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Research Article

Productivity Improvement through Line Balancing by Using Simulation Modeling (Case study Almeda Garment Factory)

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Abstract

The typical problems facing garment manufacturers are long production lead time, bottlenecking, and low productivity. The most critical phase of garment manufacturing is the sewing phase, as it generally involves a number of operations or for the simple reason that it's labor intensive. In assembly line balancing, allocation of jobs to machines is based on the objective of minimizing the workflow among the operators, reducing the throughput time as well as the work in progress and thus increasing the productivity. Sharing a job of work between several people is called division of labor. Division of labor should be balanced equally by ensuring the time spent at each station approximately the same. Each individual step in the assembly of product has to be analyzed carefully, and allocated to stations in a balanced way over the available workstations. Each operator then carries out operations properly and the work flow is synchronized. In a detailed work flow, synchronized line includes short distances between stations, low volume of work in process, precise of planning of production times, and predictable production quantity. This study deals with modeling of assembly line balancing by combining both manual line balancing techniques with computer simulation to find the optimal solution in the sewing line of Almeda textile plc so as to improve productivity. In this research arena software, is employed to model and measure the performance of the existing and proposed sewing line of the federal police trousers sewing line model. For each operation, the researchers have taken 15 sampling observations using stopwatch and recorded the result. All the collected data are statistically analyzed with arena input analyzer for statistical significance and determination of expressions to be used to the simulation modeling; SAM is also calculated for these operations to be used to the manual line balancing. An existing systems simulation model is developed and run for 160 replications by the researchers to measure the current performance of the system in terms of resource utilization, WIP, and waiting time. The existing systems average utilization is 0.53 with a line efficiency of 42%. This study has developed a new Sewing assembly line model which has increased the system utilization to 0.69 at a line efficiency of 58.42% without incurring additional cost.

Keywords: Line Balancing; Productivity; SAM; Simulation; Trouser; WIP

1. Introduction

Historically, many countries began their process of industrialization through focusing on labor-intensive industries, typically the textile industry. This industry was at the forefront of industries leading the Industrial Revolution in the United Kingdom from the mid-eighteenth to the mid-nineteenth centuries. Japan is another nation that exploited the labor-intensive nature of the textile industry to promote industrialization and the absorption of the country's abundant labor (fukishini & yamagata, 2014). The case is the same with our country Ethiopia; the industry have shown a great growth since the US preferential trade policy AGOA (the African Growth and Opportunity Act) was signed into law in 2000. It has provided garment Industries in sub-Saharan Africa with duty-free and quota-free access to the US market (otsuka & sonobe, 2011). Due to this many textile industries have been installed in the country to meet the extended demand of customers.

Nowadays, it becomes vital to maximize utilization of the resources, working efficiency of the employees, and are seeking various effective ways to improve their industrial productivity through minimization of wastes without hampering the product quality (Dr.Kesavan, Elanchezhain, & vijaya, 2008). The demand for higher value at lower price is increasing and to survive, garment manufacturers must need to improve their operations through producing right first time quality while reducing waste (Khan, 2013). Assembly line is an industrial arrangement of machines, equipment's and workers for continuous flow of work pieces in mass production operation. Manufacturing a product in an assembly line requires partitioning the total amount of work into a set of elementary operations called tasks (Breginski, Cleto, & Junior, 2013).

Therefore sewing process is of critical importance and needs to be planned more carefully. As a consequence, good line balancing with small stocks has to be drawn up to increase the efficiency and quality. So the aim of assembly line balancing in sewing line is to assign tasks to the workstations, so that the machines of the workstation can perform the assigned task with a balanced loading with different labor skill levels.

This research project will provide some suggestive remarks to the Almeda garment manufacturers about their

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industrial productivity improvement and cost reduction along with the implemented tools.

Out of the four sections of garment department of textile companies sewing section is mostly prone to various problems since most tasks are complex, labor intensive and are operated over extended (long) operations; some of the problems that are being faced in the aforementioned company are; Operators do not meet their standard target due to a large queue of pieces of cloths, Idleness of operators, and over stretched (too long) line since most operations which can be done by one operator and one machine are made to be done by adding another operator and machine which eventually causes an over stretched line.

2. Literature Review

Productivity is a measure of the efficiency and effectiveness to which organizational resources (inputs) are utilized for the creation of products or services (outputs) (Bheda, 2014) (Dr.Kesavan, Elanchezhain, & vijaya, 2008)**.** In readymade garments industry, output can be taken as the number of products manufactured, whilst input is the people, machinery and factory resources required to create those products within a given time frame. In fact, in an ideal situation, input should be controlled and minimized whilst output is maximized. Productivity can be expressed in many ways but mostly productivity is measured as labor productivity, machine productivity or value productivity (Sudarshan & Nageswara, 2014) (Khatun, 2016). In simple words productivity is the quantitative relationship between what we produce output and the resources inputs which are consumed (s.anilkumar & N.suresh, 2006). Productivity gains are vital to the economy; because they allow us to accomplish more with less. A garment production system is a way how fabric is being transformed into a garment in a manufacturing system. Production systems are named according to the various factors such as number of machine used to make a garment, machines layout, total number of operators involved to sew a complete garment and number of pieces moving in a line during making a garment. Among the various production systems progressive bundle system and one piece flow system are most commonly found in the readymade garments industries (Chen, Chen, Su, Wu, & Sun, 2012) (Bheda, 2014) (ashkan, hamid, & hesam, 2014.) (bobby & jenson, 2013) .

Facility layout is the most effective physical arrangement of machines, processing equipment and service departments to have maximum co-ordination and efficiency of man, machine and material in a plant (Syduzzaman & Golder, 2015) (Labour management in development , 2001). A good layout scheme would contribute to the overall efficiency of operations. Layouts can be classified into four classes such as product layout, process layout, group technology layout and fixed position layout (Chan, Hui, & Yeung, 1998). Among those product layout is mostly used in the garments industries like Almeda textile. In product layout machines are arranged according to the product manufacturing sequences. It is a layout in where workstations or departments are arranged in a linear path. This strategy is also known as line flow layout.

Design of the workstation layout widely vary from one operation to another depending on size of work, number of components to be worked on and type of machine to handle during operation. An efficient layout in plant could help to reduce the production cycles, work-in-progress, idle times, number of bottlenecks, material handling times and increase the productivity (Dwijayanti, 2010) (Chan, Hui, & Yeung, 1998)**.**

2.1 Productivity improvement Techniques

Higher productivity brings higher profit margin in a business. And increment in productivity level reduces garment manufacturing cost. Hence, factory can make more profit through productivity improvement. Machine productivity as well as labor productivity increases when a factory produces more pieces by the existing resources such as manpower, time and machinery. In garment sector productivity improvement is defined as the improvement of the production time and reduction of the wastage (Sudarshan & Nageswara, 2014).

2.1.1 Work measurement (Time Study)

Besides other sectors work study can also be used in garments sector which includes method study and work measurement. Time study is a work measurement technique for recording the times of performing a certain specific job or its elements carried out under specified conditions, and for analyzing the data to obtain the time necessary for an operator to carry it out at a defined rate of performance. Most common methods of work measurements are stopwatch time study, historical time study, predetermined motion time system (PMTS) and work sampling. Among these time study by stopwatch is considered to be one of the most widely used means of work measurement. Time study leads to the establishment of work standard. Development of time standard involves calculation of three times such as observed time (OT), normal time (NT) or basic time (BT) and standard time (ST).

Time study concept was originally proposed by Fredrick Taylor (1880) and was modified to include a performance rating adjustment. Time study helps a manufacturing company to understand its production, investigate the level of individual skill, planning and production control system etc (Kanawaty, 1992)**.** One problem of time study is the Hawthorne effect where it is found that employees change their behavior when they come to know that they are being measured (Farhatun, 2016)

2.1.2 Assembly Line Balancing

Line Balancing is leveling the workload across all processes in a value stream to remove bottlenecks and excess capacity (Saptari, Lai, & Salleh, 2011). The main objective of line balancing is to distribute the task evenly over the work station so that idle time of man or machine can be minimized (Kumar & Mahto, Productivity Improvement through Process Analysis for Optimizing Assembly Line in Packaging Industries, 2013). Assembly line may be classified as single model assembly line, mixed model assembly line and multi model assembly line (Amardeep & Gautham, 2013).

Assembly line balancing in Indian garment industries improved the productivity by decreasing the total equipment cost and number of work stations (Kumar & Mahto, 2013) (Amen, 2000). To meet the production target, maintaining level work flow in the line is very essential. Line balancing can be classified as initial line balancing, rebalancing, reactive balancing and late hour balancing (Breginski, Cleto, & Junior, 2013).

Line balancing is very effective technique in improving productivity; for example in Bangladeshi garment industry labor productivity was increased by 22% with the application of line balancing techniques (Shumon, Arif-Uz-Zaman, & Rahman, 2010).

2.1.3 Fishbone Analysis

The fishbone analysis is a tool to evaluate the business process and its effectiveness. It is defined as a fishbone because of its structural outlook and appearance (Mahto & Kumar, 2008) (Bose, 2012). Because of the function of the Fishbone diagram, it may be referred to as a cause-and-effect diagram. Fishbone diagram mainly represents a diagrammatic model of suggestive presentation for the correlations between an event (effect) and its multiple happening causes. A cause-and-effect diagram can help to identify the reasons why a process goes out of control and why it is not able to meet the standard. It helps to identify root causes and ensures a common understanding of the causes.

Root-cause identification for quality and productivity related problems are key issues for manufacturing processes. Tools that assist groups or individuals in identifying the root causes of problems are known as root-cause analysis tools. Every equipment failure happens for a number of reasons and root-cause Analysis is a systematic method that leads to the discovery of faults or root cause. A root-cause analysis (RCA) investigation traces the cause and effect trail from the end failure back to the root cause (Bon, Rahman, Bolhassan, & Nordin, 2013). Fishbone analysis was practiced to evaluate the supply chain and business process of a Hospital. The analysis reveals that the problem areas are lack of proper equipment, faulty process, misdirected people, poor materials management, improper environment, and inefficient overall management (BGMEA's Chittagong unit, 2009), (Bose, 2012). Application of fishbone analysis in garment industries is essential to identify various problem areas for productivity improvement.

2.1.4 Simulation Modeling

Simulation modeling is a common paradigm for analyzing complex systems. In a nutshell, this paradigm creates a simplified representation of a system under study. This simulation model then proceeds to experiment with the system, guided by a prescribed set of goals, such as improved system design, cost–benefit analysis, sensitivity to design parameters, and so on (davidKelton, 2006).

Modeling is the enterprise of devising a simplified representation of a complex system with the goal of providing and Predictions of the system's performance measures (metrics) of interest.

Modeling and simulation are potential tools for analyzing as well as studying sewing assembly lines in garment industries (Bahadir & senem, 2013).

3. Methodology

The methodology as shown in the figure below is to be followed to improve the operational performance of the production system.

3.1 Product Selection for the Study

Product selection is critical and crucial step as it provides focus to the project and produce tangible improvements in an effective manner. Trying to solve all problems at the same time creates confusion, inefficient use of resources and delays. Product selection refers to the process of identifying a "product" or "family" of similar products to be the target of an improvement project or study.

In our case we will be doing our project in federal police trouser since it is prone to problems due to the length and number of operations.

3.2 Time Study

Time study is a technique used to establish a time standard to perform a given assembly operation. It is based on the measuring the work content of the selected sewing assembly line, including any personal allowances and unavoidable delays. It is the primary step required to determine the opportunities that improve assembly operations and set production standards (s.anilkumar & N.suresh, 2006).

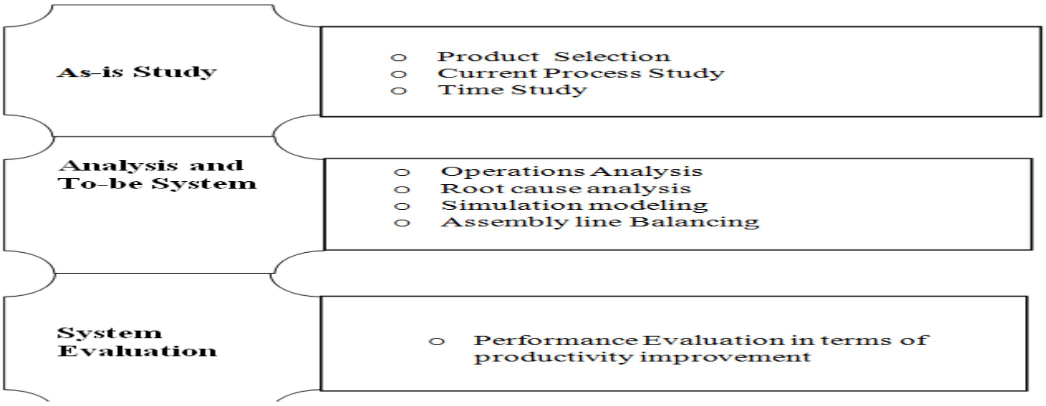

Fig. 1. Methodology chart for productivity improvement

Fig. 2. A sample of federal police trousers

3.3 Simulation modeling

For a successful completion of a simulation project it is a must to follow an established methodology or guide lines. This simple guide provides a basic framework for ensuring success with simulation projects.

Step 1: Develop the Functional Specification Document
Step 2: Identify and Collect Data
Step 3: Build the Model
Step 4: Document the model
Step5: Verification and Validation
Step 6: Analysis
Step 7: Project Deliverables

4. Data Collection and Analysis

Table 1
Estimated distributions for processes

No.	Operation name	Machine type	Operator number	M/C number	Expression
1	back patch press	IRON	1	1	TRIA(25.2, 27.9, 30)
2	mark bkpkt	table2	1	0	UNIF(19.3, 24)
3,4	back patch attach	S.N.L.S	2	2	UNIF(56, 59.7)
6	bk+pkt+flapatttach	APW	1	1	NORM(23.1, 0.745)
6T	pick trouser panel	table6	1	0	NORM(8.91, 0.38)
5,7,8	bkpkt+flap top s/t	S.N.L.S	3	3	NORM(155, 1.15)
9	back pkt bag close	5 TH	1	1	TRIA(50, 52.3, 53)
10	sew back rise	MH-380	1	1	NORM(52.2, 0.562)
11A	back flap BH	BH	1	1	28 + GAMM(0.759, 2.39)
11B	thigh flap B.H	BH	1	1	NORM(33.5, 0.949)
12	back pkt flap inner s/t	S.N.L.S	1	1	44.3 + 4.75 * BETA(1.37, 1.29)
13	thigh pkt flap inner s/t	S.N.L.S	1	1	37 + 5 * BETA(1.21, 0.994)
12T	turn bkpkt flap	table12	1	0	29 + 5 * BETA(1.26, 1.49)
13T	turn thigh pkt flap	table13	1	0	27 + 5 * BETA(1.16, 1.19)
14	top s/t bkpkt flap	S.N.L.S	1	1	34 + 3.69 * BETA(1.36, 1.72)
15	top s/t thigh pkt flap	S.N.L.S	1	1	UNIF(37.2, 40)
16	thigh pkt 2carego edge s/t&tuck	S.N.L.S	1	1	79 + 12 * BETA(0.676, 0.732)
17	top s/t 2care go	S.N.L.S	1	1	66.1 + 9.92 * BETA(1.28, 0.991)
18	att.thighpkt facing edge s/t	S.N.L.S	1	1	54.1 + WEIB(2.61, 1.79)
19	att. Thigh pkt facing	S.N.L.S	1	1	44.2 + WEIB(2.15, 1.66)
20	top s/t&3rd carego	S.N.L.S	1	1	TRIA(79, 83.7, 89)
21	thigh pkt edge press	IRON	1	1	50.3 + WEIB(2.91, 2.18)
22	fly o/l	3 TH	1	1	NORM(23.3, 0.61)
23	front rise	3TH	1	1	29.4 + 6.58 * BETA(1.16, 1.55)

24	knee patch press	IRON	1	1	TRIA(16.8, 17.8, 19)
25,26	knee patch attach	D.N.L.S	2	2	TRIA(44.5, 47.2, 49.8)
27	tuck front knee patch	S.N.L.S	1	1	26.2 + ERLA(0.537, 4)
28	side pktatt.&top s/t	S.N.L.S	1	1	TRIA(77, 79.1, 84)
29	outer side pkt top s/t	S.N.L.S	1	1	69.1 + ERLA(1.09, 4)
30	side pkt bag close	5 TH	1	1	TRIA(38, 41.4, 44)
31	buttone hole left fly	BH	1	1	NORM(129, 3.06)
32	side pkt side tuck	S.N.L.S	1	1	NORM(56.5, 0.613)
33	att.&top s/t left fly	S.N.L.S	1	1	141 + 10 * BETA(1.13, 1.63)
34	tuck left fly+J-s/t	S.N.L.S	1	1	45 + 4 * BETA(1.74, 1.17)
35	att.&top s/t righ fly	S.N.L.S	1	1	TRIA(104, 110, 117)
36	front rise attach	D.N.L.S	1	1	TRIA(48, 50.3, 52.5)
37,38T	machnumberig	table 37,38	2	0	NORM(32.8, 0.842)
37,38	sew side seam	5 TH	2	2	NORM(88.1, 0.665)
39,40	top s/t sew side seam	F.O.A	2	2	85 + ERLA(0.589, 2)
39,40T	mark thigh pktpostion	table 39,40	2	0	TRIA(45, 46.3, 47.5)
40,39T	match thigh pkt flaps	table 40,39	2	0	27 + 2.4 * BETA(0.794, 1.06)
41,42,44	thigh pkt attach	S.N.L.S	3	3	126 + 3.44 * BETA(1.03, 1.29)
43	flap attach	D.N.L.S	1	1	53 + LOGN(0.548, 0.292)
45	close inseam	5 TH	1	1	TRIA(45.6, 46.9, 48.3)
46	In seam top s/t	F.O.A	1	1	TRIA(42.5, 44, 45.5)
55BLM	belt loop mak&cut	BLM	1	1	NORM(26.6, 0.508)
47,48	mark belt loops tuck	S.N.L.S	2	2	NORM(59.3, 0.659)
48 F	wast band press	fusing m/c	1	1	28 + GAMM(0.503, 4.34)
49,50	w.band attach	S.N.L.S	2	2	NORM(56.5, 0.53)
51,52	w.band edge s/t	S.N.L.S	2	2	NORM(68.9, 0.714)
53,54	w.band close & label	S.N.L.S	2	2	TRIA(70.2, 71.1, 72)
56,57	belt loop lower tuck	S.N.L.S	2	2	73.7 + LOGN(0.975, 0.699)
58	button hole	BH	1	1	NORM(38.9, 0.777)
58T	insert ropes	table 58	1	0	TRIA(27, 29.1, 31)
59,60	bottom hem	S.N.L.S	2	2	62.5 + WEIB(1.75, 2.44)
61T	mark butten set postion	table 61	1	0	TRIA(23, 24.5, 25.6)
61	button attach	BA	1	1	TRIA(73, 75.7, 77)
62,63,64	bar tuck	BT	3	3	TRIA(157, 160, 161)
65	trimming	table 65	6	0	273 + LOGN(1.73, 1.27)
66	inspection	table66	2	0	TRIA(57.1, 60.1, 61)
67	ironing	big IRON	2	2	TRIA(17.2, 18.6, 20)
68	folding + packaging	table 68	3	0	57 + WEIB(1.19, 1.94)

5. Development of Simulation Model for the Existing Production System

As mentioned in our methodology, the study of the as is system or just the existing system involves simulation modeling using arena software. The aim of developing the model for the existing system is for bottleneck identification and further experimentation using various scenarios. The construction of the model is based on a production process flow of the company's sewing line. This study represents discrete-event modeling and the sewing line works for 450 minutes (7.5 hours) in a day. The following assumptions are taken in to consideration while modeling the system;

- At the beginning of each order, the production line is assumed to begin empty,
- There is no maintenance process performed during the working period,
- 450 minutes working time does not include breaks,
- Set-up times are not taken into consideration while modeling the system, because in a real system the setup process is usually carried out at the end of the working time,
- The trousers assembly line is never lacking input materials from cutting section.
- Transportation of raw materials (bundle man/woman) is performed by workers who aren't used for sewing operations.

In this study, among other products in the sewing section the case under consideration is the production of federal police trousers (line 29 30). The production of federal police trousers (line 29 30) consists of a total of 88 operators. The line works for 7.5 hrs per shift. To model and run the simulation model, the seven phase procedures outlined in the methodology of the study have been used.

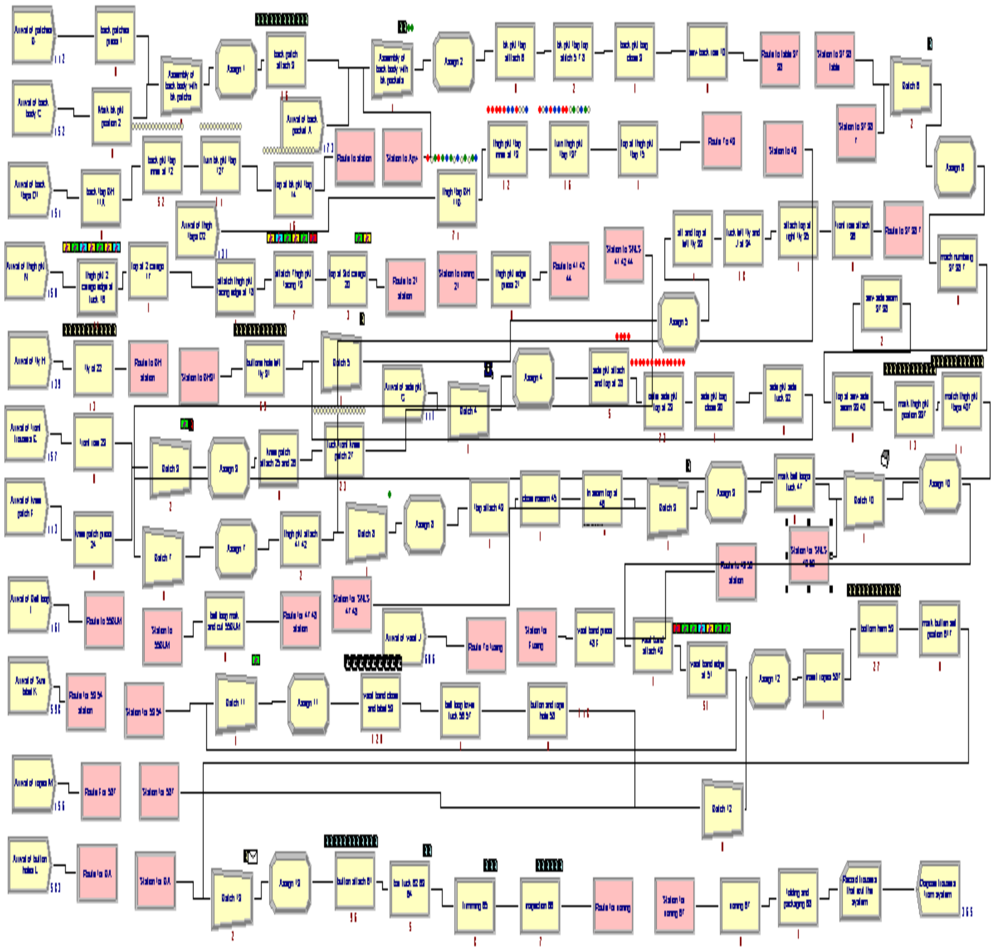

Fig. 3. Simulation model of the existing production system

5.1 Model validation and verification

A model is simplified representation of a real system which includes the most important system components and the interaction between them, a model should represent the real system a model cannot represent the real system exactly rather it can approximate the system how it behaves and interact. This is mainly due to the assumptions made while developing the model. The performance measures extracted from a model will only represent the real system if the model is a good representation of the system. So Verification and validation of the simulation model of this study were carried out using the daily production statistic validity by comparing

The actual system and the simulation model results for the existing federal police trousers model. We made simulation trial runs under a variety of settings of the run parameters, and checked the model output result for its appropriateness. We have taken the real (actual) data (i.e. the plant produces 364 per shift on average) from the production line. The simulation model output is tested to run for 7.5 hrs and its output is 365which is almost the same with that of actual data and this is a clear indication that the model is valid (w.davidkelton & p.sadowski, 2000). In addition to this some work stations which are found to be idle in the actual system were having lower utilization in the simulation model.

5.2 Model verification

One way for verification is by reviewing the SIMAN code and check if the model is performing exactly what was planned for it to do. But, this way of verification requires a skill in the SIMAN programming language. So the best way for us to verify the model is by looking at the animation. In this verification method it's allowed only a single entity to enter the system and follow that entity to be sure that the model logic and data are correct. In this simulation model, allowing only a single entity to go through the system has shown that the entity is going through every module as per programmed.

5.3 Simulation Run Results and Interpretation

Although, there are many possibilities to manipulate the developed simulation model, this study has addressed two major options. Since the objective of this thesis is to model the sewing assembly line and balance the activities that assemble the trousers in the sewing line; we have identified the bottleneck and idle operations for further analysis so as to balance the sewing line. A bottleneck is

one process in the chain of processes, such that its limited capacity reduces the
capacity of the whole assembly process or simply the output of the system is determined by this process; we have identified some variations in process capacity from the benchmark target and the lower capacity from the benchmark target is the bottleneck process; as production flow would stuck on the bottleneck point; Whereas those which work under capacity are termed as idle processes. Total production has been blocked in these seven work stations and large WIP has been stuck in these bottleneck processes. The bottlenecks of the existing system are summarized as follows;

Table 2
Bottleneck operations in the existing production system

R-no;	Operations	Numbers waiting (Items)
1	Button Hole left fly 31	151
2	Attach & top stitch left fly 33	44.5
3	thigh flap B.H 11B	62.5
4	Button attach 61	75.4
5	back flap B.H 11A	98.4
6	Thigh pkt 2 cargo edge stitch & tuck 16	134
7	Side pkt attach & top stitch 28	91.2

From the study of the existing simulation model we have found out the idle and bottleneck stations. This will be the input for carrying out line balancing calculations in the next sections, but before proceeding to that let's see the possible root causes of variation between the actual and target output of the sewing line.

5.4. Root causes of variation between the actual and target output of the sewing line

A cause-and-effect diagram can help to identify the reasons why a process goes out of control. It helps to identify root causes and ensures a common understanding of the causes (Bose, 2012). We have interviewed the production managers of the garment section, operators, quality assurance manager, planning manager, and supervisors of the lines in the production line and discussed about the causes and the effects of why the company did not meet the planned output; or in other words the causes of high variation between actual output and target output. In this study, we have summarized the main causes as follows in the root cause analysis diagram.

Table 3
The idle stations of the existing production system

R-no;	Operations	Instantaneous Utilization
1	Fly O/l 22	0.3666
2	Ironing 67	0.3775
3	mark button set position 61T	0.3673
4	Match numbering 37, 38T	0.1725
5	mark thigh pkt postion39, 40T	0.2921
6	Pick trouser panel 6T	0.1344
7	Knee patch press 24	0.2820
8	trimming 65	0.5861
9	Back pktflap attach 6 (APW)	0.3487
10	knee patch attach 25 26	0.3706
11	w.band attach 49 50	0.4183
12	mark belt loops tuck 47 48	0.4143
13	mark bkpkt table 2	0.3409
14	Inspection table 66A	0.3788
15	Inspection table 66B	0.3768
16	insert ropes table 58	0.4510
17	turn thigh pkt flap table 12	0.4303
18	turn bkpkt flap table 13	0.4149
19	bottom hemS.N.L.S 59 60	0.4966
20	w.bandattachS.N.L.S 49 50	0.4183
21	back patch attachS.N.L.S 3	0.4541
22	belt loop mak&cutBLM55	0.4180
23	top s/t sew side seamFOA 39	0.4511
24	top s/t sew side seamFOA 40	0.4503
25	wast band pressFusing machine 1	0.4740
26	top s/t bkpktflapS.N.L.S 14	0.4890
27	tuck front knee patchS.N.L.S 27	0.4451
28	tuck left fly+J-s/tS.N.L.S 34	0.3021
29	back patch attachS.N.L.S 4	0.4541
30	thigh pkt attach S.N.L.S 41	0.4520
31	thigh pkt attach S.N.L.S 42	0.4529
32	thigh pkt attach S.N.L.S 44	0.4497

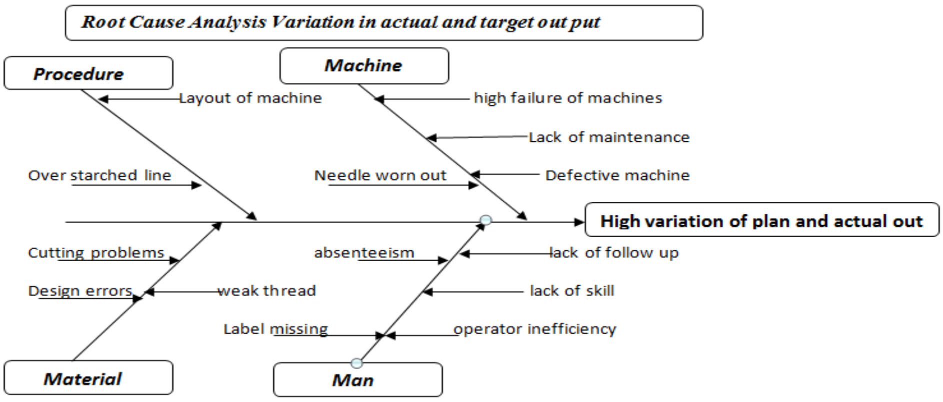

Fig. 4. Root cause analysis for variation between actual and target output

6. Balancing of the Sewing Assembly Line

In line balancing of operations, the optimum calculating method of the workstation number and the minimum calculating procedure of the cycle time are studied by using the concept of unbalanced time. These calculating methods are then applied to a sewing process in practical clothes making (Nakajima, Uchiyama, & Yoshito Miura, 1980) (Patrick & Frency, 1999).

Balancing method is very essential to make the production flow smoother compare to the previous layout. Considering working distance, type of machines and efficiency, workers who have extra time to work after completing their works, have been made to share their work to complete the bottleneck processes; in some cases we have also merged some underutilized (idle) operations based on the desired cycle time. Before balancing the line, in appendix, time study sheet is attached showing the different types of machine used, number of operators and helpers, basic and SPT and cycle time. Process wise capacity of each work station has been shown in Appendix where SAM has been calculated by adding SPT of each process. We have done the line balancing calculations as follows;

Desired cycle time= 1/ output rate

Cycle time= 7.5hrs*60min/382

Cycle time=1.18min/piece

Theoretical Minimum(TM)= a bench mark or goal for the smallest number of station possible;

$$TM = \frac{SAM}{C} = \frac{49.25}{1.18} = 41.737 = 42$$

There for the researchers needed at minimum 42 work stations.

Now let's see how operations are balanced by accessing various alternatives in the sewing line;

Alternative 1

In order to determine bottlenecks and idle stations in the reference layout model; a number of the existing system's machine utilization, waiting time of jobs, average output, number busy, number waiting etc..as well as desired cycle time were taken into account. It was observed that process 31,33 11B, 61, 11A 16,28 are busy and process 22, 67,61T, (37 38T),(39,40T), 6T, 24, 65,6,(25 26), 12T, (49 50), (47 48) e.t.c are idle. By this way, we have developed the first Alternative by merging, decreasing capacity, and adding of machines in order to overcome the processes problems. The result of this alternative was obtained by running the simulation model for 160 numbers of replications. The following table summarizes results based on alternative 1, when six extra machines with their operator are added to the busy operations and when idle operations are merged, in the reference model.

Table 4
Performance measures of alternative 1

R no:	Performance measures	Value
1	The standard deviation for average number of jobs waiting in queues (WIP)	21.8
2	Average daily output/shift	364
3	Average Resource utilization	0.6545
4	Total number of machines the line requires	62
5	Total number of operators the line requires	75
6	Number of newly added machines	6
7	Number of newly added operators	6
8	Standard minute value (SMV)	47.25
9	Labor productivity	4.85
10	Machine productivity	5.87

Alternative 2

Taking in to account all the conditions of the existing (reference) model we have developed the second alternative by merging, decreasing capacity, and by letting operators work over time instead of adding machine in order to overcome the processes problems. The result of this Alternative was obtained by running the simulation model for 160 numbers of replications. The sewing line works 2 shifts a day 7.5 hrs each; so the only suitable time to schedule for over time is in the lunch hours between 11:00 am to 11:30 am. So, only 30 minutes of working hour is to be added to the existing system schedule for those operations which are busy.

Table 5
Performance measures of alternative

Rno:	Performance measures	Value
1	The standard deviation for average number of jobs waiting in queues (WIP)	28.14
2	Average daily output/shift	379
3	Average Resource utilization	0.653
4	Total number of machines the line requires	57
5	Total number of operators the line requires	70
6	Number of newly added machines	0
7	Number of newly added operators	Over time for 30min (8)
8	SMV	50.71
9	Labor productivity	5.34
10	Machine productivity	5.97

Alternative 3

Taking in to account all the conditions of the existing (reference) model we have developed the third alternative by sharing of operational time between idle and busy operations as well as merging of idle operations in order to overcome the processes problem. The result of this alternative was obtained by running the simulation model for 160 numbers of replications.
With this alternative we have accessed the existing system problems with the available machines and man power. So with this concept of sharing and merging of idle and busy operations the average output of the system is 364 per shift. Moreover, other performance measures were also considered, as a result it was also observed that average utilization of machines is increased; besides the average staying of jobs (WIP) in queues is also decreased. In reference to the existing production system the performance measures of alternative 3 are summarized in the following table;

Table 6
Performance measures of alternative 3

R.no;	Performance measures	Value
1	The standard deviation for average number of jobs waiting in queues (WIP)	25.34
2	Average daily output/shift	364
3	Average Resource utilization	0.663
4	Total number of machines the line requires	56
5	Total number of operators the line requires	69
6	Number of newly added machines	0
7	Number of newly added operators	0
8	SMV	52.7
9	Labor productivity	5.28
10	Machine productivity	6.5

Alternative 4

Taking in to account all the conditions of the existing (reference) model; we have developed the fourth alternative by combining the above three alternatives. In this alternative, things like; sharing of operational time between idle and busy Operations, merging of idle operations or capacity decreasing, adding of operators working hours by means of over time were used in order to overcome the processes problem. The result of this alternative was obtained by running the simulation model for 160 numbers of replication.
Having seen the performance measures of the four line balancing alternatives, we can select the one which is best and which can be applied in the sewing line of the existing garment section sewing line system. But before the selection process we must identify the performance measures which can clearly tell us how much a line is balanced. A well balanced line is characterized by a balanced distribution of jobs across the assembly line, efficient resource utilization and higher output. So the

performance measures of the four alternatives are summed up in the table that follows for further comparison;

Table 7
Performance measures of alternative 4

R.no:	Performance measures	Value
1	The standard deviation for average number of jobs waiting in queues (WIP)	21.6992
2	Average daily output/shift(7.5hrs)	379
3	Average Resource utilization	0.69
4	Total number of machines the line requires	59
5	Total number of operators the line requires	72
6	Number of newly added machines	3
7	Number of newly added operators	3
8	SMV	49.25
9	Labor productivity	5.26
10	Machine productivity	6.42

Table 8
comparison of all alternatives in terms of various performance measures

Rno;	Performance measures	Alternative 1	Alternative 2	Alternative 3	Alternative 4
1	Average Resource utilization	0.6545	0.653	0.663	0.69
2	The standard deviation for average number of jobs waiting in queues (WIP)	21.8 0	28.140	25.34	21.6992
3	Average daily output/shift (7.5hrs)	364	379	364	379

Here, in the above table we can see that the fourth alternative is to way better than the rest of three alternatives in terms of these performance measures, therefore this fourth alternative model will be applied in the line balancing of the existing sewing line. The four alternatives of line balancing models are developed similarly, but here we have only shown their performance measures for the sake of comparison. So it will be necessary to show all the steps for the selected alternative model; so that readers can have a clear picture of what the model development will be like. Now let's see how this model is developed step by step;

7. Development of the Proposed Model

(Alternative 4)

The Proposed model is built after the analysis of existing model's performance. During the analysis, the bottlenecks and idle stations were identified. The bottlenecks are identified based on waiting time and numbers waiting in queue; whereas the idle stations are identified based on resource utilization. In the development of the proposed model the first thing to be done is to balance the line manually using the time study at hand and then interpret it to simulation model. To balance a line manually there are various techniques we use like, sharing of operational time between idle and busy operations, merging of idle operations, capacity decreasing, adding of machines and of operators. Now let's see how the line is balanced by combining these various techniques.

Sharing of operational time between idle and busy operations;

The following table summarizes the line balancing of processes done by sharing of smv between idle and busy operations; keep in mind that for operations to share operational time they must use the same resource.

Table 9
Balanced operating time (SMV/ piece) by sharing

R.no;		Idle operations			Bottleneck operations		
		Process code	SMV	Balanced Time	Process code	SMV	Balanced Time
1		14	0.59	1	16	1.41	1
	Remark: Process#14 can work 0.59 min and share work with process#16 for the last 0.41 min						
2		15	0.64	0.92	17	1.19	0.92
	Remark: Process#15 can work 0.64 min & share work with process#17 for the last 0.27 min						
3		19	0.77	1.09	20	1.4	1.09
	Remark: Process#19 can work 0.77 min & share work with process#20 for the last 0.31 min						
4		27	0.47	0.9	28	1.33	0.9
	Remark: Process#27 can work 0.47 min & share work with process#28 for the last 0.43 min						

The researchers have shown how idle and busy operations can be balanced by sharing of smv time now let's see how to balance a line by merging of operations.

Merging of operations;

Process3,4 (Eliminate one process) This operation is done by 2 operators who use the same machine (SNLS) with 0.48 min smv, but we can see that they are to way idle since the cycle time is 1.18min. so we can merge these operations to be done by one operator and one machine by removing operator 4 along with SNLS4.
So the new SMV= 2*0.48
SMV=0.96min/piece

Process 65A,65B,65C,65D,65E&65F:

This operation is done by 6 operators who use the same resource (table) with 0.76 min SMV, but we can see that they are to way idle since the cycle time is 1.18min. so we can
Remove one operator, so that it will done by 5 operators and 5 table by removing operator 65F along with table 65F.
So the new SMV is 6*0.76/5
SMV= 0.9 min/piece
Process 6,6T (Merge): These 6, 6T are side by side (near) operations where back pkt flap attach and picking of trousers panel are done with SMV 0.39 and 0.15 respectively. So since both are working under capacity, we can remove 6T and let the work be done by operator 6.
So the new SMV= 0.39+0.15
SMV=0.54min/piece
The rest of the processes are balanced using the same techniques; either by decreasing machine (eliminating process) or merging of operations.
Now we will be developing computer simulation model for the purpose of experimentation with the system. It will be developed based on the findings of the manual line balancing which were carried out in the above sections. So before Proceeding to the development of the proposed simulation model, we must specify how the line balancing techniques are correlated with arena simulation.

Table 10
Relating manual line balancing technique to simulation model

Manual line balancing Technique	In simulation model
1.Sharing of work from idle to busy operations	1.adding time to standard time ST of busy operation from idle
2.merging different operation have similar M/C	2.in each process module use similar resource
3.merging one or more similar process having similar M/C	3.Decrease capacity in the process module

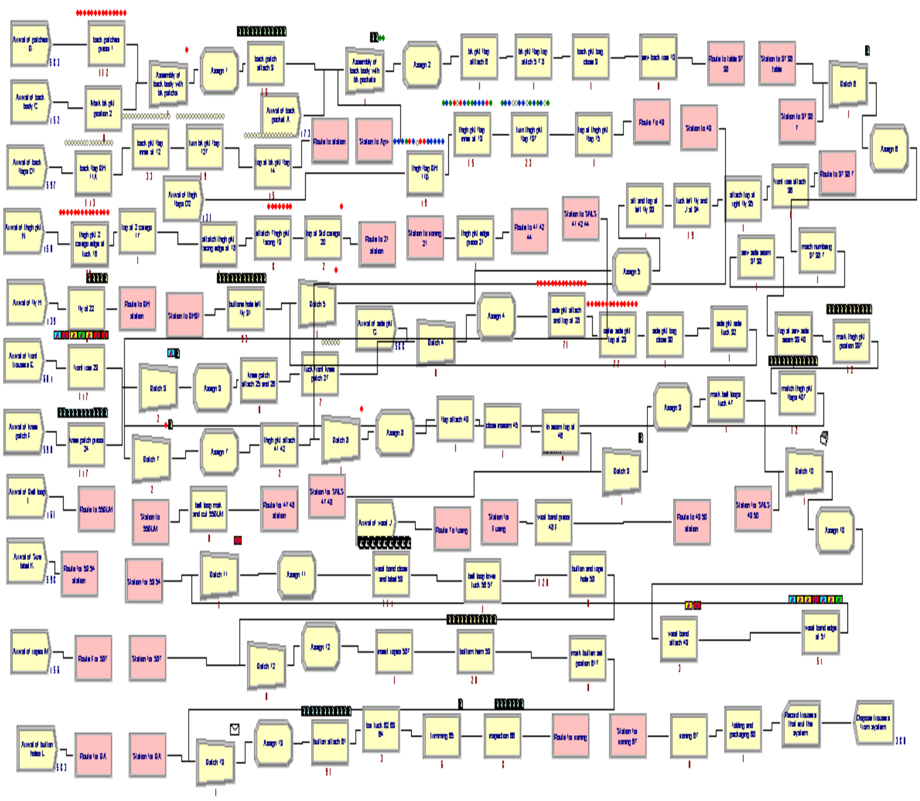

Fig. 5. The newly developed simulation model of the Assembly line

7.1 Proposed Simulation model run results and interpretation

The aim of this proposed simulation is to show the improved sewing line layout and balancing activities that assemble the federal police trousers parts and analyze their performance. Therefore, to alleviate the problems the proposed simulation model for the line balancing of Federal police trousers production, provides the planning manager with a simulation based optimization tool that helps to gain information without disturbing the actual system, and improve system Performance to increase productivity of the company.

From this generated output of the proposed simulation model it can be clearly seen that the utilization of resources like SNLS 3, SNLS 41 42, SNLS 27, 12T, 37T, 39T and other resources which were idle (underutilized) in the existing system have dramatically increased

7.2 Layout of the existing and proposed model

The layout model of the existing assembly line is too long having a length 42. 7 meter, but according to the company's building layout one sewing line of garment section can only be extended up to 36.5meters to the maximum. For this reason operations such as mark button set position (table61),button attach (61), bar tuck (62,63,64), trimming and inspection are transferred to the next line code named 29 which is 6.2 meter length to complete the assembly process.

Calculation of length for the new assembly line layout;

One work station has 0.9meter length, the gap between subassembly lines is 1.5 meters, trimming table 2 meter and inspection table 1.5 meter; this is according to the case company actual workstation space and machineries measurement. The researchers have minimized 8 machines and 2 tables; total of 10 work stations. Therefore we have minimized; 10*0.9=9 meter, then the proposed line length = existing line length (42.7meter)-minimized length (9meter) =33.7meter. Unlike the existing assembly line the new assembly line will stretch over a one straight 33.7meter line.

Comparison of the existing and proposed model in terms of various performance measures

Table 11
Comparison of the existing and proposed Sewing assembly line

Rno:	Performance measures	Existing Simulation model	Proposed Simulation model
1	The standard deviation for average number of jobs waiting in queues (WIP)	29.98	21.7
2	Average daily output/shift(7.5hrs)	364 trousers	379 trousers
3	Average Resource utilization	0.53	0.69
4	Total number of machines	66	59
5	Total number of operators	88	72
6	Labor productivity	4.14	5.26
7	Machine productivity	5.52	6.42
8	Line Efficiency	42%	58.42%
9	Line length	42.7m	33.7m

8. Conclusion

This study addresses the development of a line balancing model for assembly line-balancing problem; in order to improve the line balance of federal police trouser's sewing line. Initially a simulation model was developed for the existing system since it's essential to know the current situation of a system. Based on the results of the existing simulation modeling; Button Hole left fly 31, Attach & top stitch left fly 33, thigh flap B.H 11B, Button attach 61, back flap B.H 11A, Thigh pkt 2 cargo edge stitch & tuck 16, Side pkt attach & top stitch 28 were found to be bottleneck (busy) operations and Fly O/l 22, Ironing 67, mark button set position 61T, Match numbering 37 38T, mark thigh pkt postion39 40T, Pick trouser panel 6T, Knee patch press 24, tuck front knee patch S.N.L.S 27, Inspection table 66A, Inspection table 66B, tuck left fly+J-s/t S.N.L.S 34, mark bkpkt table 2 idle operations. Therefore, to alleviate the problems the proposed model for the trousers sewing line was developed by combining both manual line balancing techniques with computer simulation model. Four alternatives were developed and compared with the performance of the existing system as well as with each other using various performance measures and the fourth alternatives were found to be optimal. The proposed line balancing model has decreased the number of operators from 88 to 72, the number of machines from 66 to 59 at the same time the daily output per shift is increased from 365 to 379 trousers per line. The performance comparison demonstrates that the proposed line balancing model out performs the industry practice; by increasing the assembly line efficiency from 42% to 58.42% without incurring additional costs for machines and operators. Finally this line balancing model can be applied to the federal police trousers sewing lines and save 40284 birr which were allocated to machines and 20800birr which were allocated to the wages of operators over monthly bases.

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