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Right-First-Time dyeing in Textile using Six Sigma methods

Dr. Anupama Prashar

Abstract—The purpose of this study is to demonstrate the application of Six Sigma DMAIC methodology to improve the Right-First-Time (RFT) % in fabric dyeing process in an Indian textile unit. The study adopted Six Sigma DMAIC (define-measure-analyse-improve-control) methodology to identify critical parameters and to arrive at remedial solutions.The analysis revealed 'shade mismatch' as the major deterrent to the successful achievement of the objective of Right-First-Time in dyeing. The root cause analysis further exposed "dye-ability of yarn", "dye strength variation" and "water quality" (pH value) as the root causes of the 'shade mismatch' defect. Actions taken on critical activities improved the RFT yield by 4% thereby registering a cost saving of INR 2.951 million per month.The study exhibited successful adoption of Six Sigma DMAIC methodology to standardize the fabric dyeing process in a textile unit. However, in general, such a roadmap can be adopted for any business process with a drive to save costs and enjoy bottom line benefits.

Index Terms—DMAIC, Fabric Dyeing, RFT yield, Right-First-Time, Root cause analysis, Six Sigma, Textile manufacturing

1 Introduction

There cannot be a principle as simple, powerful and effective as "Doing-Things-Right-First-Time". It stands true in any scenario, whatsoever. However, the stunning observation in the current case that registers its worth as almost INR 36 million annually, has raised the eyebrows of those who consider Right-First-Time as another expert suggestion.

In the extremely competitive scenario that exists today, a practice of incremental improvements in the production processes can only help as breathers. However, a big leap ahead of your competition requires a radical cultural change in the way we work. The proven principles of Six Sigma help you do precisely that. This has been proven true many a time for both sectors – industrial as well as service. Those who reason that the textile sector is different, will be forced to rethink in the light of findings of the current study. Keeping a check on production costs and simultaneously enhancing product quality are as vital for a textile unit as it is for any other industry. A number of textile-related companies in US such as Milliken & Co, Burlington Industries, Unifi, Collins and Aikman have implemented quality management initiatives to reduce costs and improve both products and customer satisfaction (Clapp et al, 2001; Singletary & Winchester, 1996).

In India, textile companies have by far realized the significance of effective implementation of quality management systems to meet the expectations of both industry and customers (Purushothama, 2010). Studies point out a growth in the adoption and implementation of ISO 9001 standard based Quality Management System in the textile industry (Karthi et al, 2013). Nonetheless, there are still few cases of successful adoption of quality improvement initiatives such as Six Sigma and Lean manufacturing (Das et al, 2007; Mukhopadhyay& Ray (2006); Roy, 2011)

Modern textile units have complex processes generating a lot of variation and defects and therefore, posing same challenges as are seen in other industrial sectors. The shortening of product life cycles and increasing demand for just-in-time delivery are just adding to this list of challenges. Thus, a consistent approach to process improvement is essential to make a significant leap ahead of your competition. Six Sigma is an ultimate quality improvement initiative for improving textile processes by reducing variation and defects (Senthil &Sundaresan, 2010; Das et al, 2007). There are already abundant cases of successful application of Six sigma DMAIC methodology in automotive industry (Chen et al, 2005), small scale enterprises (Desai, 2006), manufacturing operations (Kumar et al, 2007; Tong et al 2004) and services (Dreachslin& Lee, 2007; Kumar et al., 2008a). However the systematic adoption of Six Sigma DMAIC methodology in textile is feeble (Das et al, 2007).

The production of textiles involves a step-by-step processing of the yarn. Dyeing is the final and the most vital step where defects and in that way the production cost can be controlled. Introduced in 1970, the Right-first-time (RFT) dyeing concept meant that at each dyeing the target shade be achieved the first time. This was a radical shift from the traditional ways of starting with a base recipe and re-dyeing until the shade is matched (Park & Shore, 2009). The textile dyeing-houses are increasingly adopting the RFT dyeing to achieve shorter lead times and improving their profitability and competitiveness (Holme, 2012).

This study presents the case of a textile company engaged in manufacturing of terry towels in India. The company was struggling with huge production losses due to extended lead time of fabric dyeing process. The company adopted Six Sigma DMAIC methodology to improve RFT in fabric dyeing processes thus eliminating reprocessing cost and delays in material delivery.

The rest of the paper is organized as follows: the second session briefly reviews the literature on status and adoption of quality management systems in Indian context. The following sections provide an overview of the five phases of the DMAIC methodology to provide a framework of the case study. The discussion of the implementation and its fruits are presented

• *Dr.Anupama Prashar is currently Associate Dean – Academics with IILM, Gurgaon, India, M-8826492111. E-mail: prasharanu@gmail.com*

in the last section.

2 Literature Review

Before diving deeper into the case, let us briefly review the literature on successful application of Six Sigma DMAIC methodology in Indian manufacturing sector:

Karthi et al (2013) highlighted the rising instances of implementing ISO 9001 standard based Quality Management System (QMS) in the textile industry. They proposed an integrated model of Lean Six Sigma and ISO 9001:2008 standard based QMS, named as L6QMS-2008. The study presented a case on the successful implementation of integrated L6QMS-2008 model in a textile mill. The findings revealed annual savings of INR 2 million.

Kaushik et al. (2012) in a study on a small bicycle chain manufacturing unit justified that successful implementation of Six Sigma, which is normally presumed to be the domain of large industries, in the small manufacturing companies. The study demonstrated the application of Six Sigma methodology to improve productivity levels. After applying Six Sigma it was found that the chain manufacturing firm increased its bottom line by controlling high rejection rate of cycle chain bush improving its process sigma level from 1.40 to 5.46. This was done by controlling the variation of bush diameter in the manufacturing process of bicycle chain bush.

Soti et al (2011) presented the current standing of Six Sigma implementation in Indian manufacturing industries. The study explored the needs, benefits and critical success for Six Sigma adoption through an empirical study in Indian manufacturing industries. A structured questionnaire was used to collect responses of 90 Six Sigma practitioners on critical success factors for Six Sigma implementation. It was found that improving financial performance, profitability of business, customer focus, functionality, utilization of resources and rationality of decision making were the highest rated needs of Six Sigma implementation. Observed benefits were reduction in process variability and operational cost. The study revealed that the maximum rated success factors are 'management commitment and involvement' and 'understanding of Six Sigma methodology, tools and techniques'.

Kaushik&Khanduja (2008) applied Six Sigma DMAIC methodology to a specific case of thermal power plant for the conservation of energy. They implemented Six Sigma project recommendations to reduce the consumption of demineralized (DM) make-up water from 0.90% to 0.54% of maximum continuous rating (MCR) resulting in a comprehensive energy saving of INR 30.477 million per annum.

Kumar &Sosnoski (2008) highlighted the potential of DMAIC Six Sigma in realizing the cost savings and improving quality by using the case study of a leading manufacturer of tools. The study examined one of the chronic quality issues on shop floor by utilizing Six Sigma tools. The study showed that DMAIC Six Sigma process is an effective and novel approach for the machining and fabrication industries to improve the quality of their processes and products and ensuring profitability by driving down manufacturing costs.

Das et al (2007) presented a case of a leading textile company facing the problem of shade variation of dyed fabrics leading to an increase in the process cycle time. The company adopted DMAIC cycle of disciplined Six Sigma methodology to resolve this problem. The goal was to reduce the shade matching time in the fabric dyeing process by optimizing the effect of the controllable parameters. The study demonstrated the application of Six Sigma tools such as Cause and Effect Diagram, Pareto Analysis and Design of Experiment (DOE) to identify the critical activities. The implementation of remedies resulted in improved yield of 82% and sigma level of 2.34 (from base sigma level of 0.81). This contributed to an estimated cost saving of INR 1.8 million / annum.

Mukhopadhyay& Ray (2006) illustrated the use of Six Sigma methods to solve the problem of high rejection of yarn cones in a textile company. It was found that variation in yarn length; yarn count, empty yarn container weight, and yarn moisture content were the root causes for this rejection. Statistical hypothesis testing established that the observed weight was significantly more than the set weight of yarn at the assembly winding stage. The measurement system analysis exposed that electronic length measuring devices (LMDs) on all assembly winding machines were not capable. Regression analysis revealed association between gross yarn weight and length of yarn. These findings were used to derive the optimum process parameters.

Kumar et al (2006) proposed a Lean Six Sigma framework to reduce the defect occurring in the final product (automobile accessories) manufactured by a die-casting process. They integrated Lean tools such as Current State Map, 5S System, and Total Productive Maintenance (TPM) within Six Sigma DMAIC methodology to improve the bottom-line results and enhanced customer satisfaction. The findings showed marked improvement in the yield of die-casting process thereby generating substantial cost saving.

Sekhar&Mahati (2006) illustrated an integrated application of Simulation and Six Sigma in order to improve the ambient air quality in foundry industries. The study used Six Sigma tools such as Cause and Effect Diagrams and Failure Mode and Effect Analysis to explore the root causes responsible for the problem and cost-effective remedies to solve the problem. Further, the study applied simulation to improve and control the environmental efficiency by monitoring the performance of the pollution control equipment. The findings showed that the implementation reduced the particulate emissions by over 90% from 200 milligrams per cubic meter to less than 20 milligrams per cubic meter and sulphur dioxide emissions from 45 milligrams per cubic meter to less than 4.5 milligrams per cubic meter, thus reducing air pollution.

3 Case Study

The study refers to one of the largest manufacturers of terry towels having a textile unit located in Northern India. The unit has a vertically integrated set-up with facilities dedicated for weaving, processing and finishing which work in close coordination. The complete process of terry towel manufacturing – from yarn manufacturing, to weaving, to dyeing and to final packing is completed in house. Figure 1 gives an overview of

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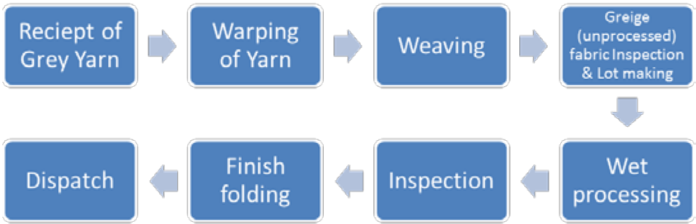
complete process at the unit.

Fig. 1: Terry towel manufacturing process



Analysis of past performance of the company revealed a huge gap between the targeted and actual performance. In order to recover from this situation, three areas of improvement were identified. Further, based on calculation of Project Prioritization Index (PPI), enhancing RFT percentage in fabric dyeing process was targeted for initiating a Six Sigma improvement project (Table 1).

Table 1: Project selection

Areas of improvement	Stakeholder impact (10)	Need for improvement(10)	Enthusiasm Potential(10)	PPI
	A	B	C	A*B*C
Improve RFT % in fabric dyeing	8	9	9	648*
Improve Overall Equipment Efficiency (OEE)	8	8	6	384
Reduce packing material cost	5	8	5	200

*Note: *Highest PPI (Improve RFT in fabric dyeing process)*

The processing division of the unit initiated a project in August 2012 with the aim of improving RFT % in fabric dyeing process. A cross functional team was created. The team adopted Six Sigma DMAIC methodology for solving the problem.

3.1 Methodology: Six Sigma DMAIC

The team adopted Six Sigma DMAIC (Define-Measure-Analyze-Improve-Control) methodology for improving the fabric dyeing process. Six Sigma has been an established methodology to achieve dramatic improvements in cost, quality, and production time with focus on process improvement (Linderman et al. 2003). Table 2 lists the tools used in different phases of the project.

A brief overview of these phases is presented in the following sections.

3.1.1 Define

This phase involves creating a project charter, identifying projects critical to quality (CTQs) characteristics and high level process mapping (SIPOC).

Table 2: Six Sigma framework

Phases	Tools
Define	Project charter, SIPOC, CTQ
Measure	"As is" process map, Measurement System Analysis, Data collection plan, Base level sigma
Analyse	Pareto chart, Cause & effect diagram, 5-why analysis, hypothesis testing
Improve	Counter measure matrix
Control	Control plan

A project charter outlines the problem statement, mission statement, project goals, process boundaries, project team composition, project milestones etc (Kubiak&Benbow, 2010). The team framed the problem statement as follows:

Data analysis for the period April '12 to Sep'12 indicates that 6% of the fabric dyed material is not Right-first-time (RFT); resulting in a productivity loss of 132 metric tonnes per month (MT/month) and producing a financial loss of INR 4.4 million per month.

The mission statement was framed as follows:

To improve RFT % in fabric dyeing process by 4% (from current level of 94% to 98%) by the end of December 2012

The project charter is annexed as Annexure I.

Critical to Quality (CTQ): CTQ is a characteristics related to an assembly, sub-assembly, product or process that has direct or significant impact on its direct or perceived quality (Lucas, 2002). The CTQ identified for this project was defined as – "Right-First-Time (RFT %)", which is the measure of target shade achieved the first time of fabric dyeing process.

SIPOC (High level process map): A SIPOC (supplier-input-process-output-customer) is a high level picture of process which depicts how the process is serving the customer (Kubiak&Benbow, 2010). Figure 2 shows the SIPOC for the fabric dyeing process.

3.1.2 Measure

The objective of this phase is to measure the current performance of the process. It involves developing "as is" process map, analyzing the measurement system (MSA), preparing data collection plan, and calculation of baseline sigma (present sigma level) (Kubiak&Benbow, 2010). Figure 4 shows the "as is" flow chart for fabric dyeing process.

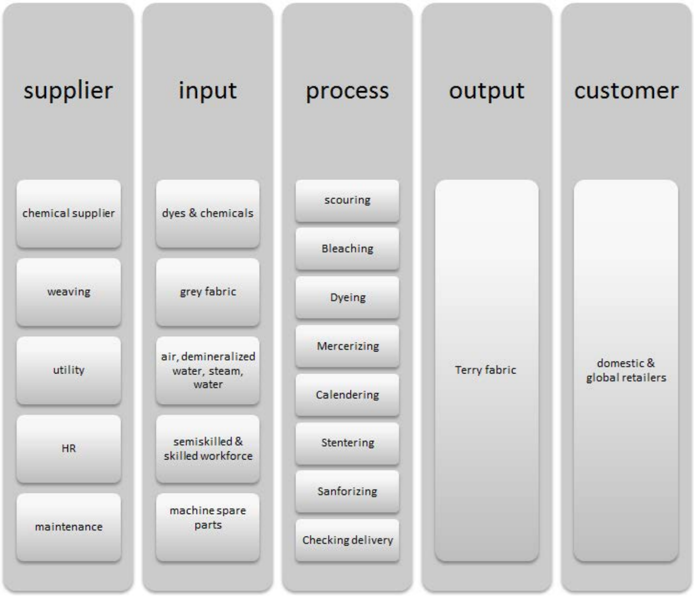
Measurement system analysis (MSA): Gauge R & R study was carried out to test the accuracy of weighing & dispensing systems and pressure & temperature gauges. The results are annexed in Annexure II.

Data collection plan: The team prepared a systematic data collection plan of collecting data on RFT % for a period of six months (from April, 2012 to September 2012). Data collected using the plan is annexed in Annexure II.

Baseline sigma level: The data collected (Annexure III) was used to calculate the present process performance. The base line sigma was found to be 3.1(at 94% yield).

- *Anupama Prashar is currently Associate Dean – Academics at IILM, Gurgaon, Haryana, INDIA, M-+918826492111. E-mail: prasharanu@gmail.com*

Fig. 2: SIPOC



3.1.3 Analyze

During this phase the team analyzed the data collected in the preceding phase in order to identify the root cause(s) of defects. The tools used were Pareto chart, Cause & effect Diagram and 5-Why Analysis. The results are explained below:

Pareto chart: In order to draw attention to the major defects, the team plotted Pareto chart using the defect-wise data collected from April, 2012 to September 2012 annexed as annexure III (Figure 3).

The chart revealed 'shade mismatch' was contributing to 65.5% of total defects. So, the team decided to dig deeper to diagnose the cause(s) of this defect.

Cause & Effect Diagram: The team brainstormed the potential causes for the defect of "shade mismatch" and categorized the causes in form of a Cause & Effect Diagram (Figure 5).

Fig3: Pareto chart

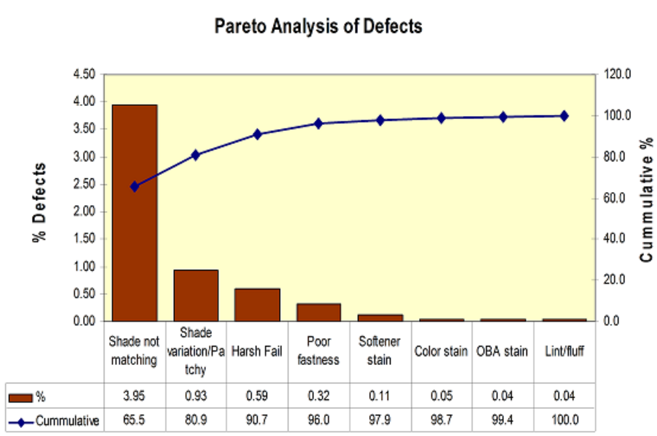


Fig.4: "as is" flow chart

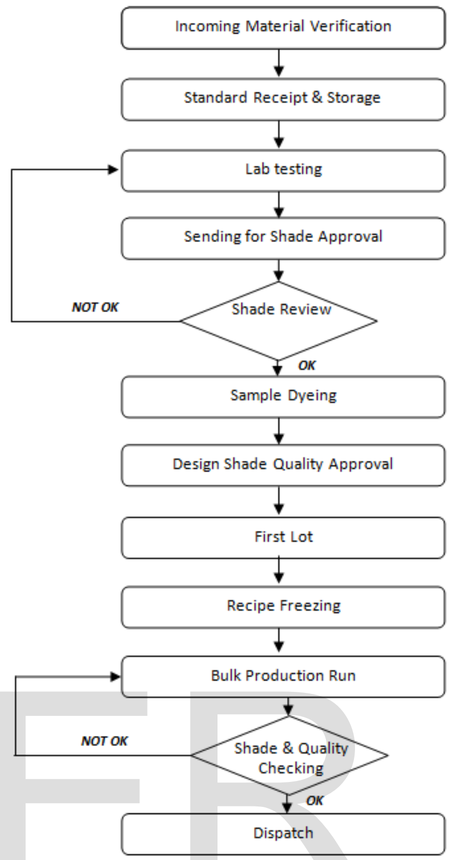
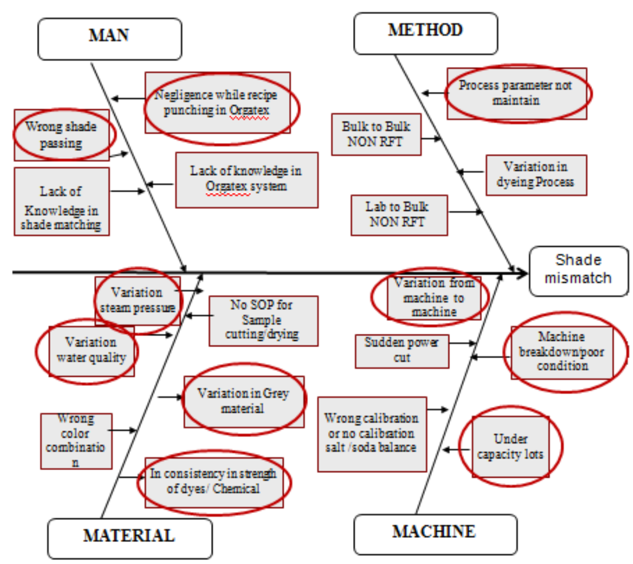


Fig. 5: Cause & Effect Diagram



** Potential causes are circled in red*

Root cause analysis: The identified potential causes were scrutinized individually through the "5-why" analysis (Table 3).

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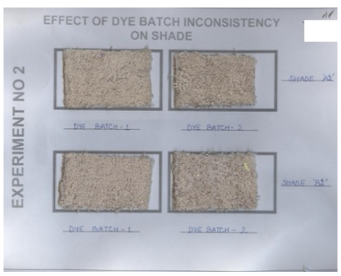
Hypothesis testing: In order to validate the root cause, the team formulated and tested the following hypothesis by conducting experiments in the color lab:

Hypothesis 1: Effect of yarn dye-ability on shade
Experiment No 1

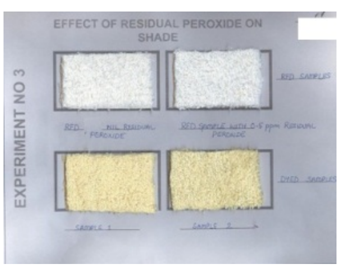
Hypothesis valid

Hypothesis 2: Effect of dye strength variation on shade
Experiment No: 2



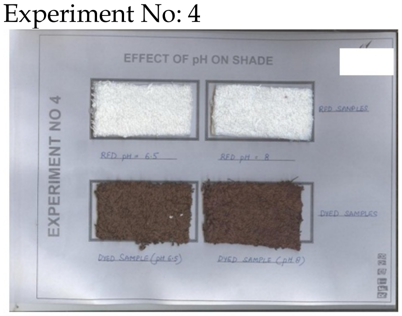
Hypothesis valid

Hypothesis 3: Effect of residual peroxide on shade
Experiment No: 3



Hypothesis invalid

Hypothesis 4: Effect of water quality (pH value) on shade
Experiment No: 4



Hypothesis valid

Hypothesis 5: Effect of whiteness of grey material on shade
Experiment 5

Hypothesis invalid

Table 3: "5-Why"analysis for Shade mismatch

Problem: Shade mismatch			
Why 1	**Why 2**	**Why 3**	**Why 4**
Shade mismatch?	Variation in Grey fabric	Variation in dye-ability of yarn	No SOP for segregation and lot preparation in Grey folding
			No SOP for informing the dye-ability difference to Process house
	Batch-to-batch variation in strength of dyes/chemicals	No testing of dyes/chemicals	Lack of testing equipment in laboratory
			Lack of trained manpower
			No SOP for testing of incoming material
			Specification not given to suppliers
	Variation in water quality (pH, hardness, purity etc.)	No testing of processed water	No SOP for testing water quality
			No SOP for informing the water quality to Process house
	Variation in steam pressure	No testing of steam pressure	No SOP for process control
			No SOP for informing the Engineering and Boiler house if steam pressure is found less than required
	Non-adherence to dyeing standard operating procedure(SOP)	Lack of process control	No SOP for process control
		Lack of skilled manpower	Inadequate training
		Negligence of manpower	No awareness
			Inadequate training
	Machine breakdown	No follow-up for preventive maintenance schedule	No SOP for preventive maintenance
		Inappropriate machine audits	No SOP for machine audits
	Variation in machine efficiency	No SOP for comparing machine competency	
	Wrong recipe followed for dyeing	No recipe reconfirmation from laboratory	Lack of adequate lab equipment
		No recipe checking system	Lack of skilled manpower
			No SOP for recipe making
	Wrong shade cleared	Subjectivity	No SOP for shade clearing
	Different standards followed at QA and shop floor	No SOP for standard formulation	
	Under capacity lots	Lack of awareness about its impact at all levels	No consideration of under- capacity lots in SOPs

3.3.3 Improve

During this phase, the team explored the possible remedies for the identified root cause. The details of remedies along with its method of implementation are presented in Table 4.

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Table 4: Counter measure matrix

Root Cause	Remedy	Method of implementation
Variation in ready for dyeing material ground	Material attached for reference	Attached ready for dying material from lab to compare before dyeing starts
Variation in dye ability of Grey fabric	Dye ability testing to have clear idea before dyeing	Dye ability test in every new grey material
Wrong color combination in recipe	Test right color combination before recipe generation	Checking color exhaustion graph & dyes behavior in View Dye Analyser (VDA) & View Dyeing Unit (VDU) machine before recipe generation.
Process parameter not checked	Process parameter monitoring before dyeing	Update the existing SOPs & training operator
Variation in dyeing process	Process standardization in Orgatex (process control system)	Process standardization in Orgatex & codification as per program requirement.
SOPs not followed	Updating existing SOPs and training operator's in the same	Update the existing SOPs & training operator
High temperature in dye bath	Program modification in orgatex	Program modification in orgatex
pH not maintained in dye bath	Updating existing SOPs and training operator's in the same	Update the existing SOPs & training operator
Quality of dyes/chemicals not consistent	Checking of incoming new consignment of dyes/chemicals	Chemicals/dyes testing as per Quality inspection plan
Variation in grey fabric lots	Checking of yarn weight variation	Calculation of yarn weight and display of same on Job card

Cost benefit analysis: A cost benefit analysis was carried by the team to compare the cost incurred in the project versus the benefits achieved (Table 5).

Table 5: Cost benefit analysis

Expenses/Investment	
View Dye Analysis(VDA) for studying exhaustion	INR 1.2 million
Technorama Multi fastest (for quick color fastness testing	INR 1 million
Total expenses/investment	**INR 2.2 million**
Benefits	
Reprocessing cost saved per month	INR 1.336 million
Cost benefit due to increase in fresh production per month	INR 1.625 million
Benefits per month	**INR 2.951 million**

After implementing the recommended process changes and actions, the following results were achieved:

- An estimated reprocessing cost saving (including utilities, dyes & chemicals) of INR 1.336 million per million.
- Cost benefit of INR 1.625 million per month due to increase in production volume.

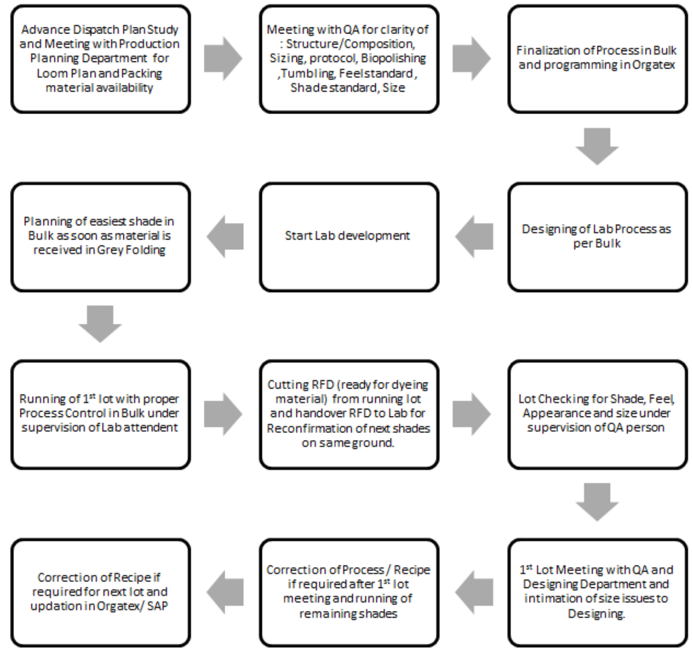
Detailed calculation of benefits is annexed in Annexure IV

3.3.4 Control

An effective problem solving strategy requires long term retention of benefits. So the objective of control phase was to hold gains and ensure that benefits of improvement continue in the future. The control plan included the following:

Developing SOPs for supporting Lab to achieve Bulk RFT (Figure 6)

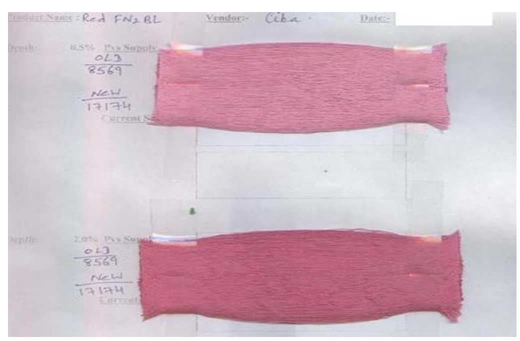
Fig. 6: Modified SOP



Testing of dye samples

Testing of dye samples from each batch against the standard dye batch sample was carried out to ensure consistency in dye strength or tone. This test was conducted by the application of standard dye sample and advanced dye sample on yarn in lab. The dyed yarn samples were compared by the help of Computer Color Matching (CCM) machine and accordingly the batch was accepted or rejected (Figure 7).

Fig. 7: Dye samples



Training

Regular trainings for enhancing process knowledge and skill level of operators were scheduled. Apart from the above steps, SOPs were introduced for the following processes:

- Monitoring the pH, hardness, purity, and chlorine amount etc. of water at least once a week.
- Checking the strength, moisture content, fastness properties of dyes.
- Checking the dye-ability of grey fabric for every new lot must be carried out to ease out recipe formulation.

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Conclusion and Discussion

Six Sigma is a disciplined problem solving methodology for reducing process variation and tumbling defects. It provides an ultimate approach for improving textile processes which generate a lot of variation and defects due to their inherent complexity. The present case is apropos a textile unit facing huge production losses due to defects in fabric dyeing process and consequential delays in delivery of material to customer. The processing division of the unit took on a Six Sigma DMAIC project with the goal of improving RFT % in fabric dyeing process. The team established that the problem of "shade mismatch" was contributing towards 65.5% of total defects. The root cause analysis revealed yarn dye-ability, dye batch inconsistency, water quality (pH value) as the root causes. After remedial action, the RFT improved by 4% (from earlier level of 94% to 98%). This resulted in an estimated cost saving of INR 2.951 million per month (including reprocessing cost worth INR 1.336 million & increased production worth INR 1.625 million).

The study exhibited successful adoption of Six Sigma DMAIC methodology to standardize the fabric dyeing process in a textile unit. However, in general, this roadmap through DMAIC methodology can be followed for any business process with a drive to save costs and enjoy bottom line benefits.

Appendices

Appendix A: Project Charter

PROJECT CHARTER WORKSHEET		Date:05/09/12
Project Title: Achieving Right-First-Time dyeing in Textile using Six Sigma methods		
Problem Statement: Data analysis for the period April '12 to Sep'12 indicates that 6% of the fabric dyed material is not Right-first-time (RFT) resulting in a productivity loss of 132 metric ton per month (MT/month) and producing a financial loss of INR 4.4 million per month.		
Mission Statement: To improve RFT % in fabric dyeing process by 4% (from current level of 94% to 98%) by the end of December 2012.		
Process Boundaries:		
Start point: receipt of grey yarn from supplier Stop Point: Dispatch of finished fabric		
Impacted Functions: Processing color lab, Finishing		
Mentor Name:	**Team Leader:**	
Team Members	**Functional Areas of Team Members**	
Project Milestones		
Name of Phase	**Target Completion Date**	**Actual Completion Date**
Define Phase / Plan		
Measure Phase / Do		
Analyze Phase / Do		
Improve Phase / Check		
Control Phase / Act		

Appendix B: Measurement System Analysis

GAGE REPRODUCIBILITY STUDY

Experment 1.
Reproducibility test in weighing balance in lab .

Operator	Set amount Grams	Actual amount Grams	Variation Grams	Variation%
1	10	10.05	0.05	0.5
2	10	10.03	0.03	0.3
3	10	10	0	0
4	10	9.98	-0.02	-0.2
5	10	9.9	-0.1	-1
6	10	10.01	0.01	0.1
7	10	10.03	0.03	0.3
8	10	10	0	0
9	10	9.99	-0.01	-0.1
10	10	10.05	0.05	0.5

Experment 3.
Reproducibility test in weighing balance in lab .

Operator	Set amount. Grams	Actual amou Grams	Variation Grams	Variation%
1	5	5.01	0.01	0.2
2	5	5	0	0
3	5	5	0	0
4	5	5.01	0.01	0.2
5	5	5.02	0.02	0.4
6	5	4.99	-0.01	-0.2
7	5	4.99	-0.01	-0.2
8	5	4.98	-0.02	-0.4
9	5	5	0	0
10	5	5.01	0.01	0.2

Experment 2.
Reproducibility test in weighing balance in lab .

Operator	Set amount Grams	Actual amount Grams	Variation Grams	Variation%
1	16	16.01	0.01	0.0625
2	16	16	0	0
3	16	15.99	-0.01	-0.0625
4	16	16	0	0
5	16	16.02	0.02	0.125
6	16	16.03	0.03	0.1875
7	16	16	0	0
8	16	15.98	-0.02	-0.125
9	16	15.99	-0.01	-0.0625
10	16	16	0	0

Experment 4.
Reproducibility test in weighing balance in lab .

Operator	Set amount. Grams	Actual amou Grams	Variation Grams	Variation%
1	8	8.01	0.01	0.125
2	8	8	0	0
3	8	8.01	0.01	0.125
4	8	7.99	-0.01	-0.125
5	8	8.01	0.01	0.125
6	8	8	0	0
7	8	8.02	0.02	0.25
8	8	7.98	-0.02	-0.25
9	8	7.99	-0.01	-0.125
10	8	8	0	0

GAGE REPEATABILITY STUDY

Experment 1.
Repeatability test in Salt auto dispensing balance.

No of call	Set amount Kgs	Actual amount Kgs	Variation Kgs	Variation%
1	10	10.02	0.02	0.2
2	10	10.03	0.03	0.3
3	10	10.01	0.01	0.1
4	10	9.99	-0.01	-0.1
5	10	9.98	-0.02	-0.2
6	10	10.02	0.02	0.2
7	10	10.03	0.03	0.3
8	10	10	0	0
9	10	9.99	-0.01	-0.1
10	10	10.02	0.02	0.2

Experment 3.
Repeatability test in Soda auto dispensing balance.

No of call.	Set amount. Kgs	Actual amou Kgs	Variation Kgs	Variation%
1	10	10.01	0.01	0.1
2	10	10	0	0
3	10	10.03	0.03	0.3
4	10	10	0	0
5	10	9.98	-0.02	-0.2
6	10	10.021	0.021	0.21
7	10	10.03	0.03	0.3
8	10	9.99	-0.01	-0.1
9	10	9.96	-0.04	-0.4
10	10	10.02	0.02	0.2

Experment 2.
Repeatability test in salt auto dispensing balance.

No of call	Set amount Kgs	Actual amount Kgs	Variation Kgs	Variation%
1	20	20.02	0.02	0.1
2	20	20.05	0.05	0.25
3	20	20.01	0.01	0.05
4	20	20.03	0.03	0.15
5	20	20	0	0
6	20	20	0	0
7	20	19.99	-0.01	-0.05
8	20	19.98	-0.02	-0.1
9	20	20	0	0
10	20	20.06	0.06	0.3

Experment 4.
Repeatability test in Soda auto dispensing balance.

No of call.	Set amount. Kgs	Actual amou Kgs	Variation Kgs	Variation%
1	20	20	0	0
2	20	20.02	0.02	0.1
3	20	20	0	0
4	20	20.01	0.01	0.05
5	20	19.99	-0.01	-0.05
6	20	19.99	-0.01	-0.05
7	20	20	0	0
8	20	20.03	0.03	0.15
9	20	20	0	0
10	20	20.01	0.01	0.05

Appendix C: Data Collection Plan

Monthly RFT% Data

April '12		May '12		June '12		July '12		Aug '12		Sep '12	
Date	RFT %	Date	RFT %	Date	RFT %	Date	RFT %	Date	RFT %	Date	RFT %
1	93.6	1	96	1	93	1	94	1	92.4	1	90.3
2	94.5	2	97	2	93.2	2	92	2	98.1	2	98
3	98	3	90.5	3	97	3	94	3	92.4	3	95.7
4	94	4	93.1	4	94	4	91	4	92.8	4	90.5
5	93.2	5	90	5	93.9	5	98	5	98.3	5	98.5
6	92.4	6	91	6	92	6	96	6	97.5	6	90.5
7	93	7	92.5	7	97	7	97	7	95.4	7	98.5
8	96	8	95.4	8	93	8	91	8	94.6	8	95.4
9	92	9	94	9	92	9	93	9	95.3	9	92
10	96	10	96	10	95	10	93	10	94	10	98.7
11	91	11	93.1	11	98	11	97.2	11	93.5	11	93.1
12	94.3	12	94.3	12	92	12	91.3	12	98.6	12	98.5
13	96	13	95	13	96	13	94	13	91	13	90.3
14	93.5	14	92	14	90.2	14	93	14	90.5	14	93
15	94.2	15	93.8	15	96	15	90.1	15	90.6	15	95.3
16	92.4	16	91	16	91	16	91	16	92.67	16	91
17	98	17	97	17	97	17	97	17	92	17	92
18	94	18	93.7	18	93	18	93.7	18	97	18	93.6
19	95.6	19	95.4	19	92.6	19	93	19	95.6	19	95.6
20	96.2	20	96.2	20	97.1	20	96	20	96.2	20	92
21	94	21	96.3	21	93.4	21	93	21	94.3	21	93
22	94.3	22	98	22	93	22	98	22	90	22	90
23	94	23	94	23	95.4	23	91	23	95	23	92
24	93.9	24	92.5	24	98	24	92.4	24	93.9	24	90.6
25	94	25	94	25	93.4	25	94	25	93	25	97
26	93.2	26	93	26	93	26	93.2	26	90	26	95
27	94.5	27	91	27	94.3	27	93	27	90.6	27	96
28	92.1	28	98.2	28	91	28	94	28	98	28	94
29	91	29	97.4	29	90	29	97.4	29	96.9	29	97.4
30	90	30	93	30	92	30	91.2	30	90	30	93
		31	93.2			31	93.2			31	93.2

Monthly Defect-wise Data

Defect	April '12	May '12	June '12	July '12	Aug '12	Sep '12
Shade not matching	3.9	4.1	3.8	4.3	3.7	3.9
Shade variation	0.9	0.73	1.2	0.85	1	0.9
Harsh fail	0.6	0.64	0.52	0.65	0.55	0.6
Poor color fastness	0.35	0.2	0.34	0.33	0.35	0.35
Softener stain	0.12	0.12	0.1	0.11	0.1	0.12
Color stain	0.05	0.05	0.04	0.06	0.04	0.05
OBA stain	0.04	004	0.06	0.05	0.03	0.04

Appendix D: Calculation of Benefits

Average production per day	72 metric tons
% RFT Improvement	4%
Increase in fresh production per day	2.88 metric ton
Increase in fresh production per month	87.84 metric ton
Reprocessing cost(including utilities, dyes & chemicals)	INR 15.1 per kg
Cost contribution/value addition of fresh production	INR 15.1 per kg
Reprocessing cost saved per month	INR 1.336 million

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