Pertanika J. Soc. Sci. & Hum. 26 (T): 71 - 88 (2018)

SOCIAL SCIENCES & HUMANITIES

Journal homepage: http://www.pertanika.upm.edu.my/

A Six Sigma Application for the Reduction of Floor Covering Defects

Sambudi Hamali*, Shelvy Kurniawan, Cecep Hidayat, An Nisaa Amalia Fitriani, Garvin Osmond and Natasha Evanti

Management Department, BINUS Business School, Undergraduate Program, Bina Nusantara University, Jl. K. H. Syahdan No. 9, Kemanggisan / Palmerah, Jakarta Barat, Indonesia 11480

ABSTRACT

Quality of a product is a key to improving a company's competitiveness. PT. "X" is a company engaged in plastic waste processing. It converts the waste into a floor carpet. The purpose of this study was to determine the number of sigma levels generated by PT. "X" in producing Floor covering, what caused the defects and how to reduce defective products using Six Sigma methods based on DMAIC step. Data for the study was collected from interviews and production statistics. The results showed the level of product quality was sigma 3.67, which is an average industry standard for Indonesia. Further, it was found that man (worker) is the major factor for occurrence of defective products. Therefore, a new employment policy at PT. "X" is needed.

Keywords: Defective products, DMAIC, quality control, Six Sigma

INTRODUCTION

Successful strategies using differentiation, low cost, or response are part quality management. Increases in sales can occur if the company has responds quickly both in increasing or decreasing their selling prices and increasing their reputation based on the quality of the product. When these steps are done correctly, the organisation usually can satisfy their customers and gain competitive advantage (Heizer, Render, & Munson, 2016).

ARTICLE INFO

Article history:
Received: 06 October 2017
Accepted: 28 March 2018

E-mail addresses:
sambudi_hamali@binus.ac.id (Sambudi Hamali)
shelvy.kurniawan001@binus.ac.id (Shelvy Kurniawan)
ceceph1267@binus.ac.id (Cecep Hidayat)
an.nisa_amalia@yahoo.co.id (An Nisaa Amalia Fitriani)
garvinosmond@ymail.com (Garvin Osmond)
natasha.evanti@yahoo.com (Natasha Evanti)
* Corresponding author

ISSN: 0128-7702

PT. "X" is engaged in plastic processing industry. Currently, its focus is on producing floor covering with PVC as the basic ingredient. PT. "X" has two types of product: 2-layer products (bottom layer and printing) and 3-layer products (bottom layer, printing and mica layer). The company is currently experiencing problems with product defects, with "Pataya 20 M" and "Original 20 M" as 2-layer products which have a high percentage of defects. This happens because of the incompatibility of the products based on the established company standards. The company's tolerance for defective products is 2% -2.5%, while the percentage of defective products for Pataya 20 M is 4.49% and for Original 20 M is 4.31%. Therefore, a tool to reduce defects, minimise variation as well as improve capability in manufacturing processes is Six Sigma (Kabir, Boby, & Lutfi, 2013).

Six Sigma is a management philosophy that focuses on eliminating errors, waste and rework. The Six Sigma implementation framework has many versions. A widely used version is DMAIC (define-measure-analyse-improve-control) that systematically helps organisations solve problems and improve the process (Hadidi, Bubshait, & Khreishi, 2017; Jirasukprasert, Arturo Garza-Reyes, Kumar, & Lim, 2014). Several previous studies have demonstrated the successful application of Six Sigma with DMAIC. Among them is Hadidi et al. (2017) on the extruded aluminium profile, Sanny, Scherly and Novela (2016) on the tofu production, Laosiritaworn, Rangsee, Chanduen and Klanarong (2015) in the lost-wax casting, Jirasukprasert et al. (2014) on the manufacturing process of rubber gloves.

Based on the above description, to overcome the problems faced by PT. "X" and considering the limited studies that discussed the use of Six Sigma in the floor covering industry with PVC as the basic materials, this study was aimed at finding out (1) how many sigma levels were generated by PT. "X" in producing floor covering, (2) factors which caused the defective products and (3) how to reduce the defective products at PT. "X".

LITERATURE REVIEW

Total Quality Management (TQM) focuses on quality that requires continuous improvement that includes people, tools, suppliers, materials, and procedures. It is important because quality decisions affect each of the 10 decisions made by the operations manager. One of the most effective TQM programmes is Six Sigma (Heizer et al., 2016).

Six Sigma is an approach first introduced by Motorola in 1986, focusing on improvements relating to process and quality by identifying the causes of errors and reducing variability. This methodology is known as a powerful tool for process improvement with wide applications in many industries (Hadidi et al., 2017). Six Sigma's goal is to increase profit margins, improve financial conditions by minimising the level of defective product (Kabir et al., 2013).

The Six Sigma has two methodologies which consist of:

Six Sigma – DMAIC (Define, Measure, Analyse, Improve, Control)

Design for Six Sigma (DFSS), DMADV (Define, Measure, Analyse, Design, Verify).

The DMAIC model is used when it is applied to an existing product, process, or service performance improvement and when the goal of the project is the development of product, process or service which is redesigned radically. DMADV is part of the Six Sigma toolkit design (DFSS) (Pyzdek & Keller, 2010). It consists of five main stages (Pyzdek & Keller, 2010):

"Define the goals of the improvement activity and incorporate into a Project Charter. Obtain sponsorship and assemble team."

"Measure the existing system. Establish valid and reliable metrics to help monitor progress toward the goals which is defined at the previous step. Establish current process baseline performance using metric."

"Analyse the system to identify ways to eliminate the gap between the current performance of the system or process and the desired goal. Use exploratory and descriptive data analysis to help you understand the data. Use statistical tools to guide the analysis."

"Improve the system. Be creative in finding new ways to do things better, cheaper, or faster. Use project management and other planning and management tools to implement the new approach. Use statistical methods to validate the improvement."

"Control the new system. Institutionalize the improved system by modifying compensation and incentive systems, policies, procedures, MRP, budgets, operating instructions and other management systems. You may wish to utilize standardization such as ISO 9000 to ensure that documentation is correct. Use statistical tools to monitor stability of the new systems."

Several previous studies have shown the successful application of Six Sigma by using DMAIC. Hadidi et al. (2017) showed DMAIC can significantly reduce aesthetic defects in the extruded aluminium profile by reaching the Four Sigma quality level. Laosiritaworn et al. (2015) using DMAIC was able to reduce damaged mould and leak in lost-wax casting. In addition, Jirasukprasert et al. (2014) applied DMAIC framework to reduce defects in the rubber gloves manufacturing process from 19.5 to 8.4 percent.

Although some previous studies have demonstrated the successful application of Six Sigma with DMAIC, according to Wu, Yang and Chiang (2012), its implementation must pay attention to several determinants of its success, including executive management support, leadership, cohesiveness of members, and resource management. In addition, Goh (2010) suggested industries should take advantage of the power of Six Sigma which he called "triumphs" and be careful not to become victims who are not aware of the weaknesses they call "tragedies." However, Hadidi et al. (2017) asserted that Six Sigma methodology is a well-known quality improvement framework that is used to control defects in quantities (quantitative data) such as weight and altitude, but also to control qualitative data as well as aesthetic.

MATERIALS AND METHODS

This is a descriptive study. This research was conducted between January 2015 and June 2016 with PT. "X" as the research object. The instruments used in data collection are literature review as well as field research through interviews and observations. Data was analysed using *Six Sigma* which is based on using *DMAIC* (*Define, Measure, Analyse, Improve and Control*).

Definition

In this first stage, a SIPOC diagram was created by identifying the Supplier (all suppliers involved), Input (all inputs into the process), Process (process which will be improved), Output (all output coming from process), and Customer (those who receive output from the process) (Basu, 2009). Supplier, Input, Process, Output, and Customer data from PT. "X" is obtained from production process data and interview results with General Manager and Manager of HRD PT. "X". The author also uses the CTQ (Critical to Quality) tool, which is used to describe the main output characteristics of a process (Basu, 2009).

Measurement

In this stage, a Control Chart is created to monitor the stability of a process and to study process changes from time to time (Heizer et al., 2016). P-Chart is created using production data, and defect product data owned by PT. "X", are then calculated according to the formula (Heizer et al., 2016):

Lower Control Limit (LCL): $\bar{p} - 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n}}$ (1)

Upper Control Limit (UCL): $\bar{p} + 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n}}$ (2)

The DPMO (Defect per Million Opportunities) measures where the position of product quality level of PT. "X" at this time using the data production and data defect products owned by PT. "X" which is then calculated using the formula DPMO (Wahyani, Chobir, & Rahmanto, 2010) as follows:

$$\textbf{DPMO} = \frac{1{,}000{,}000 * \text{The number of defects found}}{\text{Number of units checked} * \text{Number of CTQ}} (3)$$

The sigma level is often associated with process capability, which is calculated in defects per million opportunities. Some levels of sigma are:

Table 1
Level of sigma achievement

%	DPMO	Sigma Level	Description
31%	691.462	1-sigma	Very uncompetitive
69.20%	308.538	2-sigma	Average industry of Indonesia
93.32%	66.807	3-sigma	
99.379%	6.210	4-sigma	Average industry of USA
99.977%	233	5-sigma	
99.9997%	3,4	6-sigma	World-class industry

Source: Wahyani, Chobir and Rahmanto (2011)

The next step is to create a Pareto Chart that is used to identify the cause of poor quality. Data used is the frequency of types of defects in PT. "X".

Analysis

This stage determines factors that affect the production process, as well as the desired output or target of a process by using Cause & Effect Diagram or Fishbone Diagram (Russell & Taylor, 2011). The next step is making FMEA (Failure Mode and Error Analysis), a systematic approach to identify all possible failures in a design, manufacturing process or service process (Verma & Boyer, 2010).

Improvement

After identifying the root of the problem and validating it, it is necessary to take corrective action to the problem by testing and experimenting to optimising the solution so that it is really useful to solve the problem (Russell & Taylor, 2011). This is done via brainstorming which is a tool used to obtain the best ideas from every member of the team which is done in a structured (Round Robin) and unstructured (Free Wheeling) way (Basu, 2009). The ideas can be based on the results of previous research by creating an Effort Benefit Matrix that is a graph that discusses all the details of potential initiative gained compared to effort within the required timeframe and resources (Meran, John, Roenpage, Staudter, & Lunau, 2013).

Control

The last stage is the Control phase that provides suggestions to improve the standard operating procedures or existing production systems. These proposals are expected to improve the quality of products that can be maintained and prevent similar potential problems.

RESULTS AND DISCUSSIONS

Define

In the early stages, the production process from raw materials to finished goods is clarified, namely floor covering by looking at five variables to clarify SIPOC (Supplier, Input, Process, Output and Customer) diagram.

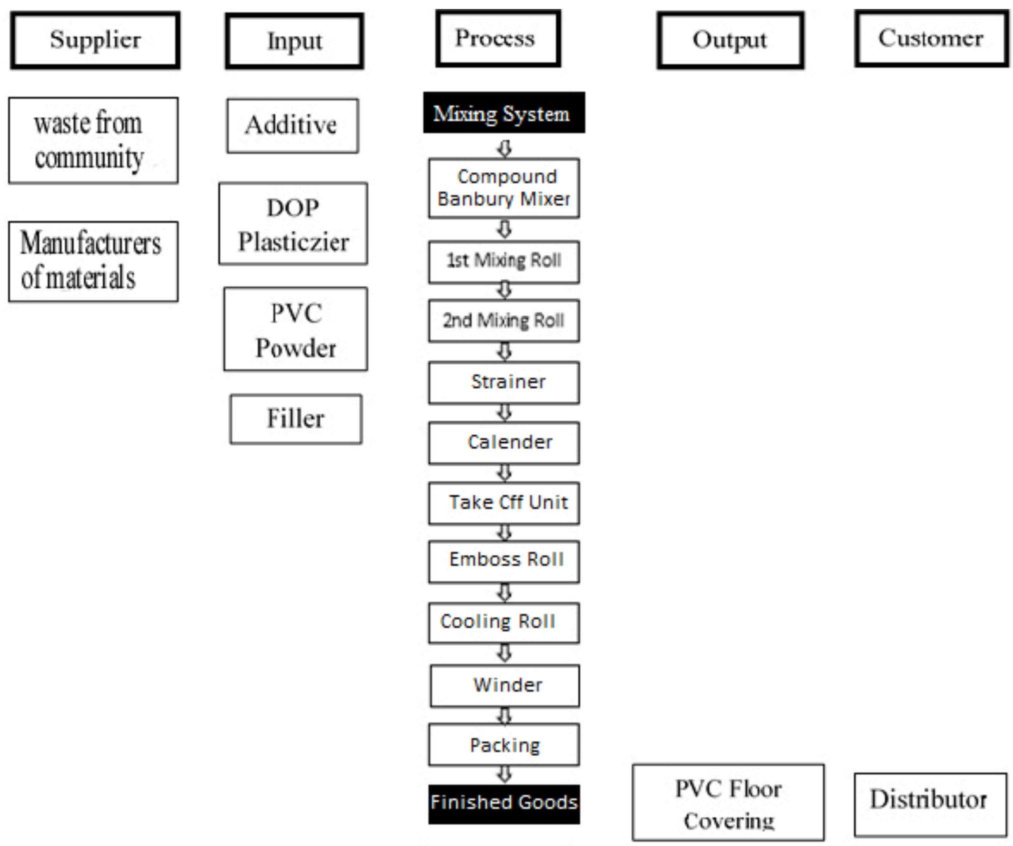

Figure 1. SIPOC

What are the factors that affect the quality of Floor Covering products? Based on the interview result, these factors are Man, Machine, Method, Material, and Environment. In addition, the type of defect in the floor covering products are hollow, folded, early pull and the position of motives or colours that are not appropriate.

Table 2
Critical to quality

No	Type of defect	Explanation
1	The carpets are hollow	This is a result of the remaining foreign particles from the raw material which are not filtered thoroughly using Strainer; the raw materials that become the sheet will be seen as hole calendar process.
2	Early pull	The distance between the first withdrawal process of the previous roll and the next roll causes the tip of the carpet to be unfilled. This happens in the Emboss Roll process
3	Folded	Inaccurate method causes the arrangement between Calendar and Take Off Units to be unstable, so the machine does not roll well and crease.
4	Motive position and colour is not appropriate	Motifs and colours produced by the Emboss roll process, not in accordance with predetermined positions.

Measurement

In this stage, Pareto analysis, Control and DPMO calculation is done to see the level of sigma PT. "X" in producing floor covering. From the Pareto chart analysis, it is clear the largest type of defect of the two types of floor carpets (Pataya 20M and Original 20M) is the folded and early pulled (Figures 2 & 3).

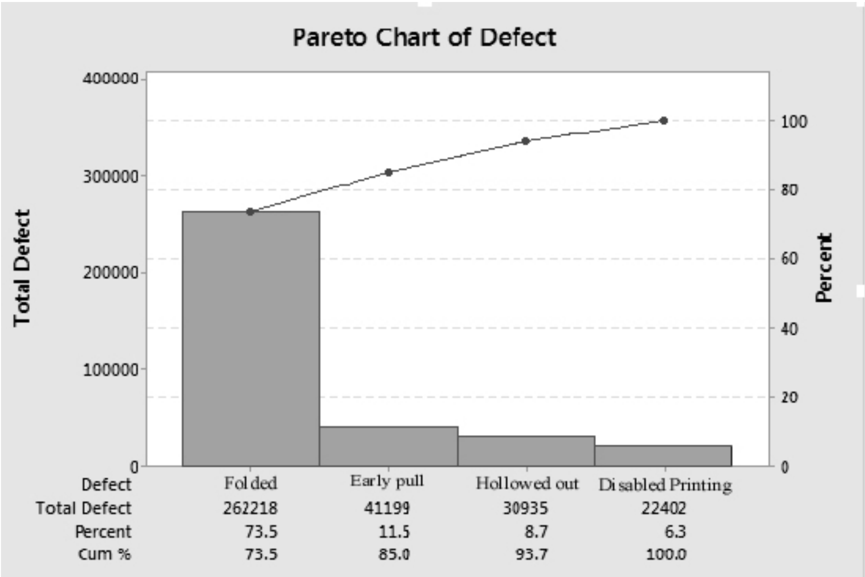

Figure 2. Pareto chart of Pataya 20M

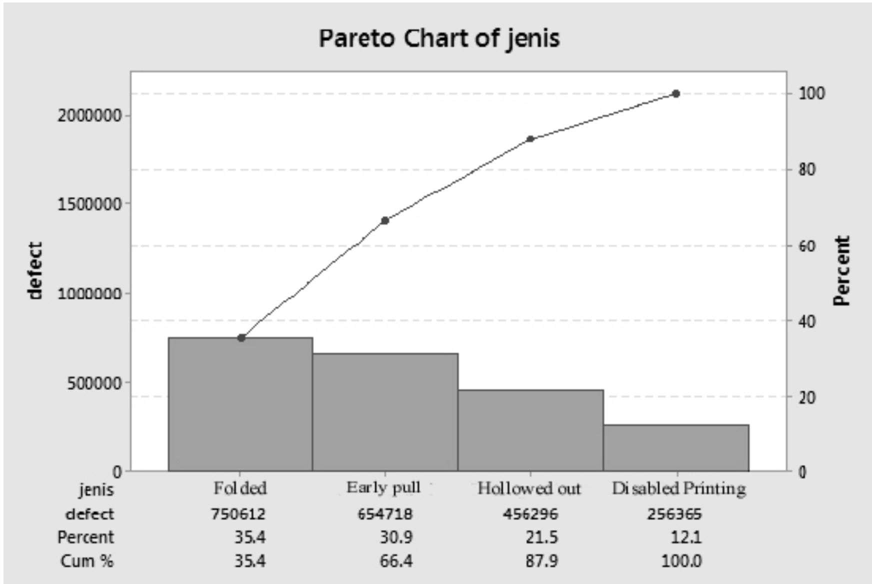

Figure 3. Pareto chart of Original 20M

The Control Chart tool shows the production process conducted by PT. "X" is still out of control and needs supervision (Figures 4 & 5).

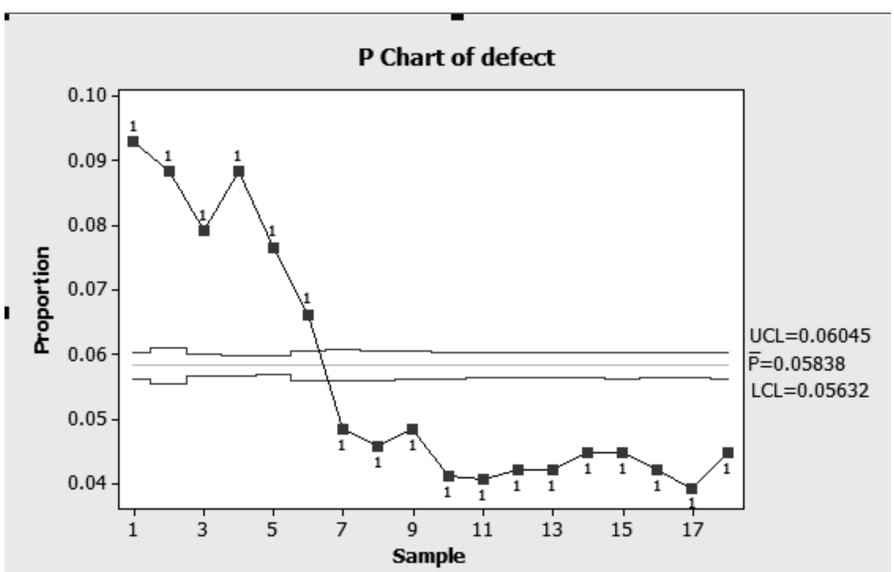

Figure 4. P-Chart Pataya

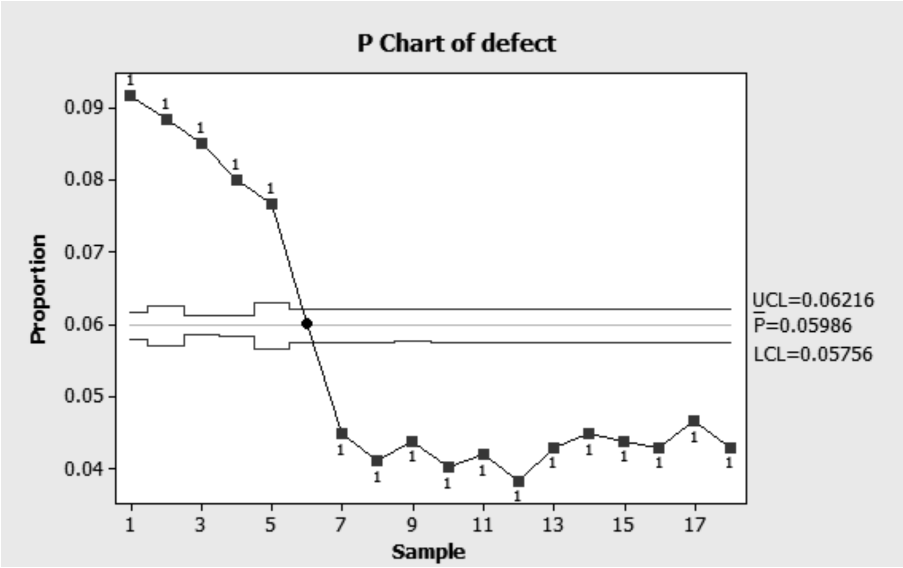

Figure 5. P-Chart Original

The DPMO tool (Defect per Million Opportunities) shows the product quality achieved by PT. "X" in producing floor carpet. Table 3 shows the result of DPMO for Pataya 20 M and Original 20 M:

Table 3
Defect per million opportunities (DPMO) Pataya 20 m

Month	Production Total	Defect Total	Opportunities	Defect Per Unit	DMPO	Sigma Level
January	119,158	11078	4	0.092968999	23242.24979	3.5
February	66,939	5919	4	0.088423789	22105.94721	3.5
March	167,787	13287	4	0.079189687	19797.42173	3.6
April	215,275	19035	4	0.088421786	22105.44652	3.5
May	238,520	18280	4	0.076639276	19159.81888	3.6
June	94,205	6245	4	0.066291598	16572.89953	3.6
July	86,203	4183	4	0.048524993	12131.24833	3.8
August	94,383	4323	4	0.04580274	11450.68498	3.8
September	105,184	5104	4	0.04852449	12131.1226	3.8
October	114,750	4730	4	0.041220044	10305.01089	3.8
November	125,163	5103	4	0.040770835	10192.70871	3.8
December	135,803	5723	4	0.042141926	10535.48154	3.8

Table 3 *(continue)*

Month	Production Total	Defect Total	Opportunities	Defect Per Unit	DMPO	Sigma Level
January	130,552	5502	4	0.042144126	10536.03162	3.8
February	134,121	6021	4	0.044892299	11223.07469	3.8
March	115,170	5170	4	0.044890162	11222.54059	3.8
April	135,720	5720	4	0.042145594	10536.39847	3.8
May	130,750	5150	4	0.039388145	9847.036329	3.8
June	116,008	5208	4	0.044893456	11223.36391	3.8
Total	2,325,691	135,781				

Table 4
Defect per million opportunities (DPMO) Original 20m

Month	Production Total	Defect Total	Opportunities	Defect Per Unit	DMPO	Sigma Level
January	153,413	14,053	4	0.091602407	22900.60164	3.5
February	69,945	6,185	4	0.088426621	22106.65523	3.5
March	286,125	24,345	4	0.08508519	21271.29751	3.5
April	263,445	21,085	4	0.080035681	20008.92027	3.6
May	49,038	3,758	4	0.076634447	19158.61169	3.6
June	98,399	5,919	4	0.06015305	15038.26258	3.7
July	99,025	4,445	4	0.044887655	11221.91366	3.8
August	100,754	4,154	4	0.041229132	10307.28309	3.8
September	103,345	4,545	4	0.043978906	10994.7264	3.8
October	99,198	3,998	4	0.040303232	10075.80798	3.8
November	100,850	4,250	4	0.042141795	10535.44869	3.8
December	102,752	3,952	4	0.038461538	9615.384615	3.8
January	99,379	4,279	4	0.043057386	10764.34659	3.8
February	100,721	4,521	4	0.044886369	11221.59232	3.8
March	99,056	4,356	4	0.043975125	10993.7813	3.8
April	101,470	4,370	4	0.043066916	10766.72908	3.8
May	95,249	4,449	4	0.046709152	11677.28795	3.8
June	95,827	4,127	4	0.043067194	10766.7985	3.8
Total	2,117,991	126,791				

Based on DPMO calculation data at PT. “X”, overall it can be seen that the sigma and DPMO levels are 3.68 and 14595.76 for Original 20M products and 3.67 and 14965.95 for Pataya 20M products. Therefore, product quality owned by PT. “X” meets the industry average standard in Indonesia at the level of sigma 2 and 3 (See Table 1).

Analysis

Cause & Effect Diagram or fishbone and Failure Mode and Effect Analysis (FMEA) are used to analyse results.

Based on the Pareto diagram, two types of defects are common: folded and pull early products. The Cause and Effect Diagram analysis indicates the defects.

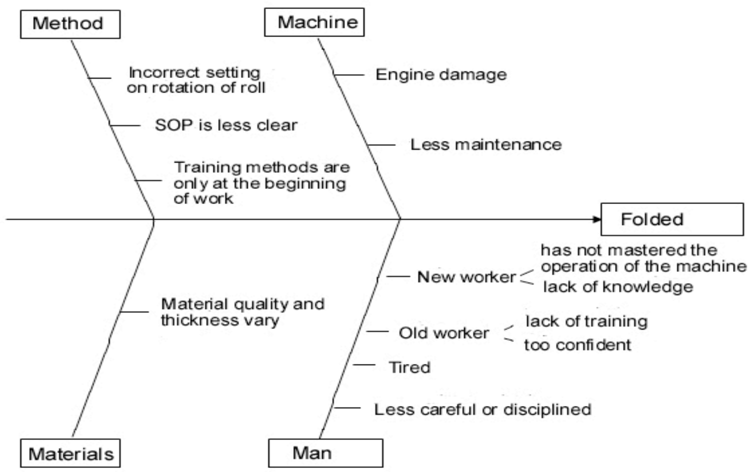

Figure 6. Cause and effect diagram analysis of folded defect

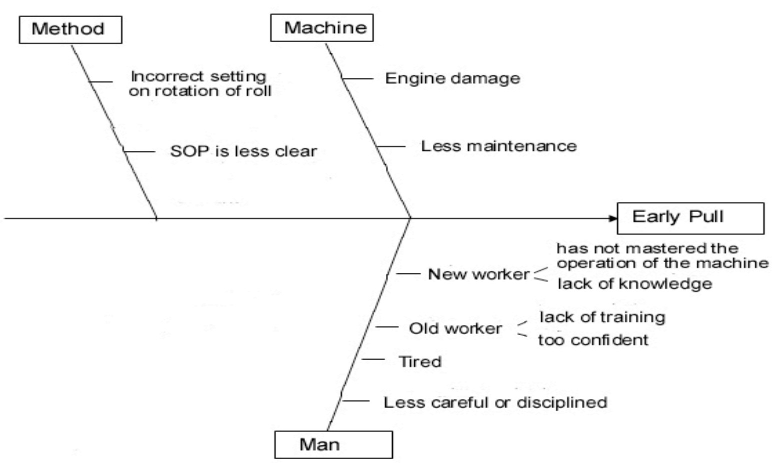

Figure 7. Cause and effect diagram analysis of pull early defect

Based on the analysis of Cause and Effect Diagram, it has been identified the defects are a result of man, material, method, and machine errors.

Furthermore, Failure mode and effects analysis (FMEA) is the stage to identify the causes, check the potential weak points, assess the risks and determine what needs to be addressed first based on the problems experienced by PT. "X".

Table 5
Failure mode and effect (FMEA)

Process	Potential Failure Mode	Potential Failure Effects	S	Potential Causes	O	Current Controls	D	RPN	Actions Recommended
Mixing	Incorrect composition	Product results vary	1	Negligence and lack of knowledge of workers	7	Workers are instructed to follow SPK.	5	35	1. Checking the composition measurement before starting production activities, 2. Improving methods for training workers.
	Lack of quality of raw materials	Product result is defective	7	1. Lack of quality control, 2. Lack of good storage, 3. worker's skill	8	Inspection of raw materials upon arrival at the factory	3	168	1. Improving quality control of raw materials, 2. Adding 15 Minutes of rest time.
	Filtering raw materials are not perfect	Hollow products	6	1. Worker negligence, 2. Filtering machine does not work optimally, 3. Too many and large foreign particles	8	Regular change of machine filter	3	144	1. Improved machine checking before and after production process. 2. Adding the filtering process.
Strainer	Deliberate by worker	1. Slow down the production process, 2. Product Perforated.	8	Lack of workers welfare (less rest period & less holiday)	4	Provide reward and punishment	7	224	1. Increase Compensation and Benefit, Establish good relationships with workers.

Table 5 *(continue)*

Process	Potential Failure Mode	Potential Failure Effects	S	Potential Causes	O	Current Controls	D	RPN	Actions Recommended
	Wrong setting	1. Accumulation and vacuum of material to be processed on strainer, 2.Delay production process, 3. product defect	8	1. Lack of knowledge of workers, 2. worker fatigue due to excessive working hours	7	1. Initial training for 3 months, 2. The existence of SOP, regarding the setting of the machine	7	392	1. Conducting Training every six months, 2. Form a special team to check preparation before production process.
Calendar	Wrong setting	The layer becomes too thin	4	Worker negligence	4	Determining the min. limit of carpet thickness is 2.5ml.	4	64	The team in charge should be given a SPK briefing before starting production
Take Off Unit	Wrong setting	The material becomes disconnected and folded	6	Lack of worker knowledge and negligence	7	Provision of clear SPK, initial training, and the existence of SOP	6	252	1. Perform regular training every 6 months, 2. Form a special team to check the preparation before the production process
Printing/ Emboss Roll	Wrong setting	Colour and image layout are not appropriate	8	Lack of worker knowledge and negligence	7	Provision of clear SPK, initial training, and the existence of SOP	6	336	1. Perform regular every 6 months, 2. Form a special team to check the preparation before the production process
Cooling Roll	Machine damage	Delays the production process due to leakage in the water flow cylinder	6	The existence of a foreign object (Nail)	3	Perform maintenance periodically	3	54	Shorten the 6-month machine-wide checking period

Based on the analysis, the potential weak point is the *Stainer process*, which has setting flaws, with a total RPN (Risk Priority Number) of 392. This error results in the build-up and void of raw materials to be processed on the *strainer*, delays the production process and making defective products. This is due to fatigue among workers which has an impact on the accuracy machine setting done manually in addition to workers' lack of knowledge in this matter.

Improve

Recommendation from the brainstorming session is presented in the Effort Benefit Matrix. Table 6 presents the results of brainstorming session.

Table 6
Brainstorming

No	Solution
1	Training for all workers every 6 months. (Training in machine operation, safety and understanding in reading SPK (Work Order) and IK (Work Instructions)).
2	Conduct additional training, such as leadership training. It is useful for the team leader to be able to lead its members, make decisions, communicate and maintain good relationships.
3	Provide Reward to workers in the form of bonuses if they successfully produce at least 8000 meters/shift (1 shift = 8-10 people), additional holidays, and others. There should be penalty for violation of rules or company policy, to improve discipline of workers.
4	Provide motivation to workers by hosting events, such as lunch, get togethers, Independence Day event or breakfast during Ramadhan.
5	Increase/provide additional rest periods (at least 60 minutes) to minimise fatigue.
6	The company has a special team (2-3 people) to ensure the machine's settings are based on the SPK (Work Order) and IK (Work instructions) specifications before starting the production process.
7	Make SOP (Standard Operating Procedure), IK (Work Instruction) and SPK (Work Order) detailed and easy to understand by other workers so that it can be applied to minimise errors
8	Have a written schedule about work hygiene after production process (machine and environment), such as daily picket schedule.
9	Improve quality control and screening process, in particular ensuring raw materials are checked for its condition upon arrival at the factory. The PVC Powder material for example have to be separated, to prevent there is no contamination of foreign particles.
10	Periodic evaluation and system maintenance or scheduling machine repair for all machines (daily, weekly, monthly and yearly) every 6 months.

Data was analysed using Effort Benefit Matrix:

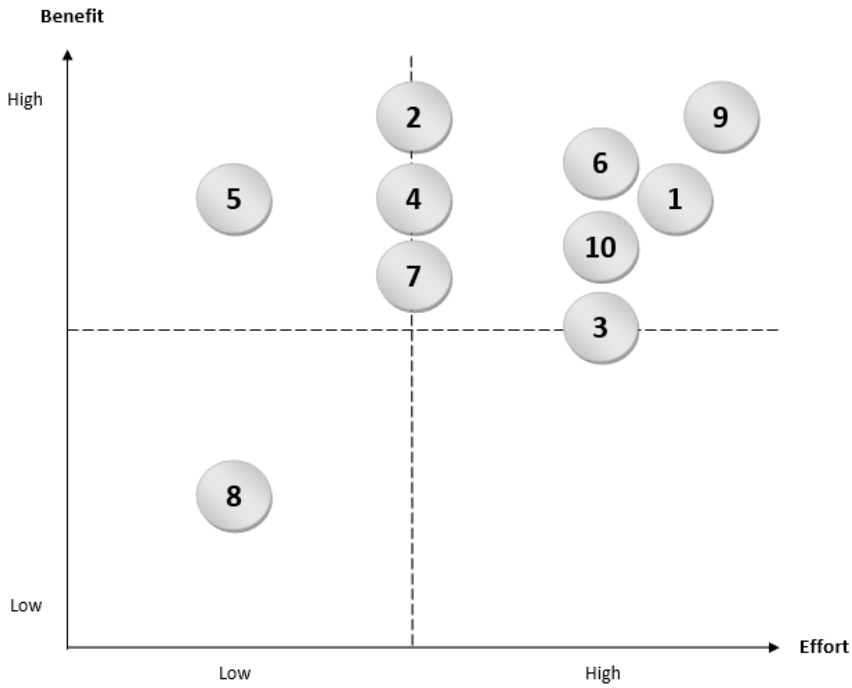

Figure 8. Effort benefit matrix

Based on the results of the Effort Benefit Matrix, point solution 5 is a point that has high profits with a low level of effort; for point number 5, PT. "X" should provide additional time break for workers to reach 60 minutes (one hour). t=The results can answer the third research objective to know the best way to reduce defective products in PT. "X".

Control

In the last stage, we provided recommendation which is found through the previous stage (improve), that is by providing additional or extra worker rest time becoming 60 minutes (one hour). With these recommendations, PT. "X" is expected to improve the quality of the product and furthermore, is expected to prevent similar potential problems in the future.

CONCLUSION

Based on the measurement of product quality level at PT. "X" with Defect per Million Opportunity (DPMO), it can be analysed the level of quality of PVC floor covering are 3.68 and 14595.76 for Original 20M products and 3.67 and 14965.95 for Pataya 20M products. With these results, it can be concluded that the level of product quality owned by PT. "X" is still an average standard.

Factors that cause defective products experienced by PT. "X" include methods, machine, materials, and man. However, the factor of man or worker is the factor that most affected the occurrence of defective products. The main factor causing the defective product on the worker is wrong in the arrangement. It can be analysed from the Risk Priority Number (RPN) value of 392. The recommendation given to overcome this is by the addition of rest time and knowledge of the workers.

The managerial implication of this research is that company should use Six Sigma method of DMAIC method (Define, Measure, Analyse, Improve, and Control) periodically. This is to improve its quality regarding the products and processes, and it can also identify the cause in case of defective products and correct the production error. In addition, the company should also update the policy that addresses the issue of creating employment, providing training and provision of time off.

REFERENCES

Basu, R. (2009). *Implementing Six Sigma and Lean: A practical guide to tools and techniques.* Oxford: Elsevier.

Goh, T. N. (2010). Six triumphs and six tragedies of six sigma. *Quality Engineering, 22*(4), 299-305.

Hadidi, L. A., Bubshait, A. A., & Khreishi, S. (2017). Six-sigma for improving aesthetic defects in aluminium profiles facility. *Facilities, 35*(3/4), 242-267.

Heizer, J., Render, B., & Munson, C. (2016). *Operations management: Sustainability and supply chain management* (12th ed.). Boston: Pearson.

Jirasukprasert, P., Arturo Garza-Reyes, J., Kumar, V., & Lim, M. K. (2014). A six sigma and DMAIC application for the reduction of defects in a rubber gloves manufacturing process. *International Journal of Lean Six Sigma, 5*(1), 2-21.

Kabir, M. E., Boby, S. M. I., & Lutfi, M. (2013). Productivity improvement by using six-sigma. *International Journal of Engineering and Technology, 3*(12), 1056-1084.

Laosiritaworn, W., Rangsee, P., Chanduen, P., & Klanarong, P. (2015). Improving lost-wax casting with six sigma methodology. *Applied Engineering Sciences*, Vol. 1, pp. 59-64.

Meran, R., John, A., Roenpage, O., Staudter, C., & Lunau, S. (Ed.). (2013). *Six sigma+lean toolset mindset for successful implementation of improvement projects*. Berlin: Springer Heidelberg.

Pyzdek, T., & Keller, P. A. (2010). *The six sigma handbook: A complete guide for green belts, black belts, and managers at all levels*. New York: McGraw-Hill Companies.

Russell, R. S., & Taylor III, B. W. (2011). *Operations management, creating value along the supply chain* (7th ed.). New Jerseys: John Wiley and Sons, Inc.

Sanny, L., Scherly, N., & Novela, S. (2016). Product quality development analysis with six sigma method: Case of sme tofu production in Indonesia. *Pertanika Journal of Social Sciences and Humanities, 24*, 155-168.

Verma, R., & Boyer, K. (2010). *Operations and supply chain management: World class theory and practice.* Boston: Cengage Learning.

Wahyani, W., Chobir, A., & Rahmanto, D. D. (2010). Penerapan metode six sigma dengan konsep dmaic sebagai alat pengendali kualitas. *Prosiding Seminar Nasional, Manajemen Teknologi XII*, Program Studi Magister Manajemen Teknologi, Program Pasca Sarjana, Institut Teknologi Sepuluh Nopember, Surabaya.

Wu, K. S., Yang, L. R., & Chiang, I. C. (2012). Leadership and six sigma project success: The role of member cohesiveness and resource management. *Production Planning and Control, 23*(9), 707-717.