Literature review on the usage of six sigma techniques for improvement of quality in soft drink beverage and bottling industries

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Abstract. The main goals of a manufacturing plant is to improve quality, throughput and increase productivity by reducing ineffective time. In order to do so various areas needs to be looked at and one such focus is on quality improvement, quality has various dimension’s and meeting all these dimension require a sound approach like Six Sigma. The soft drink beverage industry has a complex manufacturing process and there are strict quality measures due to the direct relation which it has with its consumers. In order to accomplish such a need six sigma approach is essential. In regard to the beverage industry quality issues starts of from carbon dioxide yield to bottle filling issues. This study focusses on bringing in different literature which have used six sigma tools and techniques in the bottle and beverage industry. Based on the study it was found techniques such as pareto analysis, fish bone diagram, design of experiment, analysis of variance (ANOVA), control charts are widely used. This is done in order to provide a sound framework on what techniques can be applied when an issue on quality arises.

Keywords: Six sigma, DMAIC, Bottle Industry, Design of experiments, Statistics.

1. Introduction
As competition increases, the focus is on continually improving the process to ensure quality standards are met. The focus of quality has been changing from focus on customers to focus on latent requirements [1]. In today’s world for achieving sound quality all the various revolution of quality which evolved at various times are needed to achieve global excellence. When it comes to improvement in quality, adopting total quality management (TQM) or six sigma approach can be useful in solving quality related issues. A detailed study on highlighting the difference TQM and Six sigma approaches for solving quality related issues are quite important in understanding the quality management process [2]. TQM approach is based towards customers and six sigma approach is more towards no defect. There are various focus areas of six sigma varying from cost, waste, cycle time reductions to yield and capacity improvements and when it comes to process issues six sigma is a sound approach to solve process issues [3]. The define, analyze, measure, improve and control (DMAIC) methodology is used to understand, analyze and improve the process. The DMAIC approach is a “structured problem solving procedure” used in solving quality and process related issues [4].

The methodology adopted by six sigma approach includes DMAIC and the tools used include the seven quality control (seven QC) tools and other complex statistical tools. Beverage Industry is one of the industry which faces quality related problems, wherein the usage of quality management tools become useful. This particular work focusses on providing information on the various tools and...
techniques used in the beverage industry and accordingly making it suitable for conducting analysis. For long run sustainability of bottling and beverage industry there needs to flexibility, sustainability, productivity, minimal packaging and product security [5]. To achieve such needs six sigma approach would be useful to ensure that such needs are met.

2. Literature Review

The bottling industry can be divided into various segments starting from the initial stage of filling up CO2 to finished bottles. There are several issues faced in the bottling industry which start of from CO2 yield, Waste of water to Bottling defects. The literature is divided into various segment which include Yield issues and Bottling defects.

2.1 Literature review on Yield Issues for Bottling/Beverage Industry

The usage of the term loss in this context refers to issues where the material supply is loss during the bottling process, the typical loss arises from water or from CO2 supply. Few literatures have addressed the issue of loss in a bottling plant. Typically beverage industry water consumption is large and finding an optimal solution on the water consumption would be an efficient way of optimizing the process. A study was conducted by using six sigma tools in understanding the areas of high and low water consumption in coca cola plant [6]. The study focused on using the DMAIC approach to obtain realistic picture of the water consumption. Pareto analysis was used in identifying the areas of water consumption wherein areas of high consumption are production and cleaning department. In order to analyze root cause and monitor the consumption histogram, individual moving range control charts were used and accordingly the time and area of wastage occurred was identified. Based on brainstorming session areas of possible causes were identified and accordingly control action plan was created [6]. This shows that loss can be also looked at as lack of optimization in the overall process.

The beverage industry faces various quality and process yield issues, coca cola had highlighted some process issues with respect to CO2 yield loss where in their target was to bridge the gap between current yield and global benchmark [7]. Their work had highlighted the areas where the yield loss due to CO2 occurs, the areas which was mentioned include storage tank area, carbonation area and filling area. In order to solve the problem two approaches were provided which include Total preventive maintenance and six sigma approaches, it was found that losses due to process area (filling) had more losses in comparison to other areas [7]. In addition it was also seen that based on six sigma approaches especially usage of design of experiment could provide insight into which factor would affect CO2 loss from the filler process point of view some of which include bowl pressure, paramix pressure, sniffing pressure and bowl level [7]. There are only minimal amount of literature available in process issues dealing with CO2 yield in soft drink facility. Thus creating a sound area for research.

2.2 Literature review on Yield Issues for Beverage/ Bottling Defects

The most important and one of the oldest paper which had captured the application of statistical techniques was on filling weight in a bottle filling industry [8]. This paper had focused on a providing the difference in the usage of several statistical techniques in capturing the difference in fill volume obtained by usage of multiple heads. The objective of this study was to obtain the statistical difference of fill weight between heads and record changes with respect to sampling time. Comparison were done across various groups wherein a particular group would consist of fill weight obtained due to various head type and a particular time period. This would lead to comparing statistical difference across various groups of fill weight for various head and also comparing fill weight of group across various time period. This is to conduct to check whether variation are based on differences in head or based on sampling interval or are they confounded. Three types of analysis were carried out which include simple data visualization such as line graph, residual analysis and Analysis of variance. In such complicated case it would be worth using ANOVA due to confounding effect of sampling time and heads used. It was seen that ANOVA and residual analysis would be effective technique in analyzing
variation in fill weight [8]

Design of experiments makes use of ANOVA to analyze the statistical difference across various factors. When analyzing bottling defects design of experiments can be made useful. Typical design of experiment with full factorial experiment have been conducted for deviation in filling height by considering percent carbonation, line speed and operating pressure [9].

There are several papers which have focused on bottling issues, bottle filing issues in beverage industry and have used six sigma approaches in solving quality related problem. Techniques such fault tree diagram for identify the faults responsible for not filling the bottle. The fault tree diagram was constructed using various failure modes which include operator sight error, improper washing, filler fault and crowner fault. Based on these fault a complex fault tree was constructed [10].

Six sigma approach was used in the water bottling industry to reduce scrap and to increase line efficiency [11]. Using supplier input output and customer process (SIPOC) and voice of customer (VOC) the define phase was achieved thereby creating critical quality characteristic. Based on these characteristic’s line efficiency, scrap information were collected and analysed. Pareto analysis was used to identify the losses created and it was found that major losses occurred due to shrink wrapper machine, blower and labeller machine. Further root cause analysis was done to identify based on the cause and effect diagram for example some of include bottle defects, label defect, temperature and pressure. Likewise several different causes were established by using cause and effect and accordingly doing brain storming. Finally control charts such as individual charts and pareto charts were used to monitor and control [11].

Loss at filler station is one of the major losses which happens in a beverage industry [Dewa et al [12]. The work was focused on conducting root cause analysis for the liquid loss by using various seven QC tools. By using a pareto chart they identified two major issues at filler operations one was underfilling and the other was missing crown. Based on the cause and effect diagram several categories were created to understand which group can create more variability. Based on the cause and effect several factors were checked and adjusted according to the specified condition and accordingly improvement was achieved [12].

Process capability is an important and easy measure to assess the capability of a process. One of the important characteristic in medical bottles is the bottle diameter, height, weight and thickness [13]. The study focused on determining the process capability of medical bottling plant by using various process capability indices and also had done a check on the assumption of normality before calculating the indices.

Based on the process capability values given by a soft drink company simulation models have been created to understand how data should be generated to keep the process within the capability index [14].

Monitoring and controlling of brix and CO₂ level were done in a soft drink beverage plant to understand the changes in the process parameter. The control charts used were X bar chart, R chart and CUSUM chart, these charts to monitor large changes in mean, variance and small changes in mean. These charts proved to be effective in identifying out of control points [15].

ANOVA techniques have been used to compare the performance of various soft drink by using three different response variable which include gas volume, brix and filled bottle torque. In addition control charts were used to observe pattern for each of the soft drink for these various responses and process capability were calculated for short and long terms and accordingly concluded [16].

Control charts such as shewhart charts usage is sound enough when there large amount of data, however for short run production Q charts are useful [17]. These charts were applied to wine bottling industry from the perspective of univariate and multivariate data. Since the production was short run and there were limited samples Q chart was used, the quality characteristic analysed were fill volume and torque for breaking of the seal. The Q charts for sample average and sample standard deviation were analysed. However there is a possibility of covariance existing between these two variables, hence based on the variance covariance structure a multivariate Q chart was constructed and accordingly sensitivity of the
chart was improved in comparison to univariate q charts [18].

Lean tools and six sigma approach have been combined to improve bottling process by identifying the problematic area which include crown, labels and bottle filling areas. Seven QC tools such as fish bone diagram to identify the root cause of the defects [19].

Several type of defects occur in water bottling industry which include defects such as lid defects (Lid lea, tilted lid, lid inside the bottle and not aligned with bottle), cup defects (Broken, empty), defects occurring due to sliding machine (bottles failing to fall in conveyor) and fill volume defects. DMAIC approach was used to identify the major defects in bottling industry. Based on pareto analysis it was found that lid defects was the major defect which led them to monitor the defect by using P chart. The reduction of defects was achieved by using fish bone diagram which provided insight into possible causes of the defect. Based on the cause’s improvement were suggested [20].

Lean tools such as value stream mapping has been used to define the problem objective in a water bottling plant. Lean six sigma tools were used to reduce waste in beverage by combining value stream mapping, pareto chart and ishikawa diagram. Based on the pareto analysis it was found that water volume variation and alignment error in shrink wrapper machine were the major causes of defects. A individual moving range chart was used to monitor the variation and a cause and effect diagram was accordingly created. Based on this it and by conducting ANOVA it was found that there was significant difference among fillers and was the major source of variation. The shrink machine wrapper had belt wear problems and was accordingly rectified thereby reducing the defects [21]

Bottles are used in pesticide industry and several types of defects occurs right from bottle leakage to mislabeling. Lean six sigma tools which include value stream mapping, pareto chart, fish bone diagram along with question strategy (why) were used to identify and solve the defect issue [22]

Waste can happen in various forms right from waste due to production line inefficiency, lack of sound six sigma or lean techniques. Various waste reduction and the different types, sources of waste have been addressed and some important techniques such as value stream mapping, line balancing, just in time and six sigma approaches have been addressed for beverage industry [23]

With respect to bottling industry, there is minimal application of combining techniques other than the traditional seven QC tools. The usage of combining six sigma techniques, decision tree and failure mode effect analysis (FMEA) in analysis bottling defects have been studied in bottle manufacturing plant [24]. This highlights that there seems to be a starting trend of integrating various technique to make the manufacturing process productive and effective.

3. Results
It can be seen from the literature that the main tools and techniques which were used are pareto chart fish bone or cause and effect diagram, control charts. Based on these literature studies a general fish bone diagram can be drawn for CO₂ yield loss and Bottling defects. Figure 1 and Figure 2 represents the cause and effect diagram for the various responses. Table 1 provides a general summary of the various issues and tools and techniques used in solving the quality issues.
Table 1. Summary of literature review

| Issue  | Defects/Problem Identified | Tools & Techniques used                          | Source |
|--------|---------------------------|-------------------------------------------------|--------|
| Yield  | Water loss                | Pareto analysis, Histogram, IMR                 | 6      |
| Yield  | CO2 Yield Issues          | SIPOC, Cause and effect, Histogram, Pareto, DOE, Control Charts | 7      |
| Quality| Fill Weight               | Line graph, ANOVA, residual analysis            | 8      |
| Quality| Fill Height               | DOE                                             | 9      |
4. Conclusion
It is seen that there is growing trend towards application of six sigma techniques and usage of pareto analysis, cause and effect diagram, control charts, ANOVA and design of experiment approach are proving to be quite effective in reduction of defects. It is also seen that the above mentioned techniques are most of often used for analysis. However there needs to be further advancement of the usage of statistical techniques, since data by itself is multivariate in nature, usage of multivariate techniques are essential in understanding the complexity of process. Minimal literature have been found in the usage of CO2 yield improvement and this can be looked as an area of research. The usage of design of experiments have also been applied but the literature with respect to its application with respect to yield improvement in bottling industry is minimal. Hence creating a full factorial or fractional factorial design by considering multitude of factors would prove beneficial to the yield improvement of bottling industry. Based on the above studies it is also seen that there are lot of related variable in the analysis in such cases usage of multivariate charts would prove more effective to monitor and control and with current trend set towards data analytics it would be worthwhile to explore the usage of principal component analysis, $T^2$ chart and accordingly create control measures. Also seen is that there are scant literature of usage of machine learning techniques with respect to analyze phase of six sigma approach, these approaches can be combined with six sigma techniques to obtain the complex behavior of a process. In order to have a tighter control and with additional new requirements from customer wherein health, lifestyle changes are becoming a norm, the complexity of soft beverage process is going to increase. When complexity increases, more factors can have effect on process behavior and this can be understood by using such multivariate techniques and machine

| Quality   | Filling issues | Fault tree                      |
|-----------|----------------|---------------------------------|
| Quality   | Bottle defect, Label Defect | SIPOC, VOC, Pareto, Cause and Effect |
| Quality   | Filler loss      | Pareto, Cause and Effect       |
| Quality   | Bottle diameter, height, weight, thickness | Process capability indices |
| Quality   | Fill Volume      | Process capability indices     |
| Quality   | Brix and Co2 Level | Control charts (X bar, CUSUM, R chart) |
| Quality   | Gas, Brix volumes and Torque | ANOVA, Process capability indices |
| Quality   | Fill Volume, Torque | Univariate and multivariate Q charts |
| Quality   | Bottle defects   | Lean and Cause effect diagram   |
| Quality   | Bottle defects   | Pareto analysis, Cause and effect, p chart |
| Quality   | Fill volume      | Pareto analysis, Cause and effect, ANOVA |
| Quality   | Bottle leakage, Labels | Pareto analysis |
| Waste     | Bottle defects, process inefficiency | Value stream mapping, Line balancing |
| Quality   | Bottling defects | P chart, Decision tree, FMEA   |

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| Waste     | Bottle defects, process inefficiency | Value stream mapping, Line balancing |
| Quality   | Bottling defects | P chart, Decision tree, FMEA   |
learning algorithms. Hence there is a need to make the change happen which can provide a huge benefit to the beverage industry.

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