Six Sigma Implementation in Quality Evaluation of Raw Material: A Case Study

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Abstract. The study aims to evaluate the quality level of raw material in order to improve its quality. This study is constructed based on the implementation of six sigma methodology. Six Sigma is one powerful tool that used in this study to identify the problem, determine the quality level, and to develop the improvement comprehensively. Five phases of the model has been structured by stages respectively. Six sigma had been implemented in many kinds of industry, particularly in production process phase. However, there is a challenge to implement the methodology in other phase in supply chain in the context of developing country. The implementation was conducted on receiving raw material process part in the industry. The result showed some defects identified dominantly; damage seed, broken seed, insects, and moldy seed. There are 6734.13 possibilities of raw material in experiencing defect per million opportunities (DPMO). Lack of knowledge of the workers about the raw material and lack of supporting equipment are the two main causes of poor quality of receiving raw material process.

1. Introduction
Quality is one important indicator to ensure that product meet the requirements along supply chain in order to satisfy the customer. The awareness about the quality had been increased since some decades ago. Quality can determine overall success of company [1]. The quality management had experienced development from the meaning to ensure the product meet the requirement by product inspection and then go through meet the customer satisfaction. In its journey, many methodologies were also developed as tools in planning, controlling, improving and assuring the quality.

One tool that used generally and relatively powerful in order to enhance the quality of production in industry is Six Sigma. Six Sigma has been recognized as a comprehensive tool in improving the quality of process structurally. This method has been known as primary factors for the success of many industries. TQM has also been supported by six sigma in attaining continues improvement by contributing the developed systems and method. Many scholars have conducted many research regarding the research development and application of Six Sigma in many kinds of industries in developed countries [2]. Factors that impacted in application of six sigma must be concerned by developing countries. Furthermore, the study related to implementation of six sigma and its advantage in a developing country, such as India [3]. Involvement and commitment of top management, training and education, cultural change and industrial infrastructure are factors that successfully contributed in six sigma implementation in developing country (Indonesia). The implementation of six sigma affected positively to the performance of small and medium industries in Indonesia as well [4].
Planning and evaluation in order to improve the quality of production became the important part in production system. It is general that quality evaluation was conducted holistically in production floor (production systems). Moreover, in production floor, the material experienced transformation process to be an added value product that different from its origin. There is quality control along the transformation process of product in ensuring that product meet the specific requirements. Quality control existed as a guardian in keeping and evaluating the quality of product. However, generally in wider scale in supply chain management, beside of production process in manufacturer, supply of raw material also plays important role and vital in supporting production process by contributing high quality raw material. Studies in this context is still limited, however some studies have been developed related to the implementation of six sigma on raw material such as the quality of water as raw material in food production [5], and raw material in pharmaceutical industry [6].

Corn seed is one of the material that most widely used in this industry. For this reason, it is important to pay attention in supply process of material where the raw material distributed from its origin to manufacturer. Raw material referred in this study is corn seed that used to produce fodder for animal.

As figure 1, supply chain integrating activities of material from their source to the end user. In this part included purchasing raw material, manufacturing, storage, distribution, retailing, demand planning, supply planning, and supply chain management [7].

This research aimed to minimize the number of defects in the raw material during receiving process, to improve the quality of raw material processing, and to enhance customer satisfaction. Research objectives consist of three parts: mapping the level of quality by identifying, measuring performance dimension of raw material through analysis the process capability, identify the factors that caused the defects, and develop some action plan to improve the quality of raw material.

2. Methodology

Study that related to the implementation of six sigma conducted since late eighties where Motorola used this methodology in the first time in 1986. Six sigma is a tool that extremely important to improve the quality [8]. Particularly, this methodology had been implemented in many kinds of manufacture industry, and then applied in services industry as well [9-11]. Six Sigma is one comprehensive tool used to define the quality in several of ways. Motorola defined six sigma as a quality improvement method in reducing the number of defects to 3.4 parts per million opportunities.

The research was conducted in one industry that produced grain/fodder/forage in Makassar, Sulawesi Selatan. Data was collected by identifying the types of defect, and calculate the number of defects of each type of defect. Furthermore, the result of measuring process then analysed using fishbone diagram. Root caused analysis deeply by interviewing the key people that involved in receiving raw material in the industry.

![Figure 1. Supply chain management](image)

![Figure 2. Flow of raw material](image)
Raw materials are distributed by suppliers from their origin to the factory. In the process of receiving materials as shown in Figure 2, there are several stages, namely: receipt of material from suppliers, carried out tests by physical inspection of raw materials (decision to reject and accept at this phase), the material received is then taken to the silo drier for grinding process. At the physical test stage, raw materials play an important role to determine the quality of raw materials to the next process, some of the quality standards measured in this test are water content, damage/broken seed, moldy seed, other material content beside corn. Raw materials that have passed the physical test will be stored in storage to wait for requests from production department. The rejected raw material will be returned to the supplier.

Plant manager is fully responsible in the production process cycle at the manufacturer. There are two kinds of raw material that will be mixed in production process. First, the raw material in the silo containing corn will be put into a rough bin and then it will be grinding or mashed and put into a fine bin. Second, raw materials in the form of wheat grains, soybean stalks, copra and several other materials that are in the warehouse (bulk / bag storage) are put into a rough bin and then crushed or grinding, after that it goes into the fine bin. Raw materials that have been refined will be directly inserted into the refined bin. Then all the raw materials in the refined bin will be mixed and will be formed into pellets (pills, granules) and then packed. After packaging, the final products will be put in the storage for finished products.

3. Result Analysis

3.1. Define

Identifying the process, number and types of defects of raw material are the major thing that purposed in this phase [12, 13]. This stage is based on collecting data and interview conducted with the silo dryer head and observation.. There are six types of defects that appeared frequently in this industry, which are: damage seed, insects, moldy seed, broken seed, drier damage, and foreign material.

Damage seed

This type of defect is caused by the activity of respiration or hot air caused by an artificial fainting method, its characteristics are usually brownish on the germ and soft and acidic. In the case of severely damaged seeds the corn seeds swell and peel.

![Figure 3. Defects of raw material](image-url)
Insects
This type of defect is caused by an insect attack which results a hole in the seed or there is a white line of the path from the insect.

Moldy seed
This type of defect is caused by the humid and warm weather so that the fungus on the seeds will easily grow. Generally, the seeds are green or grey in colour.

Broken seed
This type of defect is caused by truck transportation, usually the characteristics of broken / crushed seeds are that there are cracked one third of the corn seeds or completely separated.

Drier damage
This type of defect is commonly due to extreme external drying methods, usually this defect arises if the corn kernels are stored too long in the silo and exposed to excessive heat.

Foreign Material
This type of damage is caused by unwanted contaminants in corn, such as corncobs, blades, gravel, grass weeds and other contaminants.

3.2. Measure
Output of this stage was resulted by measuring the quality level by involving DPMO (Defect Per Million Opportunities) as a base in identifying industry performance on quality side. In this stage data were collected from 48 sub group sample in 48 weeks. Data then plotted to pareto diagram to determine the critical to quality of defect as in Figure 4.

Based on pareto diagram in Figure 4, the number of defects were dominated by four kinds of defects. Whereas the damage seed attained the most defects, and then followed by broken seed, insect damage, and moldy seeds respectively. And the rests are drier damage and foreign material.


### Capability Process

**Figure 5. P chart of defect**

Observing P chart in Figure 5, it can be seen that the number of defect for 29 data has jumped out of UCL and LCL. On further investigation, that some of sample need to observed the cause. To ensure that to all samples is in control, the sample existed out of LCL and UCL were excluded from data provided from calculation. The data then recalculated and p chart were plotted in Figure 4.

**Figure 7. P chart of defect (II)**

In this calculation, one data (week 41) still jumped out from LCL, simply then the data was excluded from calculation and recalculated. P chart was plotted in Figure 7. The process was within statistical control after excluding data in week 41.

In overall, DPMO and Sigma level was calculated from 48 group samples. From calculations, DPMO was valued as 6734.13. This indicates that there are 6734.13 possibilities of raw material in experiencing defect per million opportunities (DPMO).

3.3. **Analyze**

In analyze stage, the result of measurement was as a base of analyzing and conclusion. Fishbone diagram as one tool from seven tools of quality is relatively powerful to identify the cause in detail. The cause of defect was explored by using fishbone diagram involved five factors. By this result, the improvement was set by each factor. To further reduce the defects, some options were set to improve the process. Prior to that the cause and effect was analyzed, in particularly for data that existed jumped out from LCL and UCL. Using fishbone diagram to analyse the cause and effect by observation and interviewing the personnel and key people involved in process directly. There were five factors that caused the defect of raw material.
Some of the causes of defects in raw materials in terms of several factors, namely:

a. Humans: lack of basic knowledge of workers related to raw materials, weaknesses in the sorting process, employee indiscipline, and worker fatigue.

b. Method: Material buildup exceeds load limits, humid warehouse conditions, water content in raw materials exceeds standard levels,

c. Machine: maintenance of machines that are not optimal, especially material collector.

3.4. Improve and Control

This phase is a stage of improving the quality of raw materials by proposing some recommendations for improvement, analyzing the causes and providing solutions with the 5W + 1H kaizen approach (what, why, when, where, who, and how). Improvement carried out related to defects that occur in raw material in the silo drier. These factors consisted of human factor, machines, methods, raw materials, and the environment.

1. Providing assistance and intensive training for workers in order to enhance their knowledge and accuracy in measurement.

2. Replacing proximity sensor which is not feasible for use or damaged so that the measurement of moisture content can be accurate

3. Adding Luprosil NC machine to minimize insect nesting in seeds.

4. Procuring of automatic sensor which can detect or sort of foreign material attached to the seed

5. Increase the awareness of raw material which does not meet the qualifications. For this reason, the QC must be selective in sorting raw material.

4. Discussion

The implementation of six sigma providing methodology in gaining information in some stages structurally. This can enrich in analyzing and enhancing the understanding of process that was reflected in improvement of process. In context of raw material processing, particularly of some raw material that used dominantly in a production process, must be the main concern. Raw materials are the primary factor in assuring the quality of product and production process. Some studies have been developed related to the implementation of six sigma on raw material such as the quality of water as raw material in production of food [5], and raw material in pharmaceutical industry [6]. However, the study that related to quality improvement in the process of receiving raw material is still limited. For that reason, it is important to study widely in this area. Of course the process and procedures have to concern to satisfy the customer requirements and customer delight.

References

[1] Jenab, K., Wu, C., & Moslehpour, S. (2018). Design for Six Sigma: A review. Management Science Letter, 1-18.

[2] Venkatesh, N., & Sumangala, C. (2018). Succes of manufacturing industries - Role of Six Sigma. MATEC Web of Conferences (p. 144). RiMES 2017.

[3] Padhy, R. K., S.Sahu, & Das, R. (2011). Implementation of Six Sigma in India Industries - a delphy study. International Journal Computer Aided Engineering and Technology, 19-33.

[4] Zagloel, T. Y., Ardi, R., & Poncotoyo, W. (2018). Six sigma Implementation model based on critical success factor (CSFs) for Indonesia Small Medium Industries. ICIEE 2018 (p. 218). MATEC Web of Conference.

[5] Rimantho, D., & Mariani, D. M. (2017). Penerapan Metode Six Sigma Pada Pengendalian Kualitas Air Baku pada Produksi Makanan. Jurnal Ilmiah Teknik Industri, 1-12.

[6] Rimantho, D., Hernadi, D., Cahyadi, B., Prasetyani, R., & Kurniawan, Y. (2017). The Application of six sigma in process control of raw water quality on pharmaceutical industry at Indonesia. International Journal of Applied Engineering Research, 848-860.
[7] Elbermawy, M. F., Manhawy, A. A., & Ibrahim, H. (2014). Implementation of Lean Six Sigma For Improving Supply Chain Processes in a Pharmaceutical Industry. *International Journal of Scientific & Engineering Research*, 519-529.

[8] Goh, T. N. (2010). Six triumphs and six strategies of Six Sigma. *Quality Engineering*, 299-305.

[9] Al-Qatawneh, L., Abdallah, A. A., & Zalloum, S. S. (2019). Six Sigma Application in Healthcare Logistics: A Framework and A Case Study. *Journal of Healthcare Engineering*, 2-12.

[10] Antunes, D. L., Souza, S. D., & Nunes, E. (2013). Using Project Six Sigma and Lean Concepts in Internal Logistics. *World Congress on Engineering*. London: Proceedings of the World Congress on Engineering.

[11] Erbiyik, H., & Saru, M. (2015). Six Sigma Implementation in Supply Chain: An Application for an Automotive Subsidiary Industry in Bursa in Turkey. *Word Conference on Technology, Innovation, and Entrepreneurship* (pp. 2556-2565). Istanbul: Elsevier Ltd.

[12] Fauziah, A., Harsono, A., & Liansari, G. (2014). Usulan Perbaikan Kualitas Menggunakan Metode Six Sigma Untuk Mengurang Jumlah Cacat Produk Tahu Pada Perusahaan Pengrajin Tahu Boga Rasa. *Jurnal Online Institut Teknologi Nasional*.

[13] Purnama, Dwi Adi., Shinta, Riadho Clara., Helia, Vembri Noor. (2018). Quality Improvement on Creative Industry by using Six Sigma: a study case. *Matec Web of Conference*. 