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Implementation of the Six Sigma Methodology for Reducing Fabric Defects on the Knitting Production Floor: A Sustainable Approach for Knitting Industry

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Article

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ABSTRACT

Reducing fabric faults in the textile knitting industry is one of the main challenges for knit fabric production. Due to the fabric defects, the sigma level of knit fabric production is between 3 to 3.5. This study aims to increase the sigma level of knit fabric productions. Here, we implement a six sigma strategy in the textile knitting industry. The Six Sigma methodology is applied step by step on the knitting fabric production floor. The DMAIC approach is clearly stated through the phases of defining, measurement, analysis, improvement and control. The types and reasons for different fabric defects are identified by using the cause and effect diagram. The Pareto chart showed that the highest percentages (51%) of defects are related to yarn quality. In the improvement phase, the defects are eliminated by utilizing the Six Sigma methodology. Then, the sigma level of our knit fabric production went to 4. The risk priority number was calculated and suggestions for preventive actions were analysed in the control phase. Implementing the six sigma methodology on the knitting production floor also reduces the cost of production. As a result, this real time study on the knitting production floor has proved to be an economically sustainable production of knit fabric.

KEYWORDS

Six Sigma, DMAIC approach, fabric defects, knit fabric, sustainability

INTRODUCTION

One of the world's most globally interconnected industries is the textile and apparel business, which is crucial to human existence. The demand from developed countries has increased significantly, resulting in higher output and employment, increased growth in the agricultural sector, and an increase in the amount of foreign currency generated for developing economies [1]. Textile industries are the contributions of different part-by-part industries [2]. The fabric manufacturing industries are divided into two main categories [3]. One is the weaving industry [4] and another is the knitting industry [5]. The knit fabrics are produced by the textile knitting industries. The word "knitting" came into use in the middle of the 16th century, with earlier words like "cnyttan" and "nahyat" being less precise. This suggests that knitting came from knotting and Coptic knitting [6]. At present, the knitting industries employ the warp knitting and the weft knitting process. There have been many potentials for fabric manufacturing by using the knitting process [7, 8]. Knitting has a unique loop structure that makes it possible to use a small number of yarns, change the size of the loops, and make loops that change shape when under tension. This makes it possible to knit single-face, double-face, open-work, and surface-interest structures, as well as to make different types of loops in different widths and depths [9]. The production efficiency of knitted fabric is decreased due to the occurrence of knitting faults on the production floor. The reduction of knitting faults and the increase of the knitting production efficiency is one of the key challenges on the knitting production floors. To reduce the faults, Six Sigma approach can be used as a sustainable approach to knitted fabric production.

Six Sigma is frequently used to guide overall organizational advancement activities because of its structured project strategy that includes a vast range of problem-solving tools that are easy to apply. It is intended for eliminating defective products and other wastes from operational processes by applying the Define, Measure, Analyse, Improve, and Control (DMAIC) methodology in a disciplined and data-driven manner [10]. While Six Sigma was originally created for and employed in industrial environments, its application has expanded to include a wide range of other industries. In fact, the services industry is the second most prevalent sector to employ this practice [11]. Using the DMAIC approach, for example, considerable performance improvements have been achieved in service operations, such as banking and finance, education, government, and healthcare. Specific examples of its application in healthcare include lowering the length of clinic appointments, reducing the number of insurance claim denials, and cutting the time it takes to dispatch medical reports. Consulting, communications, human resources, information technology, and marketing are just a few of the professional services where this technique has been used successfully in the past [12]. The introduction of Six Sigma into the industrial field in the early 1980s by Motorola was a watershed moment in the expansion of the scope and application of quality systems in today's business environment [13]. The application of Six Sigma in the textile industries can increase the production efficiency of textile manufacturing.

Numerous studies have been conducted in various areas of textiles to improve product quality and defect reduction through the application of Six Sigma methodologies [14]. Adikorley et al. reported on the implementation and completion of Lean Six Sigma (LSS) projects and programs in the textile and apparel industries [15]. Bongomin et al. described a technique for increasing the efficiency of garment assembly lines through line balancing [16]. Prasad et al. documented the implementation of lean manufacturing in the Indian textile industry in their studies [17]. Mukhopadhyay et al. used the Six Sigma methodology to minimize yarn packing defects [18]. Karthi et al. presented a case study of lean Six Sigma implementation in a textile mill using an ISO 9001:2008-based quality management system [19]. Hussain et al. demonstrated the application of Six Sigma methodology in reducing defects in Pakistan's textile weaving industry [20]. Although some reports have analysed the Six Sigma methodology in relation to the knitting industry, the ultimate objects and their findings are far from our study. For example, (a) Ortega et al. developed dynamic model of the system for the manufacture of knitted textiles using Six Sigma, but they only increased the sigma level from 1.3 to 1.9. [21]; (b) Kurnia et al. studied the amount of sigma faults in sock knitting and give solutions for minimizing the percentage of socks with defects, which is mainly conducted in the garments industries [22]. Hence, there has been no study attempted to date that can provide a cost-effective and sustainable approach to six sigma application in the textile knitting industry.

Therefore, this study is conducted with the aim of implementation of the Six Sigma methodology on the knitting production floor. Industrial applications using DMAIC approaches are introduced part by part. The different phases are clearly stated and the cost of production after implementing Six Sigma are calculated. During the control phase, the risk priority number is calculated and possible preventive measures are examined. As a consequence of this real-time investigation on the knitting manufacturing floor, it is clear that knit fabric production will be economically sustainable.

EXPERIMENTAL DETAILS

Materials

There are several types of knitting machines in the industry, such as single-jersey knitting machines. Those machines’ dia and needle gauge are given respectively (24×24, 26×24, 28×24, 28×28, 30×20, 30×24, 30×28, 38×24, 42×24). In addition, there are a few double-jersey knitting machines, and those machines’ dia and needle gauge are given respectively (32×9, 32×18, 34×18, 36× 18, 40×18, 42×18). This knitting fabric produced basic single-jersey fabric, loose-knit single jersey, heavy jersey, terry, pique, single Lacoste, double Lacoste, full-feeder Lycra single jersey, 1×1 normal rib, 1×1 full-feeder Lycra rib, 2×1 normal rib, 2×2 normal rib, 3×2 normal rib, 4×4 normal rib, 4×4 full-feeder Lycra rib during this study time. The yarn counts that were mostly used (English count) were 20's, 28's, 30's, 34's, and 40's - these yarns are 100% cotton. Along with cotton yarns, 34's (80% cotton, 20% recycled cotton), 30's (50% cotton, 50% polyester), Lycra yarns, 20 deniers, 40 deniers and 70 deniers are commonly used on the production floor. Among all the produced fabrics, the defects could vary from fabric to fabric, widely known as knitted fabric defects.

Methodology

In this particular research piece, the methodology used is a case study. The "X Knitting Industry Limited" in Gazipur, Bangladesh, was selected as the location for the case study. An initial analysis of the knitted floor section with illustrations is presented. It has come to our attention that the knitting area contains many defects and rework concerns. Based on prior research findings, several different industries use the DMAIC method in combination with the Six Sigma method to fix defects. In addition to that, this study will also measure the level of sigma in the knitting industry. There is no study to this date that provides a cost-effective and sustainable approach to six sigma application in the knitting industry.

The study decided to use the DMAIC approach for the Six Sigma methodology to reduce the defect percentage on the knitting floor by a significant margin. The factory's management furnished secondary data on the knitting division and only Plants' data was gathered. Using the data provided by the management, we were able to identify a few quality-related issues in the knitting department. The collected data and information was organized in a way that would allow for further investigation and analysis. In our research, we used the Pareto Analysis and the Cause-and-Effect Diagram. Our team needed to perform a Failure Modes and Effects Analysis [FMEA] during the control stage in order to identify potential failure modes, the effects and severity of those failures, as well as the causes, risk priority numbers [RPN], and preventive measures. This research employed FMEA to improve quality with the Six Sigma method. It is undertaken in stages, as illustrated in Figure 1.

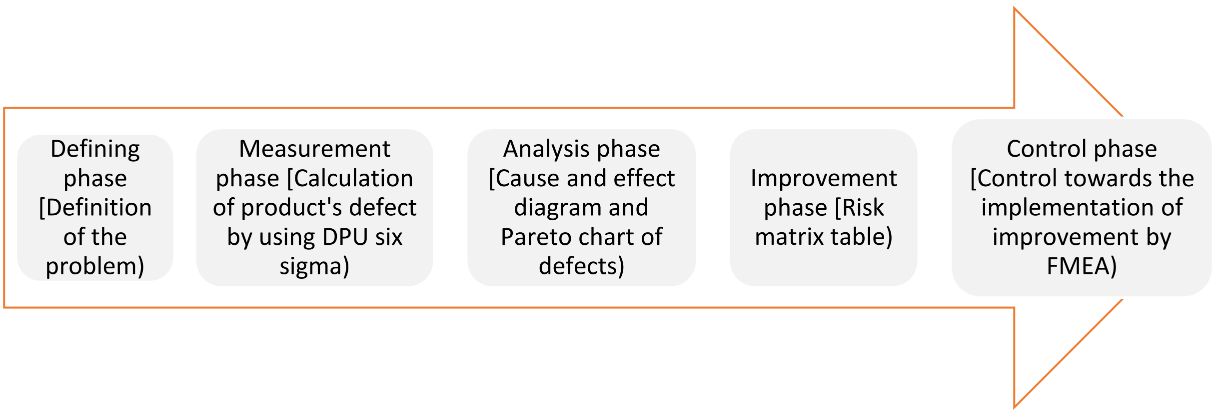


Figure 1. Schematic diagram of the implementation of Six Sigma

RESULTS AND DISCUSSION: APPLICATION OF THE SIX SIGMA DMAIC METHODOLOGY

Defining Phase

In the defining step of the Six Sigma approach, the problem, the scope of the research, the objective, the research team, and the timetable are all defined. This study's problem was defined as a high percentage of B-grade and C-grade knitted fabrics production in the knitting sector due to a large number of faults in the fabric. The study's objective was to reduce the production of B-grade fabric. A team of people from the fabric manufacturing department, quality control workers, management, and researchers were assembled to accomplish the work. Figure 2 shows the flow chart of the knitting process.

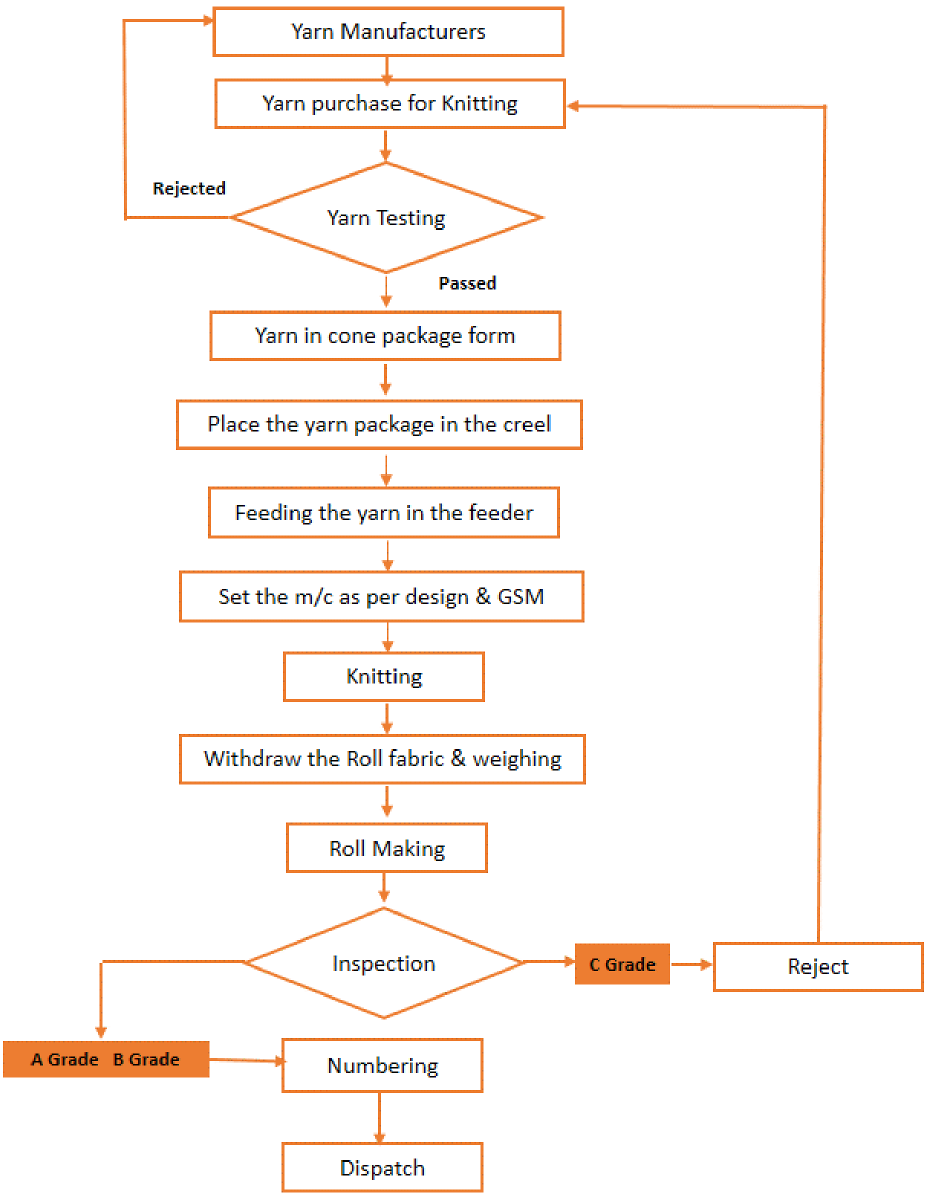


Figure 2. Process flow diagram of the knitting floor

Initially, yarn was purchased from the manufacturers as per the merchandiser provided for every particular order. Then the knitting production person ordered the required yarn. In the meantime, the yarn testing team tested the yarn to see if it could fulfil the requirements of the physical and chemical properties or not. They checked for various imperfections to match the reports provided by the yarn manufacturers to produce good fabrics. If yarns were not able to meet the requirements, they were sent back to the manufacturers. As per order, yarn was placed on the machine and then into the creel of the machine by a one-by-one system. After that, yarn was fed into the yarn feeder through an inching motion. Then, as per the order requirement, fabric design and stitch length were checked. If the design was okay, then GSM was checked as per stitch length. Finally, the machine was prepared for production. The roll of the fabric was withdrawn and the weight of the fabric measured. Furthermore, the quality department inspected the fabric and numbered the roll of the fabric as per grading. If the fabric was grade A and B, it was marked separately. Moreover, C-grade fabric was rejected. To fulfil the quantity, they again ordered the yarn to makeover the production quantity.

Measurement Phase

Each identified problem was alternated with a measurable phase in the measurement phase. An evaluation was made in light of the information gathered on these issues. Over the course of a week, all of the knitted fabrics on display were thoroughly inspected. Same as in the assessment, A- grade, B-grade and rejected (C-grade) fabrics were identified. During fabric grading, all the fabrics were counted as major and minor problems. The fabrics that were characterized by major defects would not be considered as acceptable for customers. In between, these fabrics would be considered as rejected. The rest of the inspected fabrics with minor defects would have a fair chance of acceptance.

The established sigma level of the knitting procedures was determined as follows, based on the data collected:

Total knit fabrics checked = 22910 meters

Total amount of major defects = 4149 meters

Total amount of minor defects = 4057 meters

Total amount of defects = 8206 meters

Opportunity per unit = 4

Total opportunities= Opportunity per unit X Total knit fabrics checked = 4 X 22910 = 91640

$$\text{Defects per unit (DPU)} = \frac{\text{Total amount of defects}}{\text{Total fabrics inspected}} = \frac{8206}{22910} = 0.358$$

Hence,

Yield= $e^{-0.358}$ = 0.699

PPM=$-\ln(yield) \times 1000000$ = $-\ln(0.699) \times 1000000$= 358105 (approx.)

After calculating the findings from the table, the existing sigma level was 3.5.

Analysis Phase

After the measurement phase, we analysed the diagram of cause and effect using brainstorming with the purpose of identifying all the factors that affect knitted fabric performance. Figure 3 shows the cause-and-effect diagram. The chart below gives a clear overview of all the potential problems, along with the areas of improvement, respectively. The fabrics were inspected and all faults were recorded; the causes and the severity of the faults were also recorded in Table 1. According to the table below, the total length of the inspected fabric was 22910 meters and the total length of major and minor faults was 4149 and 4057 meters, respectively.

Table 1. Defects identified after knit fabric inspection

Lot No.	Fabric Length inspected (m)	Major Defects (m)	Reason	Minor Defects (m)	Reason
1	4050	568	Yarn Quality	1000	Machine Setting
2	3340	500	Yarn Quality	400	Yarn Quality
3	2873	490	Machine Setting	637	Yarn Quality
4	2426	405	Yarn Quality	550	Yarn Quality
5	2140	370	Yarn Quality	623	Material Handling
6	1748	304	Machine Setting	500	Machine Setting
7	1573	270	Yarn Quality	100	Machine Setting
8	1236	160	Yarn Quality	145	Yarn Quality
9	834	189	Material Handling	10	Material Handling
10	738	100	Material Handling	17	Machine Maintenance
11	580	85	Machine Maintenance	25	Machine Maintenance
12	523	419	Yarn Quality	0	N/A
13	487	236	Machine Setting	10	Yarn Quality
14	362	53	Yarn Quality	40	Yarn Quality

Figure 4 illustrates a Pareto chart of the notable faults. We could easily distinguish the 'vital view' from the 'trivial many' in the Pareto chart. It was observed that 51% of the defects were related to yarn quality, 30% to machine setting and the rest of the defects came from machine maintenance and material handling.

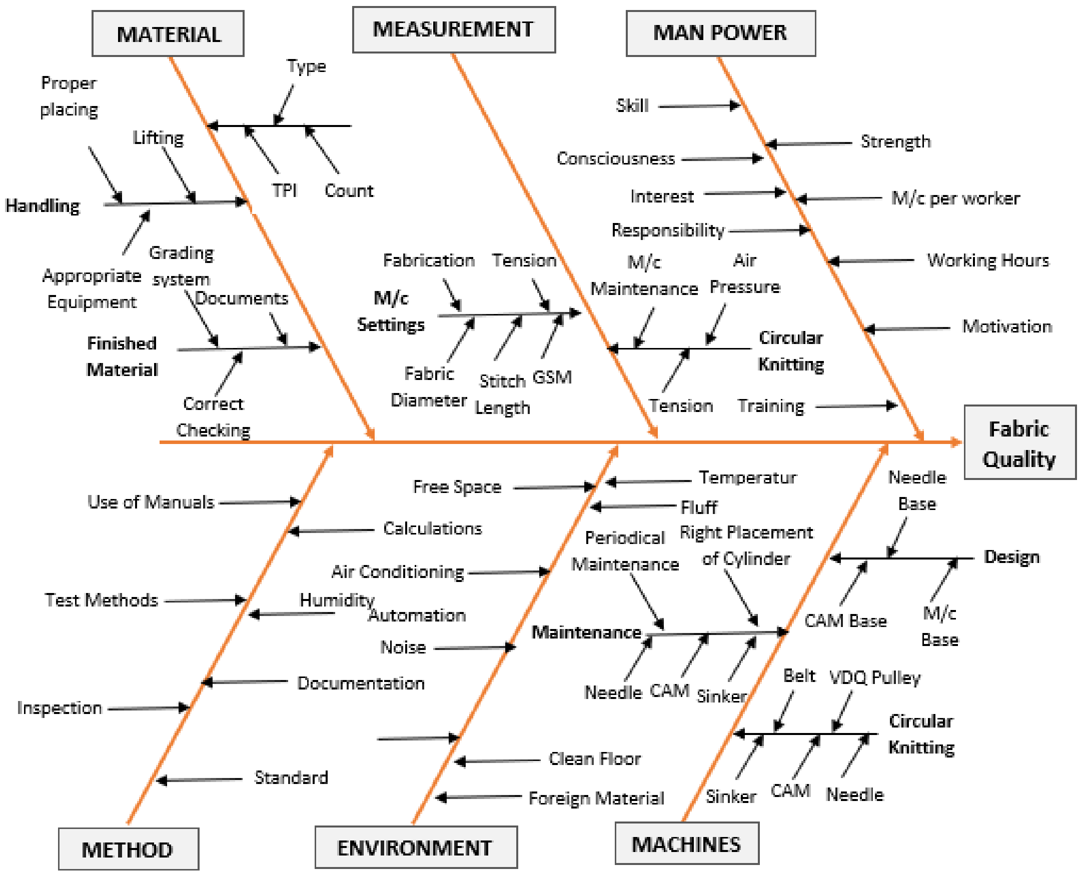
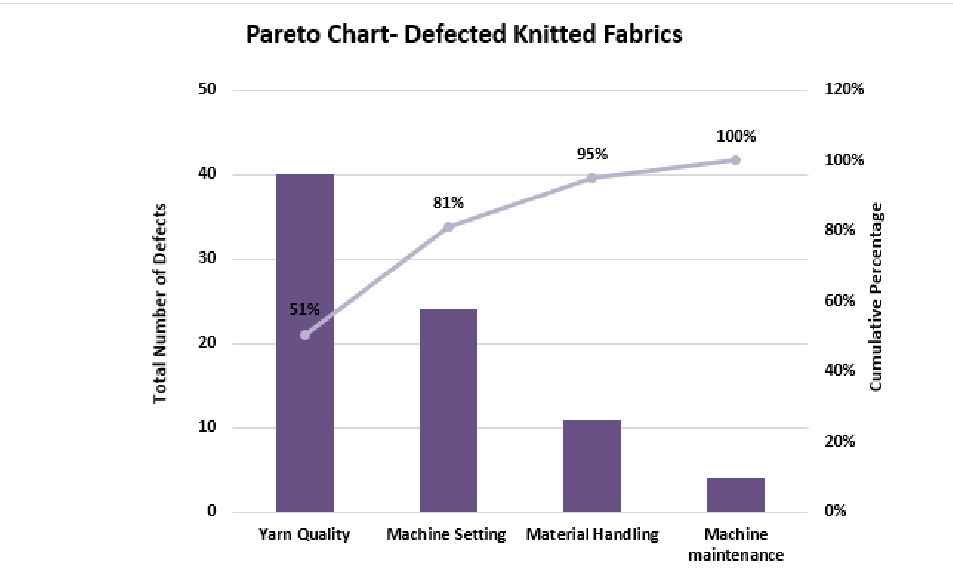


Figure 3. Cause and Effect diagram results



Total Number of Defects	40	24	11	4
Defect Percentage	51%	30%	14%	5%
Cumulative Percentage	51%	81%	95%	100%

Figure 4. Pareto chart of knitted fabrics defect analysis

Improvement Phase

The improvement phase assures the tasks of elimination of the root causes of the faults, the design of improved processes and their implementation. The risk matrix in this table depicts the likelihood, the impact, and the risk of the potential knitted fabric faults shown in Table 2. All of the above-mentioned issues were noted and possible solutions were devised. The major areas of concern found by the Pareto chart are yarn quality, machine setting, machine maintenance, material handling viz. count mix, lot mix, tension variation, Lycra cut, cylinder and dial placement, congested floor, and lack of operator consciousness, respectively. All possible machine configurations and machine maintenance procedures were investigated, and the improved results were implemented in consultation with the machine manufacturer and the well-equipped, well-trained technical personnel. Before deciding on a better quality yarn, the research and development team should be more proactive about the yarn, yarn manufacturers, and factory quality. Human Resources and Development department should deliver better operators by ensuring proper knowledge about production and quality for the purpose of reducing faults.

Table 2. Identification of risk matrix table of knitted fabrics defect

Activity	Risk	Likelihood	Impact	Level of Risk
Yarn Quality	Count Mix	Likely	Major	Extreme
	Lot Mix	Likely	Major	Extreme
	Thick Thin Yarn	Rarely	Minor	Moderate
	Double Yarn	Rarely	Minor	Moderate
	Cockled Yarn	Rarely	Minor	Low
	Slubby Yarn	Possible	Minor	Low
	Weak Yarn	Rarely	Minor	Low
	Reconning Yarn	Rarely	Minor	Low
Machine Setting	Dia Mark	Likely	Major	Moderate
	Oil Spot	Rarely	Minor	Moderate
	Needle Mark	Likely	Major	Moderate
	Sinker Mark	Likely	Major	Moderate
	Needle Broken	Possible	Minor	Moderate
	Hole	Possible	Minor	Moderate
	Loop	Rarely	Minor	Low
	Tension Variation [Patta]	Likely	Major	Extreme
	Contamination	Possible	Minor	Low
	Lycra Cut	Likely	Major	Extreme
Machine Maintenance	Latch Problem	Possible	Minor	Moderate
	Corrosion Sinker	Rarely	Minor	Moderate

Activity	Risk	Likelihood	Impact	Level of Risk
Machine Maintenance	Cylinder & Dial Placement	Likely	Major	Extreme
	Oil Line adjustment	Rarely	Minor	Low
	Wrong Cam Placement	Rarely	Moderate	Moderate
	Sinker Cam Placement	Rarely	Moderate	Moderate
	Fly/ dust/ foreign yarn	Possible	Minor	Low
Material Handling	Improper Material Handling	Possible	Moderate	Moderate
	Congested floor	Likely	Major	Extreme
	Frequent change of program	Likely	Major	Extreme

The manufacturer of the circular knitting machine advised proper machine setting during each design change into single- or double-jersey fabrics. The technical and maintenance teams always follow those kinds of machine settings to ensure preventive maintenance. However, in some cases, companies use needles, cams, sinkers, or other machine parts, beyond their life span, which affects the quality in the long run. Mostly, it causes rejection. In order to maintain proper quality, the maintenance of machines and the parts needs to be done properly. This would reduce 90% of the faults related to the machine. Proper training for workers is essential in order to ensure proper quality. There is also a proverb, 'workers are the best quality'. Training is the first and foremost tool for ensuring proper quality, making every worker aware of the long-term issues that may affect the quality. This would reduce material handling problems by 70%.

Along with the above-mentioned corrective actions, some other related corrective actions were implemented which are referred to in the risk matrix table.

- In the case of all problems related to yarn quality, spinning technology was improved. Testing of yarns should be given more priority to identify more excellent yarns before knitting.
- Ensure more of the preventive measures before the machine runs any new program.
- Set up a training zone for new workers so that they get proper knowledge about the machine and the materials.
- Focus on quality along with quantity.
- Performance based incentives for all workers were ensured so that they could motivate themselves for the bigger aspects of the manufacturer.

After eliminating all kinds of major defects in knitted fabrics related to yarns, machine setting, and material handling, the quantity of rejected and B-grade fabrics was reduced. After implementing Six Sigma, the improved sigma level of the knitting process was calculated as follows:

Total fabrics inspected = 13210 meters

Total amount of major defects = 3020 meters

Total amount of minor defects = 2250 meters

Total amount of defects = 5270 meters

Opportunity per unit = 4

Total opportunities = Opportunity per unit X Total knit fabrics checked = 4 X 13210 = 52840

$$\text{Defects per unit (DPU)} = \frac{\text{Total amount of defects}}{\text{Total fabrics inspected}} = \frac{5270}{13210} = 0.399 \text{ (approximately)}$$

Again,

Yield= $e^{-0.399}$ =0.671

PPM=$-\ln(yiel) \times 1{,}000{,}000$

=$-\ln(0.671) \times 1{,}000{,}000$

= 398986.142

After implementing, the improved sigma level is 4.

Cost Calculation

From the implementation of Six Sigma methodologies, the total amount of cost savings is summarized below. We have observed that after implementing the above measures, the knitting charge per kg of fabric is reduced. This scenario in Table 3 shows how this method can enhance the effectiveness of the products in the industry. Because of the increasing cost of yarn purchase and less increment in buyer's purchasing rate, Six Sigma methodology shows a positive tendency to decrease the cost of the production. The annual savings for single-jersey plain, loose knit, heavy jersey, pique, full-feeder Lycra, 3-thread fleece, and terry fabrics are 620, 170, 250, 64, 340, 148 and 86 US dollars, respectively. The annual savings are 77, 232, 114, 150, and 127 US dollars, respectively. Therefore, overall savings per annum of 2378 US dollars shows the improvement of fabric production in comparison with the conventional production method. As a result, the level of improvement of the sigma level was increased to 4 from 3.5 and the profit per annum was increased to 2378 US dollars.

Table 3. Identification of risk matrix table

Fabrics Type	Fabrics Name	Knitting Charge/ Kg Before (US$)	Knitting Charge/ Kg After (US$)	Save Per Annum (US$)	Total Save Per Annum (US$)
Single Jersey	Plain	0.160	0.140	620	
Single Jersey	Loose Knit	0.210	0.198	170	
Single Jersey	Heavy Jersey	0.470	0.460	250	
Single Jersey	Pique	0.330	0.303	64	
Single Jersey	Full Feeder Lycra	0.396	0.384	340	
Single Jersey	Fleece [3 Thread]	0.524	0.513	148	
Single Jersey	Terry	0.315	0.303	86	
Double Jersey	Half Feeder 1×1 Lycra Rib	0.300	0.280	77	2378
Double Jersey	Full Feeder 1×1 Lycra Rib	0.490	0.480	232	
Double Jersey	1×1 Normal Rib	0.330	0.315	114	
Double Jersey	Full Feeder 2×1 Lycra Rib	0.524	0.513	150	
Double Jersey	Full Feeder 4×4 Lycra Rib	0.630	0.620	127	

Control Phase

A procedure is adjusted, monitored, and regulated in such a way that the integrated improvements from the preceding measure phase are sustained in the control phase. The control phase covered all processes, including the control strategy (Poka Yoke), statistical process control (SPC), and failure mode and effect analysis (FMEA) [18]. We executed the FMEA at the measurement control stage, for all specific issues having do with potential failure, probable failure modes, their impacts and severity, causes, risk priority numbers (RPN), and preventive actions. In order to do FMEA, it was required to collect all the data relating to errors that occurred during the knitting process throughout the entire process. In Table 4, the results of the completed FMEA are shown.

Here, S stands for Severity, which indicates the impact of failure mode. It is scored from 1 to 10, where 1 is the lowest impact mode and 10 is the highest impact mode. O means Occurrence, which indicates the frequency of the failure mode. It ranges from 1 to 10, where 1 is the lowest occurrence and 10 is the highest occurrence of the failure mode. D means Detection, which indicates the ability to detect the failure mode during process control. It is scored from 1 to 10. The low scores indicate that the failure mode is easily detectable, high scores indicate the opposite. RPN means Risk Priority Number, which indicates the total risk score of the mode. If the mode shows high RPN then it needs immediate action, while low RPN is vice versa. It is calculated using the equation [1].

$$RPN = S \times O \times D \quad (1)$$

Where, RPN – risk priority number, S – severity, O – occurrence, D – detection

Table 4. Identification of FMEA for knit fabrics

Issues	Potential Failure	Potential effect of failure mode	S	Potential cause of failure mode	O	D	RPN	Preventive action
Yarn	Count Mix	Uneven appearance & shade variation	5	Negligence of the worker	4	3	60	Proper training of workers
	Lot Mix	Shade Variation	4	Negligence of the worker	3	2	24	Proper training of workers
	Thick Thin Yarn	Poor Appearance in fabric	2	Improper spinning	2	2	8	Proper spinning / Right yarn selection
	Slubby Yarn	Imperfection into fabric appearance	1	Improper spinning	0	0	0	Proper spinning/ Right Yarn selection
	Cockled Yarn	Distortion of loop during loop formation	1	Improper spinning	1	0	0	Proper spinning/ Right yarn selection
	Double Yarn	Poor appearance into the fabric	1	Winding fault	0	0	0	Proper winding
	Weak Yarn	Frequently breakage of yarn	2	Improper Spinning	1	2	4	Proper spinning/ Right yarn selection
	Reconning Yarn	Patta, Thick-thin, count & lot mistake	3	Unawareness of long-term effect	3	2	18	Training & raise proper knowledge about yarn
Machine Setting	Día Mark	Crease mark opposite of the open side of the fabric	1	Excessive tension of the fabric during winding inti cloth roller	1	1	1	Proper tension of the fabric
	Oil spot	Oil spot into the fabric	2	Leakage or negligence of worker	1	1	2	Proper training of the worker
	Needle mark	Straight mark into the direction course	3	Breakage of needle / bending needle	2	2	12	No bent needle
	Sinker mark	Straight mark into the direction course	2	Bending sinker / corrosion sinker	1	1	2	No corrosive sinker
	Needle broken	Straight mark into the direction of Wales	3	Broken batch of the needle	2	2	12	More use than lifetime
	Hole	Hole into the fabric	3	Badly knot / lack of strength of the yarn	3	3	27	Proper knot in the yarn after breakage
	Loop	Missing loop in the Wales direction	2	Latch problem / broken needle	2	1	4	Proper maintenance of needle
	Tension Variation	Waviness into the direction of course	4	Yarn improper tension / wrong machine setting	2	3	24	Exact machine setting/ proper tension of yarn

Issues	Potential Failure	Potential effect of failure mode	S	Potential cause of failure mode	O	D	RPN	Preventive action
Machine Setting	Lycra cut	Missing Lycra into direction of course of the Lycra fabric	3	Breakage of Lycra yarn / uneven tension of Lycra	3	2	18	Even tension of Lycra
	Contamination	Bad Appearance in the surface	1	Yarn contains foreign yarn / lack of consciousness	1	0	0	Faultless spinning
Machine maintenance	Latch Problem	Hole, Loop, Pin hole, needle mark problem	2	Negligence of the technical team	1	1	2	Proper maintenance
	Corrosion Sinker	Sinker mark into the fabric	1	Negligence of the technical team	1	1	1	Proper maintenance
	Cylinder & Dial Placement	Tension problem, hole	2	Unawareness of long-time effect	1	2	4	Awareness of technical team
	Oil Line adjustment	Oil mark into fabric	1	Negligence of the technical team	1	0	0	Awareness of technical team
	Wrong Cam Placement	Faulty fabric	1	Wrong cam Design	1	0	0	Consciousness of technical team
	Sinker Cam Placement	Faulty fabric	1	Wrong Design	1	0	0	Consciousness of technical team
	Fly/ dust/ foreign yarn	Bad surface appearance	1	Online quality control lacking	1	1	1	Ensure online control
Material Handling	Improper material handling	Severe problem to fabric	3	Lack of communication between production team	3	3	27	Increase & motivate for working friendly environment
	Congested floor	Create hazardous situation for movement and placement of yarns	4	Lack of space for placing yarns/ Time consumed for searching yarns	4	3	48	Proper layout plan for man, machine and materials
	Frequent change of program	Affect productivity, more hazardous situation for extra yarns	4	Lack of communication between planner and merchandiser	3	2	24	Proper production planning

CONCLUSION

This research started because of the increasing defects of the knitting production floor. We were prompted to reduce the defects to increase the productivity and efficiency. Proper data collection was the most important part of identifying the accurate solution for any problem. In this study, we collected accurate data and recognized major areas that need improvement. During data collection, we focused on all the possible defects along with the areas related to that particular defect. The collected data steered us towards the fruitful identification of the faults and towards the solutions for improvement. The identified defects were observed in the analysis phase and dealt with in the improvement phase. The entire knitting production team was also investigated and informed of the respective corrective measures taken, so that they could be seasoned continuously to keep the knitting process in control. The main recommendations of our research are: (1) new circular knitting machine setting should be noted, implemented, and instructed on routinely; (2) proper yarn quality has to be ensured before knitting; (3) training of the new workers and follow up on the performance is required for setting up the benchmark performance of workers; (4) online quality check panel should be established for reducing faults; (5) overall equipment efficiency needs to be established for every machine. The finding of the research, along with the proper remedies to the problems, resulted in improvement. The initial findings of the sigma level were 3.5 and that was improved to 4 at the end of the study. The end result reduced the rejection of the knitted fabric to around 50%. The implementation of the Six Sigma strategy in the textile industry is a sustainable approach that also reduces the cost of production. As a result, the Six Sigma methodology in the textile industry will reduce the knitted fabric defects as well as an increase of production efficiency.

Author Contributions

Conceptualization – Ahmed T, Toki GFI and Mia R; methodology – Li J and Islam SR; formal analysis – Ahmed T and Toki GFI; investigation – Mia R; resources – Li J; writing-original draft preparation – Ahmed T, Li J and Rishad MMA; writing-review and editing – Mia R and Islam SR; visualization – Ahmed T; supervision – Li J. All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

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