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Integration of Six Sigma with Total Quality Management for reducing waste and improving quality in the Beverage Industry

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Abstract

The combination of Six Sigma with Total Quality Management (TQM) has emerged as an effective technique for increasing operational efficiency and reducing faults, particularly in the beverage industry. This study looks at how Six Sigma methodologies, specifically DMAIC (Define, Measure, Analyze, Improve, Control), Cause and Effect (CE) analysis, the 5W2H framework, the PDCA (Plan, Do, Check, Act) cycle, and Control Charts, can be used within the TQM framework to reduce defects significantly. The study examines production data both before and after these approaches are put into practice using a quantitative approach. The results show a significant decrease in defects, proving that Six Sigma tools combined with TQM techniques efficiently optimize workflows and enhance product quality. Production processes were significantly improved by the application of PDCA and DMAIC cycles, and CE analysis and 5W2H highlighted important areas for development. Throughout the deployment, control charts played a crucial role in monitoring and preserving process stability. Despite those positive findings, the study recognizes many shortcomings such as the difficulties in incorporating Six Sigma into current organizational designs and the substantial resources needed for effective execution. The outcomes highlight how crucial an effective support system and the commitment of senior management are to attaining long-term gains. Future studies should examine how sustainable the defect reduction made possible by this integrated approach is over the long run and whether it can be applied to other areas of the food and beverage industry. Further research is necessary to fully understand the possibilities of utilizing advanced technologies like artificial intelligence and machine learning to improve defect minimization processes.

Keywords
Defect Reduction, Six Sigma, TQM, DMAIC, Quality Control, Beverage Industry, DPMO, Control Charts.

1. Introduction
Six Sigma is a data-driven technique developed in the manufacturing industry to reduce variations, increase efficiency, and identify process flaws. It uses the DMAIC framework to optimize operations, aiming for near-perfection with 3.4 flaws per million chances. Total Quality Management (TQM) is a management approach that integrates quality into all aspects of an organization, focusing on customer satisfaction and continuous improvement. It differs from Six Sigma, which is data-driven and project-focused. TQM incorporates process-centric thinking, employee participation, and customer focus, often resulting in long-term quality gains. The beverage industry requires a combination of Six Sigma and Total Quality Management (TQM) to maintain quality and operational efficiency. This integration can reduce errors, optimize workflows, and enhance product quality, promoting cost savings, increased productivity, and a competitive market while meeting customer expectations and regulatory standards. Every company wants to stay in business and make a profit, so it works to minimize the amount of defective products it produces while maintaining quality as competition increases. As a result, producers of soft drinks and other goods aim to please consumers by improving the quality of their products. (Elfanda 2021)

Beverage companies today face competition in the market. However, due to a few issues, it isn't quite comfortable. The main flaws found in soft drink producers include dirty environments, leaky bottles, and mold. (SM 2020)
In the beverage industry, Preforms are the main source of defects. Must prioritize cutting down on Preform waste. Because of this, this task can be perfectly finished by using extremely powerful tools. For defect reduction, Six Sigma is recommended for a number of reasons. Variation is the Six Sigma discipline's main focus. more especially, the management and reduction of process variance. As a best practice, apply Six Sigma to attain quality (R. Anderson,2006). For further reasons, TQM is an excellent choice for decreasing faults. TQM focuses a lot of emphasis on process improvement rather than process quality inspection. Because of this, it is not only not essential to hire a team of quality assurance specialists, but it also reduces the time required to fix errors (R. Anderson 2006). The beverage sector is a competitive market. Once more, the planned production is not as profitable as anticipated. The goal of the quality department is to produce in huge quantities while making the most profit. In the end, control charts meet the requirement of minimizing waste. When production is under control, the curve remains within the range of the limit. It clearly shows how much of a drop is needed to keep the value between the LCL and UCL limits (Md. Zahid Hasan 2018)

The beverage industry faces challenges in managing various waste types, necessitating a set standard value for each type to maintain waste values within tolerances. High volume garbage must exceed the threshold, ensuring no upper or lower control limit is exceeded. (Md. Zahid Hasan 2018) Control charts are used in this study to measure the degree of quality, and TQM and Six Sigma are applied to reduce defects. If the waste values fall between the upper and lower control limits, they are equivalent to the standard waste value. As a result, it is a relevant research topic and a resolution to a major problem facing the beverage industry.

Reducing waste is a prevalent issue in the beverage sector. It takes some waste data to reduce waste. Waste data is gathered from Bangladesh's XYZ Beverage Industry Ltd., a beverage industry. A major force in the beverage production industry, XYZ Beverage Industry Ltd. produces a variety of soft drinks and water bottles, as seen in Figure 1 (Foodstuff-Africa). Upon recognizing the need for waste reduction and process optimization, the organization launched an extensive quality improvement program incorporating TQM and Six Sigma methodologies. XYZ Beverage Industry implemented a waste reduction plan by collecting data from every stage of production, including procurement, manufacturing, packaging, and distribution. They identified significant waste, particularly in filled bottles and preform trash, using Six Sigma techniques for targeted improvements.

Figure 1. The production process of XYZ Beverage Industry Ltd

This essay discusses the effectiveness of combining TQM tools with Six Sigma to improve quality and reduce faults. It contrasts Six Sigma's approach to quality problems and defects, and explores other Six Sigma topics like DMAIC, Control Charts, and Sigma level. Several approaches can be taken to solve the issues. Obtaining waste data from the beverage industry proved to be challenging. Four different types of production lines have a lot of waste that needs to be eliminated (R. Anderson, 2006). It is necessary to determine the root cause using the fishbone diagram. A possible solution for altering the production process to cut waste is the 5W2H method. A standard number of wastes is used to determine the least quantity of waste. One of the control limit's most potent features is the ability to compare the waste limit and the actual limit. Those graphs can be used by the industry to assess whether waste numbers are under control. (Jirasukprasertm 2012)

Examine the effects of TQM and Six Sigma both before and after each method was put into practice. Create a TQM wheel to increase customer satisfaction by involving staff members in the process, as control chart values have an impact on quality (Md. Zahid Hasan, 2018). This study highlights the benefits of using Six Sigma and Total Quality Management (TQM) techniques to address quality-related issues, promoting holistic management, customer satisfaction, and ongoing development, ultimately leading to long-term commercial success in a competitive environment. (Md. Zahid Hasan 2018)

1.1 Objectives

To highlight how TQM and Six Sigma techniques integrate when it comes to handling quality-related problems in bottling industries.
To figure out a waste limit and maintain the waste value inside the limit, use control charts.
To provide a solid framework for the methods by identifying the root cause and offering a solution that can be used when a quality-related problem occurs in the sector.

2. Literature Review

2.1 Introduction

The beverage industry encompasses a diverse range of sectors, from raw material processing to final packaging. Ensuring quality throughout this complex process is essential, as the industry faces multiple challenges, particularly in the bottling sector. Issues such as Preform waste, water waste, and bottling defects are significant concerns that impact efficiency and product integrity. Quality, as defined by Goetsch, Davis, and Yamit, is a dynamic condition that involves meeting expectations across products, services, human factors, processes, and the environment. Addressing these challenges is crucial for maintaining high standards within the industry.

2.2 Affect Estimation

Khwaja Mohinuddin SM (SM, 2020) focuses on utilizing Six Sigma to reduce defects and raise quality in the beverage sector. Through the use of TQM, the number of product defects was practically cut in half. Waste management (Hassan, 2013), Taguchi Loss function (Chen 2014), and SIPOC (Vanany 2020) could all be used in various research projects. They are using their tools to minimize defects and raise quality, as the next section discusses. Again Md. Zahid Hasan (Md. Zahid Hasan* 2018) applied control charts to satisfy the need for reducing waste.

2.3 Active Learning Framework

Elfanda (Elfanda 2021) works with Six Sigma to reduce defects. The goal is to find and fix the majority of damage caused to minimize the quantity of defective or damaged items that arise throughout the production process. In addition, the article highlights the significance of product quality in the souvenir business, especially in regions with natural tourist attractions, as it is essential to outperforming rivals and expanding product marketing to different places. DMAIC is the most common useful tool of the Six Sigma process. There are also many other tools of Six Sigma. But DMAIC is the most effective. The DMAIC approach, which consists of five stages, is a regularly used statistical tool that is used in this study to find the aspects that most determine improving the quality process and will generate profits (Elfanda 2021).

The three quality management theories—Total Quality Management (TQM), Six Sigma, and Lean—are compared and contrasted in this paper. To assess and analyze each idea, Roy Andersson et. al. (Andersson 2006) conducted a case study, a literature review, and in-person interviews. Although the three ideas are very similar, they also have significant key differences, particularly in terms of their central theories, methods, and points of critique. Roy Andersson et. al. (Andersson 2006) argues that while the Lean concept differs slightly from TQM and Six Sigma, organizations can still benefit from adopting all three ideas because they are complementary. The study serves as a foundation for more research in this area and offers advice to businesses regarding the applicability and characteristics of quality ideas (Andersson 2006).

The DMAIC technique is used by Ploytip Jirasukprasert (Jirasukprasert 2012) to evaluate faults, identify their root causes, and offer an approach for their reduction. The number of defective gloves produced was affected by the temperature and speed of the conveyor, according to the analysis done using Six Sigma and DMAIC. The temperature of the oven and the speed of the conveyor were statistically correlated with defects, and their optimum values needed to decrease or eliminate defects were defined using the design of experiments (DOE) and two-way analysis of variance (ANOVA) approaches (Jirasukprasert 2012). The "leaking" glove fault was reduced by nearly 50% as a result shown in Figure 2.

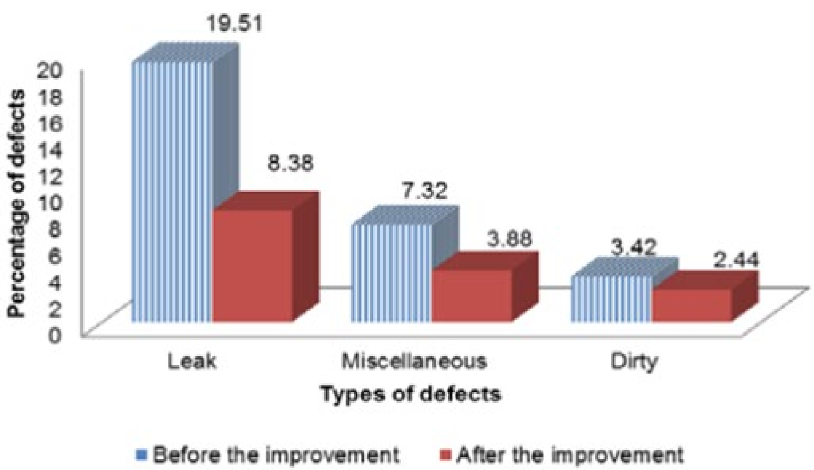

Figure 2. “Before and after” states of conducting the Six Sigma

This allowed the organization study lower its defects per million opportunities (DPMO) from 195,095 to 83,750 and raise its Sigma level from 2.4 to 2.9 (Jirasukprasert 2012). Condé, G.C.P. (Conde 2022) mentions that Six Sigma is a project-driven strategy and its first adoption was in 1987 by Motorola resulting in more than 10 billion dollars in savings. Since then, it has spread over many areas, including finance and health. The research identifies defects in die casting and machining processes, affecting mold temperature, metal, and second-stage injection speed. Fixation methods affect machining flaw frequency. Solutions reduced defect incidence, increasing the sigma level from 3.4 to 4. (Conde 2022). The research paper analyzes the use of efficient quality tools to lower the part defect rate in an electrical parts manufacturing unit and discusses the problem of faulty parts in manufacturing. To develop high-quality products at each level of manufacturing, Raja Sreedharan V. et. al. concentrate on the primary data gathered from the XYZ electric manufacturer and employ quality initiatives like Total Quality Management (TQM) and Lean Six Sigma (LSS).

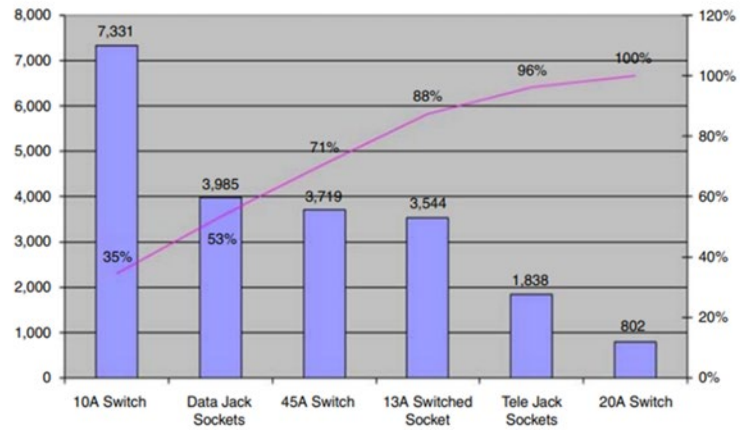

Figure 3. Pareto chart for defective products.

Lean Six Sigma (LSS). According to Raja Sreedharan V. et. al, implementing TQM and LSS in manufacturing can eventually lower the customer return rate to 1,000 PPM from its current 1,300 PPM level. Sreedharan shows in Figure 3. a pareto chart for defective products. The study, which can also apply to other types of items, is particularly concentrated on a specific kind of switch product. Only 88 percent of the defective items have been assessed, and in order to eliminate more faults, the remaining defective products will be analyzed using the same methodology (v, 2018).

Muslim Diekola et. al. (Diekola 2021) discusses the relationship between sustainability and TQM standards in Malaysia's food and beverage sector. A survey questionnaire was used in the study to collect data from 303 companies. Results show that a positive and significant impact on sustainability can be achieved through the effective implementation of continuous process improvement, benchmarking, quality assurance, service design, and information and analysis. Additionally, the study divides sustainable performance into three categories: environmental, social, and economic. Policy and decision-makers in the sector can use the study's suggested model, and practitioners can use it to put important policies into effect on the road. The study demonstrates how crucial institutions and backup plans are to any effective strategy practice that uses TQM to improve sustainable performance (Diekola 2021). To comprehend the connection between TQM practices, sustainability, and organizational performance, the study puts forth a conceptual model researched by Asif Nawaz Wassan et. al (Wassan 2022).

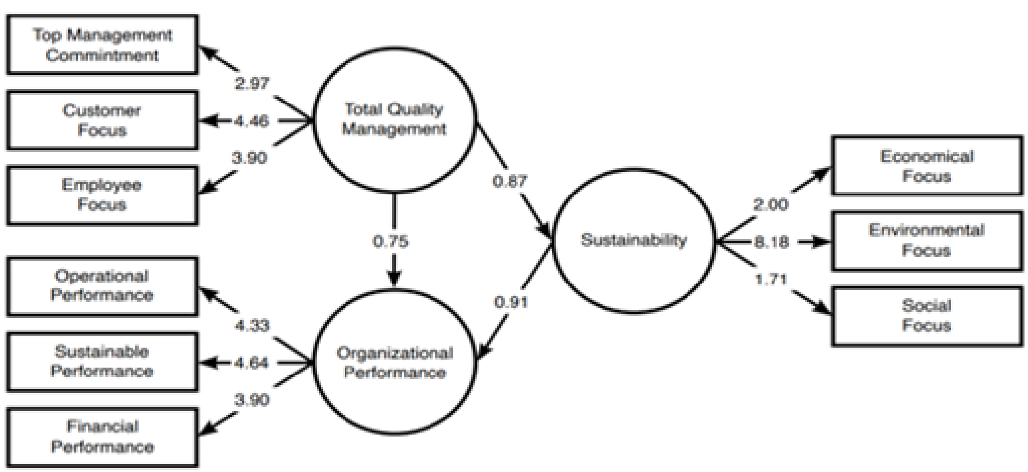

Figure 4. Research Framework

A questionnaire survey was used to gather the data, and factor analysis and confirmatory factor analysis (CFA) was used to analyze it. The results point to the benefits of TQM and sustainability for organizational performance, and a framework was developed to show how important TQM, sustainability, and organizational performance practices relate to one another. A research framework is shown in Figure 4. The study highlights the significance of sustainability and total quality management (TQM) techniques in accomplishing corporate goals and objectives in the industrial sector (Wassan 2022).

Muhammad Fatah (Fatah 2022) analyzes in his paper the application of Six Sigma, a potent methodology, to raise the sigma level and enhance product quality in the food sector. The case study is on PT XYZ, a well-known FMCG company in Indonesia. The packaging stage of the production process was found to be challenging. To provide solutions and lower the incidence of empty outer packaging, the Six Sigma sub-methodologies DMAIC and DMADV were applied (Fatah 2022). The study's objectives are to increase the value of the sigma level and reduce corporate losses brought on by ethical and material problems. This paper offers valuable perspectives for scholars investigating quality management, professionals operating in the manufacturing industry, and anybody with an interest in enhancing quality (Fatah 2022).

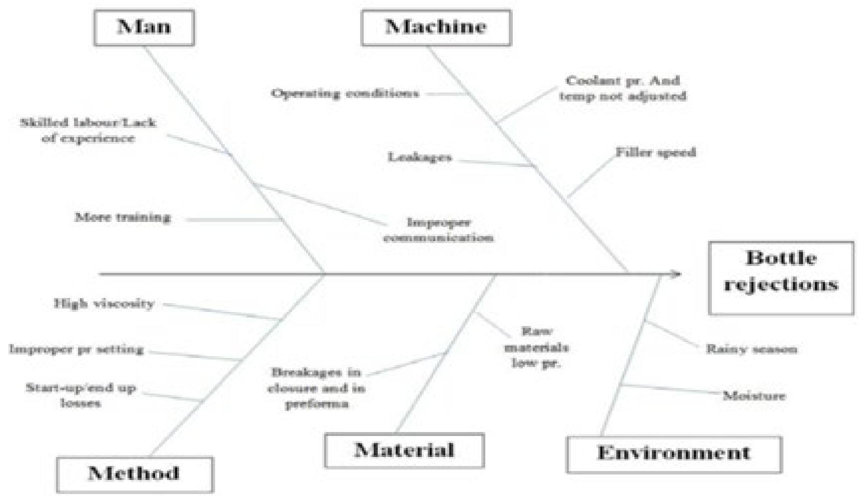

Figure 5. Cause and Effect Diagram for Bottle Defects

Khwaja Mohinuddin SM (SM 2020) highlights the several quality problems that the industry faces and offers Six Sigma methods for solving them. The industry's primary tools and methods include control charts, cause and effect diagrams, and Pareto charts. A general fishbone diagram for bottling flaws is also provided in Figure 5. The study concludes that Six Sigma is a crucial strategy for industry quality improvement. Data charts based on DPMO from the table are used to gather sigma level values, in addition to DPMO and sigma levels assessed to demonstrate the increase in quality. To reduce halal food defects and enhance compliance in the food business, Iwan Vanany et al. (Vanany, 2020) suggest a Six Sigma (HSS) framework that is based on halal. It is divided into five parts based on the DMAIC approach. The root cause analysis, Pareto diagram, SIPOC tools and improvement process flows are among the tools utilized in the proposed model. A case study in the chicken meat industry is also included in the article to verify and test the suggested framework. Figure 6 Shows the high-level SIPOC and the flow of food processing.

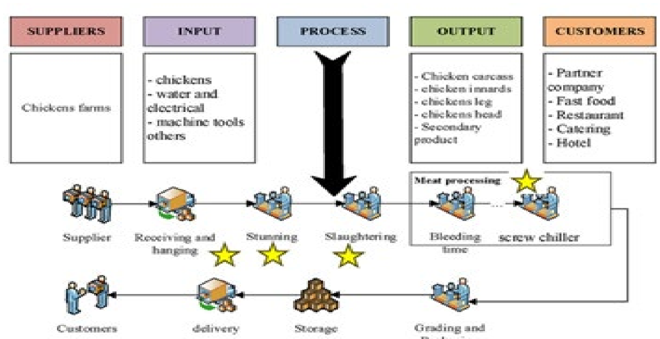

Figure 6. The high-level SIPOC and the flow of food processing

The Taguchi loss function is discussed by Joseph C Chen (Chen 2014) as well and the Six Sigma DMAIC methodology is applied to the metal casting industry to identify and solve major problems in the green sand-casting process. The goal is to decrease the defect rate from 31% to 4%. The case study demonstrates step-by-step implementation, focusing on minimizing losses, improving processes, and reducing defects.

According to Md. Zahid Hasan (Md. Zahid Hasan 2018), the foundation of organizational excellence is total quality management, which provides a road map for improving productivity and lowering errors. TQM crosses boundaries and promotes a culture of quality and innovation in businesses of all sizes, from little startups to large conglomerates. Even if achieving zero faults may not be easy, TQM is a reliable ally that helps companies succeed in the long run and satisfy customers. Control charts are an essential part of any TQM professional's toolkit. Control charts offer important insights into the performance and stability of processes by graphing data points across time. Control charts are essential tools in the Total Quality Management system for promoting fault prevention and continuous improvement. Organizations may identify deviations from intended standards instantly by setting control limits based on past data and process capabilities (Md. Zahid Hasan 2018).

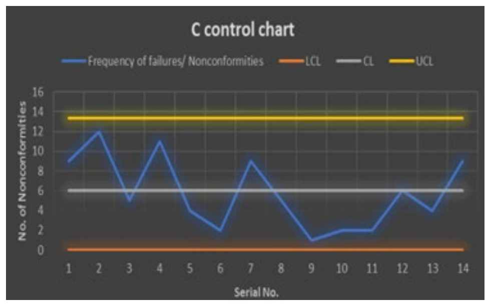

Figure 7. C control chart of crackers manufacturing before methodology.

The Plan-Do-Check-Action (PDCA) approach is used in Fredy's (Sumasto 2023) research article to eliminate potential product faults in the automobile component business. The study, which concentrated on the creation of SLJ 91 parts, was carried out in an Indonesian company that makes automobile components (Sumasto 2023). The PDCA method was used to pinpoint the source of errors, put improvements to the system into place, analyze their effects, and standardize them for ongoing maintenance. According to the study, SLJ 91 goods had a defect rate reduction of 12.7% to 8% and a dent defect reduction of 7.8% to 5.3%. The use of control charts and regular machine maintenance to prevent problems is also covered in the article (Sumasto 2023).

According to Hassan's (Hassan 2013) papers, the plant's performance is compared in the study between its pre- and post-implementation state for the suggested waste reduction strategies. There were gains in sigma levels, waste, yield, and Defects Per Million Opportunities (DPMO). To rank the sources of waste, the LSS approach was connected to the Analytic Hierarchy Process (AHP). To improve the methodology's efficacy and enable some simplicity of use in the practical field, the goal was to utilize an analytical approach to judge the influence of the waste sources on the amount of waste (Hassan 2013).

3 Methodology

3.1 Introduction:

The research method follows Six Sigma methods with TQM to investigate the main cause of defects and improve quality. Six Sigma is a system that has a great impact on the industry to make a business successful by setting up a benchmark on how a production process works and controlling the desired quality. Whereas TQM is a growing system of tools and training techniques to fulfill customer satisfaction by improving quality.

3.2 Working Principle:

Six Sigma (6σ) is a set of methods and equipment for process improvement. Six Sigma contains DMAIC, which stands for Define, Measure, Analyze, Improve, and Control. Total quality management (TQM) is a management method that focuses on long-term success through customer satisfaction. TQM has some tools like Checklists, Histograms, Scatter diagrams, Pareto charts, and Fishbone Diagrams. With the collaboration of these tools, Six Sigma and TQM can easily reduce defects and improve quality. It is now breaking down each phase of the DMAIC process.

3.2.1 Define:

Define is the first step in the DMAIC process, which involves identifying the issue and organizing it. The objectives of Define are to fully understand the project, recognize the issue, and come up with a solution. The reason for choosing a soft drink company is that there are common defects like yield or quality issues. To solve these issues, we need to understand the supply chain of these processes. The quality control unit is the most important link in the supply chain. They experience some challenges in their section. Figure 8. shows supply chain of the beverage industry.

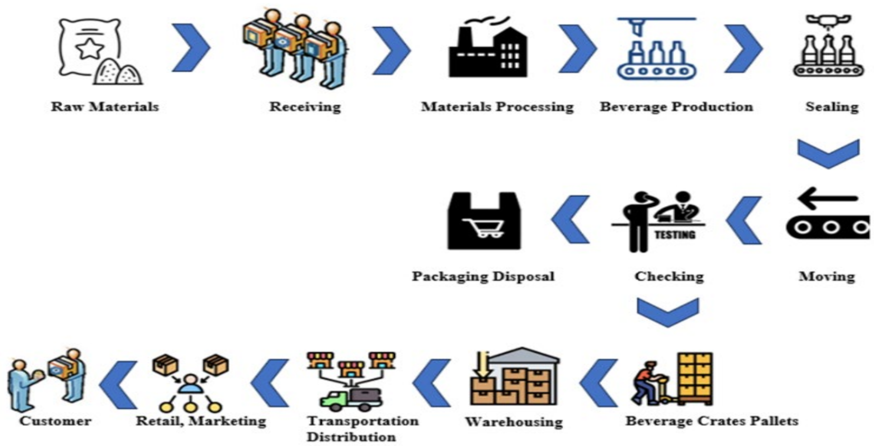

Figure 8. Supply chain of the beverage industry

The beverage sector frequently has some flaws. The sorts of defects and potential solutions are displayed in the table on the next stage, measure.

3.2.2 Measure:

The next step is to measure. A team is needed to complete this stage, which is formed by a production manager, an experienced operator, and a quality control manager. They track out every cause of faults & create check sheets. A check sheet is a document used to compile all the inaccurate data at the source.

This checklist was generated by inaccurate data gathering from the beverage industry on a certain date. These check sheets provide an overview of all the issues the quality manager found. Additionally, make the solutions following the check sheets. There are several kinds of defects in the beverage industry. The largest impact on waste is caused by performance flaws. The preform made of polyethylene terephthalate (PET) generates the most waste. These issues need to be fixed, as check sheets make it easier to understand every issue. Table 1. Summarizes Check sheet of breakage type of PET preform. Table 2 shows check sheet for filled rejection type of production line 2 and Table 3. shows check sheet for filled rejection type of production line 3.

Table 1. Check sheet of breakage type of PET preforms

Product Name: PQR Beverage		Product ID:
Rejection Type	Frequency	Percentages
1st Rinse	70	7.04%
Last Rinse	50	5.03%
High Filled	119	11.96%
Low Filled	299.67	30.12%
Filled Breakage	30.29	3.04%
Lab Test	426	42.82%
Total	994.96	100%

Both filled rejections in production lines 2 & 3 are not without issues. The following table makes it is rather visible. Various production lines show common waste categories. The beverage sector produces quite a bit of waste. Nevertheless, the rates are low. The common waste categories, with the largest waste rate, are the focus of the discussion here,

Table 2. Check sheet for filled rejection type of production line 2

Product Name: PQR Beverage (PET Preform)		Product ID:
Breakage Type	Frequency	Percentages
Washer Load Breakage	3.75	2.04%
Washer Un-Load Breakage	3	1.63%
Cheap Neck	35	18.92%
Case Loading	15	8.14%
Uncase	3.5	1.89%
Empty Inspection	13.5	7.33%
Filler Breakage	4.5	2.44%
Filled Inspection	42	22.82%
Case Packer	5	2.71%
Case Unloading	37	20.1%
Logo Fade	22	11.98%
Total	184.25	100%

Similar in the next production line.

Table 3. Check sheet for filled rejection type of production line 3

Product Name: PQR Beverage		Product ID:
Rejection Type	Frequency	Percentages
1st Rinse	10	1.08%
Last Rinse	10	1.08%
High Filled	96	10.39%
Low Filled	218.84	23.69%
Lab Test	589	63.76%
Total	923.84	100%

Product analysis in laboratories often results in waste, with high-fill and low-filled issues affecting overall production. Common waste categories include logo fade, dirty products, and uncrowned filling and filled breakage. To minimize waste, focus on the table with the highest waste rate and work towards improving overall efficiency. Production lines 2 and 3 have a lab test section for filled bottle issues, which accounts for almost half of waste. Reducing these sections is crucial for quality control, but low-filling items have a high rate of waste. To minimize losses, a large number of reductions are needed, and factors leading to waste must be analyzed.

3.2.3 Analyze:
This DMAIC step analyses the flawed data and examines opportunities to enhance the final result. Continue after this stage to raise the standard of the final output. Leaky bottles, problems with preform wastes, and non-compliance with product content criteria are reasons why the product is inappropriate for market sale. All types of waste are common scenarios in the beverage industry. A large number of products have been wasted without finding out the reason behind them. The main issue in this industry is the unorganized production process. Every industry has six common sections. These sections have some manageable issues. The reasons need to be found out. Give a few reasons on how it might be enhanced for better quality.

A cause-and-effect diagram, also known as a fishbone diagram, is a visual aid used to identify and analyze the root causes of an issue or outcome, categorizing factors into people, processes, equipment, environment, and materials, promoting effective management and insight generation.

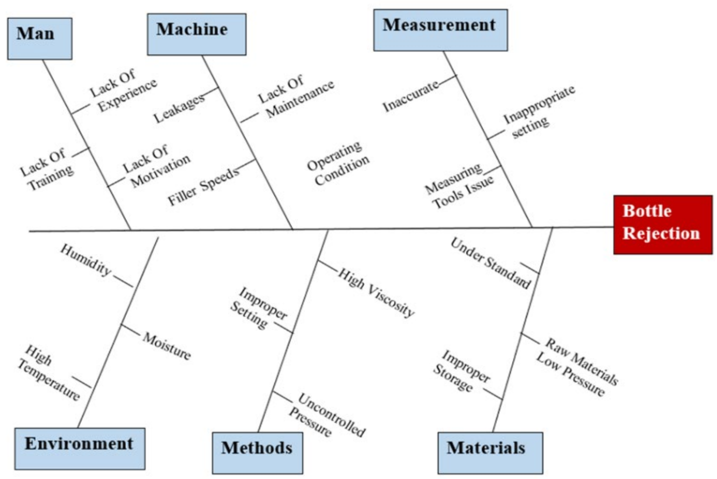

Figure 9. Cause & Effect Diagram.

Cause-and-effect diagrams, also referred to as fishbone or Ishikawa diagrams, provide an organized method for comprehending the complicated structure of variables affecting waste production. It is an effective instrument for the beverage industry's waste reduction programs. Now apply 5W2H methods to solve the issues.

3.2.3.1 5W2H Methods:
A useful tool, 5W2H consists of a list of seven principles shown in table 4. Here are the cause and its solution. This methodical analysis ensures that every relevant factor is carefully considered and helps with planning, problem-solving, and decision-making in waste management.

Table 4. 5W2H

Factor	What	Why	How	Where	When	Who	How much
Man	Due to lack of experience, unable to handle the machine.	To avoid defects.	By creating work instructions.	Production line.	During the production process.	Production Operator.	Investment on humans.
Machine	Fixed leaks, managed filler speeds, and performed maintenance.	Produce standard products.	Perform routine machine maintenance.	Production line.	Before the production Process.	Production Operator.	Maintenance costs.
Measurement	Measuring tools.	Accurate measurement.	Increase accuracy.	Production line.	Before the production Process.	Production Operator.	Maintenance costs.
Environments	Temperatures & Humidity.	The operators can work in a focused & comfortable.	Examine the production environment.	Production line.	Before the production Process.	Maintenance division.	Maintenance Costs.
Materials	Material placement.	Produce standard products.	By doing work instructions.	Production line.	During the production process.	Production Operator.	Materials cost.
Method	Machine Maintenance.	Produce standard products.	Trained the operators.	Production line.	Before the production.	Production Operator.	Training costs.

3.2.4 Improve:
This stage is mainly Designing and implementing the most effective solution. Cost-benefit analyses should be used to identify the best solution (Andersson, 2006). The ideal way to improve quality is through the PDCA cycle and create a PDCA cycle employing the cause and its solution.

3.2.4.1 PDCA Cycle:
The PDCA cycle, also referred to as the Deming cycle, is a lean manufacturing process that was created in 1930 (Sumasto, 2023), a time when there were fewer distinct products and a greater focus on quality control due to increased worldwide market competition (Sumasto, 2023). Four phases make up the PDCA cycle: (1) Plan, (2) Do, (3) Check, and (4) Act. The applications of each PDCA phase in this project are discussed in the subsections that follow.

3.2.4.1.1 Plan Stage:
Finding a cause for problems and using 5W2H approaches to take action are shown in Table 4. This technique helps in taking planned action against defective products. This approach will enable a systematic solution to the issue.

3.2.4.1.2 Do Stage:
The stage 1 improvement opportunities were put into practice. The following changes were made, among others:

i. Making a workstation & training the operators.
ii. Manage the machine maintenance.
iii. Create a comfortable environment.
iv. Perform routine maintenance on the machine

3.2.4.1.3 Check Stage:

After making improvements, the percentage of defects is once again measured at the check stage. statistics on the quantity of production and statistics on the number of defects were collected.

The percentages of defects may drop after using TQM and Six Sigma methodologies. Here is an expected chart that will display once you have complied with the following instructions as well as 5W2H charts. The effect of 5W2H is shown in Table 5 which is a comparison between before & after the improvement. All things considered, the 5W2H framework is a useful tool for increasing success, cooperation, and clarity in organizational activities. The framework improves efficiency and effectiveness in project or task planning, execution, and evaluation by providing direction for problem-solving and decision-making processes. Table 5. shows the comparison between before & after PET Preform.

Table 5. Comparison between before & after PET Preform.

Breakage type of PET preforms		
Defects	Frequency	
	Before	After
Washer Load Breakage	3.75	2
Washer Un-Load Breakage	3	0.75
Cheap Neck	35	12.5
Case Loading	15	5.5
Uncase	3.5	2
Empty Inspection	13.5	5.5
Filler Breakage	4.5	3.25
Filled Inspection	42	13.5
Case Packer	5	2.75
Case Unloading	37	13.25
Logo Fade	22	8
Total	184.25	69

Similarly, the waste in production lines 2 & 3 is also controllable by the same method. The comparison between before and after in production line 2 and 3 is shown in Table 6 and 7 respectively.

Table 6. Comparison between before & after in production line 2.

Filled rejection type of production line 2		
Defects	Frequency	
	Before	After
1st Rinse	70	56
Last Rinse	50	39
High Filled	119	84
Low Filled	299.67	82
Filled Breakage	60.29	43
Lab Test	426	426
Total	1024.96	730

Lab tests are mandatory for improving quality. So, it can't be counted as a waste. So, it is not added when control charts are measured in the control section. All of this table indicates how the Six Sigma process, when combined with TQM tools, significantly reduced the number of flaws. Ideally, it will drop even more and raise both customer happiness and quality. For this reason, it is not considered waste. If these sections reduce quality, it may cause a drop in sales of the product in any industry especially in the beverage sector.

Table 7. Comparison between before & after in production line 3.

Filled rejection type of production line 3		
Defects	Frequency	
	Before	After
1st Rinse	30	23
Last Rinse	30	24
High Filled	96	59
Low Filled	218.84	60
Lab Test	589	589
Total	963.84	755

Next move to the next stage.

3.2.4.1.4 Action Stage:

By establishing standards for the company following improvement, quality control data are kept during the action stage to prevent the recurrence of the same issue and reduce the number of failures going forward. Standardizing the production process is a common corrective technique to deal with prevent issues.

3.2.5 Control:

The "control" phase aims to sustain the gains from processes that have been improved by institutionalizing process or product improvements and controlling ongoing operations (Jirasukprasert, 2012). Control can control the processes that have been carried out (Elfanda 2021). The timetable outlines key improvements, including improved raw material management, product documentation, and staff rewards. The improvement section addresses waste causes and provides solutions. The Control Chart (CL) is the most efficient TQM tool for presenting waste levels, identifying nonconformities, and comparing production systems before and after technology implementation. Table 8. shows the number of wastes of Breakage type of PET preform

Table 8. Number of wastes of Breakage type of PET preform

Breakage type of PET preforms		
Defects	Frequency	
	Before	After
Washer Load Breakage	3.75	2
Washer Un-Load Breakage	3	0.75
Cheap Neck	35	12.5
Case Loading	15	5.5
Uncase	3.5	2
Empty Inspection	13.5	5.5
Filler Breakage	4.5	3.25
Filled Inspection	42	13.5
Case Packer	5	2.75
Case Unloading	37	13.25
Logo Fade	22	8
Total	184.25	69

To create the control chart, the mean number of wastes, the Upper Control Limit (UCL), and the Lower Control Limit (LCL) must be measured using the following formulas from the data table.

Mean no. of wastes: (Before)

$$\bar{c} = \frac{184.25}{11} = 16.75$$

Control limits before:

$$UCL = \bar{c} + 3\sqrt{\bar{c}} = 29.03$$

$$LCL = \overline{c} - 3\sqrt{\overline{c}} = 4.17$$

The waste value is out of range shown clearly in Figure 10. After reducing the product's waste limit using TQM tools, control charts need to be created. A significant number is needed for waste values to keep the data in the range of upper and lower control limits. The number of wastes after processes is listed in Table 8. Now measure the waste value after improvement of the production process.

Mean no. of wastes: (After)

$$\overline{c} = \frac{69}{11} = 6.27$$

Control limits After:

$$UCL = \overline{c} + 3\sqrt{\overline{c}} = 13.78$$

$$LCL = \overline{c} - 3\sqrt{\overline{c}} = -1.24 \approx 0$$

[N.B. LCL is taken 0 when it is negative in actual calculation]

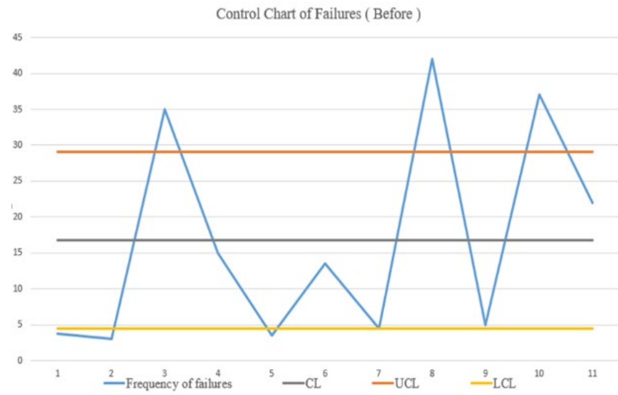

Figure 10. C Control Chart before PET preform.

Control charts after waste after improvement shown in Figure 10. As it is clear that the waste value does not cross the range of control limit.

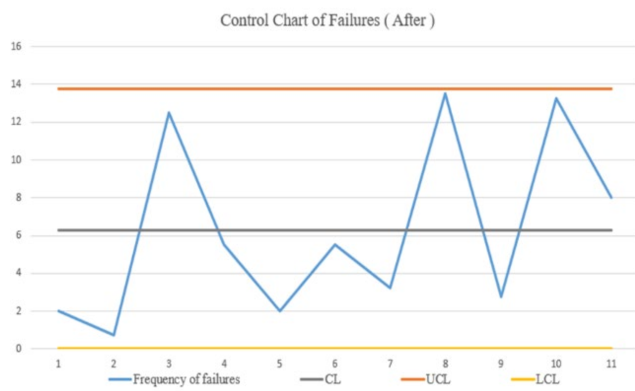

Figure 11. C Control Chart After PET preform.

We see that the value of the mean number of nonconformities is under control after applying the TQM tools in Figure 11, but we need to reduce the waste, which is measured in Table 9. The Lab Test section generates the highest number of wastes in production line 2, despite its importance in maintaining beverage quality. Control charts are not fully controlled due to waste values crossing LCL and UCL limits. Addressing these issues can improve waste management and prepare control charts for production line 2, which addresses bottle issues.

Table 9. Number of wastes of Filled rejection type of production line 2

Filled rejection type of production line 2		
Defects	Frequency	
	Before	After
1st Rinse	70	56
Last Rinse	50	39
High Filled	119	84
Low Filled	299.67	82
Filled Breakage	60.29	43
Total	598.96	304

Mean no. of failures: (Before)

$$\overline{c} = \frac{598.96}{5} = 119.8$$

Control limits before:

$$UCL = \overline{c} + 3\sqrt{\overline{c}} = 152.64$$
$$LCL = \overline{c} - 3\sqrt{\overline{c}} = 86.96$$

The control charts before improvement in the production line are not in the range clearly shown in **Figure 10.** Here A large number of modifications is needed. In **Table 9,** the Lab Test takes place but for plotting the control charts Lab Test cannot be added. As it is the mandatory segment of production to keep good quality products, it is not counted as an improvement in waste management. By removing this section, control charts are plotted in both before and after improvement. As a result, it does not cross the line between the upper control limit (UCL) and the lower control limit (LCL). Next, draw the graphs by measuring the value of control limits.

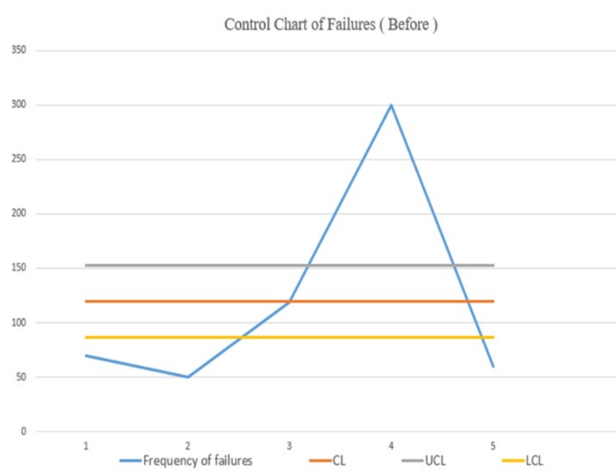

Figure 12. C Control Chart of before in production line 2.

Mean no. of failures: (After)

$$\overline{c} = \frac{304}{5} = 60.8$$

Control limits After:

$$UCL = \overline{c} + 3\sqrt{\overline{c}} = 84.2$$
$$LCL = \overline{c} - 3\sqrt{\overline{c}} = 37.41$$

The standard values of waste match the range of control charts. As mentioned before the Lab Test section has a large number of wastes, which is a mandatory part of production. This section is totally unavoidable waste. So that these curves should cross the Upper & Lower lines easily if this segment are considered in the calculation. Again, all the waste types do not have similar importance. Low-filled has the highest number of wastes. On the other hand, other types of waste don't have a significant number. As a result, it is tough to control every waste value in the range. The lowest values need little improvement & the highest number of waste needs maximum improvement. After keeping in mind this matter, plot the values and get controllable charts.

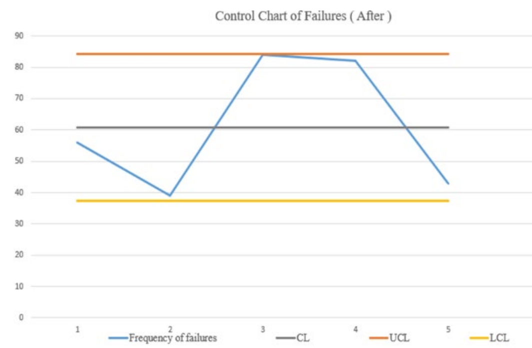

Figure 13. C Control Chart of after in production line 2.

Similarly, the waste limit in production line 3 is also controllable if we don't consider the Lab Test waste as the matter mentioned before Lab Test waste is unavoidable. The number of wastes in production line 3 is shown in **Table 10** which is the representation of before and after improvement. The Lab Test section is not considered when measuring the control limits as it is an unavoidable waste. So, the waste value does not cross the control limit as same as before.

Table 10. Number of wastes of Filled rejection type of production line 3

Filled rejection type of production line 3		
Defects	Frequency	
	Before	After
1st Rinse	30	23
Last Rinse	30	24
High Filled	96	59
Low Filled	218.84	60
Total	374.84	166

Mean no. of failures: (Before)

$$\bar{c} = \frac{374.84}{4} = 93.71$$

Control limits before:

$$UCL = \bar{c} + 3\sqrt{\bar{c}} = 122.75$$

$$LCL = \bar{c} - 3\sqrt{\bar{c}} = 64.67$$

The control charts of before improvement in production line is not in the range

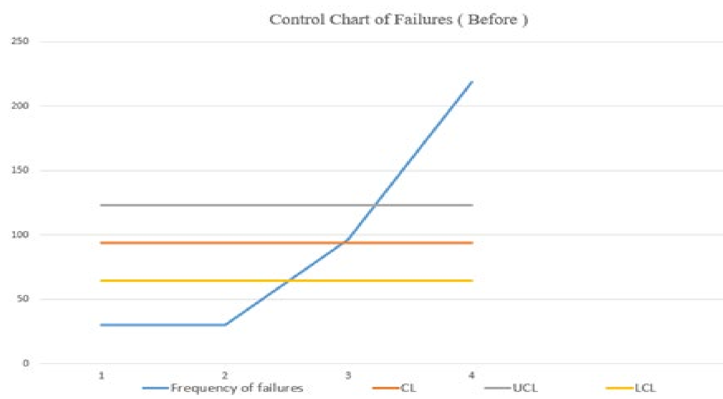

Figure 14. C Control Chart of before in production line 3.

Mean no. of failures: (After)

$$\overline{c} = \frac{166}{4} = 41.5$$

Control limits After:

$$UCL = \overline{c} + 3\sqrt{\overline{c}} = 60.83$$

$$LCL = \overline{c} - 3\sqrt{\overline{c}} = 22.71$$

Similar to before in production line 2, Lab Test is not added when control charts are plotted as this section has the highest waste values in production line 3 also. So, it is necessary to measure the upper control limit & lower control limit without considering the Lab Test section as it does not count as a waste.

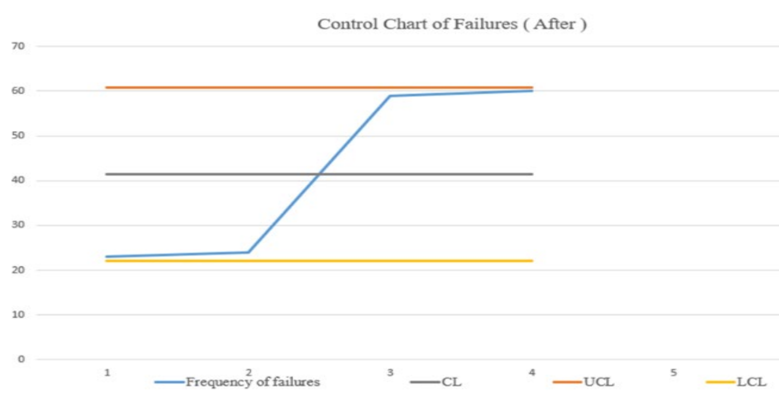

Figure 15. C Control Chart of after in production line 3.

The control stage of DMAIC ends after measuring the range limit of waste.

4.Results and discussion

This study applies TQM techniques and Six Sigma ideas to the problem-solving of waste items. A considerable decrease in overall waste has been obtained after the application of all TQM tools. This enhanced the industry's overall benefit and contributed to the long-term development of an effective system. DPMO and sigma levels of the defects verify the product's quality. DPMO is a Six Sigma metric used in quality management that stands for defects per million opportunities (htt). To calculate DPMO,

DPMO = (total number of defects in sample / (sample size units x number of defect opportunities per unit in the sample) x 1,000,000.

Sigma levels are statistical calculations that analyze process variation and fault frequency, examining the correlation between the two. They take short-term information about a process's DPMO, consider its shift over time, and provide a level value score to determine its quality capability. (htt1). To measure DPMO value, convert total productions into per-case production, as every case has 6 PET preform products and 12 filled bottles in production lines 2 & 3. Again, the sigma level is measured from DPMO values (htt1). A fixed range of DPMO values has a fixed number of sigma levels which are measured by using a formula. The formula has some calculation of probability which is measured automatically using DPMO values. The table shows waste and its values which helps to measure DPMO and sigma level.

Table 11. Different types of wastes according to production.

Waste Sectors	Total number of Production	Number of Wastes	
		Before	After
PET Preform	16550	184.25	69
Production line 2	48145	1024.96	730
Production line 3	104490	963.84	755

The next table shows DPMO and sigma level values, measured by using the previously mentioned formula.

Table 12. Values of DPMO, Sigma Level & Defects Percentages.

Factors	PET Preform		Production line 2		Production line 2	
	Before	After	Before	After	Before	After
Total number of defects	184.25	69	1024.96	730	963.84	755
Opportunities	11	11	5	5	4	4
Total number of units	16550	16550	48145	48145	104490	104490
DPMO	1013	380	4258	3033	2307	1807
Sigma Level	4.59	4.87	4.13	4.24	4.33	4.41
Defects Percentages	1.11	0.42	2.13	1.52	0.92	0.72

The table makes it obvious how waste management has improved. The beverage industry is focusing on reducing waste and improving product quality through the use of Six Sigma and TQM. The study uses various tools to measure product quality, with DPMO and Sigma levels serving as indicators. Meeting these criteria is crucial for profitability in the beverage sector. This shows how the organization is expected to get benefits like cost savings, improved product quality, and increased customer satisfaction as long as it maintains its integration of Six Sigma within its continuous improvement culture and applies its concepts and principles to systematically solve quality problems. The Pareto diagram in Figure 16 showing the differences in waste in various areas before and after improvements finally completed the study.

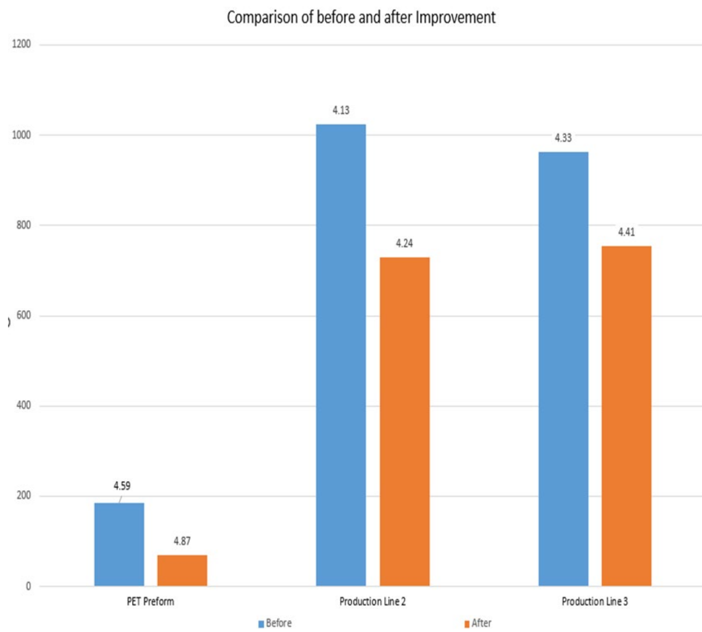

Figure 16. Overall waste reduction Pareto Diagram.

There is a noticeable improvement, showing that the values have changed significantly. Each section's top displays the sigma-level values. As quality improves, the sigma level rises. It can improve quality and reduce waste management. also achieve our objectives.

5 Conclusions

The broad theme of this paper is the quality issue that is being attempted to be resolved with various tools. The purpose of the study was achieved through a collaborative effort of TQM and Six Sigma. The advanced tool needs to be utilized at the highest level for improved quality and fewer errors. Multivariate techniques and quality control tools will be employed to get around complexity when it appears. The fishbone diagram identifies waste issues in the beverage sector due to disorganized production processes. The 5W2H tools address six sectors, requiring departmental implementation to reduce waste and achieve objectives. The improvement part aims to reduce waste by setting goals, creating control charts, and displaying quality changes at DPMO and Sigma levels. Further development is possible in various areas.

5.1 Future recommendations:

The beverage industry can enhance waste reduction by implementing lean manufacturing, employee training, and data analytics, thereby reducing material losses and equipment failures. In the beverage business, the Analytic Hierarchy Process (AHP) can be useful in reducing waste, particularly in decision-making procedures where several factors must be taken into account. AHP is an organized approach to decision-making that helps in the categorization of options by methodically evaluating and contrasting factors according to their relative significance (Hassan, 2013). Kaizen, a Japanese philosophy promoting continuous improvement, can significantly aid the beverage industry in waste reduction by utilizing machine learning algorithms for process optimization and improved yield.

However, Integrating Six Sigma and TQM into the beverage sector can lead to high-quality products and a waste-free environment, ensuring profitability and increased consumer satisfaction.

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Biographies:

Niaz Uddin has emerged as a dedicated professional in Mechatronics and Industrial Engineering, with a keen focus on process improvement and automation. A noteworthy undergraduate thesis on the application of Six Sigma and Total Quality Management (TQM) to reduce waste and increase operational efficiency in the beverage industry served as a highlight of his academic career. His work shows how well engineering principles may be applied to real-world problems. Niaz's technical expertise includes automation technologies like PLCs and HMIs, and his SolidWorks modeling abilities enhance his project work. In addition to his academic background, he has six months of experience in the real world as an Assistant SEO Expert at FireFlag, an Australian IT business. Graduating with a BSc in Mechatronics and Industrial Engineering from Chittagong University of Engineering and Technology (CUET), Niaz is now focused on establishing his career in academia, with a particular interest in teaching and research, while continuing to pursue opportunities in industrial process optimization, control systems, and automation. Niaz is now working as an adjunct faculty member in the Department of EEE at Uttara University.

Hrittik Mural has made notable contributions to industrial and system engineering through various projects and research. His work includes analyzing casting defects in gas burners using the Taguchi method, and he is preparing a review paper on advancements in wearable sensor technologies. He successfully integrated Six Sigma with Total Quality Management (TQM) to improve quality and reduce waste in the beverage industry, and utilized Multi-Criteria Decision-Making (MCDM) techniques to address supply chain disruptions in the steel and rolling industries in Bangladesh. His undergraduate thesis focused on real-time Bangla sign language detection using Long Short-Term Memory (LSTM) networks, achieving 96% accuracy. Mural has also designed and fabricated several innovative systems, including a pulley-based horizontal belt grinding machine, a contactless air conveyor, a smart door lock using RFID technology, and an automatic car washing system with IoT integration. He holds a certification as a Supply Chain Analyst from ISCEA. Mural graduated with a BSc in Mechatronics and Industrial Engineering from Chittagong University of Engineering and Technology (CUET). He currently serves as a Lecturer in Industrial Production Engineering at **BAUST**.

Tasmia Binte Hai (Lecturer) is a faculty member specializing in Mechatronics and Industrial Engineering at Chittagong University of Engineering and Technology (CUET). She is dedicated to not only advancing her field but also to fostering a collaborative and supportive environment for students and colleagues alike.

Md. Mushiur Rahman is a Lecturer in the Department of Industrial and Production Engineering at the Bangladesh Army University of Science and Technology (BAUST). He completed his Bachelor of Science (B.Sc.) in Industrial & Production Engineering (IPE) from Rajshahi University of Engineering & Technology (RUET). He was born and raised in Gazipur, Dhaka. His research interests include Ergonomics and Human Factors, Multi-Criteria Decision Making (MCDM), Supply Chain Management, and Quality Control. Md. Mushiur Rahman is committed to exploring innovative approaches to enhance workplace efficiency, optimize decision-making, and improve supply chain resilience, contributing to both academic and industry advancements.

Assistant Professor Sanjeeb Roy is a faculty member specializing in Mechatronics and Industrial Engineering at Chittagong University of Engineering and Technology (CUET). With a strong background in Industrial Management, Supply chain, Dr. Tonmoy’s research centers on Environment Sustainability, Supply Chain, Abrasive Machining, Machine Learning Implementations. He is dedicated to not only advancing his field but also to fostering a collaborative and supportive environment for students and colleagues alike.