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Defects Minimization through DMAIC Methodology of Six Sigma

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ABSTRACT
The demand for higher value at lower price is increasing and to survive, garment manufacturers need to improve their operations through producing "right first time" quality product. Minimization of defects is the prerequisite to the quality improvement. This paper presents how to minimize the defects rate by introducing and implementing the DMAIC Methodology of Six Sigma into a sewing section of a selected garment factory. This is a systematic approach towards defects minimization through five phases of DMAIC methodology named Define, Measure, Analyze, Improve and Control. Pareto chart was used to identify the top occurring defects. After identifying the major defects, brainstorming tool was used to identify the probable causes and then potential root causes were identified by online inspections and root cause analysis. The result found after implementation of the methodology was very significant. The defect percentage was reduced from 11.229 to 7.604 and the Sigma level was improved from 2.714 to 2.93.

Keywords: Defects, DMAIC, Pareto Chart, Cause & Effect Diagram, Sigma level.

1. Introduction

Ready-made garment (RMG) is the most important sector in Bangladesh in terms of employment, foreign exchange earnings and its contribution to Gross Domestic Product (GDP). It is the largest exporting industry in Bangladesh, which experienced phenomenal growth during the last 20 years. According to the annual financial report of BKMEA, in the financial year 2012-2013, 79.63% of Bangladesh's export earnings came from the garment industry and its contribution to the GDP was 8.07% [1]. The export-quota system and the availability of cheap labor are the two main reasons behind the success of this industry. But, the phase-out of the export-quota system from the beginning of 2005 has raised the competitiveness issue of the Bangladesh Readymade Garments industry as a top priority topic.

According to Tennant and Geoff, "A systematic continuous improvement process can largely minimize the defect percentage and increase the productivity" [2]. On the other hand, most of the garments factories in Bangladesh have not any particular quality management system. In order to minimize the defect rate, it is very important to follow a particular methodology in their quality management system. Considering the reasons above, this study makes an attempt to introduce and implement the DMAIC methodology of Six Sigma in a selected garment industry to minimize the defect percentage. DMAIC methodology of Six Sigma is a problem solving technique where process data is analyzed by different Six Sigma tools and identify the problems which cause the defects produce in the product.

Six Sigma is a quality improvement process of final product by reducing the defects, minimizing the variation and improving capability in the manufacturing process. A study by Antony et al. indicates Six Sigma as a more advanced level of quality, which will certainly implement those organizations that tend to business excellence after QMS certification per ISO 9000 series [3]. It is a set of techniques based on Statistical Process Control (SPC) which can help companies to achieve significant improvement in product quality and therefore increase competitiveness. The term Six Sigma originated from terminology associated with statistical modeling of manufacturing processes. By definition, Six Sigma is less than 3.4 Defect per Million Opportunities (DPMO) or parts per million (PPM). Six Sigma concept typically involves using process roadmaps and problem-solving tools. The Six Sigma DMAIC (Define, Measure, Analyze, Improve and Control) methodology helps to improve existing processes through incremental improvements.

2. Background of the Study

Defects play a vital role in the productivity of the garments factory. If a defect creates in one section of the production process and it is detected in the final inspection then defective garment has to travel a long distance before being identified. Money spent during the production process on a defective garment is a waste as the product cannot be exported. Even if it is made exportable with alterations, it is done so only by spending more money, which is of no value to a factory owner.

A study by Saroj Bala concluded that the demand for higher value at lower price is increasing and to survive, garments manufacturers need to improve their

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operations through producing right first time quality and waste reduction. The industry can gain higher productivity and profitability with improved quality product by minimizing the need for reworks. It also minimizes cost and improves internal throughout time [4].

In a garment factory, defects may originate from the fabric section, cutting section, sewing section or finishing section. Among those the sewing section is the largest and most complex in operation. A study by Kayaalp I. and Erdogan, M. showed that more than 75% garment defects were found in the final inspection coming from sewing section [5]. In this context, defect minimization in the sewing section of Readymade Garments factory is selected for this research work. The major defects occur from the sewing section are open seams, wrong stitching techniques, non matching threads, missing stitches, improper creasing of the garment, improper thread tension etc.

3. Methodology

The research methodology adopted for this study is done by the case study and brain storming. The case study conducted on a garment factory named "Vision Composite Knit Limited" located at Savar, Dhaka. At first preliminary investigation was carried out at cutting, sewing, washing, finishing and packing section to identify the area where most of the defects are occurred. It is found the sewing section is highly suffered from defect and rework problems. For this reason, we decided to work on sewing line to minimize the defect percentage by using DMAIC approach of Six Sigma methodology

We collected the secondary data of the sewing section which was provided by the management of the factory. The data was collected for Pant only. According to our observation and using the end line quality data provided by the management we identified some repetitive defects that occur in the sewing section

The information and data collected were arranged so that further study and analysis could be performed. Two mostly used Six Sigma tools namely Pareto Analysis and Cause-Effect Diagram were used in our analysis part

Pareto analysis was used to identify the top occurring defects. Brainstorming session was conducted to identify the probable causes and then potential root causes were identified by online inspections. Cause-Effect Diagrams were constructed for those defects. After identifying the major causes of the top occurring defects, we provided some respective suggestions to minimize the frequency of the defects. The suggestions were made based on the brain storming session which was arranged by the management of the factory. Experts of the factory from different areas were present on that session.

Due to time constraint, management could not be able to implement all of our suggestions. But they implemented some of our suggestions in short time-frame on their pilot line and found some improvement

4. Data Analysis and Result

4.1 Data Collection

Data sheets were collected from the management for pant only. The data had been taken by the end line quality inspectors from two production lines of sewing section. The combined 16 days data for the inspection of pants is given by the table 1.

Table 1: Inspection Report for Pants

Day	Checked Pieces	Defects found
1	610	60
2	888	106
3	989	107
4	861	88
5	992	97
6	857	92
7	761	83
8	805	78
9	851	79
10	176	23
11	800	91
12	749	93
13	808	87
14	731	98
15	476	70
16	143	39
Total	11497	1291

4.2 Application of Six Sigma DMAIC Methodology

4.2.1 Define Phase

Define is the first phase of the DMAIC methodology of Six Sigma. The purpose of this phase is to define the problem, goal of the project and the process that needs to be improved to get higher sigma level. There are different six sigma tools are available for define phase. This research has applied the tool called SIPOC.

Problem Statement: The garment industries are suffering from high rate of rejections of their products due to the defects.

Goal Statement: To reduce the defect percentage to minimum level and thereby improve the quality, reduce wastes and increase productivity.

SIPOC

This is a process map that includes Suppliers, Inputs, Process, Outputs and Customers. Quality is judged based on the output of a process. Table 2 shows the SIPOC flow of the selected factory.

Table 2: SIPOC Flow of Vision Composite Knit Ltd

Suppliers	Inputs	Processes	Outputs	Customers
-Altex Fabrics Ltd. -Fabian Group	Unstitched cloth Machinery Thread Needles Button Zipper Label	Cutting Sewing Washing Ironing Finishing Packaging	T-shirt Polo-shirt Pant	C & A Tesco Masko s

4.2.2 Measure Phase

At this phase, percentage of defects, existing DPMO (Defect per Million Opportunity) and Sigma Level of the selected factory were calculated which is indicated in table 3. The frequency of defects of the inspected pants was also calculated and recorded in table 4. Pareto Chart was used as a Six Sigma tool here.

Table 3: DPMO and Sigma Level of Existing Process

Total Checked	11497
No. of Defectives	1291
% Defectives	11.229
DPO	0.11229
DPMO	112290
Sigma level	2.714

Table 4: Frequency of Defects of the Inspected Pants

Defects	Total Occurrence	% of Occurrence
Over Stitch	87	6.739
Down Stitch	135	10.457
Skip Stitch	147	11.387
Raw Edge	152	11.774
Joint Stitch	249	19.287
Thread Tension	87	6.739
Uneven Stitch	85	6.584
Puckering	24	1.859
Fabric Fault	2	0.155
Bar tack Missing	27	2.091
Spot	39	3.021
Slanted Stitch	140	10.844
Others	117	9.063
Total	1291	100

4.2.2.1 Pareto Chart

Pareto Chart is used to graphically summarize and display the relative importance of the differences between groups of data. It is a bar graph. The lengths of the bars represent frequency and are arranged with longest bars on the left and the shortest to the right. In this way the chart visually depicts which areas are more significant.

In this research, the major causes or types of defects were identified through Pareto Chart. The chart was constructed by the MiniTab Software. From the Pareto Chart following major sewing defects were identified.

1. Joint Stitch
2. Raw edge
3. Skip Stitch
4. Slanted Stitch
5. Down Stitch
6. Over Stitch
7. Thread Tension
8. Uneven Stitch

Among all, only these 8 defects are responsible for 86.3% of total defects.

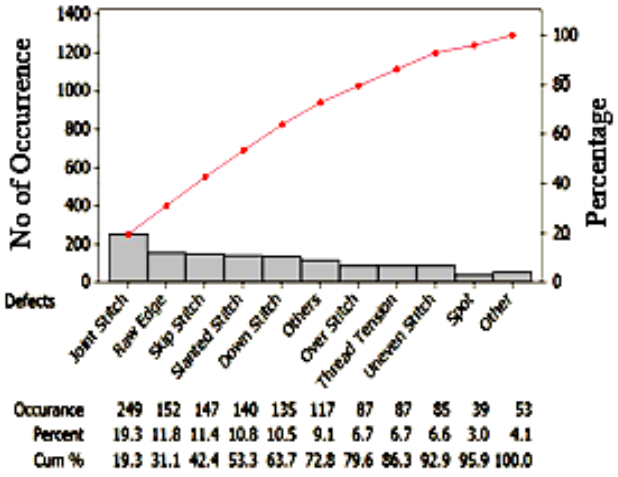

Figure 1: Pareto Chart for Identifying Major Defects

4.2.3 Analyze Phase

The purpose of the analyze phase is to target the improvement opportunities by taking a closer look at the data to determine the root causes of the process problems and inefficiencies. At the measure phase eight major types of defects were identified and the target of this phase is to find out all the potential causes of those defects. Two problem solving six sigma tools are used at Analyze Phase and these are: Brainstorming and Cause & Effect Diagram.

4.2.3.1 Brainstorming

Brainstorming is one of the most effective problem solving tools. The goal of this tool is to identify the issues, solutions and opportunities. In order to identify the probable causes of the defects and their respective solutions a Brainstorming session was arranged at the selected factory. The session was carried out by Round Robin method with the presence of factory manager, sewing floor manager, industrial engineer, end line quality inspector, line supervisor and sewing machine operator.

4.2.3.2 Cause & Effect Diagram

Cause & Effect diagram is a chart that identifies potential causes for particular quality problems. They are often called fishbone diagram. These causes could be related to the machines, workers, measurement, suppliers, materials, and many other aspects of the production process. This study has considered the causes related to 4 M's- Man, Machine, Method and Material. Cause & Effect diagrams are constructed based on the root causes identified by the online inspection. Total 470 pieces were inspected directly and 49 defects were found. The causes behind the defects were also identified immediately. There are some vital causes those have the highest frequency and mostly responsible for the defects. Table 5 shows the root causes sequentially according to their frequency of occurrence.

Table 5: Root Causes Analysis

Areas	Root Causes	No of Occurrences	Total
Man	Carelessness	9	17
	Unskilled operator	4	
	Margin not followed properly while stitching	2	
	Improper feeding	1	
	Lack of understanding about the whole operation	1	
Machine	Inappropriate thread tension	3	10
	Excessive pressure on pressure foot	2	
	Machine is threaded incorrectly	2	
	Dull sewing machine knives	2	
	Dull sewing machine needle or bent needle	1	
Method	Insufficient thread with respect to the length of the stitch	7	16
	The stitch is too long for the type of fabric in work	3	
	Machine speed is too high	2	
	Thread breaks during sewing	1	
	Improper folding	1	
	The stitch hole in the feed dog is too small or too large	1	
	Excessive abrasion or chemical degradation of the thread during the wash process	1	
Material	Poor quality thread	0	0
	Poor quality needle	0	

From table 5, it is observed that there were several man, machine and method related causes for the defects but no material related causes were found. Carelessness and lack of skills are two man related causes those have the highest frequency of occurrence (frequency: 13 of 17). Inappropriate thread tension or incorrect threading of the machines and excessive pressure on pressure foot are two major machine related causes (frequency: 7 of 10). On the other hand, insufficient thread and long stitch length are the major method related causes identified by the online inspection (frequency: 10 of 16). The identified causes are given in Cause & Effect diagram that is shown in figure 2.

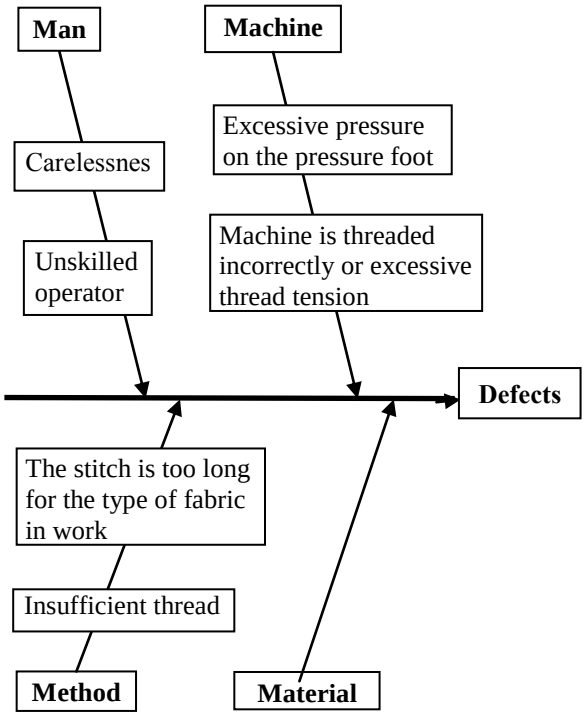

Figure 2: Cause & Effect Diagram for Major Defects

4.2.4 Improve Phase

The goal of the DMAIC Improve phase is to identify a solution to the problem that the project aims to address. This involves brainstorming potential solutions, selection of solutions to test and evaluating the results of the implemented solutions. Often a pilot implementation is conducted prior to a full-scale rollout of improvements.

4.2.4.1 Suggested Solutions

This study tried to suggest some potential solutions to minimize the causes of defects through brainstorming, direct observation and literature review. The solutions of the causes related to man, machine and method are given in table 6.

4.2.4.2 Implementation of the Solutions

This is the most difficult part for any research. Time constraint is one of the big reasons for the difficulty. Also, it is a big challenge for the research team to make an understanding to the management of an industry about the importance of the changes. This study also faced same difficulties and challenges. After a long discussion with the management, they agreed to implement some of the suggested solutions into one of their pilot sewing lines.

This study followed the Kaizen Improvement Technique that means continuous improvement. In order that the

solutions were divided into two categories: short term and long term. First, implement the short term solutions and then gradually go for the long term solutions.

Table 6: Suggested Solutions for Root Causes

Root Causes	Suggested Solutions
Man 1. Carelessness 2. Lack of skill of the operators	1. Improve supervision to make them careful 2. Provide adequate training to the operators to boost up their skill
Machine 1. Machine is threaded incorrectly or excessive thread tension 2. Excessive pressure on the presser foot 3. Dull or bent sewing machine needle and knife	1. Rethread the machine properly and make sure the thread goes through the tension discs. Ensure the stitch on the seam line is loose and be able to move if the needle hits it during a subsequent sewing operation. 2. Adjust the pressure on the presser foot. 3. Replace the needle and knife when it is dull or bent.
Method 1.Insufficient thread with respect to the length of the stitch 2. Long stitch for the type of fabric in work 3.Machine speed is too high	1. Make sure that the thread is sufficient to complete the whole length of stitch. 2. Reduce the length of the stitch by means of the stitch regulator, especially when sewing fine fabrics. 3. Start with lower speed then gradually increase the speed.

Short term solutions are:

- Replacement of dull or bent sewing machine needles and knives with new ones
- Insert the needles to the correct position
- Rethread the incorrectly threaded bobbins
- Always use good quality thread
- Use proper stitch length (as small as possible) during sewing
- Carefully follow the marked line during sewing

Long term solutions are:

- Provide adequate training to the operator
- Improve supervision
- Change faulty machine parts
- Develop a proper quality management system in order to quick detection and solution of the quality problems.

4.2.4.3 Result

Based on the solutions provided by this study, some corrective actions were taken. All short term solutions were implemented into one of their pilot sewing lines. Defects data were taken for eleven days after implementation of solutions that is recorded in table 7. The percentage of defectives, DPO, DPMO (Defect per Million Opportunity) and Sigma Level were calculated and reported on table 8.

Table 7: Number of Defects in Inspection of Pants after Improvement

Day	Checked Pieces	Defectives
1	720	45
2	839	75
3	752	53
4	690	41
5	805	64
6	731	45
7	163	12
8	792	61
9	827	67
10	878	88
11	470	32
Total	7667	583

Table 8: DPMO and Sigma Level after Improvement

Total Checked	7667
No. of Defectives	583
% Defectives	7.604
DPO	0.07604
DPMO	76040
Sigma level	2.93

4.2.5 Control Phase

After implementation of the solutions, the positive results were discussed with the management of the selected garment industry. The major defects were identified and partially reduced in amount. Now the real challenge is to sustain the improvements and make improving the process continuously. So, this research made a control plan in order to sustain the improvements and make the process improving.

4.2.5.1 Control Plan

The following are the mandatory actions that need to be taken by the management to sustain the results after Six Sigma implementation.

- The operators of garment industry must be given training on a continuous basis on the issue of quality.
- Always use good quality threads, needles and other garment accessories.
- The management should give incentives for high quality performance.
- The focus should be on preventing defects rather than correcting defects.
- Tight quality controls should be enforced.
- The organization should develop a proper Quality Management System.

5. Conclusion

Minimizing defect is very important for ensuring the quality of products. The importance of the garment industry in the economy of Bangladesh is very high. The explosive growth of the RMG industry in the country, however, has not been enough supported by the growth of backward linkage facilities. So manufacturing the quality product is mandatory to sustain in this global competitive market. Good Quality increases the value of a product or service, establishes brand name, and builds up good reputation for the garment exporter, which in turn results into consumer satisfaction, high sales and foreign exchange for the country.

From the Pareto Chart total eight defects (Joint Stitch, Raw edge, Skip Stitch, Slanted Stitch, Down Stitch, Over Stitch, Thread Tension, Uneven Stitch) were identified and those defects were responsible for near about 80% of total defects occurring in the sewing section of the garment factory for pant only. After finding the major defects, brainstorming tool was used to identify the probable causes and then potential root causes were identified by online inspections and root cause analysis.

This research found that the selected garment industry was operating at a defect percentage of 11.229. The rate was very high at this present business context. After implementing the DMAIC Methodology of Six Sigma the percentage of defect was reduced to 7.604. There was also found a significant improvement of the Sigma level of the industry. It was shift from 2.714 to 2.93. So, this methodology is very effective to the minimization of defects. As the minimization of defects is a continuous process further implementation of this methodology will help the company enjoying more reduction on defect rate and improvement on productivity.

Many medium scale garment industries in Bangladesh are not aware of the Six Sigma concepts and this study will trigger a positive wave across the garment industries and make them more competitive.

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