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Enhancing quality management in Indonesia's flexible packaging industry: A six sigma approach to defect reduction and cost savings

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ABSTRACT

Background: The flexible packaging industry is experiencing significant growth, requiring companies to improve efficiency by reducing defects and minimizing the cost of poor quality (COPQ). Effective quality control is crucial to maintaining competitiveness and reducing waste. This study focuses on assessing and improving quality control in an Indonesian flexible packaging company, XYZ, using the Six Sigma methodology. **Methods:** The research adopts the Six Sigma DMAIC (Define, Measure, Analyze, Improve, Control) approach to identify defects and propose solutions. Data collection includes statistical analysis, historical records, and interviews with company sources. The study specifically examines defects in the printing process, which accounts for 79% of total defects based on the 80/20 principle. The Failure Mode and Effects Analysis (FMEA) model is applied to identify root causes and develop recommendations for improvement. **Findings**: The study identifies multiple factors contributing to printing defects, such as register shifting, film scratching, color inconsistencies, ink transfer issues, and ink spots. Operator performance and machine-related issues are found to be the dominant causes of defects. Implementing the recommended quality control improvements can potentially reduce defect-related costs by 48%, translating to estimated cost savings of 114,734,847 IDR during the study period. **Conclusion**: This research confirms the effectiveness of Six Sigma in reducing defects and improving production efficiency in the flexible packaging industry. However, limitations include restricted access to ERP data, reliance on interviews and historical records, and the inability to evaluate the implementation of control measures. **Novelty/Originality of this article**: This study contributes to the literature by applying Six Sigma in a flexible packaging industry context in Indonesia, demonstrating its potential for substantial cost savings. Unlike previous studies, it emphasizes the human factor in quality control and suggests a systematic approach to defect reduction.

KEYWORDS: quality control; six sigma; cost of poor quality; pareto analysis; failure mode effect analysis.

1. Introduction

The flexible packaging industry is a fast-growing sector as demand for these products grows. Its development in Indonesia is inseparable from the development of other industries such as the consumer goods industry. Consumer goods products, especially food and beverages, are the main driving factor of this business. The growth of the petrochemical and food and beverage industries is relatively increasing from year to year, at around 8-10% per year. In particular, the increased performance of the food and beverage industry

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has also driven the consumption of plastic packaging products to reach 60% as of 2019 (PT Berlina Tbk, 2020). With the development of industries that require flexible packaging, the flexible packaging industry will also grow.

Nowadays, more and more products are switching from rigid packaging to flexible packaging. In 2016, Indonesia's flexible packaging market had accounted for a market share of 42% of the overall packaging market (DataM Intelligence, 2019). Research conducted that this shift is due to changes in consumer behavior, such as product consumption levels driven by the availability of surplus funds, technological advancements, such as advancements in packaging materials, and the practicalities provided by flexible packaging, such as ease of storage and transportation. In Indonesia, the flexible packaging market is segmented by various forms of packaging namely, pouches, bags, roll stocks, blister and strip packs. Bag type flexible packaging accounts for the most significant market share of 42% in the overall flexible packaging market.

Meanwhile, blister and strip pack flexible packaging accounted for the smallest share of 1% in the overall flexible packaging market in Indonesia (DataM Intelligence, 2019). Indonesia has developed industries for both flexible and rigid packaging markets. In 2019, the flexible packaging market in Indonesia had a dominating share in the Association of Southeast Asian Nations (ASEAN) market and is expected to lead the region in the coming years (DataM Intelligence, 2019). The plastic packaging industry in Indonesia is recorded at around 892 companies including small and medium industries with a total workforce of 177,300 people producing hard and soft plastic packaging (PT Berlina Tbk, 2020). The increasing number of companies that grow and enter the flexible packaging industry has led to changing market demand structure conditions (Formoso et al., 2002). This condition triggers increasingly competitive competition where industry players must be better at providing competitive prices and high quality. In a global market with intense competition issues, consumer expectations are getting higher in getting quality products and services. The competition created generates pressure for companies in the flexible packaging sector to carry out production efficiently. For this reason, companies in the flexible packaging industry need to take advantage of every opportunity to improve the efficiency of their production processes. Increasing efficiency in achieving competitive advantage can be done with a quality control system. The quality control system needs to be well implemented in the company to prevent unwanted costs. Clark (1999) states that companies will always try to reduce the costs associated with poor quality products and services referred to as the cost of poor quality (COPQ). In manufacturing, COPQ can be the total of repair costs, rework costs, warranty claims and costs resulting from obsolete finished goods (Clark, 1999).

In the production of flexible packaging, there are processes that do not add value and this affects the profitability of the company which is identified as waste. Sarkar (2009) states that waste has two categories. First, process waste, which is waste that indirectly affects the quality of the final product and production waste, which is any raw material that cannot be converted into a finished product that can be sold. Both process waste and production waste will reduce efficiency and thus decrease the productivity of the factory. This has an effect on the quality of products that will eventually be transferred to customers. Toyota categorizes waste into seven types: over production, waiting, incorrect processing, unnecessary movement, conveyance, excess inventory, and defects (Liker, 2004). Defect means that the production process produces defective parts or goods. Liker (2004) mentions that this results in repair or rework, scrap, replacement production, and inspection which means additional time and effort which is considered waste. All activities in manufacturing companies that produce defects can extend the production lead time. The company will also require additional or replacement activities that require direct or indirect costs. Therefore, additional time and costs that do not add value to the product transformation process from input to output need to be eliminated. The accumulated value of this defective production can cause the COPQ of flexible packaging companies to get bigger. Kumar and Sosnoski (2009) stated that one approach to reducing costs resulting from defects is a project-based approach with the Six Sigma DMAIC method. Tong et al. (2004) stated that the Six Sigma DMAIC Method can be used to improve existing processes and this is widely proven through previous research that has been successful in reducing costs, increasing cycle time, eliminating defects, increasing customer satisfaction and significantly increasing profitability in every industry around the world.

The basic statistical tools used in the five stages of DMAIC help to identify, measure and eliminate the root causes of defects and sustain improved production line performance with a well- executed control plan in the future (Desai, 2006; Desai & Shrivastava, 2008). The goal is to adopt an approach to prevent defects from appearing and reduce the costs that would be caused by them. One of the studies using the Six Sigma DMAIC method was conducted by Zhao (2011) who conducted research in China by applying a combination of statistical tools as an approach in determining process- oriented quality control. Based on his research, the statistical tools contained in Six Sigma are used to obtain information and take timely action to prevent costs that may be lost due to poor quality control. In flexible packaging companies, a comprehensive and effective quality management system must even be established from the early stages such as pre-press, which is to prepare the design for the packaging medium, to ensure good quality of the final product (Evans & Lindsay, 2005). The production process must also fulfill a certain set of plans that have been made. To achieve the planned quality and production volume, suitable methods for quality control are required. In this context, repair and maintenance are possible to make quality more secure (Ishikawa, 1985).

In this study, quality control in a flexible packaging company uses the research object, namely the XYZ company. XYZ Company is a company that provides packaging production for the food and beverage and pharmaceutical industries. XYZ company located in Indonesia is more focused on offering flexible packaging production with production activities in two factories based in Jakarta and Tangerang. During the production period from July 2019 to December 2019, there were variations in the defect rate in the production of XYZ company. The defect rate indicates a decrease in the production quality of the final product in accordance with specifications and limits. From the historical data obtained, COPQ constitutes 6.08% of sales for the Jakarta factory and 9.48% of sales for the Tangerang factory (Juran & Godfrey, 1998). This is a problem because COPQ cannot be passed on to customers and all costs due to poor quality are absorbed by the company as a manufacturer (Prashar, 2014). To support better quality of the production process, an approach using the Six Sigma DMAIC method was applied to solve the problem and provide recommendations related to quality control using the tools contained in the Six Sigma method. Problem solving using the Six Sigma method is expected to find an estimate of cost savings from reducing COPQ in the production process at the XYZ company which is a case study (Kumar & Suresh, 2008). However, the company is most likely to succeed if top-level management supports a culture of continuous improvement (Heizer & Render, 2014). Prevention of incidents of defects is the most desirable state for researchers. A number of quality controls can be put in place to achieve the desired outcome (Liker, 2004). Controls require an understanding of how materials are converted in the overall production process in a flexible packaging company. Improved quality control that ends the root cause of the problem is the expected outcome of this research. Therefore, the information obtained was used to look for available opportunities to make improvements. This was done to achieve the desired defect incidence limitation.

2. Methods

Based on its purpose, the study conducted is a descriptive study. According to Cooper & Schlinder (2011), a descriptive study is a study that focuses on the what, who, when, where, why, or how many aspects of an event. This research focuses on quality control in waste prevention efforts at XYZ company, in this case focusing on the defect category. Therefore, the research conducted can be categorized as a case study. XYZ Company is the subject of this research because it is a multinational company that has been operating globally in the field of flexible packaging manufacturing.

XYZ Company also has factories located in Jakarta and Tangerang, and has been able to serve the needs of packaging products in Indonesia with a variety of customers who sell products with packaging in Indonesia. XYZ Company also claims that its market share is growing significantly in Indonesia. In a competitive market, maintaining effective and efficient operating performance and future improvements will provide a competitive advantage in the market. Thus, this research aims to provide an analysis on better quality control in defect prevention efforts. This research is not limited to identifying root causes but includes the development of a better quality control framework. This research utilizes the Six Sigma method to identify the root causes of existing problems and propose recommendations that can have an impact on the company's business. The Six Sigma method can actually be implemented in two ways, DMAIC and DMADV, the difference being in the stages performed.

DMAIC is used for existing products and processes. DMAIC consists of five stages consisting of define, measure, analyze, improve and control (Yin, 2009). . DMAIC is applied when the cause of the problem is unknown or unclear, for significant savings and the project can be done in 4-6 months. While DMADV is used for new products and processes. The first three steps of DMADV are the same as DMAIC, but the last two steps focus on designing and verifying future products or processes (Mehjerdi, 2011). The choice of using these methods is based on the purpose or nature of the research conducted, namely achieving quality control in an effort to reduce defects. This is in line with Mehjerdi's (2011) opinion, that the DMAIC method has strengths that lie in its empirical, data- driven approach and the fact that it focuses on using quantitative measures to explain system performance in achieving process improvement goals (Sousa & Voss, 2002).

2.1 Quality management with six sigma

The define stage as the first step in implementing the Six Sigma method is a clear identification of the problem at hand. Before entering the define process, the potential project to be carried out is first determined. This is focused on providing a mapping of the research process for researchers and identifying parties who have a relationship with the production process. The measure stage follows the previous stage built with relevant data to determine the behavior of the production process in the company today. Measurement can be done by graphical analysis of the data such as Pareto diagrams are done in this section. From the measure stage, the target to be analyzed can then be determined. In this research, Pareto Analysis will be used in performance measurement which will provide the necessary initial focus of the research objectives as well as prioritizing the handling actions. The analyze stage aims to understand how the process actually works (Wiesenfelder, 2013). The analyze stage identifies the sources of various problems in the process and confirms the causes with appropriate analysis tools. In this research, the identification of these causes uses a Cause-and-Effect Diagram that explains the cause and effect relationship of the existing conditions. The researcher used information obtained from the literature study and historical data to identify factors and subfactors for each main category.

The results of the Cause-and-Effect Diagram were then used to create a Failure Mode Effects Analysis (FMEA) to analyze the various causes of the selected conditions. Through interviews, suggestions for improvements were collected in implementing relevant quality controls. After knowing the potential failure modes, the researcher found the causes, effects and current controls on each potential failure mode and the data used in ranking severity, occurrence and detectability. The Risk Priority Number (RPN) is the product of the severity (S), occurrence (O), and detectability (D) ratings, as shown equation 1.

$$RPN = (S)\ x\ (O)\ x\ (D) \qquad \text{(Eq. 1)}$$

From the understanding of the root cause of the problem found, the implementation of a new solution is required. The improvement stage is aimed at finding potential solutions to solve the root cause of the problem that are low-cost with the highest effectiveness. This stage includes validation of the potential solutions. Potential cost savings were calculated after the results section of the Six Sigma statistical tool was obtained. Job data is required to calculate the cost of poor quality (COPQ) after improvement and is obtained from the director of operations. The required data are as follows: (1) Costs due to poor production quality per customer and per product that the company incurred during the analysis period. This includes: quantity of defects and cost of input materials required. (2) Percentage of COPQ (cost of wastage from sales). (3) The percentage of waste that can potentially be eliminated. It is important for this data to be able to go through management justification beforehand. COPQ after improvement is estimated using the following equation 2.

$$COPQ\ After\ Improvement = \frac{COPQ\ Before\ Improvement\ x\ (\%Initial\ COPQ - \%Preventable\ Defects)}{\%Initial\ COPQ} \quad \text{(Eq. 2)}$$

Furthermore, cost savings can be calculated using the following equation 3.

$$Cost\ Savings = COPQ\ Before\ Improvement\ -\ COPQ\ After\ Improvement \quad \text{(Eq. 3)}$$

The ultimate goal of the control stage is to ensure continuous improvement and become standard operating practice. However, this research does not provide an explanation until the control stage because this function is beyond the control of the researcher. In othr hand, the recommendations provided are implemented or not by the object company studied.

2.2 Data collection technique

In researching quality control in flexible packaging companies, researchers need quantitative and qualitative data. Quantitative data was collected using documentation derived from historical data. Meanwhile, qualitative data was collected using semi-structured interviews and open questions by confirming the interviewees' answers before interpreting the data. According to Dr. Blackstone (2006), qualitative and quantitative data together can provide greater understanding. With both methods, information was analyzed using Microsoft Excel to tabulate, categorize, examine and visually represent the data. As explained earlier, in this study researchers used two sources of data collection, namely data sourced from interview activities and historical data obtained from XYZ company.

Interviews are conducted to obtain feedback on the implementation that will be provided later as a verification effort. In this study, the first purpose of the interview was to highlight the current problems experienced by XYZ company related to waste generated from the production process. Second, interviews were conducted individually to obtain a critical analysis of the implementation of the Six Sigma method. Interviews were conducted with resource persons working in the production field of XYZ company who have sufficient experience and understanding related to quality control. The interview was conducted with the aim of obtaining a description of the quantity of defect incidents and quality control that currently occurs on the production floor. Interviews are also expected to help researchers to explore the causes of a problem in detail and develop discussions related to appropriate handling. It is intended that the recommendations to be produced remain in accordance with the resources in the XYZ company.

3. Results and Discussion

3.1 Case study description

In the production of flexible packaging, there are processes that are not value-added and this affects the profitability of the company which is identified as waste. Improving the efficiency of the production process in achieving competitive advantage can be done by reducing the potential incidence of defects which are waste. This is increasingly important as competition in the marketplace generates pressure for companies in the flexible packaging sector to produce efficiently. In this study, quality control in a flexible packaging company using the research object, namely the XYZ company (the company name is kept confidential for the sake of the company's interests and security).

XYZ Company is a global company that develops and manufactures packaging for use in snacks and sweets, diary products, plastic and rigid containers for brands in the food, beverage, pharmaceutical, personal and home care segments. XYZ Company has received accreditation for food safety with evaluations covering equipment, controls, storage and safety. XYZ Company in Indonesia is more focused on offering flexible packaging production with production activities in two factories based in Jakarta and Tangerang. The company has a total of around 600 employees working in both plants. Printing, laminating, and slitting are some of the services offered by the company.

The company data shown in Table 1 shows the percentage of orders that can be fulfilled by the Tangerang factory, Jakarta factory, and overall according to customer specifications, the rest are defects. The data was taken for six months from July 2019 to December 2019. The level of orders that can be fulfilled must reach 100% to be said to have no defects. The company has a limit of defective products that can be tolerated at 2% of the total packaging production per month. Percentage of order production according to company XYZ specifications can be seen in Table 1.

Table 1. Percentage of order production according to company XYZ specifications

	Jul	Aug	Sep	Oct	Nov	Dec	Average
Tangerang Pb	85.79	96.15	89.50	96.48	85.58	89.59	90.52
Pb Jakarta	95.19	91.45	95.46	99.17	86.92	95.32	93.92
Overall	92.42	92.79	93.67	98.41	86.41	93.36	92.84
Target	98	98	98	98	98	98	

Variations in the level of defects in production indicate a decrease in service quality in order fulfillment. This impacted the number of customer complaints because thecompany failed to fulfill customer orders several times. This order fulfillment failure is due to the company not delivering the final product with the agreed delivery time due to the mismatch of the final product with the requested specifications. According to the historical data obtained, the cost of poor quality (COPQ) represents 6.08% of sales for the Jakarta plant and 9.48% of sales for the Tangerang plant. Overall, COPQ represents 7.16% of sales.

Table 2. Quantity of production process defects of XYZ company Jakarta factory

Customer	Products	Customer Complaint Type	Incidence of Disability	Defect Quantity	Value (IDR)
A	1	Printing	2 times	456,000 pcs	54,720,000
	2	Printing	19 times	1.26 roll	2,841,572
B	3	Printing	10 times	51,900 pcs = 0.83 rolls	1,904,594
	4	Rewind	5 times	1 roll	501,745
	5	Slitting	1 time	2 rolls	1,196,772
C	6	Printing	10 times	92,673 pcs = 1.37 rolls	2,801,225
D	7	Laminating	1 time	4.19 roll	8,046,895
	8	Printing	9 times	5.5 roll	7,328,750
E	9	Printing	1 time	2 rolls	2,645,000
F	10	Printing	13 times	0.94 roll (20.12 kg)	1,048,449
G	11	Printing	3 times	44 roll ex-prod. = 158 kg	10,141,862
H	12	Printing	1 time	22,275 pcs= 2.97 rolls	3.463.763
I	13	Printing	7 times	11.34 roll	11.169.900
J	14	Bag Making	1 time	6.57 kg= 0.63 roll	477.540
Total					108.288.067

In an effort to control the amount of waste, a quality control system needs to be well implemented in the company to prevent unwanted costs or COPQ. In the case study, COPQ comes from rework costs and costs generated from defective finished goods from various production lines. Tables 2 and 3 show the distribution of defect quantity by customer complaint type from 11 customer companies with 21 types of products. In addition, the COPQ arising from a number of defect incidents occurring in factories in Jakarta and Tangerang are presented respectively.

Table 3. Quantity of production process defects of company XYZ Tangerang factory

Customer	Products	Customer Complaint Type	Incidence of Disability	Defect Quantity	Value (IDR)
A	1	Printing	2 times	25 Roll	41,993,125
	15	Slitting	20 times	32.35 Roll	34,646,850
	16	Slitting	9 times	16.8 Roll	17,992,800
	17	Slitting	5 times	0.91 Roll	974,610
	18	Slitting	1 time	0.1 Roll	157,973
K	19	Slitting	10 times	6.87 Roll	27,471,358
	20	Printing	1 time	1.61 Roll	6,285,094
	21	Laminating	9 times	0.78 Roll	998,700
Total					130,520,510

The company data shown in Tables 2 and 3 show data on the quantity of defects and the cost impact arising from the number of defective goods for six months from July 2019 to December 2019. The total COPQ wasted during one semester of production was 108,288,067 IDR at the factory in Jakarta and 130,520,510 IDR at the factory in Tangerang. COPQ at XYZ company cannot be passed on to customers and all costs are absorbed by the company as a producer. Defective products go through all value- adding processes using raw materials, machinery, utilities, etc. that do not generate profits. Meanwhile, the customer will only pay for the finished product with a specified number of defects. Quality is becoming a prerequisite in today's increasingly competitive business climate. To support better quality, an approach using the Six Sigma DMAIC method is applied to solve problems and provide recommendations related to quality control in the production process at XYZ company and find estimated savings with COPQ reduction.

Among the changes in the organization accompanied by integration, the development of quality management is important. The saving of resources from various departments gives rise to a sustainable competitive advantage. According to Barney (1991), organizations need to develop heterogeneous corporate resources to gain sustainable competitive advantage. This research also highlights how quality management practices in XYZ company especially the production environment. For XYZ Company, to be the best in the flexible packaging industry would require a quality improvement plan for five to ten years. Operational excellence is implemented by XYZ company as a quality management method. Basu (2004) states that operational excellence is a broad program to improve and sustain business performance by embedding quality management. This method includes key programs such as; manufacturing excellence, service excellence, marketing excellence and supply chain excellence. The company uses a stage called operational management where business objectives are made to deliver profits by balancing customer wants with available resources (Krajewski et al., 2013). The company aims to achieve competitive advantage by benchmarking with competitors. This is supported by a continous improvement program called operational improvement. XYZ Company uses quality control tools in flexible packaging production such as thickness measurement and shrinkage measurement in production quality control inspections. On the other hand, service measurement is used to achieve better customer satisfaction. Finally, the company maintains the benefits generated by operational excellence with a continuous assessment strategy.

3.2 Implementation of six sigma DMAIC

Clearly defining the problem and objectives of the research is necessary for the research to focus improvement efforts. Due to the fact that no process performance evaluation was obtained by the researcher, how much the process would be improved was difficult to measure. This is the reason why the researcher followed a conservative approach in setting the problem and objectives. In this study, the problem determination was made by developing a high level process map. A high level process map or what can also be called a SIPOC diagram is used to define the process to be identified and map the relationship between the supplier, input, process, output, and the associated customer. After determining the problem in the first stage of the DMAIC method, the next step is data collection to understand the characteristics that affect the behavior of the production process in the measure stage. In this stage, the parameters that will be used to measure current performance and determine the extent to which performance can be improved with a clear measurement system will be indicated. To find out the actual distribution of defects, researchers must take data that can explain the source of waste based on the type of process, machine, and type of defect. The defect distribution data must be 100% accurate. Because, this data will be the standardized measure and used to determine the most relevant improvements. In addition, the data will be very important for project analysis using the Six Sigma DMAIC method.

Furthermore, from Tables 2 and 3, Pareto diagrams were developed. Pareto diagrams are essential for gaining clues and understanding of the process itself. The Pareto diagram will help to identify the most common categories in the data columns related to different types of defects. Figure 1 illustrates the distribution of defect incidents from each stage of the process. Figure 1 states that there are five variations of defect incidents defined as; printing defect, laminating defect, slitting defect, bag making defect, and rewind. The Pareto diagram of defect incidents can be seen in Figure 1.

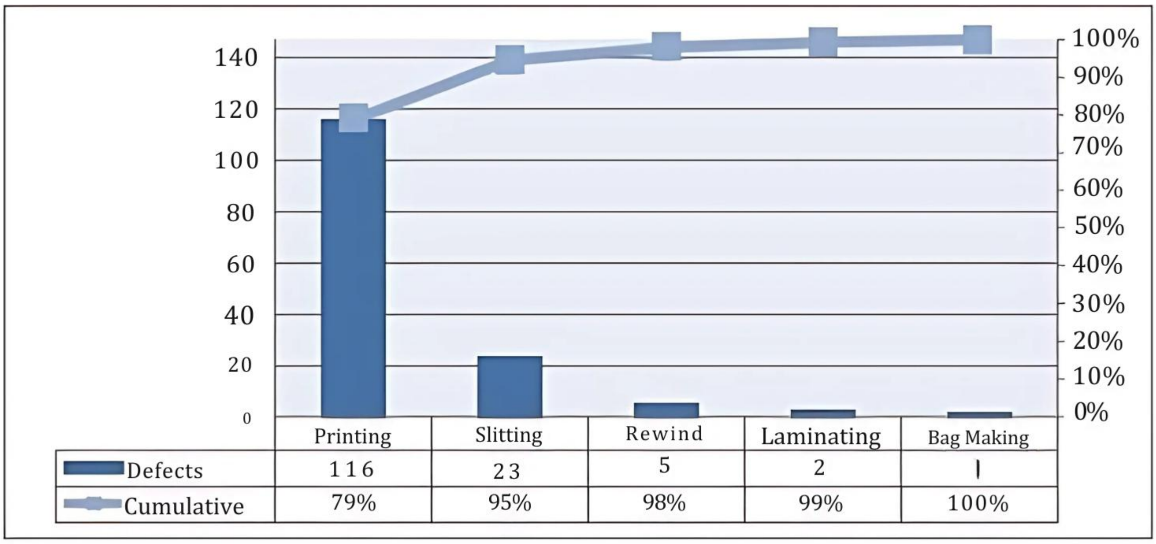

Fig. 1. Pareto diagram of defect incidence

In the production department of XYZ company, printing defect is the most frequent defect incident among the existing production workmanship stages with 116 incidents found (79%). The 80/20 principle can be seen to some extent from the data on the number of defect incidents. Cumulatively, it represents 79% of the total number of defect incidents found as shown by the cumulative curve, or 116 out of a total of 147 incidents. Slitting defect was the second most frequent defect incident with 23 incidents found (16%). Rewind was the third most frequent defect incident with 5 incidents found (3%). Defect incidents originating from laminating defects are the fourth most frequent defect incidents with 2 incidents found (1%). And bag making defect is the fifth most frequent defect incident with 1 incident found (1%). From the previous Pareto diagram, the printing process is the most critical because incidents of defects in the printing process occur most frequently among the existing workmanship stages of goods production (Simseker et al., 2012). Where, the total unexpected costs incurred due to incidents of defects in this process are the greatest compared to other workmanship processes, namely 146,343,334 IDR (61%) of the total costs for six months (July 2019 to with December 2019) at both factories amounting to 238,808,577 IDR. Therefore, the researcher focused the analysis on handling waste generated by the printing process.

3.3 Analyze the cause

In the DMAIC method, the third step is analyze. During this stage, the researcher examines the measurement results of the data collected in the measure stage and seeks a more in-depth explanation. The analyze stage aims to explore the data collected, analyze, verify and prioritize the possible root causes of the problem and their relationship to the output. According to Benbow & Kubiak (2010), the analyze stage can be conducted using tools and techniques such as brainstorming, Cause-and-Effect Diagram and Pareto Analysis. In defect cause analysis, it involves the process of identifying possible causes for the desired effect and narrowing down the root cause to a few significant variables to be able to understand the effect. Therefore, the researcher developed the Cause-and-Effect Diagram to organize and graphically display the entire knowledge of causes held for a particular problem or effect. Patel (2011) stated that the location of the cause in the diagram is not an important indicator, but subfactors can also be the main cause of the problem. Researchers can collect more data on factors that have not been previously identified.

The composition of the printing defect rate is further known and verified by identifying the sources that generate defects. Previously when the composition of the printing defect rate was not known and verified, the inability to identify the source of defects resulted in an ineffective quality control strategy. This will result in continuous loss of profit with raw materials being wasted without accurate root cause eradication. The root causes of printing defects can be caused by one or a combination of causes sorted according to the most frequent occurrence in Table 4, defect occurrence data was collected from cases for six months from July 2019 to December 2019.

Table 4. Root cause of printing defects july 2019 - december 2019

No.	Causes of Disability	Incidence of Disability
1	Uneven doctor blade	34
2	Fluid material	31
3	Unbalanced press roll cylinder (PRC) rotation	12
4	Thinning cylinder raster	12
5	Joint material	11
6	No splicing	8
7	Rough cylinder	6
8	Rolls too tight	4
9	Ink circulation is blocked	4
10	Improper tagging	3
11	White ink is too thick	3
12	Too much thinner ink	2
13	Ink-covered cylindrical cell	2
14	Incorrect ink shield position	1
15	Ink is not smooth enough	1
16	Cooling roll dirty	1
17	No cooling roll	1
18	Auto visco problem	1

By understanding the distribution of defect sources, more accurate controls can be implemented to achieve defect reduction. Uneven doctor blade is the most frequent root cause of printing defects with a total of 34 incidents. Fluid material is the second most frequent root cause of defects with a total of 31 incidents. Unbalanced press roll cylinder (PRC) rotation is the third most frequent root cause of defects with a total of 12 incidents along with Raster cylinder thinning is the fourth most frequent root cause of defects with a total of 12 incidents. Joint material and not splicing are the fifth and sixth most frequent root causes of defects with 11 incidents of joint material and 8 incidents of not splicing.

In this case study, an analysis was made for each potential failure mode that required prioritization. The proposed improvements focused on addressing the six most frequent root causes. The aim is to concentrate on the six main root causes, namely; uneven doctor blade, material fluff, unbalanced press roll cylinder (PRC) rotation, thinning cylinder raster, joint material and no splicing. Due to poor quality control of the six root causes, the company was unable to reduce the incidence of production defects, which resulted in decreased product. FMEA is used to determine the effect of causes on the product and identify actions to reduce the defect rate. FMEA is a tool that captures historical data for use in future quality control improvements. Anticipating every potential failure mode is not possible in this study (Sharma et al., 2005). This is due to the formulation of a list of possible potential failure modes that is too broad. After obtaining failure mode information, each failure mode is determined and ranked according to severity, occurrence and detectability. The quantitative process using FMEA can be done after the scale is given to each cause of the problem. The three levels aim to determine the Risk Priority Number (RPN) value of each cause of the problem.

3.4 Proposed improvements and potential cost savings

The improve stage is the fourth step of the DMAIC method where process improvements are formulated and implemented. The improve stage involves identification of possible solutions, implementation and verification of solution capabilities (Benbow & Kubiak, 2010). After each problem is analyzed and the RPN is calculated, corrective actions are developed that can be implemented starting from the problem that has the highest RPN to the problem that has the lowest RPN in order. The purpose of corrective action is to reduce one or more prioritized criteria. Corrective actions of Printing Defect can be seen in Table 5.

Table 5. Corrective action of printing defect

No.	Process	Potential Failure Mode	RPN	Corrective Action
1	Printing	Joint material or material change during the printing process	40	Provide a warning device for printing operators to give inspection marks every time there is a change of material and perform 100% sorting on the printouts.
2		Eye doctor blade less flat	40	Conduct a performance appraisal system for printing operators to implement the replacement of doctor blades and ink filters according to the SOP, and perform 100% sorting of printouts.
3		Cylinder raster condition has begun to thin	40	Regularly apply for re-chrome or cylinder making according to SOP, give cylinder condition mark and do 100% sorting on the mold result.
4		Fluid material condition or uneven thickness	25	Conduct a performance appraisal system for operators to be more disciplined in tightening material inspection, giving clear physical tags to rollers and sorting with automatic machines.
5		Unbalanced press roll cylinder rotation	12	Ensure that operators carry out PRC inspections from the start, replace PRC and perform sorting 100% in accordance with the SOP. On the other hand, also conduct regular machine inspections.
6		In addition, not by splicing	10	Provided a warning tool to the operator to cut and splice in checking the color with the standard and 100% sorting on the printout.

The high quantity of defects produced by the printing process initially confirmed the suspicion that there was a problem that required improvement. With the systematic application of Six Sigma statistical tools, improvements aimed at six potential failure modes could result in potential cost of poor quality (COPQ) savings for the company. As far as suggested, corrective actions were only taken in the printing process so that errors in the laminating to rewind process did not indicate a change in COPQ. The overall COPQ faced by the company during the analyzed period was found to be 7.16% of sales. With a printing defect percentage of 61%, the COPQ due to printing is 4.37%. This value is then reduced by the percentage of potential occurrences from other causes (which are not given improvements) by 0.93% and will be the percentage of preventable defects of 3.44%). The figure of 3.44% has also been confirmed with the company management to find out whether it is reliable or not. So, with the systematic application of Six Sigma statistical tools, improvements to the six potential failure modes left a waste of 3.72%. The total COPQ then displays the decrease presented in Figure 2.

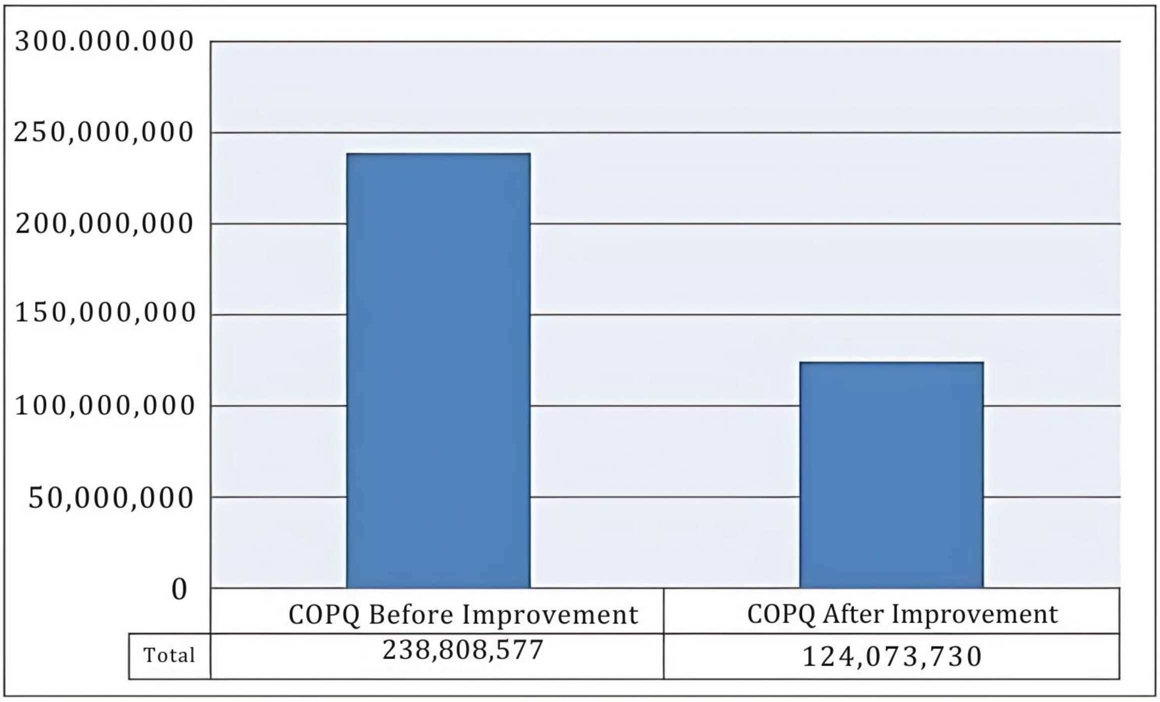

Fig. 2. Change in total COPQ July 2019 - December 2019

Overall, the cost savings are estimated to decrease by 48% (114,734,847 IDR) with a decrease in COPQ for the current period under study, from 238,808,577 IDR to 124,073,730 IDR. Based on the results of interviews with resource persons, the implementation of the proposed improvements for handling the problem does not incur additional costs because the resources come from within the company itself. With these improvements, the company is expected to get the amount of production in accordance with the target in the coming years.

4. Conclusions

The research conducted is an analysis using the Six Sigma method to assess quality control in flexible packaging production carried out by XYZ company. The Six Sigma DMAIC method is used to conduct research because it is in line with the research objectives. Statistical tools in Six Sigma are used to give researchers the ability to build accurate representations. In problem solving, the define and measure stages play an important role. Each process has a different number and incidence of defects. As far as the measure stage is concerned, the problem found lies in the printing process because it is identified as the biggest opportunity that produces defects. The 80/20 principle can be seen from the data where cumulatively, incidents in printing represent 79% of the total defect incidents.

Quality control to reduce the quantity of defects in this process involves all necessary actions to identify the causes of defects by analyzing the root cause of the problem with the Cause- and- Effect Diagram model. Defects in the printing process are affected by various factors including register shifting, film scratching, color difference, ink not transferred and ink spot.

Proposed improvements were developed from the results of the Failure Mode Effects Analysis (FMEA) model based on statistical data processing and interviews. This enabled an increase in the efficiency of the production process through better quality control. FMEA resulted in proposed improvements related to human and machine factors. Operator performance that is not in accordance with procedures is the dominant factor causing potential failures. From the interviews, it was also found that quality problems in the flexible packaging industry can be anticipated by company management. However, ultimately the human factor differentiates one flexible packaging company from another. Data processing revealed that there are possible cost savings from the prevention of defect incidents resulting from the flexible packaging production process of 48% with the systematic application of statistical tools. The cost savings from corrective actions to prevent defects in the production process at XYZ company is estimated at 114,734,847 IDR for the current period under study.

The scope of the research is limited to the data obtained because the researcher has limited access to the ERP system that records all events of the operation function in the company. Some of the data used in the research are the results of individual interviews with sources from the company and some come from historical data. Future research can use historical data with a longer period so that it can describe the problem better. Future research can also use the participant observation method so that understanding of the flexible packaging production system is more in-depth. The next limitation is that this research does not cover the implementation of controls from the solution developed with the Six Sigma DMAIC method. The ultimate goal at the DMAIC stage is to ensure continuous improvement and become a standard operating practice. However, this research does not provide an explanation until the control stage because this function is beyond the control of the researcher, whether the recommendations provided are implemented or not by the case study company. Further research can use different tools, which can then be compared with the effectiveness of current methods to obtain best practices is also needed. The findings of this study can be generally accepted and applied to flexible packaging companies. The factors that drive improvement depend on the problem at hand. In the context of successful improvement, the scope of the research can be set wider in future research with multi-site case studies. Consideration of including the full process stages (laminating and slitting) as well as the supply chain would provide a more holistic view of the flexible packaging production process.

Author Contribution

The author contributed fully to the research.

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This research was conducted by M.K., with supervision and guidance from R.D.K. M.K., was responsible for the conceptualization, methodology, data collection, analysis, and drafting of the manuscript. R.D.K., contributed through critical review, manuscript editing, and supervision throughout the research process.

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