PRODUCTIVITY IMPROVEMENT IN GARMENTS INDUSTRY THROUGH CELLULAR MANUFACTURING APPROACH

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APRIL 2013

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By

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A thesis submitted to the Department of Industrial and Production Engineering, Bangladesh University of Engineering and Technology, in partial fulfillment of the requirements for the degree of Master of Science in Industrial and Production Engineering.

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CERTIFICATE OF APPROVAL

The thesis titled **"PRODUCTIVITY IMPROVEMENT IN GARMENTS INDUSTRY THROUGH CELLULAR MANUFACTURING APPROACH"** submitted by Rupali Biswas, Roll No. 040808003(F), Session: April 2008 has been accepted as satisfactory in partial fulfillment of the requirements for the degree of **Master of Science in Industrial and Production Engineering** on 24 April 2013.

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It is hereby declared that this thesis or any part of it has not been submitted elsewhere for the award of any degree or diploma.

Rupali Biswas

DEDICATION

This thesis is dedicated to my parents whose tireless encouragement helps me to advance in future.

ACKNOWLEDGEMENT

First, I am very much grateful to the most powerful, the gracious almighty Allah for giving me knowledge, energy and patience for completing the thesis work successfully.

I would like to express my deepest indebtedness and gratitude to my thesis supervisor, Dr. M. Ahsan Akhtar Hasin, Professor, Department of Industrial and Production Engineering (IPE), Bangladesh University of Engineering and Technology (BUET), Dhaka, for his continuous guidance, invaluable suggestions, constructive comments and endless encouragement throughout the progress of this research work and the preparation of this thesis.

I am very much thankful to Md. Momenul Hoque, Incharge (IE), and other staffs of Lean transformation team, HR Textile Mills Ltd. Saver, for their cordial support and cooperation by providing me the respective information, valuable time and great support during the assessment and implementation phase while I was working there as BKMEA consultant and also for my thesis work. I am also thankful to my friend Engr. Anawer Sadath, Assistant manager (IE), Interstoff Apparels Ltd. and Engr. Mamun Mahmud, Assistant manager (Planning), Interstoff Apparels Ltd. for their support and cooperation.

In addition, thanks are due to those who helped me directly and indirectly during the different stages of the thesis work.

Finally, I would like to convey my sincere gratitude to my parents whose continuous inspiration, sacrifice and support encouraged me to complete the thesis successfully.

Rupali Biswas

ABSTRACT

Productivity isn't everything, but in the long run it is almost everything. Differences in GDP growth across countries are largely due to differences in productivity growth. In Bangladesh labor productivity is lower than that of many other competitor countries. But the low labor cost is the primary factor that makes Bangladesh a place for outsourcing the production of RMG products. However, low productivity is the main limitation for the garments industry in Bangladesh. As such, application of operations management tools and techniques is essential to increase productivity.

Elimination of global textile and apparel trade quotas on January 1, 2005 has brought a dramatic shift in the world market of textile and apparel products. The apparel industry faces a great competition among different countries. The key factors of the competition are the Cost, Quality and Lead Time. In the context of fierce global market competition, product prices are declining and Buyers are demanding shorter Lead Times with good Quality. A number of measures should be undertaken to substantially improve productivity. One of the most important tool to be implemented is Cellular Manufacturing (Team work) system.

Cellular Manufacturing (Team work) is an approach that helps build a variety of products with as little waste as possible. This is inline with Lean Manufacturing philosophy also. Equipment and workstations are arranged in a sequence that creates better workers movement from the inside of the work area which supports a smooth flow of material and components through the process, with minimal transport or delay. Here the main idea is team work – not how many products are processed by one worker, but how many quality products are completed by the line as a whole. Continuous flow processing in this work cell is inherently more flexible, more visual, and more efficient, since it eliminates unnecessary movements and enhances communications. These features also make managing the production team easier. Once "Flow Lines" based on product groups have been created, the rate of production can be matched to customer demand.

This thesis aims at developing the right approach to implement Cellular Manufacturing System through reduction of WIP inventory, reduction of material movements and handling and so forth. It is expected that these will increase productivity significantly.

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LIST OF ABBREVIATION

ABBREVIATION	ELABORATION
SMV	Standard Minute Value
M/C	Machine
O/L	Over Lock Machine
P/M	Plain Machine
F/L	Flat Lock Machine
WIP	Work In Process
LCR	Largest Candidate Rule
KWM	Kilbridge and Wester Method
RPW	Ranked Positional Weights Method
Twc	Total Work Content (Total Cycle Time)
Tc	Bottleneck Cycle Time
d	Balance Delay
n	Number of Workstation
SPC	Statistical Process Control
UCL	Upper Control Limit
LCL	Lower Control Limit
CTQ	Critical To Quality

CHAPTER – 1
INTRODUCTION

1.1 INTRODUCTION

The Ready-Made Garments (RMG) industry occupies a unique position in the Bangladesh economy. It is the largest exporting industry in Bangladesh, which experienced phenomenal growth during the last 25 years. Since the late 1970s, the RMG industry started developing in Bangladesh primarily as an export-oriented industry although the domestic market for RMG has been increasing fast due to increase in personal disposable income and change in life style. The sector rapidly attained high importance in terms of employment, foreign exchange earnings and its contribution to GDP. In 2006, the industry employed directly more than 2.1 million workers, about 80% of whom were female. With the growth of RMG industry, linkage industries supplying fabrics, yarns, accessories, packaging materials, etc. have also expanded. In addition, demand for services like transportation, banking, shipping and insurance has increased. All these have created additional employment. The total indirect employment created by the RMG industry in Bangladesh is estimated to be some 250,000 workers. In 1983-84, RMG exports earned only $31.57 million, which was 3.89% of the total export earnings of Bangladesh. Total Export Earnings from Textile & Garments was about US$ 20.13 billion (during FY 2011-12) accounting for 78.60% contribution in the national export earnings. This Sector provides employment to around 5 million (3.5 million in RMG & 1.5 million in Primary Textile Sector) people, making it the largest source of industrial employment in Bangladesh [1].

Both external and internal factors contributed to the phenomenal growth of RMG sector. One external factor was the application of the GATT-approved Multi-fiber Arrangement (MFA) which accelerated international relocation of garment production. Under MFA, large importers of RMG like USA and Canada imposed quota restrictions, which limited export of apparels from countries like Hong Kong, South Korea, Singapore, Taiwan, Thailand, Malaysia, Indonesia, Sri Lanka and India to USA and Canada. On the other hand, application of MFA worked as a blessing for Bangladesh. As a least developed country, Bangladesh received preferential treatment from the USA and European Union (EU). Initially Bangladesh was granted quota-free status. To maintain competitive edge in the world markets, the traditionally large suppliers/producers of apparels followed a strategy of relocating RMG factories in countries, which were free from quota restrictions and at the same time had enough trainable cheap labor. So RMG industry grew in Bangladesh [1].

But there are several weaknesses of the RMG industry of Bangladesh. Labor productivity in the RMG sector of Bangladesh is lower than many of its competitors. Bangladeshi workers are not as efficient as those of Hong Kong, South Korea and some other countries and in most factories, operational systems, technologies used are not the latest. So day by day RMG of Bangladesh is facing cut throat competition and challenge in the global market. This is because of reduction in buyer's price but demanding shorter Lead Times with good Quality, and increase in manufacturing cost.

In this crucial moment factory management techniques of yesterday must be replaced by more efficient methods that greatly minimize waste, reduce costs, lead time and improve quality bringing in maximum value to customers. Lean Manufacturing System doesn't tolerate any kind of waste such as overproduction, waiting, WIP, processing waste, transportation, motion, making defective products, underutilized people etc. Lean Manufacturing is a whole-systems approach that creates a culture in which everyone in the organization continuously improves processes and production. So, we can say Lean is the ultimate solution. A number of measures should be undertaken to substantially improve productivity. One of the most important tool to be implemented is Cellular Manufacturing (Team work) approach that helps build a variety of products with as little waste as possible. This is inline with Lean Manufacturing philosophy also [3].

The thesis work aims at the application of different Lean Manufacturing concepts, including the establishment of Cellular Manufacturing system in the Garments Industry.

1.2 BACKGROUND OF THE THESIS

Today the world is shrinking rapidly, forcing garment factories to think globally. Survival becomes increasingly difficult and it becomes more and more critical to find new ways to grow or sustain business. Of paramount importance is meeting the ever-shorter lead-time demands of customers. For manufacturers focusing on the three key areas of Timeliness, Quality and Cost Effectiveness, it is only through Continuous Improvement programs – of which Lean is the ultimate system – that they can survive and thrive. Looking back at North American and European business trends, strategies have evolved through the decades. “How to do more” was emphasized in the 1960s. “How to do it cheaper” becomes important in the 1970s. “How to do better quality” was the key objective of the 1980s. “How to do it quicker” has been the overriding priority since the 1990s. Time is the yardstick by which we increasingly judge those around us, particularly organizations providing manufacturing services. For those who plan to stay in export garment production, the importance of JIT production and Lean Manufacturing cannot be understated.

But the application of Lean Manufacturing concepts specially Cellular Manufacturing system in RMG sector is totally new in Bangladesh. So there is a great necessity to study the scope of implementation and the areas of improvement and the step by step methodology to do it in a positive and learned thinking. Now a days the buyers are searching market for lower price and they are getting new exporter on their hand with their requirements cost, quality and lead time. So the profit margin is narrowing and the competition is expanding as a result the production process and new technology is the only way to cope up the crisis. This thesis work aims to find out the common phenomenon to implement lean tools including Cellular Manufacturing system to overcome the barriers.

1.3 OBJECTIVES WITH SPECIAL AIMS AND POSSIBLE OUTCOMES OF THE STUDY

The specific objectives of the present research work are as follows:

a. Reduction of idle time in the production line through line balancing.
b. Reduction of materials movement time through change in facility layout.
c. Measurement of quality status through quantitative indices.
d. Measurement of Productivity.
e. Identification of necessary measures to implement Cellular Manufacturing System to maximize labor utilization time and minimize waste (Non-Value-Added activities).

The major outcomes of this research are:

a. A comprehensive guideline as to how to implement Cellular Manufacturing System in the garments industry.
b. A prototype model of Cellular Manufacturing system.

1.4 OUTLINE OF METHODOLOGY

The step-by-step methodology of the study will be as follows:

1) Study of a typical Garments Company.
2) Collection of production data and subsequently balancing the line.
3) Study of material movement-frequency, direction, etc. and subsequently developing a better layout that minimizes materials handling (cost).
4) Identification and measurement of Value-Added and Non-Value-Added activities and their times, based on Value Stream Mapping (VSM).
5) Measurement and quantification of selected factors, such as Changeover Time, Throughput Time, WIP inventory, Quality defect, etc. which are responsible for lower productivity.
6) Development of quantitative and qualitative guidelines as to how to establish a Cellular Manufacturing system.
7) Experimental implementation of the developed concepts of Cellular Manufacturing in a garments factory.
8) Comparison of Productivity level of the suggested system with that of an older traditional line.

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APPENDICES

Appendix A: VSM Data Log Sheet (Cutting Section)

Appendix B: VSM Data Log Sheet (Sewing & Finishing Section)

Appendix C: VSM Data Log Sheet (Finishing, Cartoning)

Appendix D: Variable Control Chart-Format

Appendix E: Attribute Control Chart-Format

Appendix F: CTQ (Critical to Quality) Chart

Appendix G: Table for Values of Constants

Appendix A

Lead Time and Time Utilization Analysis

Table for VSM Data Log Sheet (Cutting Section)

<table>
<tr><th colspan="6">VSM Data Log Sheet</th></tr>
<tr><th colspan="6">Factory Name: XY Apparels Ltd.</th></tr>
<tr><td colspan="2">Product Name: Long Sleeve T-Shirt</td><td colspan="4">Order No: 64674</td></tr>
<tr><td colspan="2">Buyer: Zara</td><td colspan="4">Style: A-04</td></tr>
<tr><th>Dept</th><th>Activity</th><th>Time (min)</th><th>Quantity</th><th colspan="2">Manpower</th></tr>
<tr><td rowspan="15">Cutting Section</td><td>Waiting in cutting store</td><td>1099</td><td></td><td colspan="2"></td></tr>
<tr><td>Waiting for Spreading</td><td>35</td><td>06 roll</td><td colspan="2"></td></tr>
<tr><td>Spreading</td><td>55</td><td>65 Lay</td><td colspan="2">4</td></tr>
<tr><td>Pattern Marking</td><td>25</td><td></td><td colspan="2">1</td></tr>
<tr><td>Quality Inspection</td><td>5</td><td></td><td colspan="2">1</td></tr>
<tr><td>Cutting</td><td>40</td><td></td><td colspan="2">1</td></tr>
<tr><td>Cut panel Quality checking</td><td>5</td><td></td><td colspan="2">1</td></tr>
<tr><td>Transportation for Stickering</td><td>15</td><td>24 bundle</td><td colspan="2">1</td></tr>
<tr><td>Waiting for Stickering</td><td>15</td><td>24 bundle
480 pieces</td><td colspan="2"></td></tr>
<tr><td>Stickering</td><td>40</td><td>24 bundle
480 pieces</td><td colspan="2">6</td></tr>
<tr><td>Waiting for Bundling</td><td>20</td><td>24 bundle</td><td colspan="2"></td></tr>
<tr><td>Bundling</td><td>15</td><td>24 bundle</td><td colspan="2">2</td></tr>
<tr><td>Bundle waiting for Input store</td><td>10</td><td>24 bundle</td><td colspan="2"></td></tr>
<tr><td>Bundle Transportation for Input store</td><td>15</td><td>24 bundle</td><td colspan="2">2</td></tr>
<tr><td>Bundle Inspection for Quality</td><td>18</td><td>24 bundle</td><td colspan="2">4</td></tr>
<tr><th colspan="6">CUTTING SECTION</th></tr>
<tr><td colspan="2" rowspan="2">Total Process Time</td><td colspan="2">Total Value Added Time</td><td>95</td><td rowspan="2">233 | 17%</td></tr>
<tr><td colspan="2">Unavoidable Non Value Added Time</td><td>138</td></tr>
<tr><td colspan="4">Total Non Value Added Time</td><td>1179</td><td>83%</td></tr>
<tr><td colspan="4">Total Cutting Lead Time</td><td>1,412</td><td>min</td></tr>
</table>

Appendix B

Lead Time and Time Utilization Analysis

Table for VSM Data Log Sheet (Sewing & Finishing Section)

VSM Data Log Sheet					
Factory Name: XY Apparels Ltd.					
Product Name: Long Sleeve T-Shirt			Order No: 64674		
Buyer: Zara			Style: A-04		Line: V
Dept	Activity	Time (min)	Quantity	Manpower	Equipment
Sewing & Finishing Section	Waiting for Loading	615.00	480		
	Loading for Sewing	1.20	1	2	
	Sleeve hem	0.07	1	1	F/L
	Care Label Make	0.13	1	1	P/L
	Care Label Join	0.17	1	1	P/L
	Waiting for Shoulder Join	6.00	1		
	Shoulder Join	0.40	1	2	O/L
	Trimming	0.11	1	1	
	Neck Tuck	0.28	1	2	P/L
	Folding	0.47	1	2	
	Waiting for Neck Join	20.00	1		
	Neck Join	0.29	1	2	O/L
	Size label Sewing	0.42		1	
	Marking for size Label	0.18	1	1	
	Waiting for Size Label	12.00	1		
	Size Label Join	0.20	1	2	P/L
	Waiting for Sleeve join	47.00	1		
	Sleeve Join	0.48	1	3	O/L
	Sleeve length Scissoring	0.13		1	
	Waiting for Side Seam	12.00	1		
	Side Seam	0.51	1	4	O/L
	Waiting for Sleeve Tuck	9.00	1		
	Arm tuck	0.23	1	1	P/L
	Body Hem Cut & Fold	0.25		1	
	Trimming	0.12		1	
	Sleeve Tuck	0.17	1	2	P/L
	Waiting for body hem	10.00	1		
	Body hem	0.14	1	1	F/L

Dept	Activity	Time (min)	Quantity	Manpower	Equipment
Sewing & Finishing Section	Trimming	0.15	1	2	
	Waiting for QC	55.00			
	Transportation for T/QC	0.08		1	
	QC Check	0.40		1	
	Waiting for Iron	9.00			
	Transportation for Iron	0.10	55		
	Iron	0.33		1	
	Waiting for Finishing QC	67.00			
	Sorting	0.35		1	
	Finishing QC	0.36		1	
	Waiting	17.00			
	Transportation for Measurement	0.05	55		
	Measurement	0.15		1	
	Waiting for Hand tag	52.00			
	Transportation for Hand tag	0.05	55		
	Hangtag attach	0.30		1	
	Waiting For Folding	3.00			
	Transportation for Folding	0.05	55		
	Folding	0.67		1	
	Waiting For Poly	72.00			
	Poly	0.92	55	1	

<table>
<tr><td colspan="5">Sewing & Finishing Section</td></tr>
<tr><td rowspan="2">Total process time</td><td>Total Value Added Time</td><td>188.85</td><td rowspan="2">192.13</td><td rowspan="2">16.04%</td></tr>
<tr><td>Unavoidable Non Value Added Time</td><td>3.28</td></tr>
<tr><td colspan="3">Total Non Value Added Time</td><td>1006.00</td><td>83.96%</td></tr>
<tr><td colspan="3">Total Cutting lead Time</td><td>1,198.13</td><td>min</td></tr>
</table>

Appendix C

Lead Time and Time Utilization Analysis

Table for VSM Data Log Sheet (Finishing, Cartoning)

<table>
<tr><th colspan="7">VSM Data Log Sheet</th></tr>
<tr><td colspan="7">Factory Name: XY Apparels Ltd.</td></tr>
<tr><td colspan="3">Product Name: Long Sleeve T-Shirt</td><td colspan="4">Order No: 64674</td></tr>
<tr><td colspan="3">Buyer: Zara</td><td colspan="4">Style: A-04</td></tr>
<tr><th>Dept</th><th>Activity</th><th>Time (min)</th><th>Quantity</th><th>Manpower</th><th colspan="2">Equipment</th></tr>
<tr><td rowspan="3">Finishing (Cartoning)</td><td>Transportation for Cartoning</td><td>5.00</td><td></td><td></td><td colspan="2"></td></tr>
<tr><td>Waiting for Carton</td><td>60.00</td><td></td><td></td><td colspan="2"></td></tr>
<tr><td>Cartoning</td><td>2.75</td><td>55</td><td>1</td><td colspan="2"></td></tr>
<tr><td colspan="7">Finishing (Cartoning)</td></tr>
<tr><td colspan="2" rowspan="2">Total Process Time</td><td colspan="2">Total Value Added Time</td><td>2.75</td><td rowspan="2">7.75</td><td rowspan="2">11.44%</td></tr>
<tr><td colspan="2">Unavoidable Non Value Added Time</td><td>5.00</td></tr>
<tr><td colspan="5">Total Non Value Added Time</td><td>60.00</td><td>88.56%</td></tr>
<tr><td colspan="5">Total Cutting Lead Time</td><td>67.75</td><td>min</td></tr>
</table>

Appendix D

Variable Control Chart-Format

VARIABLES CONTROL CHART	Operation	Style No/Line No	Chart Type ☐ X - R / Median Chart	☐ Others	
	Supervisor	Buyer	Median Chart X =	UCL= LCL=	Sample Suize / Frequency
Measurement	Quality Racilitator	Unit of Measure	Ranges Chart R =	UCL= LCL=	Tolerances (Specified by Buyer) Upper = Lower =

DATE																																	Interpretation Guidelines
TIME																																	
BUNDLE NO																																	
SIZE																																	Any Point Outside The Control Lin
sample mesure 1																																	A Trend of 7 Points-all Rising/Fallin
2																																	A Run of 7 Points-all Above/Below
3																																	The Centreline
4																																	Any Other Obvious Non-Random
5																																	Pattern
6																																	
TOTAL																																	
MEDIAN (X)																																	
RANGE (R)																																	

	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	2	
Median +6																											Documentation
+5																											For every change in the
+4																											processwrite
+3																											the sample number and answer
+2																											U What Happened ?
+1																											U Why Did It Happened ?
0																											U How Was It Corrected ?
-1																											U Who Correctet It ?
-2																											Formula
-3																											Median:
-4																											UCLx = X + A2R
-5																											UCLx = X - A2R
-6																											Range:
																											UCLR = D4R, LCLR = D3R

Ranges 18																											Legend
17																											
16																											1 = 1/8
15																											2 = 1/4
14																											3 = 3/8
13																											4 = 1/2
12																											5 = 5/8
11																											6 = 3/4
10																											7 = 7/8
9																											8 = 1
8																											A2 = 0.577
7																											
6																											D4 = 2.114
5																											D3 = 0
4																											
3																											

Appendix E

Attribute Control Chart-Format

ATTRIBUTES CONTROL CHART	Operation	Style	Chart Type ☐p ☐p ☐ u☐
	Supervisor	Buyer	UCL = LCL = p-bar (Control Limit, CL) =
	Quality Racilitator	Line No.	Sample Frequency

		Interpretation Guidelines
DATE		
TIME		
BUNDLE NO		
Type of Defect		Any Point Outside The Control Limits
1		
2		A Trend of 7 Points-all Rising/Falling
3		
4		A Run of 7 Points-all Above/Below
5		The Centreline
6		
7		Any Other Obvious Non-Random
8		Pattern
Total Defectives = d		
Total Sample Size = n		
Proportion of Defectives, p = d/n		

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30

50
45
40
35
30
25
20
15
10
5
0

Documentation

For every change in the process write the sample number and answer the following question:

- What Happened?
- How did it Happen?
- Why did it Happen?
- How was it Corrected?
- Who Corrected it?

Formula :

$$UCL\ (p) = p + 3\sqrt{\frac{p(1-p)}{n}}$$

$$LCL\ (p) = p - 3\sqrt{\frac{p(1-p)}{n}}$$

Appendix F

CTQ (Critical to Quality) Chart

Critical to Quality - Variable & Attribute												
S.No.	Operation	**Attribute**	Measurement Spec in case of **Variable Chart**	Possible Defects								
1	Rt fly attach to front & topstitch	Attribute	-	Uneven gap between the zip tape and fly	Other Sewing Defects							
2	J-stitch	Attribute	-	Uneven Gap	Other Sewing Defects							
3	Make Welt	Attribute	-	Uneven gap between double needles	Incorrect double needle length	In correct cut length	other sewing defects					
4	Stay stitch at Notch Corner & Topstitch Lower lip	Attribute	-	Seam Pinching	Rawedge visible	Untidy stitching	other sewing defects					
5	Sideseam	Attribute	1 Variable Chart for Seat/hip Measurement	Uneven overlock shape	Seam Puckering	Seam Pinching	Seam Rolling	Open Seam	Open Seam	other sewing defects		
6	Inseam	Attribute	2 Variable Charts for Thigh and Leg Opening Measurements	Uneven overlock shape	Seam Puckering	Seam Pinching	Seam Rolling	Open Seam	Open Seam	other sewing defects		
6	Waistband attach	Attribute	2 Variable Chart for Front rise and Back rise	Uneven Waistband shape	Seam Pinching	Skip Stitch	uneven stitch margin	Open Seam	other sewing defects			
7	Waistband closing	Attribute	1 Variable Chart for Waist Measurement	Untidy stitching	Mouth Closing not straight	Rawedge visible	Stitch condensation	Skip Stitch	Tacking not proper	uneven stitch margin	Runoff stitch	other sewing defects

Appendix G

Table for Values of Constants

Subgroup Size	A2	d2	D3	D4
2	1.88	1.128	-----	3.268
3	1.023	1.693	-----	2.574
4	0.729	2.059	-----	2.282
5	0.577	2.326	-----	2.114
6	0.483	2.534	-----	2.004
7	0.419	2.704	0.076	1.924
8	0.373	2.847	0.136	1.864
9	0.337	2.97	0.184	1.816
10	0.308	3.078	0.223	1.777
11	0.285	3.173	0.256	1.276
12	0.266	3.258	0.283	1.717
13	0.249	3.336	0.307	1.693
14	0.235	3.407	0.328	1.672
15	0.223	3.472	0.347	1.653
16	0.212	3.532	0.363	1.637
17	0.203	3.588	0.378	1.622
18	0.194	3.64	0.391	1.608
19	0.187	3.689	0.403	1.597
20	0.18	3.735	0.415	1.585
21	0.173	3.778	0.425	1.276
22	0.167	3.819	0.434	1.566
23	0.162	3.858	0.443	1.557
24	0.157	3.859	0.451	1.548
25	0.153	3.931	0.459	1.541

CHAPTER - 2
LITERATURE REVIEW

2.1 INTRODUCTION

Lean Manufacturing represents a journey that should never end since it involves the identification and elimination of waste and inefficiencies. It is the continuous improvement of all operations and processes involved in manufacturing. It seems to imply that there will always be some waste and inefficiencies, and that better operations or processes will continue to emerge due to better equipment, newer technological developments and more informed management. The implementation of Lean production systems has saved many companies millions of dollars over the last 20 years or so [4].

Recent competitive economic situations demand quicker supply of newer products with more innovative functionality to satisfy quickly changing customer requirements. In striving to remain competitive, the concept of Cellular Manufacturing has been extensively employed to the manufacturing systems [6].

Cellular manufacturing, one of the main tools of Lean Manufacturing, helps to create a concept known as single or one-piece flow. Equipment and the workstations are arranged in sequences to allow for a smooth flow of materials and components through the process. The cell is made up of workers and the equipment required to perform the steps in creating the product. The layout of the equipment and the workstations is determined by the logical sequence of production. By grouping similar products into families that can then be processed on the same equipment in the same sequence, cellular manufacturing offers companies the flexibility to give customers the variety they require. Factories converted to cellular manufacturing benefit by the reduction of overproduction and waste, shorter lead time, improved quality and productivity, improved teamwork and communication [4].

2.2 HISTORICAL BACKGROUND OF CELLULAR MANUFACTURING

Cellular Manufacturing is the application of the principles of Group Technology in manufacturing. Group Technology was proposed by Flanders in 1925 and adopted in Russia by Mitrofanov in 1933 (although the work was translated into English in 1966). Jack Burbidge (1978) did much to promote Group Technology in the UK. Although there appear to have been similar applications earlier in history Portsmouth Block Mills offers what by definition constitutes an early example of cellular manufacturing. By 1808, using machinery designed by Marc Isambard Brunel and constructed by Henry Maudslay, the Block Mills were producing 130,000 blocks (pulleys) for the Royal Navy per year in single unit lots, with 10 men operating 42 machines arranged in three production flow lines. This installation apparently reduced manpower requirements by 90% (from 110 to 10), reduced cost substantially and greatly improved block consistency and quality. Group Technology is a management strategy with long term goals of staying in business, growing, and making profits. Companies are under relentless pressure to reduce costs while meeting the high quality expectations of the customer to maintain a competitive advantage. Successfully implementing Cellular manufacturing allows companies to achieve cost savings and quality improvements, especially when combined with the other aspects of lean manufacturing tools [5].

2.3 INTRODUCTION TO LEAN MANUFACTURING

U.S. manufacturers have always searched for efficiency strategies that help reduce costs, improve output, establish competitive position, and increase market share. Early process oriented mass production manufacturing methods common before World War II shifted afterwards to the results-oriented, output-focused, production systems that control most of today's manufacturing businesses.

Japanese manufacturers re-building after the Second World War were 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, lower cost, manufacturing practices. Early Japanese leaders such as the Toyota Motor Company's Eiji Toyoda, Taiichi Ohno, and Shingeo Shingo developed a disciplined, process-focused production system now known as the "Toyota Production System", or "Lean

Production." The objective of this system was to minimize the consumption of resources that added no value to a product [9 & 14].

The "Lean Manufacturing" concept was popularized in American factories in large part by the Massachusetts Institute of Technology study of the movement from mass production toward production as described in The Machine That Changed the World, (Womack, Jones & Roos,1990), which discussed the significant performance gap between Western and Japanese automotive industries. This book described the important elements accounting for superior performance as lean production. The term "Lean" was used because Japanese business methods used less human effort, capital investment, floor space, materials, and time in all aspects of operations. The resulting competition among U.S. and Japanese automakers over the last 25 years has lead to the adoption of these principles within all U.S. manufacturing businesses [9].

2.3.1 Lean Manufacturing Definitions

"A systematic approach to identifying and eliminating waste (non-value-added activities) through continuous improvement by flowing the product at the pull of customer in pursuit of perfection."

"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 consists of best practices, tools and techniques from throughout industry with the aims of reducing waste and maximizing efficiency to achieve the ultimate customer satisfaction. Flow and the efficiency of the overall system a part sitting in a pile of inventory is waste and the goal is to keep product flowing and add value as much as possible. The focus is on the overall system and synchronizing operations so that they be aligned and produced products at a steady pace.

Lean manufacturing is a manufacturing philosophy that shortens the time between the customer order and the product build/shipment by eliminating sources of waste [5 & 9].

2.3.2 Toyota ways - 14 Principles

1. Base your management decisions on a long term philosophy at the expense of short term financial goals.
2. Create continuous process flow to bring problems to surface.
3. Use “PULL” system to avoid overproduction.
4. Level out the workload (heijunka).
5. Build a culture of stopping to fix a problem. To get quality right the first time.
6. Standardize tasks are the foundation for continuous improvement and employees empowerment.
7. Use visual controls so no problems are hidden.
8. Use only reliable, thoroughly tested technology that serves your people and processes.
9. Grow leaders who thoroughly understand the work. Live the philosophy and teach it to others.
10. Develop exceptional people and teams who follow your company’s philosophy.
11. Respect your extended network of partners and suppliers by challenging them and helping them improve.
12. Go and see for yourself to thoroughly understand the situation.
13. Make decisions slowly by consensus, thoroughly considering all options, implement decisions rapidly.
14. Become a learning organization through relentless reflection (Hansei) and continuous improvement (Kaizen).

2.3.3 Toyota – 4 rules

1. Simplify, Structure & Standardize every activity
2. Analyze, Simplify & connect every flow
3. Connect Visually workers to customers and corporate objectives
4. Improve continuously through work practices and experimentation with workers participation

2.3.4 Principles of Lean Manufacturing

Key principles behind Lean Manufacturing can be summarized as follows:

1. Recognition of waste – The first step is to recognize what does and does not create value from the customer's perspective. Any material, process or feature which is not required for creating value from the customer's perspective is waste and should be eliminated.
2. Standard processes – Lean requires an the implementation of very detailed production guidelines, called Standard Work, which clearly state the content, sequence, timing and outcome of all actions by workers. This eliminates variation in the way that workers perform their tasks.
3. Continuous flow – Lean usually aims for the implementation of a continuous production flow free of bottlenecks, interruption, detours, backflows or waiting. When this is successfully implemented, the production cycle time can be reduced by as much as 90%.
4. Pull-production – Also called Just-in-Time (JIT), Pull-production aims to produce only what is needed, when it is needed. Production is pulled by the downstream workstation so that each workstation should only produce what is requested by the next workstation.
5. Quality at the Source – Lean aims for defects to be eliminated at the source and for quality inspection to be done by the workers as part of the in-line production process.
6. Continuous improvement – A continuous improvement mentality is necessary to reach the company's goals. The term "continuous improvement" means incremental improvement of products, processes, or services over time, with the goal of reducing waste to improve workplace functionality, customer service, or product performance. Lean requires striving for perfection by continually removing layers of waste as they are uncovered. This in turn requires a high level of worker involvement in the continuous improvement process.
7. Customer Focus - A lean manufacturing enterprise thinks more about its customers than it does about running machines fast to absorb labor and overhead. Ensuring customer input and feedback assures quality and customer satisfaction, all of which support sales [8].

8. Value - In lean production, the value of a product is defined solely by the customer. The product must meet the customer's needs at both a specific time and price. Identifying the value in lean production means to understand all the activities required to produce a specific product, and then to optimize the whole process from the view of the customer.
9. Perfection - The concept of perfection in lean production means that there are endless opportunities for improving the utilization of all types of assets. The systematic elimination of waste will reduce the costs of operating the extended enterprise and fulfills customer's desire for maximum value at the lowest price [8].

2.4 FOCUS ON WASTE IDENTIFICATION

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 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.

Essentially, a "waste" is anything that the customer is not willing to pay for. Typically the types of waste considered in a lean manufacturing system include: [8].

Overproduction: to produce more than demanded or produce it before it is needed. It is visible as storage of material. It is the result of producing to speculative demand. Overproduction means making more than is required by the next process, making earlier than is required by the next process, or making faster than is required by the next process. Causes for overproduction waste include:

- Just-in-case logic
- Misuse of automation
- Long process setup
- Unlevel scheduling
- Unbalanced work load
- Over engineered
- Redundant inspections

Figure 2.1: Overproduction

Waiting: for a machine to process should be eliminated. The principle is to maximize the utilization/efficiency of the worker instead of maximizing the utilization of the machines. Causes of waiting waste include:

- Unbalanced work load
- Unplanned maintenance
- Long process set-up times
- Misuses of automation
- Upstream quality problems
- Unleveled scheduling

Figure 2.2: Waiting

Excess Inventory: is material between operations due to large lot production or processes with long cycle times. Causes of excess inventory include:

- Protecting the company from inefficiencies and unexpected problems
- Product complexity
- Unleveled scheduling
- Poor market forecast
- Unbalanced workload
- Unreliable shipments by suppliers
- Misunderstood communications
- Reward systems

Figure 2.3: Excess Inventory

Over Processing: should be minimized by asking why a specific processing step is needed and why a specific product is produced. All unnecessary processing steps should be eliminated. Causes for processing waste include:

- Product changes without process changes
- Just-in-case logic
- True customer requirements undefined
- Over processing to accommodate downtime
- Lack of communications
- Redundant approvals
- Extra copies/excessive information

Figure 2.4: Over Processing

Excess Transportation: does not add any value to the product. Instead of improving the transportation, it should be minimized or eliminated (e.g. forming cells). A cause of transportation waste includes:

- Poor plant layout
- Poor understanding of the process flow for production
- Large batch sizes, long lead times, and large storage areas

Figure 2.5: Excess Transportation

Excess Motion: of the workers, machines, and transport (e.g. due to the inappropriate location of tools and parts) is waste. Instead of automating wasted motion, the operation itself should be improved. Causes of motion waste include:

- Poor people/machine effectiveness
- Inconsistent work methods
- Unfavorable facility or cell layout
- Poor workplace organization and housekeeping
- Extra "busy" movements while waiting

Figure 2.6: Excess Motion

Rework: is pure waste. Prevent the occurrence of defects instead of finding and repairing defects. Causes of processing waste include:

- Weak process control
- Unbalanced inventory level
- Deficient planned maintenance
- Product design
- Customer needs not understood
- Inadequate education/training/work instructions

Figure 2.7: Rework

Underutilizing People: Losing time, ideas, skills, improvements, and learning opportunities by not engaging or listening to the employees. Causes of people waste include: [13].

- Old guard thinking, politics, the business culture
- Poor hiring practices
- Low or no investment in training
- Low pay, high turnover strategy

Nearly every waste in the production process can fit into at least one of these categories. Those that understand the concept deeply view waste as the singular enemy that greatly limits business performance and threatens prosperity unless it is relentlessly eliminated over time. Lean manufacturing is an approach that eliminates waste by reducing costs in the overall production process, in operations within that process, and in the utilization of production labor.

2.5 LEAN TOOLS

Many manufacturers are now critically evaluating their processes to determine their effectiveness in bringing maximum value to customers. Factory management techniques of yesterday are being replaced by more efficient methods that greatly minimize delays, reduce costs, and improve quality.

Lean manufacturing is a whole-systems approach that creates a culture in which everyone in the organization continuously improves processes and production. It is a system focused on and driven by customers, both internal and external.

2.5.1 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". VSM 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", 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 [18].

Taking a value stream perspective means working on the big picture, not just individual processes, and improving the whole, not just optimizing the parts.

Value Stream Mapping is a pencil and paper tool that helps you to see and understand the flow of material and information as a product makes its way through the value stream. The meaning is simple: Follow a product's production path from customer to supplier, and carefully draw a visual representation of every process in the material and information flow. Then ask a set of key questions and draw a "future state" map of how value should flow.

Within the production flow, the movement of material through the factory is the flow that usually comes to mind. But there is another flow - of information - that tells each process what to make or do next. You must map both of these flows.
Value Stream Mapping can be a communication tool, a business planning tool, and a tool to manage your change process. The first step is drawing the current state, which is done by gathering information on the shop floor. This provides the information needed to map a future state. The final step is to prepare and begin actively using an implementation plan that describes, on one page, how you plan to achieve the future state [18].

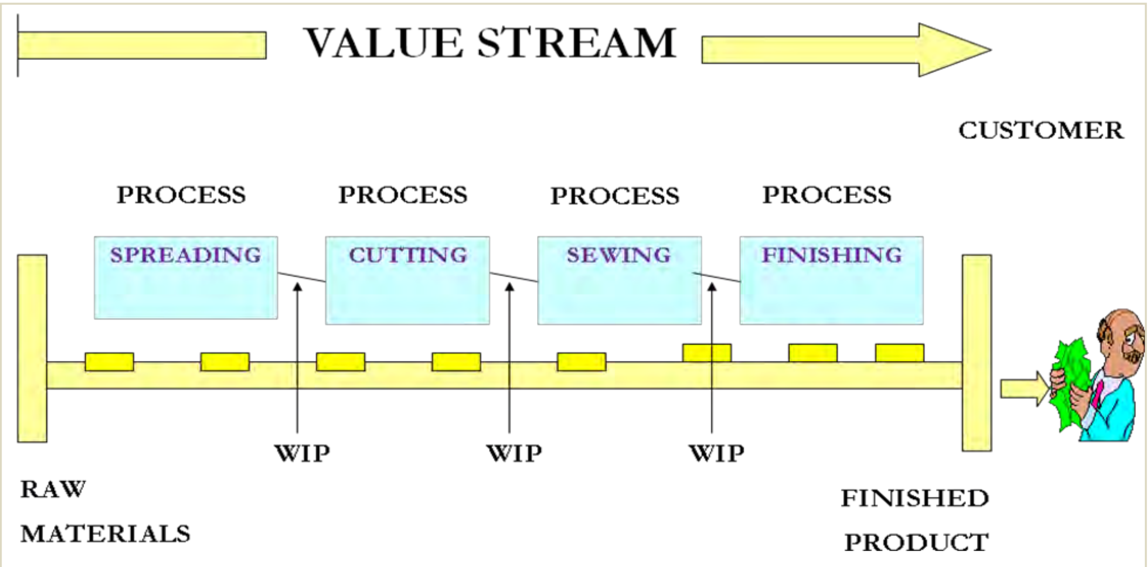


Figure 2.8: Value Stream Mapping

More and more organizations with successful shop-floor lean efforts are also applying Value Stream Mapping methods and lean principles to administrative areas. Value Stream Mapping provides a simple, yet thorough methodology that relies on relevant data analysis and display.

It links reporting requirements, metrics, people, and lean tools to sustain improvement and promote process learning. It gives managers and employees the same tool and language to communicate.

Why Value Stream Mapping is a good place to start Lean Journey –

- it helps you visualize more than just the single-process level, i.e. assembly, welding, etc.
- it helps you see more than waste it helps you see the sources of waste in your value stream
- it provides a common language for talking about manufacturing processes
- it makes decisions about the flow apparent, so you can discuss them
- it ties together lean concepts and techniques helps you avoid "cherry picking"
- it forms the basis of an implementation plan
- it shows the linkage between the information flow and the material flow

It is much more useful than quantitative tools and layout diagrams that produce a tally of non-value added steps, lead time, and distance traveled, the amount of inventory, and so on [18].

2.5.2 Cellular Manufacturing

Cellular manufacturing is an approach that helps build a variety of products with as little waste as possible. Equipment and workstations are arranged in a sequence that supports a smooth flow of materials and components through the process, with minimal transport or delay (Kanban production and Transport).

A manufacturing cell consists of the people and the machines or workstations required for performing the steps in a process or process segment, with the machines arranged in the processing sequence.

Arranging people and equipment into cells helps companies achieve two important goals of lean manufacturing one-piece flow and high-variety production [12].

Goals of Lean Manufacturing through manufacturing Cellular:

One Piece Flow:

One-piece flow is the state that exists when products move through a process one unit at a time, at a rate determined by the needs of the customer. The goals of one-piece flow are to make one part at a time all the time, without unplanned interruptions, and to achieve this without lengthy queue times.

One-piece flow (also commonly referred to as continuous flow manufacturing) is a technique used to manufacture components in a cellular environment. The cell is an area where everything that is needed to process the part is within easy reach, and no part is allowed to go to the next operation until the previous operation has been completed [11].

The goals of one-piece flow are: to make one part at a time correctly all the time to achieve this without unplanned interruptions to achieve this without lengthy queue times

High-Variety Production:

Given the fact that customers expect variety and customization, as well as specific quantities delivered at a specific time, it is necessary to remain flexible enough to serve their needs. This eliminates a major reason for making products in large lots that changeovers take too long to change the product type frequently.

Benefits of Cellular Manufacturing:

Cellular manufacturing helps employees by strengthening the company's competitiveness, which helps support job security. It also makes daily production work go smoother by removing the clutter of WIP inventory, reducing transport and handling, reducing the walking required and addressing causes of defects and machine problems.

Common benefits associated with Cellular Manufacturing include:

- WIP reduction
- Space utilization
- Lead time reduction

- Productivity improvement
- Quality improvement
- Enhanced teamwork and communication
- Enhanced flexibility and visibility

2.5.3 Quick Changeover / Set up Reduction

Quick Changeover is a method for rapidly and efficiently converting a process from running the current product to running the next product. Sometimes known as set-up reduction, this is the process of reducing the amount of time needed to change over from the last piece of the previous product to the first good piece of the next product. Changeover Time is the elapsed time between the last good previous product, and the first good next product at the right speed.

Customers today want a variety of products in just the quantities they need. They expect high quality, a good price, and speedy delivery. Producing to customer requirements means getting batch processes to produce in small lots. Doing this usually creates a need to reduce setup times. The goal of setup reduction and changeover improvement should be to develop a production system that gets as close as possible to making only what the customer wants, when the customer wants it, throughout the production chain. The result being a strong, flexible manufacturing operation that is adaptable to changes [7].

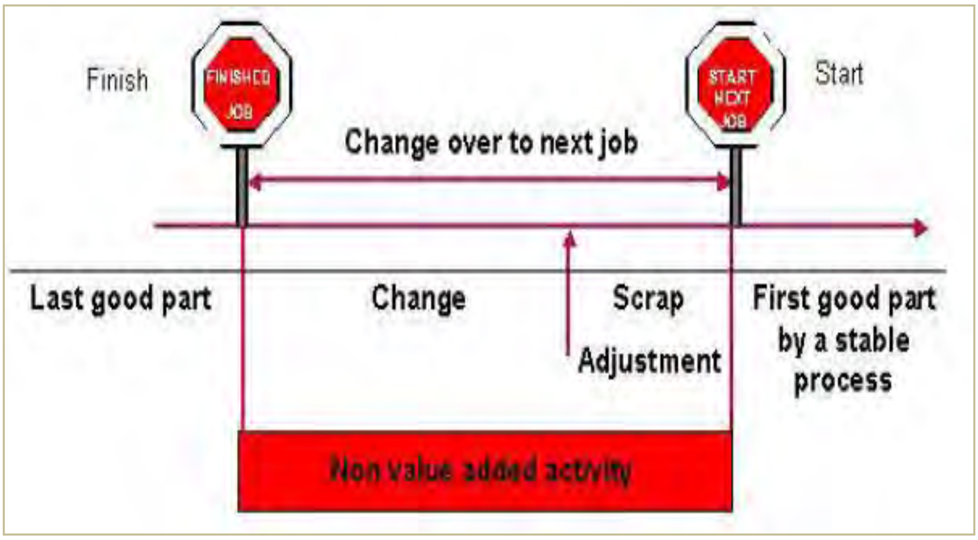


Figure 2.9: Changeover Time

2 Key elements of Changeover :

1. Internal Activities:

Must be performed while the machine / process is stopped i.e. not making parts.
Examples of Internal Activities are:

- Removing work from the machine
- Removing tools dies etc
- Cleaning down the work surfaces
- Fixing new tools in place
- Fixing the new work piece in place
- Trial run and adjustment the machine

2. External Activities:

Can be performed whilst the machine / process is running i.e. making parts.
Examples of External Activities are:

- Getting instructions for the next job
- Getting material for the next job from stores
- Getting tools for the next job from tool stores
- Returning tools for the last job to tool stores
- Arranging for lifting equipment to be available when required
- Arranging for a setter to be available when required

6 Steps of Quick Changeover Methodology:

1. Observed the current changeover process
    - By video
    - By time study
2. Identify Internal and External Activities
    - Internal: Activities to be performed whilst the machine is stopped

- External: Activities that can be performed away from the machine, while the line is running

3. Convert activities from Internal to External setup
    - Example preheating
4. Increase efficiency of the remaining internal activities (or Reduce internal activities)
    - Minimize or eliminate adjustments
    - Parallel operations
    - Develop team work
5. Optimize the start up time
    - Minimize or eliminate adjustments
    - If you have to do adjustments, make them measurable and repeatable
6. Increase efficiency of external activities (or Reduce external activities)
    - Apply 5S principles

Many companies produce goods in large lots simply because long changeover times make it costly to frequently change products. Large-lot production has several disadvantages:

- Inventory waste - sorting out what is not sold costs money and ties up company resources without adding any value to the product
- Delay - customers must wait for the company to produce entire lots rather than just the quantities a customer needs
- Declining quality - storing unsold inventory increases the chance that it will have to be scrapped or reworked, which adds cost to the product

When methods are in place to accommodate quick changeover, setups can be done as often as needed. This means you can make products in smaller lots, which has many advantages:

- Flexibility - can meet changing customer needs without the expense of excess inventory
- Quicker delivery - small-lot production means less lead time and less customer waiting time
- Better quality - less inventory storage means fewer storage-related defects. Quick changeover methods lower defects by reducing setup errors and eliminating trial runs of the new product

- Higher productivity - shorter changeovers reduce downtime, which means a higher equipment productivity rate

As a broad term setup covers not only the replacement of tooling and production parts, but also other operations, such as the revision of standards and the replacements of assembly parts and other materials.

Usually, we begin by reducing setup time as an objective and rarely go further to change equipment more frequently and run smaller batches. In other words, the focus is on the technique of setup reduction rather than the objective of lean manufacturing. Setup reduction is an important technique that supports lean manufacturing, but it is lean manufacturing that is the driver for when and where you apply setup reduction [7].

2.5.4 5S (Workplace Organization)

Based on Japanese words that begin with S, the 5S Philosophy focuses on effective work place organization and standardized work procedures. 5S simplifies work environment, reduces waste and non-value added activity while improving quality efficiency and safety [8].

The First S: Sort (Seiri)

The first S focuses on eliminating unnecessary items from the workplace.
Sort is the first pillar of the visual work place, corresponds to the just in tine (JIT) principle of "only what is needed, only in the amounts needed, and only when it is needed."

Implementing this pillar creates a work environment in which space, time, money energy, and other resources can be managed and used most effectively.

Examples:

- Identify all necessary and unnecessary items.
- Move unnecessary items from workplace to a designated area or "throw it out".
- Remove all excess items from working areas – work pieces, personal items etc.
- Organize all remaining necessary items.

- Designate a team to “hunt down unnecessary items”.

Red tagging: An effective visual method to identify these unneeded items is called red tagging. A red tag is placed on all items not required to complete your job. These items are then moved to a central holding area. This process is for evaluation of the red tag items. Occasionally used items are moved to a more organized storage location outside of the work area while unneeded items are discarded.

The Second S: Set-in-Order (Seiton)

The second **S** focuses on efficient and effective storage methods. Arrange needed items so that they are easy to use and label them so that anyone can find them and put them away. The second pillar, Set in order can be implemented only when the first pillar is in place. Similarly, if sorting is implemented without Setting in order, it is much less effective. Sort and Set in order work best when they are implemented together.

One must ask these questions in implementing Set-in-Order :

1. What do I need to do my job?
2. Where should I locate this item?
3. How many do I need?

Strategies for effective Set In Order are:

- Painting floors
- Outlining work areas and locations
- Shadow boards
- Modular shelving and cabinets

The Third S: Shine (Seiso)

It is the component that emphasizes the removal of dirt, grime and dust from the workplace. As such shine means that we keep everything swept and clean. Having clean and bright environment everyone can enjoy the working. When everything is kept in top condition, so that when someone needs to use something, it is ready to be used.

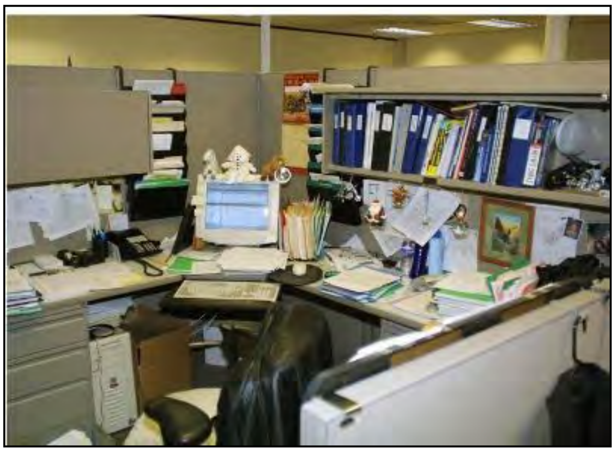


Figure 2.10: Without 5S

Figure 2.11: With 5S

The Fourth S: Standardize (Seiketsu)

Once the first three of the 5S's have been implemented, one must concentrate on standardizing best practice in the work area. Allow employees to participate in the development and documentation of such standards. They are a valuable but often overlooked source of information regarding their work.

Standardize means establishing "Best Manufacturing Practices, including:

- Workplace Layout and Design
- Materials Handling Analysis
- Clear and Concise Work Instructions
- Well Defined Work Methods
- Safe (Ergonomic) Working Practices
- Cycle Time Reduction
- Training
- Documentation

The Fifth S: Sustain (Shitsuke)

This is by far the most difficult **S** to implement and achieve. Human nature is to resist change and more than a few organizations have found themselves with a dirty cluttered shop a few months following their attempt to implement 5S. The tendency is to return to the status quo and the comfort zone of the "old way" of doing things.

Sustain focuses on defining a new status quo and standard of work place organization.

Factory must create conditions or structures that will help to sustain a commitment to the five pillars such as:

- Awareness: Everyone need to understand what the five pillars are and how to important to sustain them.
- Time: Everyone need to have or make enough time in the work schedule to perform 5S daily.
- Structure: Everyone need to have support for the efforts from management, in terms of acknowledgment, leadership and resources.
- Rewards & recognition: Everyones effort need to be rewarded.
- Satisfaction & Excitement: Implementation of 5 Pillars must be fun and satisfying for Everyone and the company. Excitement gets communicated from person to person allowing 5S to build as it involves more people [8].

Figure 2.12: 5S Team of the Month

Tools & Techniques to Sustain 5S Implementation:

- 5S Slogans: Communicate the themes of the five pillar campaign in the factory. They can be displayed on machines, stickers, flags, or posters.
- 5S Posters: 5S slogans descriptions of 5S activities can be posted throughout the workplace.
- 5S Photo: Story board "Picture is worth a thousand words." Photo exhibits and Story board showing the before and after of 5S implementation activities.
- 5S News letters: Are in-house news bulletin centered on five pillar topics.
- 5S Maps: Can also be used to get employee involved in five pillar improvement on an ongoing basis. Those should be hung in a central location with suggestion cards attached so anyone can suggest improvements.
- 5S Pocket manuals: Can be created that contains five pillar definitions and descriptions, and is small enough to fit into the pocket of work clothes.
- 5S Department tours: When one department in a company has implemented the five pillars successfully, it can serve as a model area for other departments to come visit. Since "seeing is believing," this technique is extremely effective for promoting 5S implementation throughout a company.
- 5S Months: Campaigns should be designate two, three or four months every year as "5S Months." During these months, various activities such as 5S seminars, field trips, and contests can be carried out to further promote 5S implementation in the company [8].

2.5.5 Visual Control System

The intent of a visual factory is that the whole workplace is set-up with signs, labels, color-coded markings, etc. such that anyone unfamiliar with the process can, in a matter of minutes, know what is going on, understand the process, and know what is being done correctly and what is out of place.

Facts and concepts:

There are two types of application in visual factory: displays and controls. A visual display relates information and data to employees in the area. For example, charts showing monthly revenues of the company or a graphic depicting a certain type of quality issue that group members should be aware of.

Figure 2.13: Visual Display Board

A visual control is intended to actually control or guide the action of the group members. Examples of controls are readily apparent in production: Inventory limits, goals, allowances of production delays, etc.

Visual controls describe workplace safety, production throughput, material flow, quality metrics, or other information. The most important benefit of a visual factory is that it shows when something is out of place or missing. Visual displays and controls help keep things running as efficiently as they were designed to run. The efficient design of the production process that results from lean manufacturing application carries with it a set of assumptions. Visual management is an important support for cellular manufacturing. Visual management techniques express information in a way that can be understood quickly by everyone. Sharing information through visual tools helps keep production running smoothly and safely. Shop floor teams are often involved in devising and implementing these tools through 5S and other improvement activities.

Visual information can also help prevent mistakes. Color coding is a form of visual display often used to prevent errors used for sizes, part of the product.

2.5.6 Kaizen (Continuous Improvement)

Kaizen is a Japanese hybrid word. "Kai" means change and "Zen" means good (for the better). Basically kaizen is for small incremental improvements, but carried out on a continual basis and involve all people in the organization [8].

Ten basic principles for Improvement in the view of Kaizen:

1. Throw out all of your fixed ideas about how to do things.
2. Think of how the new method will work-not how it won't.
3. Don't accept excuses. Totally deny the status quo.
4. Don't seek perfection. A 50-percent implementation rate is fine as long as it's done on the spot.
5. Correct mistakes the moment they're found.
6. Don't spend a lot of money on improvement.
7. Problems give you a chance to use your brain.
8. Ask "why" at least five times until you find the ultimate cause.
9. Ten people's ideas are better than one person's.
10. Improvement knows no limit.

Kaizen steps:

Step-1 Brain Storming (5 W 1 H, 4 M)
Step-2 Theme and Goal Set-up
Step-3 Data Collection
Step-4 Classification
Step-5 Cause and Effect Analysis
Step-6 Countermeasure Set-up
Step-7 Implementation

Step-8 Effectiveness of Results

Step-9 Correction of Countermeasure

Step-10 Monitoring

Step-11 Standardization

2.5.7 Kanban

The Kanban system determines the production quantity in every process. It is known as the nervous system of Lean Production. Kanban is a Japanese word that means "instruction card". Kanbans are manual pull devices that allow an efficient means to transfer parts from one department to another and automatically reorder products using minimum/maximum inventory levels. A Kanban is a signal, such as an empty container returned to the start of the assembly line, that signals the need for replenishment of materials to a user [18].

Kanban Characteristics:

Kanban is based on management inventory system called “reordering point method”. Kanban minimize waste by using “Level Production”. Level production depends on setup time reduction “Quick Changeover”. Kanban system serves as the production order for the Pull system. The order point is determined by the pacemaker based on the Takt time. Order Information travels Upstream from sales demand to assembly to Suppliers - The Pull system travels from Downstream to Upstream [19].

Functions of Kanban:

The Kanban system has several important functions:

1. A communication system
2. Pick Up and work order information
3. Elimination of overproduction waste
4. A tool for visual control
5. A tool for promoting improvement

2.5.8 Supermarkets

Kanban system is inspired by the way Supermarkets work to supply. The upstream process produces equal quantity to what was withdrawn by the downstream process. Supermarket is located near the area where the products are produced.

Figure 2.14: Supermarket

Withdrawal and production Kanban control this process of the supermarket. If any one can not use Supermarket because too many different parts are used, then the FIFO system. Create lanes to store dissimilar parts so that the parts are always withdrawn in the same sequence they were made.

2.5.9 Pull Production System

The concept of pull in lean production means to respond to the pull, or demand, of the customer. Lean manufacturers design their operations to respond to the ever-changing requirements of customers. Those able to produce to the pull of customers do not need to manufacture goods that traditional batch-and-queue manufacturers must rely on. The planning for delivery of product to customers is less troublesome, and demand becomes more stable if customers have confidence in knowing that they can get what they want when they want it.

Pull Production has 2 Aspects:

1. In manufacturing, Pull production is the production of items only as demanded or consumed by the customer.
2. In material control, Pull production is the withdrawal of inventory only as demanded by the using operation. Materials are used only when a signal comes from the downstream user.
Three unique aspects of Pull:

1. Production is Music: In a factory the melody is the flow of work pieces down the line Kanban and 1 Piece flow creates the melodic result.
2. The next process is Your Customer: The downstream process is the customer of the upstream process Creates reliability, consistency and just in time compare to the PUSH system.
3. Stop & Go versus Process & Go Production:

2.5.10 Pull Quality System

In a Pull System, quality inspection and prevention become every operator's responsibility.

There are 5 levels of quality systems in lean production:

1. Independent Inspection
2. Operator inspection of product as they are made
3. Inspection by downstream operator as they are received
4. Mistake – proofing on errors – standardization
5. Supplier process control

The rules of quality in PULL Production:

1. Never allow a defective product to be pulled into your workstation
2. Never produce a defective product at your workstation.
3. Never allow a defective part to be pulled from your workstation.

2.6 SUPPORTING STRATEGIES FOR LEAN

2.6.1 Takt Time

Takt" is the German word for musical meter, which came into Japan in the 1930s when the Japanese were learning aircraft production from German aerospace engineers.

Takt time is the tool to link production to the customer by matching the pace of production to the pace of actual final sales. First, calculate actual Takt times for each product and part. Then use the time required for each product and part to determine the time that should be allotted to each actual process in the entire production chain.

Simply, Takt Time is the rate of customer demand. How often the customer requires one finished item. Takt time is used to design assembly and pacemaker processes, to assess production conditions, to calculate pitch, to develop containers and routes for material handling, to determine problem-response requirements, and so on. Takt is the heartbeat of a lean system [8].

Takt Time as Pace of Sales:

It is used to synchronize the pace of production with the pace of sales.

$$\text{Takt time} = \frac{\text{Effective working time (minutes worked-breaks)}}{\text{Customer demand during that time (Pieces)}}$$

2.6.2 Team Building

Building an organization that effectively uses teams throughout its operation is challenging in and of itself. Just trying to establish teams is unlikely to do much for introducing lean manufacturing. Good teamwork in the front office and on the shop floor does take training and development, but it is during the development and transformation to lean manufacturing that creates both a need and an environment for teams.

Establishing product- based work arrangements make individual processing steps dependent on another. In such a production environment, individuals must be able to work as a team. Producing only to customer requirements takes out work-in-process and demand producing and delivering high quality throughout the production chain. These types of changes lay the groundwork for individuals to become part of teams. The natural progression is to incorporate team building into the implementation of lean manufacturing [14].

2.6.3 Balanced Flow

In principle, it is best to start Lean Manufacturing improvements as close as possible to the customer. That would mean taking the "next process is your customer" approach to all activities. This is called vertical development of Lean Manufacturing improvements - lateral improvements are when they are moved to other products.

Many think of leveling as leveling out two factors - capacity and load. For Lean Manufacturing improvement, leveling means thoroughly leveling out product types and volumes in accordance with customer needs. Begin by breaking down the production output into small (usually daily units). Then compare the daily volume of product with the operating hours and calculate how many minutes it should take to turn out each product unit. This unit production is "cycle time". Then figure how many people are needed and what the capacity is.

2.6.4 Quality at the Source

In traditional manufacturing environments, quality inspections usually occur at receipt of goods and through sampling after a product's final assembly. In lean manufacturing environments, inspections (and product rework) are accommodated at any point in a product's life, as it is being produced [17].

Facts and concepts:

- This is accomplished by determining equipment (or other manufacturing) parameters that produce good parts, then rigorously monitoring and adjusting each operation to meet these parameters.

- Employees are empowered to stop the equipment (or the equipment is built to stop on its own) when the process drifts outside the parameter limits.
- Often combined with this is a program to error-proof each manufacturing step (called Poka-Yoke). This involves equipping machines or workstations with devices to assure that parts can only be made the correct way.

2.6.5 Zero Quality Control

Product defects hurt the company's reputation with its customers and waste valuable resources in scrap and rework. Companies that pursue low-inventory production no longer have a large buffer to absorb quality defects. To keep production moving smoothly, it is especially important to prevent defects [17].

Mistake proofing is an effective quality assurance approach that prevents defects by catching errors and other nonstandard conditions before they actually turn into defects. The mistake-proofing system known as Zero Quality Control ensures zero defects by inspecting the processing conditions for 100 percent of the work, ideally just before an operation is performed. If an error is discovered, the process shuts down and gives immediate feedback with lights, warning sounds, and so on.
Zero Quality Control Elements:

- Source inspection to catch errors before they become defects
- 100 percent inspection to check every work piece, not just a sample
- Immediate feedback to shorten the time for corrective action
- Poka-yoke (mistake-proofing) devices to check automatically for abnormalities

2.6.6 Poka - Yoke (Mistake-Proofing)

Because people can make mistakes even in inspection, mistake-proofing often relies on sensing mechanisms called Poka-Yoke, which check conditions automatically and signal when problems occur. Poka-Yoke devices include electronic sensors such as limit switches and photoelectric eyes, as well as passive devices such a positioning pins that prevent backward insertion of a work piece. Poka-Yoke devices may use counters to make sure an operation is repeated the correct number of times.

The key to effective mistake-proofing is determining when and where defect-causing conditions arise and then figuring out how to detect or prevent these conditions, every time. Shop floor people have important knowledge and ideas to share for developing and implementing poka-yoke systems that check every item and give immediate feedback about the problem [13].

2.6.7 Employee Involvement

All innovations and improvements start with everyone in the organization becoming aware of the need for change and the role each will play in the realization of that change. The most important step is to begin by catching people's attention and raising their awareness.

Lean manufacturing means more than changing production methods. The awareness for change must begin at the top of the company and establish a sense of urgency that "trickles" down to the next level and ultimately to the shop floor. There are many ways to start this chain-reaction (in-house training, team building work shops, shop floor study or work teams, etc.) The one key element is that it must be fully understood that the status quo is not enough to ensure the company's survival in the future [14].

Following are some considerations regarding employee involvement when implementing Lean strategies:

- Ensure that people are fully trained and truly empowered
- Provide widespread orientation to continuous improvement, quality, training and recruiting workers with appropriate skills
- Create common understanding of the need to change to lean
- Fully prepare and motivate people
- Share information and manage expectations
- Identify and empower champions, particularly operations managers
- Remove roadblocks (i.e. people, layout, systems)
- Create an atmosphere of experimentation, toleration, patience, risk taking
- Install "enlightened" and realistic performance measures, evaluation, and reward systems
- Do away with rigid performance goals during implementation

2.6.8 Stabilized Operations

It is difficult if not impossible to improve your aim at a moving target. The same principle applies to lean manufacturing. It is important to establish a baseline in order to take the next steps in improving the capability of the production system. Having established product-based work cells, synchronized flow and small lot production, you want to achieve not just demonstrated performance but proven performance. Demonstrated performance is the ability to do it once. Proven performance is the repeatability that comes from having an effective process in place and having the supporting infrastructure holding it up.

Having made the transformation to lean, how can we keep the systems operating at a high level of efficiency and continually improving? Without continuous improvement the lean system will not just stay the same - they will degrade. Achieving a stabilized operation or demonstrated performance is the first challenge - proven performance is the next [15].

2.6.9 Standardized Work

Standard work is a term used to systematize how a part is processed, and includes man-machine interactions and studies of human motion. Operations are safely carried out with all tasks organized in the best known sequence and by using the most effective combination of resources:

- People, Materials, Methods, Machines

Facts and concepts:

- Manufacturing engineers break down each operation into small pieces, making certain that each worker is given all the tools to make the part quickly and with the highest quality.
- The process is documented in writing, with photographs and video, and examples of defective products nearby. This is done to eliminate errors that waste time and money, and ensure reproducibility from operator-to-operator.
- One of the challenges of senior management is to ensure that everyone in the organization understands the challenges of the marketplace, accepts the performance metrics, and believes in the company's values, mission, and vision.

Standardization must occur not only within the area, but across the entire plant as well. This will include paint and color standards for safety elements, equipment operation instructions, floor markings, building interior and exterior, material labeling, etc. By creating standards and defining procedures, there will be commonality across the entire organization [15].

Benefits:

Successful standardization of work processes helps assure high quality product, proud workers, satisfied customers, workplace safety, and strong factory cost performance. Reducing variation in the shop floor environment leads to remarkable productivity improvements.

2.6.10 Equipment Replacement

There are many ways to make the same product. Sometimes all it takes is a very simple tool. New technologies and improvements to equipment should not be overlooked. However, the principle issue is to build in quality and designing operations and equipment so that people are not tied to machines but is free to perform value-added work that is appropriate for humans.
If you invest in new equipment or new technology that requires people to watch them just to make sure they are performing properly, you must ask "Who is working for whom?"

2.6.11 Continuous Improvement

The transition to a lean environment does not occur overnight. A continuous improvement mentality is necessary to reach your company's goals. The term "continuous improvement" means incremental improvement of products, processes, or services over time, with the goal of reducing waste to improve workplace functionality, customer service, or product performance (Suzaki, 1987). Continuous improvement principles, as practiced by the most devoted manufacturers, result in astonishing improvements in performance that competitors find nearly impossible to achieve. Lean production, applied correctly, results in the ability of an organization to learn. As in any organization, mistakes will always be made. However, mistakes are not usually repeated because this is a form of waste that the lean production philosophy and its methods seek to eliminate [8].

CHAPTER - 3
ESTABLISHING CELLULAR LAYOUT

3.1 INTRODUCTION

Companies converting to Cellular Manufacturing (CM) often struggle with implementation and achieve results that are less than anticipated. The reorganization of work necessary to convert from functional to cellular manufacturing (CM) has an impact on an organization's culture. However, organizational culture, acting as a strong barrier to change, also affects how cells are designed and implemented [11].

Conveyors and Skill centers are still well suited for mass production lines. They force everyone to maintain a certain pace and production yield tends to reach the estimated levels. But they are not suited for wide-variety small lot production lines, however, because they require simultaneous changeover for the whole line and this creates changeover waste [12].

Cellular manufacturing emerged as a production strategy capable of solving the problems of complexity and long manufacturing lead times in batch production.

3.2 CELL DESIGN

Cell Layout Categories:
There are many shape designs depending on the type of product: Is it continuous on product or variety of products.

- U– Shaped Cell
- L - Shaped Cell
- II - Shaped Cell
- S – Shaped Cell

U – Shaped Cell is ideal As per Toyota Sewing System:

U-Shaped design creates better employees movement from the inside of the work area. The leader will be in charge of the first and last process for monitoring the quality and the output.

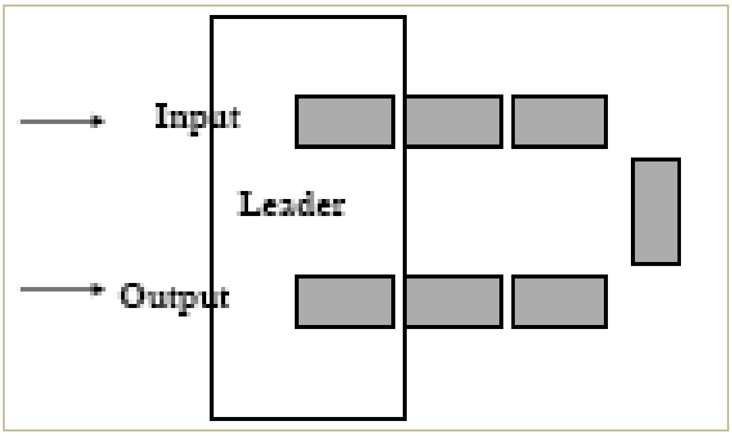


Figure 3.1: U – Shaped Cell

3.3 PLANNING AND PREPARATION TO DESIGN U-SHAPED CELL

3.3.1 Initial Approach with Upper Management

- Commitment from top management, Clarify goals and Expectations
- Selection of Steering Committee (no need if Lean Forum is in place)
- Initial training session with steering committee (related to Manufacturing Cells)
- Define the type and reason of the U-Shaped cell (Is it assembly, total garment, only finishing, etc…based on Value Stream Mapping Analysis)
- Configuration of modular? Stand up vs. sit down?
- Get approval of "Plan" from top management and reaffirm corporate commitment
- Top management meets with staff to communicate commitment
- Pick an area for Pilot Site and Select Class-room training sessions with management staff
- Announcement to the entire workforce

3.3.2 Preparation Set Up of U – Shaped Cell

- Select one family of product for operations analysis.
- Analyze operations breakdown and critical path *(where parts must join for continuous flow)*
- Design tools and method for critical path to reach the hands of next operator.
- Machines Limitation? Specialty machines? Amount of spares equipment?
- Regroup the operations by type of machines as possible as you can for better machineries utilization. *(Follow the value flow no the process)*
- Simulate and determine the best number of workers for better machineries utilization.
- Define all tools and equipments required to set up the U-Shaped cell *(for materials storage, tools, visual control and handling).*
- Design an area if requires for quick changeover

3.3.3 Design U – Shaped Cell

- The Input must be designed from the side where is identified for the pick up of the operator, to avoid Excess motions.
- The evacuation or drop to second operator must be to the side of the next machine or from the rear of current machine.

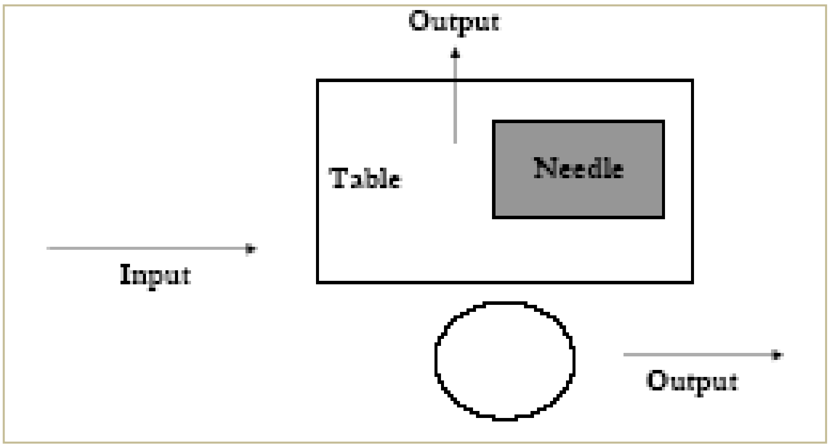


Figure: Economic Pick up & Evacuation to avoid Excess motions

- The evacuation or drop to second operator must be to the side of the next machine or from the rear of current machine.
- Reduce the travel distances for all parts required or balancing action.
- Design tools where parts could be placed close to the machine
- Design side tables where minimum and maximum inventory can be noticeable with a glance.
- Implement Visual controls indicators that team members can visualize easily.
- Place the machineries as close as to each other for quick flow
- Assure parts movement close to next operators hands
- Determine extra space for additional machineries for support when is needed.

3.4 PLANNING, PREPARING AND STABILIZING THE CONCEPT

If it is trial concept, the core team must assure the best selection methodology that suits the core objectives. Trial concept is initiated to develop best practices, so having positive attitude and good skill workers make much easier to successfully achieve the objctives.

3.4.1 Selection of the team

Method One:
Management typically, selects operators for its first module in the 95% to 120% range performance. The selection process begins by looking at a number of criteria.

Criteria (1)	Skilled operators (as per product selection)
Criteria (2)	Flexibility
Criteria (3)	Attitude
Criteria (4)	Attendance
Criteria (5)	Quality

Method Two:
Management selects two team leaders, who then select the remainder of the team.
The goal here is to select two outstanding operators. Team members actively participate in the selection process. This typically helps to form a bond or commitment within the team. Members should be capable to get along.

3.4.2 Evaluation Prior to Implementation

This is related to layout design, handling, 5S and visual management

- Evaluate the Ergonomic Aspect of the Set up
- Assure Pathway is clear as per compliance
- Assure the set up is based 5S and visual management System
- Assure parts are at the reach of each worker without incurring any Waste
- Assure measurements systems are in place for workers to monitor the corporate objectives
- Assure the special machineries are used efficiently
- Assure the Non start buffer is visually indicated

3.4.3 Management System, Responsibilities and Procedures

Management system and procedures must be set such as Kanban, Visuals, Quality at the source, etc.

Further to Kaizen Events, the leader has to standardize the developed ideas within the new concept.

- Anticipated levels of inventory?
- Procedures for quality and handling repairs?
- Quality Procedures? In-Line? Audits? Quality grades?
- Operating procedures? Size of Cut lots? Bundles sizes? Pay coupons?
- Supplies - threads, tickets, etc.?
- Level of group participation in decision-making? What kind of decision?
- How to cover for absenteeism?
- Procedure for selecting the team? By efficiency levels ? Volunteers? Self-selection ?
- Type of incentive Pay Plan?

Skill, Management system and Investment:

- Define Skill Requirement
- Set Training / Cross training programme as per Skill requirements?
- Supervision role?
- Start-up Costs? Moving machines, operators training costs?
- Start and time frame?

3.4.4 Team Criteria

Three criteria that the members should remember:

- Team must perform a complete task
- Team work together to achieve objectives (quality, cost, lead-time)
- Their Pay is a result of group performance

3.4.5 Flexibility Development

Once the contingency plan is made, there should be a listing of topics in addition to who will need to be cross-trained? Cross training must be completed before launching line balancing kaizen event. Need to integrate the management information system into the Flexibility Development.

- Define Skill Requirement (as per operation simulation of the value stream)
- Evaluate Team Members Skill (Use an operation matrix to determine the cross – training requirement)
- Create Cross – Training plan:
  - ✓ Skill development (members could help each other)
  - ✓ Machineries adjustment
  - ✓ Quality requirements, measure, adjust and correct
- Teach about Lean:
  - ✓ Why team work? Advantages to the conventional system
  - ✓ Objectives, Rules and Policies
  - ✓ Quality Policies
  - ✓ 5S, Quick Changeover, Zero Defect Quality
  - ✓ Introduction to all reports and documents
  - ✓ Cell Design and procedures
  - ✓ Role of members and Leader
- Scientific elements (Takt time, Leveling, balanced flow, etc)
- Team activities (empowerment, involvement, etc.)

CHAPTER - 4
ORGANIZATIONAL PROFILE

4.1 FACTORY PROFILE

XY Apparels Ltd. is an export oriented vendor located in Karnapara, Saver, Dhaka.

XY Apparels Ltd. typically operates on FOB Basis with average plant efficiency of 33%. Given this poor performance compared to world standards it is clear that a major improvement in productivity could turn the manufacturing activities into profitable operations and thereby enable XY Apparels Ltd. to absorb the reduction in prices. Obviously, the financial performance of the entire plant is keyed to the performance of the sewing machine operators and other line employees, working on SMV (direct labor).

XY Apparels Ltd. produces range of Knitwear as styling depends on market requirement and orders availability. Their core competency relies on Knitted Garments. The main buyers are ZARA & BERSHKA on high season.

XY Apparels Ltd. total workforce consists of 2808 employees of which 2527 workers are directly involved in the manufacturing process split over 36 production lines with 26 operators per line and 12 helpers.

4.2 MANAGEMENT SYSTEM ATTRIBUTES

4.2.1 Quality Practices

Workers :

- Workers are not well informed regarding Quality issues before starting the production.
- No training on new style about Quality Issues to SMO.
- After entering the input the line QC checks the Quality of the garments.
- Not given any paper or written documents to the SMO related to Quality.
- There is not any pre-discussion with SMO, discussion only when problem rise.

Line QC :

- Line QC Receives measurement sheet form the Quality Control Manager.
- Line QC sends Production report regarding quality to the Quality Manager per day.
- Line QC doesn’t attend PP meeting.

End Line QC :

- Hourly Quality report to the manager but not practicing.
- Measurement sheet on board by Line QC.

Quality Auditor :

- Informed about all Quality issues from P.P. Meeting.
- After P.P meeting QA arrange meeting with Line QC about quality issues.

Quality Control Manager :

- Arrange a meeting after P.P Meeting regarding Quality
- Participants: Quality Control Manger, Quality Controller, Quality Auditor and Line Quality Controller
- Line chief, Supervisor, SMO don’t attend the meeting
- There is no training activities to SMO regarding Quality
- There no visual control activities to SMO.

4.2.2 Planning Department

- Planning executive (PE) & head of the Operations execute planning according to merchandising dept. info
- PE uses the software (Excel formula) for planning for every dept.
- Planning dept. give the plan to every dept (Knitting, dyeing, cutting, sewing etc. dept.)
- Sewing floor production plan done by PM
- PM see the operators target provided by IE, but doesn’t exactly follow the SMV , he actually do the sewing production plan on experiences
- They do preproduction planning (IE, PM, Line Chief)
- PM decide the line Chief for what style will be running

- According to PM instruction the supervisor go to the cutting to see that style cutting was completed
- Line supervisor collect the cut fabrics & accessories, for that they collect approval from production accounts (using KANDARI soft)
- But some time accessories are not available on time at store
- They are running production some times without ensuring all type of accessories, so they face problem.
- No coordination between what is planned and what is required.

4.2.3 Labor

- Absenteeism is 5-7% but no action plan to control it;
- Following Govt. labor law for labor issues;
- Required no of workers is measured by IE dept. based on SMV but problem in measurement process;
- There is no standardization of job description and job responsibility but they are going to make it standardize;
- No incentive reward system for workers except 100% attendance bonus;
- Arrangement of sewing training for newly recruited helpers which takes 1 month
- Overtime is imposed in many of the cases averaging 3 hours per day per worker
- XY Apparels Ltd. is going to arrange worker awareness program
- Management is going to introduce KPI for worker and supportive management and after that reword or inventive will be provided based on it.

4.2.4 Industrial Engineering

- Using GSD to establish minutes.
- Despite using GSD, Targets are adjusted manually based on production recommendations
- When target is not achieved, adding extra workers as the ultimate solution
- They do not include time of (Helper) in SMV
- Helpers are contributing to the SMV which false the productivity calculation
- SMV data and skill inventory are available
- Cutting plan is prepared based on cycle time

- Training school is available.
- One month training for fresh operators.

4.3 FACTORY PERFORMANCE

Performance improvement is suffering at all levels causing an increase in the unit' cost. XY Apparels Ltd. unknowingly invests significant amounts of resources into unprofitable product lines or activity, rather than concentrating efforts on more profitable products and added-value activities.

4.3.1 Financial Issues

Based upon on-site observations, It found that SMV in relation to the production process covering the operations is based on predetermined time system, such as those developed by GSD etc. There are many instances discrepancy and misleading data in unit costing and productivity analyses. Productivity analysis is based only on sewing operators as a result they do not reflect the reality of factories practices in which 12 helpers in each line are contributing to this SMV.

4.3.2 Production and set-up issues

Variation in SMV (Standard Minutes Value) is very high as there are no industrial engineering follow-ups to transfer methods to workers as designed. Moreover to that, the activities are not standardized so that every activity can be performed in the same manner. Therefore machine operators are doing their job as they want resulting different method adaptation for same operation in different work stations.

Variation in SMOP (Sewing Machine Operator' Paste**)** due to workers skill specialization. Workers paste fluctuates continuously leading to lack of balancing amongst workstations. Workers are more individual players rather than team player. Lack of Line balancing is averaging in **41%.**

"Production lines" are too large employing large numbers of employees. This makes it impossible to handle order less than 4 days of production in term of line balancing and production loading to each workstation on a continuous flow in the current condition of parts handling.

Machineries changeover in the course of style change is extremely high averaging in 44.92 minutes per employee per day. Workers must change location depend on layout planning creating another unavoidable delay related to labor utilization. This concept will make it difficult if XY Apparels Ltd. move into only 5 to 8 days production.

"Machineries Adjustment" to the quality standards and the sewing norms is totally dedicated to the maintenance department and sewing operator are not trained yet to undertake any minor adjustment or to adjust the machine back in case of quality issues. Therefore the time taken to take precaution action for any malfunction of machineries, are very high affecting the total supply chain, one is down the entire chain is down. In many cases sewing operators are idle while the mechanics staffs are feeding and setting new production line.

4.3.3 Labor Issues

Sewing machines operators are not performing as well as they can despite the great dexterity and high speed they have. Due to lack of systems and work methods, this speed hasn't been put into a continuous motion and high productivity and as a result is a major contributor to hesitation, delays, and poor performance. The key to improvement is the middle management and the integration of industrial engineering activities. The more skills and knowledge they have the easier to improve the situation quickly.

Absenteeism among the direct workers represents 7% which is significant. This clearly indicates that there is lot of reasons which generates within XY Apparels Ltd. for the employees to be absent that ultimately cut into the productivity.

4.3.4 Management Issues

Line Staffs and middle management aren't objective oriented in relation to cost and lead time. Line supervisors' act as general workers, middle management is chasing orders troubleshooting, and there is no creativity input from the work-studies staffs to the production lines.

Lack of "Industrial Engineering" through the cutting and sewing processes had resulted in a big factor of delay for the cutting workers and sewing operators. Work-studies staffs' role is to seek the most economical and practical method of flowing the parts from the previous to the next operation and then implementing this among the sewing operators and manual workers rather than having batches of chain.

There's no costing analysis per section based on product - buyers – unit costing to determine the product profitability and to specify the areas of improvement through the development and production process. This should be done on a daily basis. The factories have a hard time in evaluating the losses and overcoming the problems in order to eliminate excess costs and to improve profitability. Reducing unit price becomes a puzzle for them. Learning the techniques of problem solving and troubleshooting is must to continuously improve.

4.3.5 Quality Issues

Quality is suffering at all levels, resulting in time waste. Generally, quality cost is too high due to lack of knowledge of the quality standards and flexibility on behalf of the sewing operators. Information relative to the buyer quality criteria is not communicated to the line people in many cases.

So awareness of quality improvement techniques, initiation to the quality requirement and what is expecting as quality result don't get to those best able to use them, the sewing operators.

CHAPTER - 5

WORK PLAN: CURRENT STATE

5.1 ASSESSMENT (CURRENT STATE)

This Lean assessment process is used as a getting-started tool to identify the waste that blocking corporate performance. Both qualitative and quantitative, the assessment covers 8 wide-ranging categories — from material and information flow, to process razing and to problem-solving. A quantitative score helps to measure progress year-over-year, while qualitative feedback includes specific details, information on broad trends and issues as well as suggestions on how XY Apparels Ltd. can eliminate the waste meeting the management desired state.

The Lean assessment study covers the Manufacturing Processes such as: Cutting, Sewing, Finishing, Packing and Cartooning.

XY Apparels Ltd. data:

Daily Working hours:	8 hours
Daily Overtime Peak season	2 hours
Yearly Working Days:	295
Selected Product for mapping:	Long sleeve T-shirt
Absenteeism:	7%
Selected Production line:	Line: V
Days for order changeover:	4 Days

5.2 LEAN METRICS - FINDINGS

Table 5.1: Lead Time and Time Utilization Analysis

Factory Name: XY Apparels Ltd.		
Product Name: Long Sleeve T-Shirt	Order No: 64674	
Buyer: Zara	Style: A-04	Line: V

Methods of Measurement: VSM (Value Stream Mapping)						
Activity category	**Details**	**Cutting** *(Minutes)*	**Sewing & Finishing** *(Minutes)*	**Finishing (Cartooning)** *(Minutes)*	**Current State** *(Minutes)*	
Value added		95	188.85	2.75	286.60	**11%**
Unavoidable Non Value Added Activities	Marking Spreading Quality inspection Folding , unfolding Trimming Bundling Sorting Travel to next operation Travel to next process	138	3.28	5	146.28	**5%**
Non Value Added Activities	Waiting for next operation Waiting for next process	1179	1006	60	2245.00	**84%**
Processing time *(Value Added and Unavoidable Activities)*		233.00	192.13	7.75	432.88	**16%**
Retention time *(Non Value Added Activities)*		1179.00	1006.00	60.00	2245.00	**84%**
			Lead Time		2677.88	**4.06 Day**

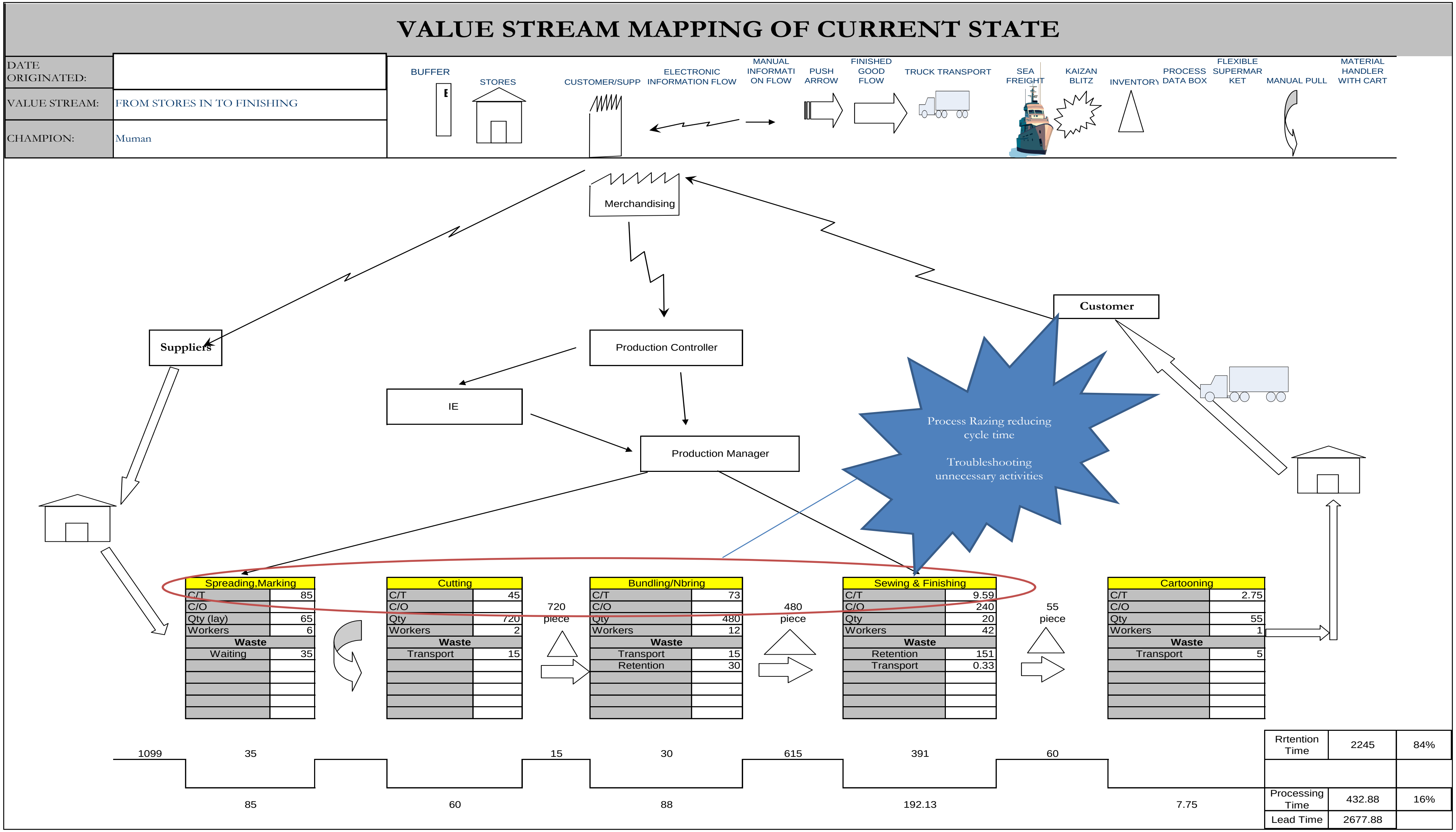


Figure 5.1: Current Map

Table 5.2: Unavoidable Activities

Unavoidable Activities				
	Production/Day:		50000	Pieces
Activities		**Minute/pc**	**Minute per day**	**Methods of Measurement**
1	Stickering	0.500	25000	VSM & Cycle Time Based
2	Bundling	0.031	1550	
3	Marking	0.215	10750	
4	Transport	0.190	9500	
5	Loading	0.120	6000	
6	Sorting	0.350	17500	
Total Time		**1.406**	**70300**	
Manpower used Due to Unavoidable Activities				117

Table 5.3: Inventories and Work In Progress

Inventories and WIP					
Plant:	**XY Apparels Ltd.**		**Daily Target sewing (pieces)**		**50000**
Dept	**Pieces not start**	**Reasons**	**Pieces in Progress**	**Inventories (days)**	**Total Days of Inventories per process**
Cutting	83331	Waiting to be cut	7046	1.81	1.81
Sewing	72000	Waiting to be sewn	18000	1.80	3.61
Finishing	1800	Waiting to be finished	6000	0.16	3.764
Total	**157,131**		**31,046**	**4**	

Table 5.4: Quality Rework Analysis

Quality Rework				
Floor: FKGL	**Buyer: Tom Tailor**	**Order No: 686**	**Line No: G**	
Group	**Type of Rework**	**Total Defect Quantity**	**Rework time/pieces**	**Total Rework time/day**
Label	Label Missing	2	0.98	1.96
	Wrong size	4	1.65	6.60
	Poor Stitching	3	1.15	3.45
Neck/ Collar /Placket	Broken Stitch	1	0.97	0.97
	Skip / Miss stitch	1	1.35	1.35
	Over Lapping	2	1.2	2.40
	Shading Placket	1	1.2	1.20
Sleeve / Side Seam Attach	Skip / Miss stitch	2	1.35	2.70
	Oil / Stain Mark	1	2.15	2.15
	Puckering	1	1.24	1.24
Sleeve/Bottom Hem	Open Seam	1	1.7	1.70
Total Rework Quantity		**19**		**25.72**
Average time/rework				1.35
Daily sewing rework				7524
Total rework time/day				10,185.12
Total worker				2527
Rework/day/worker				**4.03**

Table 5.5: Changeover Time Analysis

Changeover Time			
Measurement Keys	**Waste**	**Current State**	**Remarks**
Order Changeover	Machines Adjustment	240	Basic T-shirt / Tang top/ Set (top or bottom) / Polo shirt
	Operators movement		
	Machines Movement		
	Training		
Monthly changeover			180
Monthly changeover time (min)			43200
Total Worker / Line			32
Days for order changeover			6
Changeover/day/ worker			**40.00**

Table 5.6: Productivity Analysis

Productivity	
Factory Name: XY Apparels Ltd.	
Order No: 64674	Dept: Sewing
Buyer: Zara	Product Name: Long Sleeve T-Shirt
Style: A-04	Line: V
Total Manpower	32
SMV	3.2
Output	2200
Working min	660
Productivity	33%

Table 5.7: Time Utilization Analysis

<table>
<tr><th colspan="11">Time Utilization - Monthly</th></tr>
<tr><th colspan="11">Current State</th></tr>
<tr><td colspan="7">Lead time: 4.06 Days</td><td colspan="4">Total Direct Labor: 2527 Workers</td></tr>
<tr><td colspan="7">Days per months: 26 Days</td><td colspan="4">Minutes Worked per Day: 660 Minutes</td></tr>
<tr><th colspan="11">Data Simulation</th></tr>
<tr><th rowspan="2">Items</th><th rowspan="2">Worked Minutes</th><th rowspan="2">Description</th><td rowspan="2">Absenteeism (min)</td><th colspan="4">Before Production</th><th colspan="2">During Production</th><td rowspan="2">Time Utilization</td></tr>
<tr><td>Changeover</td><td>Feeding /Cleaning</td><td>Quality</td><td>Delays</td><td>Line Balancing</td><td>Others</td></tr>
<tr><td rowspan="4">Current</td><td rowspan="4">43,363,320</td><td>Minutes Loss</td><td>3,035,432</td><td>2,628,080</td><td>323254</td><td>264,779</td><td>93,954</td><td>11,235,699</td><td>6,445,530</td><td rowspan="4">44.60%</td></tr>
<tr><td>% of total waste</td><td>12.60%</td><td>10.90%</td><td>1.30%</td><td>1.10%</td><td>0.40%</td><td>46.80%</td><td>26.80%</td></tr>
<tr><td>% Loss</td><td>7.00%</td><td>6.06%</td><td>0.75%</td><td>0.61%</td><td>0.22%</td><td>25.91%</td><td>14.86%</td></tr>
<tr><td>Minutes Available</td><td>40327888</td><td>37699808</td><td>37376554</td><td>37111775</td><td>37017821</td><td>25782122</td><td>19336591</td></tr>
</table>

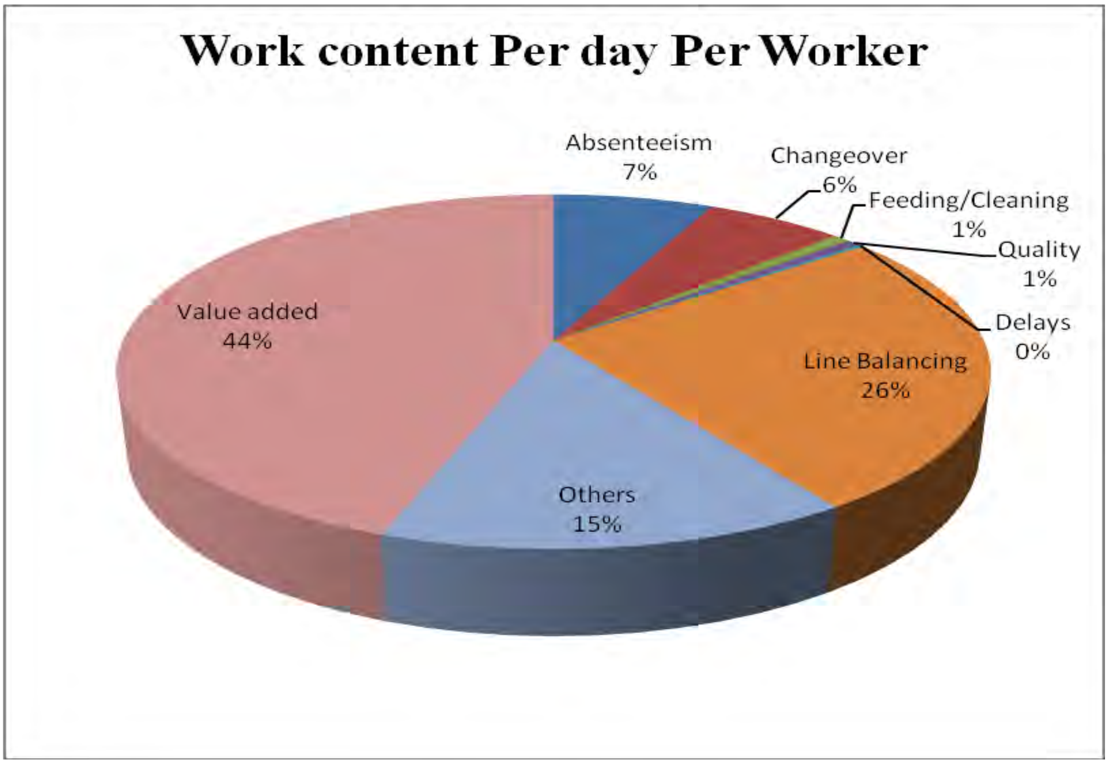


Figure 5.2: Work content per day per Worker

Table 5.8: Summary of Current State

Corporate Measurement Keys	Unit of Measure	Value
Line Efficiency	Percentage	33%
Time Utilization	Percentage	44.60%
Cycle Time (Long sleeve T-shirt)	Minutes	4.90
Total Quality Rework Time	Minutes / Day	10,185
Daily WIP – Factory	Pieces In progress	31046
	Pieces at initial start up	157130.8
Daily Output	Pieces Per Factory	50000
Total rework time/day		10,185.12

Table 5.9: The wide-ranging categories affecting the Cost and Lead Time

	Categories *(affecting operating Cost)*	Findings: Metrics	Findings: Loss
1	**Order Changeover**	• Machineries movement and adjustment • Feeding and flashing the line	40 min/day/worker
2	**Unnecessary activities**	• Stickering • Bundling • Marking • Loading • Sorting • Transport	0.50 min/piece 0.031 min/piece 0.215 min/piece 0.12 min/piece 0.35 min/piece 0.19 min/piece
3	**Rework**	• Over-processing by workers	4.03 min/day/worker
	Categories *(affecting Lead time)*	**Findings**	
4	**WIP (Work In Process)**	• Waiting to be cut • Safety Stock to be sewn • Waiting for Finishing	83330 pieces/day 72000 pieces/day 1800 pieces/day
5	**Retention Time**	• Material Waiting Time	2245 min
6	**Processing Time**	• Flowing Materials	432.88 min
	Categories *(affecting additional Capacity)*	**Findings**	
7	**Underutilized Resources**	• Space Utilization • Excessive Workers (due to category 4, Unnecessary activities) • Turnover WIP	25.92 sqft/worker 117 Workers 4 Days

- **Turnover WIP** (not taking into consideration the time in relation to materials in the warehouse & in the store)

CHAPTER – 6

IMPLEMENTING TRIAL PILOT (CELLULAR LAYOUT)

6.1 CELLULAR MANUFACTURING (CELLULAR LAYOUT)

Trial Pilot is based on **Cellular Line**. It is the effective Layout System for better Productivity as well as flexibility for the production.

Cellular manufacturing is an approach that helps manufacturing a variety of products with as little waste as possible. Equipment and workstations are arranged in a sequence that supports a smooth flow of materials and components through the process, with minimal transport or delay.

Figure 6.1: Cellular Line

Figure 6.2: Traditional Line

- Cellular manufacturing can help make the company more competitive by cutting out costly transport and delay, shortening the production lead time, saving factory space that can be used for other value-adding purposes, and promoting continuous improvement by forcing the company to address problems that block low-inventory production.
- Cellular manufacturing helps employees by strengthening the company's competitiveness, which helps support job security. It also makes daily production work go smoother by removing the clutter of WIP inventory, reducing transport and

handling, reducing the walking required and addressing causes of defects and machine problems.

6.2 COMMON BENEFITS ASSOCIATED WITH CELLULAR LINE

- Eliminating unnecessary activities *(Time saving)*
- Reduced Retention time *(Lead time – Throughput)*
- Minimized WIP *(Work In Process)*
- Changeover time reduction
- Quality improvement
- Enhanced teamwork and communication
- Enhanced flexibility and visibility
- Better Line balancing
- Productivity improvement

6.3 ACHIEVEMENTS

6.3.1 Efficiency Status

Efficiency of Labor is defined as the standard time generated from the total time worked during the reporting period.

Table 6.1: Comparison of Efficiency Status

Efficiency Status							
BUYER : ZARA		STYLE : A-03		SMV: 4.72		Total Working Hour: 10	
Line Type	**Manpower**	**Operator**	**Manual Operator**	**Total production /day**	**Pieces/ Worker /Day**	**Efficiency**	**Improvement in Efficiency**
Traditional Line	40	27	13	2138	53	42%	43%
Cellular Line	15	14	1	1140	76	60%	

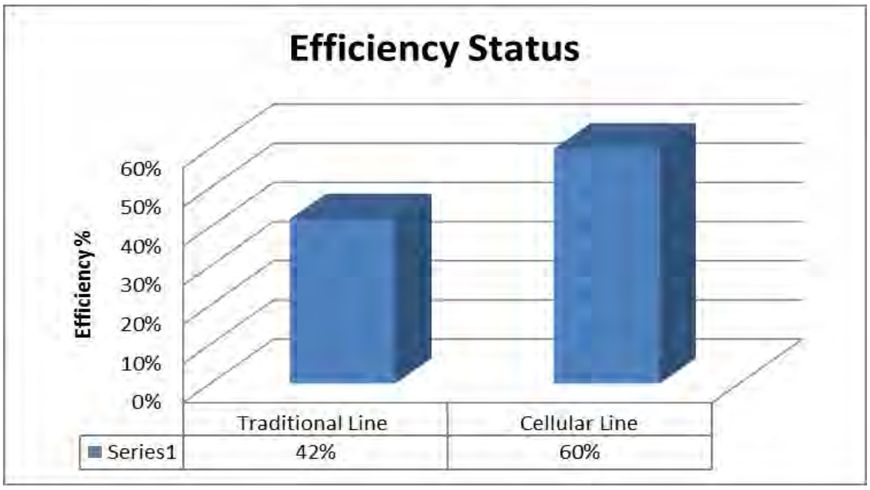


Figure 6.3: Efficiency Status

6.3.2 Quality Status

In the modular production team the quality grade is monitored regularly. So the rate of alter is low due to continuous inter workstation training and instant rework of the alter garment. The quality standard is informed to the worker.

Table 6.2: Comparison of Quality Alter

Quality Status				
Line	**Production**	**Quality Alter**	**Quality Alter %**	**Reduction in Quality Alter**
Traditional Line	2138	210	9.82	54%
Cellular Line	1140	52	4.56	

Figure 6.4: Quality Status

6.3.3 WIP Status

Work In process (WIP) means the pieces of materials or job waiting between operation steps to be processed.

Table 6.3: Comparison of WIP Status

Line	WIP (Work In Process) (pieces)	WIP Reduction
Traditional Line	430	67%
Cellular Line	140	

Table 6.4: Comparison of Line Balancing Status

Line	Line Balancing	Improving Line Balancing
Traditional Line	68 %	25 %
Cellular Line	85 %	

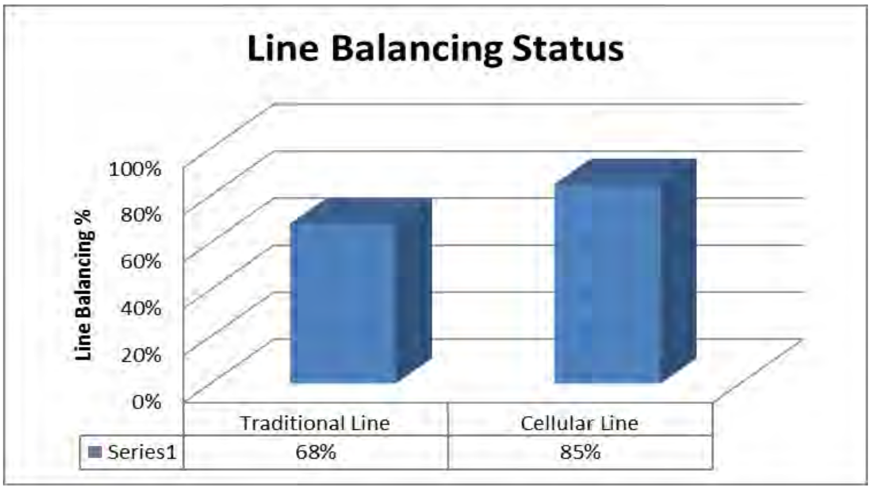


Figure 6.5: Line Balancing Status

6.3.4 Changeover Time Status

Changeover Time is the Elapsed time between the last good piece of previous product, and the first good piece of next product at the right speed.

Table 6.5: Comparison of Changeover Time

Line	Changeover Time in Min	Changeover time Reduction
Traditional Line	240	63%
Cellular Line	90	

6.3.5 Throughput Time Status

Throughput time is the total time required from "input" to "output" of finished quality garment. In the traditional line the Throughput time is high due to huge WIP in relation to the modular line where the WIP is low and the lead time is short.

Table 6.6: Comparison of Throughput Time

Line	Throughput time in Min	Throughput time Reduction
Traditional Line	180	56%
Cellular Line	80	

6.4 OVERALL SCENARIO

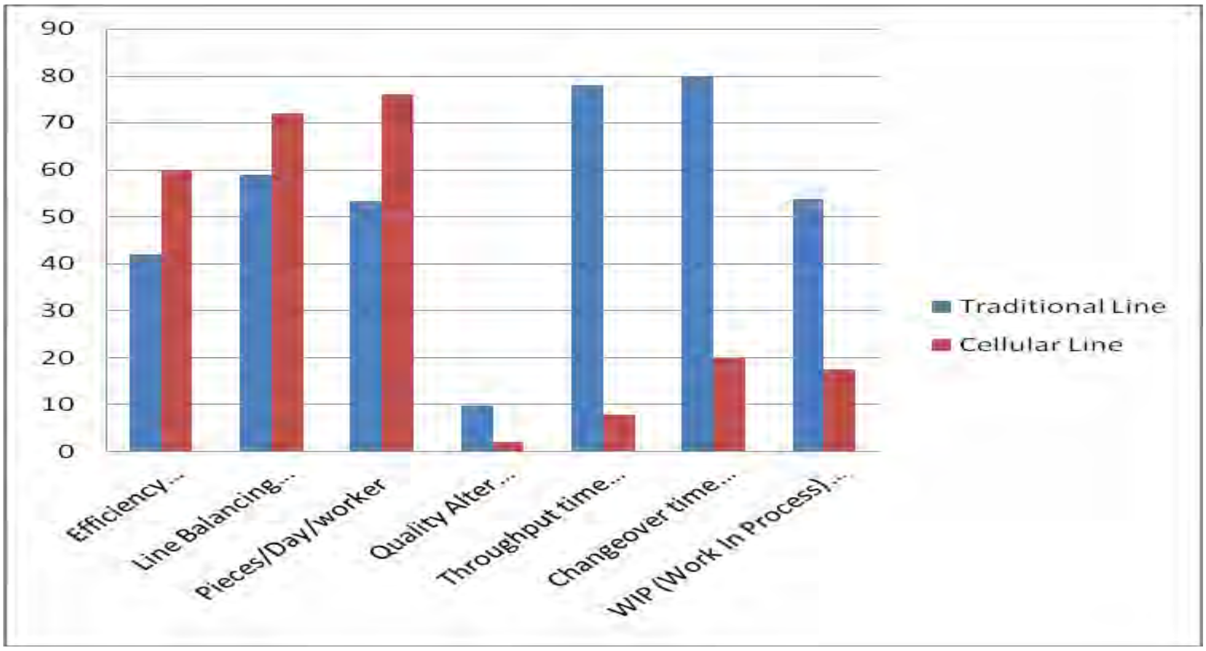


Figure 6.6: Overall Comparison between Traditional Line & Cellular Line

CHAPTER – 7

IMPLEMENTING LINE BALANCING ALGORITHMS

7.1 INTRODUCTION

A flow line can be divided into elemental tasks. Each of these tasks will require a specified time to complete. It also has a sequential relationship with other tasks in the flow line. In order to ensure that the line is run efficiently, efforts have to be made to balance the line.

The line balancing problem is to arrange the individual processing and assembly tasks at the workstations sothat the total time required at each workstation is approximately the same.

If the work elements can be grouped so that all the station times are exactly equal, we have perfect balanceon the line and we can expect the production to flow smoothly. In most practical situations it is very difficult to achieve perfect balance. When workstation times areunequal, the slowest station determines the overall production rate of the line.

7.2 OBJECTIVES OF LINE BALANCING

1. To minimize the total amount of unassigned or idle times at the work station.
2. To eliminate bottlenecks, ensuring a smoother flow of production.
3. To determine the optimal number of work stations and operations in each station.
4. To maintain the morale of workers since the work content of the different workers will not be of great difference.
5. To maximize the manpower utilization by minimizing the idle times of the operators.
6. To minimize intermediate stock or work-in-progress(zero inventory or just-in-time concept).
7. To improve the quality and productivity of the FinalProducts.
8. To reduce waste of production and delay.

7.3TERMINOLOGY FOR LINE BALANCING

7.3.1 Minimum Rational Work Element (Cycle Time)

The length of work time, or operating time, that a product is available at each work station is the cycle time. It is the amount of time available for a worker at a work station to complete his work. It determines the maximum time allowed for any operation with the required output.

Minimum Rational Work Element(Cycle Time) is the smallest practical indivisible task time into which the job can be divided.

T_{ej}: where j is used to identify the element out of the n_e elements that make up the total work.

7.3.2 Total Work Content&Takt Time

Total work, T_{wc}, content is the aggregate of all the work elements to be done on the line.

$$\text{Twc} = \sum_{j=1}^{ne} \text{Tej}$$

$$\text{Line Balancing Takt Time} = \frac{\text{Total Work Content, Twc}}{\text{Number of Workstation, n}}$$

7.3.3 Bottleneck Cycle Time

Bottleneck Cycle Time, T_c, is the ideal or theoretical cycle time of the Production line, which is the time interval between partscoming off the line.The minimum possible value of T_c is established by the bottleneck station, the one with the largest value.

$$T_c \geq T_{ej}$$

7.3.4 Precedence Constraints

Technological sequencing requirements, the order in which the work elements can be accomplished is limited.

7.3.5 Precedence Diagram

Agraphical representation of the sequence of work elements as defined by the precedence constraints.

7.3.6 Balance Delay (Balancing Loss)& Line Balancing Efficiency

Balance delay is a measure of the line inefficiency which results from idle time due to imperfect allocationof work among station.

$$\text{Balance Delay} = \frac{(\text{Total Workstation Time - Total Work Content})}{\text{Total Workstation Time}} \times 100\%$$

$$\text{Balance Delay, d} = \frac{nTc - Twc}{nTc} \times 100\%$$

Here, n = Station Number

Line Balancing Efficiency = (100- Balance Delay) %

$$\text{Line Balancing Efficiency} = \frac{\text{Takt Time}}{\text{Bottleneck Cycle Time, Tc}} \times 100\%$$

7.4 STEPS FOR LINE BALANCING

1. Determine tasks (operations) & task times.
2. Determine sequence of tasks.
3. Draw precedence diagram.
4. Determine the Total Work Content &Takt Timerequired.
5. Determine the theoretical minimum number of Work Stations required, n. This is done by adding up all the task times and dividing the Total Work Content by the Takt Time.
6. Select either the Kilbridge&Wester method or the Rank Positional Weights Method to allocate task elements to each work station.
7. Each work station should not exceed the cycle time determined earlier. Use a table, setting out the work stations from left to right.

8. Use the Longest Operation Time (LOT) rule; select the task with the longest operation time next. Consider adding to the station any task whose time fits within the remaining time for that station.
9. Ensure that the sequencing is in order, even for the task elements in each station. Precedence relationships may interfere with assigning two tasks to the same workstation.
10. Ensure that the restrictions or constraints for the flow line are adhered to.
11. Analyze the balanced flow line to improve efficiency and to reduce idle times. An efficient balance will minimize the amount of idle time.
12. Calculate the idle times, and hence the Balancing Loss (Balancing Delay) or Line Efficiency.

7.5 ASSEMBLY LINE BALANCING

Manual Assembly Lines are used in high-production situations where the work to be performed can be divided into small tasks andtasks assigned to the workstations on the line.

Key advantage of using manual assembly line is specialization of labor –By giving each worker a limited set of tasks to do repeatedly.

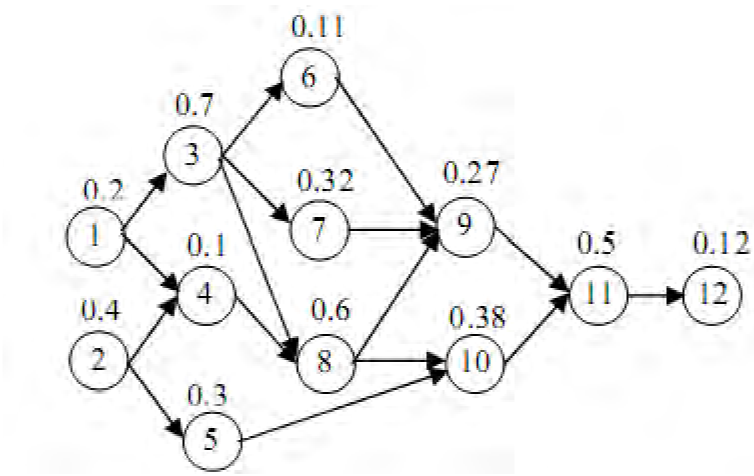
Table 7.1: Work Elements for Ladies T-Shirt Sewing

Work Elements			
Buyer: H & M		Style: Ladies T-Shirt	
Order: 943456		Dept: Sewing	
No.	Element Description (Operation)	Average Cycle Time Tej (min.)	Must be Precedence by
1	Front Part, Back Part & Hanger Loop Match	0.20	….
2	Two Sleeve Match & Shoulder Tape Cut	0.40	….
3	Front & Back Neck Pipping	0.70	1
4	Shoulder Band Prepare	0.10	1,2
5	Sleeve Hem	0.30	2
6	Care Label Make	0.11	3
7	Motif Folding & Tuck	0.32	3
8	Shoulder Join & Lace Folding	0.60	3,4
9	Side Seam	0.27	6,7,8
10	Lace Join with Sleeve	0.38	5,8
11	Sleeve Edge Seam & Sleeve Join	0.50	9,10
12	Body Hem	0.12	11
Total Work Content, Twc (min.)		**4.00**	

Here, Total Work Content, Twc = 4 minutes

Bottleneck Cycle Time, Tc = 0.7 minutes

7.5.1Precedence Diagram



$$\text{Line Balancing Takt Time} = \frac{\text{Total Work Content, Twc}}{\text{Number of Workstation, n}}$$

$$= \frac{4 \text{ minutes}}{12}$$

= 0.33 minutes

Bottleneck Cycle Time, Tc = 0.7 minutes

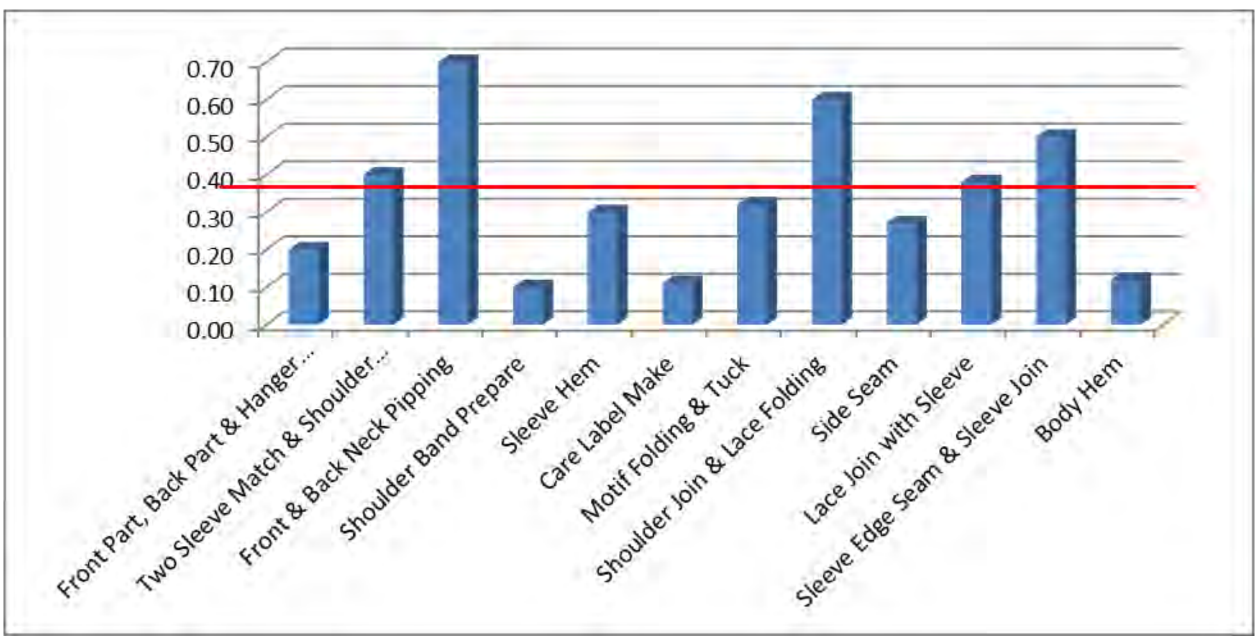


Figure 7.1: Assembly Line Balancing

7.5.2 Performance Criteria for Assembly Line Balancing

Balance Delay is ideal time over paid time.

$$\text{Balance Delay} = \frac{\text{(Total Workstation Time - Total Work Content)}}{\text{Total Workstation Time}} \times 100\%$$

$$\text{Balance Delay, d} = \frac{nTc - Twc}{nTc} \times 100\%$$

Where Total Workstation Time = No of Stations X Tc

$$\text{Balance Delay, d} = \frac{12 * 0.7 - 4}{12 * 0.7} \times 100\%$$

$$= 52\%$$

Line Balancing Efficiency = 100% - 52% = 48%

7.6LINE BALANCING ALGORITHMS

1. Largest Candidate Rule (LCR)
2. Kilbridge and Wester Method (KWM)
3. Ranked Positional Weights Method (RPW)

7.6.1 Largest-Candidate Rule (LCR)

Procedure for Largest-Candidate Rule (LCR)

Step 1. List all elements in descending order of Tej value, largest Tej at the top of the list.

Step 2. To assign elements to the first workstation, start at the top of the list and work done, selecting the first feasible element for placement at the station. A feasible element is one that satisfies the precedence requirements and does not cause the sum of the Tej value at station to exceed the Bottleneck Cycle Time Tc.

Step 3. Repeat step 2.

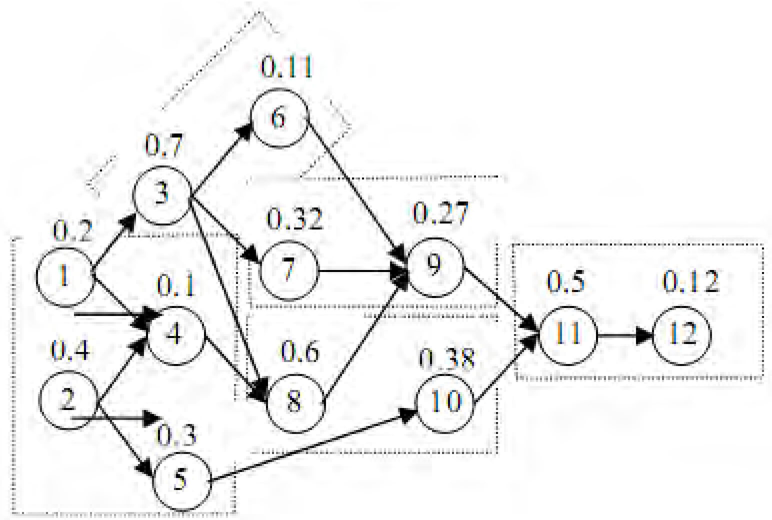
Step 1.

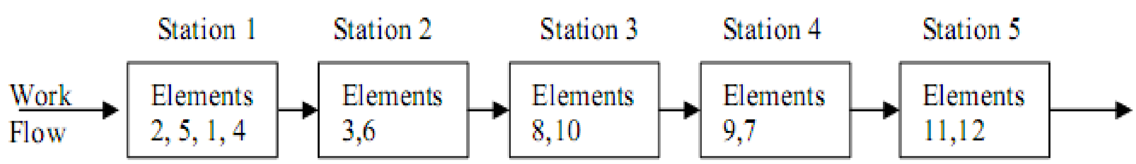
Work Element	Average Cycle Time Tej (min.)	Immediate Predecessor
3	0.7	1
8	0.6	3,4
11	0.5	9,10
2	0.4	….
10	0.38	5,8
7	0.32	3
5	0.3	2
9	0.27	6,7,8
1	0.2	….
12	0.12	11
6	0.11	3
4	0.1	1,2

Step 2,3. Here the stations are arranged in a manner so that Stations Bottleneck Cycle Time, Tc will not exceed 1.00 min.

Station	Element	Tej	∑Tej at Station
1	2	0.4	1
	5	0.3	
	1	0.2	
	4	0.1	
2	3	0.7	0.81
	6	0.11	
3	8	0.6	0.98
	10	0.38	
4	7	0.32	0.59
	9	0.27	
5	11	0.5	0.62
	12	0.12	

Precedence Diagram





Performance Criteria for Largest-Candidate Rule (LCR)

Balance Delay is ideal time over paid time.

$$\text{Balance Delay} = \frac{(\text{Total Workstation Time - Total Work Content})}{\text{Total Workstation Time}} \times 100\%$$

$$\text{Balance Delay, d} = \frac{nTc - Twc}{nTc} \times 100\%$$

Where Total Workstation Time = No of Stations X Tc

Tc = Max. Station Process Time = Bottleneck Cycle Time = 1.00 minutes

$$\text{Balance Delay, d} = \frac{5 \times 1 - 4}{5 \times 1} \times 100\%$$

$$= 20\%$$

Line Balancing Efficiency = 100% - 20% = 80%

7.6.2 Kilbridge and Wester Method (KWM)

It is a heuristic procedure which selects work elements for assignment to stations according to their positionin the precedence diagram.
This overcomes one of the difficulties with the largest candidate rule (LCR), with which elements at the endof the precedence diagram might be the first candidates to be considered, simply because their values arelarge.

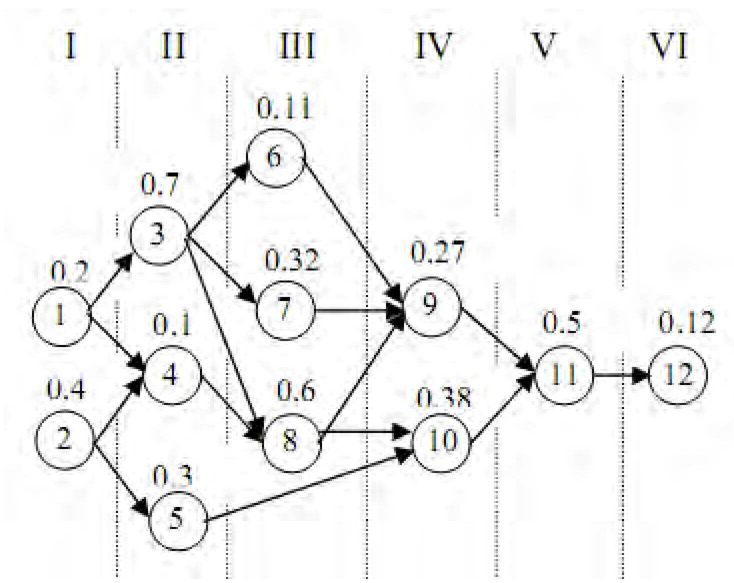
Procedure for Kilbridge and Wester Method (KWM)

Step 1. Construct the precedence diagram so those nodes representing work elements of identical precedenceare arranged vertically in columns.

Step 2. List the elements in order of their columns, column I at the top of the list. If an element can be locatedin more than one column, list all columns by the element to show the transferability of the element.

Step 3. To assign elements to workstations, start with the column I elements. Continue the assignmentprocedure in order of column number until the cycle time is reached (Tc).

Step 1.



Step 2. Work elements arranged according to columns

Work Element	Column	Tej	∑Tej at Column
1	I	0.2	0.6
2	I	0.4	
3	II	0.7	1.1
4	II	0.1	
5	II,III	0.3	
6	III	0.11	1.03
7	III	0.32	
8	III	0.6	
9	IV	0.27	0.65
10	IV	0.38	
11	V	0.5	0.62
12	VI	0.12	

Step 3. Work elements assigned to stations

Station	Element	Tej	∑Tej at Station
1	1	0.2	1.00
	2	0.4	
	4	0.1	
	5	0.3	
2	3	0.7	0.81
	6	0.11	
3	7	0.32	0.92
	8	0.6	
4	9	0.27	0.65
	10	0.38	
5	11	0.5	0.62
	12	0.12	

Performance Criteria for Kilbridge and Wester Method (KWM)

Balance Delay is ideal time over paid time.

$$\text{Balance Delay} = \frac{(\text{Total Workstation Time - Total Work Content})}{\text{Total Workstation Time}} \times 100\%$$

$$\text{Balance Delay, d} = \frac{\text{nTc} - \text{Twc}}{\text{nTc}} \times 100\%$$

Where Total Workstation Time = No of Stations X Tc

Tc = Max. Station Process Time = Bottleneck Cycle Time = 1.00 minutes

$$\text{Balance Delay, d} = \frac{5 \times 1 - 4}{5 \times 1} \times 100\%$$

$$= 20\%$$

Line Balancing Efficiency = 100% - 20% = 80%

7.6.3 Ranked Positional Weights Method (RPW)

Ranked Positional Weights Method (RPW) introduced by Helgeson and Birnie in 1961. This Method Combined the Largest Candidate Rule (LCR) and Kilbridge and Wester Method (KWM).

The RPWtakes account of both the Te value of the element and its position in the precedence diagram. Then, the elements are assigned to workstations in the general order of their RPWvalues.

Procedure for Ranked Positional Weights Method (RPW)

Step 1. Calculate the RPWfor each element by summing the elements Te together with the Te values for allthe elements that follow it in the arrow chain of the precedence diagram.

Step 2 List the elements in the order of their RPW, largest RPW at the top of the list. For convenience,include the Te value and immediate predecessors for each element.

Step 3. Assign elements to stations according to RPW, avoiding precedence constraint and time cycleviolations.

Step 1. Sample Calculation:

For element 1, the elements that follow it in the arrow chain are 3, 4, 6, 7, 8, 9, 10, 11, and 12. The RPW for element 1 would be the sum of the Te's for allthese elements, plus Te for element 1.

Step 2.

Work Element	RPW	Average Cycle Time Tej (min.)	Immediate Predecessor
1	3.3	0.2	….
3	3	0.7	1
2	2.67	0.4	….
4	1.97	0.1	1,2
8	1.87	0.6	3,4
5	1.3	0.3	2
7	1.21	0.32	3
6	1	0.11	3
10	1	0.38	5,8
9	0.89	0.27	6,7,8
11	0.62	0.5	6,10
12	0.12	0.12	11

Step 3. Work element assigned to stations

<table>
<tr><th>Station</th><th>Element</th><th>Tej</th><th>∑Tej at Station</th></tr>
<tr><td rowspan="2">1</td><td>1</td><td>0.2</td><td rowspan="2">0.90</td></tr>
<tr><td>3</td><td>0.7</td></tr>
<tr><td rowspan="4">2</td><td>2</td><td>0.4</td><td rowspan="4">0.91</td></tr>
<tr><td>4</td><td>0.1</td></tr>
<tr><td>5</td><td>0.3</td></tr>
<tr><td>6</td><td>0.11</td></tr>
<tr><td rowspan="2">3</td><td>8</td><td>0.6</td><td rowspan="2">0.92</td></tr>
<tr><td>7</td><td>0.32</td></tr>
<tr><td rowspan="2">4</td><td>10</td><td>0.38</td><td rowspan="2">0.65</td></tr>
<tr><td>9</td><td>0.27</td></tr>
<tr><td rowspan="2">5</td><td>11</td><td>0.5</td><td rowspan="2">0.62</td></tr>
<tr><td>12</td><td>0.12</td></tr>
</table>

Performance Criteria for Kilbridge and Wester Method (KWM)

Balance Delay is ideal time over paid time.

$$\text{Balance Delay} = \frac{\text{(Total Workstation Time - Total Work Content)}}{\text{Total Workstation Time}} \times 100\%$$

$$\text{Balance Delay, d} = \frac{nTc - Twc}{nTc} \times 100\%$$

Where Total Workstation Time = No of Stations X Tc

Tc = Max. Station Process Time = Bottleneck Cycle Time = 0.92 minutes

$$\text{Balance Delay, d} = \frac{5 \times 0.92 - 4}{5 \times 0.92} \times 100\%$$

$$= 13\%$$

Line Balancing Efficiency = 100% - 13% = 87%

7.6.4 Compare LCR, K-W, and RPW

The RPWsolution represents a more efficient assignment of work elements to station than either of the twopreceding solutions.

However, this result is accordingly by the acceptance of Bottleneck Cycle Time, Tc = 1 and make those methodsdifferent.

Table 7.2: Line Balancing Comparison

Traditional Method	**Bottleneck Cycle Time, Tc (min)**	**Balance Delay**	**Line Balancing Efficiency**
Assembly Line Balancing	0.70 min	52%	48%
Line Balancing Algorithms	**Bottleneck Cycle Time, Tc (min)**	**Balance Delay**	**Line Balancing Efficiency**
1. Largest Candidate Rule (LCR)	1.00 min	20%	80%
2. Kilbridge and Wester Method (KWM)	1.00 min	20%	80%
3. Ranked Positional Weights Method (RPW)	0.92 min	13%	87%

7.7FACTORS AFFECTING LINE BALANCING & PROBLEMS ENCOUNTERED

a. There are constraints in operations in terms of style variation, workers skill, machine type, quality requirements etc.
b. The workers in the line have great variations in level of skill and aptitudes for certain jobs. Thus, it is difficult to synchronize the time.
c. Some work content cannot be broken down further into elements.
d. Long operation times can become bottlenecks.
e. The design of parts, shape and size of materials may pose constraints.
f. Special processes, such as printing, embroidery, washing by batch, have fixed sequences.
g. Long set-up times.
h. Small production volumes do not justify the use of line balancing.

CHAPTER - 8

IMPLEMENTINGSTATISTICAL PROCESS CONTROL (SPC)

8.1 INTRODUCTION AND BACKGROUND

The concepts of Statistical Process Control (SPC) were initially developed by Dr. Walter Shewhart of Bell Laboratories in the 1920's, and were expanded upon by Dr. W. Edwards Deming, who introduced SPC to Japanese industry after WWII. After early successful adoption by Japanese firms, Statistical Process Control has now been incorporated by organizations around the world as a primary tool to improve product quality by reducing process variation. Dr. Shewhart identified two sources of process variation: Chance variation that is inherent in process, and stable over time, and Assignable, or Uncontrolled variation, which is unstable over time - the result of specific events outside the system. Dr. Deming relabeled chance variation as Common Cause variation, and assignable variation as Special Cause variation.

Based on experience with many types of process data, and supported by the laws of statistics and probability, Dr. Shewhart devised control charts used to plot data over time and identify both Common Cause variation and Special Cause variation.

The use of statistical techniques to analyze a process or output so as to take its appropriate actions to achieve or maintain a state of statistical control.

Statistical = Use of Data, Graphical, Analysis, Capability

Process = Operation or a group of Operations

Control = Stable and Predictable, decreases Variation

8.2 VARIABLE AND ATTRIBUTE DATA

Variables: A variable is a characteristic which can be measured in units of some kind and over a continuous Scale. Linear Dimensions such as "Seam Width" are typical variables

Attributes: An attribute is a characteristic of a product which is countable rather than measurable. It is either: Present or not, Acceptable or defective, Hit or miss

Examples are "holes or fabric flaws, open seam and puckering". These are all judged to be faults or otherwise

8.3 TYPES OF CONTROL CHARTS

Variables Control Charts			Attributes control Charts	
Type	**What is monitored**		**Type**	**What is monitored**
X-R	Average and Range of a sample		Np	Number of defective parts in a sample
Median	Middle measurement and range of a sample		P	Proportion of defective parts in a sample
Individuals	Individual items and range between items		C	Number of defects in a sample
			u	Number of defects per unit in a sample

Usually Application of two types of charts are found in Garment Industry which are:

i. Variable Chart: Median Charts (X, R)
ii. Attribute Chart: p chart

8.4 STEPS FOLLOWED FOR SPC IMPLEMENTATION

a. Deciding CTQs (Critical To Quality) for both attributes and variables
b. Data collection for control charts (starts after the style has run for 3-4 days in line)
c. Control chart graph plotting for both variables and attributes
d. Calculation and drawing of control limits (first drawn based on the collected data of 8-10 hours)
e. Corrective actions for samples beyond control limits
f. Redefining, calculating and drawing new control limits further
g. Refining CTQs as per requirement

8.5 DECIDING CRITERIA FOR CTQS

Variables:

- Critical measurements are selected and operations are chosen where this measurement gets completely fixed and no chance of any variations in the further operations. It should also be taken care of that the measurement should be taken from the operations as early as possible (from the earliest operation where it gets fixed) for effective corrective actions.

Attributes:

- Critical operations and processes according to operation layout and bulletin
- Operation-wise and defect-wise most problematic processes in terms of highest DHU and repair percentage
- CTQs chosen at the initial stage should be modified as per requirement like addition of new CTQs (highest defect category) and subtraction of processes which are in control

8.6 VARIABLE CONTROL CHARTS

- Control charts for variables are tools that can be used when measurements (linear, volume, temperature, etc.) from a process are available.

- Statistical Terms:
  - Median: The median is the middle value in the list of numbers.
  - R is the range of values within each sample (highest minus lowest) = a measure of spread
  - X is the average of the values of a sample = a measure of location.

8.6.1 Control Chart Plotting Procedures

- The number of units within a sample is ten or less. The most convenient being odd number of units such as 3, 5, 7 or 9. Here it has been taken as 5.
- All the measurements (variations) are recorded in the data table using legends and the median and range of the set of data are calculated below that
- All medians are plotted in the graph and connected by drawing a line
- Range chart is also plotted same way with the range data of the samples

8.6.2 Control Limits Calculation

Median Chart:

- The average of the sample medians are calculated which is referred as X
- Then the control limits are calculated. The formulas for the median chart is as follows:

Upper Control Limit Median----------UCLX = X + A2R

Lower Control Limit Median----------LCLX = X - A2R

- Limits are drawn in the median control chart

Range Chart:

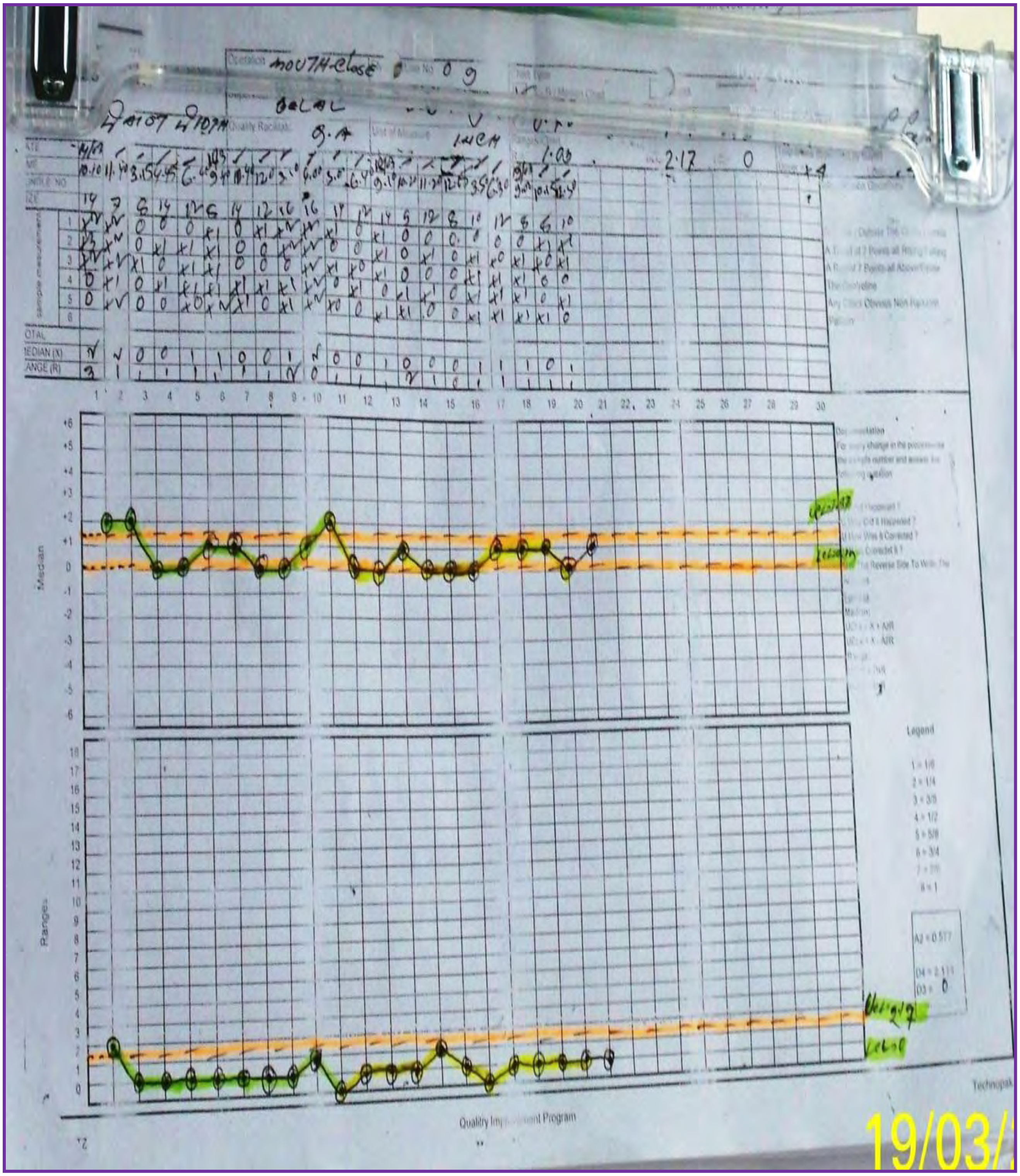
- The average of the sample ranges are calculated which is referred as R
- Then the control limits are calculated. The formulas for the range chart is as follows:

Upper Control Limit Range----------UCLR = D4R

Lower Control Limit Range----------LCLR = D3R

(There are no lower control limits for ranges for sample sizes below 7)

8.6.3 Variable Control Chart (Sample: Waist Measurement)



Control Limits Calculation

- Here, average of all the medians, X = 0.66
- and average of all the ranges, R = 1.09
- For sample size= 5,
  - A2 = 0.577,
  - D4 = 2.114, D3 = 0

Median Chart:

Upper Control Limit Median, UCLX = X + A2R

UCLX= 0.66 + (0.577x 1.09) = 1.28

Lower Control Limit Median, LCL X = X - A2R

LCLX= 0.66 - (0.577x 1.09) = 0.03

Range Chart:

Upper Control Limit Range, UCLR = D4R

UCLR = (2.114 x 1.09) = 2.30

Lower Control Limit Range, LCLR = D3R

LCLR = 0

- These control limits are followed for all the samples and actions taken for each point beyond the limit

8.7 CONTROL CHART FOR ATTRIBUTES

Data Collection (p Charts):
Size, Frequency and number of Samples are selected (here taken as 15%-20% of hourly production). Defects are recorded by checking sample units from the operation decided as CTQ

Proportion of defectives is calculated in this manner:

Proportion of defective, P = (Total defectives/ sample size); Values of P from all the sample sizes are plotted in the graph below data table

8.7.1 Control Limits Calculation

The average of the samples p is calculated and this is considered as the central line and referred as P-bar for limit calculation. The formulas are as follows:

Upper Control Limit,

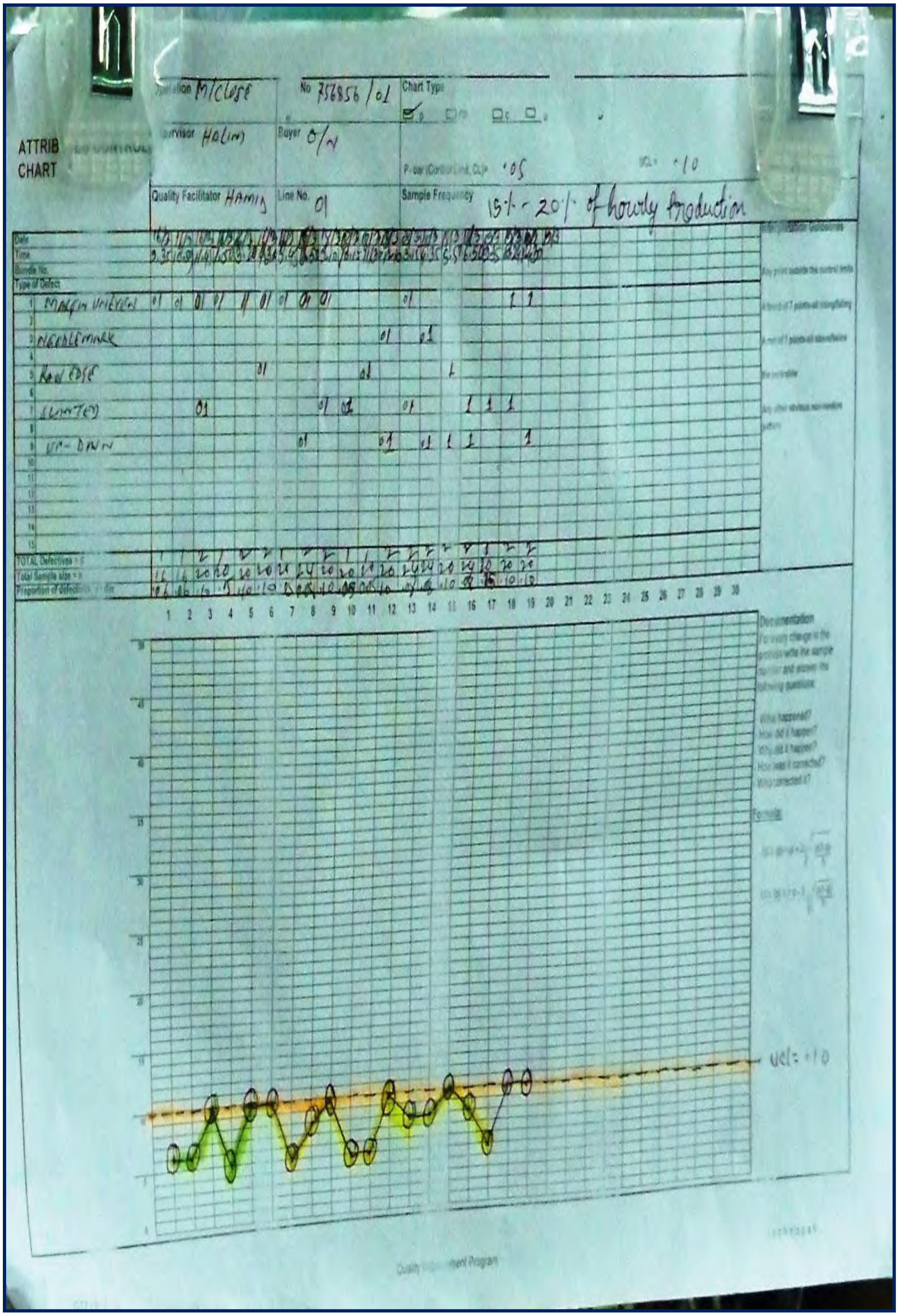
$$UCL\ (p) = p + 3\sqrt{\frac{p(1-p)}{n}}$$

Lower Control Limit,

$$LCL\ (p) = = p - 3\sqrt{\frac{p(1-p)}{n}}$$

Limits are drawn in the control chart and labeled. Right now a decided UCL is being followed in XY Apparels Ltd. which is UCL (P)=0.1
Corrective actions are taken for all the points beyond control limits

8.7.2 Attribute Control Chart (Sample: Mouth-Close)



8.8 ANALYZE DATA TO IDENTIFY ROOT CAUSE AND CORRECT

After establishing control limits, the next step is to assess whether or not the process is in control (statistically stable over time).

If an out-of-control condition is noted, the next step is to collect and analyze data to identify the root cause.

8.8.1 Action Responsibility Chart

S.No.	Sample No.	Operator	What Happened?	Why Did It Happen ?	How Was It Corrected ?	Who Corrected It?	When Was It Corrected ?	Signature		
								Supervisor	Quality Facilitator	Exceptional case
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
13										
14										
15										
16										
17										
18										
19										
20										

Figure 8.1: Taking and documenting Corrective Actions for out of limit occurrences

8.9 BENEFITS OF CONTROL CHARTS

1. Gives the people closestto the operation reliable information on what actionshould be taken.
2. Reliability on consistentquality levels for both thecustomer and the producer.
3. A process in statistical controlcan be further improvedthrough reduction of commoncause variability andimproved process centering.
4. Provide a common languagefor communicatinginformation about the performanceof a process.
5. By identifying special causefrom common causevariation, indicates if problemscan be correctedlocally at the process orwill require managementaction. This reduces the confusion, frustration, and excessive cost of misdirectedproblem-solving efforts.

8.10 SPC IMPLEMENTATION REQUIREMENTS

- Top management commitment
- Project champion
- Initial workable project
- Employee education and training
- Accurate measurement system

CHAPTER - 9
CONCLUSIONS AND RECOMMENDATIONS

9.1 CONCLUSIONS

The Ready-Made Garments (RMG) industry occupies a unique position in the Bangladesh economy. It is the largest exporting industry in Bangladesh, which experienced phenomenal growth during the last 30 years. The industry plays a key role in employment generation and in the provision of income to the poor. From the above study we see that Total Lead time for a specific order only for Cutting to Finishing is around 2677.88 minutes or 4.06 days, where Processing Time is only 16% and Waiting Time or Non Value Added Activity Time is 84%. That means we work on that specific Style only 16% Time and 84% time that style waits between the processes or workers as WIP for work or processing. If we identify that Waiting Time or Non Value Added Activity Time and take steps to reduce or minimize time, ultimately it will reduce the Lead Time & will increase Capacity. In this regard we implemented Cellular Manufacturing System, Line Balancing Algorithms & Statistical Process Control (SPC) tools & Techniques. As a result we get significant improvements. Efficiency has been increased by 43% and Throughput Time, Changeover Time has been decreased by respectively 56% and 63%. This type of continuous improvement will help Bangladesh to attain a high profile in terms of foreign exchange earnings, exports, industrialization and contribution to GDP within a short span of time as targeted level.

9.2 RECOMMENDATIONS

a. Workers and Management personnel should have trust in waste elimination philosophy.
b. Workers should be involved in common understanding about Lean Principles by awareness program.
c. All workers should be trained about team building and work sharing.
d. Establishment and Enrichment of Industrial Engineering Department.
e. The government and the RMG sector would have to jointly work together to maintain competitiveness in the global RMG market.

f. Workers should be counseled for reduction in production output, poor quality of garments and so on.
g. To achieve positive results like avoiding turnover and absenteeism motivation tools such as training, appropriate wage structure and incentive along with annual productivity linked bonus can be provided.
h. Some of the available unskilled labor force can be converted into suitable skilled labour force.
i. Audio-Visual training can be provided in the factories daily half an hour before or after working hours with overtime paid and during off-season of the business.
j. The work environment must be changed so that Workers will feel it a pleasant one to work.
k. All should be involved in common understanding about Lean Principles by awareness program.
l. Create an atmosphere of experimentation, toleration, patience and risk taking.