

# **Layout Optimization and Workplace Engineering for Improving Manufacturing Performance with Referenceto A RMG Industry**

**Shanjoy Chowdhury, Md. Asadujjaman and Md. Mosharraf Hossain**

Department of Industrial & Production Engineering  
Rajshahi University of Engineering & Technology  
Rajshahi, Bangladesh

chowdhury.ipebd@gmail.com, jonikhan007@yahoo.com, mosharraf80@yahoo.com

## **Abstract**

The ready-made garment (RMG) industry in Bangladesh, with the gradual increase of manufacturing costs, is an indispensable requirement to initiate improvement in manufacturing to continue sustainable growth for long run. With the customer expectation, it is required for the manufacturer to improve capacity, on-time delivery, efficiency, and financial condition. To achieve that, it is required to optimize cycle time to improve capacity, reduce work-in-process (WIP) and throughput time to get faster flow and delivery, optimize process and resources fulfilling the expected quality. This study aims to improve manufacturing performance using a layout optimization methodology and workplace engineering through the work study. The proposed methodology is implemented in a RMG finishing production line. The results show that, about 19.5 sec cycle time is reduced by increasing 16 pcs capacity per hour from the line. Also, 2 manpower is optimized from 8 lines through process elimination which impacts 3% efficiency improvement, whereas throughput time is reduced to 26 min by cycle time minimization and WIP reduction to improve on-time delivery. These are the two most effective tools for improving the workplace, work environment as well as manufacturing performance. The proposed layout optimization and workplace engineering can be implemented in any type of industry to improve lead time, quality, material handling as well as customer satisfaction.

## **Keywords**

Layout Optimization, Workplace Engineering and Optimize Process, Manufacturing Performance.

## **1. Introduction**

RMG is the major driving sector in Bangladesh. Chowdhury and Hossain (2021) found in a survey that only 8.5% of the industries have implemented Lean Six-Sigma up to some extent and major 91.5% industry has yet not implemented any of these. This presents the status that improvement initiatives are not up to the mark in this industry. To meet customer requirements within reasonable resources and cost, manufacturing improvement must drive to optimize cycle time, improve capacity, reduce throughput time, process optimization, and optimize resources make an impact on manufacturing performance. Riyad et al. (2014) explained that the facility layout design defines how to organize, locate, and distribute the equipment and support activities in a manufacturing facility to accomplish the minimization of overall production time, maximization of operational efficiency, growth of revenue, and maximization of factory output in conformance with production and strategic goals. Tompkins et al. (2010) found that an ineffective layout design and material handling represents between 20% and 50% of the total production costs. Schuh et al. (2011) explained that manufacturing companies are redesigning their production systems to address new production technologies or product changes, which require a comprehensive planning process to form the final design changes.

Cycle time is the time from when the operation begins to the point-of-time at which the operation ends. Based on cycle time, the capacity of any operation and production line is identified. Throughput time is a measure of the time required for a material or part to pass through a manufacturing process following the release of an order to the manufacturing floor. Throughput time or manufacturing cycle time consists of process time, inspection time, move time, and queue time. The process time is the time during which work is performed on the product itself. Inspection time is the time during which the quality of the product is confirmed. Move time is the time during which materials

or works-in-process are moved from one workstation to another. Queue time is the time during which the product awaits transfer to a workstation, undergoes further inspection, and subsequent manufacturing process. Manufacturing companies reduce throughput time by minimizing the time consumed by inspecting, moving, and queuing activities. As a result of minimizing such activities, the manufacturing lead time is also reduced, and delivery performance is improved. Regardless of the production strategy, throughput time is an important factor, which impacts the planning and management of the conversion process. Throughput time is the amount of time it takes for a single unit of a style to go through the production process, cutting to shipping. This includes the actual processing time plus the time a style waits to be processed ahead of each operation. Throughput time impacts lead time and the total cost of producing a garment. Manufacturing efficiency can be calculated by dividing process time by the total wait time, inspection time, move time, and queue time. The problem statement is Bangladesh RMG needs to improve manufacturing capacity, on-time delivery, efficiency, and resources to have long-term sustainable business.

### **1.1 Objectives**

To achieve manufacturing performance, it is required to optimize cycle time to improve capacity, reduce WIP and throughput time to get faster flow and delivery, optimize process and resources fulfilling the expected quality. The objective of this study is to improve manufacturing performance by using layout optimization and workplace engineering throughout the work study. The proposed approach is implemented in the RMG industry of Bangladesh. The outline of this study is as follows. The next section describes the literature review on layout design and workplace engineering. Section 3 presents the methodologies. Section 4 presents the managerial implication of the study. Section 5 describes the results and discussion. Finally, conclusions are drawn in section 6.

## **2. Literature Review**

There exists an extensive volume of work on layout optimization and workplace engineering. According to Slack et. al. (2018), physical arrangement is one of the most evident characteristics of a productive operation, as it determines the shape and appearance of its environment. It is possible to visually perceive some problems in the layout of associations, such as the crossing of flows or excessive movement, but to propose an improvement in the layout of a productive arrangement, it is necessary to follow a methodology, using tools for this purpose. Liu et al. (2018) mentioned in their research that the facility layout problem is the problem of placing facilities on a certain shop floor so that facilities do not overlap each other and are satisfied with some given objectives. For instance, Kulkarni et al (2013) mentioned that layout optimization helps in decreasing bottleneck rate, and minimize material handling cost, thereby reducing idle time, and enhancing the efficiency and utilization of resources. Karthik and Kumar (2012) stated that the selection of the best Labor allocation strategies should simultaneously consider production output, lead times, and the amount of work in process inventories in the system. Mohsen (1995) mentioned that the detailed plant layout problem includes machine layout problems such as space distribution for different machines and cellular manufacturing design problems are critical factors. Rosenblatt and Kropp (1992) explained that, if the objective is to minimize the expected material handling cost, then it is equivalent to solve the layout problem and such a result allows one to effectively use traditional layout algorithms that consider one flow matrix. Eberle et al (2004) said that, in a detailed workflow, a synchronized line includes short distances between stations, low volume of work in process, precise planning of production times, and predictable production quantity.

## **3. Methodology and Model Formulation**

This section presents the mathematical formulation for layout optimization and workplace engineering. The optimization model presents in this study is unconstrained optimizations. The methodology followed here is layout optimization and workplace engineering with work study procedure to identify wastages to eliminate and improve manufacturing performances. This study presents three formulations below to improve manufacturing performance.

1. Capacity and Cycle Time: Capacity improvement through cycle time minimization
2. Throughput Time and WIP: Throughput time minimization by cycle time minimization and WIP reduction
3. Efficiency and Manpower: Efficiency improvement through process and manpower elimination

Below are the formulations for cycle time minimization to improve capacity, WIP reduction to minimize throughput time, processes, or manpower elimination to improve efficiency.

### 3.1 Capacity Improvement Through Cycle Time Minimization

Cycle time is the time from when an operation starts from a point of time at which the operation ends. Cycle time is calculated in RMG by observed time for 10 to 20 cycles between completions of units. Allowance of 10%-15% has been added with an average value of this observed time. Work study procedures used for calculating process cycle time.

Cycle time of an operation = Average observed time \* Allowance %  
 Total cycle time of GMTs (SAM) = Sum of all operation's cycle time.

$$\text{Min, } Z_1 = \sum_{x_i=1}^7 C_{x_i} = C_{x_1} + C_{x_2} + C_{x_3} + C_{x_4} + C_{x_5} + C_{x_6} + C_{x_7}$$

Here,  $C_x$  is the operation's cycle time, where  $C_x \geq 0$ .  
 SAM = Standard Allowable Minutes

The capacity of operations increased for cycle time minimization and line capacity will also increase for the minimization of operation's cycle time and for process elimination.

$$\text{Production Line Capacity (100\% Efficiency) } Z_4 = \frac{\text{Manpower} \times \text{Working Hour}}{\text{SAM}}$$

$$\text{Max, } Z_4 = \frac{\sum_{x_i=1}^7 M_{x_i} \times H}{\sum_{x_i=1}^7 C_{x_i}}$$

Were,

$$\sum_{x_i=1}^7 M_{x_i} = M_{x_1} + M_{x_2} + M_{x_3} + M_{x_4} + M_{x_5} + M_{x_6} + M_{x_7}$$

$$\sum_{x_i=1}^7 C_{x_i} = C_{x_1} + C_{x_2} + C_{x_3} + C_{x_4} + C_{x_5} + C_{x_6} + C_{x_7}$$

Here,  $M_x$  is operation's manpower, where  $M_x \geq 0$ ,  
 $C_x$  is operation's cycle time, where  $C_x \geq 0$ ,  
 $H$  is the working hour of the production line,  $H \geq 0$ .

### 3.2 Throughput Time Minimization by Cycle Time Minimization and WIP Reduction

Throughput time for any garment, which will enter in the line, is the addition of process time, which is equal to the cycle time value of the garment and waiting time. This includes the actual processing time plus the time a style waits to be processed ahead of each operation. Waiting time is calculated by multiplying cycle time work in process (WIP)

Throughput time = Process time + Waiting time  
 = Total Cycle Time of GMTs + (Operation's Cycle Time × WIP)

$$\text{Min, } Z_2 = \sum_{x_i=1}^7 C_{x_i} + \sum_{x_i=1}^7 (C_{x_i} \times W_{x_i})$$

$$\sum_{x_i=1}^7 C_{x_i} = C_{x_1} + C_{x_2} + C_{x_3} + C_{x_4} + C_{x_5} + C_{x_6} + C_{x_7}$$

Where,

$$\sum_{x_i=1}^7 (C_{x_i} \times W_{x_i}) = (C_{x_1} \times W_{x_1}) + (C_{x_2} \times W_{x_2}) + (C_{x_3} \times W_{x_3}) + (C_{x_4} \times W_{x_4}) + (C_{x_5} \times W_{x_5}) + (C_{x_6} \times W_{x_6}) + (C_{x_7} \times W_{x_7})$$

Here,  $C_x$  is the operation's cycle time, where  $C_x \geq 0$ .

$W_x$  is the WIP of operation, where  $W_x \geq 0$ .

### 3.3 Efficiency Improvement Through Process or Manpower Elimination

The manufacturing efficiency of these finishing production lines increases with manpower minimization. It increases more with the gradual productivity improvement as capacity increases also.

$$\text{Min, } Z_3 = \sum_{x_i=1}^7 M_{x_i} = M_{x_1} + M_{x_2} + M_{x_3} + M_{x_4} + M_{x_5} + M_{x_6} + M_{x_7}$$

Here,  $M_x$  is manpower on operation, where  $M_x \geq 0$ .

$$\text{Production Line Efficiency, } Z_5 = \frac{\text{Production} \times \text{SAM}}{\text{Manpower} \times \text{Working Hour}}$$

Where,

$$\sum_{x_i=1}^7 C_{x_i} = C_{x_1} + C_{x_2} + C_{x_3} + C_{x_4} + C_{x_5} + C_{x_6} + C_{x_7}$$

$$\sum_{x_i=1}^7 M_{x_i} = M_{x_1} + M_{x_2} + M_{x_3} + M_{x_4} + M_{x_5} + M_{x_6} + M_{x_7}$$

Here,  $C_x$  is operation's cycle time, where  $C_x \geq 0$ ,

$M_x$  is operation's manpower, where  $M_x \geq 0$ ,

$H$  is the working hours of the production line.

## 4. Implementation and Before-After Comparisons

Here is the previous finishing process flow and garments handling of a finishing production line of a woven top manufacturing industry after layout optimization and workplace engineering. There were 4 finishing production lines which were in a combined layout of two lines together in one flow. Following were the problems faced in the previous layout –

- Higher throughput time
- Huge transportation and motion of worker
- Poor product quality for handling and stacking
- Product mix, defective and good product mix

**Process and Measurement Check QC**– In the previous layout, after pressing operations, garments were sent to the production line input stand shown in Fig. 1 as input of the process and Measurement check operation. After the quality check, both pass and altered garments have been kept in same stand. Input, pass garments, and alter were kept in the same stand causing product mix, and high searching time for the checker and next process operator. After layout optimization and workplace engineering in the present layout, a specific input stand helps with visual input availability identification for input supply, a specific alter stand helps with visual alter rectification status identification for rapid rectification, and specific pass garments stand helps with visual output identification and searching time of next getup check process. All these arrangements improve input, output, and alter garments management, improve smooth flow and handling.

**Getup Check QC** – In the previous layout, for each 20 pcs input getup checker is required to travel all processes and measurement checkers stand to collect input. After implementing the newly designed garments flow stand made of SS material shown in Fig. 2, garments from both process and measurement checkers will flow to getup checkers

automatically. For each 20 pcs input getup checker is not required to travel all processes and measurement checkers stand as previously. It has improved the capacity of checkers and garment handling improved. Not required to sort passed garments, and here also specific alter stand helps on visual alter rectification status identification for rapid rectification. It helps visual input availability identification of getup checkers for input arranging. All these arrangements searching, travelling time elimination, and alter garments management, flow, and handling.

**Hang Tag Attach, SKU Check, and Audit** – After implementing the newly designed garments flow stand, these garments handling improved drastically for these operations. In the previous layout, for 4 lines total 2 manpower as of per line 0.25 manpower was utilized for SKU (stock keeping unit) pass garments transferring to the next folding operation. Presently this is not required, manpower has been saved, and the process eliminated as shown in Fig. 1. Specific alter stands for audit, helps with visual alter rectification status identification for rapid rectification.

**Folding and Poly** – In the previous layout, folding and poly were done in a separate table and had additional transport. It eliminated garments handling from folding to poly. It helps to have less handling to improve the quality of folding.



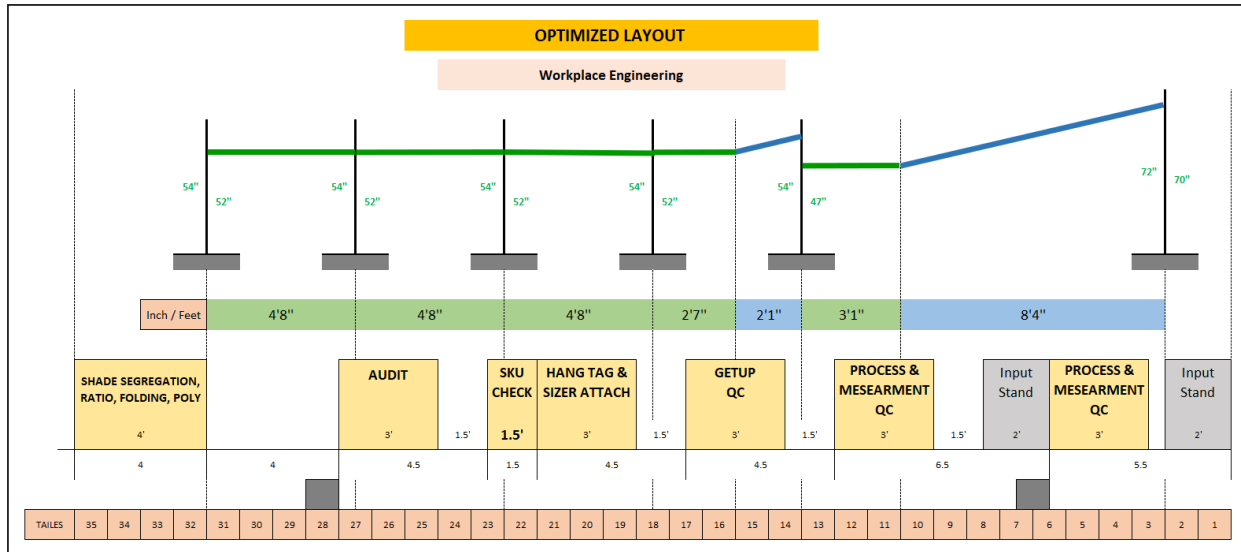


Figure 2. Newly Designed Product Flow Hanger

Fig. 2 is the newly designed garment transport stand for garments flowing through the finishing lines, while earlier using various types of small stands causing garments dumping, huge transportation etc. This is made of SS (Stainless Steel) shown in Fig. 3 having less friction and a good surface. The major point is getup check QC is not required to travel any processes and the measurement check QC stand that earlier they used to. In all other points also, an operator is not required to travel, garments move to his place to some work stand, and others are placed so that operators are not required to travel.



Figure 3. Installed Newly Designed Product Flow Hanger by SS Material

Fig 3 is shown the newly designed and installed product flow hanger made from SS materials. As shown in Fig. 3, this stand has a new alter stand, only the right quality product moves on this. Overall, ergonomically improved pick-up and dispose of motion in all points, especially QC Points. It will drastically improve garments handling which helps directly with quality improvement. Visual control is the key to these layouts to have identified every garment quantity in every point to understand input availability, alter rectification status, bottleneck points to easily identify, smooth flow, and problem identification. The transport process is eliminated, and throughput time gets minimized which helps to hit delivery on time.

Data Collection - Working shift per day = 1 Working hours per shift = 10 hours  
Available time per shift = 600 minutes

#### 4.1 Comparison of Previous and Proposed Layout

Here is the detail of processes with pickup and drop time as calculated with work study. Optimized process, reduced cycle times, and improved capacity. The garment transfer process eliminated, and travelling, searching, sorting, picking, drop eliminated of getup check QC. Also, move time from folding to the poly table has been eliminated as shown in Figure 1.

Table 1. Comparison of cycle time and manpower of previous and modified layout

PROCESS, MOTION, CYCLE TIME & MANPOWER STRUCTURE									
PROCESSES	O.	PREVIOUS			MODIFIED				
		Cycle Time (Sec)	WIP	Manpower	Cycle Time (Sec)	WIP	Manpower		
Pick	1	2	54.5	30	2	2	54.5	30	2
PROCESS & MESEARMENT Check		51				51			
Drop		1.5				1.5			
Travel + Search + Sort + Pick + Travel + Drop	2	6	16	30	0.5		Eliminated	30	0.5
Pick		2				2			
GETUP Check		6.5				6.5			
Drop		1.5				1.5			
Pick	3	2	15.5	20	0.5	2	15.5	20	0.5
HANGTAG Attach		12				12			
Drop		1.5				1.5			
SKU Check	4	7	7.0	20	0.5	7	7	20	0.5
Pick	5	2	8.50	40	0.25	0	Eliminated	40	Eliminated
BODY TRANSFER To Ratio Stand		5				0			
Drop		1.5				0			
RATIO FOLDING	6	24	24.0	50	2	24	24	50	2
Move To Poly Table	7	5	28.0	20	1		Eliminated	20	1
POLY		23				23			
<b>Total -</b>			<b>153.5</b>	<b>210</b>	<b>6.75</b>		<b>134.0</b>	<b>210</b>	<b>6.50</b>

Table 1 presents the comparison of process wise cycle time, WIP and manpower of 7 operations of the previous and optimized layout. As a result, the cycle time of finishing reduced from 153.5 sec to 134 sec, which is 19.5 sec reduced shown in Table 1. Getup and poly capacity improved and 16 pcs capacity improved of a production line.

PROCESS WISE COMPARISON - Cycle Time, Capacity, WIP, Throughput Time, Manpower																		
PROCESSES / STAFFS	OP.	PREVIOUS						MODIFIED						IMPROVEMENT				
		Cycle Time Cx		WIP	Manpower Mx	Capacity	Throughput Time	Cycle Time Cx		WIP	Manpower Mx	Capacity	Throughput Time	Cycle Time Minimized		Manpower Minimized	Capacity Improved	Throughput Minimized
		Sec.	Min.	Pcs	No.	Pcs	Min.	Sec.	Min.	Pcs	No.	Pcs	Min.	Sec.	Min.			
UNIT																		
PROCESS & MESEARMENT QC	1 X1	54.5	0.91	30	2	132	27	54.5	0.91	30	2	132	27					
GETUP QC	2 X2	16	0.27	30	0.5	113	8	10	0.17	15	0.5	180	3	6	0.10		68	6
HANGTAG Attach	3 X3	15.5	0.26	20	0.5	116	5	15.5	0.26	15	0.5	116	4					1
SKU CK	4 X4	7	0.12	20	0.50	257	2	7	0.12	10	0.50	257	1					1
BODY TRANSFER To Ratio Stand	5 X5	9	0.14	40	0.25	106	6	-	-	0	-	-	0	8.5	0.14	0.25	-	6
RATIO FOLDING (Team)	6 X6	24	0.40	50	2	150	20	24	0.40	40	2	150	16					4
POLY (Team)	7 X7	28	0.47	20	1	129	9	23	0.38	10	1	157	4	5.0	0.08		28	6
		153.5	2.56	210	6.75	158	78	134.0	2.23	120	6.50	175	55	19.5	0.33	0.25	16	23
Throughput time reduce -																		23 Min

Figure 4. Process wise comparison of previous and modified layout



Fig.4 is a process wise comparison of the previous and modified layout and Table 2 shows efficiency improvement due to manpower reduction. In the present layout, 2 manpower was eliminated from 8 lines, which causes a 3% manufacturing efficiency improvement for the same production, SAM, and working hour which is shown in Table 2.

Table 2. Efficiency Improvement for Manpower Reduction

Criteria	PREVIOUS	PRESENT	Remarks
Avg. Production - Pcs	120	120	Efficiency improved for manpower reduction
Cycle Time - Min	2.56	2.56	
Manpower	6.75	6.50	
Working Hour - Min	60	60	
Efficiency	76%	79%	3%

As shown in Fig. 4, by the minimization of cycle time to 33 min and WIP reduction by 90 pcs, the throughput time was reduced to 55 min from 78 min resulting in 23 min less. This causes faster output, improved garments handling, fast problem identification and rectification etc.

Table 3. After and Before Cycle Time, Capacity and Manpower Optimization Table

SL	Operation	MP	Process Time (Sec)	Capacity (PCS)	WIP (Pcs)
1	PRO. & MES. Check - BEFORE	2	54.5	132	30
	PRO. & MES. Check - AFTER	2	54.5	132	30
2	GETUP Check - BEFORE	0.5	16	113	30
	GETUP Check - AFTER	0.5	10	180	15
3	HANGTAG Attach - BEFORE	0.5	15.5	116	20
	HANGTAG Attach - AFTER	0.5	15.5	116	15
4	SKU Check - BEFORE	0.25	7	129	20
	SKU Check - AFTER	0.25	7	129	10
5	GTM's TRANSFER - BEFORE	0.25	9	-	40
	GTM's TRANSFER - AFTER	-	-	-	-
6	RATIO FOLDING - BEFORE	3	24	150	50
	RATIO FOLDING - AFTER	3	24	150	40
7	POLY - BEFORE	2	28	129	20
	POLY - AFTER	2	23	157	10

Table 3 presents after and before Cycle Time, Capacity, Manpower and WIP status. A huge WIP reduction causes for newly designed stand and flow system. After and before optimization cycle time, capacity and manpower optimization are mentioned in Table 3. Operation wise manpower, cycle time, capacity, WIP etc. are mentioned here.

Fig.5 is mentioned the improvement in processes for cycle time, throughput time, manpower and WIP after and present. Here, it is shown that, cycle time were minimized for three processes, capacity maximized for two operations, manpower eliminated for one operation and WIP reduced for six operations.

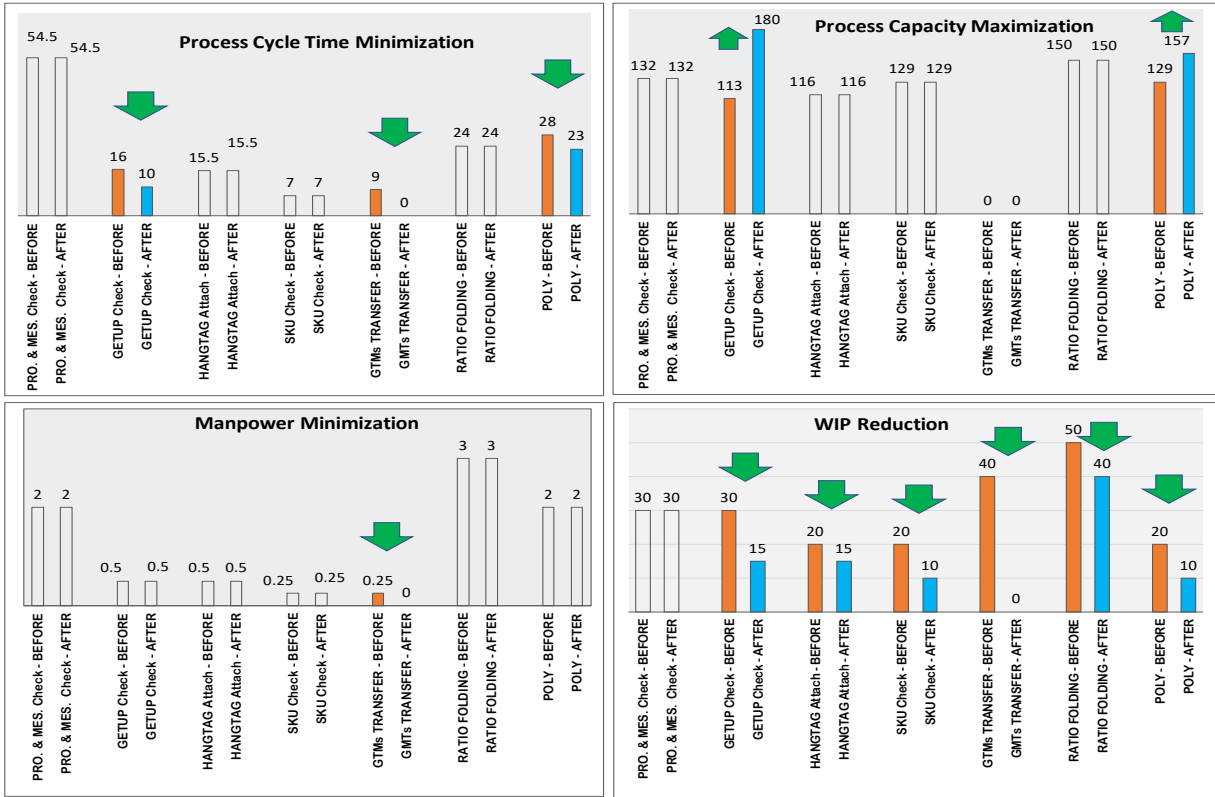


Figure 5. After and Before Cycle Time, WIP, Capacity and Manpower Optimization Chart

## 5. Results and Findings

Table 4 presents the results of layout optimization and Workplace Engineering. Layout optimization and workplace engineering drive improvements and money value savings. The results of this study are mentioned below. Though some investment was involved while implementing for 8 lines, it was one time, and maintenance costs are too low for this facility of garments flow stand but it makes a good mount yearly for the company.

Table 4. Results of Layout Optimization and Workplace Engineering

Criteria	Operation	Previous	Present	Variation	Improvements	Savings
Cycle Time	GETUP Check -	0.3	0.2	0.1	Reduced <b>0.33 Min</b> or <b>19.5 Sec</b>	
	BODY TRANSFER -	0.1	-	0.1		
	POLY (Team) -	0.5	0.4	0.1		
	<b>Overall -</b>	<b>2.56</b>	<b>2.23</b>	<b>0.33</b>		
Capacity	GETUP Check -	113	180	67.50	Increased <b>16 Pcs @ Per Hour</b> Per Line	\$ <b>2,304,000</b> Per Year @ \$ 7680 per day, 12 months, 25 days, 8 lines, 10 Hour, 16 Pcs Per Hour, \$6 FOB Per Pcs
	BODY TRANSFER -	106	-	-		
	POLY (Team) -	129	157	27.95		
	<b>Overall -</b>	<b>158</b>	<b>175</b>	<b>16.32</b>		
WIP		<b>210</b>	<b>120</b>	<b>90</b>	Reduced <b>90 Pcs</b>	
Throughput Time		1 H 18 Min	55 Min	23 Min	Reduced <b>23 Min</b>	
Manpower		6.75	6.50	0.25	Eliminated <b>0.25 Man/Line</b>	\$ <b>1800</b> Per Year @ \$ 150 per manpower, 2 Manpower
Efficiency		76%	79%	3%	<b>3% Improvement</b>	
						<b>\$2,305,800</b>

## **6. Conclusion, Limitations, and Future Research Directions**

### **6.1 Conclusion**

Layout optimization and workplace engineering are the basic methodologies for manufacturing improvement. In this study, these initiatives are done for a manufacturing finishing production line of a Ready-made garment industry. Here, this is done through observation, brainstorming, employee feedback, management and customer requirements for productivity improvement and quality assurance. It was observed that there are non-value-adding movements, and bottlenecks in the production line due to layout, distance, and motions. Based on analysis, a modified material handling stand has been designed and implemented. In a result, great success in cycle time reduction, motion elimination, and improved material handling is achieved. RMG sector sustainability is deeply related to how this sector is driven for optimizations, improvements, innovations, engineering etc. The best way to stay competitive in a globalized market is to become efficient. Layout optimization and workplace engineering create opportunities for improvements. In this research work, cycle time was reduced, relevant capacity increased, throughput time reduced, WIP reduced, manpower was reduced, and relevant efficiency increased due to layout optimization and workplace engineering. More engineering will create more optimization and waste elimination.

### **6.2 Limitations and Future Scopes**

There is no limitation for layout improvement and workplace engineering rather than cost involvement. But the industry should invest a certain amount of profit every time for improvement for sustaining the market. This work is implemented in a finishing production line, but the same can be implemented in every section, each and every operation to get the maximum benefit of this work. This type of layout optimization and workplace engineering is well applicable to any industry.

### **Acknowledgment**

The author would like to acknowledge Southern Services Limited (SSL), for the use of Production Data. Also, the authors are grateful to the Department of Industrial and Production Engineering, Rajshahi University of Engineering and Technology, Rajshahi-6204, Bangladesh for providing the opportunity for this research work.

### **References**

- Bheda, R., Narag, A.S. and Singla, M.L., Apparel Manufacturing a Strategy for Productivity Improvement, *Journal of Fashion Marketing and Management*, vol. 7, no.1, pp. 12-22, 2003.
- Chowdhury. S., Hossain M. M., “Scenario of Implementation of Lean Six-Sigma in Ready-made Garment Manufacturing Industry of Bangladesh”, 4th International Conference on Industrial & Mechanical Engineering and Operations Management (IMEOM), ISSN 2691-7734 (print) ISSN 2691-7726 (online), Bangladesh, 2021.
- Drew, J., Blair, M. and Stefan, R., *Journey to Lean: Making Operational Change Stick*. Gordonsville, VA, USA: Palgrave Macmillan, pp. 5-25, 2004.
- Dal, V., Akcagun, E., Yilmaz, A., Using Lean Manufacturing Techniques to improve Production Efficiency in the Ready Wear Industry and a Case Study, *FIBRES & TESTILES in Eastern Europe*, vol. 4 , no. 100, pp. 16-22, 2013.
- Eberle, H., Hermeling, H., Hornberger, M., Kilgus, R. Menzer, D., and Ring, W., *Clothing Technology*, Beuth-Verlag GmbH, Berlin, 2004.
- Ferdousi, F., and Ahmed, A., An Investigating of Manufacturing performance improvement through Lean Production: A Study on Bangladeshi Garmants Firms, *International Journal of Business & Management*, 2009.
- Hassan, M. M. D., Layout Design in Group Technology Manufacturing, *International Journal of Production Economics*, vol. 38, pp. 173-188, 1995.
- Kumar, B. S., and Sampath, V. R., Garment Manufacturing Through Lean Initiative-An Empirical Study On WIP Fluctuation In T-Shirt Production Unit, *International Journal of Lean Thinking*, vol. 3, no. 2, 2012
- Kulkarni, C. N., Talib, M. I., and Jahagirdar, R.S., Simulation Methodology for facility layout problems, *The International Journal of Engineering & Science*, vol. 2, no.2, 2013.
- Karthik, .T, and Senthilkumar, M., Improvization of productivity through layout optimization in pump industry, *International Journal of Lean Thinking*, vol. 3, no. 2, 2012.

- Liu, J., Zhang, H., He, K., Shengyi, J., Multi-objective particle swarm optimization algorithm based on objective space division for the unequal-area facility layout problem. *Expert Systems with Applications*, v. 102, p. 179-192, 2018.
- Riyad, M. H., Rasel, M. K., and Talapatra, S., Increasing productivity through facility layout improvement using systematic layout planning pattern theory, *Global Journal of Researches in Engineering*, Vol 14, Issue 17, 2014.
- Rosenblatt, M. J., and D H Kropp, D. H., The Single Period Stochastic Plant Layout Problem, *II Transaction*, vol. 24, pp. 169-176, 1992.
- Rathod, B., Shinde, P., Raut, D., and Waghmare, G., Optimization of cycle time by Lean Manufacturing Technique – Line Balancing Approach, *International Journal for Research in Applied Science & Engineering Technology (IJRASET)*, IC Vol. 13.98, vol. 4, no. 5, 2016.
- Ratnayake, V., Mars, J., and Taylor D., Cellular Lean Model to reduce WIP Fluctuation in Garments Manufacturing, *Lean Enterprise Research centre*, Cardiff, pp. 3-43, 2010
- Shahram, T. and Cristian, M., The Impact of Lean Operations on the Chinese Manufacturing Performance. *Journal of Manufacturing Technology Management*, vol. 22, no. 2, pp. 223-240, 2011.
- Slack, N., Chambers, S., Johnston, R., *Administração da Produção*, 8<sup>a</sup> Edição. São Paulo: Editora Atlas, 2018.
- Schuh, G., Aghassi, S., Orilski, S., Schubert, J., Bamcach, M., Freudenberg, R., Hinke, C., Schiffer, M., Technology roadmapping for the production in high-wage countries. *Production Engineering*, v. 5, n. 4, p. 463-473, 2011.
- Tompkins, J. A., White, J. A., Bozer, Y. A., Tanchoco, J. M., *Facilities planning*. John Wiley & Sons, 2010.

## **Biographies**

**Shanjoy Chowdhury** is currently working as a Manager of the Department of Production Planning and Coordination in a multinational RMG manufacturing company named EPIC Group, where he experienced in production planning, ERP software, supply chain and logistics etc. He also worked as a Manager of the Department of Business Process Excellence in the same organization where he practiced lean manufacturing, system development, automation, standard operating procedure, improvement projects, resource optimization etc. He received the degree B. Sc. and M.Sc. in Industrial and Production Engineering from the Department of Industrial and Production Engineering (IPE) of Rajshahi University of Engineering and Technology (RUET), Rajshahi. He has certification on Lean Six Sigma Black Belt (LSSBB) and Lean Six Sigma Green Belt (LSSGB) from Beingcert & Bangladesh IT Institute under the workforce development training of Bangladesh ICT Division, Hi-tech Park Authority.

**Md. Asadujjaman** is an Assistant Professor in the Department of Industrial & Production Engineering (IPE) at the Rajshahi University of Engineering & Technology (RUET). He completed the Bachelor of Science in Industrial & Production Engineering from RUET in 2012 by securing the 1st class 1st position in order of merit. He was awarded the University Gold Medal for his outstanding academic performance at the undergraduate level. He completed the Master of Science in Industrial & Production Engineering from the Bangladesh University of Engineering & Technology (BUET) in 2015. At present, he is pursuing his PhD in Systems Engineering at the University of New South Wales, Australia. His research covers a wide range of topics including Supply Chain Integrated Project Scheduling, Operations Research, Financial Engineering, Ergonomics and Human Factors Engineering, Forensic Anthropometry and Biostatistics. He is the author/co-author of over 30 refereed journal and conference papers.

**Dr. Md. Mosharraf Hossain** is currently serving as a Professor and Head of the Department of Industrial and Production Engineering of Rajshahi University of Engineering and Technology (RUET), Rajshahi. He received the degree B. Sc. in Mechanical Engineering from the Department of Mechanical Engineering of Rajshahi University of Engineering and Technology (RUET), Rajshahi. He also achieved his M.Eng. from AIT and Ph.D. from the University of Nottingham. He has supervised a couple of PhD and post-graduate students and has published more than 50 journal papers and conference articles. He was Organizing Secretary of 2<sup>nd</sup> ICMIME 2019, Faculty of Mechanical Engineering, Rajshahi University of Engineering & Technology. And he was involved as an organizing member of ICMIME 4 times. He is an organizing Member of several conferences such IC4ME2 jointly organized by Faculty of Engineering, RU and RUET, 4th ICIMEOM 2021 Dhaka, Bangladesh of Industrial Engineering and Operations Management (IEOM) Society of Bangladesh, a country chapter of IEOM Society International.