Developing Methodology for Process Capability Enhancement & Rework Reduction on an FMCG Processing Plant using DMAIC approach.

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Declaration

I hereby certify that this research study is entirely my own work and has been submitted for the partial fulfillment of requirements for the degree of Master of Science in Design & Manufacturing Engineering. I hereby declare that I have exercised reasonable care to ensure that the work is original, and does not to the best of knowledge breach any law of copyright, and has not been taken from the work of others save and to the extent that such work has been cited and acknowledged within the text of my work.

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Master's Thesis Work

We hereby recommend that the dissertation prepared under our supervision by **Arbab Shahid (NUST201260376MSMME62012F)**, titled**: Developing methodology for Process Capability Enhancement & Rework Reduction on an FMCG Processing plant using DMAIC approach** be accepted in partial fulfillment of the requirements for the award of **MS Design and Manufacturing Engineering** degree with ___ Grade.

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To

Abu & Ammi Ji

For all the support and love

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Abstract

In the world of manufacturing focused process improvement and continuous excellence using six sigma (DMAIC) for an overall reduced manufacturing cost, reworking, process improvement and semi-filed losses have become the need of the time. This became an inspiration for developing a new methodology of process improvement using the tools and techniques of DMIAC. The industry selected for the development was the fast manufacturing consumer good (powder milk production) plant.

The objective of the research was to reduce the rework, semi filled losses(material losses) and enhance the overall process capability of the production plant with a specific focus on documenting and developing the skills of the employees in on organized and structured way.

The methodology devised followed the 5 step DMAIC framework with specific tailored changes to suit the specific needs of the project.

The DMAIC methodology adopted with real production data analysis revealed 38.5% reduction in losses, 0.98% to 1.34% loss reduction per shift and decreased standard deviation from 1.48 to 0.78, while providing cost savings of up to PKR 13 million. The research also incorporated documented skill development program that proved to be an essential tool for skill enhancement and management. The process capability was greatly enhanced by the methodology resulting is a process sigma level enhancement from 1.65 to 2.56.

Key Words: DMAIC, SIX SIGMA, CTQ, VOC, Fish-bone diagram, Prioritization, 5w2h tool, SWOT, Process Management, Skill Matrix

1 INTRODUCTION

1.1 Case History

Quality and Reliability is one of the leading concepts in every Industry especially in FMCG where the shelf life of the product is limited great emphasis is paid on the quality and reliability enhancement of the process product along the complete value stream.

The company under observation is one of the leading Manufacturer and supplier of food and beverages Industry worldwide. The company has a sales volume of about 100billion yearly worldwide with about 2000 brands and about 400000 employees in 150 countries of the world. Due to the company's zero tolerance on shearing data and policies the name of the company will not be disclosed.

The company wants to be recognized leader in Nutrition, Health and Wellness and the industry reference for financial performance so it is doing a lot of research and efforts to enhance the Industrial performance and reduce Non Quality Cost. The main focus of improvement is the 486 factories in about 86 countries of the world.

The focus of our research will be how to implement 6σ to reduce waste and non-quality cost.

The company has adopted a policy of Continuous Excellence with emphasizes on enhancing efficiency to 100% using focused Improvement methodology.

This study includes different Quality and statistical analysis by using Six Sigma Methodology. Main focus of this study is to reduce the losses in the Production plant of the company using 6σ specifically DMAIC methodology keeping in view the science of continuous excellence and focused improvement principals. This study will help to bring the rejection rate rework non quality cost & result in cost saving and to bring the processes in the acceptable sigma limits as a result both rejection rate and rework will be minimized and operational loses will be reduced.

Along with implementation of 6σ to do cost saving we will study the new concepts of focused improvement and continuous excellence and how they are applied with 6σ (DMAIC) in practical Industrial environment.

1.2 Factory Overview

The scope of our research will be one of the manufacturing plants of the company in Pakistan.

The company has an extensive data collection system and a special stoppage analysis module embedded in its ERP that will be used to find all the stoppages and reworks. The company has a very well established system to identify and prioritize problems and losses.

Initially we will be using this tool to find out the areas where we can bring some improvement and cost saving. A method called loss tree analysis is being used to predict where errors are persistent and causing maximum damages in terms of cost.

The Focus Improvement method will be used to first analyze the complete factory and find the major losses in terms of rework and Industrial performance point of view. Once the main issues have been highlighted as per the Business and market Priorities and aligned with the Operational Master Planning the Loss tree analysis and IPA (identify Prioritize assign) methods are used to find specific areas where projects of Improvement can be done.

If all normal methods of removing loses and reducing rework have failed and the savings exceed a pre-defined value only then the full force of a six sigma or DMAIC is employed.

Then the project is started and 6σ is applied and DMAIC is introduced after the formation of team and Project Charter. Finally the results are verified to see if the sigma level has changed, money has been saved and rework and production loses are reduced.

1.3Company Profile

The company is a Multinational food making company with operations in about 86 countries of the world. In Pakistan with Headquartered in Lahore, the Company operates five production facilities. The company operates in many ways but people, products and brands are the main flag bearers of the Company's image. The plant that we have selected for research is a multi-product manufacturing facility. The plant has a continuous excellence system in place that monitors all problem solving and Quality. The Industrial Performance department is the statistical data control and responsible for training and oversight of all improvement projects. It gets its input from R&D department, business, market and corporate IP.

Range of products manufactured by the Factory's

1. UHT milk (liquid dairy)
2. Powder milk (area under consideration in research)
3. Confectionary plant
4. Fresh Cream
5. Noodles

Due to the secrecy of the product and procedures only categories are listed here and no brand names are shared. But the overall range of the products manufactured here is above 10.

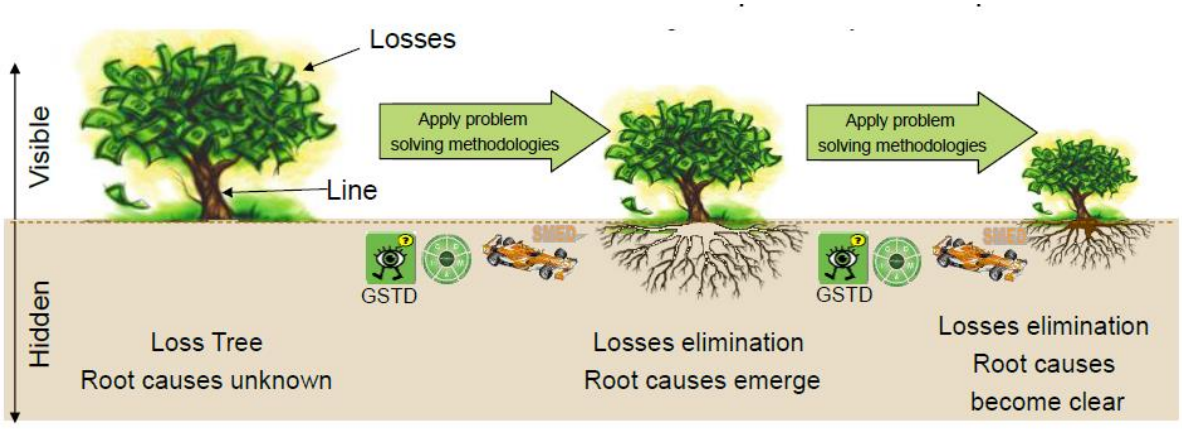
1.4 Formulation of Problem

From the previous study it was decided to first apply Loss Tree Analysis to the complete manufacturing unit in order to find the top relevant losses from the factory. Calculating the difference between standard and actual losses in the tree major categories does this.

We find both the hidden and visible losses and losses relevant to Machine, Material and Man

Based on financial impact and other operational master planning priorities

Using the time series plots and Pareto charts we came to the conclusion that the most difficult to manage losses are Man losses followed by Material losses and then the Machine losses which are the easiest to manage.



But on comparison of cost of production data and volume of losses it was confirmed that the most losses are due to raw and packaging which comes under material losses. The data says that almost 60 to 70 % of losses comprises of material losses so we narrow down our focus to Raw and Packaging.

Then on further investigation it was confirmed that Currently the filling and packing process at WOLF (name of packaging plant) lines are out of control resulting in high Semi finished products (Rework + Overfilling + Cattle Feed) losses of 41.6 million PKR in last 4 months Current methods of controlling the process and reporting that control are not successful.

So it was decided to apply 6σ (DMAIC) on the specific line.

1.5 Scope of Study

The scope of study includes the implementation of 6σ (DMAIC) to reduce the Powder (Rework + Cattle Feed + Overfilling) losses at (Powder Filling & Packing machines) by 20% till end of March. The total quality of the process will be increased and the Non Quality Cost of the product has to be decreased.

1.6 Objectives of Study

One of the key objectives of our research is to apply DMAIC 6σ methodology to apply quality analysis to the packaging lines of the manufacturing activity at the company. The key achievable over this period will be the following

- Reduced semi-finished product using statically data analysis tools
- Statistical Quality Analysis to achieve Cost saving by reduction of Non Quality cost
- Find critical factors resulting in reduced quality
- Process mapping and study of current Process
- Stake Holder Analysis & Before and After skill Matrix of the team involved
- Pareto Analysis, Data collection Plan, Control Charts
- Calculations of Process Capability (sigma level) current and after completion
- Brainstorming using Fish-bone diagram & GAMBA
- Use prioritization tool to classify root causes and there reasons
- Data Analysis to confirm Root causes
- Implementation of solutions proposed in the improve phase using (5w2h tool)
- Before & after analysis
- SWOT (strengths-weakness-opportunities-threats)
- Review and deliver standard operating procedure and one point leanings

- Process Management chart (control tool)
- Study the Continuous excellence concept and specifically Focused Improvement

1.7 Research Benefits

Apart from the problem solving quality improvement and Process improvement of the manufacturing facility of the company there are a number of benefit which are forecasted at this stage:

- Improved Customer Satisfaction (internal customer)
- A step towards implementation of lean (zero waste)
- Apply the study to other Production units
- Training and coaching on DMAIC of the Project team.
- Increased Revenues by reducing Cost of Production
- Enhanced completive advantage (company core principal)
- Proper evaluation of resources and manpower skills.
- Zero defect Machines delivering zero complaints
- Competent employees (Man) able to prevent defects and manage conditions
- Robust Methods and capable processes
- Minimum Material variation

1.8 Area of Application

The factory chosen for the implementation is the milk production factory of the company in Pakistan. The specific plant which is chosen was the powder milk production plant and only the Packaging and filling machines due to the focus that we had set on the Raw and Packaging section of the company in earlier Loss tree analysis procedure. The departments that were involved were the Industrial Performance, Engineering and Production. But the corporate industrial performance black belt certified coaches provided the training and guidance.

The software primarily used was Mini Tab, SAP& Stoppage Analysis Module that the company was more than generous to provide access.

1.9 Quality Importance to the company

Being a food and beverages brand quality is kept in first priority of the company. And in order to

Meet its objective of cost saving and financial benefits and to comply with the continuous excellence principal industrial performance improvement is kept in highest regard as far as the priorities are concerned. The principal of zero losses and waste being the quality principal makes DMAIC and 6σ a must to comply with the high quality standards. In order to achieve zero stoppages and rework the company emphasis a lot on process improvement. The company has a very structured quality & reliability mechanism that is embedded into the operations of the company.

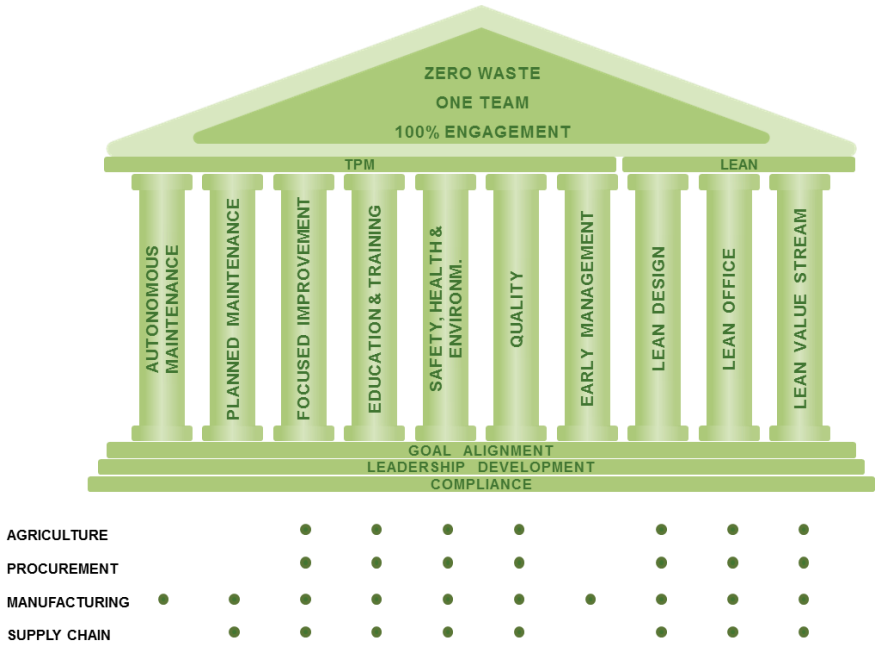


Figure 1 Brief Description of Continuous Excellence Structure at the firm

2 Literature Review

2.1 Overview of Continuous Excellence:

Continuous Improvement is about consistently finding ways to make things better and better, until we reach the best possible way of doing something. A number of markets have been piloting new ways for continuous improvement e.g. Lean (Reduction of all kinds of losses), TPM (Total Performance Management), JIT (Just in Time), SMED (Single Minute Exchange of Dye), MDWT (Mission Directed Work Team), Kaizen (Continuous Improvement) etc. The company's continuous excellence (CE) gives us one model for improving performance by using world-class tools and best practices.

The 3C's in the company's CE are

1. Delight Consumer

2. Deliver Competitive Advantage

3. Excel in Compliance.

The company has adopted the slogan of Zero Waste, One Team and 100% Engagement.

In short the company's CE is engaging the heart and mind of people in their respective jobs.

2.2 Basic Terminology and Principals:

100% Engagement mean developing excellence leadership and engaging all employees to improve performance.

One Team means aligning goals between Business and Operation through cascading consistent objectives and reviews across all levels. Goal Alignment is the foundation of Continuous Excellence. The purpose and scope of the Goal Alignment is on the management of standard work and incremental improvement.

These three are called as Goal Alignment Foundation Modules.

Measure:

1. Cascading measures from the master planning to the shop floor.

2. Ensure people understand the measures relevant to their area.

3. Develop people ownership and accountability for their measures.

Operation Review:

1. Drive the key measures and maintains the control over the process.

2. Identify and challenge actions to improve results.

3. Escalate results and issues.

Problem Solving:

Use the six-sigma DMAIC improvement cycle (Define, Measure, Analyze, Improve and Control) as an integrated problem solving methodology to improve efficiency. These Goal Alignment Foundation Modules strengthens the base of CE.

Zero waste means to eliminate all kinds of wastes from our Business. Waste includes (TIMWOOD) Transportation, Inventory, Motion, Waiting, Over Production, Over Processing, and Defects etc. The system stresses for constantly challenging how the Works Is done based on the fact that our competitors are changing the rules of the game.

The company has declared a war on waste in order to achieve zero Loss.

Figure 2 Show's the types of wastes in process industry

2.3 Continuous Excellence objectives:

The following are the main objectives or achievable for the continuous excellence of the company which believes in operational efficiency principal of doing the right thing, right the first time.

- Consumer and Customer focus

- Business and Operations Goal Alignment
- Excellence in leadership and competence development
- ONE Model for improving Performance
- To sustain on-going savings to support business growth
- Using world class tools and best practices
- Engaging everybody's heart & mind

2.4 Continuous Excellence Structure:

The company has a very well defined Continuous Excellence structured it comprises of 3foundations and 7TPM pillars and 3lean pillars which all when implemented results in zero waste one team and 100% engagement the results of the continuous excellence system.

What is a Pillar in Continuous Excellence?

Teams of people, who have expertise, disseminate the methodology and tools of a continuous excellence practice. This builds competences in the organization on a set of methodologies and tools through training, coaching and assessing.

Setting up of a pillar team is a three-step procedure in a continuous excellence environment, which is applicable to all the pillars of the company's CE. And the last step of setting up pillar is to device a comprehensive control and monitoring system to measure the output of the pillar and how competent it was in delivering the assigned objectives.

Composition of Pillars in Continuous Excellence:

1. Members are defined according to areas that have to be represented and require competences of the pillar practices

2. Pillar members are responsible for training, coaching and assessment of Pillar methodology in their respective areas.
3. Deep knowledge of Pillar methodology and tools
4. Strong facilitation and presentation skills, good influencing skills, good change management skills, good training and coaching skills.
5. Knowledge of other Pillars in order to support alignment of CE Pillars

2.5 Continuous Excellence Foundations:

The CE has three foundations for achieving its 0waste, one team, and 100% engagement

- Goal Alignment
- Leadership Development
- Compliance

2.5.1 Compliance:

The compliance foundation is a must do of the company and it is applicable to all departments including engineering safety hygiene environment Quality etc. The compliance foundation covers Policies, Guidelines, Standards, Best Practices and Certifications.

The following are the main contributors of this foundation of CE

1. Compliance to Company's Quality and SHE policy such as External certification of NQMS, ISO 22000, ISO 14001 and OHSAS 18001 which are most important to the company it being a food manufacturer.
2. Compliance to Human Resources Policies and Guidelines
3. Compliance to specific Company's internal Standards and Practices
4. Satisfactory Company Group or Market Audit rating.

2.5.2 Leadership Development:

The key objectives or mission of Leadership development is the continuous excellence environment is to create and manage Talent Pool, Success Profiles, Succession Planning, Leadership Development and Coaching .To optimize people, performance and culture in partnership with Line managers.

Develop leaders with the actions and mindset to enable company's employees to delight consumers, deliver competitive advantage and excel in compliance and continuously evolve our

Leaders towards a High Performing Organization and also to Embed and sustain these actions over time.

The aim of this foundation like all others and pillars in to achieve delighted consumers, excel in compliance and to deliver completive advantage. And this will be achieved by using behavioral methods, which contribute about 80%, and the rest 20% is *done using* Tools such as Goal Alignment Focused Improvement & LEAN.

The Leadership Development pillar has 3 components:

- Identify and develop the right Leadership mindset and actions
- Leverage company People Practices to sustain and embed them
- Measurement and continuous learning

Figure 3Pictorial representation of the goals and roles of Leadership development

Why leadership development is so important in the company's Continuous Excellence System is because experience has shown that the CE journey is 80% about behavior change and 20% about tools.

- Mindset: the company's CE implies a different mindset for Leaders It is more about helping people to achieve the business outcomes agreed It is less about directing, controlling and micro-managing
- Company's Leaders' Research From interviews of 180 Leaders in company how they foresee the future capabilities required of leaders The 3 most mentioned challenges were

improving how we lead and manage, how we deal with complexity and how we manage performance.

The leadership development is based on the fact that Training is not sufficient. The right leadership actions must be supported in all People Practices and it has a framework in CE to implement right people practices.

- Profile Define the mindset and leadership actions required Plans
- Train the right leadership mindset and action
- Perform role model the right actions and hold others accountable for the same
- Encourage and recognize right actions and mindset. Don't reward poor examples
- Develop and promote people with the right mindset and actions with 360, PDGs, talent reviews and succession plans
- Recruit people who have demonstrated success with the right mindset and actions

This process of Leadership development will deliver Desired Behaviours and Workforce Climate

2.5.3 Goal Alignment:

Goal Alignment foundation of the company's Continuous Excellence system provides ownership & engagement to achieve objective aligned with the Business to

- Build the appropriate capabilities to apply the GA methodology & tools and provide coaching through the Pillar structure to support delivery of strategic goals.
- Strengthen Factory processes management, assuring the delivery of results, standards and knowledge.
- Promote the link between the GA Pillar and the other Foundation Modules.
- Ensure the Pillar steps are implemented and deployed to the entire factory
- Training of the methodology and tools.
- Provide coaching on methodology and tools
- Ensure the right application of the concepts, methodology and tools**.**

Preparation: This phase is designed the lay down the foundations and clear the hurdles before the GA is implemented.

- Factory governance structure defined
- Factory implementation plan created

- Pilot area(s) defined
- Communication and promotion plan through CE defined and launched
- Prepare with HR synchronization with Leadership Dev. module: Everyday Coaching and Engaging People in change

The three steps in implementation of Preparation phase are

- Communication Establishment:
- Leading Bold**:**
- Everyday Coaching:

Operational Master Planning (OMP): The next phase of implementation of Goal Alignment is OMP it ensures business and functional alignment via an agreed 3 year Operational Master plan through relevant stakeholders sign off. Include key priorities, Drivers, KPI's & milestones to measure progress as well as an action plan.

Operational Master plan visually managed including awareness of key priorities for employees and Cascaded Operational Master plan including key priorities. The tools used in this process are OMP board/template, OMP Coaching Tool, SWOT analysis, OMP Business Alignment Survey, Prioritization Matrix, Fishbone and 5Whys, Pareto analysis and Brainstorming.
The basic OMP is done in six phases, which are explained below

1 Preparation:
In this phase BEMs, Function Manager, Factory Manager, Market and/or GA Pillar Leader sit down to Understand Market Business Strategy and agree on Business Priorities.

2 Identify opportunities Where are we:
In this phase Understanding of current situation in terms of practices and results Agreement are analyzed and considered for accurate planning. This phase is important in order to have the accurate analysis of the current situation.

3 Where do we need to go?
In this phase the Factory Manager Departmental Heads and GA foundation leader finalize the agreement on 3 to 5 Key Priorities where improvements are required Interactive

4 How do we get there?

The top leadership gives a plan on how to achieve the identified targets. It is done by Interactive preparation to define Drivers and Activities to develop the OMP draft

5 Align and agree Operational Master Plan Agreement on Final OMP and deployment of Communication Strategy by BEMs, Function Manager, Market and/or GA Pillar Leader

6 Implementation & Reviews

The final phase of goal alignment OMP preparation is the implementation and review phase where the BEMs, Function Manager, Market and/or GA Pillar Leader and departmental heads implement activities and perform regular reviews Cascade OMP to relevant Units/ areas.

Cascade Measures & Objectives "Performance Measures": It is the responsibility of the GA to design and manage performance measures, which should be clear, easy to understand and aligned with the business goals and are universally same.

- Measures cascaded from Operational Master plan to all relevant levels and time horizons
- Measures cascaded from Operational Master plan complemented with maintain measures where appropriate
- Balanced measures in place (according to the 5 principals of Performance Measures)
- Targets set and in place for chosen measures including planned improvements where applicable

Tools used: Performance Measures Coaching Tool, Templates for visual display of measures, Visual management guidelines for measures, Measures tree, Fishbone and 5Whys, Pareto analysis and Brainstorming

Proper Measures should follow 5 main principles given below in the diagram

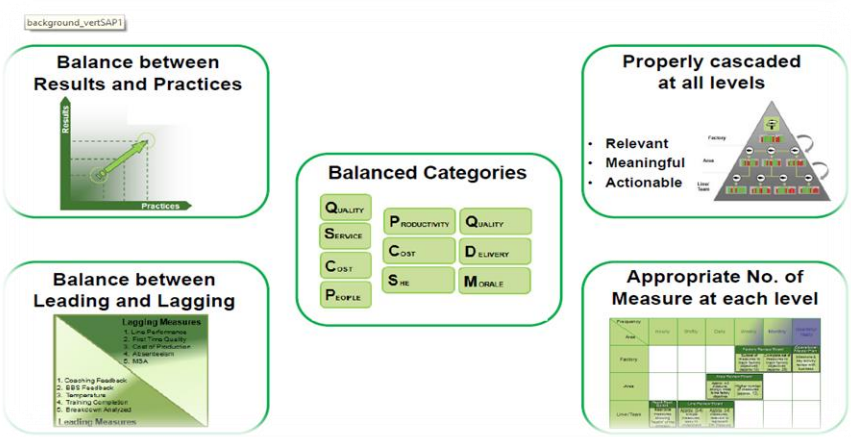


Figure 4 the basic principles which are used to make measure

- Relevant Must be aligned with Key Priorities, to have an impact on the performance and processes
- Meaningful Should ensure clear understanding at each level to monitor and improve performance
- Actionable Owner should be able to influence the Measures on a short, medium and long term horizon

Manage performance "Operation Reviews": In order to check the progress of goal alignment and keep it on track a review system is in place, which is managed and run by the GA foundation.

- Review routine in place to manage performance to the lowest appropriate level
- Reviews occurring at regular frequency (quarterly, monthly, weekly, daily and shiftily)
- Reviews consistently performed according to standard practices and use of Communication Centers (visual management) in place, up to date and with accurate information.

Tools used: Operation Reviews Coaching Tool, Communication center (Visual management boards), Reviews agendas, and Visual management guidelines for operational review

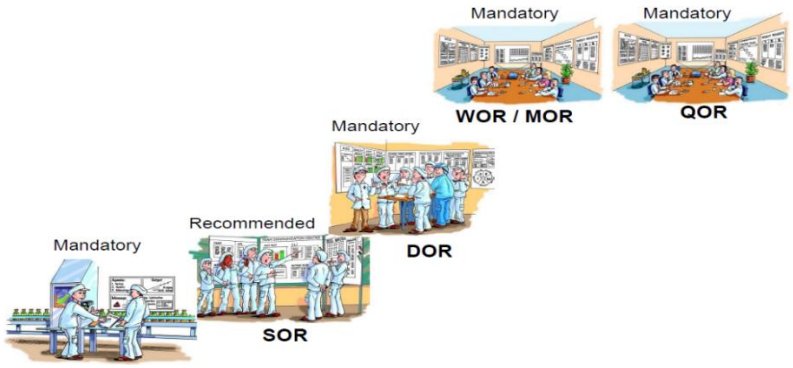


Figure 5 Structure of Operational Review

Capability to solve simple problems "Basic Problem Solving":

The Goal Alignment has also been incorporated with basic problem solving so that any improvements and changes are standardized and aligned with the priorities of the business and organization principals. The GA ensures that

- Problem solving mindset in place including frequent use of basic problem solving tools
- Go See Think Do (GSTD) frequently practiced
- Basic DMAIC trained and projects executed
- Visually managed story boards of Basic DMAIC projects in place and frequent use of OPLs to share learning's
- Management of improvement activities structured and defined

Tools used: GSTD Coaching Tool, GSTD Template, Basic DMAIC Tools and Story Board.

Problem solving has been incorporated in Goal Alignment to give people the competence and a method to solve problems by their own and to provide tools to identify and eliminate the root cause of the problem so that they have time to work on more value added activities

1. DMAIC in Continuous Excellence: DMAIC is one of the methodologies used within NCE for problem solving / improvement projects. In the frame of CE, DMAIC will be deployed in Manufacturing *(White Belt)* across the value stream. It can be used for small problems, involving a single piece of equipment, as well as highly complex issues that involve the entire value chain. Solve problems linked to a process that are recurring/ repetitive and aligned with the business needs. Solve problems that don't have a known root cause and cannot be solved using a day-to-day continuous improvement approach. It

relies on logical and rigorous project management, decisions based on facts and data whenever possible & teamwork, ongoing coaching, and engagement of staff

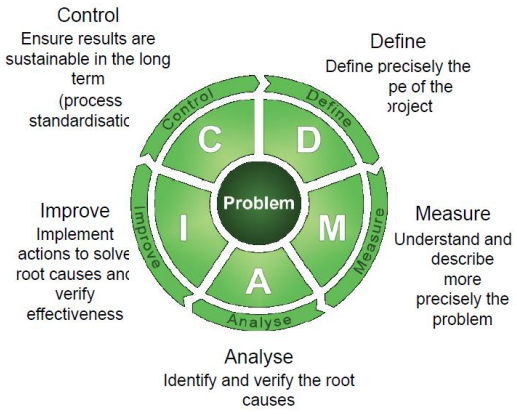


Figure 6 DMAIC explanation

2. GSTD: Go See Think Do is a simple 3-step Problem Solving approach to address day-to-day problems. The process starts by understanding the problem, finding causes, then solutions and finally implementing and standardizing solutions Go See Think Do can be practiced by everyone, every day. Go See Think Do can be applied when there is a gap on a Measure Go See Think Do tracker is one of the elements of Communication Center.

2.5.4 Autonomous Maintenance Pillar.

The basic function of the pillar is to achieve a Reliable manufacturing process with zero loss, owned by a team of autonomous operators. Autonomous Maintenance Pillar Objectives are given below:

- Develop Autonomous Work Groups (AWGs) and improve their capability to understand the difference between normal and abnormal in all phases of their work.
- Learn Problem Solving Techniques from Focus Improvement Pillar, ensuring that AWGs are capable to address problems on their equipment.
- Promote the link between Education & Training and Preventive maintenance Pillars to develop the AWGs knowledge of equipment function and structure.

- Promote the link with Quality Management & SHE Pillar to develop the AWGs knowledge of the relationship between process adjustments and quality production
- Promote the link with EM Pillar to develop the database to enable Vertical start-up of new lines.
- Develop organizational and individual capability needed to achieve process management, standardization, optimization of systems and autonomous maintenance to guarantee the correct application of AM methodology and tools.

The Autonomous Maintenance pillar is implemented using the steps given below:

1. Perform initial cleaning:

This step falls in the first phase of the learning, which is to educate people to be able to differentiate normal from abnormal. The objective of this step is to improve basic Workplace Organization. Prevent accelerated deterioration by cleaning the equipment, detect and eliminate abnormalities, establish and maintain basic equipment conditions. Eliminate contamination sources and hard to reach places:

Reduce cleaning time by eliminating sources of contamination (SOC) and improving parts that are hard to clean, inspect and operate (HTRP). Which is also a part of the learning phase of being able to differ the normal from the abnormal phase of the AM.

2. Establish provisional standards for cleaning, inspection, and lubrication:

This is the last step of education phase one of AM, which is being able to differentiate normal from abnormal. The objective of this step is Sustain equipment conditions by establishing CIL standard: perform accurate checking with help of visual controls. Free up MWG resources for preventive activities by transferring lubrication activities to AWGs.

3. General equipment inspection:

This step of AM is designed to improve equipment reliability by enabling everyone in the AWG to better clean, check and lubricate. This is achieved as a result of detailed training on every system and its components of the line.

4. General process inspection:

Improve process stability and safety through precise process control, inspection and correct operation. Understand the relationship between equipment and process components and quality are the key highlights of this step of AM.

5. Systematize autonomous maintenance:

This step establishes self-management of workplace, quality, material flow, tools, spare parts etc. Optimize everything related to the Autonomous work group's activities and Workplace Organization applying Lean tools. It prepares the team for Prepare training on Autonomous Problem Solving (DMAIC), Prepare a training of Value Stream Map & VA / NVA activities (with Lean Pillar), Support Value Stream Map development and actions definition, Support a system of self-management for workplace flow, spares, tools, Work in Progress, finished goods, Develop Team Meeting Corner standard, Monitor compliance with standards and provide

Support to QM, SHE, EM and Lean Pillars Implementation.

6. Practice full self-management:

This step Guarantee the consistency of the AWG's self-management, apply the Lean Thinking concept in everything related to the AWG's activities, monitor equipment and process conditions, increase equipment productivity and search for continuous Lead Time reduction. The main activities performed in this step are to Create autonomous teams and promote continuous improvement, Define support function roles and multi skilled operator profile, Develop an autonomous Suggestion System, Training on advanced problem solving and skill level assessment, regular Team meeting to keep the results.

2.5.5 Planned Maintenance Pillar:

The main purpose and principal behind achieve zero un-planned stops and optimizing resources. The objective of planned maintenance pillar is to consolidate the Maintenance Concepts and the PM Pillar Methodology Assure the Implementation consistency based on PM Pillar criteria. Support the PM tools application to facilitate the breakdown analyses and reduction. Increase the capability of the operators to restore and keep the machine in basic conditions. Increase the capability of the technicians to maintain and improve the machines. Foster a culture of effective Maintenance Work Groups (MWG), where the PM pillar steps are developed on all equipment

and the MWG acts as the “elder brother” to the Autonomous Work Groups Reduce the Overall Maintenance Cost through PM Methodology

The key responsibilities assigned or performed by this pillar are to define and track the PM Pillar activities within the Continuous Excellence and Rollout Plan together with Executive Committee

Participate and learn on Pilot Line, together with Maintenance Work Groups and Local Committee

- Manage the extension of the PM methodology by applying the leanings from the Pilot Line to the rest of the factory
- Coach Maintenance Work Groups (MWGs) and Local Committee on establishing the MWG activity plans and PM Methodology
- Defining role for Local Committee, which implements roles with Maintenance Work Groups routine.
- Conduct the PM Pillar self-assessments and define corrective actions
- Define training needs and ensure training is deployed to Maintenance Work Groups

The PM pillar is also implemented using six steps, as was the AM pillar.

1. Evaluate equipment and understand current conditions:

The main objective of this step is to consolidate the Maintenance concepts, Validate/check assets, and Define asset priorities, understand the current situation (survey data base), build indicators and establish objectives. It is responsible to Coach on 5S implementation

Develop Zero Breakdown Roadmap by coordinating with MWG’s the breakdown deployment process. It Updates machine lists Classify Line, machine & equipment according to ABC classification and ABC, Z for Spare parts Understand & create maintenance database.

2. Restore basic conditions and correct weaknesses:

This step is responsible for Restoring machine basic conditions, Correct weaknesses (strengthen week aspects), Enhance improvements, Identify and eliminate breakage causes, Eliminate repetitive breakages and consolidate the survey on “Component Tree”

This step is responsible for Execution of basic maintenance (restorations), Execute / enhance small improvements, Support Autonomous Maintenance (removal of tags & develop technical

training (OPL), Perform Breakdown Analysis giving priority to A&B class, Control rigorously breakdown recurrence, Apply Lubrication management system and Build up the Technical part of the MWG Skill Matrix to ensure development of internal subject expert matters.

It is also responsible for Coaching and ensures an effective breakdown analysis system is in place. It also ensures machine improvements are horizontally replicated.

3. Create or review the information management system:

The objective of this step is to define an automatized maintenance system, establish the technical information register Control schematic drawings and diagrams, consolidate the register of the "Component Tree" Manage/reduce spare parts stock levels.

4. Create or review the periodic maintenance system (TBM):

The objectives of this step are to define/revise the Maintenance Plan based on time (inspection and periodical changes), establish inspection procedure standards, implement a "Weekly Maintenance Schedule" system and assure "vertical start-up" after preventive maintenance.

It's the role of this step to implement Weekly Maintenance Schedule System. Identify basic training requirements for AM final phases. Train maintenance group in FMEA and RCM

Coach maintenance work group on defining the schedule for the TBM update and define criteria for TBM vs. corrective maintenance to help define & create system with MWG.

5. Create or review the predictive maintenance system (CBM):

This step has the objective to introduce technologies for predictive maintenance (diagnose methods) and define and execute maintenance plans based on condition. Apply and Train Maintenance in predictive techniques. Define criteria for CBM maintenance & create system with maintenance work group and CBM.it also defines places to be monitored and set time for inspection for each place and the technology used for inspection.

6. Evaluate the planned maintenance system

The final step in this pillar is to Run the maintenance budget on-line evaluates the maintenance concerning reliability and ensure availability and maintenance of assets.

2.5.6 Safety, Heath & Environnent Pillar:

The principal behind the inclusion of this pillar in the company's continuous excellence system is to achieve zero incidents & accidents and environmental sustainability through building employee capability, autonomy, mind-set and ownership for SH&E. Deploy systems and tools to foster integration, cross functional engagement and caring to continuously improve Safety Health and Environment performance.

SHE pillar is responsible to

- Develop organizational and individual knowledge and capability around SH&E systems and tools to achieve zero losses related to injuries, illnesses, incidents and environmental sustainability.
- Deploy SH&E Pillar systems to create awareness, promote healthy lifestyles, & reduce losses and absenteeism due to occupational health issues.
- Warranty of Compliance in SH&E Legal, Management Systems and other requirements during all activities and improvements performed by the OMS (Operations Management System) and consistency during TPM maturity phases implementation.
- Identify and eliminate unsafe behaviors and conditions and understand the hazards and risks of their activities.
- Identify and eliminate behaviors and conditions and understand the environmental aspects and impacts of their activities.
- Be empowered to lead SH&E main activities and empower/inspired others with the leadership wheel.
- Identify situations and apply the tools related with Management of Change like a culture driven by excellence in Compliance.

The main responsibilities assigned to this pillar are to Communicate the SH&E Pillar vision and set the factory targets and master plan for SH&E Pillar deployment. To deploy safety health and environment ownership to all levels to further embed SH&E in the company's culture and drive the continuous improvement process. It enables the application of SH&E Pillar methodology, tools and systems in the pilots and support the expansion of the SH&E Pillar methodology through sharing the learning from the pilots to the rest of the factory. Assess and track the SH&E

Pillar activities and SH&E Pillar results within the Operational Master plan together with the Executive Committee.

To define the responsibilities of the SH&E representative in functional areas, committees and work groups and to Train and coach the Committees, Pillars, Work Groups & Improvement Teams in SH&E Pillar methodology, systems and tools. Coach the Site Executive Committee to drive SH&E ownership throughout the site and to the shop floor. Support the SH&E function in reinforcing the safety health and environment prevention program to outsourced & new employees, contractors & visitors while it develops internal and external networks to benchmark performance and practices.

Safety Health & Environment is applied using 5 steps, which are aligned with education and training and autonomous maintenance pillars.

Define future and current state:

This step has the objective to align the SH&E future state and start of the pillar integration with existing other pillars. SH&E gaps are identified in this step. The main activities performed at this step are to set up Management meeting structure for pillar, Create and maintain Pillar boards.

Define Responsibility and skill matrix of the team and define the site's SH&E Pillar future state and journey. The objective of this step is to Provide support /orientation to the functional areas on how to solve the SH&E gaps with assistance from other pillars. Develop base pillar systems linked into the company's management system and into other pillars.

It is responsible to perform the following activities:

- Implement in-depth Job Hazard Analysis (to identify SH&E defects at the line level)
- Upgrade all procedures (including visual management, SH&E and QM requirements) and retrain (ET pillar)
- Implement action plan to address gaps identified
- Start detailed behaviour based safety tracking (gap analysis against requirements)
- Develop corrective actions system (focus on root cause analysis)
- Contribute to the development of the factory-wide management of change system as part of company's management system

- Continue deployment of environmental systems

Focus on Corrective Incident Management:

The objective of this step is to increase employee and pillar skills in SH&E methodology to systematically eliminate incidents and losses at root cause level.

The main activities that are performed in this step are to start up or upgrade corrective actions system RCA (Operational DMAIC), Start Execution of action plans. To Train the Teams SH&E representatives on systems and re-evaluate compliance and commence addressing gaps. This step assists in ensuring effectiveness and integration of SH&E elements into factory-wide management of change system.

Focus on Preventive Incident Management:

The objective of this step is Create focused SH&E awareness, ownership and a proactive SH&E mind-set. SH&E tools become part of daily routine. Risk factors, including environmental aspects and impacts, are identified and controlled.

The major activities performed at this step are to coordinate with AM pillar, integrate risk prediction into other TPM Pillars (PM, EM). To evaluate ergonomic and health of workstations and tasks and address A&I / HIRA gaps, and improve towards objectives and targets. Inject SH&E checks in CIL standards through AWG's AM.

Sustain and improve standards:

The objective of this step is to ensure SH&E awareness and system ownership fully cascaded to Workgroup level. Evaluate current standards in order to optimise and improve them. The main activities done are to review all standards, update as necessary and optimise using ECRS (eliminate combine reduce or simplify). It ensures all standards and activities have visual Job hazard analyses and accompanying procedures .To retrain people as required in order cascading system ownership to workgroup level. This ensures initiatives at line level are free of SH&E defects (link to EM Pillar). Create a SH&E continuous improvement mentality at all levels to Optimise current standards.

The only tools used at this stage are Conditions Management System and Eliminate, Combine, Rearrange/Reduce or simplify (ECRS). This identifies unnecessary activities, finds a way to eliminate them, combine activities to reduce necessary time and accumulation of operations.

Find new solutions to reallocate and rearrange activities and plan methods to simplify remaining activities.

2.5.7 Quality Pillar:

The Quality Pillar aims at zero quality losses by deploying methodology and coaching its implementation. We will build competencies and knowledge across all functional areas and TPM Pillars of Continuous Excellence.

The objectives of the Quality pillars are to create awareness, alignment and commitment of management and employees at all levels and ensure consistent implementation of Quality Pillar criteria

Support the application of Quality Pillar tools in order to facilitate the analysis and elimination of quality-related losses which increases the capability of the Autonomous work groups and Maintenance work groups to manage the zero defect system. The pillar Switches the mind-set from quality control to process control, and then to conditions management to implement an efficient conditions management system to hold the gains.

The major responsibilities of the pillar are

- Setting the vision, mission, targets and master plan for the pillar
- Ensure adequate training of pillar members on methodology and tools
- Provide the Quality Pillar methodologies, knowledge and tools across the factory
- Participate and learn Continuous excellence methodology on pilot line in order to prepare future Quality Pillar facilitators prior to roll-out
- Coach the Quality Work Groups (QWGs), local and executive committees on quality loss analysis, deployment and defining the QWGs projects in order to reach zero quality loss
- Benchmark cross-functional areas to drive continuous improvement

- Manage the Quality Pillar systems and deploy drivers to the appropriate level in the organisation while managing, coordinating and communicating updates to the pillar board
- Synchronize the application of Quality Pillar methodologies with other pillars steps to avoid any conflicts during implementation.

The quality pillar is implemented using the following steps

1. Understand current situation and analyse quality losses:

This step ensures building a vision for improvement and set pillar goals and targets

To understand current situation and develop a system for data collection which will allow us to identify losses and establish priorities.

The main activities performed are to set targets and vision and understand current losses in detail. It Identifies and classifies defects along with collection of data. In this step we plot defect and process steps in the quality assurance matrix

The main tools and systems employed at this step are

- Pareto graph
- QA Matrix
- Time series plot
- 5W1H
- Skill Matrix template (see ET Pillar)
- Defect mode ID card template
- Loss mapping template & Loss collection form
- Defect sampling & Complaint/Defect correlation
- Quality losses analysis
- Data collection system

2. Reduce defects by restoring the conditions of the quality system:

The step's objective is to eliminate defects associated with quality systems failures (lack of standards/ lack of discipline) and to evaluate defects on the 4Ms with the restoration of the

current conditions of the 4Ms.it is responsible to develop operator's skills to understand system failures and improve quality standards and Quality monitoring scheme (QMS).

Among the activities performed the major activities are to perform 4M analyses for each process step and defect and complete QA Matrix to evaluate the quality standards and update them or create new ones. It also restores basic conditions related to machine, material, methods and man.

Evaluate conditions and update documentation of all conditions checked.

The tools and systems used in this step are

- 4M Analysis template
- QA, QX, QM matrix template
- R+R methodology
- SPC Control chart
- Quality matrix system

2 Reduce defects by attacking sporadic losses:

This step is designed to eliminate special cause variation and with the objective to Eliminate sporadic losses using defect analysis and basic DMAIC and ensure that the operators understand the links between the process 4M conditions and the defects. It is responsible to guarantee involvement from operations, maintenance and quality to attack sporadic losses (as needed)

It is responsible for improved reaction time to sporadic losses and update or create standards to prevent re-occurrence of sporadic losses. The major activities performed are to continue rollout of SP, set up Quality Work Groups to attack recurrent sporadic losses, perform defect analysis and select sporadic losses. The main tools and systems utilized in this step of quality pillar are

- Problem solving system
- QA matrix &QX matrix
- Defect analysis
- Basic DMAIC package:
- Pareto, Fishbone
- Time Series Plot
- 5W2H / OPL/ Skill matrix

3 Reduce defects by attacking chronic losses:

In this step we reduce or remove common causes of variations using advanced techniques to handle chronic losses utilizing trained experts for the process. The objectives of this step are to analyze every single remaining defect involving engineering, operations and quality to attack chronic losses. To implement permanent corrective actions to eliminate chronic losses using advanced DMAIC. The actions, which are performed to achieve these objectives, are to avoid reoccurrence of the loss and perform P-M analysis to analyze complex chronic losses. Set up Quality Work Groups to attack the chronic losses and ensure that experts are trained to use advanced tools while identifying top chronic losses using the following tools and systems.

- Advance problem solving system
- QA, QX & QM matrix
- Intermediate & advanced DMAIC
- Hypothesis test
- ANOVA
- Regression analysis
- Design of experiment (DOE)
- Multivariable analysis
- P-M Analysis
- Skill matrix

4 Introduce and maintain the zero defect system:

The main objective is to get to ZERO defects which requires the discipline to ensure that the zero defect system is effective and reliable and optimize process based on Statistical process control. The aim is to drive variation out of the process and defining working conditions to maintain the quality level achieved by immediate response to variation. The actions performed in this step are: register improvements in the MP Database (Maintenance Prevention and analysis of defect reoccurrence. Expand the application of the five conditions to zero defect methodology while maintaining a capable process (Cpk $\geq$1.3). Standards and tools are updated in this step using QX/QM matrix with new standards. Expand the application of the 3 Quality Matrices (QA/QX/QM) to other process step so the whole factory or value chain is covered. The system used for this step is Zero Defect system and the tools used are:

- Defect analysis sheets
- OPLs and SOPs
- QX/QM Matrix, Cp and Cpk
- FMEA

5 Improve the zero defect system:

Optimize the condition management system is the base of this step. It has the objectives to

- Improve the system effectiveness on the maintenance of conditions using fewer resources to achieve equal results.
- Reduce the number of inspections when the parameter is stable
- Reduce the inspections by grouping inspection activities, reducing the time needed or implementing Poke-Yoke's
- Reduce the effort required to monitor
- Automate using in-line control systems

The major activities performed during this step are to reduce efforts through automation and making Q-points easy to manage by improving the conditions management system.

The tools it uses along with the conditions management system are Poke-yoke, ECRS, Low cost automaton and five C Questionnaire Template.

2.5.8 Education & Training Pillar:

Education and Training Pillar mission is to provide education and training practices that build capabilities and engagement of the organization through a systematic use of method and tools for competence building, training and coaching in their application, assessment of their application and to continuously improve our people and business results using these practices.

The Education and Training Pillar provides practices, processes and tools for building competencies, to support the Company's CE Journey and ultimately contribute to the achievement of the 3Cs:

- Delight Consumers
- Deliver Competitive Advantage
- Excel in Compliance

E&T pillar uses a structured methodology in developing knowledge and skills, in order to support and achieve excellence of performance at the factory through:

- Developing Competency Based Training (CBT)
- Facilitate on Job Training (OJT)
- Skills GAP Assessment
- Reinforcement of coaching
- Change Management and Communication
- Leadership Framework (Insight, Provision in serving, Proactive cooperation, Convince the other, Initiative, People leading)

Figure 7 Learning Methodology for leadership Development

It is also responsible for creating and maintaining the atmosphere of a learning organization through:

- Encouraging the learning and self-development environment
- Application of consistent Learning Best Practices
- Developing a Technical Training Centre

2.5.9 Focus Improvement Pillar:

FI Pillar mission is to empower our kin to take care of issues with a specific end goal to accomplish business goals. It gives philosophies that rouse and draw in individuals to distinguish the applicable issues and dispose of their underlying drivers. The FI pillar is

- A Competence Centre: Provides Methods and Tools to the Units.
- A Multiplier: Provides Training and Education
- An Internal Consultant: Coaches the units in application of Methods & Tools

- An Auditor: Tracks progress and audits correct implementation

The obligations of FI are to distinguish important issues/ misfortunes taking into account vital goals; with a specific end goal to dispose of them, execute Focused Improvement tasks (SMED and all DMAIC levels) and GSTDs. In Manufacturing, it is in charge of organizing and taking care of issues in each of the 5 measurements of Manufacturing Excellence in this manner adding to zero waste essential of Continuous Excellence. It is capable to add to the competency needed to backing the key destinations of the Market/ Function and Factory and manufacture the suitable competency to execute FI undertakings and give drilling through the FI Pillar structure. It is likewise capable to backing the other Pillars' targets with issue understanding strategies and honing.

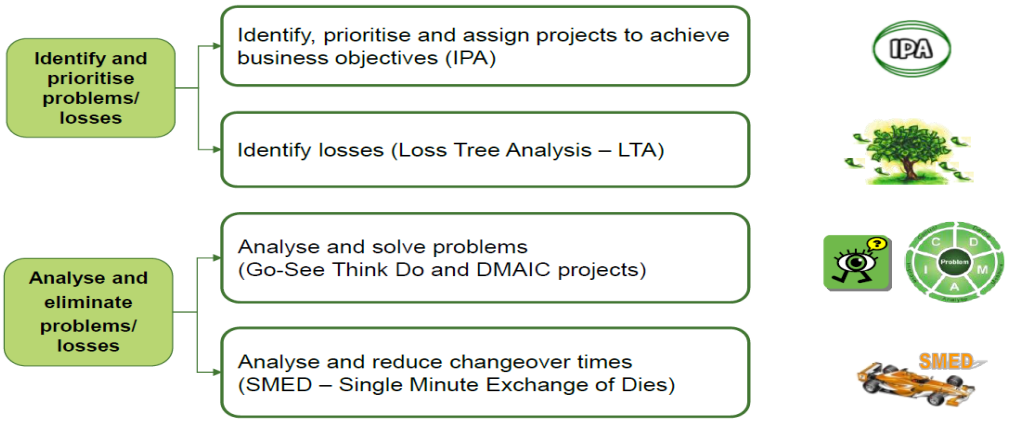


Figure 8 Focused Improvement Methodology

The roles of the Focused Improvement are divided into four activities

- Methodology: the Pillar should master the methodology and tools in order to support the organization
- Training: the Pillar provides training on Pillar methodology and tools.
- Coaching: the Pillar coaches on the application of Pillar methodology and tools.
- Assessment: the Pillar ensures the right application of the methodology and tools.

The FI Pillar develops and deploys four methodologies. The first set of methodologies aims to

Understand the Function/ Unit’s current situation with KPIs and losses and provide quantitative data to priorities projects and activities in order to reach the Function/Unit’s objectives.

The second set of methodologies provides problem-solving methodologies for problems of different types and complexity levels.

- Methodologies to identify problems / losses – IPA:

This methodology is applied once a year in line with the OMP cycle. Progress on projects and activities is assessed in quarterly reviews (QOR) and monthly follow-ups (MOR). To ensure that recognized change activities and critical thinking exercises are organized and relegated to individuals with the right competency and accessibility keeping in mind the end goal to attain to KPI and misfortune diminishment targets. The IPA philosophy builds what number of undertakings and critical thinking exercises are expected to accomplish a given target in light of the quantitative commitment and due date of every venture/action. It is a strategy that falls the destinations into activities and critical thinking exercises to be organized and doled out.

The tools used are Time Series Plot and Pareto Chart.

Methodologies to Identify problems / losses – LTA:

LTA is applied and continuously used throughout the FI Pillar implementation with frequent updates (starts with yearly updates). Raises zero misfortune mindfulness, measures and needs misfortunes as indicated by money related effect and OMP needs. The LTA procedure catches the contrast between the perfect (zero misfortune) and genuine state in three fundamental classes: Machine, Material and Man to be tackled based on financial impact and OMP priorities. It has the objective to Identify; prioritize loss categories (machine, material and man losses) with financial impact and OMP priorities and reduced losses tackled by different work groups. The tools used are Time Series Plot and Pareto Chart.

One of the LTA objectives is to give ownership of losses to operators: therefore the Local Committee (LC) is responsible for losses. The LC leads activities and projects related to loss reduction.

- Methodologies to Analyze and Eliminate problem / losses (go-see think do):

Go- See Think Do is the simplest problem-solving methodology. It is a 3-step problem solving that can be applied when an issue is identified (e.g. a gap on a measure) or a sporadic problem

appears. It starts by understanding the problem, finding root causes, agreeing on solutions and finally implementing and standardizing them.

- Methodologies to analyses and eliminate problems losses DMAIC:

Have a common and structured way to solve recurring low- to high complexity problems. DMAIC provides a systematic and structured 5-Phase problem-solving approach.

DMAIC is the methodology used within CE for problem solving / improvement projects.

In the frame of the company's continuous excellence, DMAIC will be deployed in Manufacturing within the Focused Improvement Pillar or across the value stream.

It can be used for very simple problems, involving a single piece of equipment, as well as highly complex issues that involve the entire value chain.

In the company the DMAIC is based on three principals which are Logical and rigorous project management, Decisions based on facts and data whenever possible and Teamwork, ongoing coaching, and engagement of staff.

- Methodologies to analyze and eliminate problems /losses – SMED

SMED (single minute exchange of dies) is a methodology to reduce the duration of planned activities such as changeover, planned cleaning, start-up and shutdown. Provide a specific problem-solving methodology to eliminate non-value added of planned activities. The tools it uses are 4W1H, Time series plot, Project timeline, Competency matrix, Changeover registration and analysis forms, Spaghetti Diagram, ECRS, 5W2H (Action Plan), Standards and OPL.

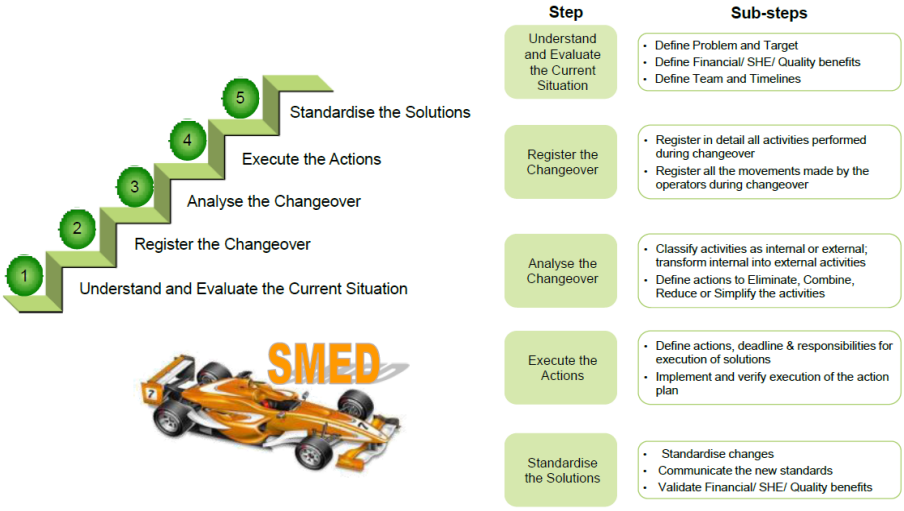


Figure 9 SMED Description

2.6 Understanding Deviation or Error

Deviation is a vital part of life. The idea of deviation expresses that no two items will be flawlessly indistinguishable regardless of the fact that compelling consideration is taken to make them indistinguishable in some angle. The deviation in the nature of item in any assembling procedure results due to two reasons in particular, Chance reason and Assignable reason. A process that is working with just risk reasons for deviation is said to be in a condition of factual control.

This implies, chance reasons brings about just minor deviation simultaneously. The real goal of measurable procedure control our territory of study is to rapidly identify the event of assignable causes so that examination of methodology and remedial move may be made before numerous non-accommodating units are stuffed and a ton of revamp is created. Finally, the eventual goal of SPC is the elimination of deviation in the processes.

2.7 Statistical Process Control (SPC)

Checking and controlling the procedure guarantees that it is working in its maximum capacity. Measurable Process Control is a system for quality control, which utilizes factual techniques. SPC is connected to screen and control a procedure. At its maximum capacity, the methodology can make however much adjusting item as could be expected with a base (if not an end) of waste (modify or garbage). SPC can be connected to any methodology where the "adjusting item" (item meeting particulars) yield can be measured. This uses the accompanying devices to get its

destinations control graphs, an attention on persistent change and the outline of examinations. We will utilize SPC to decrease our revamp and filling misfortunes.

2.8 Process Capability

So as to break down the framework and to look at the yield of the progressions or change done we utilize process ability. The procedure capacity examination has been broadly received as a definitive measure of execution to assess the capacity of a methodology to fulfil the clients as particulars. Process capacity goes about as a Continuous magnificence instrument and is depicted as a key administration procedure that assumes an essential part in the organization's operations administration. The procedure capacity study helps in planning the item, choosing the acknowledgement standards, methodology and administrators determinations in the operations administration. The assessment of procedure capacity is a critical venture in methodology quality change. It is standard to take the six-sigma prime spread in the circulation of the item quality trademark as a measure of methodology capacity. In methodology capacity investigation of specific process, six-sigma prime spread is contrasted and the distinction of Upper Specification Limit (USL) and the Lower Specification Limit (LSL).

The following are the three possible cases:

- 6s ` > (USL – LSL): In this case, the process spread is greater than the tolerance. So the process is incapable of meeting the specification.
- 6s `= (USL – LSL): In this case, the process spread is exactly equal to the tolerance. So the process is exactly capable of meeting the specifications.
- 6s ` < (USL – LSL): In this case, the process spread is less than the tolerance. So the process is capable.

It is regularly helpful approach to have a basic, quantitative approach to express process capacity. One approach to do as such is through methodology capacity records. Process capacity files (PCI) are intense method for considering the methodology capacity for assembling an item that meets details (Chen et al 2001). PCI is characterized as the degree of resilience to the methodology spread i.e. PCI = (USL – LSL)/6s. On the off chance that the PCI is more prominent than or equivalent to one, then the procedure is fit for meeting as far as possible. In the event that the PCI is under one, then the procedure is unequipped for meeting as far as possible. Cp basically measures the spread

of the particular in respect to the six-sigma spread all the while. Cpk will come into picture if the methodology is off kilter. Cpk is a list (a straightforward number) that measures how close a procedure is hurrying to its determination limits, in respect to the common variability of the methodology

Cpk = min (CPU, Cpl)

Cpk = Min (CPU = (USL - m) / 3s, Cpl = (m - LSL) / 3s), generally if Cp = Cpk, the process is centered at the midpoint of the specifications, and when Cpk is less than Cp, the process is off centered

2.9 Literature review of six sigma in continuous excellence environment

2.9.1Definitions and concept explanation

Six-Sigma is a quality change apparatus that expels vulnerability from the procedure decreases variety and uproots lapses when utilized as a part of critical thinking. This system utilizes an arrangement of value administration strategies and measurable systems to make a characterized and set order of individuals inside the association performing six-sigma ("Champions", "Dark Belts", "Green Belts", "white Belts", and so forth.) that are specialists in these exceptionally complex techniques. Every Six Sigma venture did inside an association takes after a characterized grouping of steps and has particular quantitative targets, for example, procedure process duration diminishment, consumer loyalty, decrease in contamination, cost lessening, and rate increment in benefits.

The ideas attaches back to the teachings and rationality of Dr Joseph Juran and Dr W. Edwards Deming. Six sigma is a superior, information driven strategy for enhancing quality by evacuating imperfections and their reasons in business process exercises. It focuses on the outputs important or valuable to the customer that makes is extremely customer focused. Six sigma focuses on the core causes of the business problems or the processes in order to reduce variance from the mean process value of the data [6].

The term Six Sigma began from phrasing connected with assembling, unequivocally terms joined with measurable demonstrating of assembling practices. The advancement of an assembling methodology can be portrayed by a sigma rating showing its yield or the rate of deformity free items it makes. A six sigma procedure is one in which 99.99966% of the items produced are

factually desert free (3.4 deformities every million), albeit, as examined underneath, this imperfection level compares to just a 4.5 sigma level. Motorola set an objective of "six sigma" for every last bit of its assembling operations, and this objective turned into an epitome for the administration and building practices used to attain to it.

Six sigma preaches and practices the following principals like other quality improvement processes before it

1. Continuous endeavors to accomplish steady and unsurprising procedure results (i.e., lessen process variety) are of essential significance to business achievement.
2. Manufacturing and business methods have qualities that can be measured, broke down, controlled and moved forward.
3. Achieving maintained quality change obliges responsibility from the whole association, especially from top-level administration.

Features that set Six Sigma apart from previous quality improvement initiatives include:

The first difference is the Versatility that means it can be used to change the organizational culture as the GE Company did or in operations to reduce defects and rework in the processing both in services and manufacturing and it focuses on financial results [6].

The second key difference is that it is process focus approach that instills a deeper and more transparent understanding of processes and operations. Use as structured problem solving tool is another key difference between six sigma and other tools. The process of problem solving of DMAIC is standardized and must be followed.

Customer focused is the third key difference between other quality tools and 6sigma: improvement projects are linked to customer needs by identifying Critical to Quality (CTQ) characteristics from the customer point of view.

The fourth point is the leadership involvement and commitment The fact that it’s a top down rather than a bottom up approach is the fact that the literature suggests this approach is being lead, driven and owned by some of the top CEO’s like Larry Bossily of Allied Signal and J Welch of GE [5], a concept which was lacking in other quality tools six sigma has made involvement of leadership imperative by requiring extensive and demanding involvement of top leadership.

By devising a distinctive organization comprising of ,Green Belts, Yellow Belts , Black Belts etc. to lead and implement he Six Sigma approach six sigma is making association for critical thinking with unmistakably characterized parts and structure for Project champions, Black belts and Green belts is made for the critical thinking methodology [6].

A clear commitment to making decisions on the basis of verifiable data and statistical methods, rather than assumptions and guesswork by systematic use of tools and techniques. Toolbox incorporates numerous information-based methods, for example, Control outlines, Quality capacity Deployment, Design of Experiments, Cause and Effect. Lean assembling [6]. And a clear focus on achieving measurable and quantifiable financial returns are basics and forces driving any Six Sigma project.

Training is a mandatory part of the project and it is not only an improvement process but also a learning opportunity. The training should be given to everyone in the enterprise [5] in the methodology and tools along with edited or new concepts and tools-normally in a once a week schedule, which is completed over a span of three months. It is mainly a practical project and bottom-line-oriented. The main reason for spreading it over three months is to allow peoples to apply the concepts and tools to important projects [5].

2.9.2 Six Sigma history

The history of the concept is a well-established one and hence we note only briefly here that its origin as a quality improvement approach in the 1980s can be traced to the Americas one of the largest electronics producers Motorola as discussed earlier where an aim of improving all products, goods and services was set – by an order of magnitude (e.g. a factor of ten) within five years was established. This provided a focused improvement concept with greater emphasis on production rates, it initiated a concept that had real targets not vague targets like better or improved only but that the critical consideration is that of becoming sufficiently better expeditiously. Six Sigma implementation resulted in focusing on resources at Motorola, including human resource, on reducing variation in all processes, which includes manufacturing processes, administrative processes and services. In order to gauge the improvement in the process the Six Sigma methodology was launched in 1987.

Six Sigma has been implemented all over the globe and its success story can be told by the stats of the companies that benefited from it [1]. Six Sigma got to be extraordinary after Jack Welch made it a focal center of his business system at General Electric in 1995, and today it is used in different sectors of industry as a tool to implement focused improvement and continuous excellence. Michael Hammer, author of reengineering the Corporation says in his book that at least 25% of the Fortune 200 companies are giving key importance and prioritized resources to their Six Sigma program.

A few of the common examples of large enterprises that benefited or have adopted the six sigma as a tool for improvement are Allied Signal, Gillette, Johnson Control, JP Morgan Chase, Johnson & Johnson, Bombardier, Sony, Eastman Kodak, ABB, Caterpillar, American Express, Motorola, General Electric, AlliedSignal (now Honeywell), ABB, Lockheed Martin, Polaroid, Sony, Honda, American Express, Ford, Lear Corporation and Solectron.

The Six Sigma has now got a global presence and it has moved from the US to Europe and is an emerging practice and tool in the Asia including China, Pakistan, and India and is also rising in the UAE and middle-eastern parts of the world [6].

The expression "Six Sigma" originates from a field of measurements known as procedure ability studies. Initially, it alluded to the capacity of assembling courses of action to create a high extent of yield inside detail. Forms that work with "six sigma quality" over the transient are accepted to deliver long haul deformity levels underneath 3.4 imperfections every million open doors (DPMO). Six Sigma's certain objective is to enhance all courses of action, yet not to the 3.4 DPMO level essentially. Associations need to focus a suitable sigma level for each of their most vital courses of action and endeavor to accomplish these. As a consequence of this objective, it is occupant on administration of the association to organize regions of change.

2.9.3 Implementation and success factors

A survey of aerospace companies brought to light that not even 50% of the companies are satisfied with their Six Sigma programs [2]. Another survey of healthcare companies revealed that 54% do not intend to embrace Six Sigma programs [4]. Organizations, for example, 3M and Home Depot were not fulfilled by their usage of Six Sigma programs [7]. Considering this, numerous creators address the arrival on venture of Six Sigma programs [3]. The genuine inquiry is not whether Six Sigma projects have esteem, yet why do as such numerous Six Sigma projects

fall flat? One reason numerous Six Sigma projects fizzle is on account of we do not have a model on the best way to successfully direct the execution of these projects [7].

A critical inquiry emerges why is this change technique still fruitful? One of the key variables affecting the achievement is the extraordinary backing of the upper administration. It is a built truth that not a considerable measure could have been fulfilled without the backing [5]. On the other hand, that backing could just be kept up the length of Six Sigma indicated results and created achievement. One of the main reasons for this overwhelming success is the technology which has only become available recently such as: [5]

- Autonomous monitoring and large Databases
- Easy availability of experts who can use powerful statistical tools
- Improved communication capacity by high speed Internet using email messaging etc. has resulted in swift transfer of data and easier communication via easy data shearing.

The second most important factor in the success and implementation of six sigma is the mandatory training. Six Sigma tools that are deployed normally are not new and have already been used in various forms in other quality control methods [5]. The literature argues that the results of industrial trainings are significantly reduced in the areas such as DOE, statistical process control (SPC), regression, and analysis once the trainees are back to routine work and the training is over [5] .Six Sigma has the added advantage that all these tools are used long after the formal class room training and much better retained and practiced.

One major factor resulting in successful implementation of six sigma DMAIC methodology is the organized and systematic step-wise scheme that keeps the tools and overall implementation on track [5].

- The third factor that has evolved recently and dramatically improved customer satisfaction is shifting from mean to actual. Initially it was understood that six sigma qualities could be achieved with the combination of marginalizing the mean and reducing the variability from the mean value [5]. But soon it became apparent that in most of the cases reducing the mean was easier than reducing the variability and the focus would shift to reducing the mean. However, later when the demands of the customers were analyzed it was evident that the

focus needs to shift to reducing the variance as it impacted the customers more than the reduced mean [5].

The literature argues that in the initial phases of the six sigma project it needs the support and attention of the top management and requires an enormous shifting in the resources to make the required infrastructure available to the project which it needs for its support in the initial phases [5]. But no program or system can remain the center of attention for more than a few years then it becomes the working style that is later called the working style or company practices. Every organization has a different way of doing it. At the company in question it is referred to as NCE Continuous excellence.

Some factors need to be considered in order to keep obtaining the results which includes the constant monitoring and resetting of the quality goals and objectives, thoughtful project selection, directions to the project team involved, getting used to cutting-edge tools, adaptation and editing of six sigma to the changing and growing business environment and steered training [5]. Therefore, companies that have initiated Six Sigma programs will need to devise a plan to sustain the system once it reaches maturity [5].

Literature says that in order to get success in the implementation and improve credibility of six sigma there was a need for immediate, reliable and quantifiable results which shifted the focus towards scrap and rework reduction mainly because they were thought as good short term goals [5].

The company in which we are implementing six-sigma DMAIC has been working on establishing the same credibility so the rework reduction and process improvement project we will be working on is given great importance.

The major factor still remains the involvement and support of top management. The previous research in the field of six sigma implementation including the previous research of Antony and Banuelas (2002), Coronado and Antony (2002), Lakhavani (2003), Lynch et al. (2003), Mcadam and Evans (2004), Gijon and Rao (2005), Szeto and Tsang (2005), Ladani et al. (2006), Savolainen and Haikonen (2007), and Davison and Al-Shaghana (2007). Recently, Zu et al. (2008) studied the evolving theory behind the success and implementation of six sigma. While defining Six Sigma programs and uncovering the underlying theory, Schroeder et al. (2008)

identified that the principle main impetus is the administration's association in performing numerous Six Sigma capacities, for example, selecting change experts, distinguishing undertaking determination, and encouraging Six Sigma usage [7]. Emphasize management's involvement in on-going projects for sustainability of Six Sigma programs and which is listed as the key cause of success of the program.

One other factor that improves the success ratio is the consideration of multiple Critical to Quality factors during the course of the project. The literature says that if we invest too much time and attention in improving only a limited CTQ's we might be losing the war by winning the battle. The implementation methodology as per the literature and explained examples is to consider additional CTQ's along with targets set. For example Gerald J. Hahn says that if we are working on rework reduction or scrap reduction it would be better for implementation and success of the project that we consider the reliability of the process as well.

Some other factors that are reported to have influenced the implementation and success are

- Engaging the supplier in the six sigma efforts, especially important for the project in question, FMCG industries which rallies a lot on suppliers we need to communicate our needs clearly, how we aim to measure conformance, what material we require from the vendor (including information on process changes), and who will be blamable for what in indicative of that quality and reliability goals are being met.
- Eliminating difference between six sigma project and other critical projects is also one of the factors that need to be considered for implementing six sigma in industrial environment Six Sigma becomes ingrained in the organization, this dichotomy tends to withdraw. The concept is that employees trained in six sigma at any level are expected to utilize the Six Sigma approach and methodology in their day-to-day assignments.
- It should be ensured during training and in qualifying BB and GB projects for certification and approval that the team has learned not to insist dogmatically on the use of a specific tool, but to use or adapt the available tools to best meet the problem at hand. In addition, training programs are needed to be more tailored to specific audiences and project needs.
- Execute high-level process mapping and prioritize improvement that is carried out by performing an abnormal state procedure mapping of data stream with the point of

distinguishing and organizing change opportunities. This methodical methodology ought to be equipped for comprehension the current stream of data and its related quality creation with it. The primary point ought to be to lessen variety (inefficient) exercises all through the whole process being referred to incorporating obsolete data in the frameworks database, repetitive methodology, copy and befuddling paper work, long setup times for the procedure, botches in place passage, botches in system exchange and SAP [7].

2.10 Tools and methodologies used by six sigma during DMAIC Project

The major tool and software's used during the course of the project will be explained and applied as DMAIC steps progress they will be briefly stated in this section for quick reference.

- Pareto Charts & Control Charts
- SIPOC (Suppliers, Inputs, Process, Outputs, Customers)
- VOC-CTQ (critical to quality) & Stakeholder Analysis
- Communication Plan (5W1H) & Initial & Final Skill Matrix
- Process Capability & Cause & Effect Diagram: Fishbone
- Implementation Plan (5W2H) & SWOT Analysis

The major software used is Mini Tab which is a statically data analysis tool tailored to handle and facilitate six sigma, lean and other quality improvements methodologies. Its major usage is in graphical analysis and hypothesis testing.

3 RESEARCH METHODOLGY

3.1 Continuous excellence & six sigma

The company under consideration had launched an aggressive Continuous Improvement drive based on the philosophy and methodology of 6Sigma but basic understanding of the concept was missing so an organized approach was used to merge the two concepts and tailor it for the organization then eventually DMAIC the methodology was used within Continuous excellence for problem solving and improvement projects. The basic concept of 3.4DPMO was not specifically used in our research rather the focus was on consolidating and organizing the rework and improvement projects using the DMAIC tools and techniques.

The aim was to setup a process which can be used to Solve problems that don't have a known root cause and cannot be solved using a day to day continuous improvement approach or linked to a process that are recurring/ repetitive and aligned with the business needs this is where Six sigma and CI were merged and tailored but we will be focusing on one specific project a rework reduction and efficiency improvement project.

3.2 Six sigma Project plan

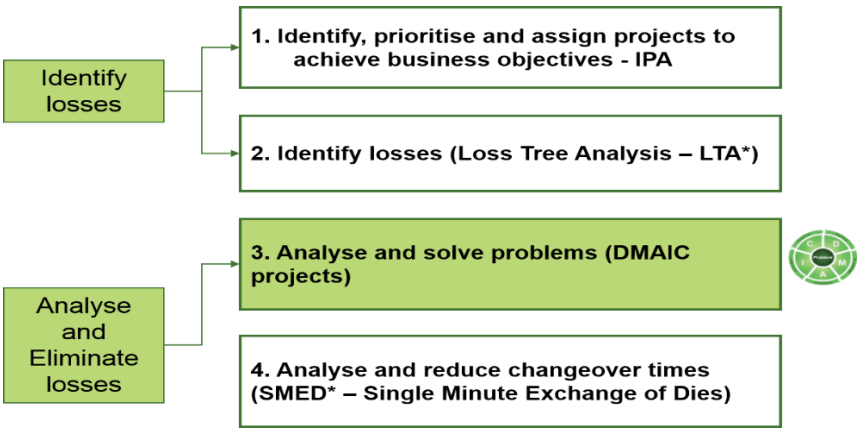


Figure 10 Identifying Projects for Improvements

During the late 90,s TQM was the leading approach in the Quality and Reliability market and on a vague observation Six sigma also looks somewhat familiar to the TQM but it is different as evident from the diagram above which explains the basics of a Six sigma Project flow at the company under question those other leading enterprises which are using six sigma are of the view that it has shifted the organizational culture and enhanced productivity [8]. These

techniques TQM and Six sigma stress the importance of cross-functional teams, customer importance, robust improvement, and quality function deployment (QFD).

Apart from the difference where six sigma stresses on structured approach of DMAIC process ownership and clear process definitions are also similar between the two quality improvement tools. The major similarity between the previous market leader TQM and Six Sigma are customer focus and involvement of Top management [9].

The basic difference between the two approaches is the training requirements of both. When TQM focuses on generalized training of all employees Six Sigma has a well-defined structure and different levels and grades for training.

3.3 Elements for successful implementation of six sigma

The implementation of six sigma and its success depends on the commitment of the top management that is evident form the literature on implementation of six sigma [10]. People from all levels including the managers and the executives should not only be involved in the projects of DMAIC one of the factor we introduced in the DMAIC continuous improvement program at the company was to add the DMAIC goals in the evaluation and job description of all involved in the project this way it was not just some fancy project without ownership and had greater chances of success. Without the top management involvement from the very beginning the project selection phase and its continued involvement during the course of the project the success of the project would not have been possible [13].

Six sigma is different in such a way that it takes into account the current culture of the organization and tries to blend in while changing the system very gradually and systematically which increases its chance of approval from all stakeholders and ensures successful implementation [4]. The basic cultural barrier that was faced and improved through changing the organizational culture was the resistance to anything unknown and not seeing mistakes as chances of improvement [11]. Despite being a company with very open shearing culture and openness to accepting mistakes it needed a foolproof shearing and change system with proper documentation was introduced with the help of six sigma which ensured those things happened in reality rather than being just done on the paper [14].

DMAIC implementing companies use a systematic approach of project selection with the top management involved so that only projects with strategic and financial importance are chosen the LTA (loss tree analysis) method was used in our project that is based on the same strategy. [15]. Keeping this perspective in mind the decision rights to initiate and finalize the project are shifted to the senior management who short down projects from the loss tree analysis of the factory keeping the critical to quality and other strategic factors in mind. Six Sigma not only utilizes its advantage of top down approach but with the active involvement of workers it takes the advantage of other quality improvement approaches which are based on bottom up approach the involvement of executive level ensures proper strategic selection of projects and not on convenience.

Black Belts specialists in six sigma are deployed in all projects even if they are manufacturing based or services based even on hybrid projects. [7]. These Black belts follow a comprehensive training program with practical implementation and on hands projects before they are handed over leadership and training of projects. The first level is Green Belt level followed by Black Bet level and then after certain further training Master Black Belts are certified which have the responsibility of training and assisting all six sigma projects [12]. For every project under the six-sigma umbrella a focused improvement team is formed after the project has been selected and validated by top management that comprises of employees who had substantial knowledge of the process, and are minimum Green belt certified. Focused Improvement Work Groups (FIWG) is a multifunctional team who work in specific focused improvement projects to analyze and eliminate losses. The team is led by a full-time Black Belt specialist, who is reporting to the team's sponsor, Champion / master black belt who must be a member of senior management, usually six sigma Certified. When we are using an organized approach in a systematic way like six sigma DMAIC (define, measure, analyze, improve, and control) method chances of successful implementation are larger. Some of key features and benefits of this approach and its role in successful implementation are listed below

- DMAIC brings rigor to small projects, with its reliance on data and emphasis on systematic analysis. It also has the scalability to be used when tackling more complex projects. DMAIC is meant to be used in any case where the root cause of a problem is not clear, as is the case in our project.

- Teamwork is very important to the process: you will not be performing all the steps alone, and in fact you will need to engage the appropriate experts from different areas doing that DMAIC becomes a much successful approach.
- Not only will you will need your team members to participate in the problem-solving process, but also you will need to engage other support staff beyond your project team to implement the improvements.
- DMAIC ensures that the process is systematic and implementation long lasting for example, receive training on any new processes, so that improvements are sustained over time

3.4 DMAIC (Define, Measure, Analyze, Improve and Control)

According to the objectives and scope of the Project as discussed in the previous chapters it is a Focused process improvement and cost saving project using the tailored DMAIC approach developed and discussed under six sigma will work best in our scenario. Key steps involved in DMAIC Methodology are given in Figure bellow

3.4.1 Define Phase

Objective: Define the project's purpose and scope and put it in a business context. There are a different tools which is used in define phase like SIPOC, Voice of Customer (CTQ Tree (Critical to Quality), Stakeholder Analysis, Quality Function deployment and developing a Communication Plan. We will also be defining an initial skill matrix to gauge where the team stands before the project was launched so that at the end of the project the training embarked can be gauged.

Results: A clear statement of the intended improvement and how it is to be measured and a clear understanding of process improvement and how it is measure by the implementation of tools discussed earlier. High level of process is attained with lot of successful factors list show that what customer requirement actually is.

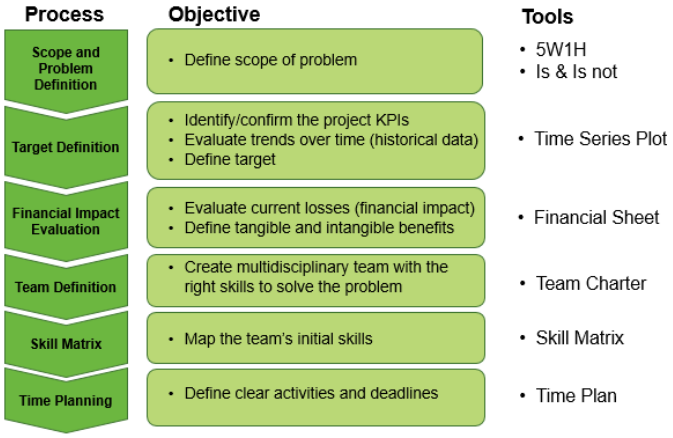


Figure 11 Define Phase

3.4.2 Measure Phase

Objective: Focus the improvement effort by gathering information on the current situation and data gather from current process in order to determine the root cause of defects. There are different methods to analysis data by sampling, Gauge R&R and capability process.

Results:

1 to 2 focused problem statements is the main output in this phase of DMAIC which is used to pinpoint the problem location due to different analysis of data and find out if the process is capable of doing the certain task.

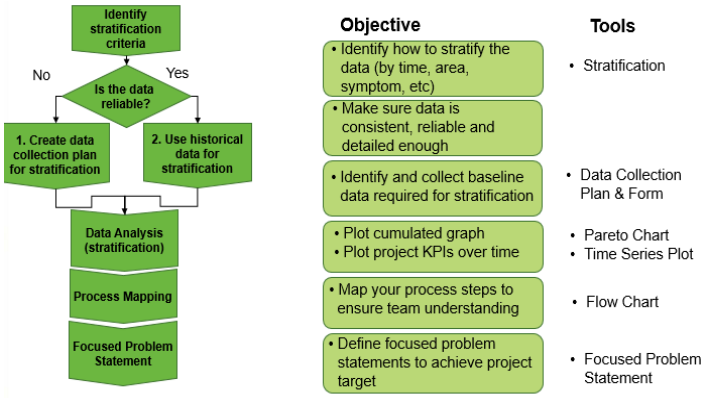


Figure 12 Basic steps involved in the measure phase are explained

3.4.3 Analyze Phase

Objective: Identify root causes and verify them, using facts and data statically. There are different methods used for this phase Gemba & Brainstorming, Cause & Effect Diagrams, Prioritization Tool and Process analysis.

Results: A theory that has been tested and verified and that tells what is the best setting for the improvement of process and also identify key areas with the help of verified data. The diagram bellow explains the basic steps involved in this analyze phase.

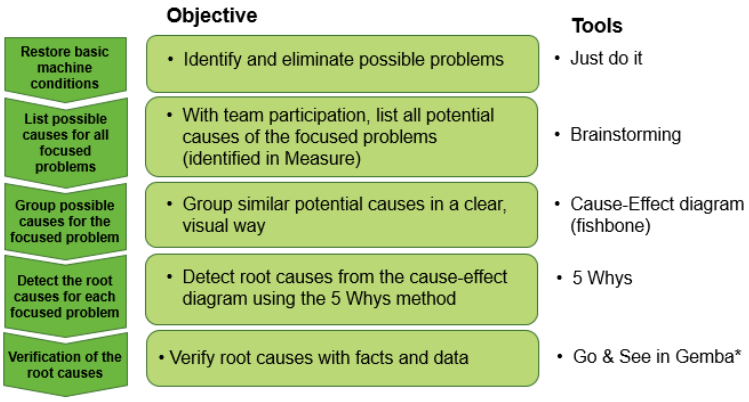


Figure 13 Analyze Phase Roadmap

3.4.4 Improve Phase

Objective: Develop, test and implement solutions that address the identified root causes and also use data to evaluate the implemented solutions using different tools like FMEA and Pilot Plan.

Results: Implemented solutions that eliminate or reduce the impact of identified root causes and do a comparison of the planned to the actual implementation for and should reduce the impact and also proposed solution for the problems. The picture below shows the contents of the improve phase of DMAIC

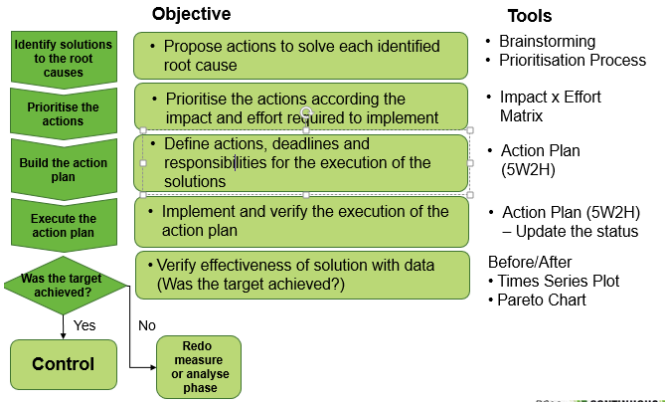


Figure 14 Improve Phase steps

3.4.5 Control Phase

Objective: Maintain the gains through standardization of work methods and processes Anticipate future improvements and capture and document the improvements and learning's of the current

project for future reference. Results: Before and after data analysis with documentation and communication of results is the main expected output along with ensuring leanings. Recommendations on how the impact of the improvement and the Standardization of improvements are retained. Training of new methods learned during the project and devising a control plan for ongoing monitoring of results.

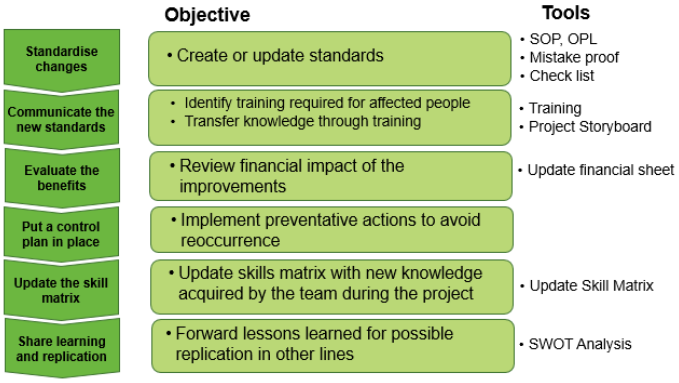


Figure 15 Control Phase explained

4 DATA AND ANALYSIS

4.1 Introduction to Data & Analysis

The actual six sigma project that was carried out at the FMCG Company will be discussed and presented in this section it will highlight some key features of the process and show the results and data analysis from Minitab.

The format of the chapter will follow the DMAIC pattern covering all phases Define, Measure, Analyze and Control and any associated steps from the project starting to its completion and handing over.

The objective of this section will be to describe and explain the quality improvements brought to reduce rework and semi-finished product losses at the plant.

4.2 Define Phase

We start off with the define phase the main aim of this phase is to identify the customers and what are the requirements of those customers. We will also establish the current status of the problem area and set the targets of the improvements we will be doing with the consultation of the top management. Some of the steps and requirements we will be doing in this phase are listed bellow

- Identify the customers and their needs and requirements
- Define the output measures and performance standards or targets
- Confirm the gap(s) between process outputs and customer requirements
- Establish project scope and objectives & Define and quantify the problem in detail
- Identify business benefits
- Identify key stakeholders and engage project team
- To define the scope of the problem & Identify process to be improved
- To determine the financial impact of the problem
- To define the Key Performance Indicators that represents the problem

4.2.1 Systematic Project selection (Loss Tree Analysis & Identify, Prioritize & Assign methods)

The project on six sigma on powder Plant at the FMCG was not selected randomly on the bases of convenience and availability of resources systematic approaches to identify prioritize and

assign was used. The technique creates what number of tasks and critical thinking exercises are expected to attain to a given target in view of the quantitative commitment and due date of every venture/movement.

Loss tree analysis is the data which is gathered an yearly basis and which tells details about key losses to the company, major stoppages and other quality and business problems than once the data is gathered it is sheared with the senior management and cross matched with the key performance indicators and other resources to finalize the improvements and suggest changes.

The LTA methodology captures the difference between the ideal (zero loss) and actual state in three main categories: Machine, Material and Man to be tackled based on financial impact and Operation management plan. We used Time series plots and Pareto charts in order to classify losses. The process uses a stoppage analysis module SAM to collect data about errors, non-producing hours and stoppages or losses. This system ensures stoppages are converted into visible financial losses and hours and Material and man losses must be visible in physical units and man hours respectively, and in money.

Not all problems are directed for six sigma or DMAIC only the ones with huge business value or larger scale or scope and recurring ones are referred for DMAIC. Financial impact and savings are the major factors that act in the selection of the project for DMAIC.

The inputs to this systematic process of selecting a project are the data from loss tree analysis, recurring problems from company's operational reviews (monthly, quarterly and yearly) and Key priorities defined in the operation management plan of the company.

Keeping all these factors in mind the success factor of projects and their practical impact on increasing efficiency is increased. The early involvement of top management before event he starts of the project and the approval ensures continued support from the management that is vital for any six-sigma project.

The process ensures the correct assignment of resource (availability and competency) to each prioritized project. It also ensures all projects are in accordance with the safety and health regulations of the regulatory bodies and resources and constraints are defined. The early assignment of Project leaders, coaches and sponsors ensures smooth transition once the project

starts. The loss tree analysis of the last six months identified the Powder milk as the main area with maximum number of losses and highest quality costs. Due to the confidentiality agreement the exact data and the name of the company cannot be shared. A number of projects were initiated to solve the problem and one of them was to reduce rework and semi filled product losses at the Powder plant using six sigma DMAIC that will be discussed at length in this chapter.

4.2.2Project Charter

A Project Charter is an agreement between management and the team about what is expected. The charter clarifies what is expected of the team and keeps the team focused and team aligned with organizational priorities. It also transfers the project from the leadership team and sponsors to the project team and quantifies and documents what is expected of the team to both higher management and the project team ensuring smooth implementation and avoid ambiguities.

Project Charter Elements are Problem statement (purpose), Business case (importance), Scope (and constraints), Resources &Team members, Goal statement (measures) and Stakeholders & Milestones.

Project Title	**To reduce the Powder (Rework + Cattle Feed + Overfilling) losses at WOLF P & Y (Powder Filling & Packing machines) by 20% till end of May 2014 Using DMAIC (SIX SIGMA)**
Business Case	**Non-Quality Cost (NQC)** is an important factory KPI (key performance Indicator) which reflects the cost of failure related to material loss. Which was the highest loss category in the last loss tree analysis of the company. Increase in NQC will increase the operational losses of our factory. This is not bearable in order to achieve **3C's (C**ompliance**, C**ompetitive-advantage**, C**ustomer-delight**)** of the company's continuous Excellence (CE) program. This project will definitely help us to reduce NQC by keeping SFP losses (Rework + Overfilling + Cattle Feed) at lower side. Also increasing the internal and external customer satisfaction level.

Problem Statement	Currently the filling and packing process at **WOLF P & Y** lines are out of control resulting in high **SFP** (Rework + Overfilling + Cattle Feed) losses of **41.6** million PKR from (Feb-May) 2014. Current methods of controlling the process and reporting that control are not successful.
Goal	To reduce semi filled product losses by 20% and an estimated cost saving of about 9million PKR
Deliverables	Review all SOP, s OPL if needed Well trained and capably enhanced operators
	Implement the results of study on other production lines
Project Scope	As the primary focus is on SKU's i.e. 2000g, 1000g and 400g so wolf P&F lines are in scope (filling and packaging lines) Toll bins, Processing are out of scope including all other lines (filling and packaging) will remain out of scope for this project.

4.2.3 SIPOC Process Map

The process flow chart in general illustrates the major activities that are a part of the process and flow connections it helps to understand interrelationships of a work process or a project.it can be a helpful tool to identify problem areas and as a planning tool to eradicate that problem.

Whereas process mapping is essential for documenting the current process and it in our case we have identified all cross-functional processes for the area that is in the scope of the project. Process owners are identified this map ensures a thorough understanding of the "as is" process at powder plant of the company and provides baseline input data for the improvement team.

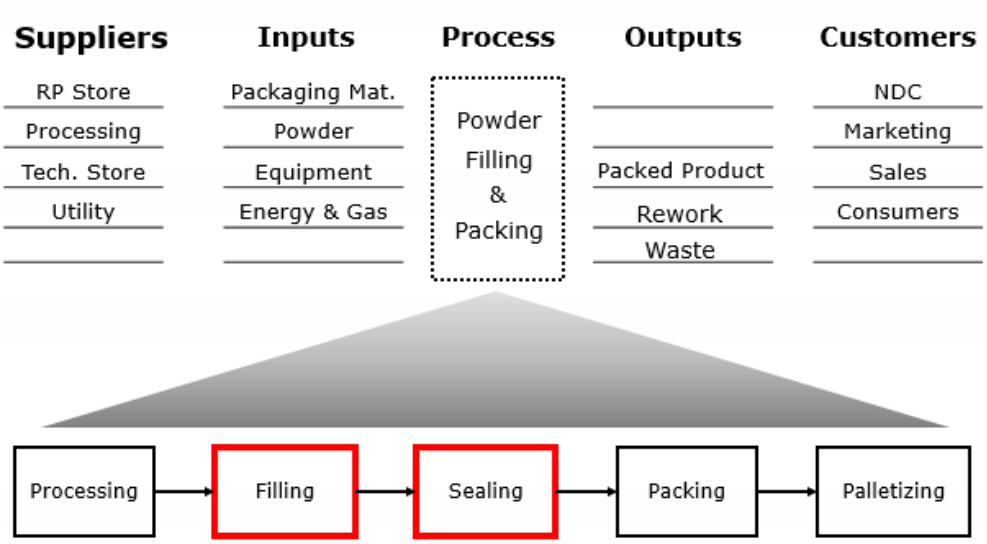


Figure 16 SIPOC process mapping

The whole point of using SIPOC and process mapping is to encourage process thinking as we begin our rework and cost saving project and to identify common elements for measuring and monitoring processes. The variables that we note and study in this part of the project are people, equipment, environment, materials and methods.

It is a high level process mapping technique and is used in the initial phases of the project to have the following advantages

- Define project boundaries (starting and ending points)
- Describe where to collect data
- SIPOC is particularly useful in determining (limiting) the scope of your project through identification of start and end points

4.2.4 CTQ Tree (Critical To Quality)

To ensure that project leaders and team members understand that the customer defines the performance requirements for the process they are improving, so they must obtain Voice of the Customer (VOC) data to determine performance targets. The purpose of this analysis is to help project teams gather, organize, and prioritize Voice of Customer data and to highlight critical-to-quality characteristics (CTQs) to guide data collection efforts in the next (MEASURE) phase.

CTQ is truly critical to the customer's perception of quality and it can be measured. One other characteristic of this is that specification can be set to tell whether the CTQ has been achieved or

not. Basically CTQ are used to convert the generic demands of the internal customers in our case into Specific demands that can be met and measured. One other element of converting this is to set limits and targets once we have the range of data. Once we have analysed the CTQ we then refine our project charter (if needed) to ensure that you still have a valid project that will bring benefit to the organization.

VOC data helps an organization:

- Decide what products and services to offer
- Identify critical features for those products and services
- Decide where to focus improvement efforts
- Get a baseline measure of customer satisfaction against which to measure improvement
- Identify key drivers of customer satisfaction

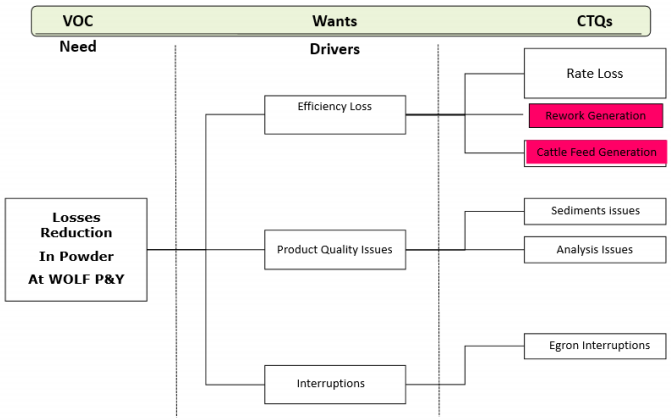


Figure 17 The CTQ mapping of the DMAIC project

4.2.5 Stakeholder Analysis (VOC)

The next step once we have done the CTQ analysis is to do the in-depth analysis of the stakeholders for our project. This step clarifies many ambiguities in understanding the customer from its demands and expectations. Doing this in the initial phases of the project we are increasing chances of batter implementation of six sigma DMAIC. The exact format of the form developed and filled for the process is given bellow that as you can see clarifies measurable needs of all stakeholders.

Our DMAIC team did this stakeholder analysis to understand who has a vested interest in the powder plant rework, what their expectations and views are in regard to this DMAIC

improvement, and how they might be influential during the whole course of the project as they are the people who can either help or hinder the project. Knowing what they demand and expect give the project a head start with the ensured support from all stakeholder.

Who	Function	Department	Role in GB	Key Concerns
M.Shakeel	PM-Powder	Powder Production	Process Owner / Sponsor/Customer	Interested in NQC reduction and improved product quality / more trained people in DMAIC methodology
Raheel Afzal	FM	General Management.	Customer	Interested in NQC reduction and improved product quality / more trained people in DMAIC methodology
Rizwan Ahmed Dard	MBB / Market FI Pillar Leader	IP	Coach	Overall project completion / more trained people in DMAIC methodology
Ashraf Sindhu	FC	F&C	Customer	Interested to check any impact on NQC & losses reduction
Shift Supervisors	Supervisor	Powder Production	Customer	More smooth shift with less losses
Shift Operators/Mechanics	Operator/Mechanic	Powder Production	Customer	More smooth shift with less losses

Figure 18 Stakeholder Analysis actual data

4.2.5 Communication Plan (5W1H)

The 5W1H method is a very well thought-out, creative tool that asks much focused set of questions regarding a problem occurred in the past or an opportunity statement and is used to systemize the communication. It is used in accordance with IS-ISNOT tool in our project

This tool forced our team to consider and question every aspect of the problem we had at our hand, the rework reduction project.

Some of the purposes for implementing this tools are to

• Scrutinize and enquire the wolf lines in question for the purpose of gaining improvement ideas.

• Find possible problem and prospects of a breakthrough

• Support a team in engendering fresh ideas.

• Determine ignored issues or reasons.

	IS	IS NOT
What / which	What specific product / service / machine / part is giving us a problem?	What similar product / service / machine / part could have been expected to give problems, but isn't?
Where	Geographic location? Specific position on / in the problem?	Where else would problem have been expected, but isn't
When	Dates and times of start and subsequent recurrences? When in process cycle?	When not found when expected?
Who	Which shift or particular technician? Which supplier?	Who not? Which not
How much How many		

Figure 19 communication tool explained

What	Why	How	Where	Who	When	Status
Kick-off Communication	To align the concerns	E-mail to all concerned	-	Team Leader	03.01.2014	Completed
Kick-off Meeting	To align the concerns	Meeting at the Factory	Factory Training hall	Team Leader, Team Members	03.01.2014	Completed
Regular weekly Meetings	To eliminate the problem by following stepwise DMAIC approach	Meeting at the Factory	Factory TPM room	Team Leader, Team Members, Resources, Sponsor	Monday of every week from 3-4 pm	10 meetings have been done
First Update to Stakeholders	To align the concerns	Meeting at the Factory	Factory Admin board room	Team Leader, Team Members	End of Define	Completed
Second Update to Stakeholders	To align the concerns	Meeting at the Factory	Factory Admin board room	Team Leader, Team Members	End of Measure	Completed
Third Update to Stakeholders	To align the concerns	Meeting at the Factory	Factory Admin board room	Team Leader, Team Members	End of Analyze	-

Figure 20 5W1H plan for the different phases of DMAIC

4.2.6 Skill Matrix of Team (Initial skill Matrix)

As training is one of the major concerns of all companies imparting six sigma programs around the globe so was the concern of the company in question and rather than leaving it on the judgment of the trainer and the efforts of the project team it was systematically included in the objectives.

There are many methods to display the skill matrix tool graphically but the basic concept of the tool is to include a scale and gauge some of the skill sets that the company needs in its employees. The Skill Matrix is an assessment tool that shows, on a scale 0 to 4, the competence level (initial, current and target) for a skills set. One for every team member.

We use this tool because it maps the knowledge areas and competence level required for a specific role and it identifies the gaps to develop training plans by comparing the current level with the target level.

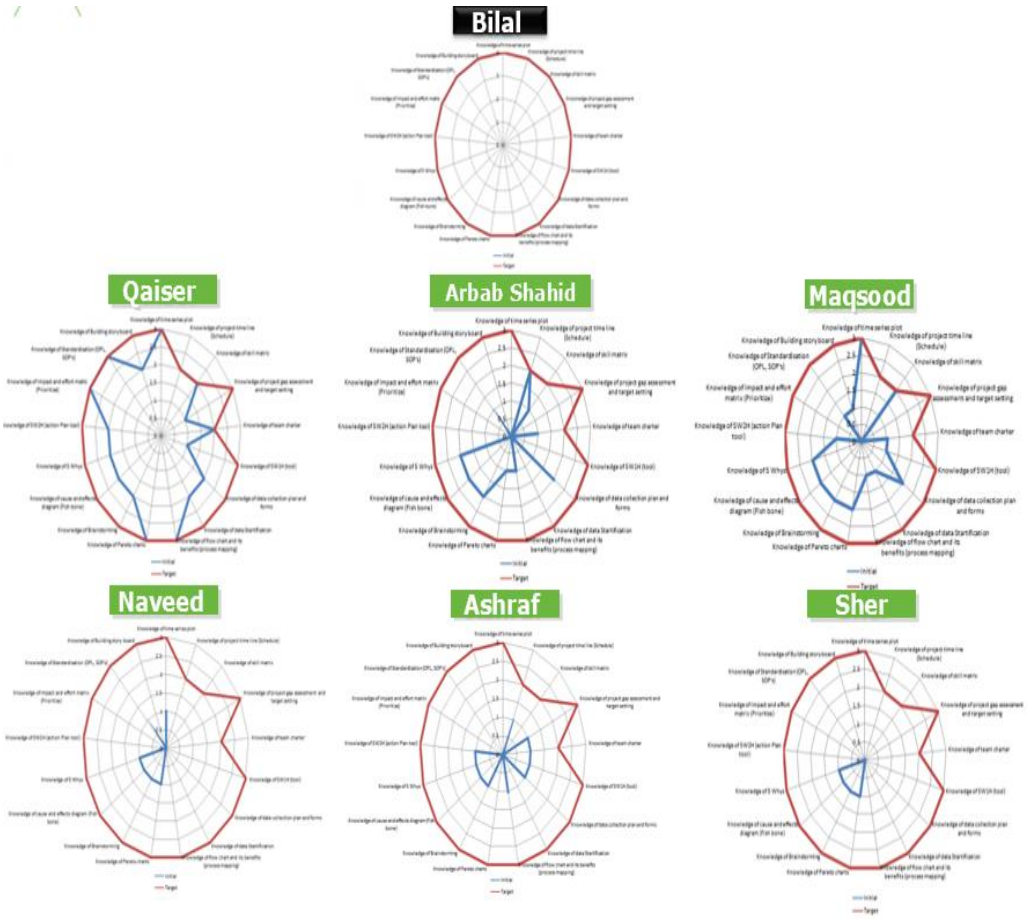


Figure 21 Initial skill matrix for the complete team

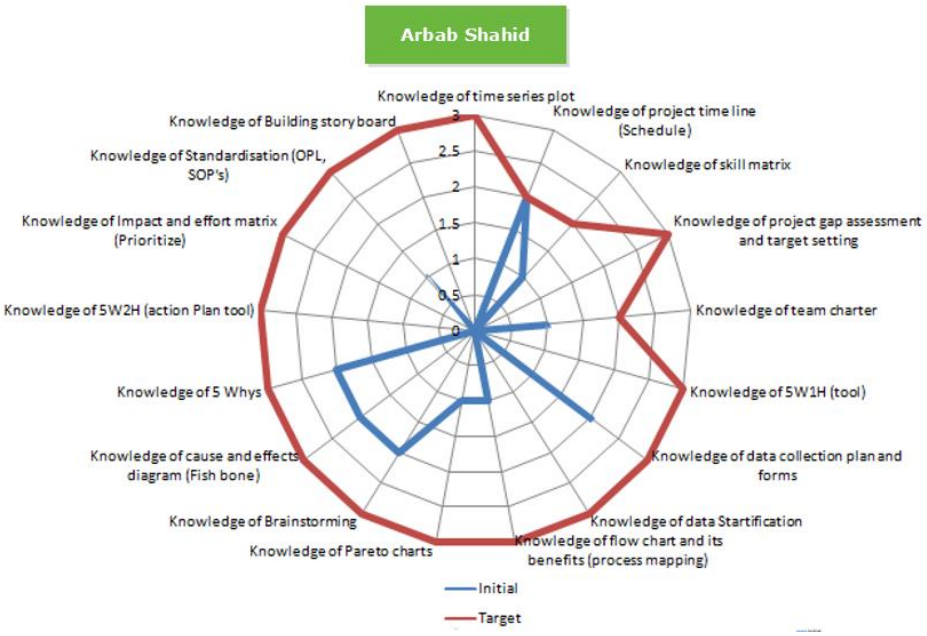


Figure 22 Details and levels of Skill matrix in detail for review

4.3 Measure Phase

The main objectives of this phase are to comprehend major measures and data types to be used during the course of the project. It is ensured in this phase that quality of measurement systems and data is up to the mark and can be used to base our project on it. Some of the other objectives of this phase were to decide standard measures for the process, Delimit process capability, arrange for thorough understanding of the current process and identify the steps on which the project will focus on. Reviewing the existing process in line with Lean thinking and recognizing opportunities for improvement and initial quick hits are also acquired from this phase.

A realistic consideration of MEASURE phase makes us understand that our information is based on data. Which means you have to know what data to collect, what to do with them, and how to interpret patterns we obtain from the data.

4.3.1 Process Mapping (detailed & elaborative)

The procedure used to document and analyze process in detail is process mapping that identifies process measures of interest for our project. This converts the focus of the problem under consideration on the process on which it's taking place. The process mapping visually represents the process with an actionable level of detail of the process and is then utilized by all the team to gain consensus on current situation and even local variations of the process and built a y=F (x)

shape of the process and problem in question. It is critical to identify bottlenecks, rework loops, redundancies, and location of defects, value-added and non-value-added steps, and measurement points.

In the measure phase out of many types of process mapping the focus will be on detail process mapping type and process boundaries for this are determined by the project scope that we have defined earlier.

As we are trying to determine the current situation as it is our map had to be very accurate on what was actually happening in the plant not how it was actually supposed to be so this step was done by conducting a team meeting on the site of the packaging and packing line with the production team and full green belt team present.

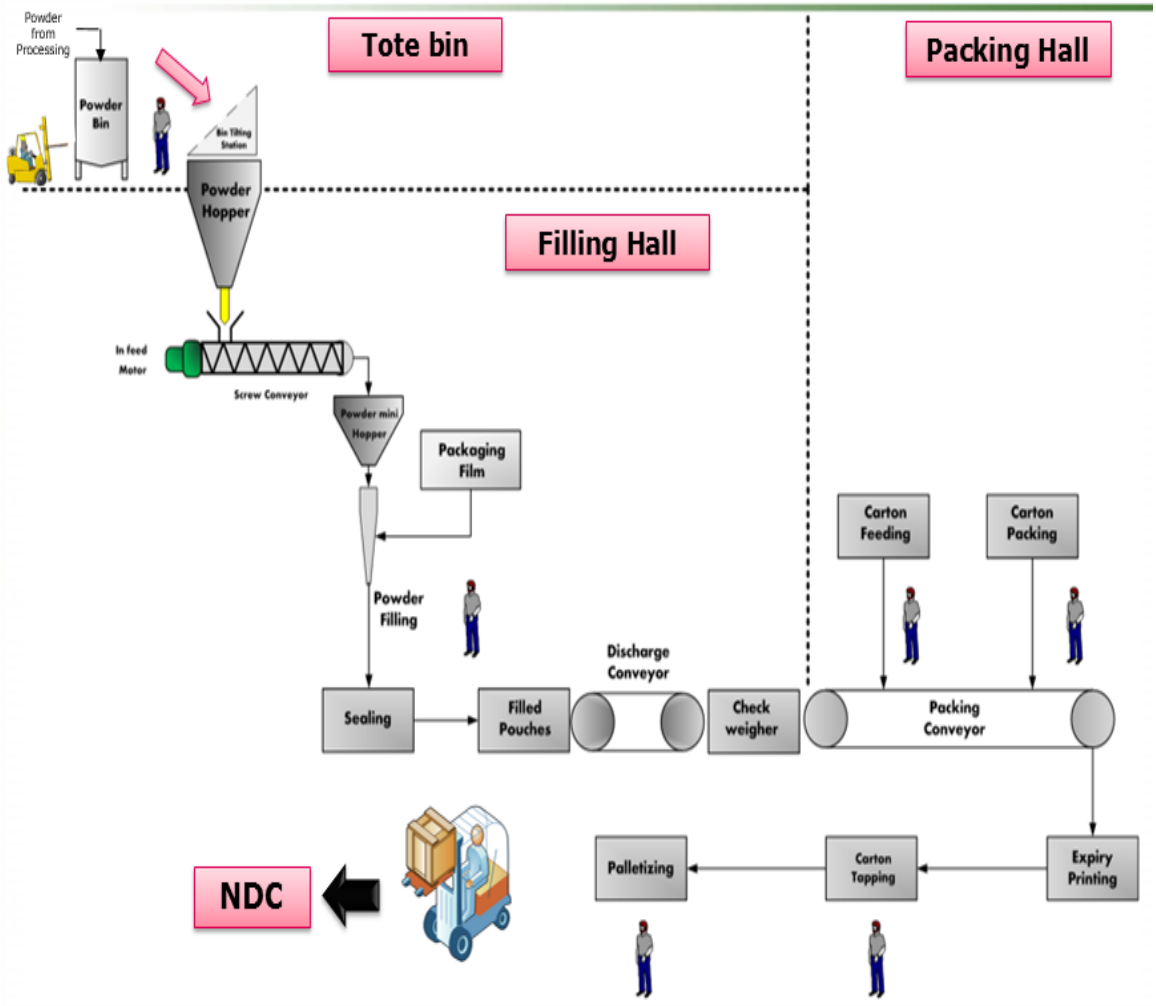


Figure 23 Detailed Process Map of the Powder Plant where DMAIC is being applied

4.3.2Data Collection Plan

This section is given a lot of importance in the measure phase as data help us to quantify the magnitude of the problem under consideration and we are very careful in this section to make sure data we collect is relevant and also provides right level of detail to solve the problem.

The characteristics of the data which we are more particular are its definition, sampling, and

Measurement system. Our aim in this section will be to develop some technique to stratify the data according to our needs of the project and identify which data to collect, from where to collect it and what will be its type. We will also be creating a form which is simple and can be used by all members or project teams to collect data for the project the tools we will be using are 5w's and stoppage analysis module.

Data collection if done appropriately helps us to separate what we think is happening from what is actually happening and confirm any theories or hypothesis we had about the problem. It is used to measure the impact of the changes and log the history of the problem over time. One of the major advantages of this approach of verifying the data and systemization of the collection process is that it avoids giving solutions that don't solve the root cause or real problem. Along with the previously existing formats and methodologies a new approach was developed which is explained in the figure bellow.

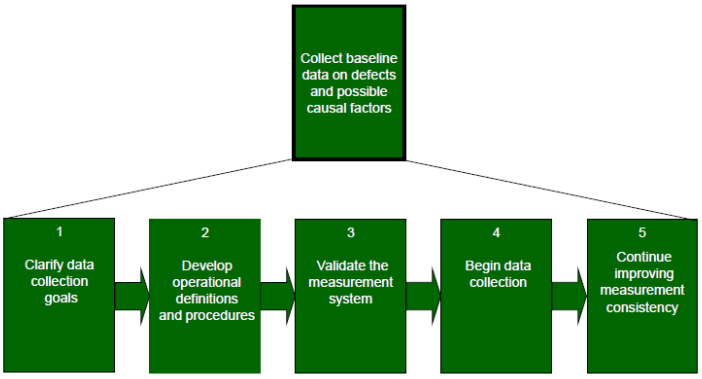


Figure 24 Data collection Scheme

Now the first step is to design and deploy a standard data collection form with the stratification criteria given and recording what data you are going to collect reminds you what you want to attain from the project in specific. Noting the type of data helps you decide how you will proceed

to analyze the data once you have collected it. We use a standard form or preset pattern so we will not have to go into the specifics of defining all the presets again every time we collect data for the project. The data collection form is put together after all data stratification groupings have been established and catered for. This form will have two parts Data (defined and explained above) and Operational Definitions and Procedures (An operational definition defines exactly how you will be collecting and recording the data.) Operational definitions were introduced with the view that everyone is on the same page because study of previous cases of unsuccessful implementation of DMAIC in the company shows that people had different views or definitions on data collection of same object which resulted in conflicting data. Operational definition is a precise depiction that states how to get a value for the characteristic or feature you are exasperating to measure. It identifies what something is and how to record it while dong so it removes obscurity so that all people in the team are on the same page as far as the characteristic or feature in question are concerned.it also lays down a path to actually measure that feature or characteristic.

Data		Operational definitions and procedures			
What	Data type	How measured	Related conditions to record	Sampling notes	How / Where recorded
Loss in PKR	Continuous	**SAP BW report:** • MUV Report •order • Target view	**What:** Loss in PKR **Which:** Nido & E-day (2000, 1100, 1000, 400)g **Where:** Powder F&P (WOLF P&Y) **When:** Next day of production **Who:** Data operator	Data should be collected in PKR	SAP

Figure 25 Data Collection Form

This clearly identifies the stratification criteria that is by Material and the two separate columns are also seen. Once this was done the next phase is using this plan to actually collect data and start our analysis. The following data helped measured the losses due to semi-filled product and rework on the powder milk production pant of the company.

Once the results were obtained they were analyzed statically using mainly Pareto charts to reach the root cause or focused problem identification.

4.3.3 Pareto chart (statically verifying root causes of Rework and losses)

A Pareto chart is a graphical means that assists you in breaking a big problem down into its portions and identify which portions are the most important for the problem at hand. It is used in the data analysis part of the measure phase of DMAIC once the data collection and data verification has been done. It is extremely useful in understanding the patterns of occurrence of problems and find out the relative impact of the parts of the problem and it clarifies the areas where to focus our efforts on if we want to obtain the targets of our DMAIC initiative. The Pareto norm is often articulated by the ―80/20 rules, which says that, in many situations, approximately 80% of the problems are caused by only 20% of the contributors. The essence of this rule is that we can solve the problem by attacking its vital few sources.

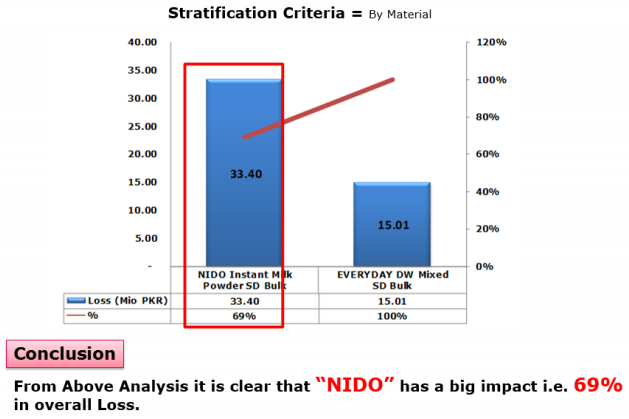


Figure 26 Pareto chart of loses categorized according to product type

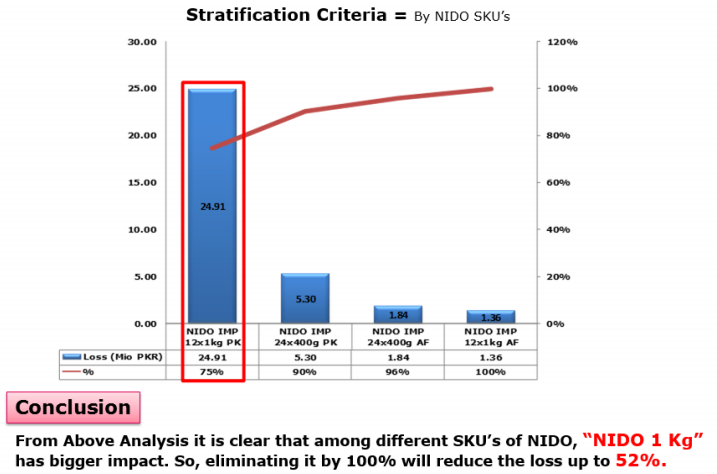


Figure 27 Pareto chart for losses categorized according to product weight

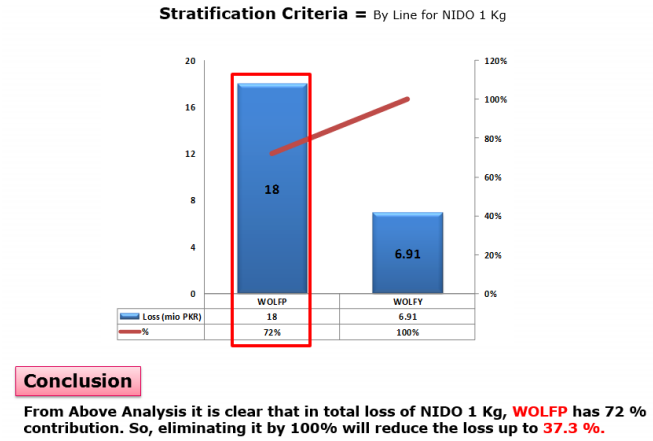


Figure 28 Pareto chart for losses

The three Pareto charts given above were constructed from the data obtained from stoppage analysis module via SAP the stratification criteria's and conclusions obtained are also listed along with the diagrams. The root cause identified from these Pareto charts is that the major losses occur during the production of NIDO and that in the one Kg and 400gms pouches. The assembly lines when compared showed that wolf p line was causing the main losses.

And according to the 80/20 principal of Prato we have got our big fish.

Note: the names of product used are only for reference purposes the Company in question has barred from using its name or product name or any data in the publication.

Now we will be using the data collection standards and forms designed earlier to collect data from specific locations we have identified.

Data		Operational definitions and procedures			
What	Data type	How measured	Related conditions to record	Sampling notes	How / Where recorded
Semi Finished Powder (Bulk)	Continuous	**SAP BW report:** • MUV Report •order • Target view	**What:** Semi Finished Powder **Which:** Nido IMP 1 Kg PK **Where:** Powder F&P (WOLF P) **When:** Next day of production **Who:** Data operator	Data should be collected as target vs Act (Qty) **(%)** of Production quantity.	SAP

Figure 29 Data Collection form

This data shows the focused problem area and will help to get the causes of loses removed from this area. The next step will be to analyze the data that we obtain from the collection and find a solution to the problems highlighted.

4.3.4 Control Charts

A control chart is a graph that plots indiscriminately selected data against time in order to investigate if the process is performing as per the specifications set, and hence is under statistical control. The chart displays whether a problem is caused by an infrequent or special cause (correctable error) or is due to natural causes of variation only.

Given bellow is the control chart that was constructed using the Mini-Tab and plotted against time with a random time interval from the performance data of last six months. The source was the SAP, stoppages analysis and error module. The results show that some points are off limits and needed further investigation. These are the potential chances of improvements and could help identify areas requiring changes. Real data has not been shared or partially changed due to non-confidentiality agreement with the company.

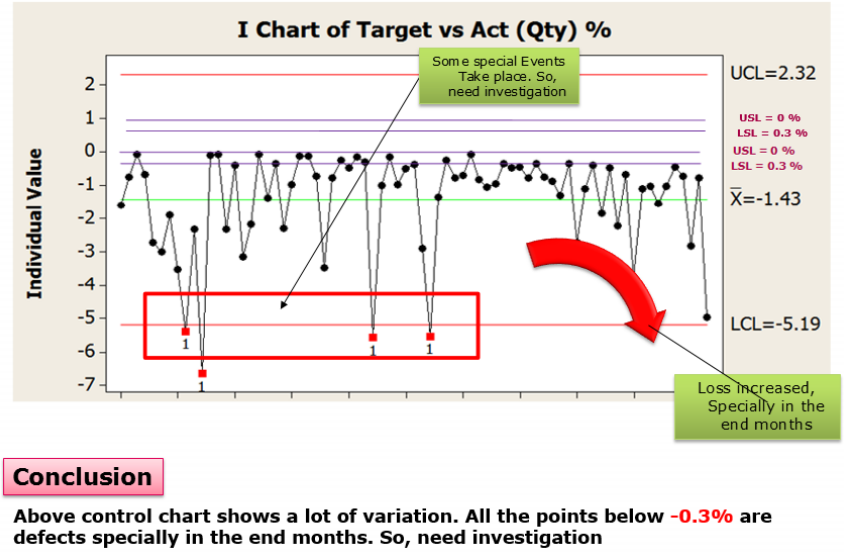


Figure 30 control chart for mean losses in powder plotted against time

4.3.5 Process Capability Analysis

The purpose of this section is to compute the process performance in the metrics of effectiveness and efficiency of the system that can then be improved. Once they have been quantified they can be compared with the industry standards and benchmarked as well. Some of the measures we

documented and used for our study were process yield, Process capability indices (Cpk, Ppk) and using them and other we obtained Process Sigma for the improvements and then set targets for improvement.

The purpose of this exercise is to provide the executive and the management with a single measure which can be used to judge performance of the system or process in question and also be able to compare two systems on which is performing better.

Since the process is continuous production of powder dairy product and the data we are obtaining is continuous we will be using estimated yield method to get the performance measures of the system.

The whole aim of using estimated yield is to focus on products not on the process as it is the process that is causing defects not the product. A continuous variable represents a single opportunity to be wrong so we don't need the defects per opportunity adjustments when calculating the process capability indexes.

In a continuous variable it is more difficult and costly to collect a samples so the sample size is smaller in our case also and we will be using normal distribution for the calculation purposes.

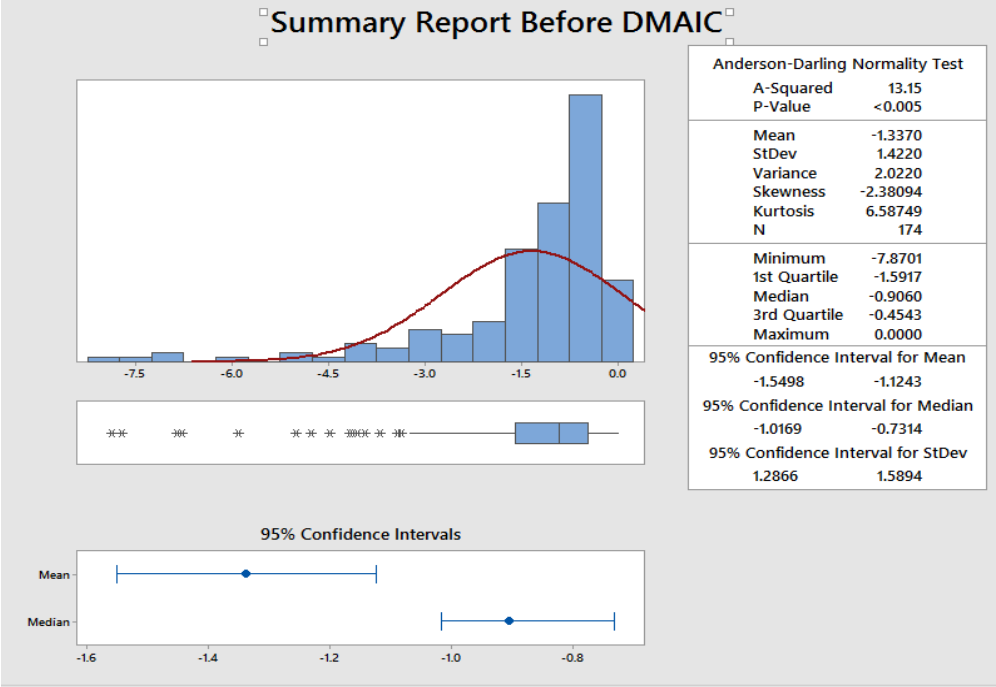


Figure 31 Summary of losses plotted from MINI_TAB before DMAIC was applied

4.3.6 Applying 5W 1H to define a Focused Problem Statement

It is a very simplified approach and a very easy to implement tool for helping describe the priority problem under observation using all the statistics we have in the measure phase. The purpose of this step is to get a precise and consolidated statement using the 5w1h tool. The approach was documented and a form created so that every time same information is collected and we avoid ambiguities in understanding of the problem before we move to analyse phase.

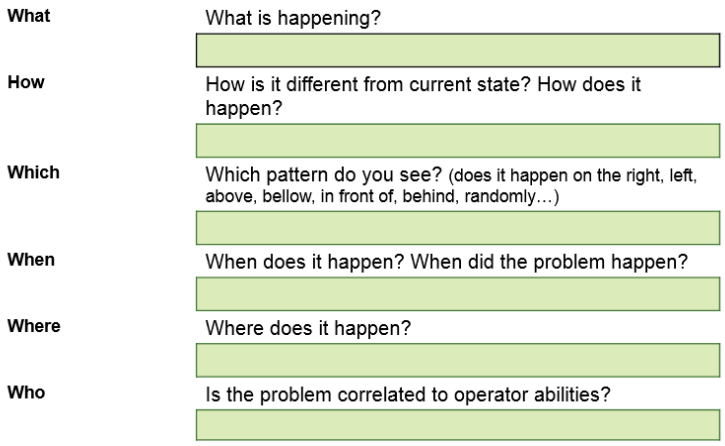


Figure 32 the form developed to find focus statement of the phase

The final statement drafted using this technique is given bellow "From above data Analysis, it is clear that our focused Product will be NIDO Instant Milk Powder 1 Kg on WOLF P. We have to reduce its loss in PKR by 55% to reduce overall loss by 20%."

4.4 Analyze Phase

The main aim of this phase is to analyze the data that points to the main causes of problems in detail. Some of the tools that are deployed in this phase are Pareto Chart, Correlation/Regression, Variance Analysis, Activity Analysis, Hypothesis Testing, Conjoint Analysis, Cycle Time Flowchart, Force Field Analysis, Matrix Data Analysis, Multivariate Chart, Opportunity Analysis, Potential Problem Analysis, Stimulus Analysis, Importance Weighting, and Cause-and-Effect Diagram. As we have accurate material data from the process for our analysis we will not be going into hypothesis testing and rather using real-time data to do changes or study improvements.

- Describe Performance Objectives
- Recognize Value/Non-Value Added Process Stages

- Classify Sources of Variation
- Decide Root Cause(s)
- Conclude Vital Few x's, Y=f (x) Correlation

4.4.1 Brainstorming (using ISHIKAWA Diagram) &GEMBA (go to machine)

In order to achieve the targets and objectives of analyze phase we begin by brainstorming using all the project team preferably at the site of the problem in order to get the first hand opinion of the process and production staff as well. We need to organize and document this activity so we will be using Fishbone diagram to do this. The ISHIKAWA diagram is used to systematically analyze cause and affect relationships and to identify potential root causes to the problem under consideration. The three steps of the process are to first explain the problem to the participants of brainstorming activity so that everyone is on the same page and then the next step is to find out the causes of the problem in depth. The last step is to document and present the causes in the form of a fishbone diagram. BEFORE and AFTER the brainstorming an on-site OBSERVATION exercise must be performed to collect additional information that cannot be obtained in the form of numerical data this is called GAMBA.

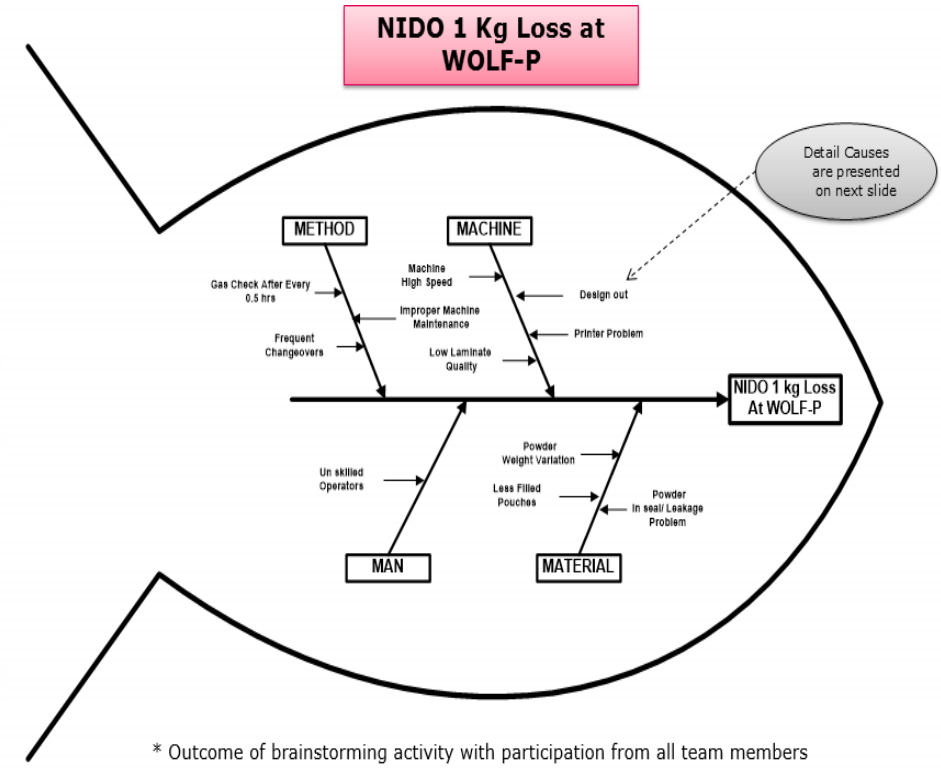


Figure 33 Fish Bone Diagram for identifying root causes

After the session it was established that the major cause was the machine category and in that the design out problem so another session was carried out to find the main causes of the second problem so that steps can be taken to solve the problem.

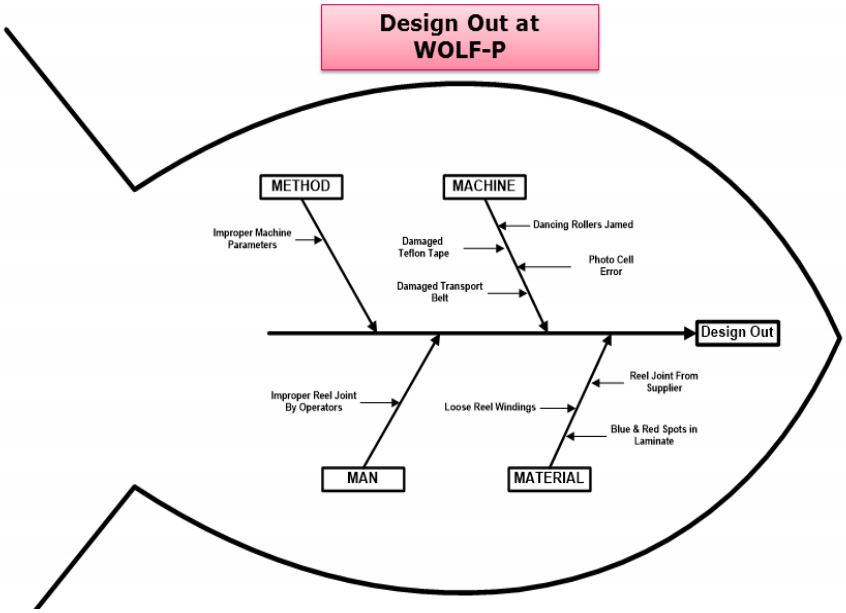


Figure 34 Exploring causes for Design out Problem using ISHIKAWA Diagram

4.4.2 Prioritization Tool (verification of causes)

It's a very simple tool in which all the potential causes that have been verified are categorized and sorted very systematically. The main aim of the tool is to help in implementation of solutions and increasing chances of success of the solutions suggested.

Rather than jumping directly to solving all the problems identified we first categorize them in terms of how much impact solving a certain problem will have on the process and how controllable is the cause.

The graphical form of the data analyzed is attached bellow we can clearly see that it has sorted out the causes that can be removed easily and with a larger impact in improving the process capability. And what causes we should explore more and what should be ignored.

The problems in the green region need to be handled first and then if possible we work on problems in the yellow region. But in order to meet the time and target constraints we ignore or do not verify the causes that fall in the difficult to control and low impact red zone such as

leakage problem. We also ignore the causes in the lower yellow portion that are easy to control but have very insignificant effect or impact such as speed of machine gas leakage after 30 minutes and printer problem. The main outcome of this step of analyze phase is that it increases efficiency of six sigma implementation and saves the wastage of resources and efforts.

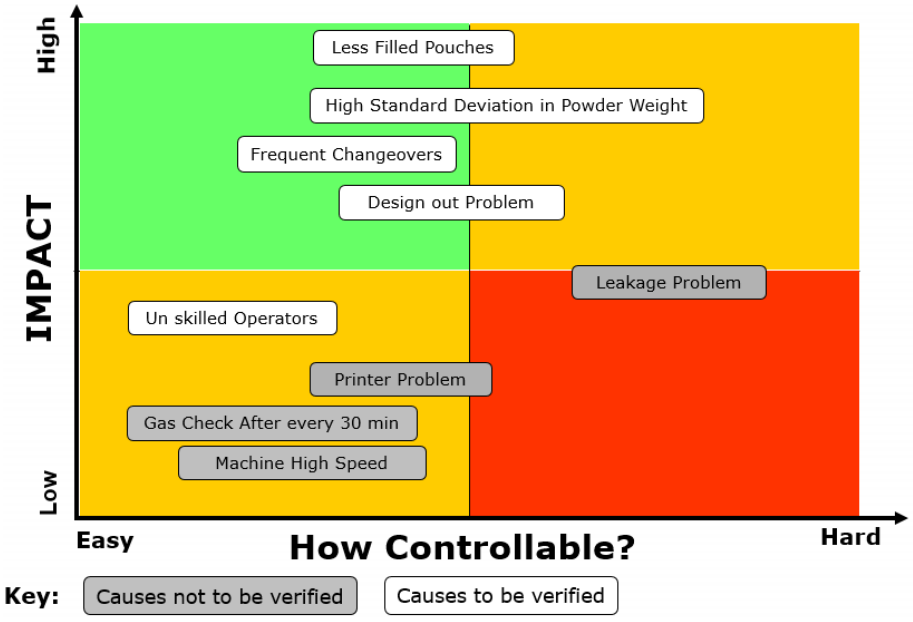


Figure 35 Prioritization Tool

4.4.3 Results (using Cause Verification plan)

Now that we have established a theory about what might be the causes of the losses in the powder production plant and also have categorized them in terms of effects and controllability.

The next step taken was to devise an action plan that could be used to verify the causes. And ensure that the problems were because of the causes we have identified. In this phase we test our hypothesis about causes by devising a plan to verify them.

The table below shows the causes and there plan for verification using different techniques and practical data. The results are also shared in the last column that tells if the cause was verified or not.

Potential Causes Xs	Theory about impact	How to verify the theory (including data & tools)	Status
Less Filled Pouches	When main hopper is empty and no bin is placed from tote bin than weight variation starts & less filled pouches produce at machine (25-30 Pouches)	Through Gemba & data Analysis	Confirmed
High Standard Deviation in powder	Due to weight variation in Powder Pouches are rejected by check weigher, which are ultimately Reworked. 1- Low powder quality 2- Miss alignment of Mini hopper Agitator & Auger	Check weigher Data Analysis	Confirmed
Frequent Changeovers	Due to change of assembly powder in mini hopper & filling tube is reworked.	Actual Production Plan Sheet	Confirmed
Design out Problem	Due to m/c basic condition is not restored & Low laminate quality	Through Gemba & data Analysis	Confirmed
Unskilled Operator	Due to less knowledge about m/c parameters, more chances of losses.	Daily Roaster Plan	Not Confirmed

Figure 36 shows the verification results

Behind all this process apart from using data from the actual SAP or GEMBA we used the 5W1H tool to get to the root of the cause.

- Unskilled Operator

Only one cause was not verified from our original theory and that was the skill level difference between the operators. The reason being that all the operators that were working on the specific line had the same level of training and experience. So we ruled out this option that the fault might be because of the operators on the plant.

- High Standard deviation in powder

From the direct data of the weight checker it was verified that the powder bags produced had high standard deviation in weight the average standard deviation in weight before the improvements were implemented was 6.120 on the line producing 1000gms packs and our main line under observation.

- Frequent Changeovers

This cause was verified using the SAP data of production on the line under observation. It was noticed that there is a lot of shift from 1000gms to 400gms frequently on this line. The production plan sheet tells that it is changed over almost twice or thrice in one production month.

Which is excessively large depending on the fact that the same thing is being done on other packing and production lines.

- Design out

When the data of rework was compared with the causes behind it from the SAP data it shows high Powder loss (Rework) due to empting of hopper & Design out, hence confirming the causes. The actual data had about 26.6% losses due to hopper emptying a design out issue and about 13.5% due to other design out problems such as Design out due to Low laminate quality. Change over, Design out due to photocell and Design out due to Hidden joint (brown tap). Some of the physically verified causes of design out were the unbalanced movement of dancing roller leads, Damaged Roller, Lose winding reel, Low quality laminate and Damaged Transport belt

Now that all the causes have been verified we document in tabular form the major causes and the possible solutions to the problems that will be further used in the improvement phase. These solutions were obtained from the team input and previously done DMAIC projects.

S No.	Potential Root Causes	Possible Solutions
1	High Standard Deviation in powder due to Miss alignment of Mini hopper Agitator & Auger	Change the Clockwise direction of mini hopper agitator to anti clockwise by reversing motor terminals
2	Production of Less Filled Pouches when main hopper is empty & no bin is placed from tote bin	Poke Yoke (Installation of sensor on main hopper) to stop the machine automatically when main hopper is empty.
3	Frequent Changeovers	Avoid all sizes on line Except 1000g & 2000g after consensus with planning
4	Improper machine basic condition leads to design out problem	Restore machine basic condition & Start its monitoring as practice in SHO
5	Improper Laminate quality leads to design out problem	Strengthen on line rejections & Conduct meeting with the supplier

Figure 37Causes and proposed solutions listed

4.5 Improve Phase (Implement Solutions and Evaluate Results)

The improvement phase has the basic goal to identify, validate and implement the improvements or changes to overcome the potential rework and losses. When we reach the improve phase we have two methods or options to implement the improvements one is the data way and the other is the process way.

The data way is taken when after analyse phase the solutions are not obvious in this option the risks of implementation are high and we use design of experiments and the approach is quantitative. This method is used when the solutions are not obvious after the analysis of data the factors have been identified but solutions for improving them are not clear yet or the risks in implementation are extremely high. In such cases we use the design of experiment to quantify and identify the solutions.

The second way is the process way this method is taken when we have clear identification of the issues and from this identification it is clear that what the solutions should be and the risks of implementing the solutions are low. The tools used are feedback from the teams and process mapping are used. This is a qualitative technique and the usual solutions are revised process, cutting out waste and NVA (Non value added process steps), and implementation of performance

Measures.

As we have clear solutions and the risks of implementation are low on our powder milk production so we will be using the Process stream in the improve phase of our DMAIC implementation.

4.5.1 Prioritization of Proposed solutions

The first step is to prioritize the solutions already established in the last phase in this step the solutions are divided into deliverable and concrete form and ready for implementation before they are categorized using the prioritization tool already discussed in the analyze phase but this time in more detail. The figure bellow highlights the solutions we will be implementing in this phase.

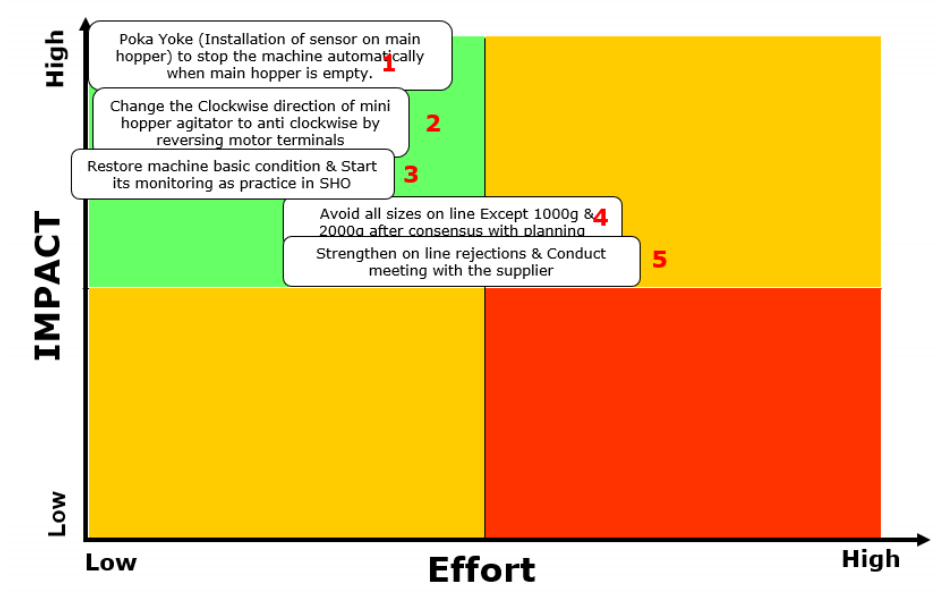


Figure 38 Prioritized matrix of proposed solutions

4.5.2 Poke Yoke (mistake proofing)

The first solution which will be disused and implemented was to error proof the design out problem using Poke yoke. Some of the chances of errors that were considered in this step are

- Human error: Processing wrong material or work piece, not following standardized practices and procedures, or not maintaining equipment.
- Equipment error: Improper setup, adjustment error, excessive wear, poor maintenance, overburden, and uneven production.
- Improper parts or materials: Missing, wrong, or defective parts.

The devises deployed to do mistake-proofing help to reduce or eliminate Mistakes made by a human, equipment, or parts error covering all sources of errors. The devices can be control devises, warning devices and devices with the ability to shutdown process in case error is identified.

The major problem in our process was the emptying of hoper during the packaging operation so we installed a sensor that stops the production in case the main hopper was empty avoiding the packing of less weight or empty pouches.

The picture shows the sensor in place and the error that appears when the hopper is empty fool proofing the system.

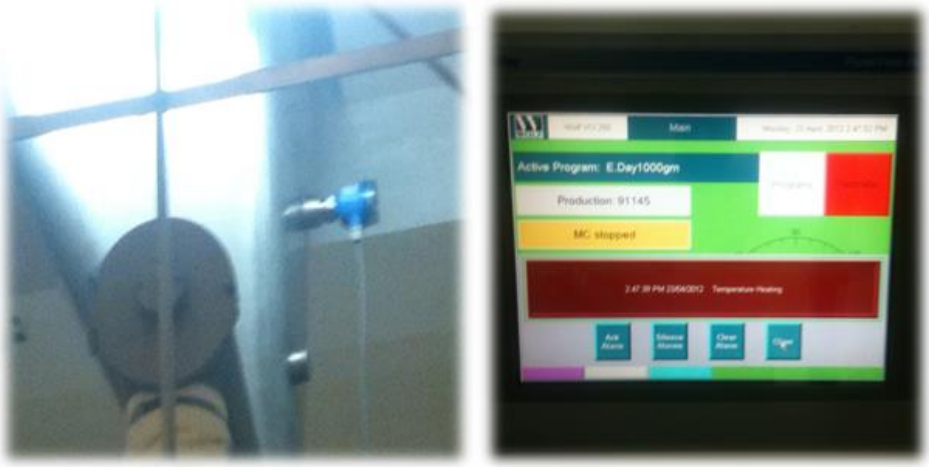


Figure 39 Poke yoke and HMI changes done on processing plant

4.5.3 Machine settings changes

One of the major problems occurring in the Mini hopper was due to its agitator that was resulting in weight variation in the filled pouches of powder milk and ultimately resulting in rework and losses. The solution that was implemented on the hopper was Change the Clockwise direction of mini hopper agitator to anti clockwise by reversing motor terminals. Which resulted in significant improvement in error due to design out. The agitator is used to shift the powder from bin into the pouches and had significant effects on powder milk packing

4.5.4 Mixed solutions

Other solutions that were implemented to reduce rework and semi filled losses are

- Restore machine basic condition & Start its monitoring as practice in SHO this monitoring formalized the process and after its addition in the standard operating procedure sheet the chances of reoccurrence of non-standard machine condition while production were very less.
- Avoid all sizes on line except 1000g & 2000g after consensus with planning this step was done by changing the production sheets and resulted in reduction of frequent changeover problem. Which was one of the major causes identified for losses in the line. The data shows no changeovers after the project was implemented.

- Strengthen on line rejections & Conduct meeting with the supplier to solve the issue of the faulty Packaging material. Which was resulting in misalignment of packing tape and resulting in rework.

4.5.5 Implementation Plan (5w1h)

To ensure smooth implementation, proper documentation and removing ambiguities we use the 5w1h tool. The aim of this step is to see tasks and their relative sequence –duration and timing break down the components of a task selected for improvement.it also has the objective to describe steps of a process and assign responsibilities so that the order is restored and chances of successful implementation increase. One of the purposes of making an implementation plan is to see tasks and their relative sequence, duration, and timing in detail.

The tools used to do all this are Tree Diagrams, Gant Charts, process maps and Planning grids (5w1h).

A planning grid helps to identify the resources and outcomes for each step in the process. A document that identifies the actions and responsibilities for those assigned to implement actions

It provides clear direction and avoids ambiguities related to the results to be achieved and it requires answers to the following questions: why, what, who, when, where, how, and in some cases how much.

What	Why	How	Where	Who	How much	When	Status
Installation of sensor on main hopper	To stop the machine automatically when main hopper is empty	By getting it from Technical Store & installing it on hopper.	WOLFP	Ashraf	-	19-05-2014	Done
Change the Clockwise direction of mini hopper agitator to anti clockwise	To avoid Weight variation issue	By reversing motor terminals	WOLFP	Imran	-	25-05-2014	Done
Restore machine basic condition & Start its monitoring as practice in SHO	To avoid unplanned stoppages and smooth working of line	By doing maintenance on the line	WOLFP	Imran	-	30-05-2014	Done
Avoid all sizes on line Except 1000g & 2000g	to avoid rework after every changeover	after consensus with planning	WOLFP	Qaiser	-	01-03-2014	Done
Strengthen on line rejections & Conduct meeting with the supplier	to avoid rework generation by cut open	By asking the supplier & Strengthening on line rejection	WOLFP	Abdur Rehman	-	25-05-2014	Done

Figure 405W1H tool implemented with status

4.5.6 Effectiveness of the solutions (results before & after)

In the last phase of improve we will be discussing statically the data from before and after the improvements were implemented and gauge how effective our improvements were. For the purpose of this study the data was tabulated against time and the quantities that were compared were the parentage losses in the powder milk.

The actual quantity of powder that should have been used was subtracted from the powder actually used in order to find the quantity of extra powder used. This can also be tabulated on how much loss it was in terms of percentage. The charts show the comparisons in before and after results that clearly indicate reduction in losses at the powder plant and significant reduction in variance and standard deviation of powder packed in the pouches.

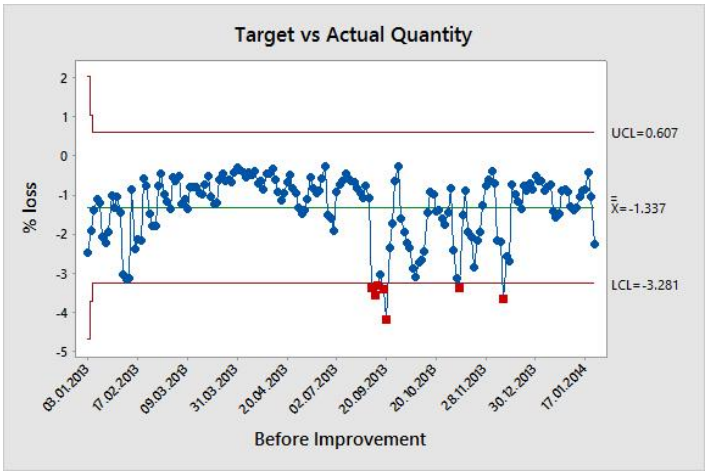


Figure 41control chart for losses before DMAIC

Figure 42control chart for losses after DMAIC

The first figure shows a larger number of losses as the mean loss is larger and also a large number of points are out of the control limits. But the second graph clearly shows reduction in mean loss and also reduction in variation. Before & after Analysis shows that the Powder loss has been reduced.

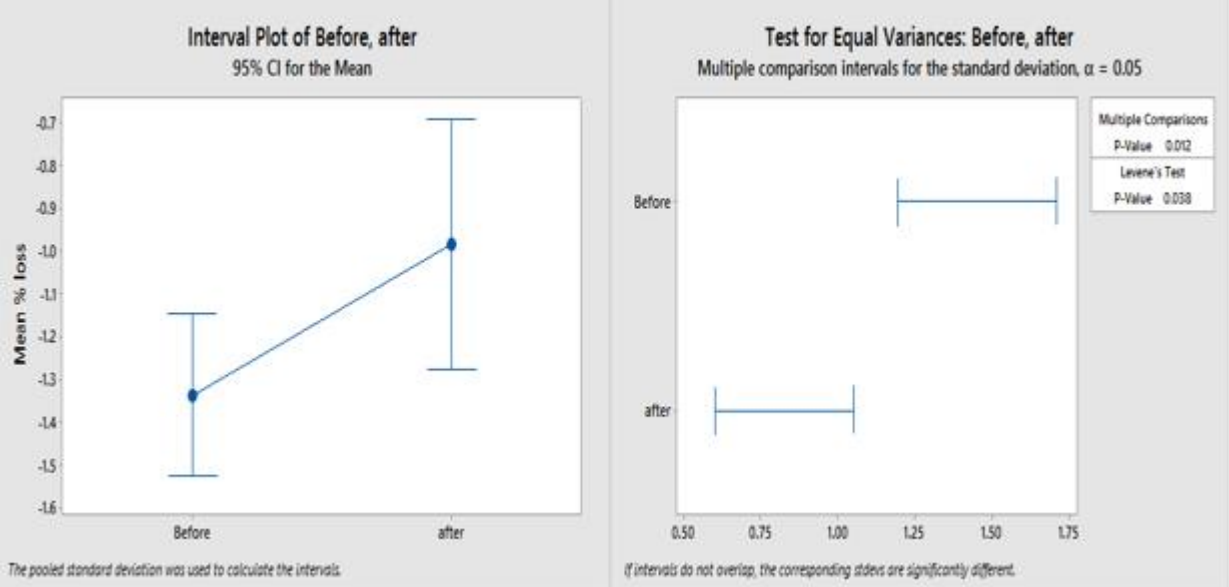


Figure 43 Comparison of mean losses before and after DMAIC using MINI_TAB

As the mean values has not changed much (this is OK - aim is to reduce variation around target of zero) need to establish whether significant reduction in variation - therefore reviewed use of ANOVA Test for Equal Variance. The P value in hypothesis tests - looking for a value of less than 0.05. Graph indicates that the p value is 0.012 that shows a highly statistically significant reduction in the variation in powder loss from "before" to "after".

4.5.6.1 Design out Comparison

Before & After Analysis shows that the losses due to less weight because of empty hopper, Changeover have been eliminated & rest all have been reduced

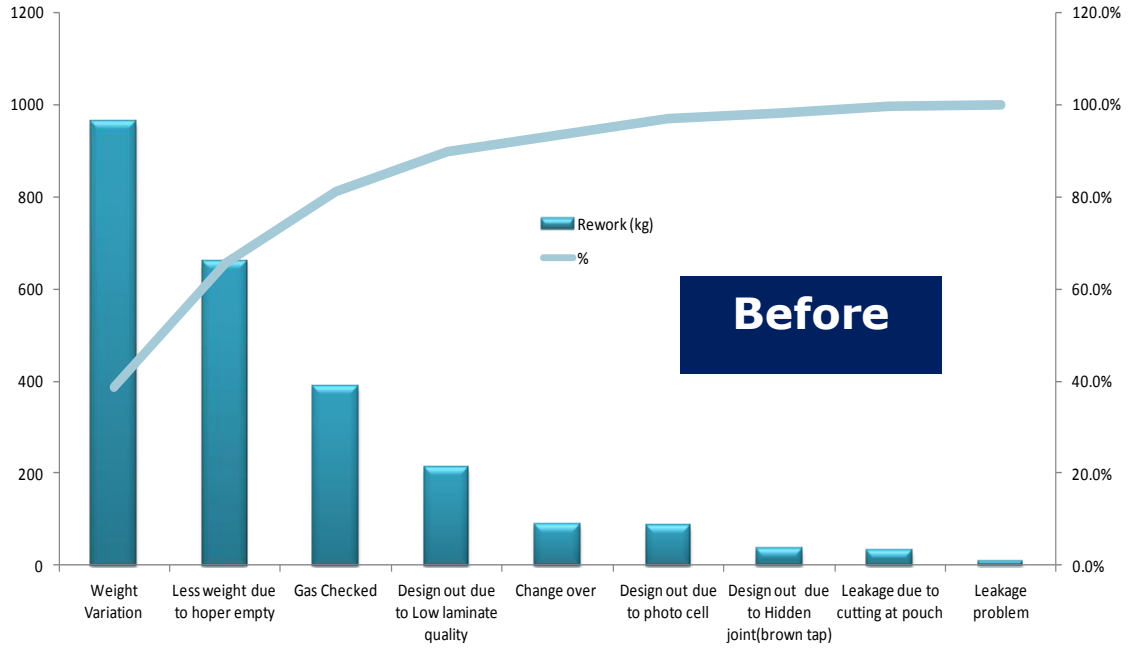


Figure 44 Pareto Chart for causes of loses before DMAIC

Figure 45 Pareto chart of losses causes after DMAIC sowing significant improvement

4.5.6.2Comparison of Standard Deviation (weight)

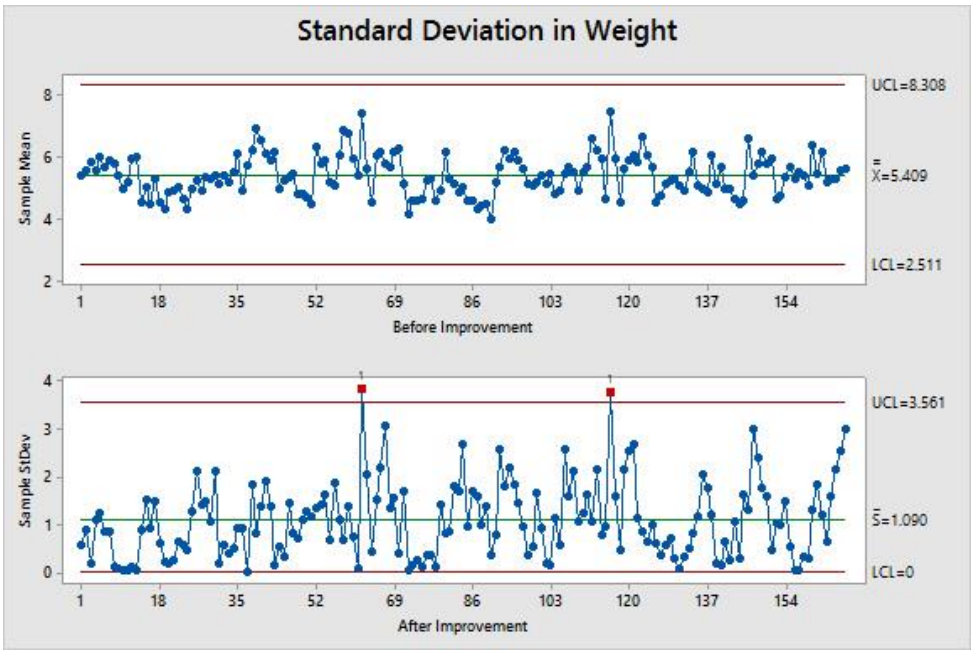


Figure 46 Comparison of standard deviation of powder weight in packed pouches

The chart shows that after the improvement there's been improvement tin the weight variation or standard deviation of packaged pouches. Resulting in reduction of loses and rework.

4.5.6.3 Comparison of Process Capability

The comparison between process capabilities shows decrease in mean losses of the process and drastically decreases in process standard deviation.

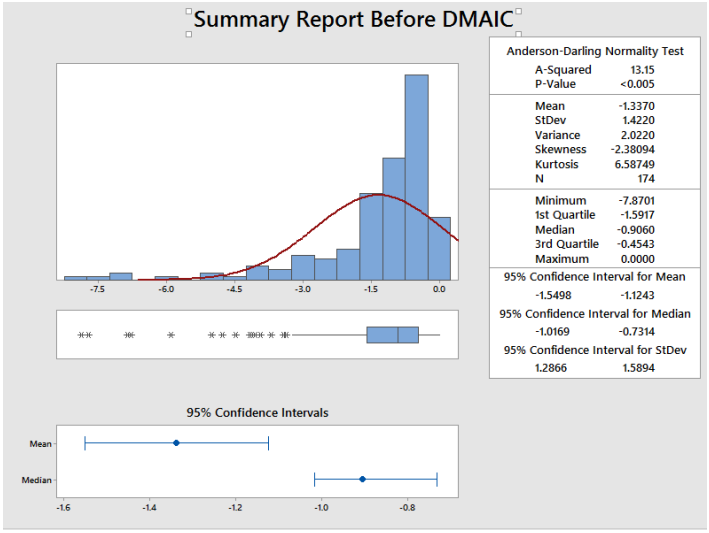


Figure 47Process capability summary before Process improvement

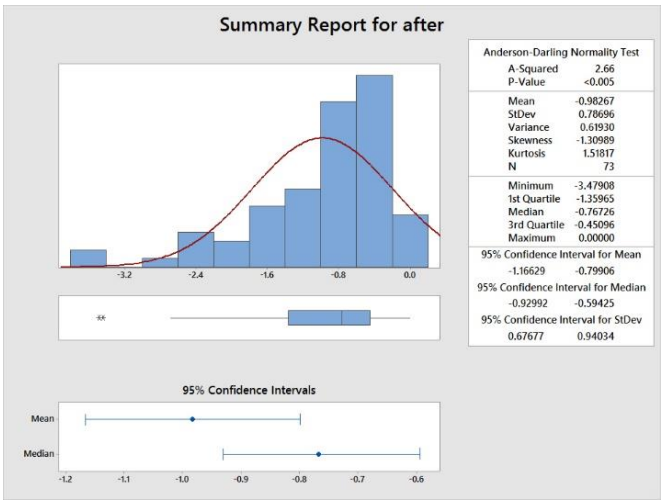


Figure 48 summary of process capability after DMAIC

Process capability calculations using the data provided shows a significant improvement in sigma level showing the capability has been enhanced due to the improvements. The sigma level before was 1.65 (using limits of 0.165 &-2.131) and after the improvement the sigma level was 2.56. The conclusions from this phase were that the process capability was increased and the rework and losses were reduced and these conclusions were drawn using real-time data from the process and the financial data of the product.

4.6 Control Phase (Develop and Document Standard Practices)

The three major steps of the control phase will be to standardize and integrate the process improvements done, implement controls, document and close the project. This all is done so the improvement and practice of six sigma become business as usual. Some of the goals of this phase of six sigma are

- Identify methods of control to ensure that improvements are sustained over the long term
- Develop and document a control plan encompassing all activities and documentation required to sustain project and process improvements
- Establish provisions to monitor process performance and thus verify that the project improvements are maintained
- Hand off to the process owner a completed, finished, and wrapped-up project with properly documented instructions and procedures if changed.

By the end of CONTROL we will have a smooth-running process with minimal variation in methods and techniques, resulting in reduced overall variation in the system.

The first part of CONTROL is to make sure that everyone is using the new process according to the developed methods. These are the methods that we have proposed to produce desired results.

4.6.1 Process Management Chart

The first step of control phase that we did was to make a proper process management chart so that the control phase is systematic. This Standardization is what allows high quality to occur on

A reliable, sustained basis and guarantee for the success of our improvements. This chart is a framework that can be quickly changed and communicated to all workers, allowing for rapid response when new change is communicated. The spirit of this step is definition of a work method wherein all variables of the method have been specified in detail.

Process management identifies the need for a project to improve or design a process. When the project is complete, the improved or redesigned process reenters the process management system.

The pillars or the factors considered while process management chart was being constructed are

- VOC—How to interpret the Voice of the Customer and link the customer's wants and desires to the process goals and measures.
- Process—How to map, analyze, and streamline a process.
- Measurement—How to determine, collect, and chart data on the overall business goals (Big Y's): how to determine, collect, and chart data on key process (x) and result (y) measures: how to display process results on dashboards.
- Roles and responsibilities—How to use process management, standardization, improvement, and design methodology in conjunction with the roles of project teams, process owners, champions, sponsors, Master Black Belts, Black Belts, and Green Belts.
- Process review—How to drive the process.
- Linking and leveraging--How to link the above activities to the strategic direction and goals of the business and to align the organizational environment (e.g., recognition and rewards) with the primary desired results.

The other major factor considered studied and applied in the control phase for the process management is the PDSA cycle that comprises of

- PLAN: Plan what needs to be monitored.
- DO: Implement the monitoring and control activities.
- CHECK: Assess whether the process is meeting performance expectations.
- ACT: Take action to address any performance problems that arise.

As our major focus was to review overall process documentation we were using process management charts

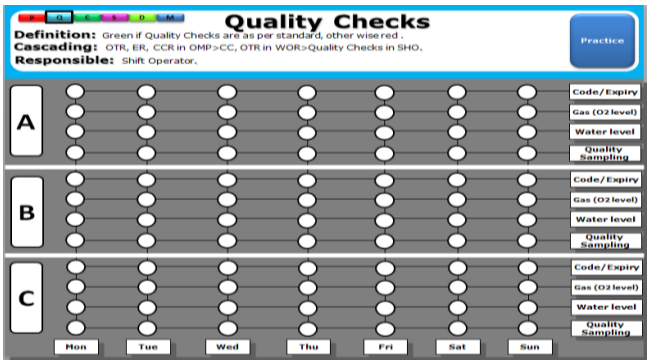
New Process	Key Process Indicators	Corrective Actions
M/C startup	DT % of GPH	1. Immediately inform Tote bin Operator for in time powder availability 2. Perform Start up as per guidelines & Time defined in LLS
M/C Basic Condition Checks	Manufacturing Checks in SHO	1. Perform Basic Machine checks in start of every Shift & Track it on SHO board. 2. Perform Annual Shut down strictly on each line per year
Filling & Sealing	As per machine Settings / Quality Checks in SHO	1. Perform quality checks once during every Shift & Track it on SHO board.
Weighing	As per Quality Guidelines & Check weigher data	1. Always take data from check weigher . 2. Calibrate your check weigher on Monthly basis
Packing	As per SOP	
Palletizing	As per SOP	

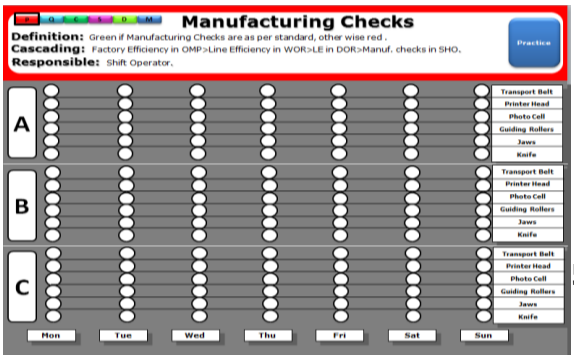
Figure 49 Process management form for controlling process

4.6.2 Control Checks

The next step was to restore machine basic conditions and control key parameters over time.

These checks or charts are used to take appropriate managerial action related to process performance over time. The following control sheets were designed and implemented on the process to control the errors from reoccurring and also monitoring the process.





Key problems from the past and performance indicators related to both quality and manufacturing have been controlled using this practice. This visual control helps taking action in time in case the problem occurs.

4.6.3 SWOT Analysis

After the completion of the project we again did a SWOT analysis to explore our implementation and have a solid future conclusion. The table is listed below which shows our strengths weaknesses and tells the opportunities and highlights the threats.

STRENGTHS (INTERNAL)	WEAKNESSES (INTERNAL)
•Strong coordination with DMAIC Team Members, Strong support system from Wolf. •Dedication, Motivation. •Team work, Technical Knowledge of Team members, Energetic Team, Trained DMAIC Team,	Time management
OPPORTUNITIES (EXTERNAL)	**THREATS (EXTERNAL)**
•Understand more in details How to optimize Cattle Feed & Rework during production. •Timely updating of project into database. •More Saving.	•If no attention is given to Machine Basic condition similar type of issues can come in future.

Figure 50 SWOT analysis

4.6.4 Savings Calculations & Results

The project was basically targeted to save powder milk losses during packaging and reduce costs due to rework and semi filled product losses. And as per the company policy at the end of the project all the savings were calculated and documented the results showed that the losses in powder before the project were 0.011378 tones per production run and after the six sigma implementation the losses were 0.007tones per production run resulting in 38.5% reduction in losses.

Powder product loss = 61466.2Kg

Powder saved =23637.1Kg

Market Rate of Prod=423.2Rupees/Kg

Savings (actual) =10million Rupees

Savings Projected =3.3million Rupees

Total Savings =13.3 Million

In order to verify the savings the data was sent to the finance for analysis and resulted in approval that meant that the data was not only real but also the projected and actual savings were also real. After which the project was closed and handed over to the production team.

5 CONCLUSION & Recommendations

Once the project outcome and achievement of its main objects were of the satisfaction level of the team and the coach, the project was closed. Conclusions that can be drawn from this Six Sigma and the brief process will be listed in this chapter.

- Being a multinational company and having a focus on continuous improvement DMAIC six sigma is a major improvement strategy. The company is a food production enterprise and is concentrating a lot on process improvement and skill set development of the employees. Identify and prioritize problems/ losses followed by Analyze and eliminate problems/ losses methodology was applied to first find the project are and then implementation of six sigma or DMAIC in that area.
- Currently the filling and packing process at WOLF P & Y lines are out of control resulting in high SFP (Rework + Overfilling + Cattle Feed) losses of 41.6 million PKR from (Feb-May) 2014. Current methods of controlling the process and reporting that control are not successful hence taking into account all the factors a six sigma green belt project was initiated
- NQC (non-quality cost) is an important factory KPI (key performance indicator) that reflects the cost of failure related to material loss. Increase in NQC will increase the operational losses of our factory. This is not bearable in order to achieve 3C's of NCE. This project will definitely help us to reduce NQC by keeping SFP losses (Rework + Overfilling + Cattle Feed) at lower side.
- In the Define phase the project charter discussed in the above points was finalized and Skill matrix, 5W1H, stakeholder Analysis, CTQ and SIPOC were used to clarify the problem and its effects and viability to the company keeping in view the voice of the customers.
- In Measure Phase critical process input and output variables were defined by Cause and effect analysis, Data of the previous months projects was collected and losses were calculated using process mapping, Pareto Graphs, control charts and finally process capability was calculated and initial sigma level was decided. From above data Analysis, it became clear that our focused Product for improvement would be Milk Powder 1 Kg on WOLF P production line. We will have to reduce its loss in PKR by 55% to reduce overall loss by 20%.

- In the Analyze phase we do the systematic brainstorming and Cause & Effect studies on the data to identify the causes of variation and then process mapping, stratification, control charts and other statistical tools to verify the causes of variation. The last phase is to highlight the verified causes.
- We started off identifying causes on the wolf P line and then moved to deep identification of the major design out problem using the brainstorming and fishbone diagram. Other identified and then verified problems were Frequent Changeovers, High Standard Deviation in powder and less filled pouches. Unskilled operator cause was not verified when tested. In the highlight phase we used prioritization matrix to highlight design-out, standard deviation in weight and frequent changeover, as causes with high impact and that were easy to control.
- Then in the improve phase the verified causes and proposed solution were once again prioritized and changes were implemented. The main changes with significant impact on results were Poke Yoke (Installation of sensor on main hopper) to stop the machine automatically when main hopper is empty, reversing motor terminals of mini hoper (design out problem solution), planning changes in production to only run 400 and 1000gms pouches to avoid frequent changeovers and Restore machine basic condition & Start its monitoring as practice in SHO were the major changes done. 5W1H, Pareto and control charts were used to compare the effectiveness of the solutions and compare process capability of before and after resulting in process capability enhancement.
- Despite the reduction in mean losses and significant reduction in process standard deviation it was necessary in control phase to systemize the changes the changes are retained, documented and others could also use them. For that purpose new control checks were implemented and process management matrices were created following a SWOT analysis to give future recommendations.

5.1 Key Leanings

Methodology: Structured approach helps prove or disprove theories about root cause.

Teamwork: Operator involvement is key in generating solutions and ensuring buy in during implementation.

Capability Building: This project has not only controlled the losses but also helped in capability building of team members so that in future they can lead other improvement projects.

5.2Future recommendations

Smaller six sigma (DMAIC) projects should be initiated to tackle other smaller problems identified during the course of this project that were not handled in this six sigma project.

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