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Improvement Efforts of Cement Bags Using the Six Sigma DMAIC Method: A Case Study at PT. Semen Tonasa, Indonesia

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The fierce competition in the industrial world encourages companies to develop more ideas and efficient ways to achieve their goals. PT. Semen Tonasa is one of the State-Owned Enterprises (SOE) engaged in the cement industry. Its mission is to produce and sell cement to gain consumer satisfaction so that it can maintain and increase its domestic cement market share enabling it to compete in the international cement market. It also strives to improve quality by eliminating defective products in the production process. Six Sigma is used to improve quality to achieve the target of 3.4 failures per million opportunities for every product and service transaction. This is a technique used to control and improve quality and is a breakthrough in quality management. The result is quality cement bags, namely, 1.49 sigma with a damage rate of 93643 per one million production (DPMO). The implementation of six sigma quality improvement shows the three highest causes of defective products, that is, those that are not registered at 38%, blurred prints at 31% and bags cut at 30%.

Key words: *Quality Control, Six Sigma, Tonasa, SOE.*

Introduction

PT. Semen Tonasa is State-Owned Enterprises (SOE) engaged in the cement industry. Its mission is to produce and sell cement and gain consumer satisfaction in order to maintain and increase the domestic cement market share and enable it to compete in the international cement market. Under these conditions, only products or services of good quality will help the company survive the competition and maintain its market position (Chen 2010). The process of improvement and quality control should be done continuously; quality is a basic factor in consumer decisions when buying products (Cahyadi 2016).

The quality control at PT Tonasa cement starts when it receives raw materials and continues throughout the production process. The quality control around the manufacturing of cement bags requires special attention. The cement bagging is the final process before the product is marketed and distributed. This has a direct effect on customer satisfaction. Quality control is one way to facilitate companies to improve their production systems and to improve the quality of products in the production process. Knowing the causes of defects in cement bag manufacturing can help minimise the damage levels (Sharma 2003). This study focuses on the collection of data of 2,800,000 cement bags in production at PT. Semen Tonasa, between August and September 2018 and defective products of 16,536 from total production. The details are that 5,135 bags had blurred writing, 6,296 bags were not registered and 5,105 bags were cut. Quality is an important aspect of the production process with respect to increasing production, but over time the quality is often not consistent with established standards. Companies must pay more attention to production process nets in order to minimise the level of defective cement bags. Action is needed in order to determine the problems, measuring the defect levels, analyse the causes of the defects, improve the process and control the process performance with the Six Sigma DMAIC method (Lim 2013, Costa et al., 2020, Fahey, Jeffers and Caroll, 2020). The Six Sigma method is a comprehensive approach to solving problems and improving the process through the DMAIC (Define, Measure, Analyse, Improve, and Control) phase. The defective products will show the sigma level of the company.

Research methods

Company Location

PT. Semen Tonasa is located at Biringkassi, Biringkassi, Jl. Poros, Boriappaka, Bungoro, Pangkajene District and Island, South Selatan, 90611, Indonesia.

Production Activities

PT. Semen Tonasa produces craft bags and woven bag types for use as cement bags.

Six Sigma Method

Six Sigma is a new management tool that is used to change the Total Quality Management (TQM). It is focused on quality control by promoting an understanding of the structure of industrial production by means of totality. The goal is to eliminate production defects, cut production time and eliminate costs. Six sigma is also called a comprehensive structure with strategies, disciplines, and tools to reach and support the business success. Six Sigma is referred to as a strategy because it is focused on increasing customer satisfaction. It is called a discipline because it follows the official form, namely DMAIC (Define, Measure, Analyse, Improve, Control). It is used in conjunction with tools, such as a Pareto Chart and Histogram. The success in improving the quality and ability of the business depends on performance which recognises and resolves problems. This performance is a fundamental condition in the Six Sigma philosophy.

The Six Sigma method was developed by a US company in 1980 and was introduced by Mikel Harry and Richaed Shroeder. Six Sigma is a systematic statistical method designed to reduce variations in every process of key business dealings. Key business refers to the basic needs of customers, including quality, competitive prices, and timely delivery. Six Sigma is defined as a comprehensive and flexible system to achieve, support and maximise business processes. It focuses on understanding customers' needs through facts, data, and statistical analysis which is done continuously by paying attention to arrangement, improvement and reviews of the business processes. Six Sigma is a high-tech method used by scientists and statisticians to improve and develop processes and products.

Six Sigma is one method focused on quality control for studying the company's overall production system. It is a business method which allows a company to improve performance by designing and monitoring daily business activities in order to achieve customer satisfaction. This method was created to replace the TQM (Total Quality Management) method designed to prevent production defects, save production time and minimise costs.

Conceptually, Six Sigma can also be called a comprehensive and flexible system which provides support, optimises production processes in order to achieve efficiency values and understand customer needs. The Six Sigma method ensures that the company will continue to pay attention to the suitability and balance between performance and the customer's needs.

Six Sigma is a method to increase both productivity and profitability. It is a methodical application of a statistical problem-solving tool to identify and measure waste and show the improvement steps.

The Stages in the Six Sigma Method

The stages in the Six Sigma method are as follows:

a. Identification. This determines the objectives of the Six Sigma quality improvement activities. This step defines the action plans that must be carried out in order to make improvements for each stage of the key business processes.

b. Measurement. This is a parameter used to assess the capability of running process. The tool used is map control. The measurement phase is also followed by the sigma level determination.

There are four stages to the measurement process, namely:

- Determine the characteristics of CTQ (Critical to Quality)
- Determine the check sheet
- Determine the control chart (P-Chart)
  1. $\bar{p}$ = (number of defects) / (production amount)
  2. BPA
     $$P = \bar{p} + 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n}}$$
  3. BPB
     $$P = \bar{p} - 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n}}$$
- Determine the sigma capability

  1. Calculating the DPMO
     DPMO = (Number of defects found / (Production quantity × CTQ)) × 1000000

  2. Convert DPMO results with six sigma tables

c. Analysis. This is the third operational step in the Six Sigma quality improvement program. There are several things that must be done at this stage, namely: Determine the stability and capability of the process, set the performance targets of key quality characteristics (CTQ), and identify the sources and root causes of the problems in quality.

- A Pareto diagram is used to ascertain the highest type of defect that is to be repaired. The calculation of potential CTQ is as follows:
  1. The defects frequency is obtained from the recapitulation of product inspection in the process
  2. Cumulative frequency
     = 0^{th} cumulative frequency + 1 defect frequency
  3. The total percentage can be calculated by an equation of 6:
     Total Percentage = (1 CTQ / Total frequency of defects) × 100%
  4. Cumulative percentage

Cumulative Percentage = 0^{th} cumulative percentage + 1^{st} total percentage

- Fishbone diagrams or cause and effect diagrams
  Fishbone diagrams are used to find the cause of defects in Semen Tonasa products.

d. Improvement. This is a stage focused on improving the quality of Six Sigma by measuring (seen from opportunities, damage and current capability processes), recommending review improvements, analysing then applying corrective actions.
e. Control. This stage improves the quality by ensuring a new level of performance in standard conditions and maintaining the improvement values. This is then documented and disseminated as a corrective measure for subsequent process performance.

Results and Discussion

Table 1 shows the production data of cement bags of PT. Semen Tonasa

Table 1: Cement Bags Production at PT. Semen Tonasa

Dates	Production Quantity of Bag	Defect Type			Defects Products of Bag	Percent of Defects Products
		Blurr Printing	Not Registered	Cut		
2-Aug-18	55,000	128	132	102	362	2.18%
3-Aug-18	65,000	147	181	87	415	2.50%
6-Aug-18	70,000	87	134	121	342	2.06%
7-Aug-18	65,000	127	178	159	404	2.80%
8-Aug-18	60,000	152	119	103	374	2.26%
9-Aug-18	70,000	166	212	101	479	2.89%
10-Aug-18	50,000	102	197	97	396	2.39%
11-Aug-18	35,000	114	143	172	429	2.59%
13-Aug-18	70,000	98	194	129	421	2.54%
14-Aug-18	70,000	86	160	98	344	2.07%
15-Aug-18	70,000	120	102	125	347	2.09%
16-Aug-18	60,000	114	179	53	346	2.09%
17-Aug-18	55,000	116	219	137	472	2.85%
20-Aug-18	25,000	112	202	124	438	2.64%
21-Aug-18	125,000	102	207	103	412	2.48%
22-Aug-18	40,000	102	215	97	414	2.50%
23-Aug-18	95,000	123	178	53	354	2.13%
24-Aug-18	35,000	124	177	109	410	2.47%
27-Aug-18	65,000	104	165	143	412	2.48%
28-Aug-18	95,000	106	157	125	388	2.34%
29-Aug-18	75,000	110	164	142	416	2.51%
30-Aug-18	65,000	116	201	126	443	2.67%
31-Aug-18	60,000	102	219	102	423	2.55%
9-Sep-18	65,000	112	188	99	399	2.41%
10-Sep-18	70,000	118	196	101	415	2.50%
11-Sep-18	70,000	121	178	76	375	2.26%
12-Sep-18	30,000	101	193	89	383	2.31%
13-Sep-18	55,000	104	124	158	386	2.33%
14-Sep-18	75,000	108	184	124	416	2.51%
16-Sep-18	100,000	112	214	72	398	2.40%
17-Sep-18	110,000	173	197	180	550	3.32%
18-Sep-18	115,000	145	163	164	472	2.85%
19-Sep-18	110,000	100	96	163	359	2.16%
20-Sep-18	85,000	102	102	161	365	2.20%
21-Sep-18	70,000	124	146	89	359	2.16%
23-Sep-18	75,000	112	125	165	402	2.42%
24-Sep-18	45,000	107	149	123	379	2.29%
25-Sep-18	25,000	129	124	162	415	2.50%
28-Sep-18	35,000	98	126	132	356	2.15%
29-Sep-18	40,000	165	153	162	480	2.89%
30-Sep-18	15,000	178	123	72	373	2.25%
Total	2,665,000.000	4,867	6,816	4,900	16,583.00	100%
Average	65000	119	166	120	404	0.02

Table 1 shows three types of defects which occur in the production of cement bags, namely blurred writing, no registration, and cuts. The production amount was 2,800,000 bags. The highest number of defects related to blur writing was 5,135 bags, there was no registration on 6,296 bags and 5,105 bags had cuts.

Data Processing

Six Sigma is one method used to continuously improve quality through the DMAIC (Define, Measure, Analysis, Improve, and Control) stages in order to achieve zero defects.

Define

The define stage is where problems with quality in cement bag production are defined at PT. Semen Tonasa. This stage identifies the causes of the product defects. There are three types of defective product, namely: Blurred prints, not registered, and cuts.

1. Defining standard quality problems or the causes of defects in cement bag production. The potential causes of final product defects are as follows:
   a. Blurred print. The printing on cement bags /logos /writing are not clear /shaded.
   b. Not registered. The mouth of the cement bag is closed meaning that the cement cannot enter the bag.
   c. Cut. The bag is cut, the printed paper has defective parts/is deformed.
2. Defining the action plan below that must be conducted based on the results of research observations and analysis:
   a. Planning a regular maintenance on machine
   b. Increasing the number of workers
   c. Clearer and more directed work procedures
3. Determining the goals and objectives of Six Sigma quality improvement based on observations in order to reduce defective products from 0.048% to 0% as evidenced by the highest number of total defective products by 4.1% while the lowest defective products total 0.89% at PT. Semen Tonasa. The problems associated with defective products can cause losses for the company. The company makes strategic plans to reduce the defective products to 0%.

Measure

This stage calculates the defective products as related to blurred writing, not registered and cut cement bags at PT. Semen Tonasa from 1st August to 30th September 2018. The measurement is divided into two stages as detailed below:

1. Control Diagram Analysis

Quality control data is measured by the number of final products. Measurements were made using a Statistical Quality Control type P-Chart on cement bags products from 1st August to 30th September 2018. The total samples numbered 2,800,000,000 cement bags.

2. The cement bags production for two months is 2,800,000,000 with defective products totalling 16,536 cement bags. The P-chart control chart steps can be detailed as follows:

   a. Calculating the mean (CL) or average end product of a cement bag:

   $CL = \frac{\sum np}{\sum p}$ $\quad CL = \frac{16.536}{2.800.000}$=0.00590

   b. Calculating the damage percentage:

   $$p = \frac{\sum np}{\sum n}$$

   $$p = \frac{362}{55.000} = 0.0066$$

   c. Calculating the Upper Control Limit (UCL) and constructing the graph in figure 1:

   $$LCL = CL + \sqrt[3]{\frac{CL(1 - CL)}{n}}$$

   $$UCL = 0.00590 + \sqrt[3]{\frac{0.00590(1 - 0.00590)}{2.800.000}} = 0.043$$

   Figure 1. Control Chart

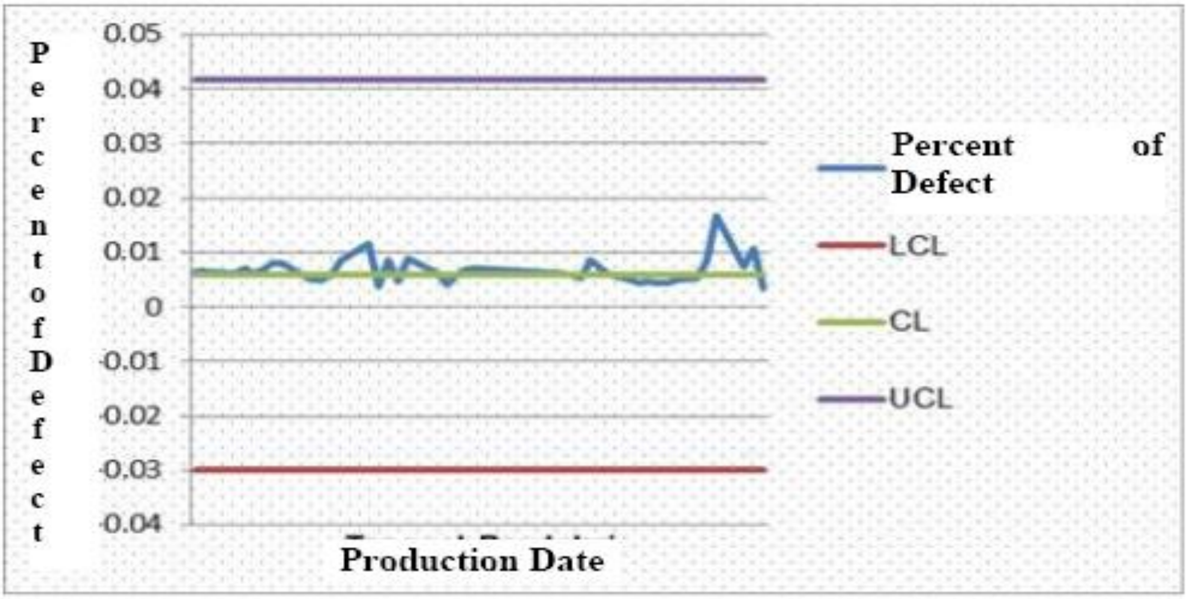

   Figure 1 shows the data is within control limits because it does not cross the two limits.

3. Calculating the Defect per Million Opportunities (DPMO) to measure the level of Six Sigma from production of cement bags (Allen 2006). The steps are as shown below:

a. Calculating DPU (Defect Per Unit)

$$DPU = \frac{\text{Defect (D)}}{\text{Unit Produced (U)}}$$

$$\text{August}/2: \ DPU = \frac{362}{55.000} = 0.0066$$

b. Calculating the Defect Per Million Opportunities (DPMO)

$$DPMO = DPU \times 1{,}000{,}000 DPMO = 0.0066 \times 1.000.000 = 6{,}582$$

c. Converting DPMO calculation results with Six Sigma tables to get sigma results. The calculation results are shown in Table 2.

Table 2: Sigma and DPMO Levels in August-September 2018

Date	Production Quantity (Sheet)	Defects	DPU	DPMO	Sigma Value
2-Aug-18	55,000	362	0.0066	6582	1.49
3-Aug-18	65,000	415	0.0064	6385	1.49
6-Aug-18	70,000	342	0.0049	4886	1.49
7-Aug-18	65,000	464	0.0071	7138	1.49
8-Aug-18	60,000	374	0.0062	6233	1.49
9-Aug-18	70,000	479	0.0068	6843	1.49
10-Aug-18	50,000	396	0.0079	7920	1.49
11-Aug-18	35,000	429	0.0123	12257	1.48
13-Aug-18	70,000	421	0.0060	6014	1.49
14-Aug-18	70,000	344	0.0049	4914	1.49
15-Aug-18	70,000	347	0.0050	4957	1.49
16-Aug-18	60,000	346	0.0058	5767	1.49
17-Aug-18	55,000	472	0.0086	8582	1.49
20-Aug-18	25,000	438	0.0175	17520	1.47
21-Aug-18	125,000	412	0.0033	3296	1.50
22-Aug-18	40,000	414	0.0104	10350	1.48
23-Aug-18	95,000	354	0.0037	3726	1.49
24-Aug-18	35,000	410	0.0117	11714	1.48
27-Aug-18	65,000	412	0.0063	6338	1.49
28-Aug-18	95,000	388	0.0041	4084	1.49
29-Aug-18	75,000	416	0.0055	5547	1.49
30-Aug-18	65,000	443	0.0068	6815	1.49
31-Aug-18	6,000	423	0.0705	70500	1.39
9–Sep-18	65,000	399	0.0061	6138	1.49
10–Sep-18	70,000	415	0.0059	5929	1.49
11–Sep-18	70,000	375	0.0054	5357	1.49
12–Sep-18	30,000	383	0.0128	12767	1.48

13–Sep-18	55,000	386	0.0070	7018	1.49
14–Sep-18	75,000	416	0.0055	5547	1.49
16–Sep-18	100,000	398	0.0040	3980	1.49
17–Sep-18	110,000	469	0.0042	4227	1.49
18–Sep-18	115,000	387	0.0034	3365	1.49
19–Sep-18	110,000	359	0.0033	3264	1.50
20–Sep-18	85,000	365	0.0043	4294	1.49
21–Sep-18	70,000	359	0.0051	5129	1.49
23–Sep-18	75,000	402	0.0054	5360	1.49
24–Sep-18	45,000	379	0.0084	8422	1.49
25–Sep-18	25,000	415	0.0166	16600	1.48
28–Sep-18	35,000	447	0.0128	12771	1.48
29–Sep-18	40,000	480	0.0120	12000	1.48
30–Sep-18	15,000	501	0.0334	33400	1.45
TOTAL	**2,611,000.000**	**16,636**			
Average	**63682.927**	**405.756**	**0.009**	**9364.332**	**1.49**

Table 2 shows that the sigma level is 1.49 with a possible damage of 16,636 pieces for one million bags in production. This is undoubtedly a disadvantage if left untreated because failed products increase production costs.

Analyse

1. Pareto diagram

The data is processed in order to determine the percentage of products rejected. The calculation uses the following formula:

$$\% \text{ Defects} = \frac{\text{Defects Type}}{\text{Total Defects}} \text{ X } 100$$

The percentage of types of defective products is as follows:

a. Blurred prints of 5,135 sheets
   Calculation:
   Damage = 5,135 / (16,536) X 100
   Damage = 31%
b. Not registered total 6,296 sheets

   Calculation:
   Damage = 6,296 / (16,536) X 100
   Damage = 38%

c. Cuts to 5,105 bags
   Damage = 5,105 / 16,536 X 100
   Damage = 30%

The above calculation can be illustrated in a Pareto diagram as shown in figure 2.

Figure 2. Pareto Diagram of Defects Bags

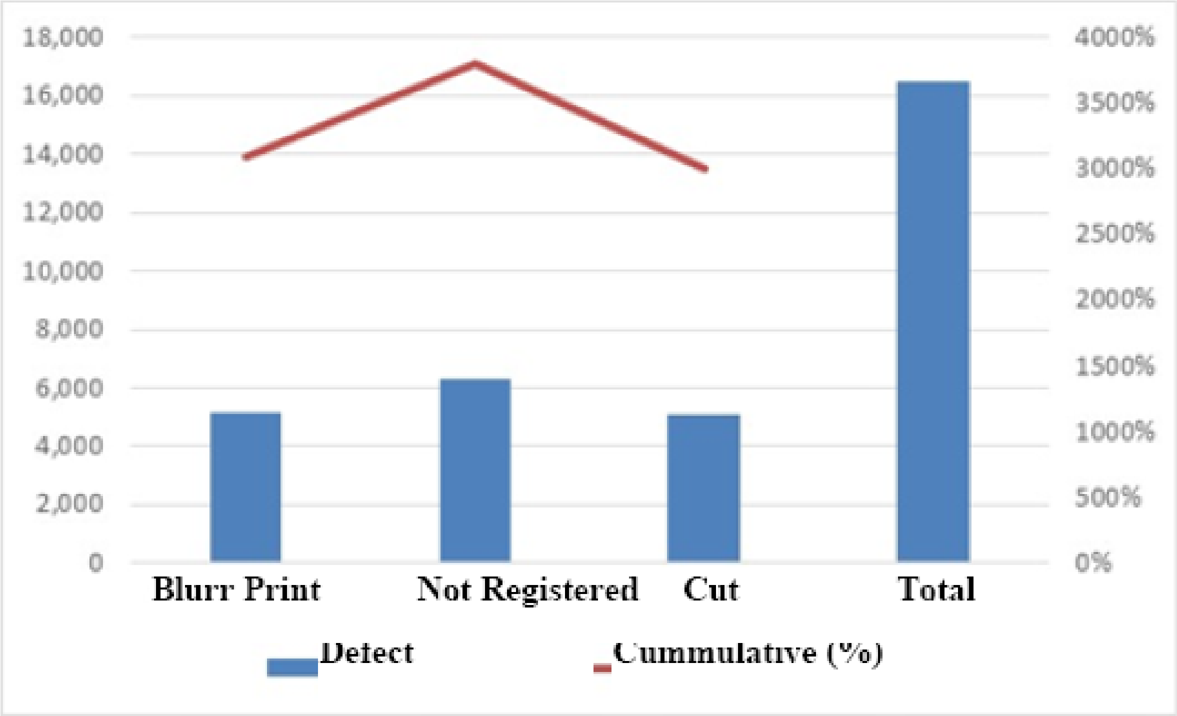

Figure 2 shows three causes of defects, namely, blurred printing, not registered, and cut bags. The largest number of defects is related to bags not registered with defects totalling 38%. Blurred print is responsible for 31% of defects and cut bags total 30%. Improvement can be achieved by focusing on three types of defect causes, namely blurred print, not registered and cut bags.

2. Cause and Effect Diagrams

Cause and effect diagrams show the relationship between the problem and the possible causes and the affecting factors. The affecting factors and defect causes can be classified as shown below:

a. Human Error. This relates to errors caused by workers involved in the production process.
b. Raw Material. This is the production component used by the company in the production process and consists of the main raw materials and auxiliary raw materials.

c. Machinery. This consists of machinery and various equipment used in the production process
d. Method. This relates to work instructions or work orders that must be followed in the production process.
e. Environment. This relates to the circumstances around the company which directly or indirectly affects the company, in general, and specifically in relation to the production process.

After establishing the type of defects, PT. Semen Tonasa needs to take corrective steps to prevent similar damage. The most important thing to do is to find the cause of damage. A tool used to find the cause of defects is referred to as a fishbone chart. The use of cause and effect diagrams to trace the type of each defect is shown in figure 3.

Figure 3. Cause - Effect Diagram

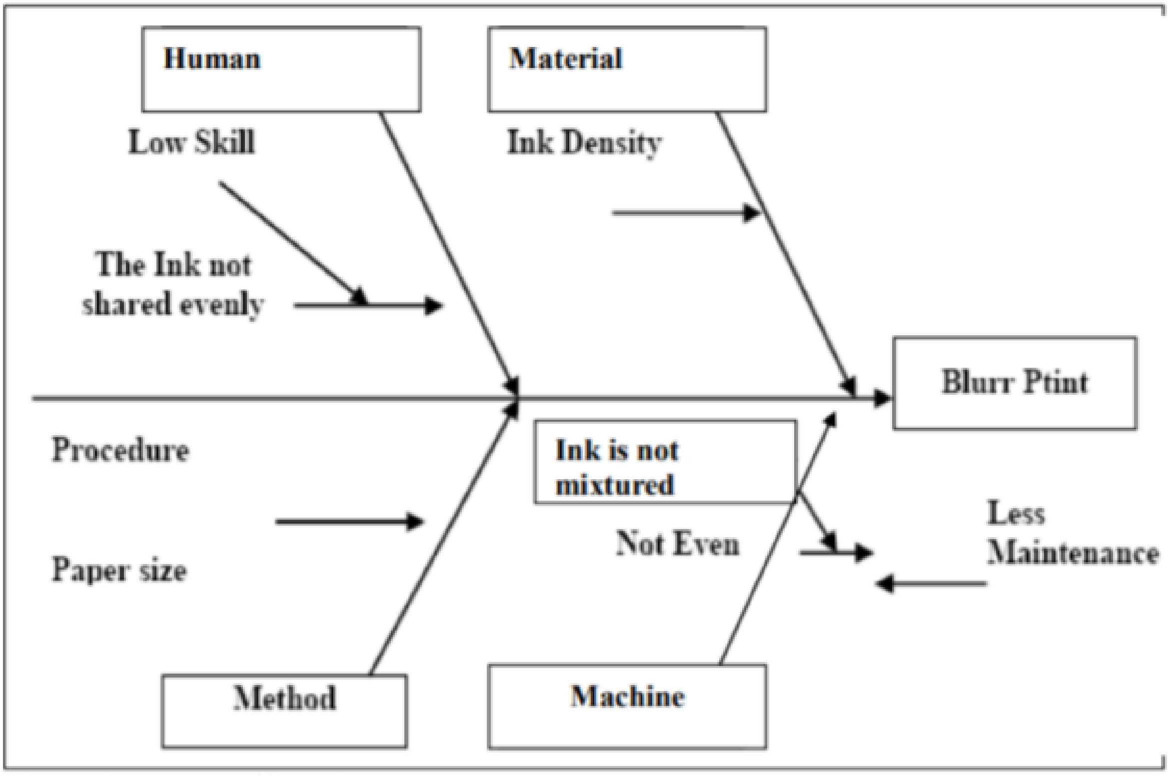

Figure 3 show the printing on the cement bags/logos/writing is not clear. This occurs at the beginning of production and is due to the following factors:

a. Human. Humans are the main element in the production process. Human beings have the potential to cause defects because they have many roles and must adjust to where they work. The defects caused by human elements are as follows: Workers are poorly skilled with regard to the setup of the machine and ensuring that the ink is distributed evenly so that it doesn’t create blurred prints.

b. Material. The quality of materials used in production process is an important aspect in producing a high-quality product according to company standards. The causes of defects from materials used at PT. Semen Tonasa are as follows: The ink is less dense and causes blurred printing.
c. Machine. The machine is an important part of processing raw materials into a product. A broken machine will automatically affect the product process. The causes of defects from a broken machine are follows: The printing machine has had a lack of maintenance.
d. Method. Attention should be given to the work methods in the production process. Obedience to procedure produces a good product. The defects caused by the methods at PT.Semen Tonasa are as follows: There is no clear procedure regarding ink sensitivity.

Improve

The plan of action is to implement Six Sigma quality improvement. Based on the cause of product defects at PT. Semen Tonasa, the recommendation for general improvement is to make additional efforts to reduce the level of product damage.

Control

This is the final analysis phase of the Six Sigma project which emphasises documentation and dissemination of actions.

1. Performing regular machine maintenance and repair.
2. Supervising the raw materials and employees in the production department in order to ensure a better quality product.
3. Recording all defective products every day for each type and machine by employees involved in the production process.
4. Reporting the defective products based on type of product in a note to the supervisor.

The fishbone diagram shows that the main cause of defects in the cement bags defect relates to both human and machine factors. Some of the workers' behaviours are not consistent with the rules. Some machines are improperly set up or need to be repaired periodically and this creates the potential for more defects. Without good handling the defect potential could be huge and more products will fail in the production process which will cause an increase in production costs. Improvements need to be carried out by the company. Workers should be trained to improve their work capabilities, and regular scheduled maintenance should be done in order to minimise potential damage.

Conclusions

1. The production process of cement bags shows that there are three types of defects, namely blurred printing, incorrect registration and cut bags. The process of quality control at PT. Semen Tonasa has not met the defects tolerance standards set by the company. The research results show that PT. Semen Tonasa has a sigma level of 1.49. This is certainly a huge loss and without good handling more defective products will cause an increase in production costs.
2. A causal or fishbone diagram shows the main causes and ways of minimising the level of defects in cement bags through improvements in both machines and human errors.
3. Targeting level 6 Six Sigma by more deeply examines the process to look for the main causes of each defect in order to drastically reduce the level of defects for each process.

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