Analysis Quality Control of TR 7864 Fabric Product Using Statistical Quality Control Method: A Case Study

Anisa Agustina
Department of Industrial Engineering, Faculty of Engineering, Universitas Sebelas Maret
Surakarta, Indonesia
anisaagustina8@student.uns.ac.id

Wahyudi Sutopo
University Centre of Excellence for Electrical Energy Storage Technology, Universitas Sebelas Maret, Surakarta, Indonesia
wahyudisutopo@staff.uns.ac.id

Abstract

In this case, we discuss efforts to control the quality of TR 7864 fabric products at PT XYZ. In terms of product quality, many defects were found which was quite high. This situation makes the company unable to meet the production targets that have been set. This study aims to analyze the existing quality control in the company. We use the Statistical Quality Control method to analyze product quality control. The quality of the studied fabric products is not within the control limits, so it is necessary to improve quality control efforts. Based on field observations, the starch cooking method used was not in accordance with the characteristics of the chemicals used. In addition, the shuttle machine used to weave cloth is very old so it often gets stuck and some components are no longer functioning. The application of process inspection in the production process is not given much attention. Whereas inspection in every production process really needs to be done properly as an effort to control quality. The need for various efforts to improve quality control is aimed at reducing the percentage of defective products so that they can reduce the cost of company losses due to defective products.

Keywords
Defect product, Quality, Statistical Quality Control.

1. Introduction
The basic needs most needed by humans are the needs of clothing, food and shelter. These three needs must be fulfilled, so that they can support all activities carried out by humans to survive. Based on the various needs that the company seeks to produce products to meet human needs. One of the most basic needs is the need for clothing. Human life cannot be separated from the needs of clothing such as clothing. There are so many industries that produce various kinds of clothing ranging from categories of adults, children, men, women, Muslim clothing, and others. The clothing industry or commonly called garment has spread widely in Indonesia. Apart from garments, there are also industries that only produce semi-finished fabrics or gray fabrics, one of which is PT XYZ. The number of companies that produce products for human clothing has led to intense industrial competition. Companies need to implement various strategies in order to be able to compete and benefit from the sale of their products.

One of the things that become the basis of consumers in choosing a product is product quality. Products that have good quality will certainly get its own value for consumers. Therefore, the quality of a product plays an important role in the existence of consumers' eyes. Consumers will be interested in using a product if the product has good quality. aims to determine the success of a product and only determine a product that is feasible to meet consumer needs throughout the product life cycle (Mrugalska and Tytyk, 2015). Quality itself is something that must be owned by every company, both manufacturing and service. The better the product quality of a company, the more likely it is that the company has many consumers (Alkatiri et al, 2015). Every company is competing to improve product quality to attract more consumers.

From the results of observations in a study conducted at PT XYZ, there are obstacles in producing lower output compared to the production target because many products are defective and do not meet standards. This can be known based on product inspection data from the Inspecting division. Inspection data for TR 7864 fabric products in December 2020 showed that every day there were always defective products. Of the 147,557 meters of TR 7864 fabric produced in December, there are 2.716,5 meters of fabric which are defective products, which of course is quite high in percentage. This is of course very detrimental to the company, because defective fabric products cannot be used to fulfill order requests. The existence of this defective product of course also makes the delivery of goods late due to production targets that are not achieved. In addition, the presence of defective products can cause consumer confidence in the company to decline. Therefore, it is necessary to control the occurrence of defective products at PT XYZ.

Quality control is an activity to ensure that the manufactured product meets the highest quality possible. One method that can be used to control product quality is the Statistical Quality Control method. Sourced on a literature review quoted from the Online Journal of the Malikussaleh University Aceh (MIEJ Journal), according to the results of research from Bakhtiar S, Suharto Tahir and Ria Asysyfa Hasni in 2013 at UD Mestika Tapaktuan, one of the effective quality control methods used is the Statistical Quality Control method. Through this method, the company is expected to be able to make improvements and evaluate the existence of defective products. Therefore, a study was conducted to find out what are the causes of defects in TR 7864 fabric products and how to propose improvements. This research is important to do because from the results of this study it is suggested that companies can implement repair solutions for defective product problems so that companies can reduce costs, time effectiveness, and can increase consumer confidence in the company.

2. Literature Review

The definition of quality has a fairly broad scope. In the industrial world, both service and goods industries, quality is a factor that brings business success, growth and increasing competitive position. is a product that has factors in it that make the product valuable in accordance with the purpose of the product being produced (Handoko, 2000). Render and Heizer (2001) also argue that quality is the totality of features and characteristics of a product or service that is able to satisfy a need that is visible or not disguised.

The quality of a product is defined as the degree or degree to which the product and service is able to satisfy the desires of consumers (Render and Heizer, 2001). A company if it effectively uses the quality of its business strategy will get an increase in profits from this strategy, consumers will decide to buy a product from a company whose quality is better than its rivals. Thus, quality becomes the basic factor in consumer decisions to get a product. Based on the definition of quality above, we can see that according to the producer's point of view, quality means the suitability of the product with predetermined specifications, while according to consumers, quality means compatibility in use, however objectively the notion of quality is a special standard where the ability, performance, constraints, convenience maintenance, and characteristics can be measured.

Quality control is a management technique, through which we measure the quality characteristics of the output and then compare it with the measurement results with the output specifications in accordance with consumer desires. To maintain and maintain good product quality, during the production process it is necessary to have quality control or quality control (Assauri, 1999). The definition of quality control is very broad, because it relates to several elements that affect quality that must be included and considered. Broadly speaking, quality control is grouped into: Quality control before processing or process, namely quality control relating to sequential and orderly processes including materials that will be processed. Quality control of finished products is control carried out on manufactured goods to ensure that the finished product is not damaged or the level of product damage is small. One of the techniques used in quality control is the control chart method. This method is used to determine the average product damage and the magnitude of the deviations that occur.

According to Yamit (2004) in general the factors that affect the quality as follows: a) Operational facilities such as the physical condition of the building. b) Equipment and Supplies. c) Raw Materials or Materials. d) Employees or staff of the organization. The objectives of quality control according to (Ahyari, 2000) are: a) To increase customer satisfaction. b) Try to use the lowest possible cost. c) In order to be able to produce finished on time.

Statistical Quality Control is a technique used to control and manage both manufacturing and service processes by using statistical methods. Statistical quality control is a problem solving technique used to monitor, control, analyze, manage and improve products and processes using statistical methods (Dorothea, 2003). Statistical methods play an important role in quality assurance. Statistical methods provide the basic methods of product sampling, testing and evaluation and information in the data used to control and improve the manufacturing process. To make decisions in Statistical Quality Control, you can use tools known as seven tools, which consist of: process flow diagrams, cause and effect (fishbone) diagrams, control charts (control charts), check sheets, Pareto diagrams, scatter plots, and histograms.

Control chart is a graphical tool used to monitor and evaluate whether an activity/process is under statistical quality control or not so that it can solve problems and produce quality improvements. The control chart shows changes in data over time, but does not indicate the cause of the deviation even though the storage will be visible on the control chart. This control chart is used to understand whether a process is running under controlled conditions or not. A process that is quite stable, but runs beyond the expected limits, must be corrected immediately to find the cause in order to get fundamental improvement results. The control chart used in this study is the P control chart. If the data obtained are not entirely within the specified control limits, then this means that the data taken is not uniform (Bakhtiar, 2013). This states that the quality control carried out still needs improvement.

According to Render and Heizer (2001), the Pareto diagram has an important role in quality improvement process. Pareto charts are bar graphs and line graphs that illustrate the comparison of each type of data to the whole. By using a Pareto diagram, it can be seen which problem is dominant so that it can determine the priority of problem solving. The function of the Pareto diagram is to identify or select the main problems for quality improvement from the largest to the smallest. The problems that occur the most are shown by the first bar graph which is the highest and is placed on the far left and so on until the problems that occur the least are shown by the last bar graph which is the lowest and is placed on the far right. The Pareto chart also identifies what is important, as well as alternative solutions that will lead to a substantial improvement in quality.

Cause and effect diagrams are often called fishbone diagrams. These diagrams are used to analyze the characteristics of a process or situation and the factors that cause it (Purnomo, 2004). Fishbone diagram is basically used to identify problems and show a collection of causes and effects called factors and the resulting effects called quality characteristics. The purpose of this diagram is to find the factors that are the cause of a problem.

3. Methods

This research was conducted at PT XYZ with the aim of analyzing the quality control of tr 7864 fabric products. At the initial identification stage, a field study was conducted by conducting direct observations and interviews with operators to determine the type and number of product defects and the causes of product defects. Furthermore, a literature study was carried out as a reference by reading previous research. Then formulated the problem to be solved and the goals to be achieved.

The method used in solving this problem is Statistical Quality Control (SQC). Statistical Quality Control is a technique used to control and manage both manufacturing and service processes by using statistical methods. The main objective of Statistical Quality Control is to minimize variability in the quality characteristics of a product or service. To make decisions in Statistical Quality Control, we use control charts, pareto diagrams, cause and effect (fishbone) diagrams.

The next stage is data collection and processing. Sources of data used are primary data, namely data obtained directly from the object to be studied. The data used in this study is TR 7864 fabric inspection data in the Inspecting division in the period December 2020. The next step is to determine the values for making the P control chart. Then calculate the percentage of each type of defect and make a Pareto diagram to determine the type of defect with the highest number. After that identify the causes of defects with fishbone diagrams. The next stage is the analysis of the results of data processing obtained. After that, suggestions for improvement related to existing problems will be given and conclusions will then be drawn.

4. Data Collection

Data collection at this study is carried out in the form of the number of production, type of product, type of machine, type of defect product, and the number of defect product at PT XYZ. The data used in this study is TR 7864 fabric inspection data in the Inspecting division in the December 2020 period that shown in Table 1. The following is the TR 7864 fabric inspection data for the December 2020 period. In the inspection data, there is information in the form of fabric grade, and total production. In the fabric grade column, fabrics are graded based on a point system in determining the grade of the fabric. There are 4 grades of fabric in the PT XYZ product grade system, namely grades A, B, BS, and RK. Determination of fabric grade based on a 4 point scoring system.

From the field studies that have been carried out, data on the amount of production and the number of defects in TR 7864 fabric products during the December 2020 period are obtained as shown in Table 2.

Table 1. Inspection Data Fabric TR 7864 December Period 2020

No.	GRADE				Total
	A	B	BS	RK	
1	10352,75	914,75	105,00		11372,50
2	5407,75	1279,50	342,00		7029,25
3	8837,25	654,25	214,75	103,50	9809,75
4	7235,25	1025,50	125,75	75,00	8461,50
5	7615,75	665,50	155,25		8436,50
6	4802,50	1570,50	323,00	36,50	6732,50
7	5908,50	1750,25	106,25		7765,00
8	5553,50	305,50	110,50		5969,50
9	8906,75	209,00	115,75	160,50	9392,00
10	5692,75	733,50	84,00		6510,25
11	5153,25		30,00		5183,25
12	4558,50	611,00	78,75		5248,25
13	4415,25	725,00	100,75		5241,00
14	4398,50	884,25	28,50		5311,25
15	3762,50	408,00	107,25	48,75	4326,50
16	4570,50	195,25	101,50	69,25	4936,50
17	3703,00	872,50	133,50		4709,00
18	3101,50	168,50	10,00		3280,00
19	2516,50	357,50	31,50		2905,50
20	3390,00		21,75		3411,75
21	2100,25	582,50	54,00		2736,75
22	2802,50	435,50	35,50		3273,50
23	2255,75	436,00	46,50		2738,25
24	2597,25	355,25	77,75		3030,25
25	2343,75		47,00		2390,75
26	1817,00	784,25	19,50		2620,75
27	2243,50	149,00	33,25	42,50	2468,25
28	1744,50	408,25	77,50	36,50	2266,75
Total	127786,75	16481,00	2716,75	572,50	147557,00

Table 2. TR 7864 Fabric Production Table for December 2020

No.	Number of Production	Number of Defect
1	11372,50	198,50
2	7029,25	106,50
3	9809,75	214,75
4	8461,50	125,75
5	8436,50	145,25
6	6732,50	147,75
7	7765,00	126,25
8	5969,50	130,50
9	9392,00	185,75
10	6510,25	94,25
11	5183,25	80,25
12	5248,25	78,75
13	5241,00	100,75
14	5311,25	88,50
15	4326,50	97,25
16	4936,50	101,50
17	4709,00	102,50
18	3280,00	60,25
19	2905,50	41,50
20	3411,75	65,75
21	2736,75	54,00
22	3273,50	65,50
23	2738,25	46,50
24	3030,25	67,75
25	2390,75	40,50
26	2620,75	59,50
27	2468,25	53,25
28	2266,75	37,50
Total	147557,00	2716,75

5. Results and Discussion

Results and Discussion include the result from P control chart, pareto diagram and fishbone diagram. P control chart describes the state of quality control process in PT XYZ. Then, from the pareto diagram we know the type of defect product that is the highest one. The highest type of defect need to describe the factor of it with the fishbone diagram. After that, describe the alternatives that can be done to solve the problem, a problem-solving system is drawn using the proposed alternatives.

5.1 Numerical Results

The numerical results that are processed in solving problems in PT XYZ are in the form of calculating the value for P control chart and pareto diagram. For the P control chart we calculate the percentage of disability (p), central line (CL), upper control limit (UCL), and lower control limit (LCL). The following Table 3 is showing the result of the P control chart calculation.

Table 3. P Control Chart Calculation Data

Number of production	Number of defect	p	CL	UCL	LCL
11.372,50	198,50	0,017	0,018	0,022	0,015
7.029,25	176,50	0,025	0,018	0,023	0,014
9.809,75	234,75	0,024	0,018	0,022	0,014
8.461,50	125,75	0,015	0,018	0,023	0,014
8.436,50	145,25	0,017	0,018	0,023	0,014
6.732,50	127,75	0,019	0,018	0,023	0,013
7.765,00	126,25	0,016	0,018	0,023	0,014
5.969,50	130,50	0,022	0,018	0,024	0,013
9.392,00	185,75	0,020	0,018	0,023	0,014
6.510,25	74,25	0,011	0,018	0,023	0,013
5.183,25	80,25	0,015	0,018	0,024	0,013
5.248,25	68,75	0,013	0,018	0,024	0,013
5.241,00	100,75	0,019	0,018	0,024	0,013
5.311,25	88,50	0,017	0,018	0,024	0,013
4.326,50	97,25	0,022	0,018	0,025	0,012
4.936,50	91,50	0,019	0,018	0,024	0,013
4.709,00	92,50	0,020	0,018	0,024	0,013
3.280,00	50,25	0,015	0,018	0,025	0,011
2.905,50	41,50	0,014	0,018	0,026	0,011
3.411,75	65,75	0,019	0,018	0,025	0,012
2.736,75	54,00	0,020	0,018	0,026	0,011
3.273,50	55,50	0,017	0,018	0,025	0,011
2.738,25	46,50	0,017	0,018	0,026	0,011
3.030,25	67,75	0,022	0,018	0,026	0,011
2.390,75	40,50	0,017	0,018	0,027	0,010
2.620,75	59,50	0,023	0,018	0,026	0,011
2.468,25	53,25	0,022	0,018	0,027	0,010
2.266,75	37,50	0,017	0,018	0,027	0,010

Based on the calculation, there are several subgroups that cross the control limit, namely subgroups 2, 3, and 10. Therefore, it is necessary to revise the P control chart by eliminating or deleting subgroup data that exceeds the control limit. After recalculation, the revised P value and control chart are obtained as follows.

Table 4. P Control Map Calculation Data After Revision

Number of production	Number of defect	p	CL	UCL	LCL
11.372,50	198,50	0,017	0,018	0,022	0,014
8.461,50	125,75	0,015	0,018	0,022	0,014
8.436,50	145,25	0,017	0,018	0,022	0,014
6.732,50	127,75	0,019	0,018	0,023	0,013
7.765,00	126,25	0,016	0,018	0,022	0,013
5.969,50	130,50	0,022	0,018	0,023	0,013
9.392,00	185,75	0,020	0,018	0,022	0,014
5.183,25	80,25	0,015	0,018	0,023	0,012
5.248,25	68,75	0,013	0,018	0,023	0,012
5.241,00	100,75	0,019	0,018	0,023	0,012
5.311,25	88,50	0,017	0,018	0,023	0,012
4.326,50	97,25	0,022	0,018	0,024	0,012
4.936,50	91,50	0,019	0,018	0,024	0,012
4.709,00	92,50	0,020	0,018	0,024	0,012
3.280,00	50,25	0,015	0,018	0,025	0,011
2.905,50	41,50	0,014	0,018	0,025	0,011
3.411,75	65,75	0,019	0,018	0,025	0,011
2.736,75	54,00	0,020	0,018	0,026	0,010
3.273,50	55,50	0,017	0,018	0,025	0,011
2.738,25	46,50	0,017	0,018	0,026	0,010
3.030,25	67,75	0,022	0,018	0,025	0,011
2.390,75	40,50	0,017	0,018	0,026	0,010
2.620,75	59,50	0,023	0,018	0,026	0,010
2.468,25	53,25	0,022	0,018	0,026	0,010
2.266,75	37,50	0,017	0,018	0,026	0,010

There are no more subgroups that pass the upper control limit or lower control limit after the revision calculation, which means that the disability proportion data is already within statistical control limits.
Based on the inspection data that has been obtained, the percentage of each type of defect that occurs can be calculated. In Table 5. below, the calculation of the percentage of each type of defect is presented.

Table 5. Recapitulation of the Percentage of Types of Defects Found

Type of defect	Number of defect	Percentage
Warp yarn defect	779,50	28,69%
Weft yarn defect	1.296,50	47,72%
Thread defect	371,50	13,67%
Other damage	269,25	9,91%
Total	2.716,75	100,00%

5.2 Graphical Results

The results of the graphs made in solving problems at PT XYZ are in the form of making P control charts and Pareto diagrams. The control chart shows changes in data over time, but does not show the cause of the deviation even though the storage will be visible on the control chart. Based on the P control chart in Figure 1, it can be seen that there are several subgroups that cross the control limits. This indicates that the quality control carried out still needs to be improved. After recalculation, no more subgroups crossed the upper control limit or lower control limit, meaning that the data on the proportion of disabilities were already within the statistical control limits. The P control chart after recalculation is shown in Figure 2. The Pareto diagram depicting the type of defect with the highest number is shown in Figure 3. In Figure 4 you can see some of the problems encountered that caused defective products at PT XYZ.

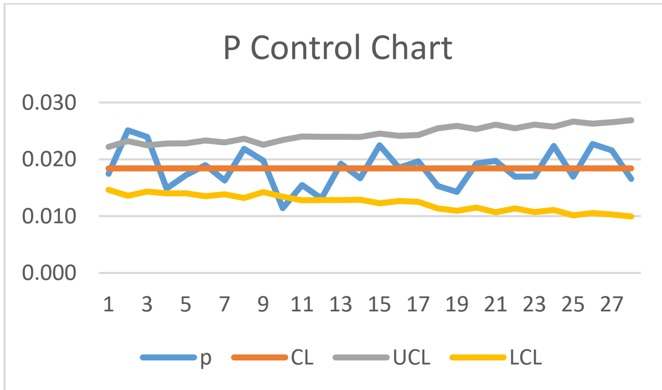

Figure 1. P Control Chart

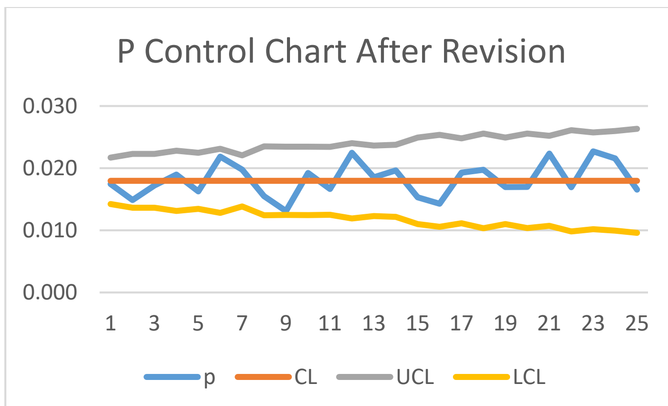

Figure 2. P Control Map After Revision

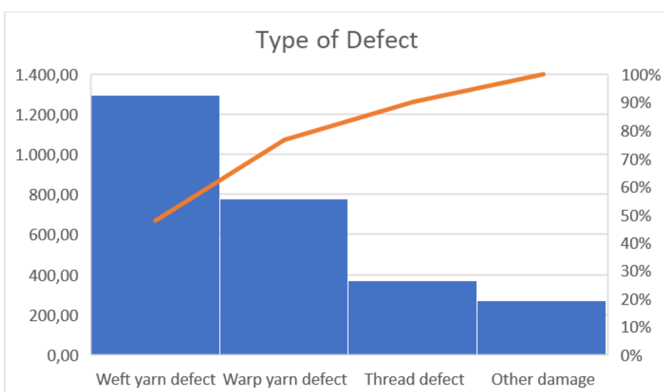

Figure 3. Pareto Chart Type of Defect

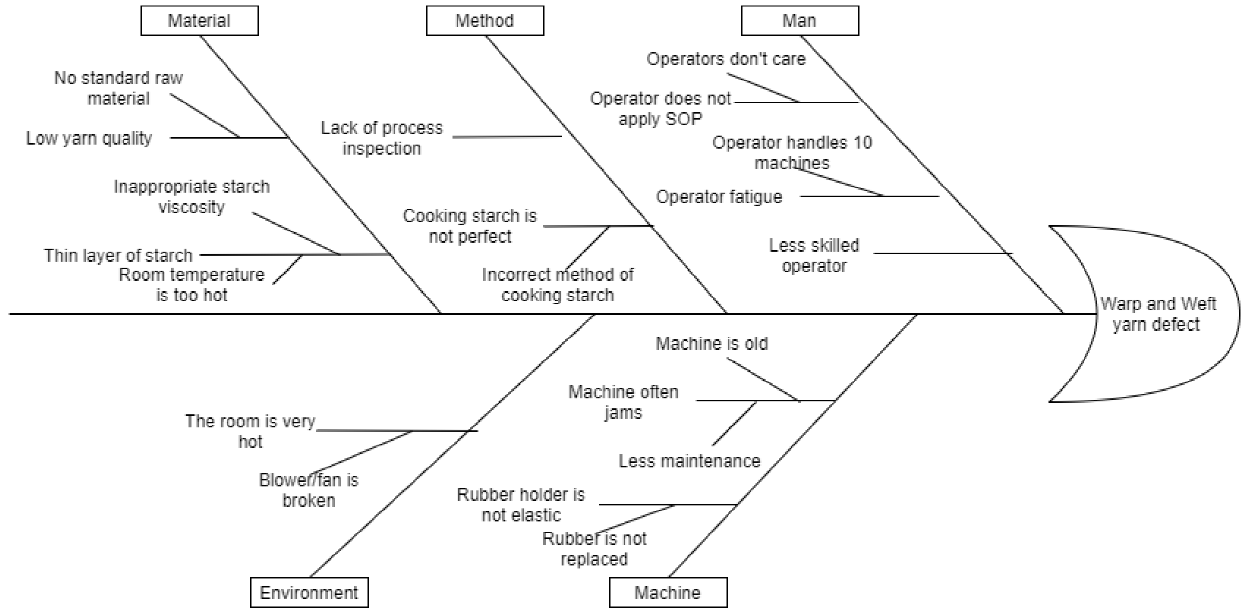

Figure 4. Fishbone Diagram

5.3 Proposed Improvements

The proposed improvements to the Inspection Division can be increasing the number of operators for equal distribution of workloads, investing by buying new machines/tools, and scheduling preventive maintenance. In the implementation of all proposed improvement solutions, investment is needed, for that it is necessary to calculate the total investment required for all proposals. Table 6 shows the calculation of the total investment.

Table 6. Total Investment

Details	Amount	Unit Price	Cost
Visco cup	10	Rp 720.000	Rp 7.200.000
Refractometer	10	Rp 2.950.000	Rp 29.500.000
Digital scales	10	Rp 145.000	Rp 1.450.000
Shuttle machine	12	Rp 39.888.100	Rp 478.657.200
Installation fee	1	Rp 10.000.000	Rp 10.000.000
Total Investment			Rp 526.807.200

From the data obtained from the company, the average defective product per month is about 1,800 m^2. Then calculated the cost savings obtained by the company after making repairs according to the proposal with the assumption that defective products will be reduced by 29.3% (based on data on defects caused by thin starch and damaged machines) from the average defective product per month. Table 7 shows the calculation of the cost saving after repair.

Table 7. Cost Saving

Parameters	The Current Condition	The Proposed Condition
Average number of defective fabric products per month	1.800 m	1.272,6 m
Average loss due to defective products per month	Rp 19.800.000	Rp 13.998.600
Cost saving per month	Rp 5.801.400	
Cost saving per year	Rp 69.616.800	

Next, the payback period is calculated from the investments made. Payback Period (PP) method is an assessment technique for the period (period) of return on investment in a project or business (Rachadian, 2013). Table 8 shows the calculation of the payback period.

Table 8. Payback Period

Period (Year)	Investment Cost (Rp)	Cost Saving (Rp)	Cumulative Cashflow (Rp)
1	526.807.200	69.616.800	-457.190.400
2		69.616.800	-387.573.600
3		69.616.800	-317.956.800
4		69.616.800	-248.340.000
5		69.616.800	-178.723.200
6		69.616.800	-109.106.400
7		69.616.800	-39.489.600
8		69.616.800	30.127.200
9		69.616.800	99.744.000
10		69.616.800	169.360.800

Based on the calculation of the payback period, it can be seen that the cumulative cash flow is positive in the eighth year. It can be concluded that the payback period of the investment is fast enough so that the investment can be considered.

6. Conclusion

Based on data processing and analysis that has been done, it can be seen that the most common types of defects are weft yarn defects by 47.72%. Then, based on the P control chart processing, there are data on defects that exceed the control limits, which means that the production defects have not been controlled and need improvement efforts. Furthermore, several causes of weft and warp defects include operators not implementing SOP, operator fatigue, unskilled operators, machines often jamming, inelastic rubber holders, imperfect starch cooking, lack of process inspection, low yarn quality, thin starch, and hot room temperature. So, the proposed solutions to overcome defective products are improving the sizing method, purchasing a new shuttle machine, and scheduling inspections for the weaving process. Based on the calculation of the investment analysis of all proposals with a total cost of Rp 526.807.200, it can be seen that the payback period table shows a positive cumulative cash flow in the eighth year. It can be concluded that the payback period of the investment is fast enough so that the investment can be considered. By implementing the proposed improvement, the company will experience a reduction in the number of defective products and be able to meet production targets faster. Meanwhile, the rate of return on investment made will be positive in the eighth year so that the proposal is worthy of consideration.

References

Ahyari, Agus. *Manajemen Produksi–Pengendalian Produksi*. Buku I. Yogyakarta: Penerbit BPFE, 2004.

Alkatiri, Hamzah Asadullah, Hari Adianto, Dan Dwi Novirani. Implemetasi Pengendalian Kualitas Untuk Mengurangi Jumlah Produk Cacat Tekstil Kain Katun Menggunakan Metode *Six Sigma* Pada Pt. SSP. Jurnal *Online* Institut Teknologi Nasional Vol. 03 No. 03 148-159, 2015.

Assauri, S. Manajemen Produksi dan Operasi, Edisi Revisi. Jakarta: LP FE-UI., 1999.

Bakhtiar S., Suharto Tahir, dan Ria Asysyfa Hasni. Analisa Pengendalian Kualitas Dengan Menggunakan Metode *Statistical Quality Control* (SQC). *Malikussaleh Industrial Engineering Journal* Vol.2 No.1 29-36., 2013.

Handoko, T. H. Dasar-Dasar Manajemen Produksi dan Operasi. Yogyakarta: BPFE, 2000.

Mrugalska, B., & Tytyk, E. *Quality Control Methods for Product Reliability and Safety*. *Elsevier*, 2730-2737, 2015.

Purnomo, H. *Pengantar Teknik Industri*. Yogyakarta: Graha Ilmu, 2004.

Rachadian, Febri Muhammad, Ereika Arie Agassi, & Wahyudi Sutopo. Analisis Kelayakan Investasi Penambahan Mesin Frais Baru Pada CV. XYZ. J@TI Undip, Vol VIII, No 1, 2013.
Render, B., & Heizer, J. Prinsip-Prinsip Manajemen Operasi. Jakarta: Salemba Empat, 2001.
W.A. Dorothea. Pengendalian Kualitas Staristik, Yogyakarta: Repository UPI, 2003.
Yamit, Zulian. Manajemen Produksi dan Operasi. Yogyakarta: Ekonisia-FEUUI, 2004.

Biography

Anisa Agustina is an undergraduate student of the Industrial Engineering Department of Universitas Sebelas Maret, Surakarta, Indonesia. Her research interests are in standardization and quality control.

Wahyudi Sutopo is a professor in industrial engineering and coordinator for the research group of industrial engineering and techno-economy (RG-RITE) of Faculty Engineering, Universitas Sebelas Maret (UNS), Indonesia. He earned his Ph.D. in Industrial Engineering & Management from Institut Teknologi Bandung in 2011. He has done projects with the Indonesia endowment fund for education (LPDP), sustainable higher education research alliances (SHERA), MIT-Indonesia research alliance (MIRA), PT Pertamina (Persero), PT Toyota Motor Manufacturing Indonesia, and various other companies. He has published more than 130 articles indexed in Scopus, and his research interests include logistics & supply chain management, engineering economy, cost analysis & estimation, and technology commercialization. He is a member of the board of industrial engineering chapter - the institute of Indonesian engineers (BKTI-PII), Indonesian Supply Chain & Logistics Institute (ISLI), Society of Industrial Engineering, and Operations Management (IEOM), and Institute of Industrial & Systems Engineers