Quality Improvement of Ceramic Insulator with Six Sigma Method

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Abstract

Quality control of a product within a company is a demand to fulfill and achieve product quality by existing standards. With quality control, a problem or defect in the product produced can be seen. Research was conducted in a company that operates in the electricity sector by producing products in the form of ceramic insulators. The problem in this company is that there are still many defects caused by several factors such as human error, environment, and also the methods used. There are 4 types of defects produced, namely broken neck of the product, the broken body of the product, broken leg of the product, and porous defects. This research purpose is to find out the causes of defects from any defects that occurred, then find out solutions or corrective actions to provide on which priority failures need to be reduced. The research was carried out using the Six Sigma method with the DMAIC stages, followed by an FMEA assessment table. After data processing, the capability process (Cp) value was 0.7467, and the Cpk was 0.6477. Then, we obtained a DPMO value is 13,250, so the Sigma level obtained for the last 6 months was 3.72. Then, using FMEA method, we obtained the biggest RPN score is broken body of the product with score 140. So, the improvement suggestion is to check and replace lamps used at glazing stations.

Keywords
Capability Process (Cp), Defects Per Million Opportunities (DPMO), Failure Mode and Effect Analysis (FMEA), Quality Control, Six Sigma.

1. Introduction
Industrial development is known to grow over time, with the times following the developments, companies have to improve their quality. The activities of a company in the industrial sector must pay attention to product quality. The production process is carried out by a company that wants to produce finished goods that comply with predetermined standards. The company is expected to be able to maintain and improve the quality of its products (Gremyr et al. 2021). Many large companies have used machines and equipment with sophisticated technology to meet the desired production targets. Even though many companies use machines with advanced technology, quality control to maintain product quality is still needed so that products have competitiveness (Gupta et al. 2021).

One step to maintain product quality is to analyze product defects, and key product quality and carry out improvement activities (Psarommatis 2022). Companies must have their standards for products produced through a quality control process, so if there are errors, the company will more easily respond to problems with existing standards. (Mrugalska and Tytyk 2015). The production process in terms of production flow is divided into 2, namely continuous process and intermittent process. A continuous process is a production process that occurs continuously or continuously, where the production process has a pattern or sequence so that it will always be the same from time to time. Meanwhile, an intermittent process is a production process that occurs intermittently, where the production process has several patterns or sequences and is always changing (Wang et al. 2021).

The research was conducted at a company that operates in the manufacturing sector with production results in the form of electrical equipment, namely ceramic insulators. The production process at the company includes the grinding process, filter process, drying, forming, glazing, firing and assembling. During the production process, this company discovered a defect in the product produced. Based on the results of interviews and field observations, there are problems in controlling the quality of ceramic insulators, causing defects in the product. This research aims to identify

and provide suggestions for improvements to reduce product defects in the production process. To reduce existing defects, the author will use the Six Sigma method with the DMAIC (Define, Measure, Analyze, Improve, Control) stages which aims to analyse the failure mode, causes of failure, and effects of failure so it can reduce defects and improve the quality of the company's products.

2. Literature Review

In the free market era, every company is required to improve its performance from one period to the next period. This performance increase can be achieved, among other things, by carrying out process improvement, which is a company activity to carry out process improvements that can continuously increase added value (Gremyr et al. 2021). The production process is said to be good if the process produces products that meet the established standards. However, in reality, various deviations and obstacles often occur in the production process which result in the product being considered defective (Gupta et al. 2021). Quality is an important indicator for companies to be able to exist at the intense competition in the industrial world (Schroder et al. 2014). Apart from TQM there are other quality systems used to improve quality such as Six Sigma. Six Sigma focuses on reducing and eliminating variation by applying an extensive set of statistical tools and techniques. This will lead to increased productivity, increased customer satisfaction, improved service quality, reduced operational costs or poor quality costs, and so on. With the Six Sigma method, you can find out the causes and factors that influence the occurrence of rejected products with the aim of reducing defects product. (Sachin and Dileeplal 2017).

3. Methods

Research conducted in the East Cikarang, Bekasi, West Java. This company was a trading business that supplied to the State Electricity Company (PLN) for the construction and development of electricity in Indonesia. The research started with observation at the company and collecting some data information that related with the research. The collecting data means data weekly production, data defects of production, production process, specification of the product, and quality control process. After collecting all the data, this research begins with focusing one product to observed. This research focuses on *PI* type of ceramic insulator. Then, DMAIC stages, the defined stage begins by creating a project charter, SIPOC diagram, and Critical To Quality (CTQ). Then the next stage is the measure stage, where there is a calculation of the control chart, capability process, and process performance level to find out the data result. Next, existing causes problems will be analyzed using the 5 whys analysis method and to find the failure mode, causes of failure, and effects of failure will be using Failure Mode and Effect Analysis (FMEA) method. After that, recommendations for improvements will be provided regarding the known causes of the problem. Then, suggestions for improvements will be provided to improvements for the company.

4. Data Collection

The data used is related to improving the quality of ceramic insulators, The following data is data production and defect that was obtained from March to August 2023 in weekly form.

Table 1. Data Production and Defects March to August 2023

Time (Weekly)	Production Amount (Unit)	Number of Defective Products (Unit)	Percentage (%)
1	6792	123	1.81
2	6586	145	2.20
3	6722	167	2.48
4	6637	179	2.70
5	7218	176	2.44
6	7231	214	2.96
7	7216	229	3.17
8	7359	207	2.81
9	7325	198	2.70
10	7207	201	2.79

Time (Weekly)	Production Amount (Unit)	Number of Defective Products (Unit)	Percentage (%)
11	7135	196	2.75
12	7740	188	2.43
13	7023	248	3.53
14	7163	183	2.55
15	7018	197	2.81
16	7091	204	2.88
17	6891	171	2.48
18	7042	172	2.44
19	6955	163	2.34
20	6994	175	2.50
21	7105	195	2.74
22	7004	203	2.90
23	7193	177	2.46
24	7021	184	2.62
Total	169,668	4,495	15.87
Average	28,278	749.17	2.64

5. Results and Discussion
With the data collection that has been carried out, the next stage of DMAIC will be carried out to find out more about the causes and repair solutions for the failures that occur.

5.1 Define Stage
The define stage is the initial stage of research to identify existing problems in the company. In this research, the problem that will be studied is the defects produced by the production process. Identification is carried out using project charters, SIPOC diagrams (Supplier, Input, Process, Output, Customer), and CTQ (Critical To Quality).

Project Charter
Defects produced after the production process is complete will be collected into one data. Then identification of project problems, limitations and assumptions, research objects and project timeline will be carried out. This project charter functions to provide an initial understanding of a project (Pakdil 2021).

Project Tittle	Quality Improvement of Ceramic Insulator with Six Sigma Method			Project	Chelvy Pricilia
Project Start Date	October 4th, 2023	Project End Date	December 16th, 2023	Leader	

Business Care
PT. TII is a company that moves in electrical sector. The product studied was PI type of ceramic insulator with defect percentage 2,64% for 6 months.

Project Scope	Deliverables
1. Research is carried out at PT. TII production area.	1. Analyze the causes of defectsof the product.
2. Research uses the Six Sigma method with DMAIC stages (Define, Measure, Analyze, Improve, Control) dan Kaizen.	2. Calculate DPMO value, Sigma level and process capability.
3. Data used is in the range from March – August 2023.	3. Give improvement suggestions to reduce the defects.
4. The focused product is PI type of ceramic insulator.	

Risk and Issues	Assumptions or Dependencies
Improvement suggestions is not provide a guarantee that the result will decrease the defect significantly.	The company provided data during the research. Improvement suggestion can be applied at improve stage, but it may also not be implemented while the research is on progress.

Milestone		Plan Start	Plan End
Define : Create project charters, SIPOC diagram, and CTQs.		October 4th, 2023	October 18th, 2023
Measure : Create P control chart, DPMO, Sigma level, and process capability.		October 19th, 2023	October 26th, 2023
Analyze : Create pareto diagram, 5 whys analysis, and FMEA assessment analysis.		November 2nd, 2023	November 9th, 2023
Improve : Provide corrective action according the result of the FMEA analysis.		November 10th, 2023	November 19th, 2023
Control : Implement the corrective actions that have been given and provide supervision over the actions that carried out.		November 23th, 2023	December 16th, 2023

Benefits
This research can be useful for the company to get improvement suggestions then it impact to reduce the defects.

Figure 1. Project charter

SIPOC diagram
The following is the flow of the process of contact with a company starting from the supplier, the process, and ending with the customer.
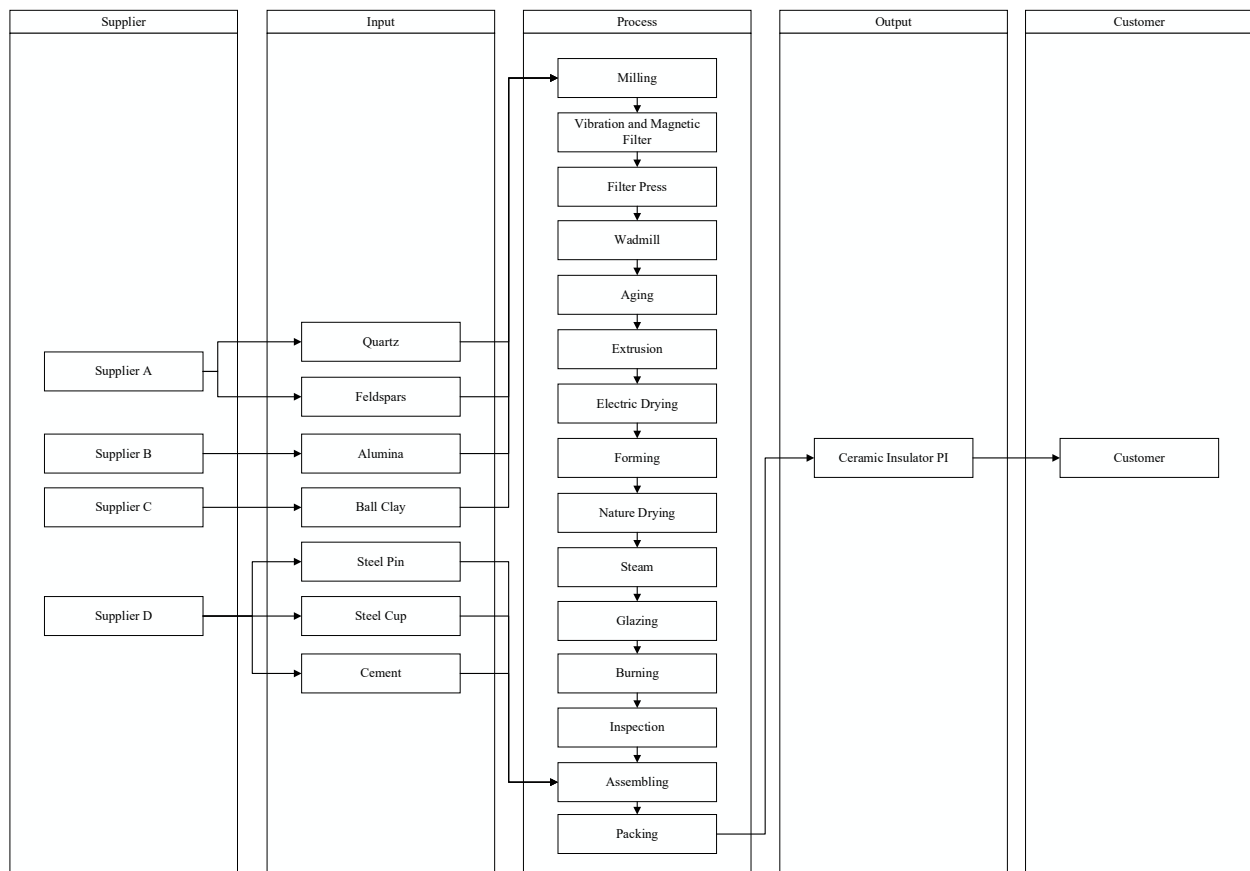

Figure 2. SIPOC diagram

Critical To Quality
The following are the requirements for meeting company product standards based on customer needs and desires. Ceramic insulators must not have cracks, the surface of the insulator must be glazed and smooth, and there must be no holes in the product.
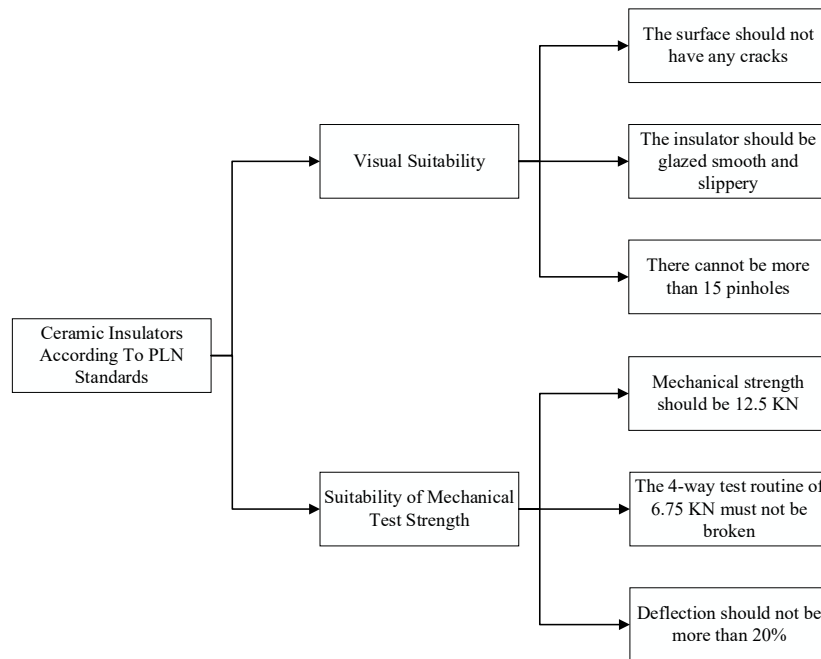

Figure 3. CTQ products

5.2 Measure Stages

Control charts are a tool to assist in controlling production processes statistically. By using a control chart, the data entered can be seen whether it is deviating or not. This can be seen from the upper and lower boundary lines, the data must be within the boundary line area (Schroder et al. 2014). Calculations carried out to create a control chart from March 2023 to August 2023, obtained CL = 0.026; UCL – 0.032 ; and LCL = 0.021. The following is a control chart that has been created.
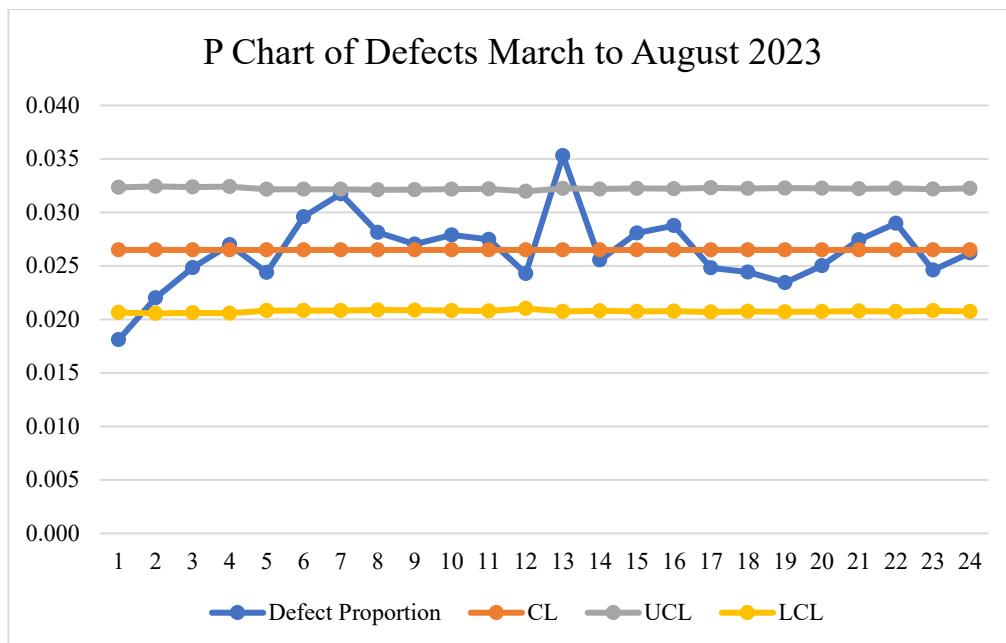

Figure 4. P chart March to August 2023

Based on the control chart obtained, some data exceeds the lower and upper limits, namely data 1 and 13. This supports the need to take corrective action to increase production and reduce defects produced by the company. Furthermore, the calculation of the defect proportion capability is 0.026 = 2.6%. Then we obtained a Capability process (Cp) value is 0.7467 and Capability index (Cpk) value is 0.6477. Based on the calculations that have been carried out, a Cp value below 1.33 and a Cpk below 1 means that corrective action still needs to be taken, so the product specifications can be achieved. Next, for the DPMO and Sigma value will be calculated, which is a measure of a product defect in one million production items. The higher Sigma value obtained, the better the company's performance (Gupta et al. 2018). The DPMO value from March to August 2023 is 13,250 and the Sigma level is 3.72.

5.3 Analyze Stages

At this stage, the causes of ceramic insulator product defects will be analyzed. To find out the causes of product defects, we will use the 5 whys analysis method and FMEA (Failure Mode and Effect Analysis).

5 Whys Analysis

An analysis is carried out to determine the cause of the defect using the 5 whys analysis method. Where a problem will be searched for the cause and then analyzed until the root cause is found. The following is a 5 whys analysis of company defects.

Table 2. 5 Whys analysis

Problems	Why 1	Why 2	Why 3	Why 4	Why 5
Broken Neck of Product	Product shape does not comply with standards (skewed, changes shape, not smooth)	The knife used is blunt	The knife has exceeded its usage limit	The knife was not replaced with a new one	There is no consistent blade change schedule
Broken Body of Product	The glazing process is not optimal	The lighting at the glazing station is not good	The lights used tend to be dim	The lights are not refurbished	No controlling is carried out at the work station
Broken Leg of Product	The combustion process is not optimal	Uneven product combustion	Inappropriate product placement	Products placed too close together	The layout of the trucks used has not yet been changed
Porous Product	There is a pinhole on the product	Hit by raindrops	There is a roof leak on the storage rack	The factory roof was not replaced or repaired	Roof renewal is not easy to do

Failure Mode and Effect Analysis

FMEA (Failure Mode and Effect Analysis) is a systematic function that functions to identify the failure mode when a failure occurs. Assessments are carried out on the level of damage (severity), possibility of occurrence (occurrence), and detection (Rana et al. 2018).

Table 3. Failure mode and effect analysis

No.	Item	Failure Mode	Effects of Failure	Causes of Failure	Criticism			RPN	Action
					S	O	D		
1.	Neck of Product	Shape does not comply with standards (skewed, changes shape, not smooth)	Broken Neck of Product	The blade used is blunt	4	5	4	80	Check the blade used.
2.	Body of Product	There are cracks in the product	Broken Body of Product	Lighting equipment tends to be dim	7	5	4	140	Check the required lighting equipment regularly and tighten QC.
3.	Leg of Product	Uneven burning	Broken Leg of Product	Inappropriate product placement	3	5	5	75	Check product placement in the combustion process.
4.	Product Integrity	Product contamination	Porous Product	The product has been exposed to raindrops	7	5	3	105	Provides protection for storage shelves during natural drying

Based on the results of analysis using the FMEA method, it is known that the causes of defects are the blades used on the forming machines are dull, the lighting at the glazing station is quite dim, the placement of the product in the firing process is not correct, and the product is contaminated by rainwater. Then, the defect with the highest RPN score is a broken product body with a score of 140, so the priority for repair is checking the required lighting equipment regularly and tightening QC.

5.4 Improve Stages
After carrying out an analysis related to defects that occur in the company, the following are suggestions for improvements related to the analysis of the causes of failure in the FMEA table.
1. Make a check sheet for checking the blade on forming machine.

Table 4. check sheet for Inspection of Blade on Forming Machine

PT. TII				check sheet for Inspection of Blade on Forming Machine	No: 1
Date	Time	Information			Inspector
		Machine 1	Machine 2		
Approved by					
(Head of Production)					

2. Make a check sheet for checking lights at the glazing station.

Table 5. Check sheet for Inspection of Lights at Glazing Station

PT. TII				check sheet for Inspection of Lights at Glazing Station	No: 1
Date	Time	Information			Inspector
		Machine 1	Machine 2		
Approved by					
(Head of Production)					

3. Make a Poka Yoke poster.

Table 6. Results of Poka Yoke

PT. TII	Poka Yoke	No: 1
Glazing Station		Factory Area
Classification: {✓} *Improvement* {} Work Safety		
		INCORRECT
		CORRECT
Made by	Checked by	Approved by
Chelvy Pricilia	Production Staff	Head of Production

5.5 Control Stages

After improvement given, the next stage is to carry out supervision so that the proposed improvement is carried out continuously and consistently so that it can provide improvements for the company and reduce defects that occur. Companies can also implement the 5S cycle so that changes can be carried out continuously and can become the next change (Mast et al. 2022). The results of improvements in the company were obtained from the application of the Six Sigma method. The data used as a comparison between the values before and after the proposed improvements were implemented is historical data in August 2023 for 21 days with total production of 21,218 and total defects of 564 units. Meanwhile, the number of productions after implementing the proposed improvements was 21,467 and the number of defects was 459. Then the control chart, process capability, DPMO value and Sigma level will be calculated and the following comparison results will be obtained.

Table 7. Comparison of Calculation Results Before and After Implementation (Within 21 Days)

Calculation	Results Before Implementation	Results After Implementation
Cp	0.7421	0.7693
Cpk	0.6423	0.6778
DPMO	13,290	10,690
Level Sigma	3.72	3.8

6. Conclusion

In this research, it was discovered that there were 4 types of defects produced, namely broken defects on the neck of the product, broken defects on the body of the product, broken defects on the legs of the product, and porous defects. From the calculations and failure analysis that have been carried out, the defect in the product body has an RPN value of 140 so suggestions are obtained as a priority for repair, namely checking and replacing the lamps used at the glazing station. For problems that occur, suggestions for improvements are given, such as making a check sheet to help operators carry out their duties, and then making a Poka Yoke as a guide for workers to distinguish between incorrect and correct work results. Then, based on data calculations after implementation, it is known that the related data leads to better value for the company. The increase that occurred was not very significant due to limited research time. In 21 days, the Cp value increased from 0.7421 to 0.7693 and the Cpk value increased from 0.6423 to 0.6778. Then the DPMO value from 13,290 decreased to 10,690, which means the defects produced were reduced, and there was an increase in the Sigma value to a higher level, namely from 3.72 to 3.8. So, it can be concluded that company defects are reduced by implementing the Six Sigma method.

References

Gremyr, I., Lenning, J., Elg, M. and Martin, J., Increasing the Value of Quality Management Systems, International Journal of Quality and Service Sciences, vol. 13, no. 3, pp. 381-394, 2021.

Gupta, S. N., Yadav, P., Sahu, S., Yadav, M. and Maurya, R. A Review: Quality Control, International Journal of Creative Research Thoughts (IJCRT), vol. 9, no. 1, pp. 1919-1924, 2021.

Gupta, V., Jain, R., Meena, M. L. and Dangayach, G. S., Six Sigma Application in Tire Manufacturing Company: a Case Study, Journal of Industrial Engineering International, vol. 14, no. 1, pp. 511-520, 2018.

Mast, J. D., Lameijer, B. A., Linderman, K. and Van de Ven, A., Exploring the Process of Management System Implementation: a Case of Six Sigma, International Journal of Operations and Production Management, vol. 42, no. 13, pp. 1-24, 2022.

Mrugalska, B and Tytyk, E., Quality Control Methods for Product Reliability and Safety, Procedia Manufacturing, vol. 3 no. 1, pp. 2730-2737, 2015.

Pakdil, F., Six Sigma Project Prioritization And Selection Methods: a Systematic Literature Review, International Journal of Lean Six Sigma, vol. 13, no. 2, pp. 382-407, 2021.

Psarommatis, F., Sousa, J., Mendonca., J. P. and Kiritsis, D. Zero Defect Manufacturing the Approach for Higher Manufacturing Sustainability in the Era of Industry 4.0: A Position Paper, International Journal of Production Research, vol. 60, no. 1, pp. 73-91, 2022

Rana, M., Zhang, X. and Akher, S. A., Determination of Factors and Quality Control of Car Painting Based on FMEA, Modern Mechanical Engineering, vol. 8, no. 2, pp. 495-508, 2018.

Sachin, S. and Dileeplal, J., Six Sigma Methodology for Improving Manufacturing Process in a Foundry Industry, International Journal of Advanced Engineering Research and Science, vol. 4, no. 5, pp. 131-136, 2017.

Schroder, M., Schmitt, S. and Schmitt, R., Design and Implementation Of Quality Control Loops: Strategies to Reach Stable Business Processes, TQM Journal, vol. 27, no. 3, pp. 294-302, 2014.

Wang, M., Lu, Y. and Pan, W., An Improved Pattern-Based Prediction Model For a Class of Industrial Processes, Sage Journal, vol. 44, no. 7, pp. 1410-1423, 2021

Biographies

Chelvy Pricilia is a student at the Industrial Engineering Department of Tarumanagara University. She was born in 2002. With her passion for analyzing things, she started to write a journal. She started her education at college in 2020. Apart from studying at college, she also likes to be active in a community and socializing.

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