

**VALUE BASED SUSTAINABLE OPERATION DRIVEN BY INTEGRATED
DIGITAL AUTOMATION TOOL AND DATA ANALYTIC**

**OPERASI BERKELANJUTAN BERBASIS NILAI YANG DIDORONG OLEH
ALAT OTOMATISASI DIGITAL TERINTEGRASI DAN ANALITIK DATA**

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ABSTRACT

In this current customer centricity era and as chemical company, stable process and consistent product quality are important that need to be ensured for customer satisfaction. Quality Assurance is the gateway through which customers can be connected and satisfied even gain ultimate customer experience. At the same time, competitive advantage over competitors can be gained by improvement and waste reduction. Considering scattered barriers of company's improvement, large amount of waste, the increment of customer complaints and out of specification rate, which deliver negative impact on company profitability, this study focuses on studying waste reduction, understanding the contribution of chosen system and exploring the development of the application software as part of cost effective system. Mixed method between qualitative and quantitative is used in this study and Six Sigma DMAIC is use as research Methodology. Current Reality Tree is performed to find root causes. Automated SPC dashboard for quality control as best solution among three alternative solutions is identified using Analytical Hierarchy Process. By implementing "automated SPC dashboard", which was developed by combining automation with Statistical Process Control initiatives using Visual Basic for Application, significant waste reduction can be achieved. It triggers cost reduction and deliver positive contribution on company profitability.

Keywords: Current Reality Tree; Analytical Hierarchy Process; Statistical Process Control; Automation; Visual Basic For Application.

ABSTRAK

Di era yang berpusat pada pelanggan ini dan sebagai perusahaan kimia, proses yang stabil dan kualitas produk yang konsisten menjadi penting dan perlu dipastikan untuk kepuasan pelanggan. Jaminan kualitas adalah pintu gerbang di mana pelanggan dapat terhubung dan merasa puas bahkan mendapatkan pengalaman terbaik. Pada saat yang sama, keunggulan kompetitif dibandingkan pesaing dapat diperoleh dengan peningkatan dan pengurangan aktifitas yang tidak menambah nilai. Dengan mempertimbangkan berbagai hambatan yang muncul dalam peningkatan kinerja perusahaan, banyaknya pemborosan, meningkatnya keluhan pelanggan, dan tingkat ketidaksesuaian spesifikasi, yang berdampak negatif pada profitabilitas perusahaan, penelitian ini berfokus pada studi pengurangan pemborosan, memahami kontribusi sistem yang dipilih, dan mengeksplorasi pengembangan perangkat lunak aplikasi sebagai bagian dari sistem yang hemat biaya. Metode campuran antara kualitatif dan kuantitatif digunakan dalam penelitian ini dan Six Sigma DMAIC digunakan sebagai metodologi penelitian. CRT dilakukan untuk menemukan akar permasalahan. Dasbor SPC otomatis untuk pengendalian mutu sebagai solusi terbaik di antara tiga solusi alternatif diidentifikasi menggunakan Proses Hirarki Analitik. Dengan menerapkan "dasbor SPC otomatis", yang dikembangkan dengan menggabungkan otomatisasi dengan inisiatif Pengendalian Proses Statistik menggunakan Visual Basic for Application, pengurangan pemborosan yang signifikan dapat dicapai. Hal ini memicu pengurangan biaya dan memberikan kontribusi positif pada profitabilitas perusahaan.

Kata Kunci: CRT- Alat Pemecahan Masalah Yang Digunakan Dalam Teori Kendala; Proses Hirarki Analitis; Kontrol Proses Statistik; Otomasi; Visual Basic Untuk Aplikasi.

INTRODUCTION

The chemical company F Sabade, which produces polymer dispersion product, engaged in the chemical B2B business. The polymer dispersion

product is based on emulsion polymerization reaction, which occurs when there are at least 3 main components, namely monomers which form the polymer structure, water as a

continuous medium in which the particles are dispersed, and an initiator which produces free radicals which will start the polymerization reaction. However, a fourth ingredient is usually added, namely a surfactant or emulsifiers, which can provide stability to the polymer particles by reducing the surfaced tension between two phases and binding both the hydrophobic or non polar molecules and hydrophilic or polar molecules (Rust, 2024). There are several departments to ensure all the required processes runs smoothly, namely Production including Planning Control, Maintenance, Quality Assurance, Waste water treatment infrastructure, Environment Health Safety Security, Logistic-Warehouse and Human Resources department. Quality Control Laboratory, which is in under Quality Assurance Department runs 24 hours a day and implements 3 shift system also as above mentioned system. Analytic works for checking samples such raw material samples, in process samples, finished good samples. Data input into database system, evaluation work are parts of daily routine works in the Quality Control Laboratory. All of works in laboratory are done manually. No automation is implemented in Quality Control laboratory. However, as an industry gets bigger, it certainly cannot be free from problems and challenges. Obstacles that keep the door to improvement closed, are scattered all over the workplace. These barriers of company's improvement can be seen in the large amount of waste that exists in the factory or manufacturing facilities. Large amount of waste is the real issue and need to be addressed. On top of that, some employees are caught up in the daily routine, hustle and bustle due to unpleasant conditions such as limited resources, excessive manual tasks, lack

of training, lack of mentoring, very rigid existing system, etc. Therefore there is a need of waste reduction initiative as new breakthrough to break down the barriers and boundaries that hold the system for improving. Waste that is left unchecked and not handled properly will have negative impact to the company competitive edge, customer satisfaction and even company's profit. Waste is not limited to the "non added value activity", but also the real chemical product waste including solid waste and waster water generated from chemical manufacturing process. In term of chemical waste reduction, not only contributing to the environmental protection, the reduction of waste can reduce cost and has positive impact to the company's profit also. Furthermore, from quality assurance point of view, inconsistent performance and quality degradation were observed recently. The rate of "out of specification" in 2024 was increased 102% if compared with previous year. Furthermore, the total number of justified customer complaints in 2024 is increased 7,1 % if compared with previous year. The above mentioned increasing number of quality problems not only has impact on cost of nonconformity increment but also direct impact on customer experience which contributed to customer satisfaction reduction and revenue loss. The cost of nonconformity is consist of cost of complain (such as administration cost, logistic cost, testing costs, cost of returns, cost of credit notes) and cost of off spec (product disposal). The total cost of nonconformity in a year was around IDR 1.86 Billion. The scope of this study is in manufacturing operation. Due to no intersection with other departments such as maintenance department, EHSS departments, WWT and infrastructure department, etc, the

focus in this study is in Quality Assurance Department point of view, especially in quality control laboratory and has a connection with production department point of view also. In response to the mentioned problems, several existing actions had been done such as: After sales service for maintaining customer satisfaction and long term relationships, Non Conformance Management by ERP system which provides access and communication between customer, supply chain , Manufacturing team & other related parties. To ensure the professionalism and fair non conformance management, finished product sample is always taken during filling activity into packaging or road-tankers before delivery. Other existing measures such as ISO 9001:2015 system, quality management System , Halal management system has been set up and maintained very well. However, these existing measures does not prevent the recent mentioned problems from occurring. That's why this study was carried out with three research questions, namely: How can company reduce waste? How does the chosen system contribute to add value to the company (including waste reduction)? How to develop the software solution as part of chosen system that is cost effective and delivers value creation for company ? and with three research objectives, namely: To study the waste reduction which contributes to cost reduction and even quality problem reduction, to understand the cost effective chosen system that can contribute to company's waste reduction, to explore the development of application program for enabling automation called also as software solution as part of chosen cost effective system.

RESEARCH METHODS

This study is based on mixed method between quantitative and qualitative method. In this case, qualitative is an explanation of quantitative. Besides quantitative data, qualitative data were collected through interview and discussion targeting manufacturing engineers, quality engineers, process improvement engineer. The Six Sigma DMAIC research methodology is used. It is a structured, data driven- problem solving and process improvement approach of five phases of Six Sigma representing words define, measure, analyze, improve and control for product, quality, service improvement and cost reduction (Soundararajan & Janardhan, 2019). The six sigma DMAIC research methodology alone which represents the technology drivers can not solve the real world problem. Therefore the interview and discussion activities as qualitative method are needed and integrated in analysis section Regarding data collection methods, The data used for this study is collected through primary data method (quantitative analysis method), where original data from laboratory data then extracted for the analysis using statistical method. Permission has been granted for education purpose only. Regarding frequency, the sampling is done everyday for certain period (between 1 month until 12 months). This quite longer period is chosen in order to ensure the enough data amount and the collected data represent the actual behaviour. Regarding DMAIC and its first phase called the define phase, the increasing number of quality problems, which were validated by the increment of out of specification rate & justified customer complained total number compared to previous year is the evidence of the presence of non ideal

conditions, that need to be addressed. Due to limited period in this research project, the focus of waste reduction in term of manual processes is limited to the statistics point of view and the scope is limited to three physical properties of 10 finished products. Regarding the measure phase as the second phase of DMAIC, analytical Measurements for several parameters are conducted to gather the physical properties data of finished product. Brookfield viscosity meter is used to test the viscosity of the samples according to ISO 2555 due to several advantages such as simple manual operation, robust instrument, affordable price and very common in customer's lab if compared with other type of viscosity meter. Furthermore, pH meter is used to check the pH (a measure for concentration of Acids and Bases) of the samples based on the principle of conductivity or electrolyte in solution. pH is parameters used to shows the level of acidity or alkalinity of a solution (Revansyah et al., 2023). This parameter provides information about the extent to which a solution is acidic or base. Furthermore, Oven is used to check the solid content in finished product and Microwave CEM Smart Turbo (which can deliver the result faster than Oven method) is used for in process samples (Bahar, 2019). Regarding the analyze phase as the third phase of DMAIC, the current reality tree is used to find the root cause of the problem. It is root cause identification and analysis tool from the theory of constraint. It is a tool for discovering the system's core driver which is also known as the constraint. Root causes are drown at the bottom and the symptoms at the top. Current Reality Trees are created using the entity classes in the built-in Effects-Based Planning domain, and primarily use the following classes: Un-Desirable Effect

(UDE), Precondition, and Intermediate Effect. Regarding the improve phase as the fourth phase of DMAIC, strategy to achieve the objective is to eliminate excessive existing manual tasks or processes with chosen tool that help company to reduce the waste (from sampling activities), which contribute to the company sustainability and less product loss (potential reduction of sampling activities) including man hour reduction during analyzing the data which have business value that contribute to the cost effective manufacturing process. The low cost or cost effective strategy is highlighted because cost-effectiveness is very important factor influencing Lean Six Sigma implementation in the company (Iyede, Fallon, & Donnellan, 2018). Regarding the control phase as the fifth of DMAIC phases, continuous efforts for sustaining the continuous improvement and the waste elimination program over the time must be ensured by several initiatives. Besides strong foundation which was provided by the ISO 9001:2015 system which has the ability to identify the process improvement, at the same time requires management's commitment in the control phase (Gupta, 2006) and has been implemented consistently, training on how to use the chosen tool for quality control supervisor including other quality control analysts and the development of procedure about the chosen tool as standardized documentation will help the users to be familiar with it.

DMAIC, RESULTS AND DISCUSSIONS DEFINE

In the define phase as first phase of DMAIC, high level process mapping is described through SIPOC

diagram (Suppliers, Inputs, Process, Outputs, and Customers - diagram)

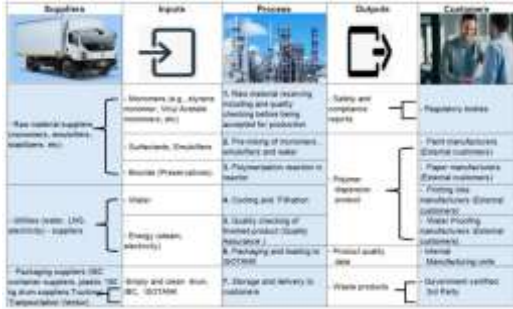


Figure 1. SIPOC Diagram

The focus in this study is in Quality Assurance Department point of view, especially in quality checking or quality control of finished products in laboratory including finished product quality data. Excessive manual repetitive tasks, possible human error, low morale including disengagement due to overload condition and lack of resources, including the weakness of evaluation process in the field of statistics are still a specter that blocks the door to improvement and entry to a higher level. To address the issue and from statistics and waste reduction point of view, three physical properties (namely pH, solid content, and viscosity) of ten finished product will be focused. Top ten finished products will be defined in order to represent and to cover the majority finished products that are produced in chemical manufacturing plant. The defined ten finished products are as follow: Product Q 62, Product S 29, Product F 55, Product G 86, Product P 70, Product EC 32, Product O 72, Product S 99, Product A 93, and Product D 03. Regarding sample amount, 293 final samples of Product Q 62 from period January 2024 until January 2025 will be used for evaluation, 311 final samples of Product S 29 from period January 2024 until January 2025 will be used for evaluation, 72 final samples of Product F 55 from period January 2024 until January 2025 will be used for

evaluation, 39 final samples of Product G 86 from period January 2024 until January 2025 will be used for evaluation, 137 final samples of Product P 70 from period January 2024 until February 2025 will be used for evaluation, 142 final samples of Product EC 32 from period January 2024 until January 2025 will be used for evaluation, 43 final samples of Product O 72 from period January 2024 until January 2025 will be used for evaluation, 116 final samples of Product S 99 from period January 2024 until January 2025 will be used for evaluation, 107 final samples of Product A 93 from period January 2024 until February 2025 will be used for evaluation, and 92 final samples of Product D 03 from period January 2024 until February 2025 will be used for evaluation. The statistical data analysis of above mentioned ten finished products will be conducted, evaluated and reported in form of capability analysis chart and control chart using automated SPC dashboard.

MEASURE

Regarding Service Level Contract (SLC) which was shaped by several insight from Voice of Customer activities, It is important that company has the ability to measure the parameters (measurable service performance targets) which had been agreed from both sides because it is impossible to manage properly by neglecting the measurement of agreed parameters (measurable service performance targets).

Table 1. Measurable service performance targets in SLC

| Measurable service performance targets | Metric | Target | Measurement Method |
|----------------------------------------|--------------------------------------------------------------------------------|----------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Lead Time | Delivery Lead time | ≤48 hours (local delivery) | Delivery tracking system |
| Price | Price Competitiveness | ± 7 % of market average | Market Price Analysis |
| Quality | Product quality meeting specifications | 100% | QC checking report including Certificate of Analysis which describes pH, Solid Content, and Viscosity of the delivered product |
| Service of Post Delivery | Customer Satisfaction score (integrated with sales forces in digital platform) | >95% satisfaction | Asking customer a single question in digital platform ("On a scale 0 to 10, How likely are you to recommend the service experience of our company to other friends?"), with following score definition (9-10: Loyal customers; 7-8: Satisfied but vulnerable to other competitive offerings; 6-6: Unhappy customers) |

In term of quality point of view, measuring three physical properties (namely pH, solid content, and viscosity) of ten finished needs robust QC instruments and analytical methods to ensure reliable result. For measurement of pH physical property for finished Product Q 62, pH meter is required and DIN ISO 976 method is used. For measurement of solid content physical property for finished Product Q 62, Oven is required and 1.5 gram sample with 140 degree Celsius for 30 minutes - method is used. For measurement of viscosity physical property for finished Product Q 62, RVT Brookfield viscosity meter is required and spindle 2 with 50 rpm at 23 degree Celsius - method is used. The result example of measurement in December 2024 can be seen in Table 2:

Table 2. Finished Product Q 62 measurement result example

| Date | Product Name | Lot No. Indication | pH Value | Solid Content in % | Viscosity mPas |
|------------|--------------|--------------------|----------|--------------------|----------------|
| 05/12/2024 | Product Q 62 | 77759877 | 8.46 | 29.96 | 52 |
| 09/12/2024 | Product Q 62 | 77766138 | 8.17 | 29.56 | 52 |
| 12/12/2024 | Product Q 62 | 77795448 | 8.30 | 29.93 | 54 |
| 16/12/2024 | Product Q 62 | 77795449 | 8.26 | 30.39 | 48 |
| 16/12/2024 | Product Q 62 | 77700808 | 8.40 | 29.61 | 48 |
| 16/12/2024 | Product Q 62 | 88806244 | 8.99 | 31.62 | 58 |
| 16/12/2024 | Product Q 62 | 88806243 | 8.61 | 31.94 | 64 |
| 16/12/2024 | Product Q 62 | 88806242 | 8.42 | 31.19 | 67 |
| 18/12/2024 | Product Q 62 | 88812055 | 8.45 | 29.68 | 68 |
| 18/12/2024 | Product Q 62 | 88812054 | 8.53 | 30.38 | 50 |
| 18/12/2024 | Product Q 62 | 88812053 | 8.58 | 31.88 | 64 |
| 18/12/2024 | Product Q 62 | 88806245 | 8.51 | 31.41 | 50 |
| 19/12/2024 | Product Q 62 | 77700811 | 8.44 | 30.54 | 40 |
| 19/12/2024 | Product Q 62 | 77700809 | 8.39 | 30.72 | 40 |
| 21/12/2024 | Product Q 62 | 78718942 | 8.50 | 29.99 | 48 |
| 23/12/2024 | Product Q 62 | 77751035 | 8.48 | 29.82 | 47 |
| 23/12/2024 | Product Q 62 | 77751034 | 8.42 | 29.72 | 42 |
| 29/12/2024 | Product Q 62 | 78751070 | 8.42 | 30.12 | 48 |
| 29/12/2024 | Product Q 62 | 78718947 | 8.40 | 29.87 | 48 |

ANALYSE

The Current Reality Tree (CRT), which is based on sufficient cause thinking and uses bottom to top orientation, is used to conduct the cause and effect analysis so that the root cause of the problem called as core driver or constraint can be found. The increment of out of specification rate if compared with previous year has impact on company profitability through loss of competition and less competitive advantage. Furthermore, The increment of customer complaints if compared with previous year has impact on the high cost of non conformity which later reduced the company profitability. The low profit is triggered by either high cost of non conformity or less revenue. The less revenue is caused by less sales due to loss of competition in the market. The loss of competition is triggered by the combination of less of competitive advantage and red ocean, which is outside company control. The less of competitive advantage, which is inside company control, is triggered by the increment of quality problem. The increment of quality problem, which has impact on the increment of justified customer complaints also, is triggered by either quality inconsistency or increment of out of specification products. At the same time, besides customer complaints, high cost of non conformity is caused by the increment of quality problem also. The increment of out of specification products is triggered by either the degradation of raw material quality or human error. The degradation of raw material quality is caused by the combination of lack of monitoring- analysis- evaluation and not reliable suppliers, which is outside company control. The lack of monitoring- analysis- evaluation is then triggered by the weak evaluation in the field of statistic, which is caused by the

combination of of excessive manual tasks and lack of training- mentoring. Human error, which has impact on the increment of out of specification products, is triggered by either lack of skill- knowledge due to lack of training- mentoring or low moral- disengagement. The low moral- disengagement is ignited by overload working condition. Furthermore, the overload working condition is caused by the combination of excessive manual tasks and limited resources, which is outside employees control. In other words, the root cause of increment of out of specification products are excessive manual tasks and lack of training and mentoring also through human error, lack of skills- knowledge or low morale- disengagement, overload condition. The quality inconsistency is triggered by the lack of process improvement. The lack of process improvement, which has impact on the quality inconsistency, is triggered by the lack of monitoring- analysis- evaluation. The weak evaluation in the field of statistic, which was triggered by the combination of excessive manual tasks and lack of training- mentoring, has impact on the lack of monitoring- analysis- evaluation. In other words, the root cause of quality inconsistency are excessive manual tasks and lack of training and mentoring through lack of process improvement, lack of monitoring analysis- evaluation and weak evaluation in the field of statistics. The presence of core driver lack of training and mentoring for personal and professional growth, shows that the root causes of the problem is not only in the realm of operations only but also in the realm of human resource especially for the new joiners and young employees . This is also reinforced by the observation results that big knowledge gap is still available between retired

employees and new young successors although there is already standardized training procedure which cover several employee development systems such as orientation training system, job specific training system and regular training system. Furthermore, this observation result is inseparable from the consequence of recent retirement wave and organizational change reality that happened in recent years. From human resource point of view, lack of training and mentoring as core driver or constraint results the realm of operations intersects with the the realm of human resource.

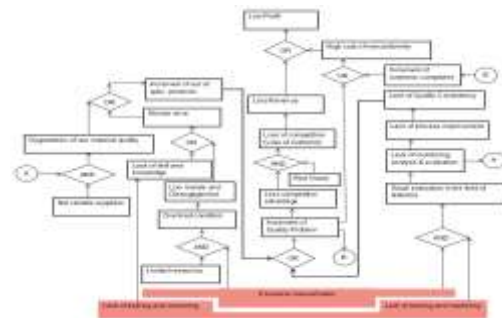


Figure 2. Flowchart of Analysis

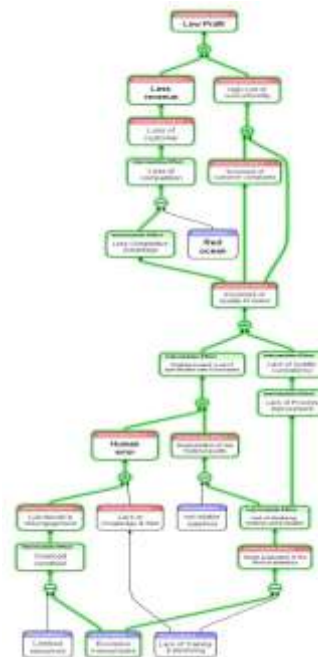


Figure 3. Current Reality Tree of Flying Logic to find the constraints

Besides training and mentoring plan and program as solution from human resource point of view, one best alternative solution out of three different alternative solutions for eliminating the core driver “excessive manual tasks” was chosen by applying Analytic Hierarchy Process (AHP) approach, which has 3 levels, in decision analysis. First level is the goal itself to find one best alternative solution. The second level is criteria and there are 4 criteria: High degree of customization (or adaptability), Easy to be maintained, High degree of deployment, and Affordable cost. The third level is alternatives and there are three different alternative solutions: adding the amount permanent employees to strengthen the Quality Control laboratory team as first alternative solution, upgrading the Quality Control Laboratory instrumentation / equipment with robotic system integration as second alternative solution, developing in-house automation in form of automated SPC dashboard in order to reduce manual tasks including existing workload, without sacrificing the quality as third alternative solution. Normalized matrix of pairwise comparison matrix was established after creation of the pairwise comparison matrix among four criteria and before the calculation of Eigenvector (priority weights) and consistency check in Analytic Hierarchy Process. The judgment was consistent because consistency ratio was smaller or equal to 0.1. The calculated Consistency Index was zero and the calculated Consistency Ratio was zero. Furthermore, After value assignment for alternatives, weighted aggregated benefit for each alternative was calculated. The weighted aggregated benefit of

alternative one is 4.5, the weighted aggregated benefit of alternative two is 4.6 and the weighted aggregated benefit of alternative three is 8.7. After comparing the result of weighted aggregated benefit for each alternative, it was found that alternative three (which is developing in-house automation in form of automated SPC dashboard in order to reduce manual tasks including existing workload, without sacrificing the quality), is rank one because it has the highest aggregate score.

Table 3. Weighted aggregated scores - calculation in AHP

| Criteria \ Alternative | Alternative 1 | Alternative 2 | Alternative 3 |
|------------------------------------------------|---------------------------------------|----------------------------------------------|----------------------------------|
| | Additional FTEs (Permanent employees) | Robotic system integrated into QC laboratory | In-House digital automation tool |
| High degree of customization (or adaptability) | 1.95 | 2.85 | 2.55 |
| Easy to be maintained | 1.20 | 0.38 | 1.05 |
| High degree of deployment | 0.30 | 1.00 | 1.60 |
| Affordable cost | 1.05 | 0.35 | 3.50 |
| SUM | 4.5 | 4.6 | 8.7 |
| RANK | 3.0 | 2.0 | 1.0 |

IMPROVE

In order eliminate the repetitive manual tasks, automation in form of automated SPC dashboard is developed. This dashboard is supported by program codes using visual basic for application language to eliminate several repetitive manual tasks by enabling several automation activities. Regarding automation of data cleaning, after analysis activity and evaluation, the user can clean or delete the data from Excel worksheet “DATA” automatically by clicking the “cleaning area” button using Visual Basic for Application program codes. 22 columns and 92 rows data can be cleaned or deleted

automatically within several seconds (<10s) using Processor 11th Gen intel@Core™ i5 @2,60GHz 2,61GHz and 16GB RAM.

Regarding automation of product data transfer, in order to transfer the raw product data automatically by operating the automated SPC dashboard correctly, First... data of certain product that need to be evaluated will be imported from SAP - ERP system to excel file (in this case, it is called “product excel file”) by clicking the excel button, checking “specification” in options windows, choose “table” in export list object to XXL - window and clicking button when “microsoft excel” pops up in export list object to XXL - window.



Figure 4. Import of certain product data from SAP

Regarding automation of data selection, after transferring data to automated SPC dashboard by clicking the ‘DATA TO BE EVALUATED’ button and before getting the SQC result automatically, the user need to let this cost effective in-house digital automation tool... filter, select, calculate and transfer all SQC result data including their specification into respective parameter worksheet of automated SPC dashboard by clicking the ‘run controller’ button. The ‘run controller’ button is available in main worksheet “DATA” of automated SPC dashboard.



Figure 5. Automated SPC Dashboard

Regarding automation result, the calculation results of Statistical Quality Control including their charts are available in each parameter worksheet of automated SPC dashboard. The user can see the SQC calculation result of pH in the worksheet “pH”.

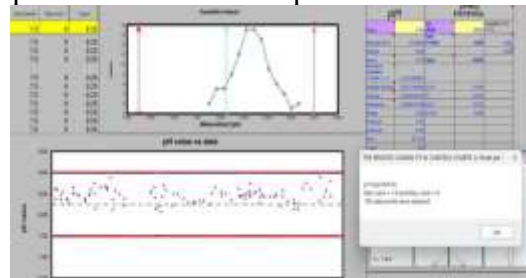


Figure 6. SQC result in automated SPC Dashboard

CONTROL

Regarding Process capability index - control, using automated SPC dashboard, The statistical process control of Several finished products are performed, evaluated and reported in form of capability analysis chart and control chart using automated SPC dashboard. The first product, called Product Q 62 whose 293 final samples from Jan. 2024 until Jan. 2025 were analyzed. The second product, called Product S 29, whose 311 final samples from Jan. 2024 until Jan. 2025 were analyzed. The third product, called Product F 55, whose 72 final samples from Jan. 2024 until Jan. 2025 were analyzed. The fourth product, called Product G 86, whose 39 final samples from Jan. 2024 until Jan. 2025 were analyzed. The fifth product, called Product P 70, whose 137 final samples from Jan. 2024 until Feb.2025 were analyzed. The sixth product, called

Product EC 32, whose 142 final samples from Jan. 2024 until Jan. 2025 were analyzed. The seventh product, called Product O 72, whose 43 final samples from Jan. 2024 until Jan. 2025 were analyzed. The eighth product, called Product S 99, whose 116 final samples from Jan. 2024 until Jan. 2025 were analyzed. The ninth product, called Product A 93, whose 107 final samples from Jan. 2024 until Feb. 2025 were analyzed. The tenth product, called Product D 03, whose 92 final samples from Jan. 2024 until Feb. 2025 were analyzed. Regarding Product Q 62, In term of pH physical property, the Cp of product Q 62 is 1,22 and the Cpk of product Q 62 is 0,816. Cp of pH physical property 1,22 which is > 1 , means that the production process can control the pH within the specification range before delivery to customer through out the year, although further optimization still can be done in order to shift up the trend slightly to the middle target of pH specification due to slightly low Cpk, namely 0,816 which is < 1 . The positive skewness value 1,15 is validated with pH capability analysis chart in Figure IV.5.1 that the tail on the right side is longer or fatter than the one left side. In other words, the data is gathered on the left (low value) and the mean value is slightly bigger than the median value. The kurtosis 3,09 which is > 3 is validated with pH capability analysis chart with longer distribution, higher and sharper peaks. In term of solid content physical property, the Cp of product Q 62 is 0,736 which is < 1 and the Cpk of product Q 62 is 0,646 which is < 1 also. Cp of solid content physical property is 0,736 means that the production process can not fully control the solid content physical property within the specification range before delivery to customer through out the year. The

reason of slightly low Cp & Cpk of solid content physical property is higher solid content value starting December 2024 until beginning of year 2025. Solid content of several samples during that period were higher than maximum limit of Solid content specification. The positive skewness value 2,13 is validated with solid content capability analysis chart in Figure IV.5.1. that the tail on the right side is longer or fatter than the one left side. In other words, the data is gathered on the left (low value) and the mean value is slightly bigger than the median value. The kurtosis 6,28 which is > 3 is validated with solid content capability analysis chart with longer distribution, higher and sharper peaks. In term of viscosity physical property, the Cp of product Q 62 is 4,432 which is > 1 significantly and the Cpk of product Q 62 is 1,241 which is > 1 also. Cp of viscosity physical property is 4,432 means that the production process has the ability to control fully the viscosity physical property within the specification range before delivery to customer through out the year. The positive skewness value 8,28 is validated with viscosity capability analysis chart that the tail on the right side is longer or fatter than the one left side. In other words, the data is gathered on the left (low value) and the mean value is bigger than the median value. The kurtosis 103,1 which is > 3 , is validated with viscosity capability analysis chart with longer distribution, higher and sharper peaks.

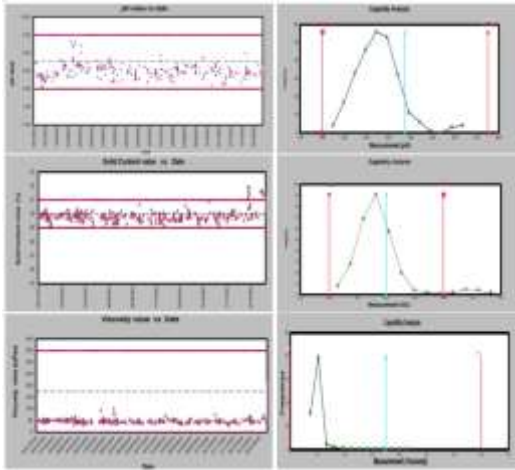


Figure 7. pH, solZid content and viscosity - charts of “Product Q 62”

By implementing the automation SPC dashboard, several improvements which led to cost reduction were observed and confirmed if compared with previous condition. The average working hours of SPC activities for 1 final finished product can be reduced from 120 minutes into 5 minutes. Human error possibility such as in correct data input including incorrect formula and incorrect calculation can be eliminated. All essential statistic data result provided automatically (in previous condition, several statistic data has never been calculated such as std error, sample variance, skewness, etc). SQC chart for each parameter is created automatically instead of manually including min. & max. Limits. Process capability analysis chart is created automatically (in previous condition, process capability analysis chart has never been made and analyzed). There is enhancement of monitoring ability, where indication and trends which lead to quality problem are easily detected (in previous condition, indication and trends which lead to quality problem are hidden).

Furthermore, based on statistical data analysis and evaluation of Product Q 62, elimination of finished product sampling for Viscosity checking in

Product Q 62 is possible to avoid non adding value activities or excessive manual works from over checking due to very good number or very high number of Cp 4.43 and Cpk 1.24. Based on statistical data analysis and evaluation of Product S 29, elimination of finished product sampling for pH checking in Product S 29 is possible to avoid non adding value activities or excessive manual works from over checking due to very good number or very high number of Cp 1.97 and Cpk 1.38. Based on statistical data analysis and evaluation of Product F 55, elimination of finished product sampling for Viscosity checking in Product F 55 is possible to avoid non adding value activities or excessive manual works from over checking due to very good number or very high number of Cp 1.51 and Cpk 1.17. Based on statistical data analysis and evaluation of Product P 70, elimination of finished product sampling for pH checking in Product P 70, is possible to avoid non adding value activities or excessive manual works from over checking due to very good number or very high number of Cp 1.52 and Cpk 1.33. Based on statistical data analysis and evaluation of Product EC 32, elimination of finished product sampling for pH checking in Product EC 32, is possible to avoid non adding value activities or excessive manual works from

over checking due to very good number or very high number of Cp 1.80 and Cpk 1.32. Based on

statistical data analysis and evaluation of Product O 72, elimination of finished product sampling for viscosity checking in Product O 72, is possible to avoid non adding value activities or excessive manual works from over checking due to very good number or very high number of Cp 2.41

and Cpk 1.21. Based on statistical data analysis and evaluation of Product S 99, elimination of finished product

sampling for pH checking in Product S 99 is possible to avoid non adding value activities or excessive manual works from over checking due to very good number or very high number of Cp 1.70 and Cpk 1.30. Based on statistical data analysis and evaluation of Product A 93, elimination of finished product sampling for pH checking in Product A 93 is possible to avoid non adding value activities or excessive manual works from over checking due to very good number or very high number of Cp 1.79 and Cpk 1.73. Based on statistical data analysis and evaluation of Product D 03, elimination of finished product sampling for Viscosity checking in Product D 03 is possible to avoid non adding value activities or excessive manual works from over checking due to very good number or very high number of Cp 5.56 and Cpk 2.95. With the fact, that the plant operator always send 1 kg sample to QC laboratory for the purpose of checking the parameter of physical property and after that the rest will be disposed to the government certified waste company after being collected and stored in temporary waste storage, it means that in a year, around 293 kg of in process sample of Product Q 62 for Viscosity checking purpose can be spared which equals to USD586, around 311 kg of in process sample of Product S 29 for pH checking purpose can be spared which equals to USD 622, around 72 kg of in process sample of Product F 55 for Viscosity checking purpose can be spared which equals to USD 144, around 137 kg of in process sample of Product P 70, for pH checking purpose can be spared which equals to USD 274, around 142 kg of in process sample of Product EC 32, for

pH checking purpose can be spared which equals to USD 284, around 43 kg of in process sample of Product O 72, for viscosity checking purpose can be spared which equals to USD 86, around 116 kg of in process sample of Product S 99 for pH checking purpose can be spared which equals to USD 232, around 107 kg of in process sample of Product A 93 for pH checking purpose can be spared which equals to USD 214, and around 92 kg of in process sample of Product D 03 for Viscosity checking purpose can be spared which equals to USD 184.



Figure 8. Result comparison between MATLAB and automated SPC Dashboard

Table 4. Benefits of waste reduction initiatives (per year)

| No | Waste reduction initiatives | Amount in unit | Cost per unit | Potential benefit |
|-------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------|-----------------------------------------------------|-----------------------------------------------------------------------------------|
| 1 | Less waste water treatment cost (for every parameter checking in QC laboratory, around 3 liter of waste water is needed for cleaning the buffer glass, pH electrodes, spoons of viscosity meter) | 6.6 ton | IDR 82 000,-/ton | IDR 541 227,- |
| 2 | Less waste disposal cost through government certified waste company (around 133 kg = 20 kg + 101 kg + 72 kg + 117 kg + 242 kg + 40 kg + 148 kg + 197 kg + 92 kg) | 1333 kg | IDR 1800,- /kg | IDR 2 363 400,- |
| 3 | Less finished product loss through eliminating over sampling & over checking activities (around 293 kg = 113 kg + 72 kg + 117 kg + 142 kg + 40 kg + 116 kg + 197 kg + 92 kg) | 1313 kg | USD 2,- /kg | USD 2626,- (With Exchange rate 1 USD = from IDR 16 692,- until IDR 16 688,3,-) |
| 4 | Time saving by using automated SPC dashboard around 100 times for statistical data analysis - activities | 192 hrs | IDR 78 125,-/hr | IDR 15 000 000,- |
| 5 | Time saving (Less analytical work) | 219 hrs | IDR 78 125,-/hr | IDR 17 109 375,- |
| 6 | Unnecessary MATLAB / Minitab license cost (replaced by in-house automated SPC dashboard) | 2 users per site | IDR 34 650 000,- for Minitab 21 per user & per year | IDR 69 300 000,- |
| TOTAL POTENTIAL BENEFIT, PER YEAR (FOR 1 SITE) | | | | IDR 148 154 872,- |
| TOTAL POTENTIAL BENEFIT, PER YEAR (FOR 3 MANUFACTURING SITES IN THE SAME COUNTRY) | | | | IDR 444 464 616,- |

CONCLUSION AND SUGGESTION

Expressing the war against waste to address research question number one, excessive manual tasks and lack of training & mentoring as root causes of the existing barriers that hold the system from improving, were found by conducting the cause and effect analysis using Current Reality Tree approach. The best alternative solution among three alternative solutions for eliminating the constraint is chosen based on Analytic Hierarchy Process decision making approach by considering hierarchical structure, pairwise comparison, weighting, prioritization and consistency checks. Furthermore, to realize the chosen best alternative solution, automated SPC dashboard (new in house developed automation software) as part of improved quality management system is manifested.

Addressing research question number two and after implementing the tailor made and in-house new developed automation software, which is called “automated SPC dashboard” as part of improved quality management system, waste reduction is achieved by optimizing the process, shortening the working hours of SPC activities, eliminating possible human error cases, fast and automatic visualization of control chart and process capability charts. The process optimization in term of eliminating or reducing excessive manual tasks by using in-house developed automated SPC dashboard, does not only increase employees or stakeholders satisfaction but also triggers the increment of employee engagement and opens the door for improving the quality management system. With all above mentioned features and improvements, the ability of product quality monitoring is improved significantly. Therefore, the

door for early detection of indications which lead to quality problem and deviate from normal trends, is widely open. It means also that potential out of specification cases or quality problems can be anticipated earlier and even avoided so that non conformity cost can be reduced over the time. 50% reduction of nonconformity, which contributes to around EUR 55 000,- or IDR 1 052 150 000,- cost reduction is estimated after 1 year implementation with exchange rate of 1 EUR is IDR 19 130,-. Further waste reduction amounted IDR 444 464 616,- per year is achieved by less waste water treatment cost, less waste disposal cost through government certified waste company, less finished product loss through eliminating over sampling & over checking activities, less time needed for statistical data analysis - activities by using automated SPC dashboard, less analytical works, eliminating unnecessary license cost of powerful tool for data analysis such as MATLAB or Minitab, in three local manufacturing sites.

To address research question number three, the development of in-house automated SPC dashboard is manifested by combining the automation initiative with the statistical process control initiative and utilizing the synergy of both initiatives after gathering requirements and stakeholders needs. In term of automation initiative, several automation features such as automatic cleaning the sheet from the previous data, automatic transfer of relevant raw data to dashboard from Excel product data after importing or downloading from SAP database, automatic calculation and automatic visualization of result and chart were developed using visual basic for application program codes and activated by clicking the macro button provided in the dashboard. Each automation

feature has each visual basic for application program codes - group. In term of statistical process control initiative, the accuracy of the calculation was calibrated and validated using MATLAB which is known as powerful tool for data analysis. The calibration result showed that mean, standard deviation, Cp and Cpk values from in-house developed automated SPC dashboard are the same with calculated mean, standard deviation, Cp and Cpk values from MATLAB. In other words, the result delivered by in-house developed automated SPC dashboard is accurate and valid.

Regarding suggestion, in order to have sustainable quality improvements, periodic evaluation meeting of SPC result need to be scheduled with committed relevant participants such as Process engineer, Quality Assurance team representative and production team representative. The commitment can be achieved by putting proposed periodic evaluation meeting of SPC result into the quality management plant procedure as new additional official meeting on top o of existing weekly Production Quality Meeting. The recommended frequency of the meeting can be monthly or biweekly, depends on the agreement of the stakeholders. Well trained team is important to analyze the statistical data and result correctly. Therefore training session of process engineer and production representative on top of quality department representative is necessary.

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