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APPLICATION OF SIX SIGMA DMAIC FRAMEWORK TO REDUCE THE REJECTION IN THE PERSONAL CARE PRODUCT MANUFACTURING UNIT: A CASE STUDY

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In a rapidly changing and highly competitive environment, each Organization is striving to deliver better quality products & services to the customer. To meet the required Quality standards, organisations work hard to reduce all variations and make the production process optimal. Six Sigma methodologies are widely being implemented by almost all core sectors e.g. Manufacturing, Healthcare, Banking, Education, Hospitality, Agriculture, Aviation, and even some of the government-allied sectors. The prime objective of "Six Sigma methodology" is to minimize "process variations"; however it results in numerous tangible benefits like enhancing the Quality of the products/services, reducing the production / operational costs, increasing profitability, minimizing the turnaround time of processes, variations, and most importantly enhancing customer satisfaction This case study is based on one of the most important Six Sigma frameworks called "DMAIC". The DMAIC method was implemented to identify and analyse various causes of higher rejection percentages during the production of a new product in the personal care product manufacturing unit. The "higher rejection" issue was not only resulting in financial loss but also impacting timely deliveries and the Customer satisfaction index. Therefore, the Six Sigma DMAIC (Define, Measure, Analyse, Improve, Control) approach was adopted, which helped in reducing rejection from 6.1% (Jan'24) to 3.1% (April'24). Consequently, it resulted in considerable cost savings, improves Product delivery compliance and eliminated the probability of getting consumer complaints due to quality defects.

Keywords *- Six Sigma, DMAIC, Cause and Effect Matrix, FMEA, 4M*

1. Introduction:

Most of the organizations are struggling to implement relevant strategies to improve their overall performance due to the increasing competition (Srinivasan, K., Muthu, S., Devadasan, S.R. and Sugumaran, C.,2016)[25].
Six Sigma tools and methodologies are well acknowledged as "Business Strategy" which helps in resulting benefits like - improve profitability, cut down manufacturing/service cost, increasing profitability, reduce turnaround time of processes, reduce variability in processes, improve efficiency & effectiveness of processes, increase customer satisfaction index, and may more. Initially, Six Sigma approaches were implemented by the manufacturing sector, mainly in the automobile industry, but later expanded to other sectors, including service, healthcare, education, and even government sectors.
Six-Sigma methodology is a systematic approach that includes "Knowledge of Process" and statistical methods. Basically, "Six Sigma" is to understand variation within products or processes, to take corrective and preventive measures so that variation can be minimized and highly consistent products or processes can be operated, resulting in better products/processes, more reliable products/processes, lower costs and improved customers' satisfaction.

The journey of Six Sigma started in the mid-1980s when Motorola was struggling to face aggressive competition from Japanese organizations. Motorola was continuously losing market share due to higher customer dissatisfaction; consequently, their operating costs increased and resulting in negative profit margins.
In 1987, the Leadership team of Motorola launched the concept of "Six Sigma" in all operations worldwide. The word "sigma" was taken from the statistical term "standard deviation" and is denoted by the Greek letter sigma (σ). The variation in a process is typically measured in terms of the number of standard deviations from the mean. Sigma values and the corresponding Defects Per Million Opportunities are mentioned in the below-mentioned table

Sigma Level	Defects per Million Opportunities	Percentage Yield
1σ	691,462	31
2σ	308,537	69
3σ	66,807	93.3
4σ	6,210	99.38
5σ	233	99.977
6σ	3.4	99.99966

Six Sigma is a systematic and organized problem-solving tool for strategic systems and new product/service development. It helps in reducing the number of defects in the order of 3.4 defects per million opportunities (Schroeder, R. G., Linderman, K., Liedtke, C., & Choo, A. S.,2009)[23].
Six Sigma follows a methodological approach like DMAIC– (Define, Measure, Analyze, Improve, and Control), It is a methodology that targets minimizing problems (process variations) by promoting continuous improvement. Kaushik and Khanduja (2009) explained that Six Sigma is a statistical and scientific approach. This cyclic process uses technology and measurement to eliminate the unproductive steps in the processes.
Implementation of Six Sigma methodology delivers better results and develops quality culture aspects such as top management commitment, focus on training, strategic integration and strong alignment of Organisational goals. For process improvement, Six Sigma is carried out using the DMAIC methodology throughout the define, measure, analyse, improve, and control phases (Schmidt, A., Sousa-Zomer, T. T., Andrietta, J. M., & Cauchick-Miguel, P. A.,2018)[22].
In this study, the problem of higher rejection percentage was identified and resolved by adopting the Six Sigma methodology. Being a systematic approach, in the first step "problem statement" statement was defined. In the second step, all potential causes got identified using other Six Sigma tools like the Cause and Effect diagram or fishbone diagram Thereafter, all causes got analyzed through FMEA (Failure Mode Effect Analysis) , it was used to quantify the causes which had a higher impact on the problem. Throughout the study, multiple rounds of brainstorming sessions were conducted with cross-functional teams of various departments. After completing the analysis step, some recommendations were advised to take corrective actions for improvement. Once all improvements were implemented, we monitored the performance of the desired parameter and observed control of the issues/causes. Consequently, we achieved the desired target to reduce the rejection percentage.

2. Literature Review:

J.W. Locke, J.M. Kowalewski Jr. (1994)[12] explained the importance of process charts, cause-and-effect considerations, and control charting in their research study. H.C. Lin (2004)[8] researched the Statistical Quality Control (SQC) process and described the benefits of process capability indices for normal distribution. J. Tong, F. Tsung, and B. Yen (2004)[11] explained the importance of the DMAIC approach in their research studies, noting that it is useful for quality improvement. They also described how the design of experiments (DOEs) is one of the core statistical tools for Six Sigma improvement. Y.D. Hwang (2006)[30] discussed the DMAIC phases in detail with application to the manufacturing implementation system.
Tjahjono, B., Ball, P., Vitanov, V.I., Scorzafave, C., Nogueira, J., Calleja, J., Minguet, M., Narasimha, L., Rivas, A., Srivastava, A., Srivastava, S. and Yadav, A. (2010)[27] explained the concept of Six Sigma under four principles. The first principle defines Six Sigma as a set of statistical tools adopted within quality management to construct a framework for process improvement. The second one defines Six Sigma as a philosophy of management. The third principle considers Six Sigma as a business culture, a top-down methodology in which the success of Six Sigma does not rely only on statistical tools and techniques but also on the commitment of the top management to ensure the involvement of the organization's staff. The fourth

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one explains Six Sigma as an analysis methodology that uses scientific knowledge.

Firka D. (2010)[6] explained in studies that “Six-Sigma” approach ensures process to be highly reliable, eliminates wastes, reduces variation and improves the process flow. He also described that “Six-Sigma” is the top management-driven technique which helps in reducing in perennial problems.

C. Sahay, S. Ghosh, P.K. Bheemarthi, (2011)[3], implemented the DMAIC approach to analyze the manufacturing lines of a brake lever at a Connecticut automotive component manufacturing company. Lee-Mortimer, A. (2007)[15] examined case study in a CNC machine tools and in a CMM manufacturing organization. He implemented the Six Sigma methodology. After applying Six-Sigma methodology, several tangible benefits were noticed e.g.- scrap rate and rework got reduced from £1,100 per month to £400 per month, and delivery performance increased to 95 percent. In nutshell, Six-Sigma approach helped to achieve significant improvement and resulting in £60,000 yearly savings.

A. Kumaravadivel, U. Natarajan, (2013)[1], dealt with the application of the six-sigma methodology to the flywheel casting process in which the primary problem-solving tools used were the cause-and-effect matrix, failure modes and effects analysis (FMEA) and process map. L.M. Gaikwad, S.N. Teli, V.S. Majali, U.M. Bhushi, (2016) [16], implemented the principles of DMAIC methodology to identify, quantify and eliminate sources of variation in an operational process, to optimize the operation variables, improve and sustain performance, namely, process yield with well-executed control plans. S.N. Teli, L.M. Gaikwad, V.S. Majali, U.M. Bhushi, V.V. Surange, (2013) [24], briefed that it is necessary to reduce costs without compromising quality and continuous quality improvement is a key factor in the strategy for competitiveness. Kuptasthien and Boonsompong (2011) [13], in their research described about “relationship between process variability and product specification. Hence using statistical tools, one can eliminate this variability or reduce it significantly by making the process efficient and product better (De Mast & Lokkerbol, 2012)[4] .

Soundararajan and Reddy, (2020) [26] explained that “DMAIC” is problem solving methodology, it is a structured process flow that includes five-steps. DMAIC methodology helps to reduce variation in the processes, improve production efficiencies, improve safety, product quality etc.

Six Sigma is a customer-centric approach that aims to reduce variation and improve the quality of a product or process. In recent years, Six Sigma methodology, through the DMAIC approach (Define, Measure, Analyse, Improve, Control), has been demonstrated to be effective in improving manufacturing processes in multiple sectors such as healthcare, metallurgy, consumer goods or aerospace, among others (Barbosa G. F.(2014) [2]; Girmanová L.(2017) [7]; Hill J.(2018) [9]; Osore E. (2020) [18]; Sajjad M. H. (2021) [21]; Thomas A. J. (2016) [28]; Wong W. Y. (2019) [29]; (Larsson T. S. (2022) [14].

3. Methodology:

Six Sigma DMAIC is a methodology used to improve processes, systems, or products, and is usually suitable for manufacturing processes The Six Sigma method has two main frameworks - DMAIC and DMADV. The Define, Measure, Analyze, Improve, and Control (DMAIC) strategy is used for process improvement, whereas, the Design, Measure, Analyze, Design, and Verify (DMADV) is used for product improvement. The DMAIC methodology used in this study is categorized into the following five basic phases:

Define: Define the problem and goal of the project.
Measure: Measure the extent and gravity of the problem.
Analyze: Analyze the current situation and find a solution to achieve the goal.
Improve: Implementation of the proposed solutions to achieve the goal.
Control: Make sure that permanent improvement takes place

3.1 Define

Define is the first phase of DMAIC methodology which aims to define the basic problem through the voice of customers, the voice of business, SIPOC, and process map. After this, the customer requirements are identified which forms the foundation for Critical to Quality (CTQ) characteristics, These are the quality parameters which are critical for satisfying the customer’s requirements. In this stage, the problem statement is clearly determined along with the project scope and role of team is also determined through this parameter. (Ng, K. C., Chong, K. E., & Goh, G. G. G. (2014,) [17]; Raman, R. S., Basavaraj, Y., Prakash, A., & Garg, A. (2017) [20].

Key Characteristics of Define Phase are

1. Define the business requirement
2. Understand the problem
3. Define The Process

3.2 Measure

In this phase, product characteristics are identified, that need to improve. Once product characteristics are defined, all of them are mapped out. For this, we have to check the measurement system record, and the corresponding data and set the level of performance that we want to achieve in the process. A cause and effect (C&E) diagram is used to identify all the problems being observed. The C&E diagram is also referred to as the Fishbone or Ishikawa diagram and the benefit is to help in identifying the causes of the problem.

Key Characteristics of the Measure Phase are

1. Collect Process Data
2. Check the Data Quality & Integrity
3. Understand Process variation
4. Baseline Process Capability and Potential

3.3 Analyze

This phase of DMAIC aims to study all the processes and the data being generated to understand the root causes of the problem. In this phase, analysis is done to identify ways to eliminate the gap between the current performance and the desired goal. Several statistical tools are used to validate probable causes of the problem. By using quality tools like the Pareto Chart, we can easily identify the root cause (Prashar, 2014) [19]. Hung, S. H., Wang, P. C., Lin, H. C., Chen, H. Y., & Su, C. T. (2015) [10], utilized Healthcare Failure mode and effect analysis (FMEA) into the framework, which mainly consists of define, measure, analyze, improve, and control (DMAIC), of Six Sigma. The reason for targeting the root cause is to find its effect on the process variation.

Key Characteristics of Analyze Phase are

1. Analyze the Process
2. Analyze the Data
3. Verify Root Causes

3.4 Improve

The prime objective of this phase is to identify possible improvement actions, prioritize them, test the improvements, and finalize the improvement action plan. This phase aims to propose and select a solution that can improve the existing system. The solution implemented in this stage must focus on keeping the existing process within the desired limit.

Key Characteristics of the Improve Phase are

1. Ideate Potential Solutions
2. Select the Best Solution
3. Assess the Risks
4. Pilot and implement the proposed solution

3.5 Control

The control phase is one of the most important steps of the DMAIC approach. In this phase, Statistical Process Control (SPC) is used once again to ensure that the process is stable and continues to deliver improvement. After implementing the new process, it is monitored till the system starts working smoothly. Erbiyik & Saru, (2015) C. Sahay [5] suggested that implementing the new process is much easier than sustaining it, hence monitoring becomes an integral part of the Control phase.

Key Characteristics of Control Phase are

1. Implement Ongoing Measurements
2. Standardize Solutions
3. Quantify the Improvement

Process Flow Diagram of DMAIC Methodology

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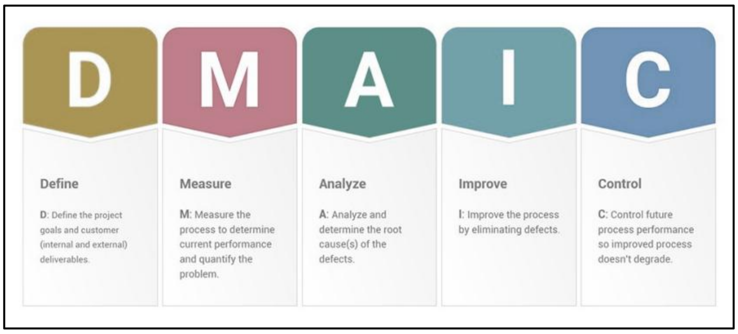


4. Summary of the Case Study:

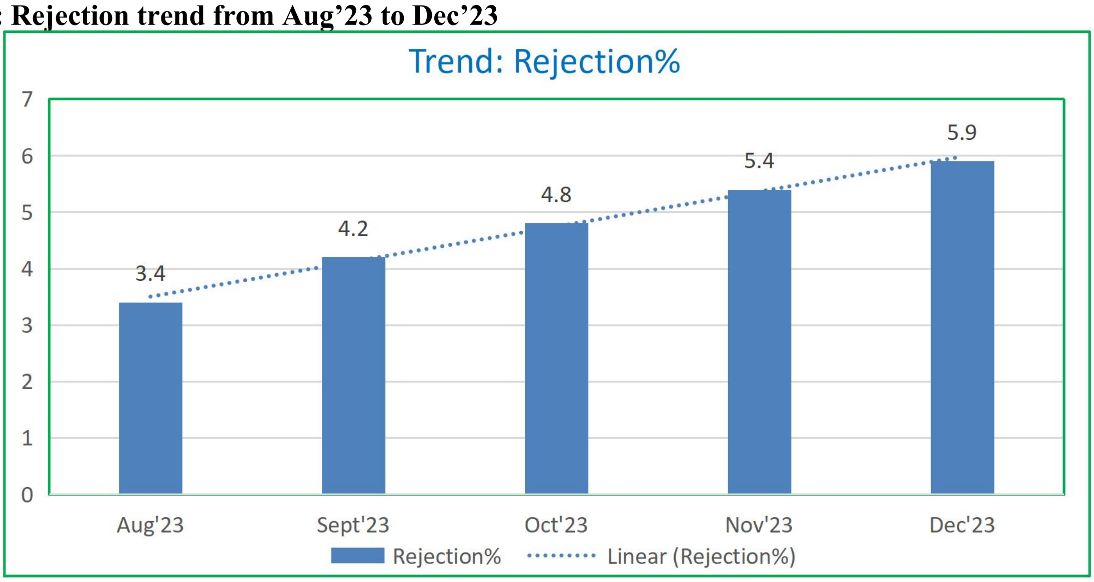
This case study was performed at the Cosmetic Products Manufacturing Unit in northern India. That manufacturing Unit has a strategic partnership and long-term association with India's Top leading FMCG organization and produces a wide range of Products / SKUs. Manufacturing Unit is well equipped with advanced and the latest technology in the manufacturing and production sections. Manufacturing Unit can produce various types of Cosmetic Products like Shampoo, Conditioners, Facial Cream, Hair Styling Gel, Body Moisturizers, etc. The unit has an installed capacity for manufacturing of 750 MT per month. Manufacturing Unit has established a very well reputation among the other "Third-Party Manufacturing Units". Manufacturing Unit always delivers premium quality products & services by implementing the latest technology.

4.1 Define Phase

The top management of the Manufacturing Unit conducts the Operations review meeting every quarter and reviews all Key Performance Indicators (KPI). It helps them to keep close track of all critical parameters like Customer Satisfaction Index, Complaints Rate, Operational Cost, Production efficiency, Rejections, SPC (Specific power consumption), SWC (Specific Water consumption), etc. During the Second Quarter (Dec'23) review meeting, the Leadership team noticed higher rejection in one Product Category. It was discussed with serious concern, and the Production Head was asked to share more insight on it.

Production Head informed that production of the new Product 'Hair Styling Gel" was started almost 5 months back. Being a new product, it was expected to have a slightly higher rejection rate due to the new type of product and packaging material. But even after 3 months of production, rejections could not be controlled and increased to 5.9%.

Graph: Rejection trend from Aug'23 to Dec'23



After getting basic information on higher rejection trends, Top management decided to form a Cross-functional team including members from the Production, Quality Control, NPD (New Product Development), Process Improvement, Utility, Maintenance, Procurement & Account departments and asked them to resolve the higher rejection issue.

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Cross functional team conducted the meeting and reviewed the rejection data of Hair Styling Gel. Based on the rejection trend of the Product of Hair Styling Gel and discussion among members of Cross functional team, Project Charter (Table 1) was prepared.

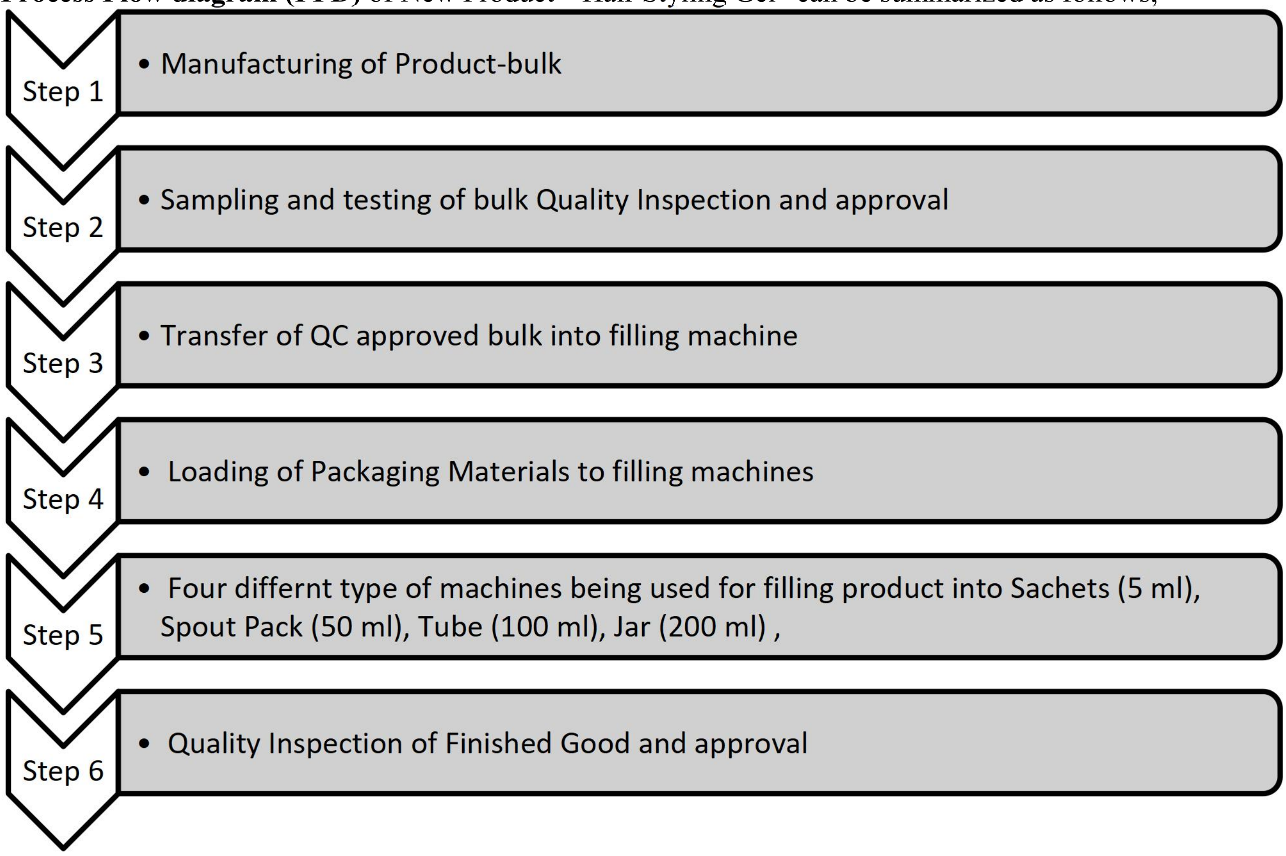
Tabel 1 : Project Charter

Project Objective	To reduce the rejection of Hair Styling Gel				
Problem Description	To reduce the rejection of the bulk of Hair Styling Gel from the current level 5.9% to 3.0 % (Benchmarking).				
Project Scope	Bulk product				
Six Sigma tools & techniques	DMAIC, Process flow diagram, Brainstorming, Cause and effect diagram, FMEA				
Cross Fucntional Team members	HOD-Production, HOD-Quality Control & Assurance, HOD-Utility & Maintenance, HOD-Procurement, Maintenance Engineer, machine operators.				
Project Plan	Define	Measure	Analyse	Improve	Control
	2 weeks	2 weeks	4 weeks	4 weeks	2 weeks

4.2. Measure Phase

The cross-functional team (CFT) studied each process of manufacturing, filling, and packing of new product "Hair Styling Gel". It was decided to schedule brainstorming sessions with HOD's and shop-floor members of all concerned functions - Production, Quality Control & Assurance, Utility & Maintenance and Procurement. CFT met weekly and conducted several brainstorming sessions to review and study each process step of the Process Flow Diagram (PFD).

Process Flow diagram (PFD) of New Product " Hair Styling Gel" can be summarized as follows;



During brainstorming sessions, various points / inputs were shared by all CFT members. All the inputs were grouped as per **4 M Methodology - Men, Machine, Method and Material** and mapped in "Cause and Effect" diagram.

4.3. Analysis Phase

In this phase detailed analysis was done on the outputs as derived from the Process Flow diagram of each step of the processing. Cross Functional team conducted brainstorming sessions with process owners of each

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processing step (Table 2) and discussed all possible causes that could result in higher bulk rejection. All those brainstorming sessions helped to develop "Cause and Effect Diagram"

Table 2: Processing steps considered for Cause and Effect Diagram

1) Batch Manufacturing
2) Quality Testing
3) Batch transfer from Manufacturing to filling section
4) Loading of packaging material to filling machine
5) Product filling into packaging material through different filling machines
   i. Sachets Filling Machine (M 1)
   ii. Spout Filling Machine (M 2)
   iii. Tube Filling Machine (M 3)
   iv. Jar Filling Machine (M 4)
6) Quality Inspection of Finished Goods

While conducting Cause and Effect diagram of each processing step of Hair Styling Gel, Cross functional team identified that three processing steps – "Quality testing, loading of packaging material to filling machine and Quality inspection of Finished goods" did not have any potential cause that could impact rejection of bulk product. However, rest all processing steps had significant numbers of potential causes. Cross Functional team summarized that total 106 potential causes (Tabel 3) were identified in rest all processing steps.

Table 3: List of identified causes which can result in higher rejections

Process Steps	**Total Causes identified**
Batch Manufacturing	10
Batch transfer to filling section	8
Sachet filling Machine (M 1)	15
Spout pack filling machine (M 2)	22
Tube filling machine (M 3)	25
Jar filling machine (M 4)	20
Quality Inspection of FG	6
Total	**106**

Practically, it was very difficult to work on all probable causes (106) and it would become long term activity to verify all causes and take corrective actions.

Therefore, it was decided to prioritize all 106 probable causes by implementing another important tool, **FMEA (Failure Mode Effect Analysis).**

FMEA is a qualitative and systematic tool that helps in identifying "What can go wrong" and "from where variation can come". FMEA also helps in finding the probable causes of failures and the likelihood of failures that can be detected before the occurrence

FMEA has three fundamental points which help in assessing the impact of any cause or problem:

1) Severity (SEV): severity of the effect on the process or product
2) Occurrence (OCC): frequency of the likelihood of occurrence of the problem
3) Detection (DET): how easily the problem can be detected -

While conducting FMEA of all above processes, it was decided to use a ranking between 1 and 10,
Where 1 = low and 10 = high for the severity, occurrence, and detection level for each of the failure modes. Finally, Risk Priority Number was calculated by multiplying ranking of all three criteria –severity, occurrence and detection.

RPN = SEV X OCC X DET

RPN = Risk Priority Number
SEV = Severity
OCC = Occurrence
DET = Detection

RPN values helps in identifying causes that have a high impact on a process or product. Based on an understanding about processes and historical data, it was decided to consider an RPN value greater than 70 as critical and need immediate action for a particular step and cause.

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After finalizing ranking criteria for SEV, OCC and DET, the cross-functional team conducted FMEA for all processes to validate and quantify impact associated with each cause. It would also help in narrow down 106 Nos of causes to critical and topmost priority Nos which can be worked upon.

Table 4 is an example of FMEA study conducted for "Tube filling machine (M 3) Operation".
During Cause-and-Effect analysis of Tube filling machine (M 3), total 21 causes were identified which had impact on higher rejections. While conducting "FMEA" study of "tube filling process" and following ranking criteria for SEV, OCC & DET, Risk Priority Number (RPN) is calculated for each cause.

Table 4: Summary : FMEA study conducted for "Tube filling machine (M 3) Operation"

Process Step	Process Description	Potential Failure Mode	Potential Effect(s) of Failure	SEV	Potential Cause(s) of Failure	OCC	Current Process Controls Detection	DET	RPN	Recommended Actions(s)	FPR	Target Completion Date
Step 1	Product transfer from Storage tank to machine hopper	Overfilling of product into hopper	Product spillage from the hopper	6	Malfunctioning of Level sensor	3	No control	5	90	Filling machine Start-up checklist to be updated	ABC	12/02/2024
Step 2	Initial Product rinse through filling nozzle	High variation in qty of product drained from standard	Loss of product qty	7	Non compliance SOP by Worker	4	No control	7	196	Calibrated Plastic beakers to be used to drain the required qty of product	KMD	12/02/2024
Step 3	Product fill volume setting	1) Filing m/c not set as per SOP 2) Product viscosity varies from standard 3) Air pressures drops 4) Fluctuation in weighing balance	1) Higher wastage of product during weight setting 2) Higher Viscosity can result higher wastage 3) Air pressure less than 5 bar unable to open filling valve and result high variation 4) Non calibrated weighing balance give higher wt. variation	8	1) Variation in filling piston displacement setting and operational error 2) Sticking loss due to higher viscosity of product 3) Variation in air supply 4) Non compliance of calibration SOP	4	1) Manual setting 2) Quality lab test report of viscosity 3)One Point Lesson (OPL) 4) No control	6	192	Engineering modification to control weight variation	ABC	24/03/2024
Step 4	Tube feeding	1) Machine setting with wrong parameters 2) Variation in the dimensions of the Tubes	1) Wrong machine setting of tubes result damages of tubes & wastages of product 2) Incorrect dimensions of tubes may create splashing of product into tubes and overall product loss	4	1) Lack of focus and negligence of the machine operator 2) Lack of process control at manufacturer of Tube	3	Random inspection by worker	6	72	1) On Job Training to workers 2)Discussion with Tube manufacturer to control dimensional variation in the Tubes	PKS	08/02/2024
Step 5	Product filling into Tubes	Variation in filled weight against the standard weight	1) Low filled weight in tubes result rejection of filled tubes 2) High filled weight in tubes result extra give away (EGA) and product loss	7	Variation in Piston displacement or Jamming impact opening of Rotating valve which causes low / high suction of product. It results filling weight low or high	4	One Point Lesson (OPL) for machine setting	6	168	1)On job training to workers for piston displacement setting 2) Engineering Solution to avoid piston jamming problem 3) Weight checking on hourly basis	KMD	08/02/2024
Step 6	Hourly check for filled tubes	Non calibrated weighing balance	Variation in filled weight	7	1) Incorrect reporting of filled weight 2) Non compliance of SOP of weighing balance daily verification	3	Standard Operating Procedure (SOP)	5	105	1).Daily verification of Weighing balance. 2) Provision of Automated Weighing balance with Audio/visual alarm for low and high weight	RKD	15/03/2024

4.4. Improve Phase

The improvement phase aims to identify remedial solutions for all the probable causes which got identified during the "analyze phase". During the Improve phase, developmental solutions are implemented after assessing the risks associated with their implementation.
During FMEA study, all the identified causes were analyzed for their potential failure mode and also quantified based as Risk Priority Number. Once again, the cross-functional team conducted brainstorming sessions with Production, Maintenance, Quality, and Utility team members and worked out a detailed action plan to complete the recommendations that were proposed during the FMEA study

Summary of FMEA of all Process Steps and Risk Priority Number (RPN)			
Process Steps	**Total Causes**	**Causes with RPN < 70**	**Causes with RPN >70**
Batch Manufacturing	10	8	2
Batch transfer to filling section	8	6	2
Sachet filling Machine (M1)	15	13	2
Spout filling machine (M2)	22	18	4
Tube filling machine(M3)	25	19	6
Jar filling machine (M4)	20	16	4

Quality Inspection of final Product	6	5	1
Total	**106**	**85**	**21**

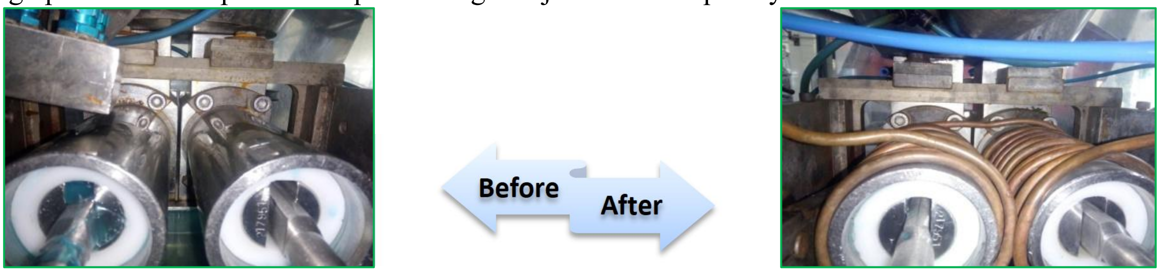
The FMEA study and RPN criteria helped to minimize the total causes from 106 to 21 causes that had an RPN greater than 70.
CFT (cross-functional team) reviewed all 21 causes and worked out solutions for each identified cause. Most of the causes were addressed by revising the working practices / Standard Operating Procedures (SOP) and minor modifications in the filling machines. Out of 21 causes, only three required major modifications to the machine. Therefore, the Production, Utilities, and Maintenance team innovated 3 Nos of “developmental solutions” to overcome identified causes.

Development of Solutions

Scope: Tube filling machine (M 3)

Problem:

In the peak of summer, when temperatures in the production zone rise above 35˚C, the product's viscosity typically decreases, resulting in a more liquid consistency. This alteration causes overflow issues, leading to the rejection of both the squeeze tubes and the product. Consequently, it became essential to pause tube feeding operations to implement required weight adjustments frequently

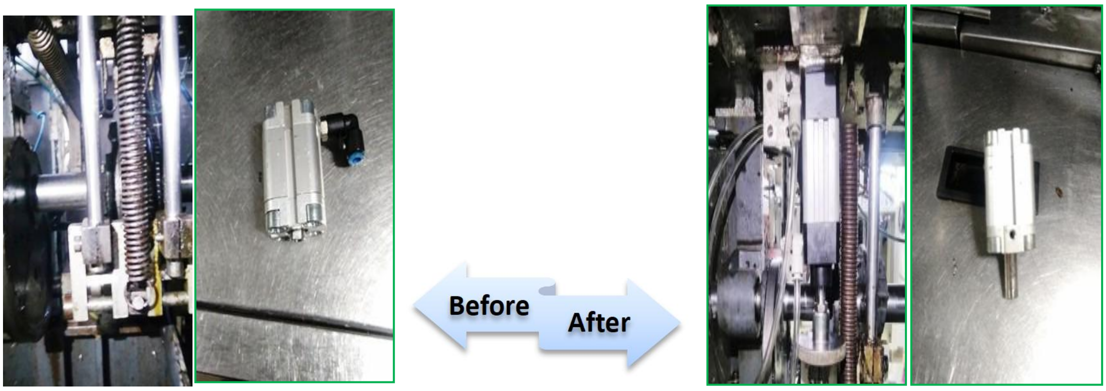


Solution:

The cross-functional team came up with the idea of integrating a copper coil within the cylinder for the purpose of cooling the product. to cool the product effectively. That measure was crucial in addressing the viscosity issues of the product. The copper coil configuration facilitated the circulation of chiller water to the cylinder, ensuring the nozzle remained cool, which successfully addressed the weight variation issue and eliminated the rejection of tubes and bulk product.

Scope: Tube filling machine (M 3)

Problem: In the event of unexpected electrical power failure, if the lifter remains elevated at the sealer, the tube could get stuck within the hot sealing burner, resulting in a minor halt of the machine and the rejection of the filled brunt tube



Solution:

One pneumatic piston was fixed in parallel to the "cam." In the event of an unexpected electrical power outage, the piston began to move the lifter assembly downwards immediately. It prevented the tube from becoming caught inside the hot sealing burner, hence eliminating the possibility of tube burn. By providing a pneumatic piston , "tube-burning issues" were avoided, and the rejection of the tube and bulk of the product was also eliminated completely.

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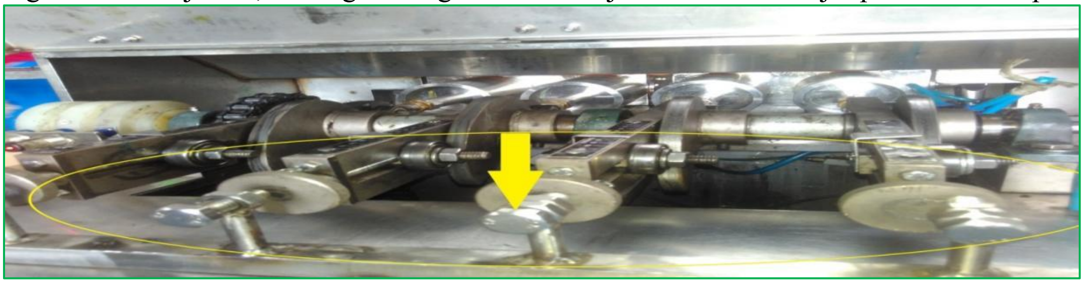
Scope: Jar filling machine (M 4)
Problem:
While filling the product, the piston was pushed forward by a cam and pulled back by suction. This mechanism allowed the weight of the product to push the cylinder back, which increased the bulk weight, resulting in additional bulk product being filled into the jar. Occasionally, due to overfilling, the product would smear on the jar's rim. This caused inadequate induction sealing of the jar's brim. As a result, jars with poor sealing had to be rejected, leading to a higher overall rejection rate of the jar pack and bulk product..



Solution:
On the Jar filling machine (M4), a stopper mechanism was affixed to the machine to prevent the piston from reverting to a backward position, which regulated the filling of additional product quantity in the Jar pack.That modification was intended to prevent any rejection of the Jar due to being overweight or product in the sealing area. It helped in achieving a significant reduction in the overall rejection of both the Jar pack and the product.

4.5. Control Phase

The control phase is the last step of the DMAIC methodology, focusing on ensuring that the improvements made during the Improve phase are maintained over time. In the improvement phase, all corrective actions were made available and implemented across all lines. To ensure that all implemented improvements were functioning effectively and efficiently, the cross-functional team conducted proper monitoring of all improvement points. This included regular on-the-job training (OJT), audits of adherence to Standard Operating Procedures (SOP), reviews of Engineering modification checklists, and compliance audits of Preventive maintenance for all filling machines.
After the successful implementation of the recommendations of the FEMA study, there was a significant reduction in the rejection percentage and within 4 months, it was reduced from 5.9 % (Dec’23) to 3.1% (April’24).

5. Results:

The prime initial objective of this case study was to reduce the product bulk rejection from 5.9 % to 3.0 % by implementing the basic tool of Six Sigma. Therefore, DMAIC methodology was adopted to understand, identify, and resolve the higher rejection percentage issue. Before the implementation of DMAIC approach, the product-bulk rejection percentage was on an increasing trend and went up to 6.1% by Jan’24.
After the successful implementation of the DMAIC framework, product-bulk rejection got reduced from 6.1% (Jan’24) to 1.8 % (June’24) as described in Table 5. It means before implementing DMAIC, the average (Aug’23 to Dec’23) bulk-product rejection was 4.74% and after Control phase of DMAIC process, it got reduced to 2.5% (average of May’24 & June’24), that was approx. 56.75% reduction.
The case study was initiated with the prime objective of decreasing the percentage of Product bulk rejection. However, throughout the implementation phases of the DMAIC framework, various additional operational advantages were realized. The main focus during the 'Improve stage' was to rectify the processes in a manner that would either eliminate or significantly reduce the Product bulk rejection. Once all proposed improvements were carried out, there was a reduction in bulk rejection, which also resulted in various other tangible benefits, such as a significant reduction in two different types of packaging materials- 1) Tubes & 2) Jars, and also marked considerable increase in Batch Yield %.

Tube (Packaging material) rejection reduced by 65.7% :
After the execution of the DMAIC methodology, the rejection rate for 'Tube (packaging material)' decreased by 65.7%. Initially, before the DMAIC methodology was put into practice, the rejection percentage for 'Tube

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(packaging material)' was 1.02%. However, after the Control phase of the DMAIC process, this figure was lowered to 0.35% (average of May 2024 and June 2024). Tabel 6

Jar (Packaging material) rejection decreased by 51.92 % :

Before the adoption of the DMAIC methodology, the jar rejection rate was recorded at 0.52% (average from August 2023 to December 2023). After the successful implementation of the Control phase, this rate fell to 0.25% (average for May 2024 and June 2024). This reflects a decrease of 51.92% in jar rejection percentage. Table 7.

Batch Yield improved by 4.04 % :

Upon implementing the DMAIC methodology, the Batch Yield percentage improved by 4.02%. Initially, before the application of the DMAIC methodology, the batch Yield of Hair Styling Gel product was recorded at 93.52% average from August 2023 to December 2023) and after the Control phase of the DMAIC process, it was increased 97.3% (average of May 2024 and June 2024)

Table 5: Product Bulk Rejection % - Before and After Implementation of DMAIC Methodology

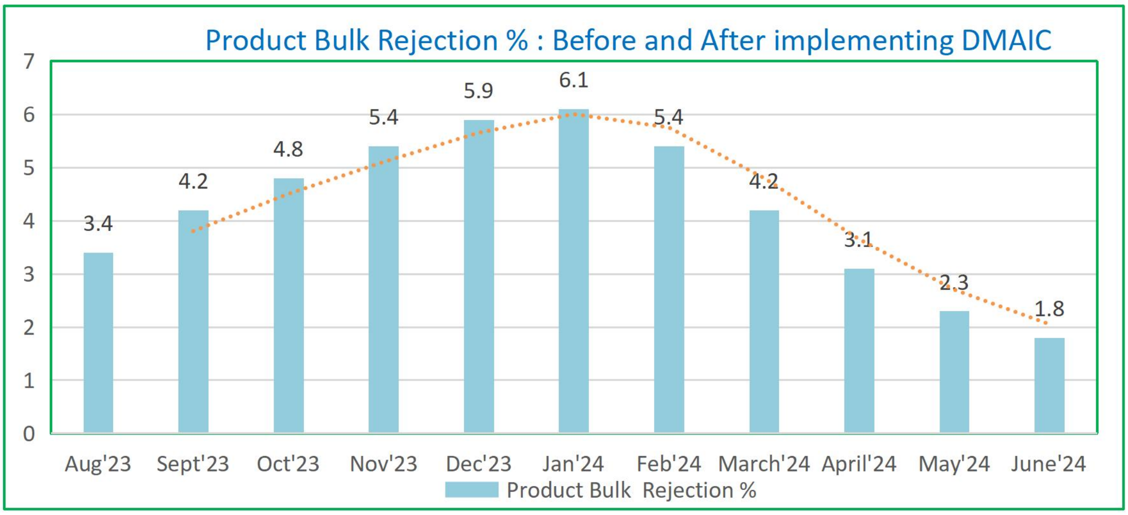


Table 6: Tube Rejection % - Before and After Implementation of DMAIC Methodology

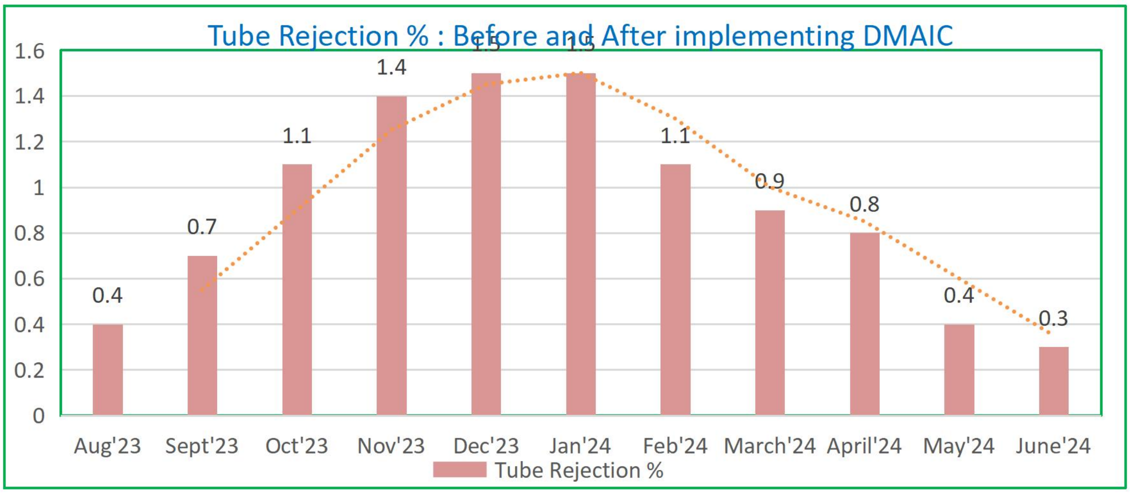


Table 7: Jar Rejection % - Before and After Implementation of DMAIC Methodology

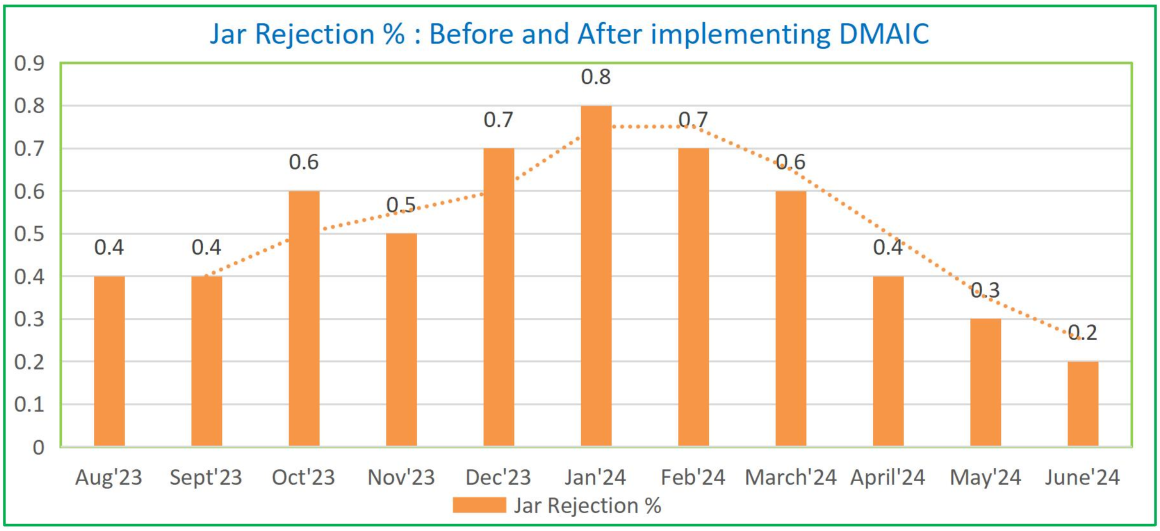
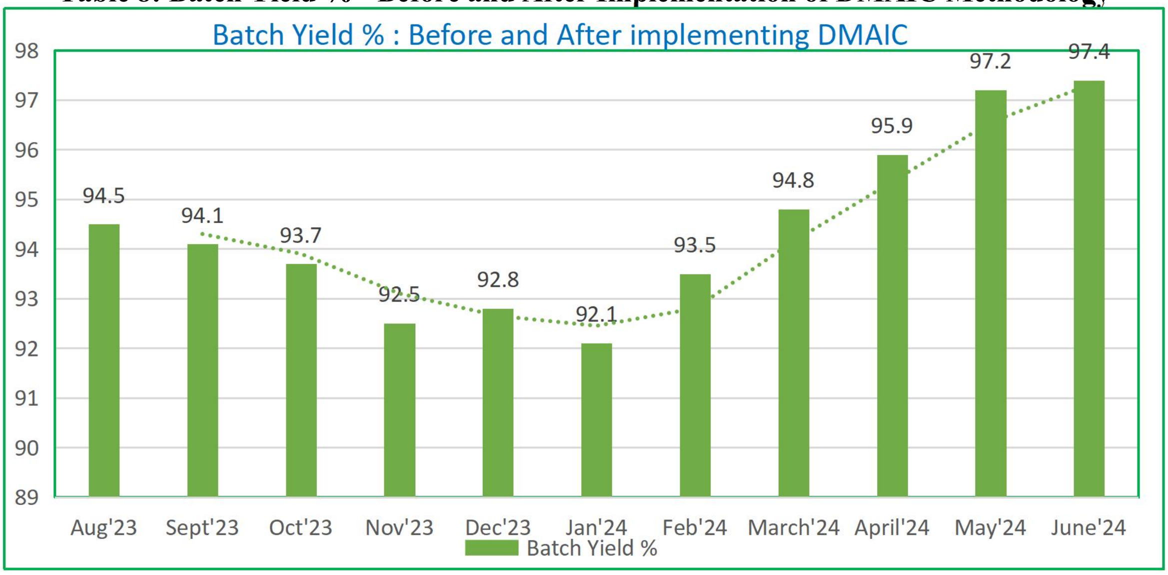


Table 8: Batch Yield % - Before and After Implementation of DMAIC Methodology



6. Conclusions and recommendations:

In general, several methodologies are being practiced for identifying the root cause of the problems, however DMAIC is one of the most effective frameworks of Six Sigma methodology, that is used in manufacturing and service sectors. identify the causes of variations in processes.

The principal objective of the case study was to apply the DMAIC framework to minimize the product bulk rejection rate during the production of a newly launched product in cosmetic manufacturing facilities.

In the define phase, a Cross Functional team was formed, and a Project charter was established with specific timelines and a well-defined problem statement. In the measure phase, extensive process mapping was executed through a Process flow diagram, and all necessary data was collected. In the analyze phase, a Cause and Effect diagram was constructed, and all potential causes were identified. An FMEA study was implemented to assess all potential failures, and a risk evaluation was conducted. According to the RPN (Risk Priority Number) criteria, all the causes were narrowed down.

In the Improve phase, actions were initiated for each cause that had an RPN value above 70. Most improvements were accomplished through slight modifications in process flow, working practices, and On-Job training. Only three improvements required alterations to the filling machine. During the control phase, the project team monitored compliance with all modifications and action plans to ensure strict adherence.

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References:

1. A. Kumaravadivel, U. Natarajan, (2013), Application of six sigma DMAIC methodology to sand casting process with response surface methodology. Int. J. Adv. Manuf. Technol. 69, 1403–1420.
2. Barbosa, G. F., de Carvalho, J., & Pereira de Souza, C. H. (2014). Deployment of a laser projection solution for stripes plotting based on Six Sigma DMAIC methodology applied to aircraft painting shop. Production & Manufacturing Research, 2(1), 697–711. https://doi. org/10.1080/21693277.2014.943432.
3. C. Sahay, S. Ghosh, P.K. Bheemarthi, (2011), Process improvement of brake lever production using DMAIC. University of Hartford, Paper No. IMECE 2011-63813, ASME, New York, 801–826.
4. De Mast, J., & Lokkerbol, J. (2012), An analysis of the Six Sigma DMAIC method from the perspective of problem solving. International Journal of Production Economics, 139(2), 604-614
5. Erbiyik, H., & Saru, M. (2015), Six Sigma Implementations in Supply Chain: An Application for an Automotive Subsidiary Industry in Bursa in Turkey. Procedia-Social and Behavioral Sciences, 195, 2556-2565
6. Firka, D. (2010), "Six Sigma: an evolutionary analysis through case studies", The TQM Journal, Vol. 22
7. No. 4, pp. 423-434.
8. Girmanová, L., Šolc, M., Kliment, J., Divoková, A., & Mikloš, V. (2017). Application of Six Sigma using DMAIC methodology in the process of product quality control in metallurgical operation. Acta Technologica Agriculturae, 20(4), 104–109. https://doi.org/10.1515/ ata-2017-0020
9. H.C. Lin (2004), The measurement of a process capability for folded normal process data. Int. J. Adv. Manuf. Technol. 24, 223–228
10. Hill, J., Thomas, A. J., Mason-Jones, R. K., & El-Kateb, S. (2018). The implementation of a Lean Six Sigma framework to enhance operational performance in an MRO facility. Production & Manufacturing Research, 6(1), 26–48.
11. Hung, S. H., Wang, P. C., Lin, H. C., Chen, H. Y., & Su, C. T. (2015). Integration of value stream map and healthcare failure mode and effect analysis into Six Sigma methodology to improve process of surgical specimen handling. Journal of Healthcare Engineering, 6(3), 377–398. https://doi.org/10.1260/ 2040-2295.6.3.377
12. J. Tong, F. Tsung, B. Yen, 531 (2004), A DMAIC approach to printed circuit board quality improvement. Int. J. Adv. Manuf. Technol. 23, 523
13. J.W. Locke, J.M. Kowalewski Jr. (1994) Statistical measurement control, quality and statistics, Total Quality Management, ASTM STP 1209.
14. Kuptasthien, N., & Boonsompong, T. (2011, September). Reduction of tombstone capacitor problem by Six Sigma technique: A case study of printed circuit cable assembly line. In Quality and Reliability (CQR), 2011 IEEE International Conference on (pp. 546-550). IEEE
15. Larsson, T. S., Ronnback, A., & Vanhatalo, E. (2022). Integrating mixture experiments and Six Sigma methodology to improve fibre-reinforced polymer composites. Quality and Reliability Engineering International, 38(4), 1–22. https://doi.org/10.1002/ qre.3067
16. Lee-Mortimer, A. (2007), "Leading UK manufacturer probes the potential of Six Sigma", Assembly Automation, Vol. 27 No. 4, pp. 302-308.
17. L.M. Gaikwad, S.N. Teli, V.S. Majali, U.M. Bhushi, (2016), An application of six sigma to reduce supplier quality cost. J. Inst. Eng. (India) Ser. C. 97(1), 93–107
18. Ng, K. C., Chong, K. E., & Goh, G. G. G. (2014, December). Improving Overall Equipment Effectiveness (OEE) through the six-sigma methodology in a semiconductor firm: A case study. In Industrial Engineering and Engineering Management (IEEM), 2014 IEEE International Conference on (pp.833-837). IEEE
19. Osore, E. A. E., Ogola, J. M., Ogot, M. M., & Guo, J. (2020). Prospects of diffusion as a Six-Sigma automation in enhancing continuous improvement of cane juice extraction in Kenya. Cogent Engineering, 7(1), 1733737.
20. Prashar, A. (2014). Adoption of Six Sigma DMAIC to reduce cost of poor quality. International Journal of Productivity and Performance Management, 63(1), 103-126.
21. Raman, R. S., Basavaraj, Y., Prakash, A., & Garg, A. (2017, February). Analysis of six sigma methodology in exporting manufacturing organizations and benefits derived: A review. In Computational Intelligence & Communication Technology (CICT), 2017 3rd International Conference on (pp. 1-5). IEEE.

22. Sajjad, M. H., Naeem, K., Zubair, M., Usman, Q. M., Khattak, S. B., Omair, M., Nawaz, R., & Guo, J. (2021). Waste reduction of polypropylene bag manufacturing process using Six Sigma DMAIC approach: A case study. Cogent Engineering, 8(1), 1896419, doi.org/10.1080/23311916.2021.1896419
23. Schmidt, A., Sousa-Zomer, T. T., Andrietta, J. M., & Cauchick-Miguel, P. A. (2018). Deploying Six Sigma practices to general electric subsidiaries in a developing economy: An empirical analysis. International Journal of Quality and Reliability Management, 35(2), 466–462. https://doi.org/10. 1108/IJQRM-09-2016-0155
24. Schroeder, R. G., Linderman, K., Liedtke, C., & Choo, A. S. (2009). Six Sigma: Definition and under Lying theory. Quality Control and Applied Statistics, 54(5), 441-445.
25. S.N. Teli, L.M. Gaikwad, V.S. Majali, U.M. Bhushi, V.V. Surange, (2013), Cost of poor quality analysis for automobile industry: a case study. J. Inst. Eng. India Ser. C 94(4), 373–384
26. Srinivasan, K., Muthu, S., Devadasan, S.R. and Sugumaran, C. (2016), “Six Sigma through DMAIC phases: a literature review”, International Journal of Productivity and Quality Management, Vol. 17 No. 2, pp. 236-257.
27. Soundararajan, K. and Reddy, K.J. (2020), “Productivity and quality improvement through DMAIC in SME”, International Journal of Productivity and Quality Management, Vol.31. No. 2, pp. 271–294.
28. Tjahjono, B., Ball, P., Vitanov, V.I., Scorzafave, C., Nogueira, J., Calleja, J., Minguet, M., Narasimha, L., Rivas, A., Srivastava, A., Srivastava, S. and Yadav, A. (2010), “Six Sigma: a literature review”, International Journal of Lean Six Sigma, Vol. 1 No. 3, pp. 216-233
29. Thomas, A. J., Francis, M., Fisher, R., & Byard, P. (2016). Implementing Lean Six Sigma to overcome the production challenges in an aerospace company”. Production Planning & Control, 27(7–8), 591–603 https://doi.org/10.1080/09537287.2016. 1165300
30. Wong, W. Y., Yu, S. W., & Chean, S. L. (2019.) “Pre-decision criteria for successful information technology project implementation: Six sigma practices and approach.” 2019 IEEE 7th Conference on Systems, Process and Control (ICSPC), 178–183.
31. Y.D. Hwang, (2006), The practices of integrating manufacturing execution system and six sigma methodology. Int. J. Adv. Manuf. Technol. 30, 761–768