

# **Edge Colouring Process Improvement by DMAIC Methodology – Efficiency Perspective**

**Md. Sajib Milki**

Department of Industrial Engineering (IE)  
BGMEA University of Fashion & Technology (BUFT)  
Dhaka – 1230, Bangladesh

Department of Industrial and Production Engineering (IPE)  
Bangladesh University of Engineering and Technology (BUET)  
Dhaka – 1000, Bangladesh  
mdsajibmilki@gmail.com

## **Abstract**

DMAIC (Define, Measure, Analyse, Improve and Control) methodology can be implemented at any stage of a system development. The methodology has been implemented in footwear industry of Bangladesh for improving the quality of the products. Besides the quality measure, this methodology can be applied in terms of efficiency. Hence this study adopted DMAIC methodology to improve the efficiency of a process called Edge Colouring process in an export oriented footwear industry of Bangladesh. The efficiency was increased 17% and the Cost of Making (CM) was decreased 38.92%. So, the DMAIC methodology can be implemented in terms of efficiency.

## **Keywords**

DMAIC, VSM, Spaghetti Diagram, Bottleneck and Efficiency.

## **1. Introduction**

In 1950s, there was a revolution about Quality Control and Management in Japan. Lean Six Sigma (LSS) is one of the good results of this revolution. It is the fusion of Lean and Six Sigma which are compliments of each other (Bloj et al. 2020). Lean increases the process velocity and Six Sigma keeps the process under statistical control (Gleeson et al. 2019). LSS DMAIC (Define, Measure, Analyse, Improve and Control) methodology is an established framework for the improvement of any system.

LSS has been implemented in different manufacturing sectors including oil & gas, garment, automobile, pharmaceutical, aerospace, telecommunications (Tampubolon and Purba 2021). It has also been applied in different service sectors. For example - healthcare, shipping, education, hospital, IT, financial, public sector etc. (Tampubolon and Purba 2021). Since LSS is applicable in both manufacturing and service sectors, we adopt it for footwear industry. This study will focus on the implementation of DMAIC methodology in Edge Colouring process of an export-oriented footwear industry of Bangladesh.

Few researchers have implemented the methodology in footwear industry of Bangladesh. But they have implemented the methodology in terms of quality measure. In this study, we have adopted the methodology for increasing the efficiency of Edge Colouring process.

### **1.1 Objectives**

The objective of the research is to increase the efficiency of the Edge Colouring process at least 10% within 3 months. The objective was achieved by -

- Increasing the efficiency 17% which exceeded the target
- Reducing the Cost of Making (CM) 38.92%

So, there is a huge cost savings in the Edge Colouring process. This continuous improvement process should be continued for the survival of the industry in this globalized world.

At first the review of the related literature has been presented. Then, the DMAIC methodology has been implemented in the intended case. The improvements have been shown in the result section. Discussion section explains the implications of the result. Finally, the study is concluded in the last section.

## **2. Literature Review**

Footwear is an intermittent manufacturing industry. Like garments industry, it has three sections called cutting section, sewing section and assembly section. Considering the complexity, there is huge potential to implement LSS DMAIC methodology in footwear industry.

In Bangladesh's footwear industry, little work has been done using the DMAIC methodology. The implementation of Lean, Green and Six Sigma have been explored in some leather industries of Bangladesh (M. M. Rahman and Ogunleye 2019). Although these industries are used to some lean tools, there is a lack of motivation in implementing the six sigma. The DMAIC methodology has been implemented in an export oriented footwear industry of Bangladesh (Sayid Mia 2017). They have done Pareto Analysis to identify the vital few defects and also examined the quality level by a parameter called defects per million opportunities (DPMO). A case study has been conducted at shoe manufacturing industry of Bangladesh (Jor et al. 2018). They have implemented the DMAIC methodology to improve the quality of the shoe. As a result, there is a lot of room for advancement in this field.

In terms of quality, i.e. sigma level, DMAIC methodology has been implemented in various industries. Reddy A et al. (2021) implemented the DMAIC methodology in the Indian shoe manufacturing industry. The sigma level was raised from three to four. Darmawan et al. (2020) used the methodology in an Indonesian grain/fodder/forage industry. They enhanced the raw material processing section. Ahmed (2019) adopted the methodology for improving Malaysian healthcare performance. Rodrigues Nogueira et al. (2017) used the DMAIC methodology in the Indian textile industry. They raise the sigma value from 2.9 to 3.1. Rahman et al. (2018) implemented the methodology in the Bangladesh garment industry. The sigma level is raised from 1.7 to 3.4. Jirasukprasert et al. (2014) applied the methodology in Malaysia's rubber manufacturing industry. They raised the Sigma value from 2.4 to 2.9. Gijo et al. (2011) used the methodology in an automotive industry fine grinding process in India. They reduced the defect rate from 16.6 percent to 1.19%. Valles et al. (2009) used the DMAIC methodology in a Mexican semiconductor company. They raise the 0.37 sigma level, which represents 1.88% unit. They used the DMAIC methodology to improve product quality by reducing defects. However, this methodology could be used to improve production efficiency. Therefore, this study will employ the DMAIC methodology to improve the efficiency of Edge Colouring process in an export-oriented footwear industry of Bangladesh.

## **3. Methodology**

'X' is an export-oriented company in Bangladesh. Edge Colouring is an important section of the Cutting Department. As a new journey of the section, there is huge potential for improvement. LSS team adopted DMAIC methodology to improve the efficiency of the Edge Colouring process.

LSS approach improves any system by reducing waste and variation. Lean increases the process capacity and Six Sigma brings the stability (Gleeson et al. 2019). LSS improves the existing system by using DMAIC approach and the new system by DFSS (Design for Six Sigma) approach. In contrast to Business Process Re-engineering (BPR), it takes small step i.e. continual improvement.

DMAIC is a problem-solving methodology used in Six Sigma. It consists of five phases: Define, Measure, Analyse, Improve, and Control.

- The define phase is used to identify the problem, establish the goals, and create a project plan.
- The measure phase is used to collect data and establish baselines.
- The analyse phase is used to identify the root cause of the problem.
- The improve phase is used to develop and implement solutions.
- The control phase is used to establish controls and monitor the process.

In the following sections, these phases will be implemented in the intended case.

### **3.1 Define Phase**

Problem definition constructs Project Charter by analysing Voice of the Customer (VoC). VoC is the starting point of any LSS project (Alfaro et al. 2020). Project Charter consists of the objectives, scopes and responsibilities of the LSS

project. It also defines milestone, deliverables and timeline of the project. These elements are described in the following sections.

### 3.1.1 Project Scope

Sewing section is the customer of the Edge Colouring section. According to the Production Manager of Sewing Section “Edge Colouring section can't meet our demand at the right time.” Figure 1 shows the VoC and its impacts in the business. Based on the scope, LSS team determines the goals and objectives of the project.

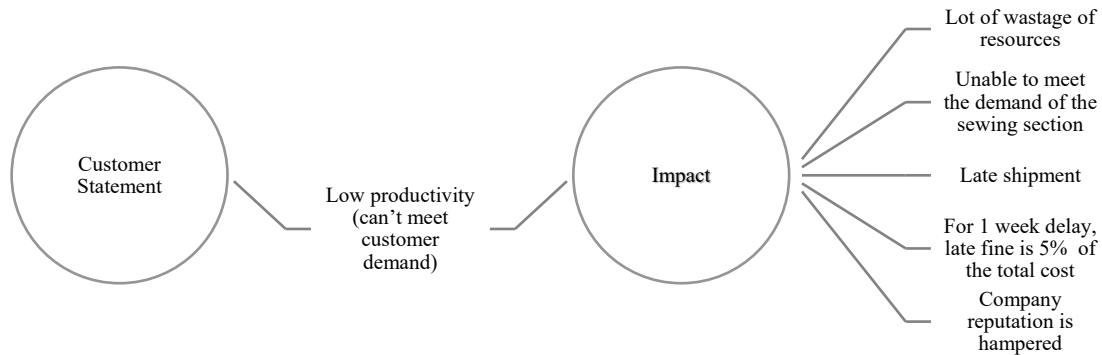


Figure 1. Project scope

### 3.1.2 Project Objectives

There are lot of benefits from the project. First of all, Edge Colouring section will meet the customer demand on due date. Besides company will avoid losses and gain reputation. Specifically, the efficiency will be increased at least 10% within 3 months. Figure 2 demonstrates the goals and objective of the project.

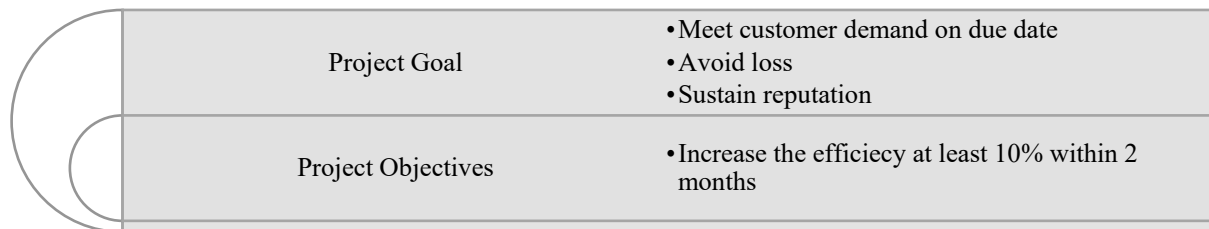


Figure 2. Project goal and objective

### 3.1.3 Project Responsibility

A wide range of people participated in this project from different departments of the company. The roles of these people are project champion, project manager, business analyst, subject matter expert and functional in-charge. Table 1 shows the stakeholders and their roles in the project.

Table 1. Stakeholders and roles

Sl. No.	Name and Designation	Role
1	Mr. A, Executive Director	Project Champion
2	Mr. B, Industrial Engineer	Project Manager
3	Mr. C, Assistant General Manager	Business Analyst
4	Mr. D, Deputy Manager	Business Analyst
5	Mr. E, Production Manager	Subject Matter Expert
6	Mr. F, Assistant General Manager	Subject Matter Expert
7	Mr. G, In-charge	Functional In-charge

### 3.1.4 Milestone, Deliverables and Timeline

Milestone and deliverables are certain. Timeline was estimated based on those certain factors. Table 2 shows the schedule along with the deliverables. Project team tried the best to maintain the timeline.

Table 2. Milestone, deliverables, and timeline

Milestone	Timeline	Deliverable
Define	January 1, 2022 to January 15, 2022	Approved report
Measure	January 16, 2022 to January 31, 2022	Process data
Analyse	February 1, 2022 to February 9, 2022	Improvement plan
Improve	February 10, 2022 to February 20, 2022	Improved result
Control	February 21, 2022 to February 28, 2022	Consistency report

This continuous improvement project achieved the objectives by utilizing the existing resources.

### 3.2 Measure Phase

Project team measured the existing performance in this phase. At first, Process Flow Diagram (PFD) or Process Mapping describes the process sequentially. Then, SIPOC (Supplier, Input, Process, Output and Customer) diagram acquaints with the process in higher level. Finally, the capacity of each step of the process were presented in the Standard Combination Sheet. On other hand Takt time expresses the required demand. Existing performance measurements are presented in the following sections.

#### 3.2.1 Process Flow Diagram (PFD)

It describes each steps visually for easy understanding of the process. Figure 3 shows the PFD of Edge Colouring process. It consists of 14 steps. SIPOC diagram also uses PFD in the process step.

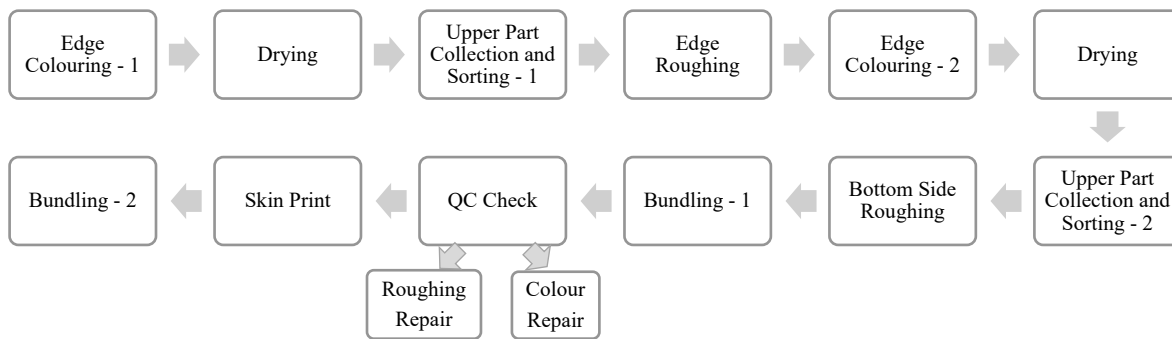


Figure 3. PFD

#### 3.2.2 SIPOC Diagram

It is a higher-level map than PFD but it gives brief information about the process. The SIPOC diagram for the Edge Colouring process is shown in Figure 4. Managers can take the right decision for any problem by using the diagram.

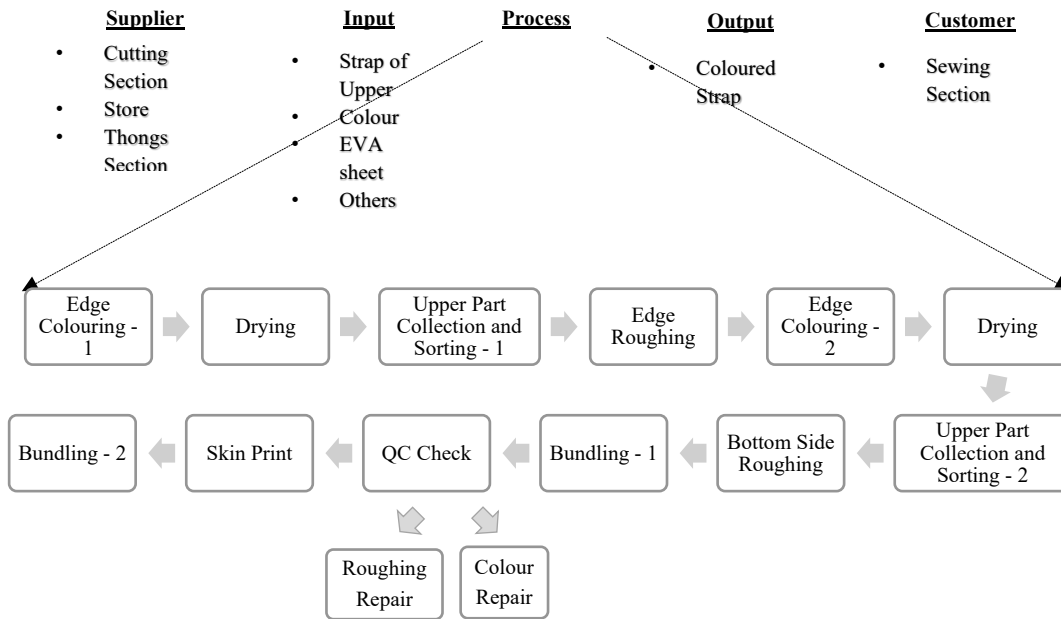


Figure 4. SIPOC diagram

### 3.2.3 Standard Combination Sheet

It helps to identify the bottlenecks. Table 3 shows the sheet. Bottleneck stations are the Bottom Side Roughing and Roughing Repair.

Table 3. Standard combination sheet

Process Step Name	Average Cycle Time (CT) (sec.)	Performance Rating (PR)	Required Step/Pair	Standard Minute Value (SMV)	Manpower	Capacity (pair)
Edge Colouring-1	6	1	6	0.69	4	348
Upper Part Collection and Sorting - 1	1	1	6	0.12	1	522
Edge Roughing	11.5	1	6	1.32	8	363
Edge Colouring-2	6	1	6	0.69	4	348
Upper Part Collection and Sorting - 2	1	1	6	0.12	1	522
Bottom Side Roughing	11.4	1	6	1.31	4	<b>183</b>
Roughing Repair	13.5	1	<b>0.84</b>	0.22	1	<b>276</b>
Colour Repair	8.3	1	1.02	0.16	1	370
Bundling-1	4.8	1	4	0.37	2	326
Skin Print	5.4	1	2	0.21	2	580
Bundling-2	4.8	1	2	0.18	1	326

### 3.2.4 Takt Time

It is also known as heartbeat of the process. It determines the rate at which the product needs to be produced to meet the customer demand. It is calculated for the Edge Colouring process as follows:

$$\text{Takt Time} = \frac{\text{Net time available to work}}{\text{Customer demand}}$$

$$= \frac{36000}{3000} \text{ sec/pair} = 12 \text{ sec./pair}$$

So, hourly required production is (3600/12) **300** pairs/hour.

### 3.3 Analyse Phase

This phase identifies the root causes of the problem. The LSS team identifies three main problems in the process. At first, many steps of the process do not add any value to the product i.e. non value added (NVA) work. Second, some steps accumulate a large number of Work-in-Process (WIP) inventory i.e. bottleneck of the process. The last one is the unnecessary motion i.e. the layout problem. Following sections describe these problems.

#### 3.3.1 Value Steam Mapping (VSM)

It is also a process mapping tool. It not only maps the process but also separates the value added (VA) and non-value added (NVA) work. Figure 5 shows the VSM of the process. 45.95% work of the process is NVA work. Following abbreviations have been used in the VSM.

- EC – Edge Colouring
- UPCS – Upper Part Collection and Sorting
- ER – Edge Roughing
- BSR – Bottom Side Roughing
- B – Bundling
- RR –Roughing Repair
- CR – Colour Repair
- SP –Skin Print

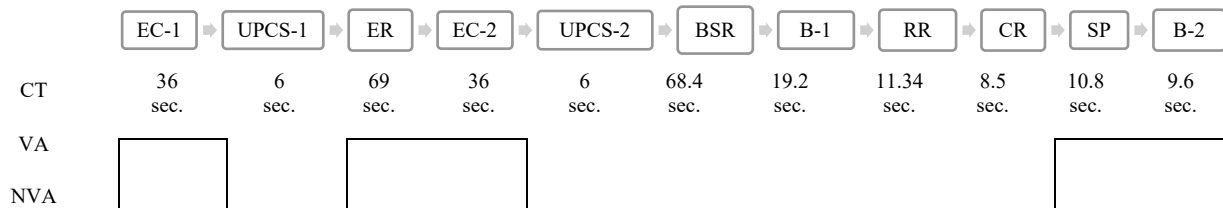


Figure 5. Present state map (VSM)

#### 3.3.2 Bottleneck Identification

Sewing section requires 300 pairs per hour. But Bottom Side Roughing and Roughing Repair processes have hourly capacity of 183 and 276 pairs respectively which are marked bold in Table 3.

#### 3.3.3 Spaghetti Diagram

It visualizes the flow in the system. Figure 6 demonstrates the previous flow in the process. The flow is not streamlined and presents unnecessary flows.

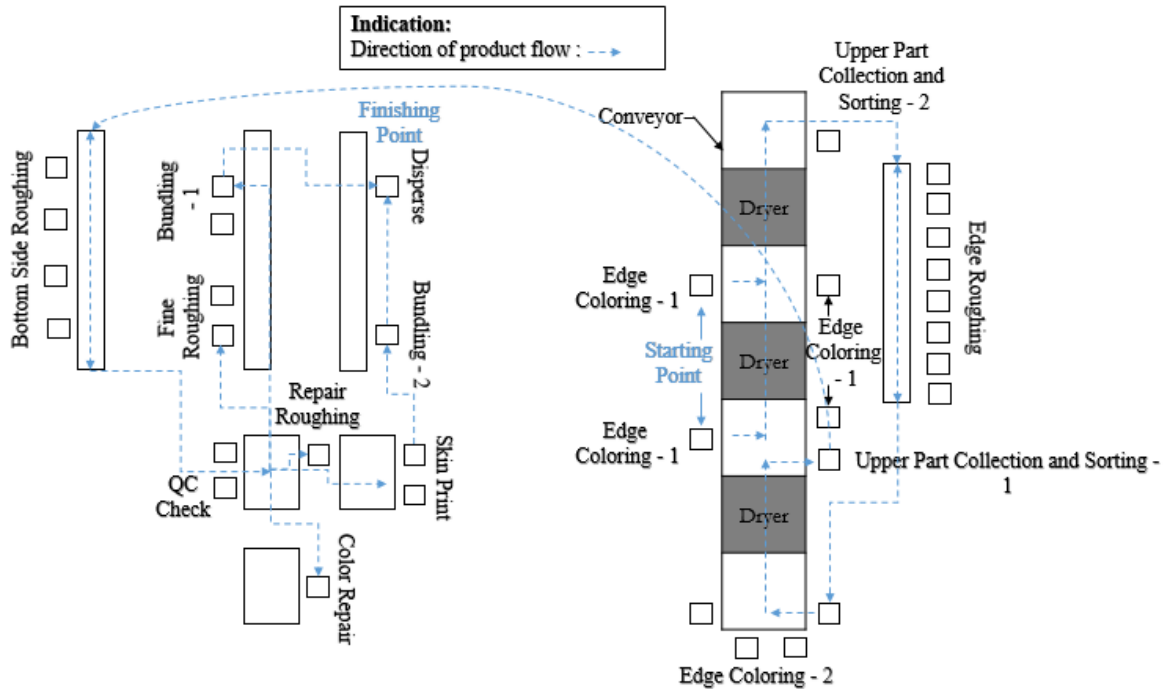


Figure 6. Spaghetti Diagram (Existing Layout)

### 3.4 Improvement Phase

The team improves the process by generating, selecting, and implementing a set of solutions. Brainstorming helps the team a lot in this phase. From the results of the analyse phase, the team has reduced the NVA activities, increased the capacity of the bottleneck and improved the layout for smoother flow. Each of the improvements will be described below.

#### 3.4.1 Improving Upper Carrying System and Reduction of NVA Time

The production department used the small EVA sheet for supporting the upper. Project team made lines (like rail line) with foam for supporting purpose. Both the previous and present systems are shown in Figure 7.

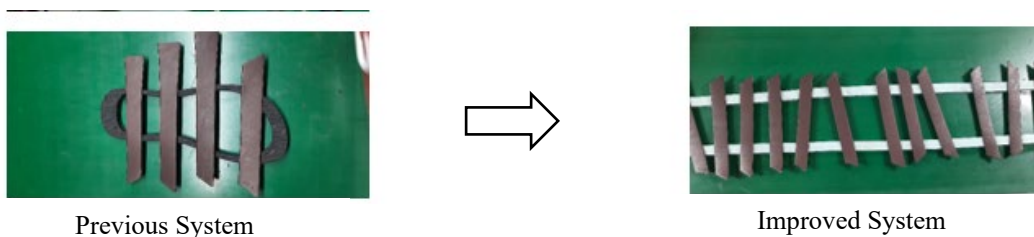


Figure 7. Upper carrying system improvement

As a result of the improvement, cycle time was reduced 15.24 sec. or 5.4% of the total cycle time. The future state map is shown in Figure 8.

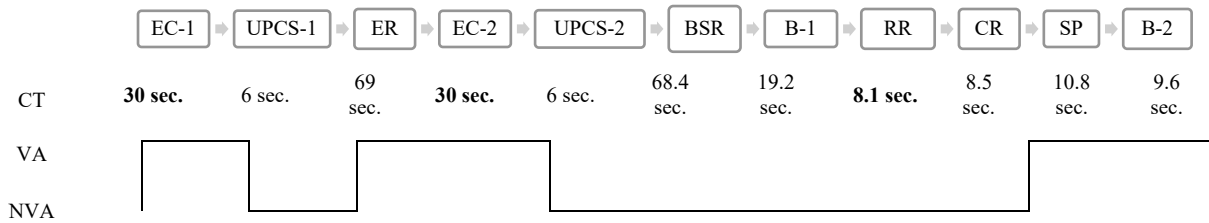


Figure 8. Future state map (VSM)

### 3.4.2 Layout Improvement

The layout of the system was improved by removing unnecessary transportation. The improved layout is shown in Figure 9. Now the flow of the product is smoother.

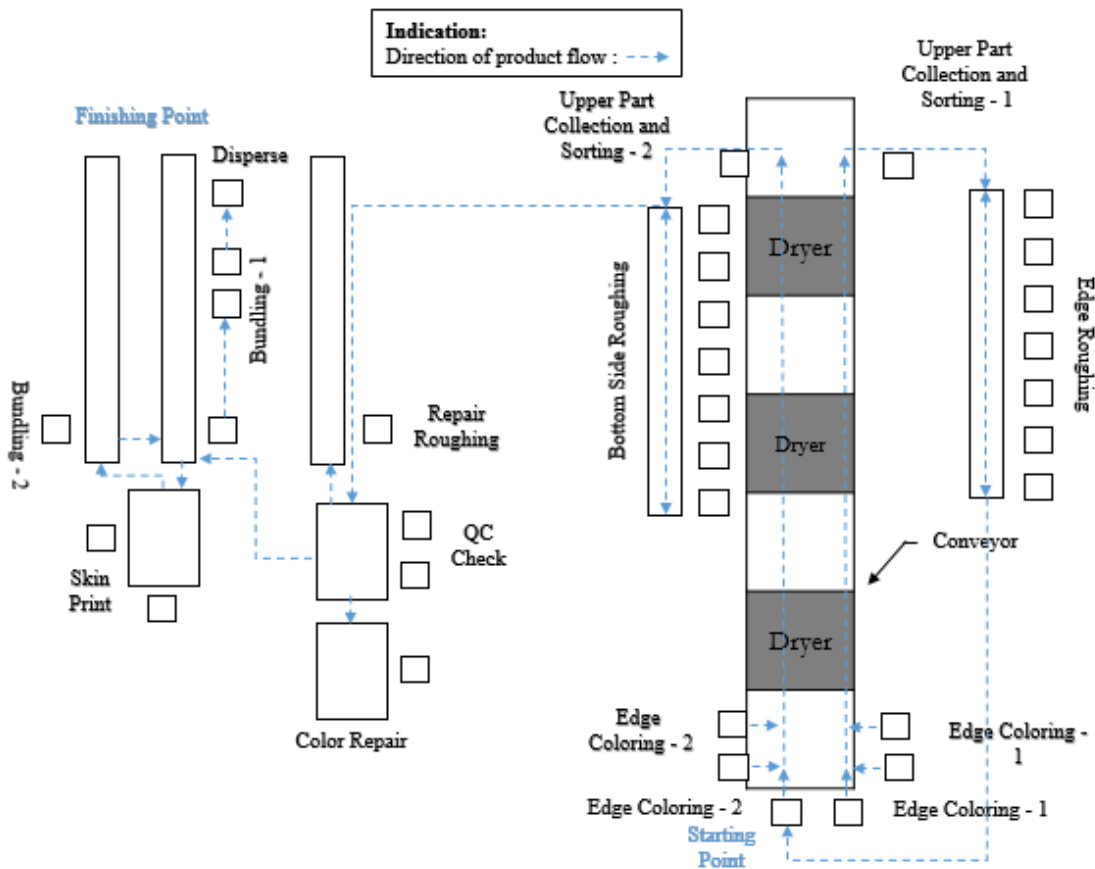


Figure 9. Improved layout

### 3.4.3 Bottleneck Improvement

Based on the Takt time, hourly target is 300 pairs. But the hourly capacity of Bottom Side Roughing and Roughing Repair are 183 and 276 pairs respectively. So the LSS team increased the capacity of the Bottom Side Roughing to 320 pair per hour by adding 3 persons. The frequency of the Roughing Repair was reduced because of the improved carrying system. So, the cycle time of the process is reduced 3.24 sec. Now the capacity of the process is 386 pairs per hour.

On the other hand, over capacity of the Edge Colouring – 1 and Edge Colouring – 2 were reduced from 348 to 313 pairs per hour. In this process, 2 manpower were saved. One manpower was also saved from the Side Roughing



process. Hence, the total manpower was conserved. Previous and present capacity of each stations are shown in Table 4.

Table 4. Comparison of capacity before and after balance

Process Step Name	Average Cycle Time (CT) (sec.)	Performance Rating (PR)	Required Step/Pair	Standard Minute Value (SMV)	Previous Manpower	Capacity (pair)	Present Manpower	Present Capacity
Edge Colouring-1	5	1	6	0.58	4	348	3	313
Upper Part Collection and Sorting - 1	1	1	6	0.12	1	522	1	522
Edge Roughing	11.5	1	6	1.32	8	363	7	318
Edge Colouring-2	5	1	6	0.58	4	348	3	313
Upper Part Collection and Sorting - 2	1	1	6	0.12	1	522	1	522
Bottom Side Roughing	11.4	1	6	1.31	4	183	7	320
Roughing Repair	13.5	1	0.6	0.16	1	276	1	386
Colour Repair	8.3	1	1.02	0.16	1	370	1	370
Bundling-1	4.8	1	4	0.37	2	326	2	326
Skin Print	5.4	1	2	0.21	2	580	2	580
Bundling-2	4.8	1	2	0.18	1	326	1	326
<b>Total</b>				<b>5.09</b>	<b>29</b>		<b>29</b>	

### 3.5 Control Phase

The LSS team sustains the improvements in this phase. Following six basic steps ensure the process performance (Alfaro et al. 2020; Jor et al. 2018).

1. The improved process need to be documented.
2. The improved outcome is verified by the accounting department.
3. Improvement must be confirmed during the working process.
4. Monitoring system need to be set up for controlling the performance.
5. The working process is organized.
6. A control plan must be created.

The LSS team has been documented define, measure, analyse, and improve phase in details. The improved outcome is shown in result section. Improved process was maintained during the working process. The performance was controlled by hourly production report. Daily efficiency report is shown in result section. For organised working process, every department actively participated in the project. LSS team planned for the following control initiatives.

- Hourly production report and daily efficiency report will be maintained by the department of Industrial Engineering (IE).
- Improved process will be maintained as standard by the production department.
- Continual improvement process will be continued by IE department.

The LSS team completed the project successfully. The result of the improvement is shown in the next section.

## 4. Data Collection

This study aims to increase the efficiency of the Edge Colouring process of the industry 'X'. So the data were collected from the industry. All of the data were collected by the LSS team under the department of IE. They collected the data by direct observation. Therefore, all of the data are primary. Tables 3, 4, and 5 contain all of the necessary information.

## 5. Result and Discussion

### 5.1 Numerical Results

The purpose of the study was to improve the efficiency of the Edge Colouring process. Daily efficiency before and after the improvement is shown in Table 5. The average efficiency before the improvement was 31.16% and the average efficiency after the improvement was 48.16%. So, the efficiency was increased 17% which is 7% more than the target.

Table 5. Daily efficiency before and after improvements

Improvement Status	Date	Production (pair)	Manpower	Working Hour	Efficiency (%)
Before	14/02/22	1165	29	10	36
	15/02/22	1229	29	10	38
	16/02/22	1294	29	10	40
	17/02/22	1100	29	10	34
	19/02/22	1100	29	10	34
	20/02/22	1132	29	10	35
	<b>Average</b>		<b>1170</b>	29	10
After	22/02/22	1262	29	10	39
	23/02/22	1779	29	10	55
	24/02/22	1553	29	10	48
	26/02/22	1197	29	10	37
	27/02/22	1747	29	10	54
	28/02/22	1812	29	10	56
	<b>Average</b>		<b>1558.3</b>	29	10

The CM before and after the improvement is shown below.

CM calculation before improvement:

$$\begin{aligned}
 \text{Cost Per Minute, CPM} &= \frac{\text{Actual salary for the day}}{\text{No. of workers} \times \text{Working hour} \times 60} \\
 &= \frac{9731}{33 \times 8 \times 60} \text{ tk} \\
 & \text{[Here, indirect manpower} = 4 \text{ and basic working hour} = 8] \\
 &= 0.61 \text{ tk } (\$ 0.00726) \text{ [Here, } \$1 = 85 \text{ tk]} \\
 \text{Cost of Making, CM} &= \frac{\text{SMV} \times \text{CPM}}{\text{Efficiency}} \\
 &= \frac{5.38 \times 0.61}{31.16} \text{ tk} \\
 &= 10.61 \text{ tk/pair } (\$ 0.126) \text{ [Here, } \$1 = 85 \text{ tk]}
 \end{aligned}$$

CM calculation after improvement:

$$\begin{aligned}
 \text{Cost Per Minute, CPM} &= \frac{\text{Actual salary for the day}}{\text{No. of workers} \times \text{Working hour} \times 60} \\
 &= \frac{9731}{33 \times 8 \times 60} \text{ tk} \\
 & \text{[Here, indirect manpower} = 4 \text{ and basic working hour} = 8] \\
 &= 0.61 \text{ tk } (\$ 0.00726) \text{ [Here, } \$1 = 85 \text{ tk]}
 \end{aligned}$$

$$\begin{aligned} \text{Cost of Making, } CM &= \frac{SMV \times CPM}{\text{Efficiency}} \\ &= \frac{5.38 \times 0.61}{48.16} \text{ tk} \\ &= 6.48 \text{ tk/pair } (\$ 0.077) \text{ [Here, } \$1 = 85 \text{ tk}] \end{aligned}$$

The CM was reduced 38.92%.

The LSS team has reduced the NVA activities, improved the layout and smoothed the flow. Therefore, the efficiency was increased and consequently reduced the CM.

## 5.2 Graphical Results

The trend of the efficiency is not clear from the numerical result. The daily efficiency and the trend are shown in Figure 10. So, the trend is positive.

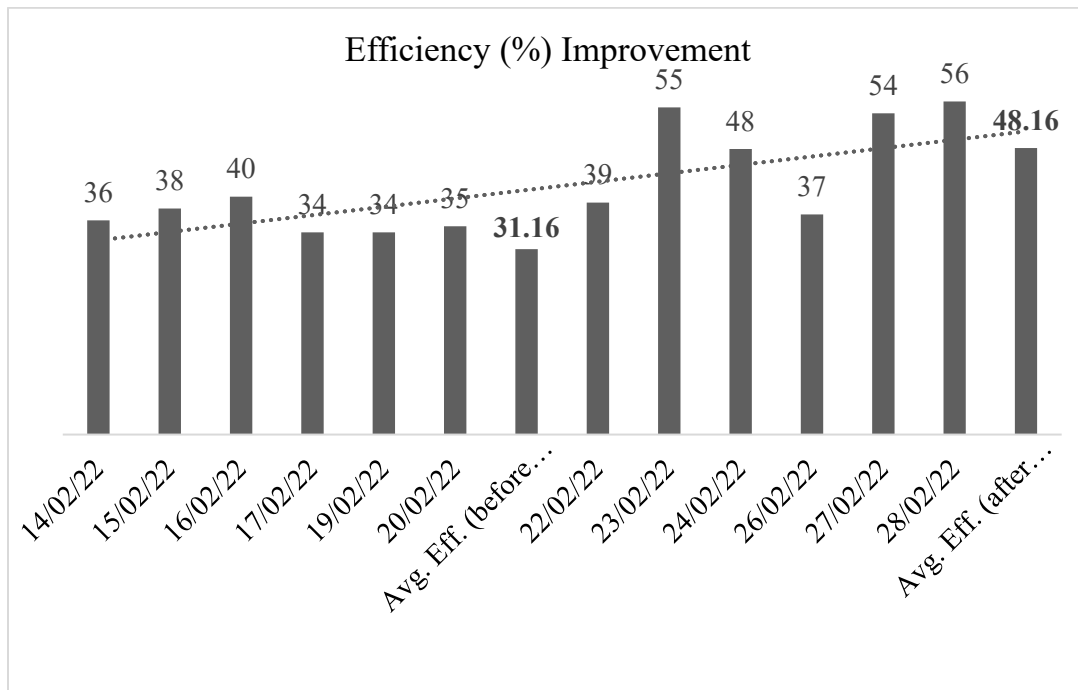


Figure 10. Efficiency before and after improvement

## 5.3 Proposed Improvements

At first, the Edge Colouring process was acquainted with the help of SIPOC diagram and PFD. The NVAs were identified with the help of VSM. The LSS team developed the upper carrying system to reduce those NVAs.

Then, the product flow was improved to reduce the unnecessary motion and transportation. Spaghetti diagram showed the previous flow of material. The improved process layout reduced those unnecessary motion and transportation.

Finally, the capacity of the bottleneck processes was increased to meet the customer's requirement. Required capacity was calculated by Takt time. The bottlenecks were identified by Standard Combination Sheet. The process line was balanced by allocating the manpower properly.

In future, DMAIC methodology can be implemented in other industries in terms of efficiency. The DFSS methodology can be implemented to improve the Edge Colouring process.

## 6. Conclusion

The DMAIC methodology can be implemented not only quality perspective but also efficiency perspective. We improved the efficiency of the Edge Colouring process by adopting DMAIC methodology. At first, the NVA activities were reduced by improving the upper supporting system. The unnecessary transportation has been reduced by improving the layout. Finally, the LSS team removed the bottlenecks for the smoother process flow. As a result of the improvements, the efficiency of the process was increased 17% and CM was reduced 38.92%. Therefore, the DMAIC methodology can be adopted in terms of efficiency.

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## Biography

**Md. Sajib Milki** is a Lecturer of Department of Industrial Engineering (IE) at the BGMEA University of Fashion & Technology (BUFT). He earned his B.Sc. in Industrial & Production Engineering from Rajshahi University of Engineering & Technology (RUET). His research activities include the area of Quality Control, Circular Supply Chain Management and Data Analytics. He has supervised some under-graduate students in these areas.