rate)}{Standard\ rate}$

=0.269*1= 0.269min

Step 6. Allowance is calculated using equation 4.

Calculate allowance= Normal time*% allowance/100 For machine and personal allowance=0.269*0.3 =0.0807min

Step 7. standard time is calculated using equation 5.

Standard time=normal time+ personal need allowance& machine allowance

=0.269+0.0807

=0.3497minute

For Shoulder attach one side SMV is =0.3497 minute

4.3. Bottleneck area analysis process

The time at which the longest time required is called bottleneck process. But also the smallest time is loss balance and the graph below figure 1 shows that the variation of SMV of different operations of the t-shirt.

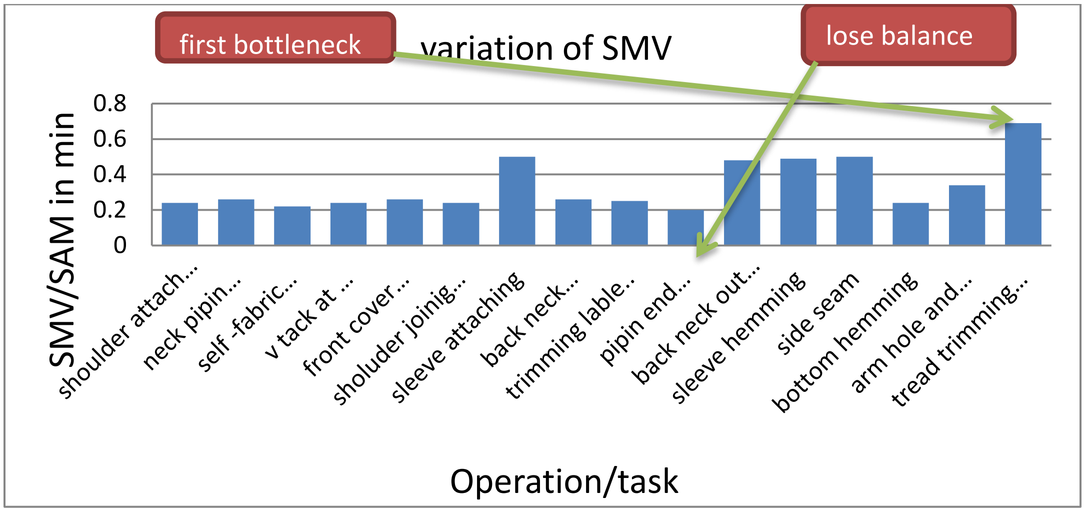

Fig. 1. the bottleneck area of the operations

The graph below figure 2 shows that, the difference between capacity per hours of each operation and bench mark target. Benchmark target is the outputs from that line at 100 efficiencies.

This study identified some variation in process capacity from the bench mark target and the low capacity from the bench mark target is the bottleneck area. This shows that, the line is unbalanced and has bottleneck operation through flow process.

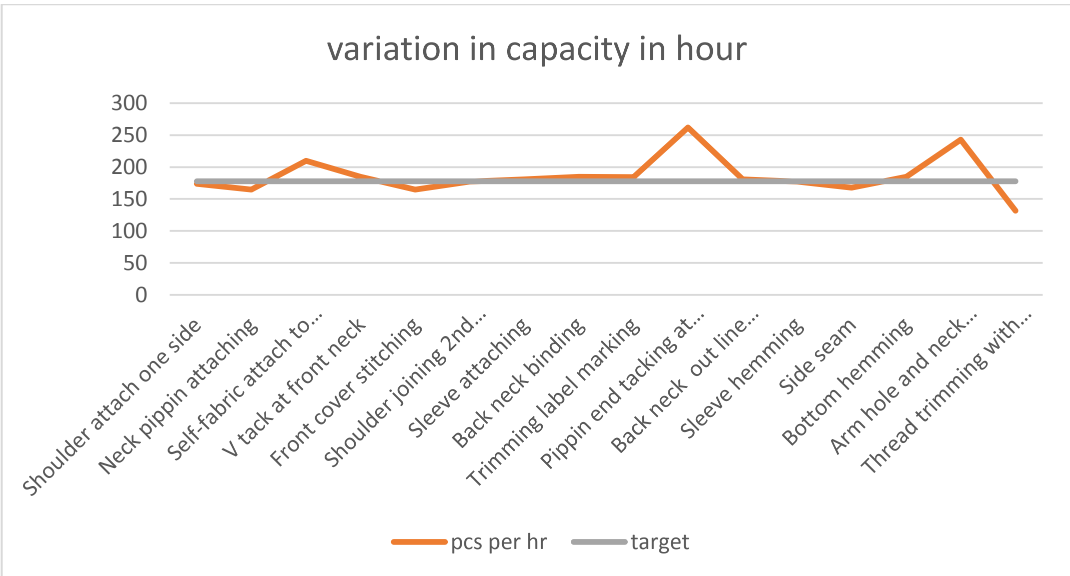

Fig. 2. Comparison between capacities and benchmark target

4.4. Control limit chart

Control limit can show us the bottleneck of the operation and the parameters are calculated as follows: -

The pitch time is calculated using equation 6 and evaluated as follows: -

Pitch time = SMV/No of man power

=7.4219/22

=0.3374 min

Upper control limit is calculated using equation 7 and it is calculated as follows: -

Upper Control Limit = pitch time / (Target organizational efficiency at 70%)

=0.3374 / (0.70)

= 0.4819 min

Lower control limit is calculated using equation 8 and it is calculated as follows: -

Lower Limit =2*Pitch Time-Upper Limit

=2*0.3374-0.4819

= 0.1929 min

The SMV that is out of the control limits is bottleneck operation.

Considering shoulder attach one side and calculate the process capacity for it.

*Process capacity (individual target)= 60/SMV = 60/0.3499 = 172pcs/hr.*8hrs=1372pcs/day* (10)

*Target line = (number of operators *working min per day)/SMV*

*= (22*480)* (11)

7.421

=1423 pieces

- TML = Line target/Process capacity

  = 1423 = 1.03

  1372

- Proposed human labor = 1

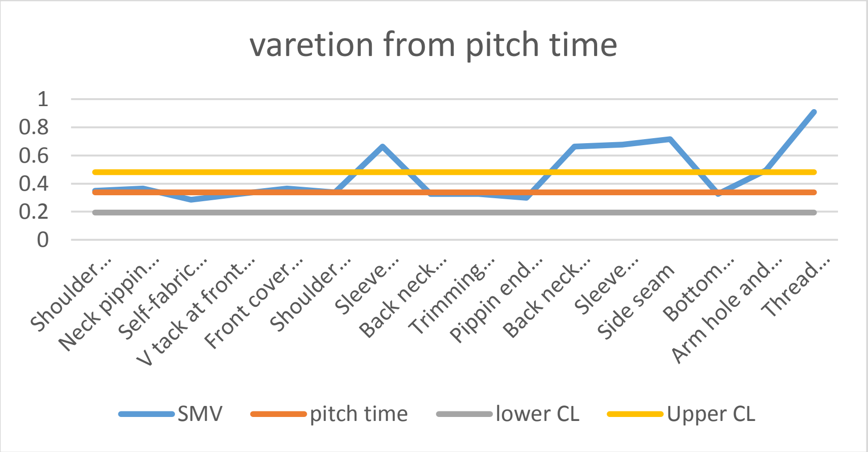

Figure 3 Summarize the bottleneck area by using control limit

4.3. Simulation model of the existing line

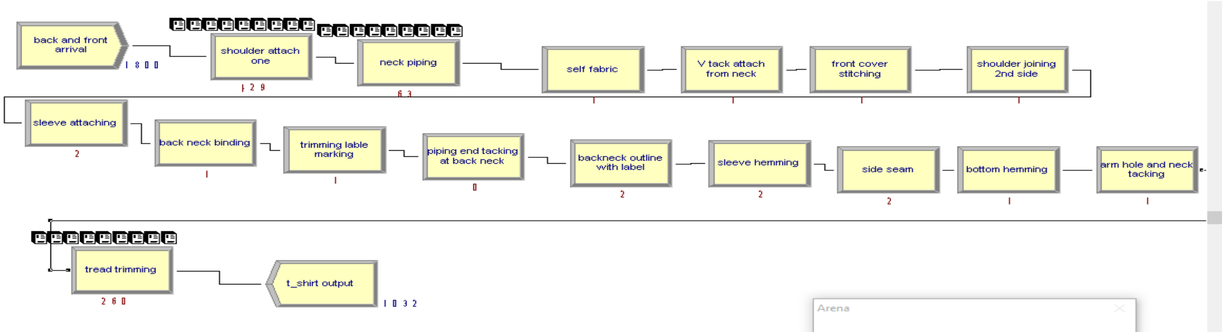

Fig. 4. Existing simulation model

From the above simulation model figure 4 and table 2 below, the number of queues is high in the tread trimming which is the bottleneck operation and this simulation is valid when compared to the existing actual output of the case company. And the simulation output and the real output is similar relatively where the simulation output is 1032 and the real existing output is 1054 t-shirts. In similar way, the number queues are high shoulder attach one side and neck piping next to the 1^{st} bottleneck operation *(aregawi, misgina, teklewold, & gebremedhin, 2020)*.

Table 2
Existing model number waiting and resource utilization

	Inst Util	Num Busy	Num Sched	Num Seized	Sched Util
2TFLop5	1.00	1.00	1.00	1,306.00	1.00
3TFLop12a	0.92	0.92	1.00	649.00	0.92
3TFLop12b	0.92	0.92	1.00	649.00	0.92
3TFLop14	0.88	0.88	1.00	1,294.00	0.88
4TFLop13a	0.97	0.97	1.00	648.00	0.97
4TFLop13b	0.97	0.97	1.00	648.00	0.97
4TOLop1	1.00	1.00	1.00	1,372.00	1.00
4TOLop2	1.00	1.00	1.00	1,309.00	1.00
4TOLop6a	0.45	0.45	1.00	649.00	0.45
4TOLop6b	0.46	0.46	1.00	656.00	0.46
4TOLop7a	0.91	0.91	1.00	652.00	0.91
4TOLop7b	0.90	0.90	1.00	652.00	0.90
op1	1.00	1.00	1.00	1,372.00	1.00
op10	0.81	0.81	1.00	1,300.00	0.81
op11 a	0.90	0.90	1.00	650.00	0.90
op11 b	0.90	0.90	1.00	650.00	0.90
op12a	0.92	0.92	1.00	649.00	0.92
op12b	0.92	0.92	1.00	649.00	0.92
op13a	0.97	0.97	1.00	648.00	0.97
op13b	0.97	0.97	1.00	648.00	0.97
op14	0.88	0.88	1.00	1,294.00	0.88
op15a	0.67	0.67	1.00	647.00	0.67
op15b	0.67	0.67	1.00	646.00	0.67
op16a	0.99	0.99	1.00	517.00	0.99
op16b	0.99	0.99	1.00	517.00	0.99
op2	1.00	1.00	1.00	1,309.00	1.00
op3	0.77	0.77	1.00	1,308.00	0.77
op4	0.88	0.88	1.00	1,307.00	0.88
op5	1.00	1.00	1.00	1,306.00	1.00
op6a	0.45	0.45	1.00	648.00	0.45
op6b	0.46	0.46	1.00	657.00	0.46
op7a	0.91	0.91	1.00	652.00	0.91
op7b	0.90	0.90	1.00	652.00	0.90
op8	0.88	0.88	1.00	1,302.00	0.88
op9	0.88	0.88	1.00	1,301.00	0.88
SNLop10	0.81	0.81	1.00	1,300.00	0.81
SNLop11 a	0.90	0.90	1.00	650.00	0.90
SNLop11 b	0.90	0.90	1.00	650.00	0.90
SNLop15a	0.67	0.67	1.00	647.00	0.67
SNLop15b	0.67	0.67	1.00	646.00	0.67
SNLop3	0.77	0.77	1.00	1,308.00	0.77
SNLop4	0.88	0.88	1.00	1,307.00	0.88
SNLop8	0.88	0.88	1.00	1,302.00	0.88

	Number Waiting
arm hole and neck tacking.Queue	0.00
back neck binding.Queue	0.00
backneck outline with label.Queue	0.00
bottom hemming.Queue	0.00
front cover stitching.Queue	0.00
neck piping.Queue	31.12
piping end tacking at back neck.Queue	0.00
self fabric.Queue	0.00
shoulder attach one.Queue	213.79
shoulder joining 2nd side.Queue	0.00
side seam.Queue	0.00
sleeve attaching.Queue	0.00
sleeve hemming.Queue	0.00
tread trimming.Queue	127.27
trimming lable marking.Queue	0.00
V tack attach from neck.Queue	0.00

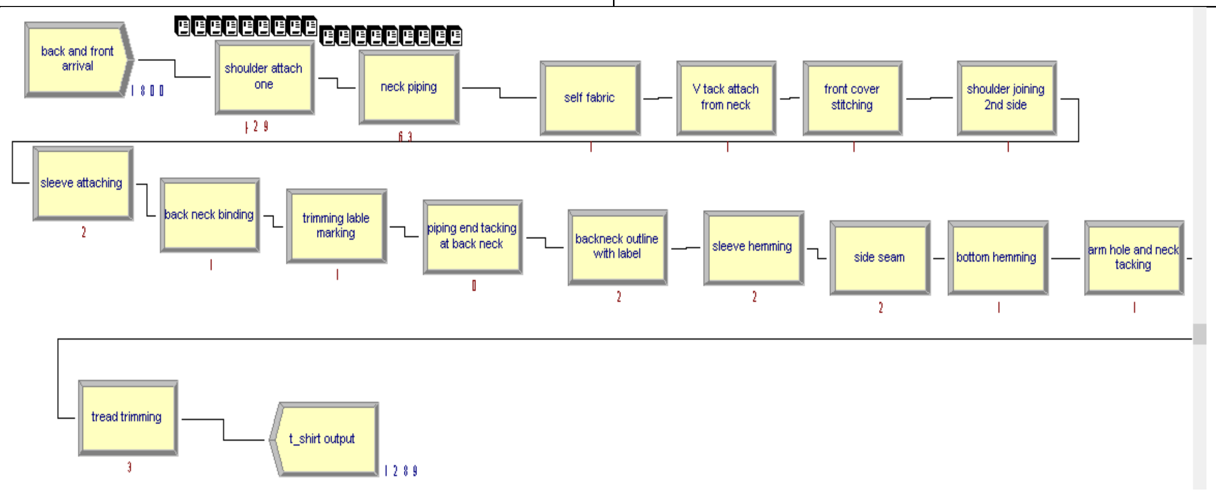

Fig. 4. Improved simulation model

4.5. Improved simulation model

After balancing the line by using control limit chart method to identify the bottleneck area and also calculating process capacity, target line and TML to balance the number of labor and machine required for each operation. By doing this the number machine reduced to 19 and 18 but man power is shifted from arm hole operation to tread trimming operation.

This above simulation model figure 5, shows when we apply the control limit analysis the man power proposed for the bottleneck operation is increased the out puts of the production line from 1032 to 1289 t-shirts and the t-shirt parts which was WIP is decreased from 128 to zero.

Other

	Number Waiting
arm hole and neck tacking.Queue	0.00
back neck binding.Queue	0.00
backneck outline with label.Queue	0.00
bottom hemming.Queue	0.00
front cover stitching.Queue	0.00
neck piping.Queue	31.12
piping end tacking at back neck.Queue	0.00
self fabric.Queue	0.00
shoulder attach one.Queue	213.79
shoulder joining 2nd side.Queue	0.00
side seam.Queue	0.00
sleeve attaching.Queue	0.00
sleeve hemming.Queue	0.00
tread trimming.Queue	0.00
trimming lable marking.Queue	0.00
V tack attach from neck.Queue	0.00

Fig. 5. number waiting improved model

From this above figure 6, we can conclude that the next bottlenecks operations are shoulder attach one side and front cover stitching operations.

4.6. Scenario analysis of existing model and improved based on control limit analysis

The number waiting for process in the existing model was 128 t-shirts but for the improved model is zero parts according to figure 7.

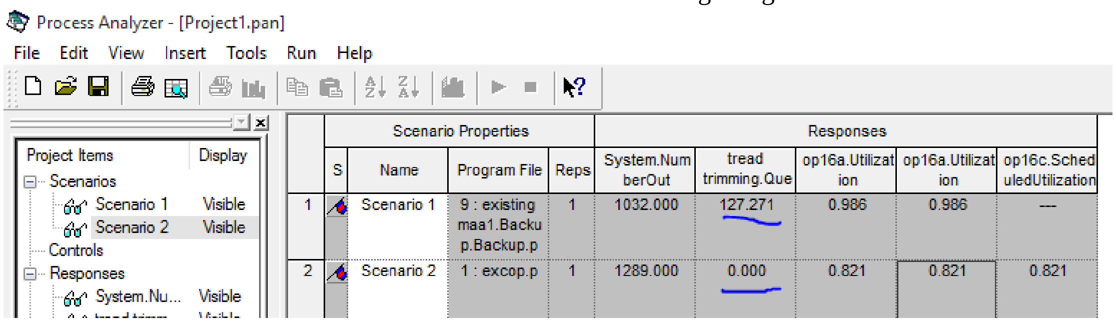

Fig. 6. Scenario analysis

4.7. Comparisons of existing and improving line

Table 2
Comparisons of existing and improving line

Comparison of parameters	Existing line	Improving line
Daily output (pieces)	1032	1289
Number of man labor per line	22	22
Number of machines per line	19	18
Machine productivity (pcs/operator)	54.32	71.61
Labor productivity (output/machine)	46.9	58.59
Profit per day (birr)	22704	28358

The above table 3, shows that a comparison of the existing model of the t-shirt and the improved model by taking an action on the bottleneck operations and the outputs are calculated as obtained in the above table.

The figure below figure 8, shows that Comparisons of existing and improving line in terms of capacity per hr.

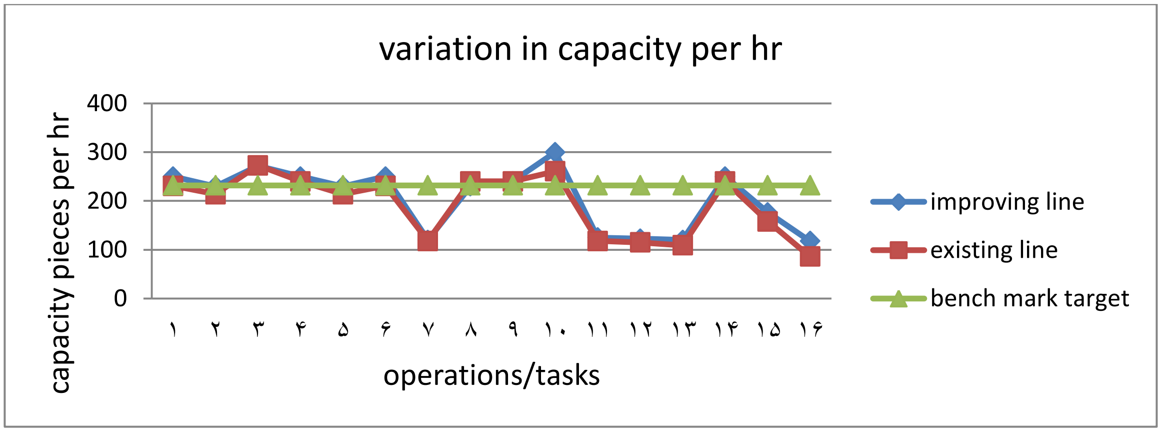

Fig. 7. Variation in capacity per hour

5. Conclusion

From this investigation and analysis, we can conclude that the establishment of line balancing has some obstacles needs good interaction and good relationship among operators, line supervisors, planning head, production manager and other community of the company's workers and skill of operators should be improved in training and other awareness in the company. But we can improve the production line with the application of control limit analyses based on the SMV of the operations. And in this paper, the researcher has conducted the line balancing using the control limit analysis and simulation modeling of the production lines. Generally; daily output has been increased from 1032 pieces to 1289 pieces. And labor productivity and machine productivity are increased from 46.9 and 54.32 to 58.59 and 71.61 respectively. And then finally, the profit that the line generated also increased from 22704 to 28358.

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Appendix
Appendix A:- Operations Sheet

Style: BOB *ITEM: T-SHERT*

Buyer: H&M *LINE NO: 7*

NO	Operation (tasks)	m/n type	No of m\n	No of labor	SMV (min)	Actual In day.
1	Shoulder attach one side	4T OL	1	1	0.349917	1391
2	Neck pipin attaching	4T OL	1	1	0.364	1318
3	Self-fabric attaches to shoulder	SNL	1	1	0.286	1678
4	V tack at front neck	SNL	1	1	0.325	1477
5	Front cover stitching	2T FL	1	1	0.364	1319
6	Shoulder joining 2nd side	4T OL	1	1	0.338	1420
7	Sleeve attaching	4T OL	2	2	0.663	1448
8	Back neck binding	SNL	1	1	0.325	1477
9	Trimming lable marking	------		1	0.325	1476
10	Pipin end tacking at back neck	SNL	1	1	0.299	2096
11	Back neck out line with lable	SNL	2	2	0.663	1448
12	Sleeve hemming	3T FL	2	2	0.676	1420
13	Side seam	4T FL	2	2	0.715	1343
14	Bottom hemming	3T FL	1	1	0.325	1477
15	Arm hole and neck tacking	SNL	2	2	0.494	1944
16	Thread trimming with stickers removing			2	0.91	1054
	Total		19	22	7.421	

Appendix B: - Cycle time and SMV

operation	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	Average	SMV	daily capacity
Shoulder attach one side	15	16	17	16.4	15	17.2	16.6	15.1	16.9	17.3	14.8	16.5	16.15	0.349917	1391
Neck pippin attaching	16.2	16.6	15.9	17.2	17.6	16.4	16.7	16.9	17.1	16.9	17.3	16.8	16.8	0.364	1318
Self-fabric attaches to shoulder	12.8	13.4	12.9	13.1	13.3	13.7	12.7	13.6	13.3	12.8	13.6	13.2	13.2	0.286	1678
V tack at front neck	14.6	15.2	14.8	15.4	15.1	14.9	15.3	15.6	14.7	14.4	14.9	15.1	15	0.325	1477
Front cover stitching	17.3	16.4	16.3	16.5	15.8	17.7	16.6	16.9	17.2	16.8	17.1	17	16.8	0.364	1319
Shoulder joining 2nd side	16.3	15.5	15.8	15.2	15.5	14.8	16.3	16.4	15.7	15.3	14.8	15.6	15.6	0.338	1420
Sleeve attaching	31.1	30.4	29.9	30.8	30.7	31.2	31.4	30.8	30.4	30.1	30.2	30.2	30.6	0.663	1448
Back neck binding	14.7	15.1	14.9	15.3	15.2	14.8	15.4	15.5	14.8	14.3	14.8	15.2	15	0.325	1477
Trimming label marking	14.8	15.2	15.2	15.1	14.2	14.9	15.1	14.7	14.9	15	15.3	15.6	15	0.325	1476
Pippin end tacking at back neck	13.6	13.9	13.2	14.1	13.9	14.3	14	13.5	13.4	14.2	13.8	13.7	13.8	0.299	2096
Back neck out line with label	31.2	30.3	29.9	30.7	31.3	30.6	31.5	30.9	30.4	30.2	30.3	29.9	30.6	0.663	1448
Sleeve hemming	31.1	31.3	30.9	31.6	31.4	31.2	30.8	31.2	30.9	31.6	31.1	31.3	31.2	0.676	1420
Side seam	33.2	33.6	32.4	32.8	33.3	32.7	32.9	33.1	33.2	32.9	33.4	32.5	33	0.715	1343
Bottom hemming	15.3	14.7	15.5	15.4	14.6	15.2	15.1	15.1	15.2	14.7	14.9	14.3	15	0.325	1477
Arm hole and neck tacking	22.2	22.4	22.6	22.6	23.2	23.4	22.1	22.3	23.5	23.7	22.9	22.7	22.8	0.494	1944
Thread trimming with stickers removing	42	42.3	42.4	41.6	42.2	41.8	41.3	41.7	41.6	42.9	42.7	41.5	42	0.91	1054
total														7.421917	

Appendix C: - Calculating of TML

no	*Tasks*	*SMV*	*Process Capacity*	*LINE Target*	*TML*	*Proposed Man labor*	*UCL*	*Pitch time*	*LCL*
1	*Shoulder attach…*	*0.349917*	*1376*	*1423*	*1.03*	*1*	*0.4819*	*0.3374*	*0.1929*
2	*Neck pipin…*	*0.364*	*1320*	*1423*	*1.08*	*1*	*0.4819*	*0.3374*	*0.1929*
3	*Self –fabric…*	*0.286*	*1680*	*1423*	*0.85*	*1*	*0.4819*	*0.3374*	*0.1929*
4	*V tack at…*	*0.325*	*1480*	*1423*	*0.96*	*1*	*0.4819*	*0.3374*	*00.1929*
5	*Front cover…*	*0.364*	*1320*	*1423*	*1.08*	*1*	*0.4819*	*0.3374*	*0.1929*
6	*Shoulder joining…*	*0.338*	*1424*	*1423*	*1*	*1*	*0.4819*	*0.3374*	*0.1929*
7	*Sleeve attaching*	*0.663*	*728*	*1423*	*1.96*	*2*	*0.4819*	*0.3374*	*0.1929*
8	*Back neck…*	*0.325*	*1476*	*1423*	*0.96*	*1*	*0.4819*	*0.3374*	*0.1929*
9	*Trimming lable…*	*0.325*	*1476*	*1423*	*0.96*	*1*	*0.4819*	*0.3374*	*0.1929*
10	*Pipin end…*	*0.299*	*1605*	*1423*	*0.9*	*1*	*0.4819*	*0.3374*	*0.1929*
11	*Back neck…*	*0.663*	*723*	*1423*	*1.97*	*2*	*0.4819*	*0.3374*	*0.1929*
12	*Sleeve hemming*	*0.676*	*710*	*1423*	*2.01*	*2*	*0.4819*	*0.3374*	*0.1929*
13	*Side seam*	*0.715*	*672*	*1423*	*2.12*	*2*	*0.4819*	*0.3374*	*0.1929*
14	*Bottom hemming*	*0.325*	*1477*	*1423*	*0.97*	*1*	*0.4819*	*0.3374*	*0.1929*
15	*Arm hole and …*	*0.494*	*972*	*1423*	*1.46*	*1*	*0.4819*	*0.3374*	*0.1929*
16	*Tread trimming…*	*0.91*	*528*	*1423*	*2.7*	*3*	*0.4819*	*0.3374*	*0.1929*
	Total	*7.421*				*22*			