Reducing variability in process and the risk of product defects: A case study in SME's

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Abstract. The study aims to determine the quality control level of mineral water packaging. Six Sigma is recognized as an essential tool used in this study in determining the quality level by measuring variability in the process, reducing product defects (packaging), and developing the improvement comprehensively. The implementation of Six Sigma has been implemented in many advanced companies. The implementation was conducted in one small-medium enterprise (SME) that produced the mineral water. However, the implementation of Six Sigma in the small-medium level of industries has relatively new challenges. The result showed that identified four defects: bottle cover defect, bottle defect, label defect, label, and process defect. The process variability was highly fluctuated and identified about 28 data out from control lines. Based on the capability process was measured and gained sigma level in 3.76. Some recommendations were set to reduce the variability of the process.

1. Introduction

The advancement of technology and business competitiveness pushed many companies to compete to produce a high-quality product. In a competitive environment, the fundamental goals of the company are to survive in the market for the long term. The companies survived in this competitiveness era, only those that can satisfy the customer by improving the quality product, enhancing cost efficiency, and increasing productivity and delivery.

Quality had become a critical factor in determining the quality of products and affected the success of the industry in the national market and international market as well. Quality control effectiveness depends based on raw material, resources, transformation process, methodology, and supported equipment/machine integrated into a system. Maintaining product quality means ensuring product met the specifications, fitted requirements, and customer satisfaction. It broadly influences the effectiveness of the process, output productivity, and efficiency in resources used. Some methods

Six Sigma is defined as one tool in integrating a systematic way in improving the quality of the production process and satisfy given needs. Customer satisfaction has a positive relationship significantly to financial benefit, company growth, equality, and productivity [1]. Furthermore, it is essential to the industry to consider the implementation of six Sigma in supporting sustainability company growth. However, the application of quality control by using scientific approach (Six Sigma) is not yet implemented comprehensively and consistently in developing countries particularly in the context of Small Medium Enterprises (SME), so that there were huge losses due to high defects in production process [2][3][4]. Instead of the latest economic development, SME contributed to the resilience and economic growth of the country and even the world. Besides that, SME was expected to
enhance the quality of production to meet demand and satisfy customers [3]. For that, the development of quality studies in the SME sector is an important thing to investigate implement.

Effective quality control will produce products that can meet quality standards that are based on individual specifications and set by the company. Besides, the factors that cause product failure will be minimized, and consumer confidence and satisfaction can be maintained and enhanced. To support effective quality control, various quality methods have been developed both partially and thoroughly. Various types of methods are developed by companies to produce better quality products. Six Sigma is a term that was first developed by the Motorola Company in the mid-1980s, which emphasizes process improvement to reduce variability and make general improvements. The Six Sigma, quality improvement process includes the Define, Measure, Analyze, Improve, Control (DMAIC) process. Then the control is carried out by analyzing the causes of disability and seeking continuous improvement with the Kaizen approach.

MKM company is a small to mid-size enterprise (SME) engaged in the production of bottled drinking water. The primary material used by the company is water from wells in the hills. Several industries use water as the primary raw material, such as pharmaceuticals and food and beverage products [5][6]. The material is then processed to meet the requirements of the Indonesian National Standard (SNI) using specific tools so that the water is suitable for drinking, where the water is clear, colorless, odorless, not turbid and there are no other foreign objects such as stones or other foreign objects. In addition to water as the primary raw material, packaging plays an essential role in a product. The packaging functions as a container to hold and place the primary material so that it can be distributed. Besides, packaging must be able to build uniqueness and attractive to consumers. A good packaging must be able to meet several factors, namely: 1) must be able to protect the product from potential that can damage the product such as the environment and others, 2) economical design, 3) distribution, packaging is easy to distribute, 4) communication, packaging must be able to communicate product, 5) ergonomic, easy to carry, hold, open, and easily take the product, 6) esthetic, the packaging must look attractive, 7) identity, show the uniqueness of different product identities. Product packaging design gives important meaning to brand values and influences consumer purchasing decisions. [7]. Besides aesthetics and identity, it can be concluded simply from several other factors related to the durability of the packaging during the production process until the product is consumed. Furthermore, there is a substantive relationship related to perception values (brand values/awareness, brand association, and brand loyalty) and purchasing decisions. The higher the perceived value, the higher the potential for consumers to buy the product [8].

Bottled drinking water production activities carried out by MKM has been established since 2008. There are four types of packaging sizes for drinking water products manufactured and marketed by the company, namely 220 ml glass, 600 ml bottles, 1.5-liter large bottles, and 19-liter gallon packaging. There are four production machines: 2 machines for the production of 220 ml glass packaging sizes, one machine for 660 ml and 1.5-liter packaging bottle sizes, and one machine for 19-liter gallon sizes. The production capacity of machines for 600 ml bottle packaging is capable of producing approximately 10,000 pcs in one working day. However, the production results often have several products that experience packaging defects in the production process. By implementing Six Sigma in this company, it is expected that it can improve and enhance product quality and can reduce inefficient costs due to defective products.

Related to the above background, research and discussion to improve the quality of processes need to be carried out by applying an integrated and effective quality control method. For this reason, It is aimed that the company can identify the type of defect and the causes of defects in the product during the production process. Also, it is intended to identify and reduce the variability in the packaging process to minimize the risk of product defects. Furthermore, to improve the quality process.

2. Methodology
Data was collected by getting information about the company's historical data, observations, and interviews. Based on the information and data collected, the product that needs to be examined is the production of 600 ml of bottled mineral water. Then, data collected was processing by a simple
statistical method to identify, map variability, and analyze the quality control level of the production process

Quality control is a sub-system of quality management (Quality Management/QM). Quality control activities include sampling, testing, monitoring, and inspection, as well as reporting the results of activities. The results of testing, monitoring, and inspection are managed as a basis for quality assurance (QA). They are used as a basis for product release to the market or quality improvement (QI). Quality control in the bottled water industry starts from the water source, each stage of the process, to the release of the product to the market. The Bottle Drinking Water (BDW) processing scheme, in principle, must meet and comply with the national regulation [9].

Six Sigma is an essential tool for production management to maintain, improve, maintain product quality, and especially to achieve quality improvement towards zero defects. In this study, the application of quality control used is the Six Sigma method that should go through five stages. But in this study, only four stages of analysis are used, namely Define, Measure, Analyze, Improve at SME. The study was carried out at the Production Department, where the production process of 600 ml bottled mineral water is very concerned about the quality of its production before it is packaged and distributed. As an object of research in the process of improving quality, at this stage, data collected from 600 ml bottled mineral water produced for 45 days.

The Head of Production is the person who is fully responsible during the production process. There are several stages during the production process, starting from the water quality checking stage to the packaging process stage. The first stage of the production process is the QC section checks the pH of water in a raw water tank by taking samples and testing them in the laboratory. After that, the production department checks and settings all production machines to meet the standards. After everything is up to standard, raw water is channeled to the sand filter tank. At this stage, raw water undergoes three processes of filtering foreign matter, carbon and cartridge. After passing through the screening process, raw water flows for the ozonization process. Furthermore, raw water enters the mixing process and finally into the finished water tank.

The next stage is the production process. The water is flowed into the machine through a UV lamp along with other materials. Then the filling process will be carried out to the packaging bottle by the filling machine, and then several samples will be taken to be tested in the laboratory. If the laboratory results meet the standard, then the next process of bottled water enters the lid (labeling) process, then goes into quality testing. The final stage is the finishing process. Products that passed quality testing will be directly packed into a box, then arranged in a pallet, then stored in a warehouse and ready to distribute.

3. Result
3.1. Define
Define is the stage of defining quality problems in the production of 600 ml of bottled mineral water. At this stage, the defective product is defined as the cause. At the stage of identifying the problem, there will be explained several causes of defects, which are potential causes in producing 600 ml bottled mineral water products. The types of defects are identified through interviews with the head of the production, employees, and direct observation in the production area. The types of defects can be seen in Figure 1 and describe as follows:

Defect bottle (A)
In this type of defect, the body of the bottle is dented and damaged on the head of the bottle. This is caused by the wrong machine flanking the head of the bottle so that the head of the bottle is damaged, and the poor quality of the bottles imported by the supplier so that during the production process takes place, the bottle becomes dented.
Defect bottle cup (B)
Bottle caps are not appropriately attached to the bottle body during the sealing process. This is usually caused by the machine or the position of the bottle cap, which is not quite right during the process of sealing the bottle.

Defect label supply (C)
In this type of defect, glue from the label comes off. This is caused by the quality of the labels that are not good. Other causes are also common because workers are not careful enough to put labels.

Defect label process (D)
In this type of defect, the label shrinks and almost melts. This is because the heat in the engine is too high and also due to negligent workers inputting the label in the right position.

3.2 Measure
At the measurement stage, it is useful to validate problems, measure or analyze problems from existing data. The measure is an action that aims to measure the dimensions of product performance, processes, and other activities. In this stage, Critical to Quality (CTQ) priorities and process stability and process capability will be determined and sorted.

The output of this stage was resulted in measuring the quality level by involving DPMO (Defect Per Million Opportunities) as a base in identifying industry performance on the quality side. In this stage, data were collected from 45 subgroup samples in 45 days. Data then plotted to the Pareto diagram to determine the critical to the quality of defect as in Figure 2. From this Pareto diagram, it shows that the highest defect is a bottle cap defect of 17,596 pcs with a percentage of 47.9%. Then it is followed by bottle defects of 17,504 pcs with a percentage of 47.7%. Next, the label defects were supplied with 814 pcs, and the percentage was 2.2%, and the last was the process label defects with 798 pcs and the percentage of 2.2%. Therefore, repairs that must be done first are defective bottle caps. This is because the defect is the most significant defect, among other types of defects.

3.3 Capability Process
From Figure 3 above, it appears that 28 data are outside the control limit. Therefore, it must be eliminated so that the process is stable so that new revision 1 data is obtained. To get new revision 1 data, first, the process stability is recalculated until the process data is within the control limits.
Figure 2. Critical to the quality

Figure 3. P chart of the defect
From Figure 4, it can be seen that there is still data that is outside the control limits, which is on the 21st day (February). Therefore, it must be eliminated so that the process is stable so that new data can be revised. To get revised new data, the process stability is recalculated first to get the process data that is within the control limits.

From the results of calculations and Figure 5, it can be seen that the production of 600 ml bottled mineral water has a sigma level of 3.756 or 3.76, with possible damage of 11,937 pcs for a million materials. The calculation shows the DPMO and Sigma levels are quite good. With good results in the industry average in Indonesia, it still needs to be controlled continuously so that it will show the DPMO pattern of the failure of the production of 600 ml bottled mineral water that continues to fall and the capability of Sigma that continues to increase.
3.4 Analyse

Causes and effects were analyzed using the fishbone diagram in particularly for data that existed jumped out from LCL and UCL. The identification process in clarifying causes and effects was conducted by observation and interviewing the personnel and key people involved in the process directly. Five factors caused the defect of raw material. Some of the causes of defects in the packaging process in terms of several factors, namely:

1. Human: Lack of knowledge of workers related to the packaging and production process in detail, especially related to production machines. Besides that, the fatigue factor on workers has an impact on decreased concentration in the process of installing labels and packaging. This also becomes a dominant factor in the packaging process.

2. Machine: Engine adjustment is unstable. This is usually because the bottle gripper rinser makes the transfer of the bottle not right, so the bottle head is damaged. The engine pump is not stable. This makes the volume of water when charging is not up to standard.

3. Method: Bottle caps are put into the machine without being sorted, and the packaging process was still done manually by the operator.

4. Material: The quality of the material does not meet qualifications such as defective bottle caps from the supplier, so it makes a dent bottle during the production process.

3.5 Improve and Control

The variability that occurs during the production and packaging processes is generally caused by product defects during the process. Furthermore, reducing variability can be carried out by reducing the number of product defects that occur during the production and packaging processes. After identifying the causes and impacts that occur, several proposals are developed to emphasize variability or increase the improvement of the production process. Some of the recommendations are as follows:

1. Giving special assistance for workers during the production and packaging process and provide intensive training to improve their knowledge and skills related to the production and packaging process.

2. Conducting a minimum material checking sampling test by random sampling of the total material ordered periodically.

3. Replacing bottle rinser gripper, which is not feasible for use or damaged so that the measurement of water content can be accurate.

4. Conducting preventive maintenance to machines regularly and replace parts that do not meet the standard.

5. Increasing attention to the sorting process of packaging, labels, and bottle caps during the receiving process so that it can detect early the process failure in the production and packaging process.

4. Discussion

The empirical results show the picture of what happened in SMEs related to huge losses along the process caused by uncontrolled variability with four major defects. Production of 600 ml bottled mineral water has a sigma level of 3.756 or 3.76, with a possible defect of 11,937 pcs for a million productions. The measurement shows the DPMO and Sigma levels are relatively good. Besides, it still needs to be controlled continuously to ensure continuous improvement.

Weaknesses in quality control generally caused by a lack of knowledge related to effective quality control methods. Therefore, tools and six sigma methods as an effective quality methodology in reducing variability and six Sigma is still needed to popularize in SMEs [10]. This is in line with the empirical finding in this study that actually in SMEs, human error still dominated in high variability along the process [11]. Besides that, mechanical maintenance had become the other concern to improve in reducing the variability. Uncontrolled variability, generally caused by specific cause (assignable cause) such as failure modes in the process, human error, and lack of knowledge.

Philosophically, Six Sigma is an approach to study, analyze, and reduce process variations. The concept of reducing variation and using statistical control tools can be applied in many areas where real understanding is needed by making direct observations on the actual process [12] [13].
The company is expected to implement or consider the Six Sigma method to reduce the variability due to defective products in the next production process. The use of the Six Sigma method needs to be carried out for the quality improvement process because the company can find out the value of DPMO and its Six Sigma level as reference material to determine the feasibility of the ongoing production process.

Aside from the strengths of six Sigma, there is certainly no perfect methodology. Likewise, this methodology has limitations where this method is so dependent on central evaluation and critical testing of the entire capability process, such as requires firm statistical experimentation \[14\]. In addition, it requires total employee engagement, and of course, the most important is related to costs.

5. Conclusion
A possible defect rate of 11,937 products per million productions indicates that it needs ongoing and continuous control. The main thing that requires attention in reducing the number of defects is to eliminate the potential for human error in the production and packaging process. Because human error is the leading cause in causing uncontrolled variability. By eliminating human error, it is expected to reduce uncontrolled variability in the production and packaging processes. Also, on the other hand, it can maintain the level of production quality and reduce the cost of product defects.

This study is still limited to specific case studies in SMEs and without considering work environment factors as developed previous work. For this reason, environmental considerations and expansion of application are opportunities for future research development.

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