Study and Implementation of Lean Manufacturing in a Garment Manufacturing Company: Bangladesh Perspective

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Abstract

Lean manufacturing is a systematic approach to identifying and eliminating wastes (non-value added activities) through continuous improvement by conveying the product at the pull of the customer in pursuit of production. In a more basic term, more value with less work. Since lean manufacturing eliminates many of the problems associated with poor production scheduling and line balancing, lean manufacturing is particularly appropriate for companies that do not have ERP systems in place or do not have strong material requirements planning (MRP), production scheduling, or production allocation systems in place. This is particularly significant in Bangladesh, where many private Bangladeshi garment manufacturing companies are operating significantly below their potential capacity, or experiencing a high level of late-deliveries, due to problems with their current production scheduling and production management systems. Considering all those facts this paper provides a roadmap as well as a framework to those manufacturing companies who are really operating significantly below their potential capacity. In this work, the existing layouts were studied and then layouts are proposed to enhance the production system and value stream mapping (VSM) is used as a basic lean manufacturing tool and some cellular manufacturing philosophies to find out the improved level of performance and productivity particularly in the garments section of Bangladesh. At the final stage, research work is reinforced by using a simulation software ARENA to judge the sustainability of proposal.

Keywords: Lean Manufacturing; Cellular Manufacturing; Value Stream Mapping; Productivity.

1. Introduction

Lean is a term to describe a system that produces what the customer wants, when they want it, with minimum waste - it is based on the Toyota production system. Lean thinking focuses on value-added lean and consists of best practices, tools and techniques from throughout industry with the aims of reducing waste and maximizing the flow and efficiency of the overall system to achieve the ultimate customer satisfaction. Lean manufacturing is a manufacturing philosophy that shortens the time between the customer order and the product build/shipment by eliminating sources of waste. Another way of looking at lean is that it aims to achieve the same output with less input- less time, less space, less human effort, less machinery, less material, less costs (Nahmias [17]). Japanese manufacturers' re-building after the Second World War was facing declining human, material and financial resources. The problems they faced in manufacturing were vastly different from their Western counterparts. These circumstances led to the development of new and lower cost manufacturing practices. Early Japanese leaders such as the Toyota Motor Company's Eiji Toyoda, Taiichi Ohno and Shigeo Shingo developed a disciplined, process-focused production system now known as the "Toyota Production System" (Monden [16]), or "Lean Production". The objective of this system was to minimize the consumption of resources that added no value to a product. When a U.S. equipment manufacturing company, Lantech, completed the implementation of lean in 1995, they reported the following improvements compared to their batch-based system in 1991: manufacturing space per machine was reduced by 45%, defects were reduced by 90%, production cycle time was reduced from 16 weeks to 14 hours-5days; and product delivery lead time was reduced from 4-20 weeks to 1-4 weeks.

Waste is anything that does not contribute to transforming a part to the customers needs. The aim of lean manufacturing is the elimination of waste in every area of production including customer relations, product design, supplier networks, and factory management. Its goal is to incorporate less human effort, less inventory, less time to

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develop products, and less space to become highly responsive to customer demand while producing top quality products in the most efficient and economical manner possible (Nakajima [18]). Essentially, a "waste" is anything that the customer is not willing to pay for. Originally seven main kinds of wastes such as transporting, overproducing, waiting, defects, unnecessary motion, inappropriate processing and unnecessary inventory (Taiichi Ohno's seven categories of waste) were identified as part of the Toyota Production System. On the other hand, applications of lean manufacturing in the continuous process sector have been far fewer (Abdullah and Rajgopal, [2]). It has sometimes been argued that in part, this is because such industries are inherently more efficient and have a relatively less urgent need for major improvement activities. Managers have also been hesitant to adopt lean manufacturing tools and techniques to the continuous sector because of other characteristics that are typical in this sector. These include large, inflexible machines, long setup times, and the general difficulty in producing in small batches. While some lean manufacturing tools might indeed be difficult to adapt to the continuous sector this does not mean that the approach is completely inapplicable; for example, Ahmad et al. [5], Melton [14], Radnor [20], Cook and Rogowski [7], and Billesbach [6]. Abdullah et al. [3] and Abdelmalek et al. [1] examined aspects of continuous production that are amenable to lean techniques and presented a classification scheme to guide lean implementation in this sector. Abdulmalek and Rajgopal [4] describe a case where lean principles were adapted for the process sector for application at a large integrated steel mill. Mo [15] implements lean manufacturing principles in small furniture company and achieved 30% increase in productivity. Yang et al. [22] explores relationships between lean manufacturing practices, environmental management (e.g., environmental management practices and environmental performance) and business performance outcomes (e.g., market and financial performance). Pool et al. [19] implements lean principles in a semi-process industry for (i) Cyclic schedules fit in a lean improvement approach for the semi-process industry, (ii) Cyclic schedules help to improve production quality and supply-chain coordination and (iii) Discrete event simulation is a useful tool in facilitating a participative design of a cyclic schedule.

Ljungberg [11] applies TPM activities and measures overall equipment efficiency. Detty and Yingling [8] quantify benefits of applying lean manufacturing. Marek et al. [12] describes Kanban and CONWIP pull systems and simulates systems. Feld [9] describes lean manufacturing principles and how to apply them.

Case study from a large integrated garments manufacturer is used here to illustrate the approach followed. In this approach, value stream mapping (VSM) is first used to map the current operating state for VG. This map is used to identify sources of waste and identify lean tools for reducing the waste. A future state map is then developed for the system with lean tools applied to it. Since the implementation of the recommendations is likely to be both expensive and time-consuming, a simulation model is developed for the managers at VG in order to quantify the benefits gained from using lean tools and techniques.

2. Process Background

Lean is most widely used in industries that are assembly oriented or have a high amount of repetitive human processes. These are typically industries for which productivity is highly influenced by the efficiency and attention to detail of the people who are working manually with tools or operating equipments. For these kinds of companies, improved systems can eliminate significant levels of waste or inefficiency. Examples of these include wood processing, garment manufacturing, automobile assembly, electronics assembly and equipment manufacturing. The study is concentrated on the finishing department of the company. It is observed that the floor condition was not good and in a haphazard situation. There were lots of in process inventories between almost every sequential operation. As a result it could not cover the daily production of the sewing department. Its output was quite less than the sewing. So there is a huge in process inventory in between. No strict and precise work distribution was followed by many workers. Materials used to travel large distance from input receiving to cartooning. Many of these movements and handlings are totally unnecessary. As a result, the productivity was hampered. It is also observed that, iron men often are not accused of their wrong ironing; the line supervisors are not strict enough to control the quality right at the first time. So lots of reworks are there and the total completion time is delayed and the proportion of non–value added time is increased. Sometimes there are delays than the buyer's required dates. So, the company has to pay significant amount of compensations for delayed shipment. This situation is very horrible and must not likely to occur. So, a smooth, streamlined and continuous flow is really necessary to avoid all such unexpected occurrence.

2.1. Cellular Manufacturing System (CMS)

Cellular Manufacturing is a model for workplace design, and is an integral part of lean manufacturing systems. The goal of lean manufacturing is the aggressive minimization of waste, called *muda*, to achieve maximum efficiency of resources. Cellular manufacturing, sometimes called cellular or cell production, arranges factory floor labor into semi-autonomous and multi-skilled teams, or work cells, who manufacture complete products or complex components. Properly trained and implemented cells are more flexible and responsive than the traditional mass-production line, and can manage processes, defects, scheduling, equipment maintenance, and other manufacturing issues more efficiently. The first step in designing CMS is to define the functional requirements (FRs) of the system at the highest level of its hierarchy in the functional domain. Cellular Manufacturing and work-cells are at the heart of Lean Manufacturing. Their benefits are many and varied. They increase productivity and quality. Cells simplify material flow, management and even accounting systems. Cellular Manufacturing seems simple. But beneath this deceptive simplicity are sophisticated Socio-Technical Systems. Proper functioning depends on subtle interactions of people and equipment. Each element must fit with the others in a smoothly functioning, self-regulating and self-improving operation.

2.2. Value Stream Mapping (VSM)

Value stream mapping is a method of visually mapping a product's production path (materials and information) from "door to door". It can serve as a starting point to help management, engineers, production associates, schedulers, suppliers and customers recognize waste and identify its causes. The process includes physically mapping your "Current State" while also focusing on where you want to be, or your "Future State". The ultimate goal of VSM is to identify all types of waste in the value stream and to take steps to try and eliminate these (Rother and Shook, [21]). While researchers have developed a number of tools to optimize individual operations within a supply chain, most of these tools fall short in linking and visualizing the nature of the material and information flow throughout the company's entire supply chain. Taking the value stream viewpoint means working on the big picture and not individual processes. VSM creates a common basis for the production process, thus facilitating more thoughtful decisions to improve the value stream (McDonald et al., [13]). VSM is a pencil and paper tool, which is created using a predefined set of standardized icons (Rother and Shook, [21]). The first step is to choose a particular product or product family as the target for improvement. The next step is to draw a current state map that is essentially a snapshot capturing how things are currently being done. This is accomplished while walking along the actual process, and provides one with a basis for analyzing the system and identifying its weaknesses. The third step in VSM is to create the future state map, which is a picture of how the system should look after the inefficiencies in it have been removed. Creating a future state map is done by answering a set of questions on issues related to efficiency, and on technical implementation related to the use of lean tools. This map then becomes the basis for making the necessary changes to the system.

3. Methodology of the Study

The main goal of this study is to ascertain how lean manufacturing (LM) practices affect layout facility designing. In order to investigate this effect, it is classified concerned company as traditional or lean. For this division, six sets of LM practices are used: (a) process focus, (b) pull production, (c) quality programs, (d) increase in equipment efficiency, (e) form of lean organization and (f) continuous improvement. It is expected that the companies in the lean companies cluster use these sets of practices more intensely than do traditional companies, thus earning a higher average score for these sets of practices.

For successful completion, a severe case study was conducted in a company more specifically their garments finishing section. At the very beginning a detailed work measurement of their existing finishing section's layout was conducted. In sewing section, the sewing procedures of T-shirt style of three of their most prominent buyers naming Puma, M&S and G-star was been targeted. Then taking 15 pieces of garments at a time, the overall value stream mapping (VSM) was designed. Then after seven days of proper monitoring of hourly production capacity and workforce analysis in their sewing section, a fruitful product cluster was formed. At the bottom part some optimum and leaned process flow patterns, facility layouts and their VSM design is proposed for that company for future implementation. Here for further justification of the proposed process flow pattern ARENA simulation software is also used. Simulation is very important to implement lean manufacturing (Law [10]). With this work, it certainly provides a road map for people who are ready to transform their traditional production system from process orientation to cellular orientation. This continuous feedback and improvement procedure is in agreement with the spirit of lean thinking and Kaizen activities.

From the schematic scenario process flow diagram for different buyers are identified. Figure 2 presents the process flow diagram for PUMA for existing layout.

4. Existing Process Flows

A schematic scenario of present finishing section layout is given in the Figure 1.

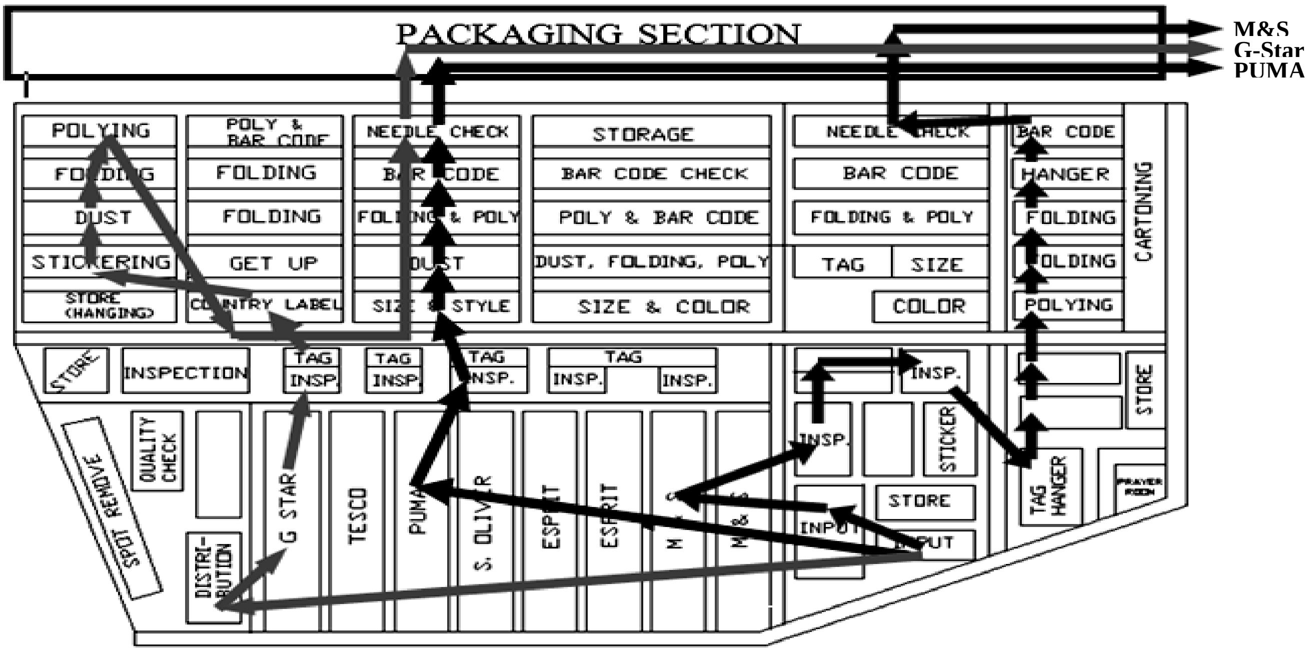


Fig.1. Schematic scenario of present finishing section layout.

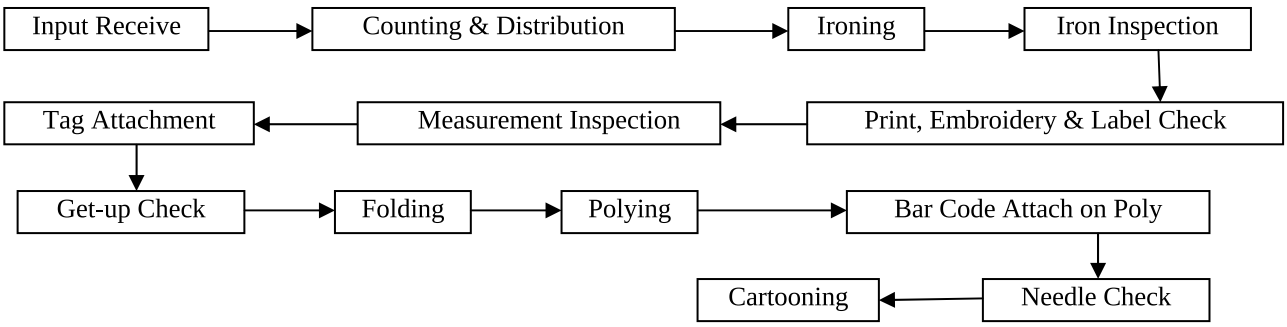


Fig. 2. Existing process flow diagram for PUMA.

There are many limitations in existing process flow, which are:

i. The flow of garments from sewing is not uniform as a result the ratio of packaging is difficult to maintain.
ii. Lack of information flow and long travel distance.
iii. High level of in-process inventory.
iv. Processes are highly disintegrated therefore; there exist a high level of non-value added time.
v. Low level of coordination and integration.
vi. Accessories are not available all the time, as a result sewed garments are stacked throughout the flow.
vii. Haphazard layout results huge amount of cross and back flows of garments.
viii. Low level of productivity than it should be with the existing level of resources.
ix. Housekeeping is not maintained properly.
x. Ineffective record keeping procedure and daily Target is set based on experience.
xi. Inefficient use of manpower which is not uniformly distributed.
xii. Processed are not broken down properly.
xiii. Garments quality should be checked properly in every stages of production; sometimes sewed garments do not satisfy their quality due to sewing and fabric properties and which is found in the finishing section, which should not be happened.

5. Work Measurement of M&S for Existing Layout

Processing time and waiting time are collected from the existing layout of the system. Data are collected for 15 pieces of products. Processing time and waiting time for M&S are collected and shown in Table 1. These data are used to develop value stream mapping (VSM) for buyer M&S.

6. VSM for M&S (Polo Shirt with Long Sleeves)

Value Stream Mapping (VSM) is a method of visually mapping a product's production path (material & information) from "door to door". The process includes physically mapping the "current state" while also focusing on the " future state", which can serve as the foundation for other Lean improvement strategies in shorten process and lead time to market. A value stream is all the actions (both value added and non-value added) currently required to bring a product through the main flows essential to every product.

Figure 3 shows the VSM for a product (Polo shirt) of M&S buyer. First of all the processes are listed squally with in a rectangular box. The arrow shows the movement of product from one process to another and the triangle under the arrow shows the in-process inventory. Then below the process flow line it is showed the value added, non-value added and necessary non-value added activities with three distinct colours. It is also listed the time required for each activity. Finally total value added and non-value added time is calculated.

For M&S polo shirt, total value added time is 27 minutes 20seconds and total non-value added time is 201min 40sec. Therefore the percentage of value added time is 12% of total processing time and non-value added time is 88% of total processing time.

The main focus is to reduce this non-value added time as much as possible with the help of cellular product design and effective manpower utilization.

7. Existing Hourly Production Report

The hourly production reports contain hourly outputs of the sewing section for all the buyers for 52 lines. It contains data for each item that is produced. From that reports how many hours each item are in production, actual outputs for those hours and the total productions for each buyer considering 11 hours a day production are sorted out. Then the percentages of production is calculated for three main buyers, PUMA, M&S and G-Star as these three buyers are considered in all calculations throughout this report. From this study it is seen that for M&S the maximum percentage of production in a day is 38% which accounts for about 15200 pcs, considering the maximum daily output of sewing section which is 40,000 pcs.

8. Proposed Clusters for Different Buyers

After studying the existing system, some drawbacks have been found. To improve the system clusters, process flow diagram and layouts are proposed and implemented. From the data of hourly production capacity report a cluster of products is proposed accordingly those have nearly similar hourly output and the same production line for those. Different production line is suggested for different cluster. Clusters and average hourly productions are shown in Table 2.

9. Proposed Process Flow Diagram

The current layouts have lots of difficulties and shortcomings. To get rid of those limitations, layout is proposed. Here cellular layout concept is incorporated. The maximum sewing output per day is considered for calculating number of required cells to meet it. Proposed process flow diagram for M&S is shown in Figure 4.

From the hourly production report, it is calculated that, for 11 hours production, the maximum percentage of production for M&S is 38% which is about 15,200pcs/day. So, the hourly sewing output for M&S can be easily calculated dividing 15,200 by 11 and the value is about 1382pcs/hour. 11 cells are proposed to meet the output. As each of the proposed cells has the hourly productivity of 131pcs, 11 cells are needed to meet the sewing output.

The productivity of the existing layout of M&S is 14,500pcs/day, whereas our proposed one which consists of 11 identical cells yields a productivity of 16,000pcs/day. So, productivity is increased by 10.34%, which is really noticeable.

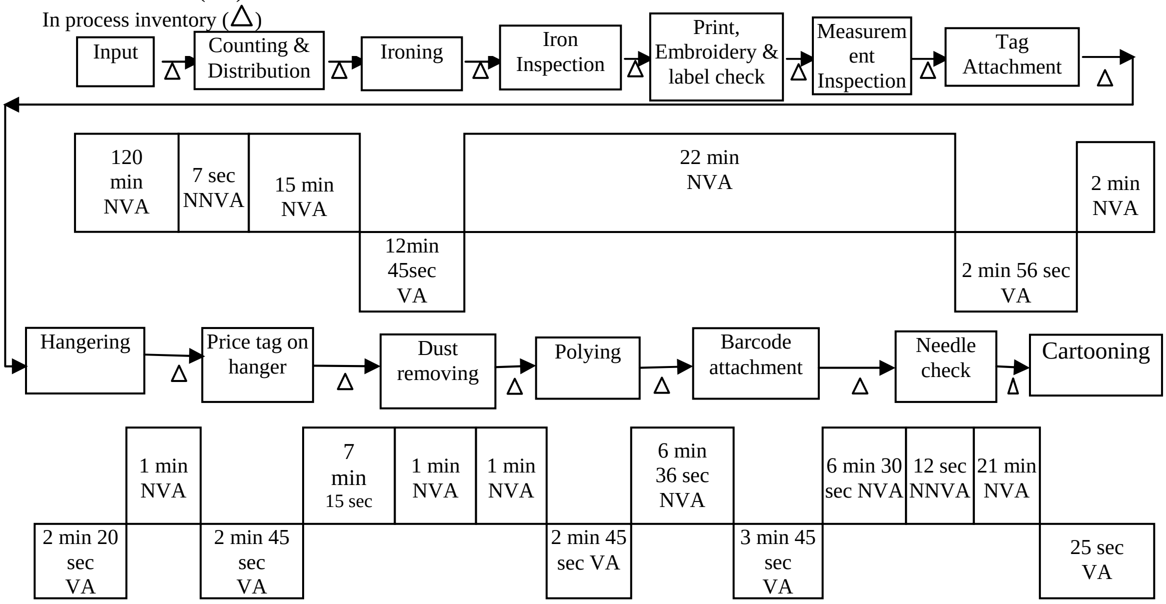
10. Proposed Layouts

As compared to the current layout, where the material has to travel much longer distance, here the distance is minimized significantly. From the layout in the figure 5, it is seen that, each cell consists of 6 workers and 6 tables. There is no gap between the tables. The table sizes are also be identical. Two workers iron the bodies and pass to the two workers in front of them who inspects the ironing, print and embroideries, measurements, labels and then attach the tags at required places. Then he passes it to the man who performs hangering, polying and then attaches the barcodes. As soon as he finishes his tasks, he passes the body to the man who stores the bodies in stand, needle check and also supervises the whole cell. Then he passes it to the cartooning section. Again, from the figure 5 and study to measure its performance, there is no chance of in-process inventory. There is a smooth and continuous material flow. The proposed layout for M&S is shown in figure 5.

Table 1
Processing Time and Waiting Time for M&S

Name of the process	Sample No	Start Time	End Time	Required Time	Avg. Required Time	Waiting Time for Next Process	Avg. Waiting Time
Input	1	8:10:48	8:45:48	35min	34min	1hr20min	1hr 18min
	2	9:05:00	9:35:00	30min		1hr10min	
	3	8:25:00	9:02:00	37min		1hr23min	
Counting & Distribution	1	10:05:48	10:06:00	12sec	14.33 sec	34min	37min
	2	10:45:00	10:45:15	15sec		30min	
	3	10:25:00	10:25:16	16sec		48min	
Ironing	1	10:40:00	10:57:33	17min33sec	17min 38sec	1min20sec	2min
	2	11:15:15	11:33:30	18min15sec		2min45sec	
	3	11:13:16	11:30:21	17min5sec		1min55sec	
Iron Inspection	1	10:58:53	11:02:36	3min43sec	3min 34sec	45sec	48sec
	2	11:36:15	11:39:40	3min25sec		40sec	
	3	11:32:16	11:35:48	3min32sec		1min	
Measurement & Inspection	1	11:03:21	11:07:41	4min20sec	4min 8sec	55sec	1min 10sec
	2	11:40:20	11:44:10	3min50sec		1min25sec	
	3	11:36:48	11:41:03	4min15sec		1min9sec	
Tag Attachment	1	11:08:36am	11:11am	2min23sec	2min 17sec	5min27sec	5min 10sec
	2	11:45:35	11:47:45	2min10sec		5min40sec	
	3	11:42:12	11:44:29	2min17sec		4min22sec	
Getup Check	1	11:16:38am	11:17:53am	1min15sec	1min 19sec	8min55sec	10min 24sec
	2	11:53:25am	11:54:45am	1min20sec		10min5sec	
	3	11:48:51am	11:50:13	1min22sec		12min10sec	
Folding & Poly	1	11:26:48am	11:31:23am	4min35sec	4min 23sec	15days	5day 2min 55sec
	2	12:04:50am	12:09:05	4min15sec		6min	
	3	12:02:23pm	12:06:43	4min20sec		2min45sec	
Barcode attach	1	11:00:00	11:03:45	3min45sec	3min 42sec	10min36sec	34min 12sec
	2	12:15:05pm	12:18:40pm	3min35sec		1hr25min	
	3	12:09:28pm	12:13:15	3min47sec		7min	
Needle Check	1	11:14:21	11:14:33	12sec	13sec	45min	50min
	2	1:43:40	1:43:53	13sec		1hr10min	
	3	12:20:15pm	12:20:30	15sec		25min	
Cartooning	1	12:00:00	12:00:30	30sec	30sec		
	2	2:43:53pm	2:44:26pm	33sec			
	3	12:45:30pm	12:46:00pm	28sec			

Indications:
Non-value added time (NVA)
Necessary non-value added time (NNVA)
Value added time (VA)
In process inventory (Δ)



Total non-value added time =201min 40sec
Total value added time =27min 20sec
Percentage of value added time = 12% of total processing time (229min)
Percentage of non- value added time = 88% of total processing time (229min)

Fig. 3. VSM for M&S (polo shirt with long sleeves).

Table 2
Clusters and production report for different buyers

Buyer	Items	Avg. Hourly Production	Cluster
	S.S.T	72	Cluster 1
PUMA	L.S.T	70	
	S.S. Polo	70	
	Tank top	60	
	Hoody Jacket	50	
			Cluster 2
PUMA	S. Pant	45	
	Jacket	40	
	S.S.T	120	
			Cluster 3
M&S	L.S.T	120	
	S.S. Polo	130	
	L. Pant	70	
			Cluster 4
M&S	L.S Polo	80	
	Pant	50	
	Hoody Jacket	20	
	S. Pant	140	
			Cluster 5
TESCO	L.S.T.	110	
	S.S.T	96	
	S.S.T	100	Cluster 6
G-Star			
	L.S.T	90	
	S.S.T	100	
			Cluster 7
ESPRIT	Tank Top	80	
	L.S.T	70	
	S.S.T	80	
			Cluster 8
S-Oliver	L.S.T	90	
	S.S. Polo	40	

Here for layout, the arrows represent the product flow, the rectangles represent the working tables and the elliptical polygons represent the positions of workers. Layouts are proposed for other two buyer PUMA and G-Star. Figure 6 and Figure 7 shows the proposed layout for PUMA and G-Star.

11. Comparison between Existing and Proposed Condition

Productivity, product travel distance, required workers and operation times are compared between existing layouts and proposed layouts. Table 3, Table 4, Table 5 and Table 6 show the comparison for productivity, product travel distance, required workers and operation times respectively.

Productivity has been improved significantly for proposed layouts. Improvement of productivity for PUMA, M&S and G-Star is 46%, 10.34% and 14.4% respectively which is shown in Table 3.

Travel distance from input to cartooning is also reduced and improvement is shown in Table 4. Required number of workers is minimized. 20 workers are saved for proposed layout and result is shown in Table 5.

Percentage of non-value added time is decreased and percentage of valued added time is increased for all buyer PUMA, M&S and G-Star in proposed layout. Table 6 shows the comparison of percentage of non-value added time and percentage of valued added time for existing and proposed layout.

12. Proposed Process Flow Analysis with “Arena” Simulation Software

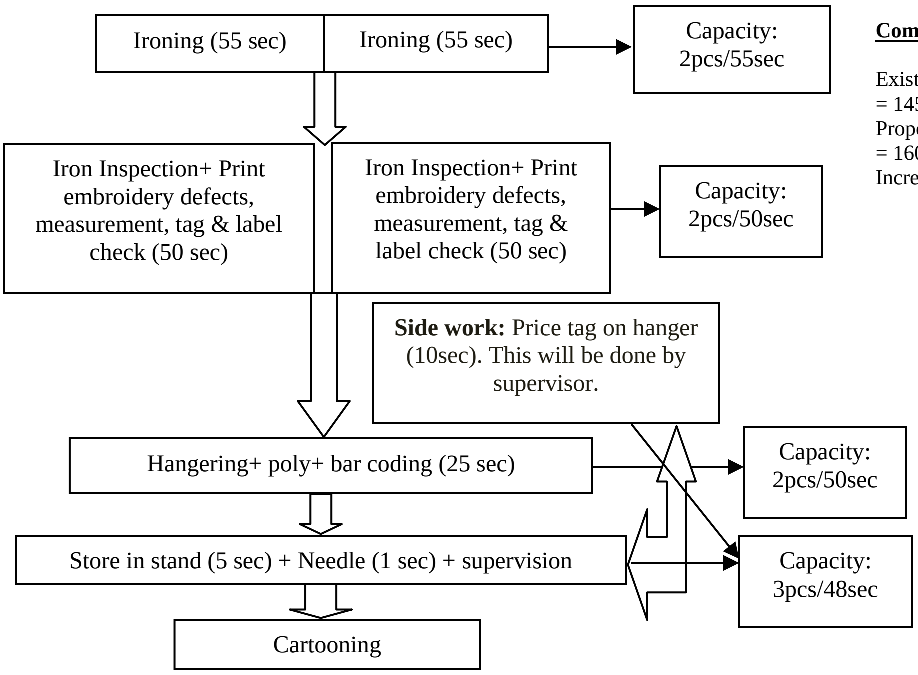
“Arena” simulation software is used to judge our proposed process design about its smoothness and effective utilization of different work station. Figure 8 of Arena simulation shows the processes and the work station design for M&S buyer. Line connecting each station shows the route to the next work station. In input station, it is assumed that a batch size of 20 will arrive at a time and the route time to the next station (Ironing) is assumed 2 sec. In the Ironing station product will follow normal distribution for processing time of mean 55 sec and standard deviation of 3 sec which means approximately 55 sec will require for a garment to be ironed. The capacity of this station is 2 as we have 2 irons in each of our proposed cell for M&S. Route time to the next station (Iron insp. + Measurement+ Print & Embroidery+ tag label check) is 2 sec. In the next station, product will follow normal distribution for processing of mean 50 sec and standard deviation of 2 sec. capacity of this section is 2. Then this garment will shipped to the next station (Hangering + Poly + Barcode) with a route time of 2 sec where the processing time is at normal distribution of mean 25 sec and std. deviation of 2 sec. The capacity of this station is 1. Again finished garments from this station go to the next station where supervision, store in stand and needle check is performed following the normal distribution of mean 16 sec and standard deviation of 2sec. After this, finished garments are sent to the cartooning section.

Figure 9 shows the Arena simulation result for M&S buyer after it was run for 3600 sec. table shows the different variable time such as delay time and average performance time for individual operation. While running the simulation it is seen that server 1 i.e. ironing is always busy because within a fixed time interval a lot is coming to it and the processing time required for this section is nearly same to the interval. For the second and third server a very little amount of idle time can be observed wherein the fourth server i.e. store in stand and needle check, a little bit more idle time is observed as the processing time required for this section is much lower than the previous section. Therefore a supervisor can be assigned here who performs the task of this station as well as supervises his cell.

Similarly for the other two buyers it is also seen that the proposed processes are quite smooth and there is no bottle neck occurred. The result also shows that there is a very little amount of idle time exists. Therefore, it can be said that the proposed design is good enough to meet the requirements.

13. Conclusions

Study and Implementation of lean manufacturing in a garment manufacturing company is carried out in this research. This research is implemented in a Bangladeshi garment manufacturing company. For the first few weeks we tried to learn the processes in the garments finishing department. Then study and analysis those processes are performed using some lean manufacturing tools and techniques and found some problems. Eventually some layouts and process flows are proposed that improves the productivity and reduces cost. The better utilization of manpower and factory floor space is also ensured by implementing the proposed layout. At the same time proposals help to develop a good relationship among the workers and will provide an easier way for the management to coordinate and integrate the factory production with the current level of resources. These techniques can be implemented in any garment manufacturing company and it will help them to improve the productivity at same level of resources.



Comparison:

Existing Finishing output for M&S = 14500 pcs/day
Proposed Finishing output for M&S = 16000 pcs/day
Increased Productivity = 10.34%

Fig. 4. Proposed process flow diagram for M&S

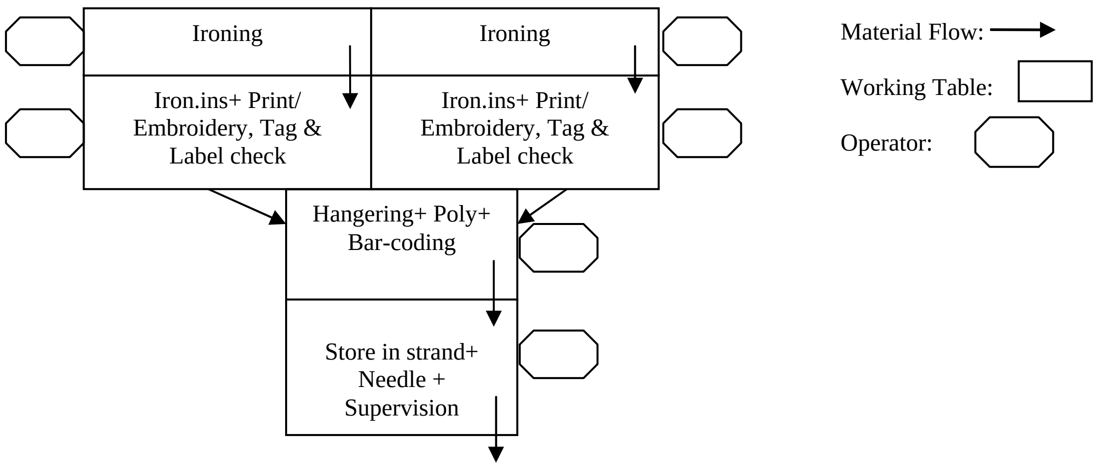


Fig. 5. Proposed layout for buyer M&S

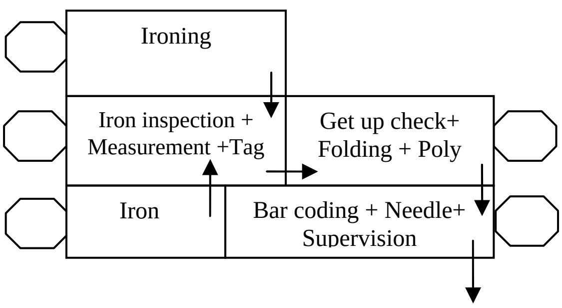


Fig. 6. Proposed layout for buyer PUMA.

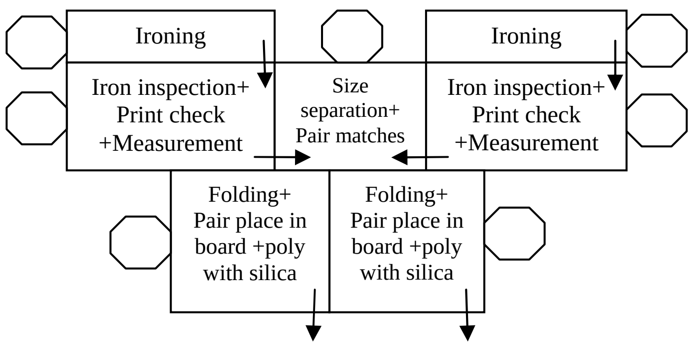


Fig. 7. Proposed layout for buyer G-Star.

Table 3
Comparison of productivity

Buyer	Existing daily production	Proposed daily production	Improvement	Percentage of improvement
PUMA	6220	9064	2844	46%
M&S	14500	16000	1500	10.34%
G-Star (Single piece pack)	2500	2860	360	14.4%

Table 4
Comparison of Product Travel Distance from Input to cartooning

Buyer	Existing Travel Distance (feet)	Travel distance in Proposed Layout (feet)	Improvement (feet)
PUMA	180	40	140
M&S	190	50	140
G-Star	320	55	265

Table 5
Comparison of Required Worker

Buyer	Existing No. of Worker	Worker in Proposed Layout	Improvement
PUMA	62	40	22
M&S	52	66	
G-Star	39	27	12
	Total workers saved		20

Table 6
Comparison of Operation Times

Buyer	Existing		Proposed		Improvement (% value added)
	% Non-value added	% value-added	% Non-value added	% value-added	
PUMA	86%	14%	72%	28%	14%
M&S	88%	12%	79%	21%	9%
G-Star (Single piece pack)	87.45%	12.55%	74%	26%	13.45%
G-Star (Double piece pack)	87.3%	12.3%	75%	25%	12.7%

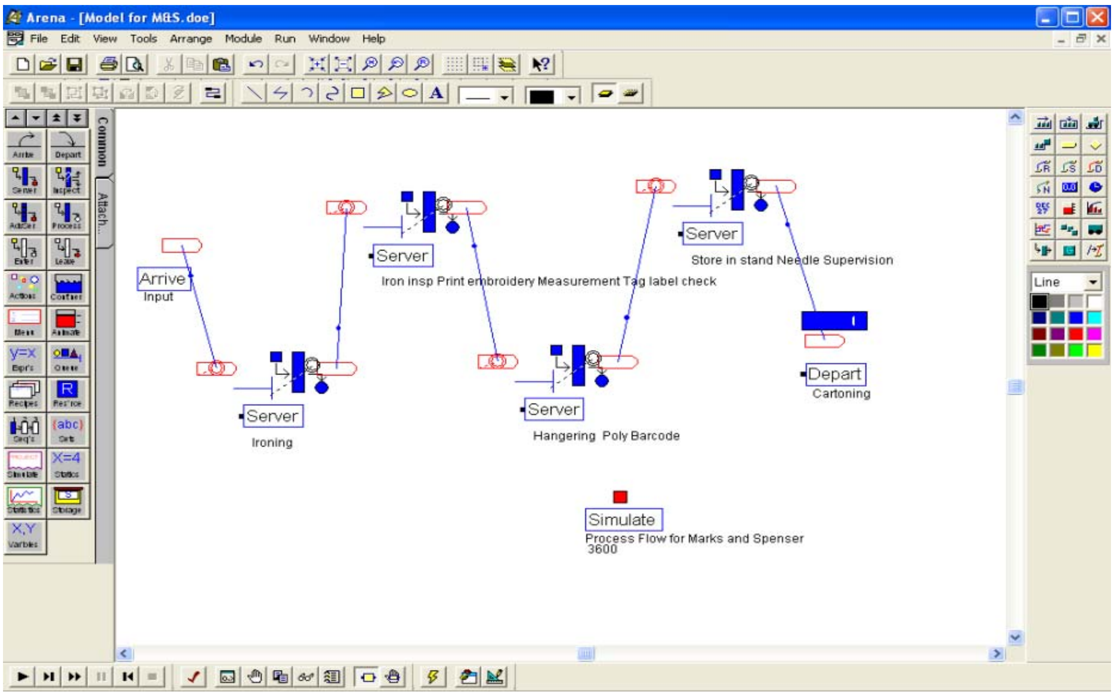
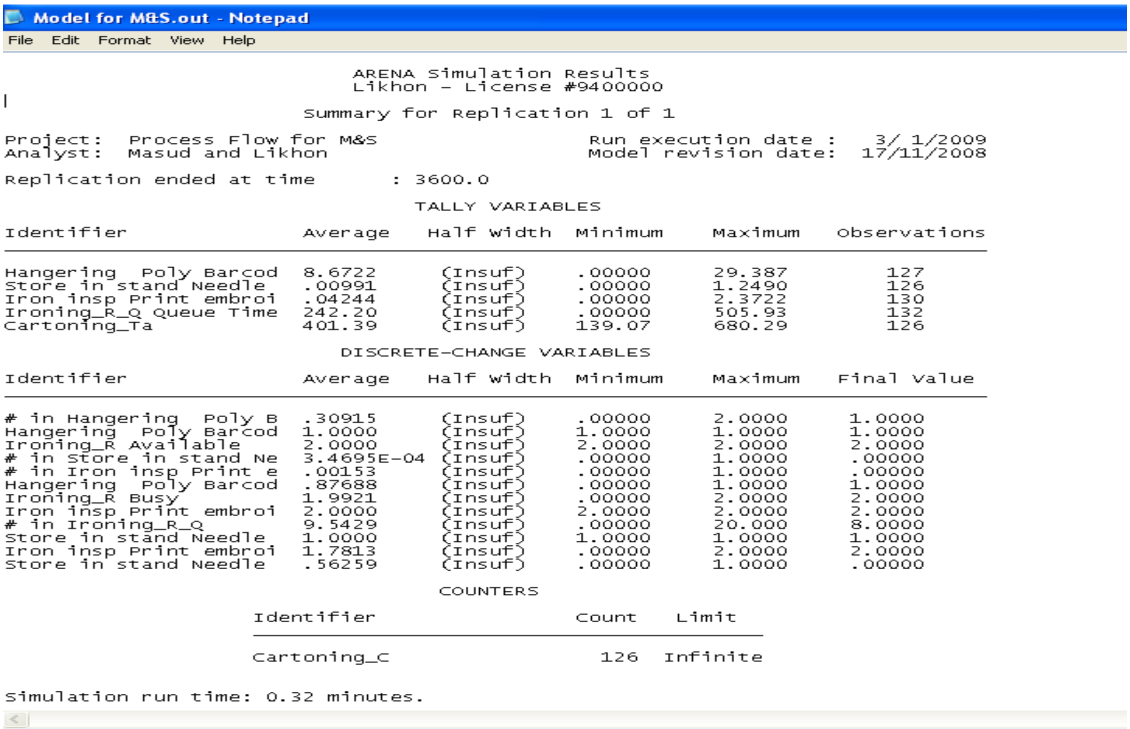


Fig. 8. Processes and work station for M&S buyer in “Arena”.



```
Model for M&S.out - Notepad
File  Edit  Format  View  Help

                         ARENA Simulation Results
                         Likhon - License #9400000

                       Summary for Replication 1 of 1

Project:  Process Flow for M&S              Run execution date :   3/ 1/2009
Analyst:  Masud and Likhon                  Model revision date:  17/11/2008

Replication ended at time       : 3600.0

                              TALLY VARIABLES

Identifier                 Average     Half Width  Minimum    Maximum    Observations
_____________________________________________________________________________________

Hangering  Poly Barcod     8.6722      (Insuf)     .00000     29.387        127
Store in stand Needle      .00991      (Insuf)     .00000     1.2490        126
Iron insp Print embroi     .04244      (Insuf)     .00000     2.3722        130
Ironing_R_Q Queue Time     242.20      (Insuf)     .00000     505.93        132
Cartoning_Ta               401.39      (Insuf)     139.07     680.29        126

                         DISCRETE-CHANGE VARIABLES

Identifier                 Average     Half Width  Minimum    Maximum    Final Value
_____________________________________________________________________________________

# in Hangering  Poly B     .30915      (Insuf)     .00000     2.0000     1.0000
Hangering  Poly Barcod     1.0000      (Insuf)     1.0000     1.0000     1.0000
Ironing_R Available        2.0000      (Insuf)     2.0000     2.0000     2.0000
# in Store in stand Ne     3.4695E-04  (Insuf)     .00000     1.0000      .00000
# in Iron insp Print e     .00153      (Insuf)     .00000     1.0000      .00000
Hangering  Poly Barcod     .87688      (Insuf)     .00000     1.0000     1.0000
Ironing_R Busy             1.9921      (Insuf)     .00000     2.0000     2.0000
Iron insp Print embroi     2.0000      (Insuf)     2.0000     2.0000     2.0000
# in Ironing_R_Q           9.5429      (Insuf)     .00000     20.000     8.0000
Store in stand Needle      1.0000      (Insuf)     1.0000     1.0000     1.0000
Iron insp Print embroi     1.7813      (Insuf)     .00000     2.0000     2.0000
Store in stand Needle      .56259      (Insuf)     .00000     1.0000      .00000

                                 COUNTERS

                    Identifier                Count    Limit
                    ________________________________________

                    Cartoning_C                 126   Infinite

Simulation run time: 0.32 minutes.
```

Fig. 9. Arena simulating result for M&S

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