FINAL PROJECT – TI 184833

# SUPPLIER RELATIONSHIP MANAGEMENT USING QUALITY BASED DATA ANALYTICS (CASE STUDY: PT. X)

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**APPROVAL SHEET**

**SUPPLIER RELATIONSHIP MANAGEMENT USING QUALITY BASED DATA ANALYTICS (CASE STUDY: PT. X)**

**FINAL PROJECT**

Submitted as a Requisite to Achieve a Bachelor Degree from
Department of Industrial and System Engineering
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Surabaya, August 2020

**SUPPLIER RELATIONSHIP MANAGEMENT USING QUALITY BASED DATA ANALYTICS (CASE STUDY: PT. X)**


| | |
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# ABSTRACT


PT. X is a branch of a global manufacturing company who focused on producing the component, equipment, and system for automation. Recently, there are 62 suppliers take as big as 70% portion of all parts. Meaning that the quality of company's product mainly derived by the quality of supplier's parts. Therefore, the company manage their suppliers through Supplier Relationship Management (SRM) activities. The suppliers are clustered using grade of supplier performance, which is the result of monthly evaluation. However, the current response from performance evaluation is not triggered by the performance grade. There is also a problem in their grading process. The supplier data within their database also not being considered optimally. Hence, this research aims to support PT. X SRM using data analytic. The data analytic uses K-Means Clustering technique resulting 3 optimal supplier clusters. The formation of these three clusters is due to the similarity of data. Therefore, each of the clusters has their own prominent characteristics that differentiate one another. The cluster characteristics and the lack on company current response are the consideration in the construction of supplier development program. This research provide supplier development program which considers that two factors. The programs are divided into basic supplier development programs for all suppliers and programs focused for the main characteristics of the cluster.



**Keywords:** Data Analytic, K-Means Clustering, Supplier Relationship Management (SRM)

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The author realizes that this research still has gap for further improvement. Therefore, constructive criticisms and suggestions are welcomed. Hopefully this research will be useful for all parties: academics, practical needs and the author herself. Thank you.

Surabaya, July 2020

Author

# TABLE OF CONTENTS

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# LIST OF FIGURES

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# LIST OF TABLES

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# CHAPTER 1
# PREFACE

This chapter explains the background in doing research, the problem formulation, the objectives and benefits of the research, scope of the report, and the report writing scope.

## 1.1. Background

PT. X is a branch of a global manufacturing company who focused on producing the component, equipment, and system for automation. The company has three types of product i.e. Relay (RY), Switch (SW) and Industrial Automation Business (IAB). Main processes are assembling parts coming from suppliers or produced internally by the company's Part Manufacturing Function. The supplier's contribution takes as big as 70% portion of all parts. Therefore, the quality of company's product mainly derived by the quality of supplier's parts.

Recently, there are 62 suppliers located within the country and abroad. The relationship between the company and suppliers are shown in series of activities from selection to development. There are several steps need to follow for candidate suppliers to join i.e. preparation stage, sample creation, and sample evaluation. Once passed all these steps, the candidate supplier allowed to do mass production according to the order quantity. The suppliers managed by the company through continuously/periodically trained, inspected and evaluated. The evaluation is an important action to examine the performance of the suppliers. All of these activities are applied to all suppliers.

Supplier evaluation is done every month with performance target 99.5% (IQC, 2020). The criteria of performance evaluation include incoming rejection, in-process rejection, special used parts, received lot and demerit of the non-responded claim. Recent performance varies amongst suppliers. The company tried to cluster suppliers based on their performance under a specific range as shown in table 1-1.

**Table 1-1. Grade of Supplier Performance**

| Grade | Range Value of Performance |
|---|---|
| A | 100 to 99.50 |
| B | 99.49 to 98.50 |
| C | 98.49 to 96.00 |
| D | 95.99 to 90.00 |
| E | 89.99 or less |

**(Source: PT. X Supplier Performance Report)**

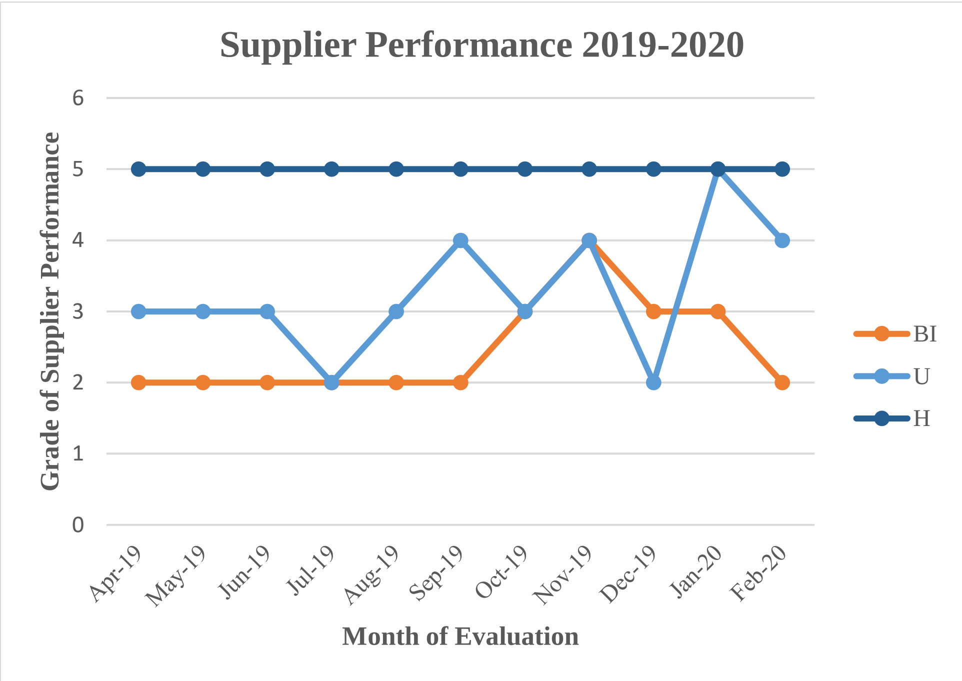


**Figure 1-1. Supplier Performance 2019-2020**
**(Source: PT. X Supplier Performance Report)**

Figure 1-1 shows the result of supplier evaluation from April 2019 to February 2020 for supplier BI, U and H. The value of supplier performance is graded into A-E. The grade of suppliers is transformed into numerical data to ease the visualization. Grade A represented by 5, grade B represented by 4, and so on. The performance grade of several suppliers may change as depicted in Figure 1-1. It also shows that not all suppliers reach the company target of performance. Based on the observation, this causes delay of parts that are going to be sent to the production line.

**Table 1-2. Comparison of Supplier BE and BH Performance in February 2020**

| Supplier Name | Lot Inspected | NRS A | NRS B | NRS C | QCI A | QCI B | QCI C | SAR | Demerit | Grade |
|---|---|---|---|---|---|---|---|---|---|---|
| **BE** | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.03 | C |
| **BH** | 2517 | 0 | 0 | 0 | 3 | 11 | 17 | 0 | 0 | C |

**(Source: PT. X Supplier Performance Report)**

In the other side, the detail of supplier performance evaluation shown in Table 1-2 comparing supplier BE and BH. As mentioned before, the supplier performance has 5 criteria. It can be seen through Table 1-2, that both supplier BE and BH has difference in number of lot inspected, QCI, and demerit. However, in the supplier performance report, both of them are graded C. Because the company will response them in the same way, it will be ineffective. With these differences, the grade of both suppliers should be different.

The current response from performance evaluation is not triggered by the performance grade. The response is mainly driven by the major problem found. For instance, if the supplier experienced subsequent defects, the company staff may visit the supplier to guide the supplier to conduct corrective actions. Moreover, the company also developed general training for all supplier e.g. Quality Management System (QMS) and Chemical Management System (CMS) training modules. Even though they have lot of supplier data within their database, they do not use it optimally. Therefore, to get the appropriate basis of response, the supplier data can be analyzed using data analytic.

By using data analytic, the company can draw inferences based on data owned, then making predictions to enable innovation and help strategic decision-making (Gudivada, 2017). The data analytic task that will be done in the research is clustering. Clustering is the process of data mining that divide the data into classes which the class form themselves from the patterns and characteristics of the datasets (Santosa & Umam, 2018). Clustering will help to group suppliers based on the same characteristics.

The clustering method that will be used to segment PT. X suppliers is K-Means Clustering. K-means clustering method is a technique of clustering which group data into k clusters (Santosa & Umam, 2018). This method is used because it is easy to interpret, implement, also can adapt to scattered data (Nabilah, 2017). After the clustering process produces optimal cluster of PT. X suppliers, they will be analyzed. The analysis aims to support the Supplier Relationship Management (SRM) within the company.

Supplier Relationship Management (SRM) is the process of engaging in activities of setting up, developing, stabilizing and dissolving relationships with in-suppliers as well as the observation of out-suppliers to create and enhance value within relationships (Moeller, et al., 2006). According to (Dickson, 1966), quality has the highest score in the supplier selection criteria. Since supplier selection criteria is related to the supplier assessment and development process (Suraraksa & Shin, 2019), therefore this research will focus on highest criteria which is quality of suppliers. In the presence of data analytic, it is expected that PT.X will consider the quality characteristics of their suppliers in their SRM. More precisely, on how they develop their suppliers based on the quality characteristics in each clusters of suppliers. As stated in (Sillanpaa, et al., 2015), supplier development can help the company to increase the supplier capabilities gradually for further improvement.

Research on supplier clustering using data mining techniques, has been carried out by several researchers. One of the research is done by (Nabilah, 2017). The aim of the research is to cluster PTPN X PG Meritjan‘s suppliers with its dynamic behavior. It results three clusters of suppliers and internet-based visualization. Another research about supplier clustering is done by (Haghighi, et al., 2014) which uses Fuzzy C-Means clustering which compares each supplier’s criterion value with exactly same criterion of other suppliers. It result an enhanced quality of results compared to another research’s findings. There are also previous research that discuss about supplier development, such as (Chavhan, et al., 2012) and (Sillanpaa, et al., 2015). These research main objectives are to explore the supplier development concept in empirical case studies. Through the researches known that supplier development increase the company competitive advantage through improving supplier factors within the supplier development programs.

This research aims to support the Supplier Relationship Management (SRM) of PT. X based on the result of data analytic. The data analytic will help to cluster PT. X suppliers, and analyze the characteristics of each clusters. The analysis will be use as the basis consideration of activities within the SRM. It is expected that the company can manage their suppliers despite the dynamic behavior of them.

## 1.2. Problem Formulation

Based on the research background, the problem that will be discussed is to cluster PT. X suppliers using data analytic in which the analysis will be used to support their SRM activities.

## 1.3. Research Objective

The objectives in doing this research are:

1. Identify PT. X supplier performance criteria to get the attributes of supplier clusters.
2. Cluster PT.X suppliers based on data characteristics.
3. Identify the characteristics of each clusters of PT. X suppliers.
4. Develop appropriate supplier development program for each cluster based on their characteristics.

## 1.4. Research Benefit

The benefits that will be gained through this research are:

1. The clusters of PT.X suppliers can be the basis of development activities so it will be more appropriate.
2. PT. X will increase their supplier performance.
3. The Supplier Relationship Management (SRM) considering data analytic can be the new concept for PT. X to review their activities using factors that previously not considered.

## 1.5. Research Scope

The scope of the research consists of some limitation and assumption as shown below.

### *1.5.1. Limitation*

- Data used are secondary data from April 2019 to February 2020.

- In the integration of Supplier Relationship Management (SRM) activities, this research focused on supplier assessment and development.
- There is no prediction of supplier performance value as the result of data analytics.
- There is no determination of minimum value to determine whether suppliers continue to work with the company or not.
- Supplier assessment only consider quality criteria in company perspectives, not operational (flexibility, lead-time, etc.)

*1.5.2. Assumption*

- There is no change in company policy regarding suppliers during data collection.

## 1.6. Report Writing Scope

Below is the explanation of the outline of the research report:

CHAPTER I – PREFACE

This chapter explains the background in doing research, the problem formulation, the objectives and benefits of the research, scope of the report, and the report writing scope.

CHAPTER II – LITERATURE REVIEW

This chapter explains theories and methods that will be used in doing the research. The theories and methods are compiled from relevant resources.

CHAPTER III – RESEARCH METHODOLOGY

This chapter explains the workflow of the research, begins from evaluation, data analytic process, analyzing the results of data analytic, until developing supplier treatment program.

CHAPTER IV – IDENTIFICATION OF SUPPLIER PERFORMANCE CRITERIA

This chapter explains the identification of supplier performance criteria in details. Begin with current evaluation method explanation, identification of supplier performance criteria, and lastly recapitulation of supplier clusters determination attributes. These steps are the results of discussion with company representatives.

CHAPTER V – PT. X SUPPLIER CLUSTER DETERMINATION

This chapter explains the step in determining PT. X supplier clusters. The step follows CRISP-DM (Cross Industry Standard Process for Data Mining) approach, which consists of business understanding, data understanding, data preparation, modelling, evaluation, and deployment.

CHAPTER VI – SUPPLIER DEVELOPMENT PROGRAM CONSTRUCTION

This chapter explains how the supplier development program is constructed. Begins with analyze current response of company towards supplier's performance. After that, examine the supplier cluster that is resulted from previous chapter. Then, construct the supplier development program based on the current response and cluster.

CHAPTER VII – CONCLUSION AND SUGGESTION

This chapter explains the conclusion and suggestion of this research. The conclusion will explain how the objectives reached through this research. Also, the suggestion will be given for future research.

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# CHAPTER 2
# LITERATURE REVIEW

This chapter explains theories and methods that will be used in doing the research. The theories and methods are compiled from relevant resources.

## 2.1. Quality

Quality is defined as fitness for use, also inversely proportional to variability (Montgomery, 2013). It can be considered as a multi dimensional philosophy that being multi-dimensional. Quality can affect a firm's competitiveness due to their capability in fulfilling the quality of customer perspectives. Quality in the customer perspectives can be translated into quality dimensions. According to (Montgomery, 2013) there are eight dimensions of quality in general and three quality dimensions for service industry. These dimensions can be seen in the able 2.1 and 2.2.

**Table 2-1. General Quality Dimensions**

| Quality Dimension | Description |
|---|---|
| Performance | Will they do the intended job? |
| Reliability | How often does the product fail? |
| Durability | How long does the product last? |
| Serviceability | How easy is it to repair the product? |
| Aesthetics | What does the product look like? |
| Features | What does the product do? |
| Perceived Quality | What is the reputation of the company or its product? |
| Conformance to Standards | Is the product made exactly as the designer intended? |

**(source: (Montgomery, 2013))**

**Table 2-2. Quality Dimensions for Service**

| Quality Dimension | Description |
|---|---|
| Responsiveness | How promptly was your request handled? |
| Professionalism | How is the skill, knowledge and competency of them to provide required service? |
| Attentiveness | How does the service provider pay attention to their customer? |

**(source: (Montgomery, 2013))**

## 2.2. Supplier Relationship Management (SRM)

In supply chain, a company deals with many parties, one of them is supplier. Supplier is a company that supplies part that cannot be produce by the buyer-company. These days, people's awareness began to change regarding efficiency and value creation. Because this is not only happening on the production line, but also in other function, one of them is procurement. Therefore, for the future, suppliers will be more considered by procurement so they can innovate and add value to the company. In addition, 40%-70% cost of the final product is the cost of purchasing materials which involves suppliers (Pujawan & ER, 2010). Hence, with suppliers who work efficiently, it is expected to increase company profits.

Because of supplier is an important part of the company, therefore it needs to create proportional relationship towards the suppliers. Suppliers come with different characteristics, such as they only supply a few items with a value of hundreds of thousands rupiah per year, or supply hundreds or even thousands of items with a transaction value of billions rupiah in a year. With these imbalances, it is better to provide different relationship from one supplier to another.

Supplier Relationship Management (SRM) is the process of engaging in activities of setting up, developing, stabilizing and dissolving relationships with in-suppliers as well as the observation of out-suppliers to create and enhance value within relationships (Moeller, et al., 2006). Based on the research of (Jongkyung, et al., 2010), an integrative SRM framework is made so that the supply chain management perform successfully. The suppliers should be selected based on their purchasing strategy, after that their performance will be evaluated. The result of evaluation will be the input of the development stage. Then, the continuous improvement is implemented. The SRM framework shown in figure 2.1.

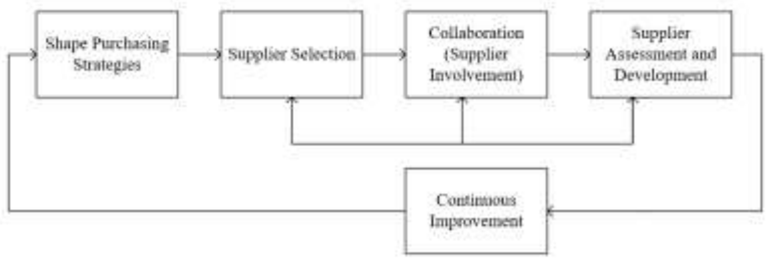


**Figure 2-1. Integrative Framework of Supplier Relationship Management (SRM)**
(source: **(Jongkyung, et al., 2010)**)

*2.2.1. Shape Purchasing Strategies*

In order to select the appropriate supplier for the company, there are several steps to do (Suraraksa & Shin, 2019). First, identify the company needs and specification. Second, the criteria of suppliers are formulated. Third, decision makers identify a group of qualified suppliers. Finally, the evaluation and final selection are performed. Expert discussion is needed to decide criteria involved in the selection process. Based on (Suraraksa & Shin, 2019) table 2.3 shows the general criteria of supplier selection.

**Table 2-3. Supplier Selection Criteria**

| Criteria | Score | Criteria | Score |
|---|---|---|---|
| Quality | 3.5 | Management and Organization | 2.3 |
| Delivery | 3.4 | Operating Controls | 2.2 |
| Performance History | 3.0 | Repair Service | 2.2 |
| Warranties and Claim Policies | 2.8 | Attitudes | 2.1 |
| Price | 2.8 | Impression | 2.1 |
| Technical Capability | 2.8 | Packaging Ability | 2.0 |
| Financial Position | 2.5 | Labor Relations Records | 2.0 |
| Procedural Compliance | 2.5 | Geographical Location | 1.9 |
| Communication System | 2.5 | Amount of Past Business | 1.6 |
| Reputation and Position in Industry | 2.4 | Training Aids | 1.5 |
| Desire for Business | 2.4 | Reciprocal Arrangements | 0.6 |

**(source: (Dickson, 1966))**

*2.2.2. Collaboration (Supplier Involvement)*

Collaboration (supplier involvement) is the activities that the internal members of the company and the suppliers collaborate in the product development and production stage (Jongkyung, et al., 2010). The commonly used collaboration techniques are Just in Time Purchasing (JITP), Vendor Managed Inventory (VMI), and Collaborative Planning, Forecasting, and Replenishment (CPFR). JITP used to make the supplier supplies on time. For VMI, the company allows suppliers to be responsible for their company. While CPFR, integrating the supply chain of the company.

*2.2.3. Supplier Selection*

Sustainable supplier selection is having an objective which is to choose and evaluate the appropriate supplier that has the best performance in the upstream supply chain in terms of economic, social, and environmental (Zimmer, et al., 2016). Supplier selection and evaluation criteria is classified as multi-criteria decision-making problem. According to (Pujawan & ER, 2010), the usually method used to select supplier is Analytical Hierarchy Process (AHP). The process of AHP:

1. Determine selection criteria
2. Determine the weight for each criteria
3. Identify the alternative (supplier) that will to be evaluated
4. Evaluate each alternative with the criteria
5. Calculate the weight value of each supplier
6. Sort suppliers by the weighted value

### *2.2.4. Supplier Assessment and Development*

Supplier assessment and development can be considered as a way of company to monitor their suppliers. These supplier-monitoring activities will maintain the company and suppliers in a long-term partnership. According to (Suraraksa & Shin, 2019), supplier monitoring is an activity that is related to the supplier selection process. Since, there are criteria that is expected from the company, therefore they need to continuously monitor their suppliers. The company also needs to regularly evaluate their suppliers and provide feedbacks for the improvement.

Supplier development can be used as one of feedbacks from the results of supplier performance evaluation. To develop the supplier, the company needs supplier development strategy. Supplier development strategy classified into two, reactive and strategic. Based on (Sillanpaa, et al., 2015). Table 2.4 shows how supplier development strategy used for each factors.

**Table 2-4. Supplier Development Strategy**

| Factors | Reactive | Strategic |
|---|---|---|
| Primary question | A supplier performance problem has occurred – what is needed to correct the specific problem? | We have dedicated resources to develop the supply base – where should resources be allocated for the greatest benefit |

**Table 2-5. Supplier Development Strategy (cont'd)**

| Factors | Reactive | Strategic |
|---|---|---|
| Primary objective | Correction of supplier deficiency | Continuous improvement of supply base |
| | Short-term improvements | Long-tern competitive advantages |
| Unit of analysis | Single supplier | Supply base |
| | Supplier development project | Supplier development program |
| Selection / prioritization process | Supplier self-selects through performance or capability deficiency | Portfolio analysis |
| | Problem-driven | Pareto analysis of commodity/suppliers |
| | | Market-driven |
| Drivers (examples) | Delivery dates missed | Supplier integration into the buying firm's operation |
| | Quality defects | Supply chain optimization |
| | Negative customer feedback | Continuous improvement |
| | Competitive threat for buying firm | Value added collaboration |
| | Production disruptions | Technology development |
| | Change in make/buy decision | Seek competitive advantage |

**(source:** (Sillanpaa, et al., 2015)**)**

In strategic development strategy, there is a supplier development program. Supplier development program has two objectives, reducing supplier problems by making immediate change and increase suppliers capability. Supplier development programs that is often used is results-oriented (Chavhan, et al., 2012). Results-oriented development program aims to take an immediate change on supplier specific problems at a time. This program can increase the performance of supplier, but not for a continuous improvement. Supplier development program classified into two: direct and indirect supplier development program (Chavhan, et al., 2012). Direct supplier development program are the activities that improves supplier capabilities through transfer knowledge and qualifications of suppliers organization. While indirect development program are the activities that improves supplier's product and delivery performance through communication and external market forces.

According to (Sanchez-Rodriguez, et al., 2005), supplier development activities based on company involvement parameters are shown in table 2.5.

**Table 2-6. Supplier Development Activities**

| **Basic Supplier Development** | **Moderate Supplier Development** | **Advanced Supplier Development** |
|---|---|---|
| - Evaluation of supplier's performance and feedback to suppliers<br>- Sourcing from limited number of suppliers<br>- Parts standardization<br>- Supplier qualification | - Visiting supplier's plant<br>- Awards and approval of supplier's performance improvements<br>- Collaboration with suppliers in materials improvement<br>- Supplier certification | - Training to suppliers<br>- Collaboration with suppliers<br>- Involvement of suppliers in new product development process<br>- Intensive information exchange with suppliers |

**(Source:** (Sanchez-Rodriguez, et al., 2005)**)**

*2.2.5. Continuous Improvement*

In this stage, the company that implement SRM will do a Plan-Do-Check-Act (PDCA) cycle in response to the result of the development stage. Based on (Jongkyung, et al., 2010), the step of the SRM continuous improvement are:

1. Plan – make plans for SRM system improvement
2. Do – operate system in accordance with the plan
3. Check – evaluate the system and the members involved
4. Act – implement the plan

## 2.3. Data Analytics

Data analytics is the science of integrating heterogeneous data from diverse sources, drawing inferences, and making predictions to enable innovation, gain competitive business advantage, and help strategic decision-making (Gudivada, 2017). Within data analytics there is data mining, which is a process of finding interesting knowledge, such as patterns, relationships, changes, peculiarities and certain structures of big data stored in databases, data warehouse, or other info storage. Data mining can be used in many cases in daily life. According to (Santosa & Umam, 2018), data mining techniques can be useful for solving problems with the following characteristics:

- Requires knowledge-based decisions.
- Has dynamic environment.
- The current method is sub-optimal.
- There is data that can be accessed, sufficient, and relevant.
- Provide high benefits if the decision taken is right.

In data mining, there are four tasks that are usually used in data mining process, which are (Santosa & Umam, 2018):

### *2.3.1. Clustering*

Clustering is the process of data mining that divide the data into classes which the class form themselves from the patterns and characteristics of the data in them. The clustering function is different with classification, because it is unsupervised which the class is not known. The main purpose of clustering is to group a number of data / objects into a cluster so that each cluster will contain as similar data as possible (Santosa & Umam, 2018). There are several methods that can be use (Chen , et al., 2015), which are hierarchical clustering, partitioning algorithms, co-occurrence clustering, scalable clustering and high dimensional clustering. In this research, clustering is chosen to group PT. X supplier data into clusters. PT. X didn't have any class, and the criteria of the class of their suppliers. Therefore, clustering can help to find any information that lies under the suppliers data to make clusters of PT. X suppliers.

*2.3.2. Classification*

Classification is one of the data mining function that assign each data processed into its accurate predetermined classes or category due to its same characteristics. The classification learning is supervised, the scheme is provided with actual outcome. The goal of classification itself is to predict the accurate class/category for the data. In classify the data, there are several methods that can be use (Chen , et al., 2015), which are decision tree, K-Nearest Neighbor (KNN), Naïve Bayes, Support Vector Machines (SVM).

*2.3.3. Regression / Estimation*

Regression is a grouping process that is almost the same as classification, but the difference is regression produces output in continues value (Santosa & Umam, 2018). Regression seek the model of relationship between predictor attributes and dependent attributes. The value of dependent attributes are also continuous.

*2.3.4. Association*

Association is a data mining task that make associations between data in a data set, usually count how many times in a data set that a transaction contains two or more related items.

## 2.3. Cross Industry Standard Process for Data Mining (CRISP-DM)

CRISP-DM (Cross Industry Standard Process for Data Mining) is a model of data mining process that describes the approach that usually used by data miners to solve the business problems. The objectives of CRISP-DM are ensuring the data analytic process to generate high quality results, reducing cost and time, and a stable methodology for model development across varying applications & generic in purpose. CRISP-DM is described in a hierarchical process model that explain from general to specific: phase, generic task, specialized task, and process instance (Sastry & Babu, 2013). There are six phases of CRISP-DM approach, and they are shown in the figure 2.2.

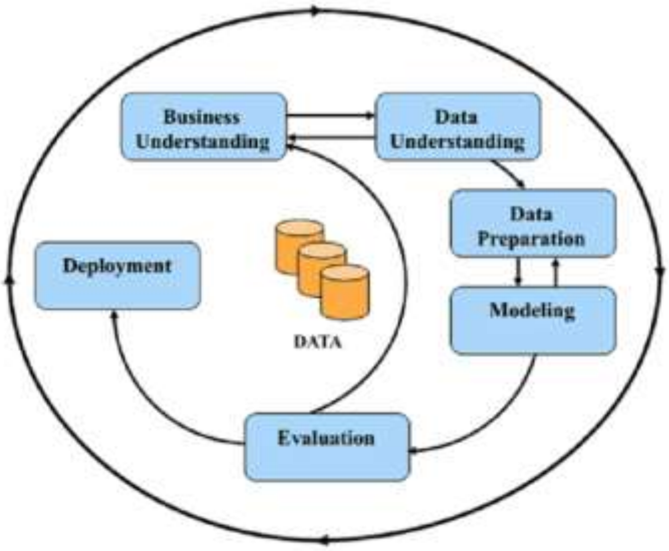


**Figure 2-2. Phase of CRISP-DM**
**(source: towardsdatascience.com)**

*2.4.1. Business understanding*

The process of understanding the objectives and requirements of the project in a business perspective that will be transformed into a data mining problem definition.

*2.4.2. Data understanding*

The process of understanding the results of data collection, identifying problems regarding data quality, get insights from data or detect information hidden in a subset of data to make a hypothesis.

*2.4.3. Data preparation*

The activity that constructs the final data set to be entered into the modeling tools, where the data set comes from the raw data. The data preparation process includes the selection of attributes, data transformation and data cleaning.

2.4.3.1. Data Cleaning

Usually data provided by the company still has incorrect data. This can be due to instrument errors, human errors or transmission errors. Therefore, data must be cleaned before being used in the data mining process. Data cleaning include filling the missing values (blank data), smoothing the missing data, identifying or eliminating outliers and eliminating consistency.

2.4.3.2. Data Transformation

After the data being cleaned, data still has different range of values. This can lead to bias. Therefore, data transformation should be done, and in this research the method used is scaling. Scaling data into range [0,1] named min-max normalization. The data will have lower limit 0 and upper limit 1. The scaling will be calculated using formula 1.

$$\hat{x} = \frac{x - x_{min}}{x_{max} - x_{min}} (UL - LL) + LL \qquad (1)$$

Where x is the data, UL is the upper limit which is 1, and LL is lower limit which is 0.

### *2.4.4. Modeling*

The process of selecting and applying modeling techniques, where the parameters are calibrated to the optimal value. In this process, there are some techniques that require some form of data, therefore this process related to the data preparation process. In this step, the process of determining PT. X suppliers are done using clustering. The clustering technique that is used is k-means clustering. K-means clustering technique, group data into k clusters. In order to group the data, the amount of k should be determined based on the information of the observed object. In detail, the size of the dissimilarity of that can be used to group data into clusters. Dissimilarity can be translated in the concept of distance, the closer the distance, the similar the data, and vice versa. Data sets is divided into clusters by minimizing its Euclidean distance between the data and the nearest cluster center point. The steps of k-means clustering are (Santosa & Umam, 2018):

1) Determine the number of clusters (k).
2) Determine random center point of cluster. After that calculate the next i-cluster centroid by using this formula:

$$v = \frac{\sum_{i=1}^{n} x_i}{n} \; ; i = 1,2,3, \ldots, n \qquad (2)$$

3) Calculate the distance of the data to the centroid. One of the famous distance measurement is Euclidean distance. Below is the formula of Euclidean distance:

$$E = \sum_{j=i}^{k} \sum_{i=1}^{n_j} \left\| x_i^j - c_j \right\|^2 \qquad (3)$$

With $x_i^j$ = i^th object in j^th cluster

$c_j$ = center of j^th cluster or centroid

k = amount of cluster

$n_j$ = amount of object within j^th cluster

4) Allocate each object into nearest centroid.
5) Allocation of objects into each cluster at iteration with k-means. Where each cluster member object has been measured the proximity distance to the cluster's center point.
6) Perform iteration until the centroid position is not change.

Due to the use of MATLAB software, these formulas are included in the K-Means algorithm.

### *2.4.5. Evaluation*

Evaluation is the process that evaluate the steps to construct the model, and the final model itself. There are two parameters that can be used to evaluate which are Sum of Squared Error (SSE) and Silhouette Width.

#### 2.4.5.1. Sum of Squared Error (SSE)

Sum of Squared Error (SSE) is sum of the squares of difference between data within the clusters and the mean of the clusters. The smaller the SSE value, the better the clustering results. SSE is the performance indicator in determining optimum number of k using elbow method (Yuan & Yang, 2019). When the number of clusters is set to approach the number of real clusters, SSE shows a rapid decline. When the number of clusters exceeds the number of real clusters, SSE will continue to decline but it will become slower. The SSE calculated using formula 4.

$$SSE = \sum_{i=1}^{k} \sum_{x \in D_i} ||x - m_i||^2 \quad (4)$$

Where $D_i$ is cluster i, x is the data point, and $m_i$ is mean value in each clusters.

2.4.5.2. Silhouette Index

Silhouette Index measure the degree of confidence in the clustering placement. If the value is close to 1 then cluster placement is correct and if it is close to -1 then the placement is bad.

$$S(i) = \frac{b_i - a_i}{\max(b_i, a_i)} \quad (5)$$

Where $a_i$is average distance i with other observations in one cluster and $b_i$is average distance between i and observation in the nearest cluster.

### *2.4.6. Deployment*

Deployment is the process in order to generate report resulted from data mining process. This step consists of graphic visualization, also the analysis of each clusters.

## 2.5. Critical Review

Research on supplier segmentation using data mining techniques, has been carried out by several researchers. Various techniques are used, one of which is clustering. Clustering is done in previous researches because there is no classification of supplier on the observed object. The objectives of the research also vary, with main objectives to cluster suppliers of objects based on their data characteristics. Some topics in the previous research are determining cluster of suppliers using K-Means Clustering and Fuzzy Clustering. In addition, there are also previous research on supplier development programs. Where the purpose of some research are to discuss supplier development programs in empirical case studies.

The research about supplier segmentation using data mining techniques is done by (Nabilah, 2017). The aim of that research is to cluster PTPN X PG Meritjan ‘s suppliers with its dynamic behavior. The method used in the research is K-Means

Clustering to cluster and RFM analysis to understand the behavior of suppliers based on delivery frequency, range of purchase, and value of materials in the form of money. The output of the research is three clusters of suppliers and internet-based visualization.

Another research about supplier segmentation using data mining technique is done by (Haghighi, et al., 2014). The aim of that research is to propose a supplier segmentation method that compares each supplier's criterion value with exactly same criterion of other suppliers. This research uses Fuzzy Clustering method. It will compare the result with other research that has the same object but using AHP method. The result states that there are several suppliers that are clustered in different group, which enhance the quality of result compared to other research's findings.

Research by (Rezaei & Fallah Lajimi, 2018) also discuss about supplier segmentation. Different with 2 previous researches explained above, this research uses Purchasing Portfolio Matrix (PPM) and Supplier Potential Matrix (SPM) to segment the suppliers. And also Best Worst Method (BWM) to determine the weights of the criteria needed for the two segmentation approaches. The results of the research shows that these combined approach improves supplier management.

Previous research about supplier development is discussed in (Chavhan, et al., 2012). The purpose of this research is to know different supplier development applied by different company. It discusses supplier development in brief such as activities, programs, the critical elements, and beneficial move by buyer. It also said that nowadays supplier innovativeness, technical capability and core competency, could be the factors that increase the competitive advantage of the company as buyer.

Research titled "Supplier Development and Buyer-Supplier Relationship Strategies – A Literature Review" by (Sillanpaa, et al., 2015) also discuss about supplier development. This research aims to explore more about buyer-supplier relationship and supplier development strategies in empirical case study. It also presents the systematic way to build buyer-supplier relationships. The research states that supplier development can help the company to increase the supplier capabilities gradually for further improvement.

Considering the previous research explained before, the writer decide to combine data mining techniques and supplier development concept to reach the objectives of this research. Data mining technique used is K-Means Clustering, while supplier development program will be used as recommendation action towards each cluster. Table 2.4 shows the comparison of previous research with research by author.

**Table 2-7. Comparison of Previous Research with Research by Author**

| Researcher | Title | Method | Object | Output |
|---|---|---|---|---|
| **Previous Research** | | | | |
| (Nabilah, 2017) | Segmentasi Supplier Menggunakan Metode K-Means Clustering (Studi Kasus: PTPN X PG Meritjan | K-Means Clustering | PTPN X PG Meritjan | Three clusters of PTPN X PG Meritjan's suppliers and internet-based visualization. |
| (Haghighi, et al., 2014) | Supplier Segmentation using Fuzzy Linguistic Preference Relations and Fuzzy Clustering | Fuzzy K-Means Clustering | Broiler company | Different member of cluster compared to other research with the same object and better quality of result. |
| (Rezaei & Fallah Lajimi, 2018) | Segmenting Supplies and Suppliers: Bringing Together the Purchasing Portfolio Matrix and the Supplier Potential Matrix | Purchasing Portfolio Matrix (PPM) and Supplier Potential Matrix (SPM) | Computer Hardware Company | The combined approach (PPM and SPM) improves supplier management. |
| (Chavhan, et al., 2012) | Supplier Development: Theories and Practices | - | - | Showing that supplier's innovativeness, technical capability and core |

| Researcher | Title | Method | Object | Output |
|---|---|---|---|---|
| | | | | competency that reached through supplier development can increase company's competitive advantage. |
| (Sillanpaa, et al., 2015) | Supplier Development and Buyer-Supplier Relationship Strategies – A Literature Review | - | Empirical Case Study | Supplier development strategies for empirical case studies and a systematic way to build buyer-supplier relationships to improve the performance. |
| **This Research** | | | | |
| (Sukma, 2020) | Supplier Relationship Management using Quality based Data Analytics (Case Study: PT. X) | K-Means Clustering | Electronic Component Manufacturer (Supplier Development Practices) | Appropriate supplier development program for dynamic behavior of PT. X supplier cluster |

# CHAPTER 3
# RESEARCH METHODOLOGY

This chapter explains the workflow of the research, begins from evaluation, data analytic process, analyzing the results of data analytic, until developing supplier treatment program. The flowchart of this research is shown in Figure 3.1. Details of the step will be discussed in the following subchapters.

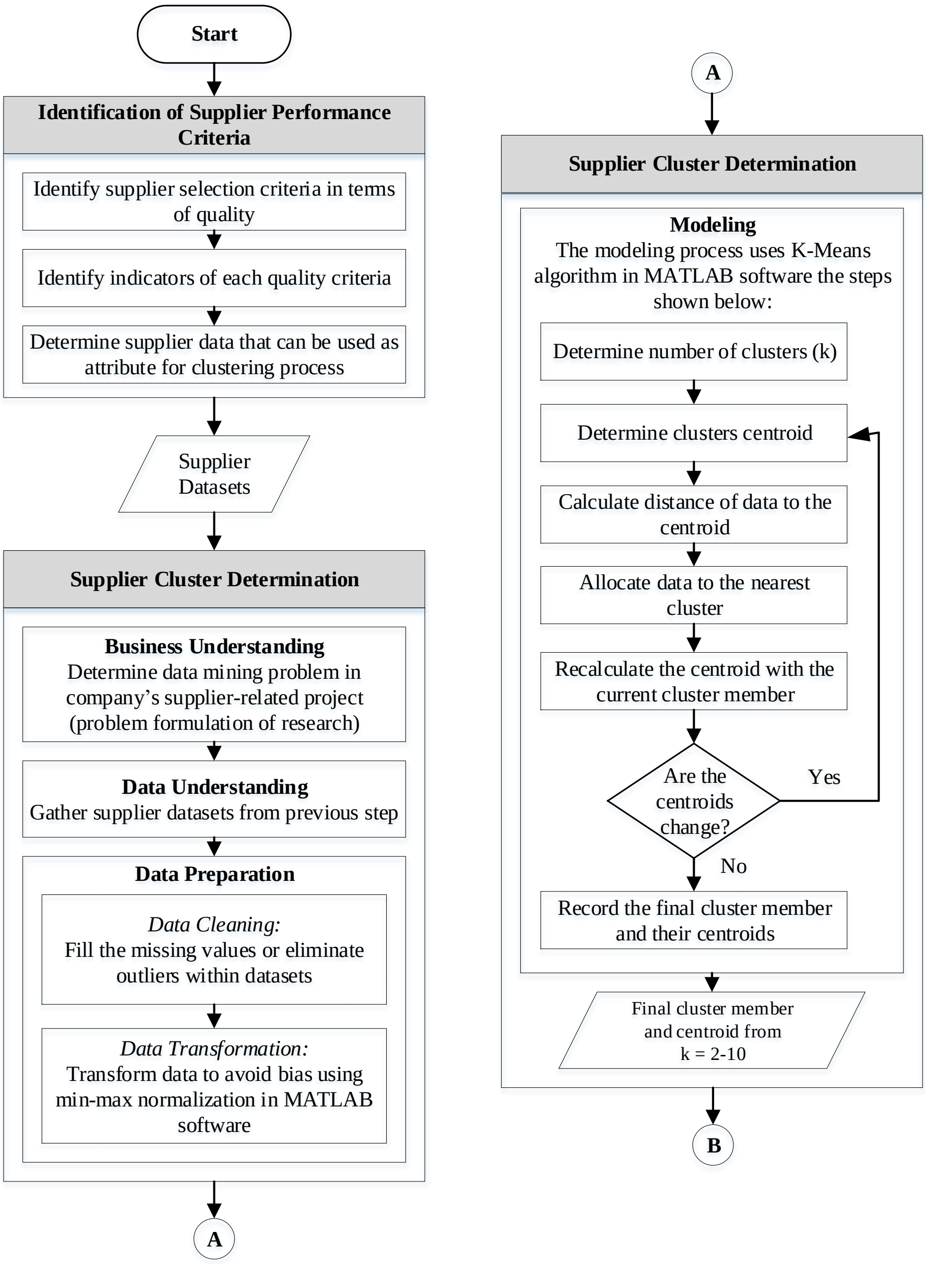


**Figure 3-1. Research Flowchart**

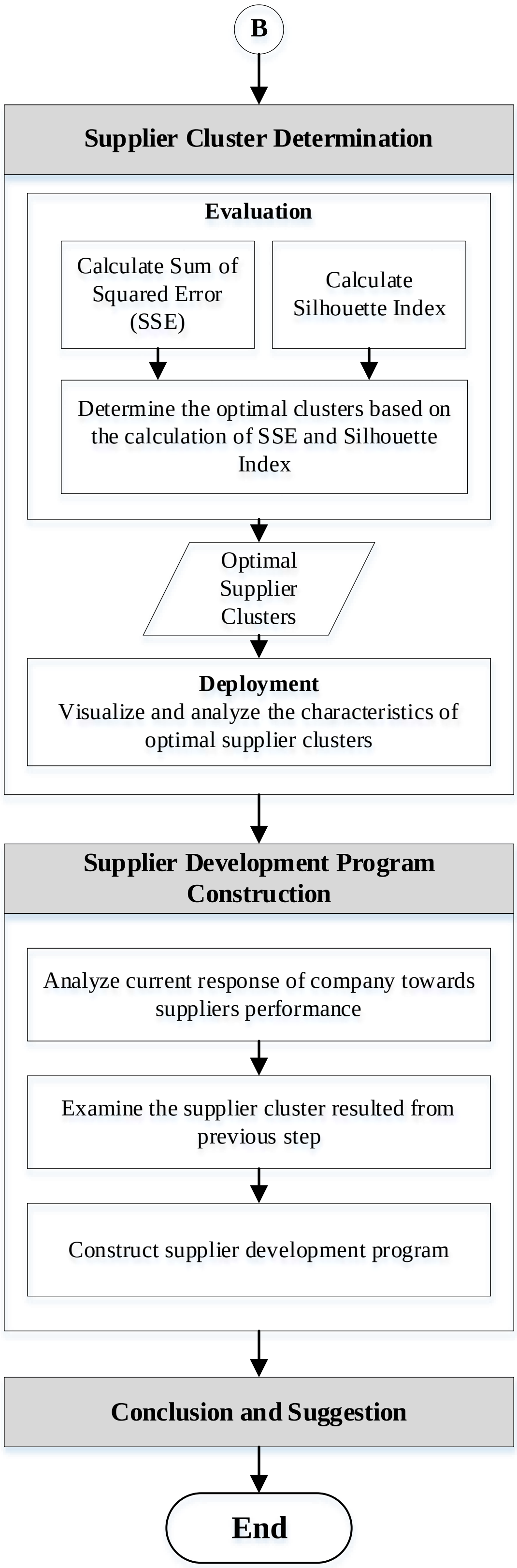


**Figure 3-2. Research Flowchart (cont'd)**

### 3.1. Identification of Supplier Performance Criteria

The preliminary step of this research is to identify the supplier performance criteria. This step explained in detail at figure 3-3.

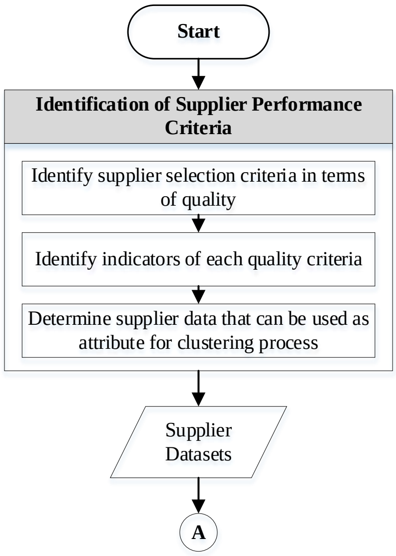


**Figure 3-3. How to Identify Supplier Performance Criteria**

Identification of supplier selection criteria done by discussion with the company representatives, which resulted in Attachment A. First, they are being explained about the problem formulation and its relation with quality dimension. As the response, company gives their perspectives about the implemented quality dimension for their suppliers. Among 11 quality dimensions in the literature (Table 2-1 and 2-2), they only implement 3 of them: performance, conformance to standards and responsiveness.

The implemented quality dimensions are broken down to find their indicators. These indicators will be used as the supplier cluster attributes. According to the result with the company discussion, each of implemented quality dimensions has their own indicators. Performance has lot inspected; incoming rejection (NRS) type A, B, and C; in-process rejection (QCI) type A, B, and C; and special used parts (SAR). Conformance to standards has final score of quality audit. While responsiveness has demerit.

As explained before, the indicators will be used as the supplier cluster attributes. However, the amount of indicators data should be equal. After all of the data are gathered, it is known that the final score of quality audit doesn't have equal amount with the rest. Therefore, final score of quality audit are not used as the supplier cluster attributes. The final supplier cluster attributes are lot inspected; incoming rejection (NRS) type A, B, and C; in-process rejection (QCI) type A, B, and C; special used parts (SAR); and demerit. These data will be called supplier datasets in further.

### 3.2. Supplier Cluster Determination

The supplier cluster are obtained from data mining techniques. To ease the process, CRISP-DM model is used which is shown in the figure 3-4.

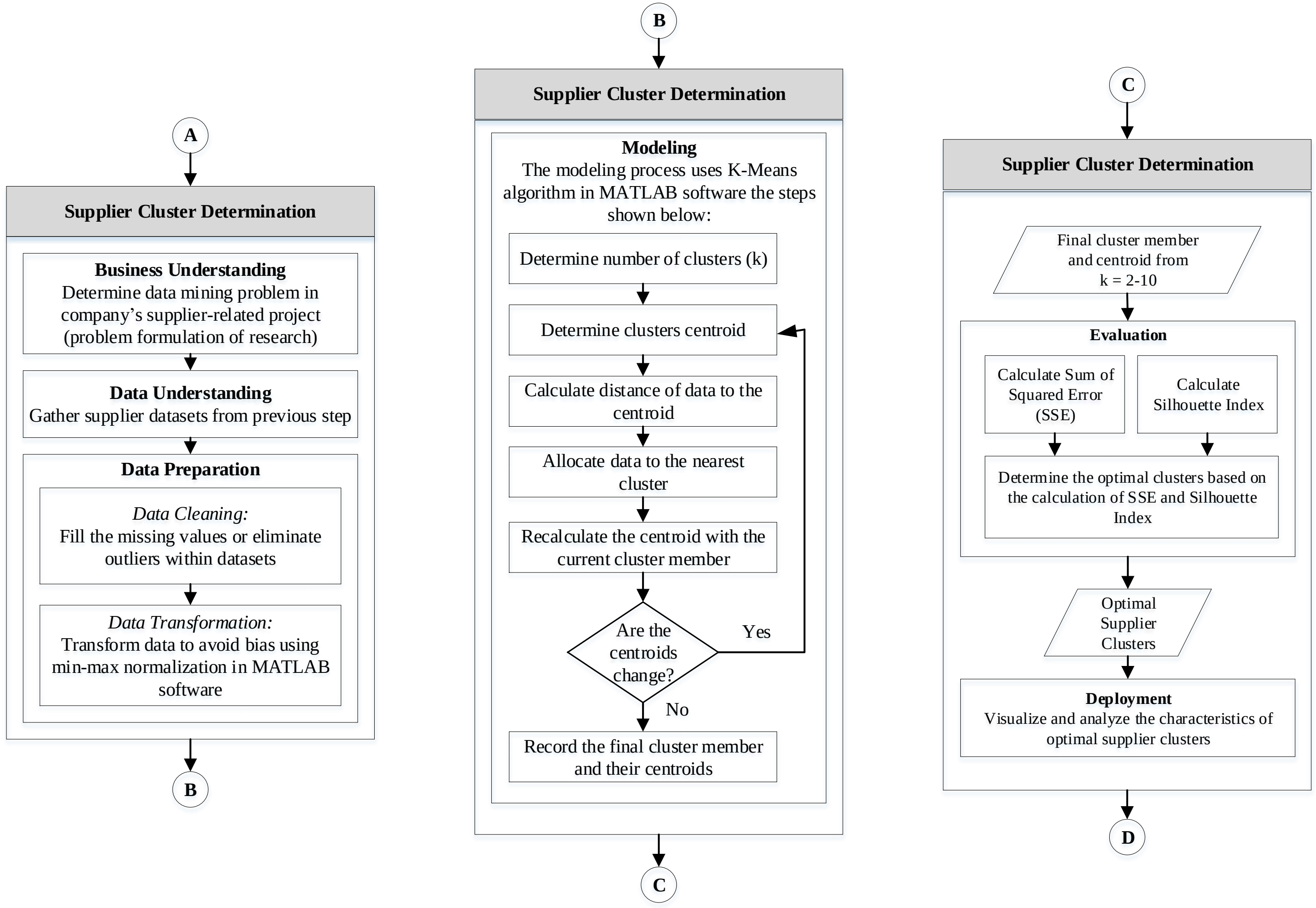


**Figure 3-4. Supplier Cluster Determination Step**

Following the CRISP DM approach, firstly, business understanding is done. In order to understand the business, therefore discussion with the company representative is held. It discuss the supplier-related project within the company. The result is a Data Mining problem, which stated as the problem formulation of this research.

Secondly, understand the data. In this step, the data related to the problem is gathered. Since the previous step resulting attributes for the supplier cluster (supplier datasets), therefore this step only state the data. The supplier datasets consist the data of supplier name, lot inspected, NRS type A B C, QCI type A B C, SAR and demerit.

Thirdly, data preparation that consist of two steps: data cleaning and data transformation. In data cleaning, the missing value of supplier datasets is filled based on company confirmation. After that, the data is transformed into the range value of 0 and 1 to prevent bias. Data transformation is done in MATLAB software using min-max normalization function (attachment D). The result is a final supplier datasets to be used in the modelling step.

Fourthly, the final supplier datasets is modelled by K-Means Clustering technique in MATLAB software. The algorithm or function to cluster the data is stated in attachment E. The input for the function are 3: number of cluster, data to be clustered, and maximum iteration number. Number of cluster (k) tried is ranged from 2 to 10. While, data to be clustered are the final supplier datasets. And maximum iteration used are 5, 50, and 100. The number of cluster (k) and maximum iteration number are varies in order to know whether the difference will affect the result. The result of this step are final cluster member (for each k) and their centroid.

Fifthly, result of the previous step are evaluated using Sum of Squared Error (SSE) and Silhouette Index. The value of SSE are calculated using formula 4 in Ms. Excel. While silhouette index value are calculated using formula 5 in MATLAB software. These values determine the optimum number of supplier clusters. The optimum number of clusters shows drastic reduction of SSE value from previous k, and a silhouette index value that is close to 1. Based on these requirements, it is determined that the optimal number of supplier clusters are three.

Sixthly, deployment step. In this step, the graphical visualization of the final cluster is shown. The cluster membership will be visualized in a chart. All of the clusters are analyzed, and compared to the existing cluster or condition of the company.

### 3.3. Supplier Development Program Construction

To conduct supplier development program, it consists of detail steps that is shown in figure 3-5.

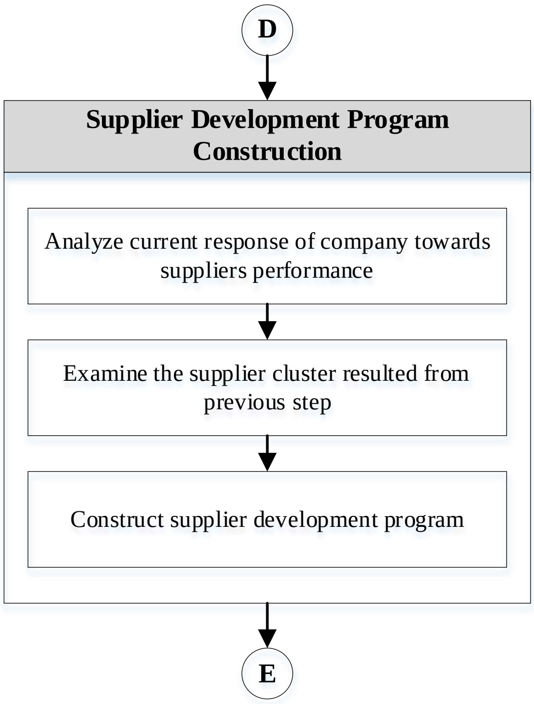


**Figure 3-5. Supplier Development Program Construction Step**

There are two consideration to construct the supplier development program, which are the disadvantages of company current response and the characteristics of supplier clusters. Therefore, the first step is to analyze the current response of company towards supplier performance. The analysis is based on discussion with company representatives (Attachment B). The current response towards actual condition are monthly evaluation and report, training and Process Review Product Verification (PRPV) activities. These responses has their own disadvantages, which will be evaluated and improved to be recommended supplier development program in further.

Secondly, analyze the characteristics of supplier cluster. Each of the supplier cluster has their prominent characteristics that differ one another. Therefore, these prominent characteristics will be consideration for development program for the clusters.

The analysis of company current response and characteristics of supplier cluster are the main consideration for supplier development program. Based on it, there are two types of supplier development programs: basic programs for all clusters and programs for each clusters. These development programs are the recommendation towards the company.

### 3.4. Final

The final step is to conduct the conclusion and suggestion (Figure 3-6). The conclusion explains the achievement of research objectives. Then the suggestion states recommendation towards future research.

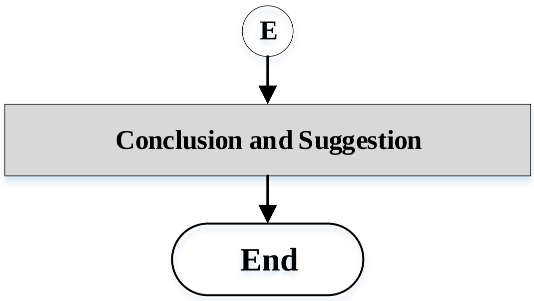


**Figure 3-6. Final Step**

# CHAPTER 4
# IDENTIFICATION OF SUPPLIER PERFORMANCE CRITERIA

This chapter explains the identification of supplier performance criteria in details. Begin with current evaluation method explanation, identification of supplier performance criteria, and lastly recapitulation of supplier clusters determination attributes. These steps are the results of discussion with company representatives.

## 4.1. Current Evaluation Method

As mentioned in the previous chapter, PT. X did monthly evaluation of supplier performance. The criteria of performance evaluation consists of incoming rejection (NRS), in-process rejection (QCI), special used parts (SAR), received lot (Lot Inspected) and demerit of the non-responded claim. These criteria will be included as the consideration of the next step. The supplier performance is being calculated using formula 6.

$$Supplier\ Performance = \left\{1 - \left[\frac{\left(NRS + QCI + \frac{1}{2}SAR\right)}{(Lot\ inspected)}\right] + Demerit\right\} \times 100\% \qquad (6)$$

The result, value of supplier performance, will be graded into A to E based on the range value shown in Table 1.1. However, the grade of suppliers are not used as the basis of supplier development program. It is because there still lacks on the grade itself where they put suppliers with different characteristics in the same grade (Table 1-2). Each grade also didn’t show prominent characteristics, which can be useful for supplier development program.

Because of the disadvantages of supplier grade, the supplier cluster will be determined. By clustering the supplier data, it will results several clusters and their prominent characteristics that the current evaluation method doesn’t have. The characteristics will be based on the attributes of clusters. The attributes of clusters will be determined by considering quality dimensions. These will be explained in detail in sub chapter 4.2-4.3.

## 4.2. Identification of Supplier Performance Criteria

In order to cluster PT. X suppliers, there are several attributes that should be determined as consideration. The attributes will use the supplier performance criteria of the company. The quality will be the basis of the supplier performance criteria. Because quality is a general terms, it will be specified into dimensions of quality as stated in Table 2.1 and 2.2. However, not all dimensions of quality stated is used, due to the results of the company discussion (Attachment A). The sub-subchapter 4.2.1 and 4.2.3 will explain the detail, including the indicator of each quality dimensions.

### *4.2.1. Performance*

Performance defined as how the product perform the intended job. So, based on the discussion, PT. X evaluate performance by using four indicators: the lot inspected, incoming rejection (NRS), in-process rejection (QCI) and special used parts (SAR).

The lot inspected record how much the suppliers can supply parts in the unit of lot. Then, the parts supplied is inspected in terms of appearance and dimension before they enter the production line. If there are major defects, it will be recorded as the incoming rejection (NRS). Besides, if there is an urgency to use the major defects and sent to the production line, it will be recorded as the special used parts (SAR).

There is also an inspection process before the parts are sent to the customers. If the end-product is rejected and the root cause of the problem is from the suppliers, therefore it will be recorded as in process rejection (QCI).

There are 3 types of NRS and QCI, which are type A, B, and C. Type A occurred when the problem affect and leads to customer claim, yet difficult to detect in normal production process. Type B occurred when the problem affect the production performance (amount of inferior product is more than 1%). Last but not least, type C occurred when the problem affect the production performance (amount of inferior product is less than 1%). Even though the type are different, both NRS and QCI has the same type of quality problem.

#### *4.2.2. Conformance to Standards*

For PT.X, conformance to standard describe the capability of their supplier to follow the company specification. To know their capability, PT. X conduct audit per 3 months. But, not all of the suppliers are being audited. They only audit several suppliers that supplies huge number of parts. The final score of audit is the indicator of the conformance to standards.

#### *4.2.3. Responsiveness*

Responsiveness describe whether the request is promptly handled or not. In this research, the responsiveness is described as how promptly the claim handled by the suppliers. So, PT. X has deadline for the suppliers to respond their claim in 5 days of work. If they exceeds the deadline, it will be recorded as demerit.

### 4.3. Attributes for Clusters Determination

Based on the identification of supplier performance criteria, the indicator of each quality dimensions will be the attributes of PT. X clusters. Meaning that the indicator will be the main consideration in clustering PT. X suppliers. The indicator used will be the indicators that have complete data of all suppliers from April 2019 to February 2020. Since the indicator of conformance to standard, audit score, is not complete, therefore it will not be used as the attributes in determining the cluster. The final quality dimensions and its indicators shown in table 4-1.

**Table 4-1. Quality Dimensions and Its Indicators**

| Quality Dimensions | Indicators |
|---|---|
| Performance | Lot inspected |
| | Incoming rejection (NRS) type A, B, and C |
| | In-process rejection (QCI) type A, B, and C |
| | Special used parts (SAR) |
| Responsiveness | Demerit |

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# CHAPTER 5
# SUPPLIER CLUSTER DETERMINATION

This chapter explains the step in determining PT. X supplier clusters. The step follows CRISP-DM (Cross Industry Standard Process for Data Mining) approach which consists of business understanding, data understanding, data preparation, modelling, evaluation, and deployment.

## 5.1. Business Understanding

In order to transform the company project into a data-mining problem, a discussion with the company representatives is conducted. The result of the discussion is the background of this research. The problem is formulated as stated in sub-subchapter 1.2, which is to cluster PT. X suppliers using data analytic in which the analysis will be used to support their SRM activities.

## 5.2. Data Understanding

The data that relates to cluster PT. X suppliers are collected. The data consists of several attributes, which resulted from the previous step (Table 4.1). The data used are from April 2019 to February 2020. The example of PT. X supplier data is shown in Table 5-1. In the step further, these data will be mentioned as datasets.

**Table 5-1. PT. X Suppliers Data**

| Supplier Name | Month | Lot Inspected | NRS A | NRS B | NRS C | QCI A | QCI B | QCI C | SAR | Demerit |
|---|---|---|---|---|---|---|---|---|---|---|
| A | Apr-19 | 14 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| B | Apr-19 | 409 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C | Apr-19 | 2066 | 0 | 2 | 3 | 1 | 11 | 1 | 0 | 0 |
| D | Apr-19 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| E | Apr-19 | 347 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| … | … | … | … | … | … | … | … | … | … | … |
| BF | Feb-20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.03 |
| BG | Feb-20 | 75 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BH | Feb-20 | 2517 | 0 | 0 | 0 | 3 | 11 | 17 | 0 | 0 |
| BI | Feb-20 | 1104 | 0 | 0 | 0 | 0 | 10 | 4 | 57 | 0.01 |
| BJ | Feb-20 | 31 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

### 5.3. Data Preparation

Data preparation consists of two steps, data cleaning and data transformation. These two steps will be explained in detail below.

#### *5.3.1. Data Cleaning*

In this step, the datasets is being cleaned since there are incorrect data due to human errors, transmission errors etc. Data cleaning include filling the missing values (blank data), smoothing the missing data, identifying or eliminating outliers and eliminating consistency. For example there is missing values in PT. X suppliers data in August 2019, therefore it is filled with the correct value based on the confirmation of PT. X.

#### *5.3.2. Data Transformation*

Data transformation is done to prevent bias results due to the large data range. The method used in data transformation is scaling, or min-max normalization. So, in this step the data will be transformed to have the range of 0 to 1 value. Before the data is transformed, the maximum and minimum value, respectively are 3440 and 0.

This step uses MATLAB software and coding in the Attachment D. The inputs are datasets, lower limit (LL) value which is 0, and UL or upper limit (UL) value which is 1. Table 5-2 shows several data after scaling. These data is the final datasets that will be used in the modeling step.

**Table 5-2. Supplier Data After Scaling**

| Supplier Name | Month | Lot Inspected | NRS A | NRS B | NRS C | QCI A | QCI B | QCI C | SAR | Demerit |
|---|---|---|---|---|---|---|---|---|---|---|
| A | Apr-19 | 0.0041 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| B | Apr-19 | 0.1189 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C | Apr-19 | 0.6006 | 0 | 0.4 | 0.375 | 0.167 | 0.423 | 0.059 | 0 | 0 |
| D | Apr-19 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| E | Apr-19 | 0.1009 | 0 | 0 | 0.125 | 0 | 0 | 0 | 0 | 0 |
| … | … | … | … | … | … | … | … | … | … | … |
| BF | Feb-20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BG | Feb-20 | 0.0218 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BH | Feb-20 | 0.7317 | 0 | 0 | 0 | 0.5 | 0.423 | 1 | 0 | 0 |
| BI | Feb-20 | 0.3209 | 0 | 0 | 0 | 0 | 0.385 | 0.235 | 0.147 | 0.333 |
| BJ | Feb-20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

### 5.4. Modeling using K-Means Clustering

Modeling is the process of selecting and applying modeling techniques, where the parameters are calibrated to the optimal value. This step uses K-Means Clustering technique, with the steps below (Santosa & Umam, 2018):

1) Determine the number of clusters (k).
2) Determine random center point of cluster. After that calculate the next i-cluster centroid by using this formula:

$$v = \frac{\sum_{i=1}^{n} x_i}{n} \; ; i = 1,2,3, \ldots, n \tag{7}$$

3) Calculate the distance of the data to the centroid. One of the famous distance measurement is Euclidean distance. Below is the formula of Euclidean distance:

$$E = \sum_{j=i}^{k} \sum_{i=1}^{n_j} \left\| x_i^j - c_j \right\|^2 \tag{8}$$

With $x_i^j$ = i$^{th}$ object in j$^{th}$ cluster

$c_j$ = center of j$^{th}$ cluster or centroid

k = amount of cluster

$n_j$ = amount of object within j$^{th}$ cluster

4) Allocate each object into nearest centroid.
5) Allocation of objects into each cluster at iteration with k-means. Where each cluster member object has been measured the proximity distance to the cluster's center point.
6) Perform iteration until the centroid position is not change.

The sequence is translated into coding (Attachment E) to be run in MATLAB software. The input of the coding are number of cluster, data to be clustered and maximum iteration number. Number of cluster or k that will be tried is from 2 to 10. The data to be clustered are the final datasets that passed the data transformation step. The maximum iteration used are varies → 5, 50, and 100. The variation of k and maximum iteration number is to know whether the difference will affect the result.

Result of modeling step are the cluster member of suppliers using k = 2 to 10. Table 5-3 shows the example of modeling result for k = 3. While the rest of the results can be seen in Attachment F.

**Table 5-3. Example of Modeling Result**

| K = 3 | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Iteration | Cluster | Centroid | | | | | | | | | Silhouette Index | SSE |
| | | Lot Inspected | NRS A | NRS B | NRS C | QCI A | QCI B | QCI C | SAR | Demerit | | |
| 5 | 1 | 0.4913 | 0.0000 | 0.1367 | 0.1813 | 0.1194 | 0.2429 | 0.2324 | 0.2941 | 0.0222 | 0.857 | 41.329 |
| | 2 | 0.0340 | 0.0000 | 0.0123 | 0.0164 | 0.0014 | 0.0057 | 0.0168 | 0.0027 | 0.0023 | | |
| | 3 | 0.0799 | 0.0286 | 0.0286 | 0.0214 | 0.0048 | 0.0319 | 0.0672 | 0.0059 | 0.9238 | | |
| 50 | 1 | 0.0799 | 0.0286 | 0.0286 | 0.0214 | 0.0048 | 0.0319 | 0.0672 | 0.0059 | 0.9238 | 0.863 | 41.223 |
| | 2 | 0.5182 | 0.0000 | 0.1148 | 0.1713 | 0.1235 | 0.2607 | 0.2538 | 0.3195 | 0.0247 | | |
| | 3 | 0.0361 | 0.0000 | 0.0155 | 0.0190 | 0.0022 | 0.0065 | 0.0171 | 0.0034 | 0.0022 | | |
| 100 | 1 | 0.0799 | 0.0286 | 0.0286 | 0.0214 | 0.0048 | 0.0319 | 0.0672 | 0.0059 | 0.9238 | 0.863 | 41.223 |
| | 2 | 0.0361 | 0.0000 | 0.0155 | 0.0190 | 0.0022 | 0.0065 | 0.0171 | 0.0034 | 0.0022 | | |
| | 3 | 0.5182 | 0.0000 | 0.1148 | 0.1713 | 0.1235 | 0.2607 | 0.2538 | 0.3195 | 0.0247 | | |

All of these clusters will be evaluated its SSE value and silhouette index in the evaluation step. After that, the optimum clusters of PT. X suppliers will be decided.

## 5.5. Evaluation of Modeling Step Result

Evaluation is the process that evaluate the steps of constructing the model, and the final model itself. To evaluate the model, calculation of Sum of Squared Error (SSE) and Silhouette Index are conducted. If the model passed the requirement of SSE and Silhouette Index, therefore the result can be used for the next step. The detail will be explained in 5.5.1 and 5.5.2.

### *5.5.1. Sum of Squared Error (SSE)*

Sum of Squared Error (SSE) is sum of the squares of difference between data within the clusters and the mean of the clusters. The smaller the SSE value, the better the clustering results. However, there is no stipulation on how small the value is said to be best. Therefore, it will be helped by elbow method. Using elbow method, the optimum k is shown when the change of k, gives significant reduction of SSE value. And after that, the reduction of SSE value will be more stable. In this research the calculation of SSE uses Ms. Excel and the result is shown in figure 5-1.


**Figure 5-1. Comparison of SSE**

Figure 5-1 shows the comparison of SSE for each number of clusters (k) in several iteration. The graph shows that the pattern in each iteration is quite the same. Due to elbow method, all of iterations agreed that the **optimum k is three**. It is because when the k is changed into three, the SSE value drastically reduced (from 67 to 41). It also shows that the change of k after three, resulting a more stable reduction of SSE value. The exact value of SSE for each iteration and k, can be seen in attachment F.

### *5.5.2. Silhouette Index*

Silhouette index is a parameter to know whether the placement of data in their cluster is correct or not. The value should be near 1 to be considered as correct. The further the value from 1, the worst the placement. The calculation of silhouette index uses Formula 5 in subchapter 2. However, this research uses MATLAB software to calculate the silhouette index with this function:

```
[s,h] = silhouette(dataNew,cluster,'sqEuclidean');
```

The input of the function are three: data, clustering result and type of distance. The result of this function is the average value of silhouette index of all data, and the figure of the calculation result. Silhouette Index value of this research are recap in the table 5-3.

**Table 5-4. Silhouette Index Value**

| k | Silhouette Index | | |
|---|---|---|---|
| | Iteration 5 | Iteration 50 | Iteration 100 |
| 2 | 0.7868 | 0.7927 | 0.7927 |
| **3** | **0.8568** | **0.8634** | **0.8634** |
| **4** | **0.853** | **0.8724** | **0.872** |
| 5 | 0.754 | 0.8234 | 0.8141 |
| 6 | 0.6561 | 0.787 | 0.7943 |
| 7 | 0.698 | 0.7723 | 0.7723 |
| 8 | 0.6114 | 0.7418 | 0.7649 |
| 9 | 0.6093 | 0.729 | 0.7133 |
| 10 | 0.5741 | 0.669 | 0.6688 |

It can be seen in the table that the value of silhouette index for each iteration are quite the same, except iteration 5 in k = 5 – 10. In modeling step, the data is going through iteration to reach stable centroid or the appropriate centroid for the data cluster. The bigger maximum iteration number will creates bigger value of silhouette index, because they can reach stable centroid in their range. However the smaller the maximum iteration number will results a smaller value of silhouette index. Due to their limit of iteration, they might have not reach stable centroids and resulting a bad data placement in the cluster or low value of silhouette index.

Table 5-3 shows that the number of cluster (k) that closest to 1 is four. When the k is four, the silhouette value index is in the range of 0.85-0.87 (variation caused by maximum iteration), which is the highest among all. It also shows that when the k is 3, the silhouette index value is in the range of 0.85-0.86, which have slight different with the highest. Therefore, if there is no other parameters to be considered, **the optimal number of cluster is 4**. However, if there is any other parameter, **k = 3 can also be considered as the optimal number of cluster**.

### 5.6. Deployment of Optimal Cluster

Based on the evaluation step, the optimum number of cluster is decided, and the result is three. Number of cluster (k) 3, fulfill the requirement of optimal number of cluster by elbow method. It is because when k is changed into 3, the SSE value drastically reduced from the previous k and producing stable reduction of

SSE value in further. The value of silhouette index is 0.85-0.86 (close to 1) meaning that the placement of data within its cluster is good.

**Table 5-5. Evaluation Result of Optimum Number of Cluster**

| | Parameter | Iteration 5 | Iteration 50 | Iteration 100 |
|---|---|---|---|---|
| K = 3 | SSE | 41.3294 | 41.2232 | 41.2232 |
| | Silhouette Index | 0.8568 | 0.8634 | 0.8634 |

It can be seen at Figure 5-2 that overall, 87% data included in cluster 3, and the rest: 5% included in cluster 1 and 8% in cluster 2. Meaning that most of the suppliers are the member of cluster 3. The formation of these three clusters is due to the similarity of data within the clusters. Therefore, each clusters has prominent characteristics so that it distinguishes one cluster to other clusters. Cluster 1 has high number of NRS type A and demerit. Cluster 2 has high number of lot inspected, NRS type B and C, QCI type A, B, and C. While cluster 3, has low number in each attributes (did not have prominent characteristics). All of these characteristics and its causes will be explained in chapter 6.

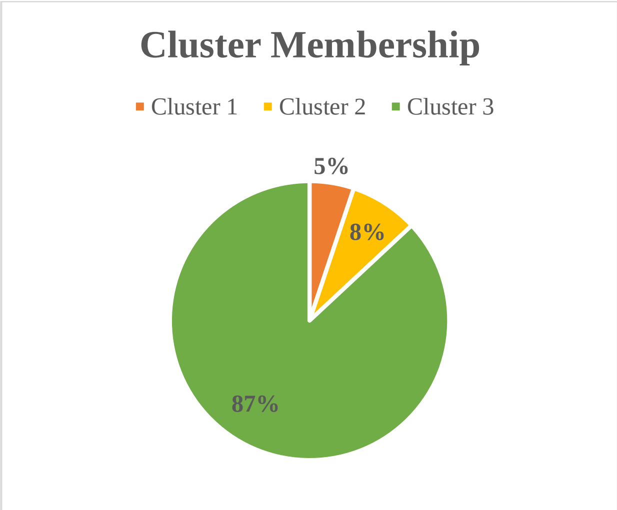



**Figure 5-2. Cluster Membership**

These characteristics makes it different with the existing supplier cluster. Previously, PT. X tried to cluster suppliers based on their performance under a specific range. The suppliers are clustered into 5 level of grade: A, B, C, D, and E. However, each grade didn’t show any characteristics of it. As explained in chapter 1, they also placed suppliers that has different characteristics into the same grade. These factors complicate the company to take the appropriate action towards their suppliers, which leads to only give them general training and corrective action.

It can be seen at Figure 1-2 in chapter 1 that supplier BE and BH is in the same grade –which is C- even though they have different number of lot inspected, QCI and demerit. The hypothesis is they should have different grade/cluster, and so does the treatment. It is proved by the result of the data mining process, that they are placed in different cluster. Supplier BE is in cluster 1, while supplier BH in cluster 2. By knowing their cluster, the company also know their characteristics. Therefore, the company can develop supplier BE and BH similar and in the same time to the suppliers within their clusters. Which means it will be more appropriate and efficient.

# CHAPTER 6
# SUPPLIER DEVELOPMENT PROGRAM CONSTRUCTION

This chapter explains how the supplier development program is constructed. Begins with analyze current response of company towards supplier's performance. After that, examine the supplier cluster that is resulted from previous chapter. Then, construct the supplier development program based on the current response and cluster. All of this step will be explained in detail in 6.1 – 6.3.

## 6.1. Current Response

PT. X has the problem of not having the same supplier performance. Due to it, they conduct several response such as corrective action and training. Both of the action are not triggered by the performance evaluation. Therefore, the performance of suppliers does not feel a significant impact of the action.

Corrective action taken by PT. X is Process Review Product Verification (PRPV). PRPV is similar to audit activity but it focused on the process, not on the system. In doing PRPV, the evaluator see the process from warehouse to production line, to know which process that produce defect sent to PT. X. To shorten the time, the evaluator will only see the process based on the problem occurred. PT. X did PRPV based on 3 factors: amount of problems, recurrence of problem, and supplier in Grade D for the last 3 months. The effect of this implementation is the suppliers cannot do continuous improvement by themselves.

Training held by PT. X mostly explained about the general system. There are two trainings: Quality Management System (QMS) and Chemical Management System (CMS). QMS training explained about the criteria that the suppliers should fulfill according to the standard of ISO 9001. While, CMS training explained about the criteria that the suppliers should fulfill according to the standard of ISO 14001. These two trainings discussed about the system, and focused on documentation. However, it did not pay attention to the process, which more vulnerable in producing defects.

Beside the above activities, PT. X also did monthly evaluation that state their supplier performance. The supplier performance is being reported to their supplier in the form of Supplier Quality Appraisal (SQA) report. The content of the SQA report consists of supplier achievement in 5 performance criteria (percentage of lot inspected, NRS, QCI, SAR, and demerit). However, there is no explanation of the value, also it didn’t explain the supplier problems in that month.

According to company representative explanation (attachment B), the current solution activities takes a lot of resource and time. In doing PRPV, they should send people from different job division, so that they can evaluate their supplier. The training and PRPV takes time, especially PRPV that did not have any schedule because it depend on when the problem occurred. Therefore, these current responses are still lack on several things. It can be improved by constructing development programs considering the analysis of cluster resulted from previous chapter.

## 6.2. Analysis of Supplier Clusters

Result of previous chapter stated that there are three clusters of PT. X suppliers. These three clusters are optimal based on the consideration of Sum of Squared Error (SSE) and Silhouette Index value. The comparison of all clusters can be seen at table 6-1. The values are the average value of the data within the clusters for each attributes. The details of clusters explained in 6.2.1-6.2.3.

**Table 6-1. Comparison of All Clusters**

| Attributes | Cluster 1 | Cluster 2 | Cluster 3 |
|---|---|---|---|
| **Lot Inspected** | 274.8286 | **1782.5926** | 124.3002 |
| **NRS A** | **0.0286** | 0.0000 | 0.0000 |
| **NRS B** | 0.1429 | **0.5741** | 0.0776 |
| **NRS C** | 0.1714 | **1.3704** | 0.1518 |
| **QCI A** | 0.0286 | **0.7407** | 0.0135 |
| **QCI B** | 0.8286 | **6.7778** | 0.1686 |
| **QCI C** | 1.1429 | **4.3148** | 0.2901 |
| **SAR** | 2.2857 | **124.2778** | 1.3170 |
| **Demerit** | **0.0277** | 0.0007 | 0.0001 |

### *6.2.1. Cluster 1*

Among three clusters (can be seen in table 6-1), cluster 1 has high number of demerit and NRS type A. The average number of demerit is 0.0271 and NRS Type A is 0.0287. The high number of demerit meaning that the supplier within this cluster has slow response towards claim from PT. X. According to attachment C, demerit caused by the company that claim several times a month but the suppliers could not keep up with it. When they are working on the first claim, the new claim occurred, so they need longer time to respond both claims. Even though, they need to finish it within the deadline given by the company. The company also less reactive to remind their suppliers, they only do it in the beginning and close to deadlines. Also, the suppliers are lacking in capability to analyze the root cause and set improvement action by themselves. This factor leads to high number of NRS type A, too. The NRS type A meaning that the supplier often supply problematic part, which affect and leads to customer claim, yet difficult to detect in normal production process. Because the suppliers lacks on the capability to analyze the root cause, the problem recurred. In the NRS, stated that the problem found is slanting.

To know the quality problem within this cluster, therefore the data of NRS and QCI in all types are traced. There are 27 problems in total. In order to know which problems affect the whole, Pareto Chart is used. The result (Figure 6-1) is there are 12 main problems that are faced by supplier within cluster 1, which are **dimension, bending, change colour, broken, lifting, short mold, plating unperfect, printing NG, black dot, cutting unperfect, excess material, and mix.** These problems should be included in developing suppliers in cluster 1.

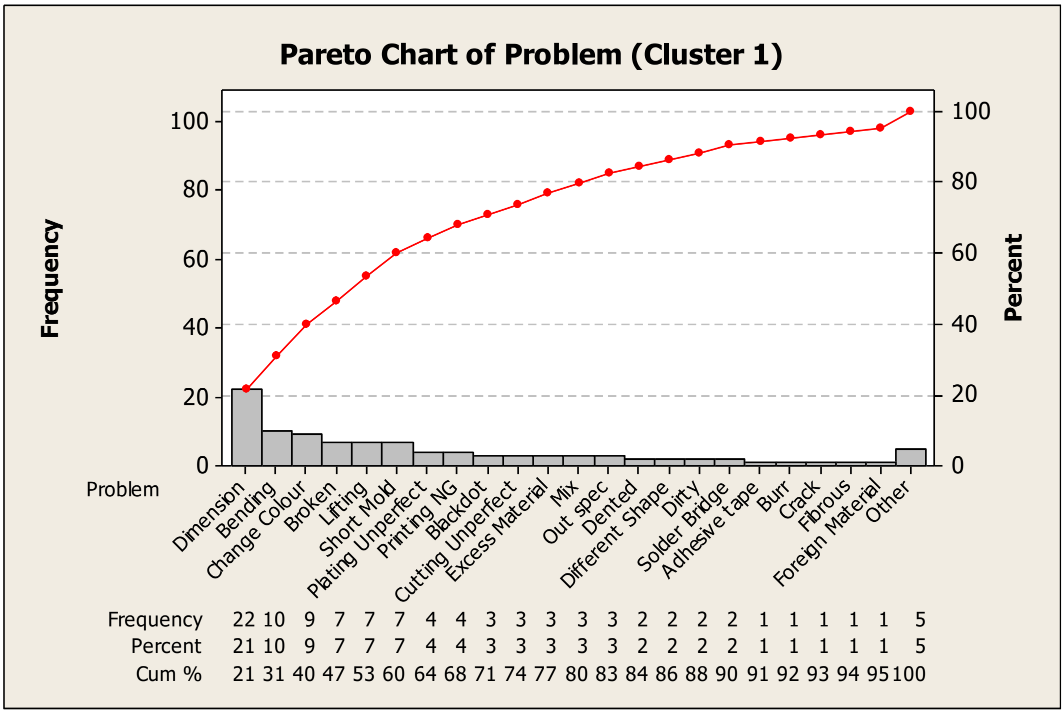
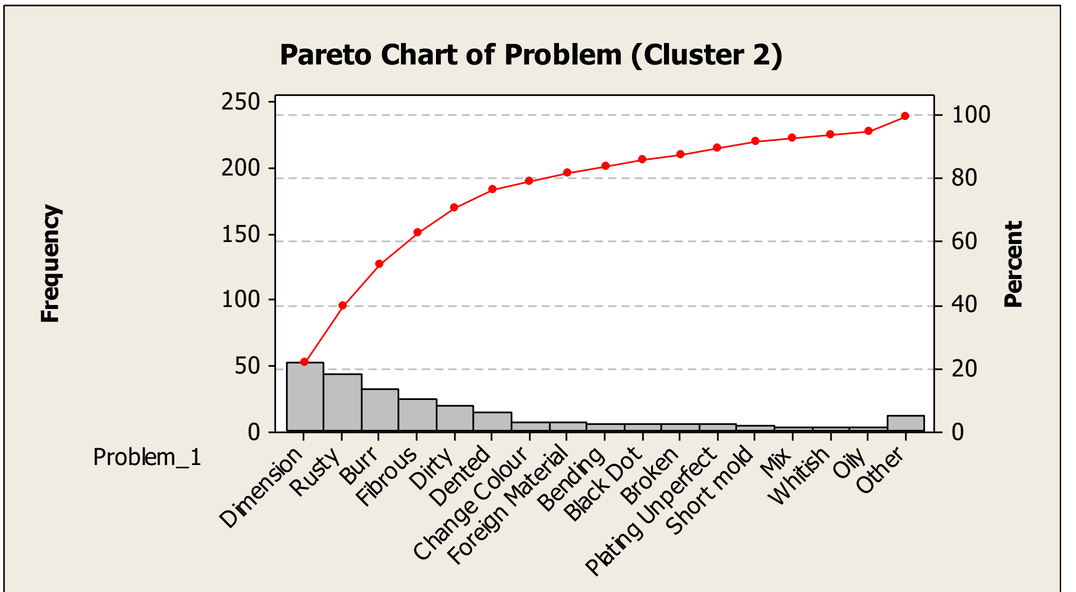



**Figure 6-1. Pareto Chart of Problem (Cluster 1)**

*6.2.2. Cluster 2*

This cluster has high number of lot inspected, meaning that the suppliers within cluster 2 supplies large quantity of parts. These suppliers has production capability to fulfill company's order more than other suppliers. But, the larger the quantity, the higher the chance of the suppliers produce defect part. The company representative said that it is caused by lack of suppliers understanding related to quality problems, how to solve it, and limitation of defect to be accepted (Attachment C). Since then, the quality problem recurred. Therefore, in this cluster, the number of SAR, NRS type B and C, also QCI type A, B and C are high.

The quality problem within this cluster is traced using NRS and QCI data. The problem that affect the whole are determined using Pareto Chart. The total of quality problem in Cluster 2 are 24 problems. There are eight problems, which affect the performance of suppliers in cluster 2. The problems are **dimension, rusty, burr, fibrous, dirty, dented, change color and foreign material**. These problems should be considered in developing suppliers in cluster 2.




| Problem_1 | Dimension | Rusty | Burr | Fibrous | Dirty | Dented | Change Colour | Foreign Material | Bending | Black Dot | Broken | Plating Unperfect | Short mold | Mix | Whitish | Oily | Other |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Frequency_1 | 52 | 43 | 32 | 24 | 19 | 14 | 6 | 6 | 5 | 5 | 5 | 5 | 4 | 3 | 3 | 2 | 12 |
| Percent | 22 | 18 | 13 | 10 | 8 | 6 | 3 | 3 | 2 | 2 | 2 | 2 | 2 | 1 | 1 | 1 | 5 |
| Cum % | 22 | 40 | 53 | 63 | 71 | 77 | 79 | 82 | 84 | 86 | 88 | 90 | 92 | 93 | 94 | 95 | 100 |

**Figure 6-2. Pareto Chart of Problem (Cluster 2)**

*6.2.3. Cluster 3*

Cluster 3 does not have prominent characteristics like other clusters. The suppliers has low number of lot inspected caused by their low production capability.

Besides, they have low number of the rest of attributes. Since the cluster still show NRS and QCI values, therefore it is concluded that cluster 3 also has quality problems. After the data of NRS and QCI are traced, there are 63 problems in total. To know which problems affect the whole performance, Pareto Chart is used. It is known from figure 6-3 that the main problems are **dimension, dirt, rusty, change color, burr, dented, short mold, scratch, stain, bending, fibrous, silver steak, broken, NG characteristic, black dot, excess material, no champer, and deform**. These problems will be considered in developing cluster 3.

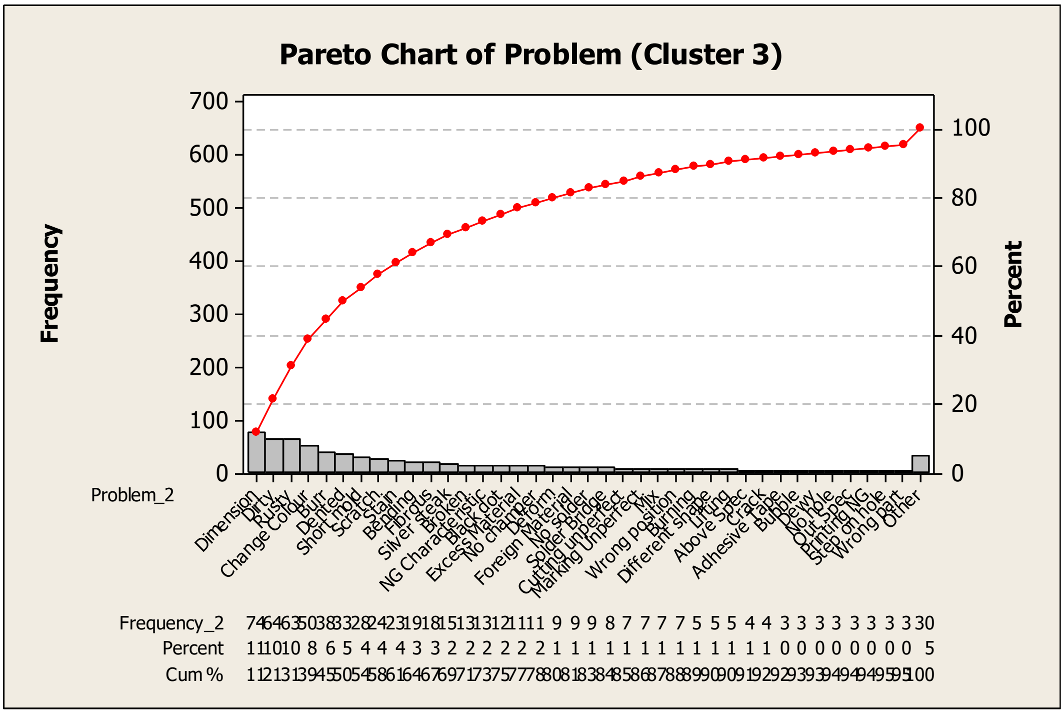



**Figure 6-3. Pareto Chart of Problem (Cluster 3)**

### 6.3. Supplier Development Program of Cluster

Based on the analysis in sub chapter 6.2, the supplier development program are constructed. Table 6-2 shows the recapitulation of previous analysis and recommended supplier development program. These recommended supplier development program will be classified into basic programs for all suppliers and specific programs for each clusters. It will be explained in detail in sub-subchapter 6.3.1 – 6.3.4.

**Table 6-2. Recapitulation of Previous Analysis and Recommended Supplier Development Program**

| Recapitulation of Previous Analysis | Recommended Supplier Development Program |
|---|---|
| Process Review Product Verification (PRPV) Activities takes lots resource and time | Focused on supplier within cluster 2 |
| Monthly evaluation and report is less informative | Improved monthly report |
| Quality problems in each clusters | Quality problem training |
| High number of demerit in Cluster 1 | Intensive information exchange with suppliers |
| High number of NRS, QCI and SAR in cluster 2 | PRPV Activities |
| Low number of attributes in cluster 3 | Incentives |

### *6.3.1. Basic Supplier Development Program for All Cluster*

All suppliers should know how they perform in the predetermined period. As stated in sub chapter 6.1, PT. X already implement evaluation of supplier's performance and give them Supplier Quality Appraisal (SQA) report in each month. However, there is a gap on it, which the company can improve. The current SQA can be seen in Figure 6-4, and the improved one is in Figure 6-5. In the improved SQA, the company might add several information such as their achievement of the company target. They can state the characteristics of the cluster where the supplier is placed, also the description of numbers within the report. By adding information and description, the suppliers will know their performance more clearly. They know where they are lacking so they can make improvements by themselves if they are not reaching the supplier performance target.

<table>
<tr><td colspan="4" rowspan="2">SUPPLIER REPORT</td><td>Signed by</td><td>Signed by</td><td>Signed by</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td colspan="4">Formula of Supplier Performance</td><td>Range of Supplier Grade</td></tr>
<tr><td colspan="2">Lot Inspected Graph</td><td colspan="5" rowspan="5">Trend of Supplier Grade for Several Month</td></tr>
<tr><td colspan="2">NRS Graph</td></tr>
<tr><td colspan="2">QCI Graph</td></tr>
<tr><td colspan="2">SAR Graph</td></tr>
<tr><td colspan="2">Demerit Graph</td></tr>
<tr><td colspan="7">Filled by Supplier:</td></tr>
<tr><td colspan="7">Supplier Comment</td></tr>
<tr><td colspan="7">SAR Note</td></tr>
<tr><td colspan="4" rowspan="2">Supplier Target</td><td>Signed by</td><td>Signed by</td><td>Signed by</td></tr>
<tr><td></td><td></td><td></td></tr>
</table>

**Figure 6-4. Current Supplier Quality Appraisal (SQA) /Report**

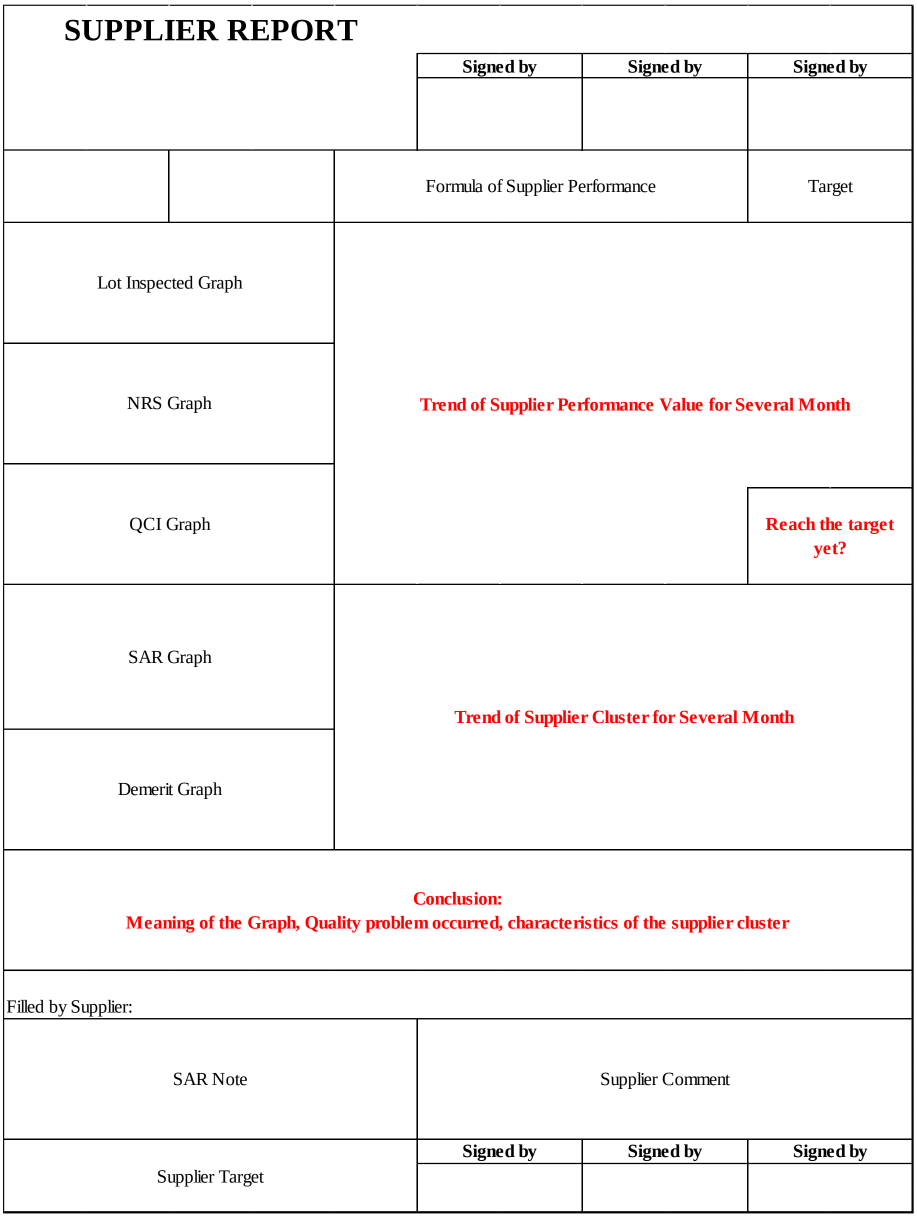



**Figure 6-5. Improved Supplier Quality Appraisal (SQA) / Report**

According to (Chavhan, et al., 2012), supplier performance can be increased by conducting the right type of training. To know the right type of training, the company should study their suppliers. In this research, it is known that the company provide training of Quality Management System (QMS) and Chemical Management System (CMS). The training discussed a general system. However, based on the result of cluster analysis, all of the suppliers are having quality problem. It is caused by the lack of supplier knowledge about quality problem, find it root causes, and how to solve it. Therefore, it is recommended to add a quality problem training.

Differ from the existing, quality problem training aiming to give knowledge on general definition of the quality problem occurred, how to find the root causes, how to solve it and the limitation of defect to be accepted. Quality problem training will be done separately based on supplier cluster and focus on their own quality problems, which are stated in 6.2.1-6.2.3. The training act as a preventive action, in which can be done in every 3 months. The benefits of giving quality problem training will increase supplier knowledge of supplier on their quality problem depend on which cluster they are. In the long term, it is expected that they can do their own continuous improvement without the company's guidance.

### *6.3.2. Supplier Development Program for Cluster 1*

Cluster 1 has two prominent characteristics: their high number of NRS type A and demerit. For NRS type A, can be solved using quality problem training that is implemented for all cluster. While, high number of demerit -as explained in 6.2.1- means that the supplier has slow response towards claim from PT. X. Therefore, it is recommended to do an intensive information exchange with the supplier. As stated in (Chavhan, et al., 2012), openness in communication is a key parameter for supplier improvement. Therefore, it can be done by informal communication such as telephone communication, or constructing a real-time information system. In this system, the company might add several features, but they should insert a deadline alert. The deadline alert will remind the suppliers to respond the claim quickly. The company can also help to summarize the claim, so that the supplier can respond them at once. Since it is a real time system, PT. X can control whenever they need.

### *6.3.3. Supplier Development Program for Cluster 2*

The prominent characteristics of cluster 2 is their high number of lot inspected followed by high number of NRS, QCI, and SAR. The high number of lot inspected should be a good sign at first, because it means that the company trusts these suppliers to supplies in huge quantity because they have huge production capacity. But, when it is followed by high number of NRS, QCI, and SAR, it becomes problems because the suppliers are not giving good quality of parts supplied.

To overcome the problem above, it is suggested that the company did a supplier's plant visit. The supplier's plant visit is the same with PRPV activity of PT. X. The difference is PRPV activity here will only focus on the supplier within cluster 2. Because of it, the amount of resource and time will be reduced and the company will be more efficient. For example: in existing monthly PRPV activities, they need to visit 10 suppliers and send 3 officer for each visitation. When it happened in the same day, therefore the company need lots of resource and time. If they only focus on suppliers within cluster 2, which is less than 10 suppliers, therefore they will reduce the amount of resource, also time. This will help the company to be more efficient in time and resource.

#### *6.3.4. Supplier Development Program for Cluster 3*

Even though cluster 3 did not have any prominent characteristic like the rest of the clusters, suppliers also deserve a different program. They should be given incentives of performance for the low number of NRS, QCI, SAR and demerit. According to (Sillanpaa, et al., 2015), incentives have important roles in improving supplier capabilities and competence. The incentives could be in the form of awards, cost savings, consideration for increased volume, etc. (Sillanpaa, et al., 2015) also state that to improve supplier performance, the incentives that can be implemented is consideration for increased volume or increased business volume. This will make them focus on their performance and maintain the required standard. Also, it will strengthen the relationship between the company and suppliers.

# CHAPTER 7
# CONCLUSION AND SUGGESTION

This chapter explains the conclusion and suggestion of this research. The conclusion will explain how the objectives reached through this research. Also, the suggestion will be given for future research.

## 7.1. Conclusion

The conclusion of this research are as follows:

1. In terms of quality, there are 2 supplier performance criteria considered by PT. X which are performance and responsiveness. The indicators of performance are number of lot inspected, NRS, QCI and demerit. Meanwhile, indicators of responsiveness is demerit.
2. Considering those indicators, the K-Means clustering algorithm in MATLAB software generate three optimal clusters of PT. X suppliers.
3. Each clusters has their own characteristics. Cluster 1 has high number of NRS type A and demerit. Cluster 2 has high number of lot inspected followed by high number of NRS type B C, QCI type A B C and SAR. While cluster 3 has no prominent characteristics, but low number of every indicators.
4. Supplier development program are divided into 2: basic supplier development programs for all suppliers and programs for main characteristics of each cluster. The basic supplier development programs for all clusters include adding information in the existing monthly evaluation and quality problem training. While the others are: an intensive information exchange with supplier for cluster 1; Process Review Product Verification (PRPV) for cluster 2; incentives for cluster 3.

## 7.2. Suggestion

Suggestions for future research are:

1. Consider other supplier performance criteria to improve the result of clustering process and to consider other supplier development programs.

2. This research aims to give recommendation of supplier development programs for manufacturing company, therefore it should be reconsidered if implemented in other type of company.

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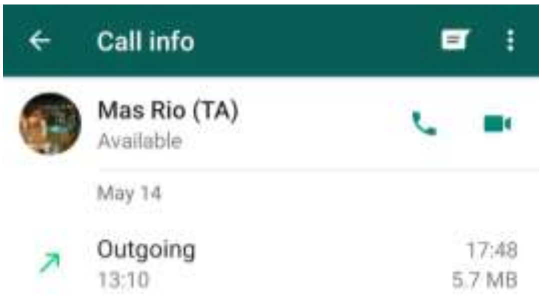
# ATTACHMENT

**Attachment A**

**<u>Minutes of Meeting</u>**

Date : Thursday, 14th May 2020
Interviewee : Rio Asruleovito
Position : Product Group Officer
Department : Incoming Quality Control
Proof :




Result of Interview:

1. Among nine quality dimensions in the literature review, PT. X only consider three of them, which are performance, conformance to standards, and responsiveness.
2. The indicator of performance are income rejection (NRS), in-process rejection (QCI) and special used parts (SAR). These indicators have data per month.
3. The indicator of conformance to standards are results of audit. The audit only done for several suppliers that has lots of quantity supplied. Also, the data gathered per 3 month.
4. The indicator of responsiveness is demerit. This indicator have data per month.

**Attachment B**

**Minutes of Meeting**

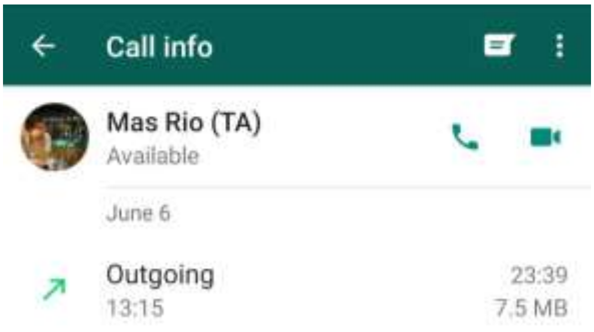
Date : Thursday, 6th June 2020

Interviewee : Rio Asruleovito

Position : Product Group Officer

Department : Incoming Quality Control

Proof :




Result of Interview:

1. Process Review Product Verification (PRPV) is an activity that is the same with system audit, but they focused on process. In PRPV the evaluator review the process begins from warehouse to the production line. The activity is done to know the process that produce defect part.
2. PRPV is done based on 3 factors: number of problem, recurrence of problem and supplier grade D for 3 months respectively. If one of the factors occurred, therefore the company should do a PRPV.
3. PRPV takes resource and time. To visit the suppliers they send officer from different job division: product group, operational, supplier development. They cannot do proper evaluation if they only send some of them. It also didn't have schedule, and it will takes time when doing PRPV.

**Attachment C**

**Minutes of Meeting**

Date : Thursday, 8th July 2020

Interviewee : Nadia Rahmah Noor Salsabila

Position : Supplier Development Officer

Department : Incoming Quality Control

Proof :


Result of Interview:

1. The company claim to their supplier several times in a month, so that the suppliers have heap of claim.
2. The suppliers are lacking in knowledge of quality problem. They also less able to analyze the root cause and set improvement action by themselves. These leads to the high number of NRS and QCI.
3. SAR caused by the suppliers did not understand well the limitation of defect that can be accepted.
4. The suppliers that have high number of lot inspected meaning that the suppliers has large production capacity.

**Attachment D**

Coding for data transformation step, using scaling function in MATLAB software.

```
function dataNew = scale_normalization(data,LL,UL)
%input:
%data = data that will be pre-processed in the format of m x
n
%m = amount of data, n = data dimension
%LL is the lower limit, UL is the upper limit

[dataMax]=max(data);
[dataMin]=min(data);
[R,C]=size(data);
dataNew = (data-ones(R,1)*dataMin).*(ones(R,1)*(UL-
LL)*(ones(1,C)./(dataMax-dataMin)))+LL;
```

**Attachment E**

Coding for modeling step, to cluster PT. X suppliers

```
function [cluster,centres] = kmeansa(k,data,niters)

%input:
%k = number of cluster
%data = data to be clustered
%niters = maximum iteration number
%Deskripsi

[ndata, data_dim]=size(data);
ncentres=k; %number of centres equals to number of cluster
if (ncentres > ndata)
    error('Too many clusters than data')
end

%determine random cluster centres
perm=randperm(ndata);
indpusat=perm(1:ncentres);
centres=data(indpusat,:);

%Loop utama
for n=1:niters
    %save old clusters
    old_centres=centres;
    %calculate distance between data and cluster centers
    d2=dist2(data,centres);
    %plot data to the nearest cluster
    [minvals,ind]=min(d2,[],2);
    post=accumarray(ind,1,[k,1]); %mencari banyak titik data
yg masuk kelas j
    cluster=ind;

    for j=1:ncentres
        if(post(j) > 0)
            centres(j,:)=sum(data(find(ind==j),:))/post(j);
%cari pusat baru
        end
    end

    change=sum(sum(abs(old_centres-centres)));
    if change < 1e-10 %is it convergent
        break
    end
end


function d2=dist2(data,centres)
ndata=size(data,1);
ncentres=size(centres,1);
```

```
d2=zeros(ndata,ncentres);
for j=1:ncentres
    d2(:,j)=sum((data-repmat(centres(j,:),ndata,1)).^2,2);
end
```

**Attachment F**

Cluster centers for each k and iteration that is resulted from modeling step.

| K = 2 | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Iteration | Cluster | Centroid | | | | | | | | | Silhouette Index | SSE |
| | | Lot Inspected | NRS A | NRS B | NRS C | QCI A | QCI B | QCI C | SAR | Demerit | | |
| 5 | 1 | 0.3276 | 0.0102 | 0.0959 | 0.1339 | 0.0697 | 0.1593 | 0.1711 | 0.1818 | 0.3571 | 0.7868 | 67.4115 |
| | 2 | 0.0344 | 0.0000 | 0.0120 | 0.0139 | 0.0023 | 0.0059 | 0.0161 | 0.0028 | 0.0000 | | |
| 50 | 1 | 0.3380 | 0.0109 | 0.0826 | 0.1168 | 0.0743 | 0.1664 | 0.1771 | 0.1898 | 0.3768 | 0.7927 | 67.2450 |
| | 2 | 0.0358 | 0.0000 | 0.0149 | 0.0178 | 0.0023 | 0.0063 | 0.0167 | 0.0034 | 0.0006 | | |
| 100 | 1 | 0.0358 | 0.0000 | 0.0149 | 0.0178 | 0.0023 | 0.0063 | 0.0167 | 0.0034 | 0.0006 | 0.7927 | 67.2450 |
| | 2 | 0.3380 | 0.0109 | 0.0826 | 0.1168 | 0.0743 | 0.1664 | 0.1771 | 0.1898 | 0.3768 | | |

| K = 3 | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Iteration | Cluster | Centroid | | | | | | | | | Silhouette Index | SSE |
| | | Lot Inspected | NRS A | NRS B | NRS C | QCI A | QCI B | QCI C | SAR | Demerit | | |
| 5 | 1 | 0.4913 | 0.0000 | 0.1367 | 0.1813 | 0.1194 | 0.2429 | 0.2324 | 0.2941 | 0.0222 | 0.8568 | 41.3294 |
| | 2 | 0.0340 | 0.0000 | 0.0123 | 0.0164 | 0.0014 | 0.0057 | 0.0168 | 0.0027 | 0.0023 | | |
| | 3 | 0.0799 | 0.0286 | 0.0286 | 0.0214 | 0.0048 | 0.0319 | 0.0672 | 0.0059 | 0.9238 | | |
| 50 | 1 | 0.0799 | 0.0286 | 0.0286 | 0.0214 | 0.0048 | 0.0319 | 0.0672 | 0.0059 | 0.9238 | 0.8634 | 41.2232 |

| K = 3 | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Iteration | Cluster | Centroid | | | | | | | | | Silhouette Index | SSE |
| | | Lot Inspected | NRS A | NRS B | NRS C | QCI A | QCI B | QCI C | SAR | Demerit | | |
| | 2 | 0.5182 | 0.0000 | 0.1148 | 0.1713 | 0.1235 | 0.2607 | 0.2538 | 0.3195 | 0.0247 | | |
| | 3 | 0.0361 | 0.0000 | 0.0155 | 0.0190 | 0.0022 | 0.0065 | 0.0171 | 0.0034 | 0.0022 | | |
| 100 | 1 | 0.0799 | 0.0286 | 0.0286 | 0.0214 | 0.0048 | 0.0319 | 0.0672 | 0.0059 | 0.9238 | 0.8634 | 41.2232 |
| | 2 | 0.0361 | 0.0000 | 0.0155 | 0.0190 | 0.0022 | 0.0065 | 0.0171 | 0.0034 | 0.0022 | | |
| | 3 | 0.5182 | 0.0000 | 0.1148 | 0.1713 | 0.1235 | 0.2607 | 0.2538 | 0.3195 | 0.0247 | | |

| K = 4 | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Iteration | Cluster | Centroid | | | | | | | | | Silhouette Index | SSE |
| | | Lot Inspected | NRS A | NRS B | NRS C | QCI A | QCI B | QCI C | SAR | Demerit | | |
| 5 | 1 | 0.0332 | 0.0000 | 0.0055 | 0.0166 | 0.0020 | 0.0057 | 0.0169 | 0.0023 | 0.0017 | 0.8530 | 36.7482 |
| | 2 | 0.1879 | 0.0000 | 0.5867 | 0.1167 | 0.0000 | 0.0410 | 0.0431 | 0.2386 | 0.0222 | | |
| | 3 | 0.5262 | 0.0000 | 0.0654 | 0.1755 | 0.1314 | 0.2692 | 0.2568 | 0.2759 | 0.0256 | | |
| | 4 | 0.0799 | 0.0286 | 0.0286 | 0.0214 | 0.0048 | 0.0319 | 0.0672 | 0.0059 | 0.9238 | | |
| 50 | 1 | 0.0346 | 0.0000 | 0.0146 | 0.0153 | 0.0014 | 0.0059 | 0.0164 | 0.0030 | 0.0023 | 0.8724 | 34.0260 |
| | 2 | 0.6088 | 0.0000 | 0.0545 | 0.0606 | 0.2172 | 0.3846 | 0.2139 | 0.1161 | 0.0303 | | |
| | 3 | 0.0799 | 0.0286 | 0.0286 | 0.0214 | 0.0048 | 0.0319 | 0.0672 | 0.0059 | 0.9238 | | |
| | 4 | 0.3456 | 0.0000 | 0.1923 | 0.3654 | 0.0000 | 0.0680 | 0.2738 | 0.5266 | 0.0128 | | |

| K = 4 | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Iteration** | **Cluster** | **Centroid** | | | | | | | | | **Silhouette Index** | **SSE** |
| | | **Lot Inspected** | **NRS A** | **NRS B** | **NRS C** | **QCI A** | **QCI B** | **QCI C** | **SAR** | **Demerit** | | |
| 100 | 1 | 0.5698 | 0.0000 | 0.0579 | 0.0954 | 0.1886 | 0.3421 | 0.2477 | 0.1288 | 0.0351 | 0.8720 | 34.5935 |
| | 2 | 0.0354 | 0.0000 | 0.0152 | 0.0198 | 0.0014 | 0.0058 | 0.0179 | 0.0033 | 0.0023 | | |
| | 3 | 0.0799 | 0.0286 | 0.0286 | 0.0214 | 0.0048 | 0.0319 | 0.0672 | 0.0059 | 0.9238 | | |
| | 4 | 0.4016 | 0.0000 | 0.2471 | 0.3015 | 0.0000 | 0.0860 | 0.2249 | 0.7286 | 0.0000 | | |

| K = 5 | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Iteration** | **Cluster** | **Centroid** | | | | | | | | | **Silhouette Index** | **SSE** |
| | | **Lot Inspected** | **NRS A** | **NRS B** | **NRS C** | **QCI A** | **QCI B** | **QCI C** | **SAR** | **Demerit** | | |
| 5 | 1 | 0.4078 | 0.0000 | 0.2444 | 0.2847 | 0.0000 | 0.0876 | 0.2320 | 0.7109 | 0.0185 | 0.7540 | 29.9055 |
| | 2 | 0.1758 | 0.0000 | 0.1050 | 0.1438 | 0.0188 | 0.0486 | 0.1287 | 0.0298 | 0.0125 | | |
| | 3 | 0.6642 | 0.0000 | 0.0370 | 0.0509 | 0.2222 | 0.4202 | 0.2527 | 0.1346 | 0.0370 | | |
| | 4 | 0.0799 | 0.0286 | 0.0286 | 0.0214 | 0.0048 | 0.0319 | 0.0672 | 0.0059 | 0.9238 | | |
| | 5 | 0.0193 | 0.0000 | 0.0031 | 0.0048 | 0.0010 | 0.0021 | 0.0048 | 0.0009 | 0.0006 | | |
| 50 | 1 | 0.2871 | 0.0000 | 0.2649 | 0.0642 | 0.0811 | 0.1164 | 0.0445 | 0.2364 | 0.0180 | 0.8234 | 32.4749 |
| | 2 | 0.1458 | 0.0000 | 0.0000 | 0.4107 | 0.0079 | 0.0055 | 0.2997 | 0.0016 | 0.0635 | | |
| | 3 | 0.0783 | 0.0294 | 0.0294 | 0.0110 | 0.0049 | 0.0328 | 0.0467 | 0.0060 | 0.9314 | | |
| | 4 | 0.0285 | 0.0000 | 0.0046 | 0.0074 | 0.0012 | 0.0051 | 0.0114 | 0.0014 | 0.0006 | | |

| K = 5 | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Iteration** | **Cluster** | **Centroid** | | | | | | | | | **Silhouette Index** | **SSE** |
| | | **Lot Inspected** | **NRS A** | **NRS B** | **NRS C** | **QCI A** | **QCI B** | **QCI C** | **SAR** | **Demerit** | | |
| | 5 | 0.6635 | 0.0000 | 0.1000 | 0.1917 | 0.1389 | 0.3551 | 0.3412 | 0.3237 | 0.0333 | | |
| 100 | 1 | 0.4078 | 0.0000 | 0.2444 | 0.2847 | 0.0000 | 0.0876 | 0.2320 | 0.7109 | 0.0185 | 0.8141 | 29.6475 |
| | 2 | 0.0799 | 0.0286 | 0.0286 | 0.0214 | 0.0048 | 0.0319 | 0.0672 | 0.0059 | 0.9238 | | |
| | 3 | 0.6532 | 0.0000 | 0.0357 | 0.0491 | 0.2202 | 0.4162 | 0.2437 | 0.1337 | 0.0357 | | |
| | 4 | 0.2005 | 0.0000 | 0.1136 | 0.2386 | 0.0265 | 0.0402 | 0.1845 | 0.0339 | 0.0152 | | |
| | 5 | 0.0269 | 0.0000 | 0.0090 | 0.0063 | 0.0012 | 0.0052 | 0.0084 | 0.0022 | 0.0012 | | |

| K = 6 | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Iteration** | **Cluster** | **Centroid** | | | | | | | | | **Silhouette Index** | **SSE** |
| | | **Lot Inspected** | **NRS A** | **NRS B** | **NRS C** | **QCI A** | **QCI B** | **QCI C** | **SAR** | **Demerit** | | |
| 5 | 1 | 0.4156 | 0.0000 | 0.2095 | 0.2440 | 0.0159 | 0.1337 | 0.2241 | 0.6823 | 0.0159 | 0.6561 | 28.5255 |
| | 2 | 0.0799 | 0.0286 | 0.0286 | 0.0214 | 0.0048 | 0.0319 | 0.0672 | 0.0059 | 0.9238 | | |
| | 3 | 0.3213 | 0.0000 | 0.1135 | 0.2736 | 0.0946 | 0.1143 | 0.1574 | 0.0587 | 0.0180 | | |
| | 4 | 0.0123 | 0.0000 | 0.0000 | 0.0034 | 0.0007 | 0.0013 | 0.0028 | 0.0006 | 0.0000 | | |
| | 5 | 0.1212 | 0.0000 | 0.0667 | 0.0341 | 0.0051 | 0.0264 | 0.0660 | 0.0113 | 0.0101 | | |
| | 6 | 0.7809 | 0.0000 | 0.0143 | 0.0179 | 0.2381 | 0.5467 | 0.3866 | 0.0977 | 0.0476 | | |
| 50 | 1 | 0.1932 | 0.0000 | 0.1725 | 0.0564 | 0.0294 | 0.0603 | 0.0957 | 0.0342 | 0.0131 | 0.7870 | 26.5736 |

| K = 6 | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Iteration | Cluster | Centroid | | | | | | | | | Silhouette Index | SSE |
| | | Lot Inspected | NRS A | NRS B | NRS C | QCI A | QCI B | QCI C | SAR | Demerit | | |
| | 2 | 0.0783 | 0.0294 | 0.0294 | 0.0110 | 0.0049 | 0.0328 | 0.0467 | 0.0060 | 0.9314 | | |
| | 3 | 0.4134 | 0.0000 | 0.2190 | 0.2560 | 0.0079 | 0.1190 | 0.2269 | 0.6727 | 0.0159 | | |
| | 4 | 0.6790 | 0.0000 | 0.0400 | 0.0550 | 0.2333 | 0.4215 | 0.2588 | 0.1037 | 0.0400 | | |
| | 5 | 0.1287 | 0.0000 | 0.0000 | 0.5268 | 0.0000 | 0.0000 | 0.3403 | 0.0024 | 0.0714 | | |
| | 6 | 0.0228 | 0.0000 | 0.0019 | 0.0072 | 0.0009 | 0.0034 | 0.0069 | 0.0014 | 0.0006 | | |
| 100 | 1 | 0.4078 | 0.0000 | 0.2444 | 0.2847 | 0.0000 | 0.0876 | 0.2320 | 0.7109 | 0.0185 | 0.7943 | 26.4945 |
| | 2 | 0.6642 | 0.0000 | 0.0370 | 0.0509 | 0.2222 | 0.4202 | 0.2527 | 0.1346 | 0.0370 | | |
| | 3 | 0.2081 | 0.0000 | 0.1750 | 0.0599 | 0.0313 | 0.0657 | 0.1042 | 0.0423 | 0.0069 | | |
| | 4 | 0.1255 | 0.0000 | 0.0000 | 0.5083 | 0.0000 | 0.0026 | 0.3255 | 0.0022 | 0.0889 | | |
| | 5 | 0.0230 | 0.0000 | 0.0030 | 0.0072 | 0.0009 | 0.0033 | 0.0069 | 0.0014 | 0.0006 | | |
| | 6 | 0.0783 | 0.0294 | 0.0294 | 0.0110 | 0.0049 | 0.0328 | 0.0467 | 0.0060 | 0.9314 | | |

| K = 7 | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Iteration | Cluster | Centroid | | | | | | | | | Silhouette Index | SSE |
| | | Lot Inspected | NRS A | NRS B | NRS C | QCI A | QCI B | QCI C | SAR | Demerit | | |
| 5 | 1 | 0.0799 | 0.0286 | 0.0286 | 0.0214 | 0.0048 | 0.0319 | 0.0672 | 0.0059 | 0.9238 | 0.6980 | 27.8919 |
| | 2 | 0.4140 | 0.0000 | 0.2267 | 0.3333 | 0.0000 | 0.0949 | 0.2392 | 0.7678 | 0.0000 | | |

| K = 7 | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Iteration | Cluster | Centroid | | | | | | | | | Silhouette Index | SSE |
| | | Lot Inspected | NRS A | NRS B | NRS C | QCI A | QCI B | QCI C | SAR | Demerit | | |
| | 3 | 0.6369 | 0.0000 | 0.0452 | 0.0484 | 0.1989 | 0.3859 | 0.2391 | 0.1495 | 0.0430 | | |
| | 4 | 0.6158 | 0.6158 | 0.6158 | 0.6158 | 0.6158 | 0.6158 | 0.6158 | 0.6158 | 0.6158 | | |
| | 5 | 0.0145 | 0.0000 | 0.0020 | 0.0035 | 0.0007 | 0.0012 | 0.0038 | 0.0006 | 0.0000 | | |
| | 6 | 0.1510 | 0.0000 | 0.0605 | 0.0494 | 0.0116 | 0.0385 | 0.0766 | 0.0174 | 0.0116 | | |
| | 7 | 0.1639 | 0.0000 | 0.2200 | 0.4000 | 0.0250 | 0.0308 | 0.2176 | 0.0666 | 0.0167 | | |
| 50 | 1 | 0.1260 | 0.0000 | 0.0000 | 0.5875 | 0.0000 | 0.0000 | 0.4471 | 0.0033 | 0.1000 | 0.7723 | 23.6306 |
| | 2 | 0.6589 | 0.0000 | 0.0429 | 0.0491 | 0.2143 | 0.4093 | 0.2563 | 0.1445 | 0.0476 | | |
| | 3 | 0.0783 | 0.0294 | 0.0294 | 0.0110 | 0.0049 | 0.0328 | 0.0467 | 0.0060 | 0.9314 | | |
| | 4 | 0.1484 | 0.0000 | 0.5667 | 0.0729 | 0.0000 | 0.0385 | 0.0098 | 0.0891 | 0.0278 | | |
| | 5 | 0.2002 | 0.0000 | 0.0276 | 0.0884 | 0.0287 | 0.0597 | 0.1116 | 0.0399 | 0.0057 | | |
| | 6 | 0.4140 | 0.0000 | 0.2267 | 0.3333 | 0.0000 | 0.0949 | 0.2392 | 0.7678 | 0.0000 | | |
| | 7 | 0.0195 | 0.0000 | 0.0046 | 0.0050 | 0.0006 | 0.0021 | 0.0053 | 0.0005 | 0.0006 | | |
| 100 | 1 | 0.6589 | 0.0000 | 0.0429 | 0.0491 | 0.2143 | 0.4093 | 0.2563 | 0.1445 | 0.0476 | 0.7723 | 23.6306 |
| | 2 | 0.4140 | 0.0000 | 0.2267 | 0.3333 | 0.0000 | 0.0949 | 0.2392 | 0.7678 | 0.0000 | | |
| | 3 | 0.0195 | 0.0000 | 0.0046 | 0.0050 | 0.0006 | 0.0021 | 0.0053 | 0.0005 | 0.0006 | | |
| | 4 | 0.1260 | 0.0000 | 0.0000 | 0.5875 | 0.0000 | 0.0000 | 0.4471 | 0.0033 | 0.1000 | | |
| | 5 | 0.0783 | 0.0294 | 0.0294 | 0.0110 | 0.0049 | 0.0328 | 0.0467 | 0.0060 | 0.9314 | | |
| | 6 | 0.1484 | 0.0000 | 0.5667 | 0.0729 | 0.0000 | 0.0385 | 0.0098 | 0.0891 | 0.0278 | | |
| | 7 | 0.2002 | 0.0000 | 0.0276 | 0.0884 | 0.0287 | 0.0597 | 0.1116 | 0.0399 | 0.0057 | | |

| K = 8 | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Iteration** | **Cluster** | **Centroid** | | | | | | | | | **Silhouette Index** | **SSE** |
| | | **Lot Inspected** | **NRS A** | **NRS B** | **NRS C** | **QCI A** | **QCI B** | **QCI C** | **SAR** | **Demerit** | | |
| 5 | 1 | 0.1466 | 0.0000 | 0.0278 | 0.0347 | 0.0116 | 0.0347 | 0.0114 | 0.0132 | 0.0046 | 0.6114 | 24.1192 |
| | 2 | 0.1388 | 0.0000 | 0.0000 | 0.4188 | 0.0083 | 0.0058 | 0.3118 | 0.0017 | 0.0667 | | |
| | 3 | 0.0078 | 0.0000 | 0.0023 | 0.0034 | 0.0004 | 0.0009 | 0.0009 | 0.0004 | 0.0000 | | |
| | 4 | 0.4275 | 0.0000 | 0.2000 | 0.3571 | 0.0000 | 0.1016 | 0.2521 | 0.7718 | 0.0000 | | |
| | 5 | 0.6168 | 0.0000 | 0.0485 | 0.0530 | 0.2020 | 0.3741 | 0.2353 | 0.1507 | 0.0404 | | |
| | 6 | 0.1789 | 0.0000 | 0.5200 | 0.0750 | 0.0000 | 0.0385 | 0.0275 | 0.1488 | 0.0222 | | |
| | 7 | 0.0743 | 0.0000 | 0.0040 | 0.0125 | 0.0033 | 0.0115 | 0.1082 | 0.0015 | 0.0000 | | |
| | 8 | 0.0783 | 0.0294 | 0.0294 | 0.0110 | 0.0049 | 0.0328 | 0.0467 | 0.0060 | 0.9314 | | |
| 50 | 1 | 3.8526 | 3.8526 | 3.8526 | 3.8526 | 3.8526 | 3.8526 | 3.8526 | 3.8526 | 3.8526 | 0.7418 | 22.4203 |
| | 2 | 0.1813 | 0.0000 | 0.0300 | 0.0833 | 0.0278 | 0.0590 | 0.1020 | 0.0209 | 0.0111 | | |
| | 3 | 3.8526 | 3.8526 | 3.8526 | 3.8526 | 3.8526 | 3.8526 | 3.8526 | 3.8526 | 3.8526 | | |
| | 4 | 0.1879 | 0.0000 | 0.5867 | 0.1167 | 0.0000 | 0.0410 | 0.0431 | 0.2386 | 0.0222 | | |
| | 5 | 0.5777 | 0.0000 | 0.0651 | 0.1337 | 0.1395 | 0.3005 | 0.2531 | 0.3283 | 0.0310 | | |
| | 6 | 0.0783 | 0.0294 | 0.0294 | 0.0110 | 0.0049 | 0.0328 | 0.0467 | 0.0060 | 0.9314 | | |
| | 7 | 0.1260 | 0.0000 | 0.0000 | 0.5875 | 0.0000 | 0.0000 | 0.4471 | 0.0033 | 0.1000 | | |
| | 8 | 0.0187 | 0.0000 | 0.0038 | 0.0048 | 0.0006 | 0.0016 | 0.0048 | 0.0005 | 0.0000 | | |
| 100 | 1 | 0.1484 | 0.0000 | 0.5667 | 0.0729 | 0.0000 | 0.0385 | 0.0098 | 0.0891 | 0.0278 | 0.7649 | 23.6435 |

| K = 8 | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Iteration** | **Cluster** | **Centroid** | | | | | | | | | **Silhouette Index** | **SSE** |
| | | **Lot Inspected** | **NRS A** | **NRS B** | **NRS C** | **QCI A** | **QCI B** | **QCI C** | **SAR** | **Demerit** | | |
| | 2 | 0.0783 | 0.0294 | 0.0294 | 0.0110 | 0.0049 | 0.0328 | 0.0467 | 0.0060 | 0.9314 | | |
| | 3 | 0.1260 | 0.0000 | 0.0000 | 0.5875 | 0.0000 | 0.0000 | 0.4471 | 0.0033 | 0.1000 | | |
| | 4 | 0.1848 | 0.0000 | 0.0295 | 0.0820 | 0.0273 | 0.0593 | 0.1041 | 0.0261 | 0.0109 | | |
| | 5 | 0.6642 | 0.0000 | 0.0370 | 0.0509 | 0.2222 | 0.4202 | 0.2527 | 0.1346 | 0.0370 | | |
| | 6 | 0.6158 | 0.6158 | 0.6158 | 0.6158 | 0.6158 | 0.6158 | 0.6158 | 0.6158 | 0.6158 | | |
| | 7 | 0.0187 | 0.0000 | 0.0038 | 0.0048 | 0.0006 | 0.0016 | 0.0048 | 0.0005 | 0.0000 | | |
| | 8 | 0.4193 | 0.0000 | 0.2111 | 0.2917 | 0.0000 | 0.0919 | 0.2418 | 0.7028 | 0.0185 | | |

| K = 9 | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Iteration** | **Cluster** | **Centroid** | | | | | | | | | **Silhouette Index** | **SSE** |
| | | **Lot Inspected** | **NRS A** | **NRS B** | **NRS C** | **QCI A** | **QCI B** | **QCI C** | **SAR** | **Demerit** | | |
| 5 | 1 | 0.4900 | 0.0000 | 0.2667 | 0.5000 | 0.0000 | 0.1026 | 0.3529 | 0.8263 | 0.0000 | 0.6093 | 24.1044 |
| | 2 | 0.0936 | 0.0000 | 0.3913 | 0.0109 | 0.0000 | 0.0217 | 0.0179 | 0.0618 | 0.0145 | | |
| | 3 | 0.1260 | 0.0000 | 0.0000 | 0.5875 | 0.0000 | 0.0000 | 0.4471 | 0.0033 | 0.1000 | | |
| | 4 | 0.2313 | 0.0000 | 0.1100 | 0.2313 | 0.0500 | 0.0750 | 0.0618 | 0.1099 | 0.0167 | | |
| | 5 | 0.0980 | 0.0000 | 0.0000 | 0.0292 | 0.0037 | 0.0132 | 0.0144 | 0.0111 | 0.0037 | | |
| | 6 | 0.0783 | 0.0294 | 0.0294 | 0.0110 | 0.0049 | 0.0328 | 0.0467 | 0.0060 | 0.9314 | | |

| K = 9 | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Iteration** | **Cluster** | **Centroid** | | | | | | | | | **Silhouette Index** | **SSE** |
| | | **Lot Inspected** | **NRS A** | **NRS B** | **NRS C** | **QCI A** | **QCI B** | **QCI C** | **SAR** | **Demerit** | | |
| | 7 | 0.6115 | 0.0000 | 0.0471 | 0.0478 | 0.1814 | 0.3575 | 0.2318 | 0.2049 | 0.0392 | | |
| | 8 | 0.0065 | 0.0000 | 0.0000 | 0.0023 | 0.0004 | 0.0009 | 0.0031 | 0.0004 | 0.0000 | | |
| | 9 | 0.1791 | 0.0000 | 0.0077 | 0.0144 | 0.0128 | 0.0488 | 0.1833 | 0.0016 | 0.0000 | | |
| 50 | 1 | 0.4354 | 0.0000 | 0.1600 | 0.2625 | 0.0167 | 0.1442 | 0.2412 | 0.6735 | 0.0167 | 0.7290 | 22.3028 |
| | 2 | 0.1349 | 0.0000 | 0.0000 | 0.5625 | 0.0000 | 0.0000 | 0.2745 | 0.0026 | 0.0278 | | |
| | 3 | 0.1543 | 0.0000 | 0.5692 | 0.0673 | 0.0000 | 0.0355 | 0.0136 | 0.1370 | 0.0256 | | |
| | 4 | 0.0520 | 0.0400 | 0.0160 | 0.0000 | 0.0000 | 0.0185 | 0.0212 | 0.0031 | 1.0000 | | |
| | 5 | 0.1002 | 0.0000 | 0.0118 | 0.0368 | 0.0098 | 0.0204 | 0.2976 | 0.0000 | 0.0000 | | |
| | 6 | 0.1496 | 0.0000 | 0.0600 | 0.0750 | 0.0167 | 0.0654 | 0.1824 | 0.0129 | 0.7333 | | |
| | 7 | 0.1896 | 0.0000 | 0.0316 | 0.0592 | 0.0175 | 0.0547 | 0.0351 | 0.0279 | 0.0117 | | |
| | 8 | 0.6706 | 0.0000 | 0.0480 | 0.0650 | 0.2467 | 0.4169 | 0.2565 | 0.0841 | 0.0400 | | |
| | 9 | 0.0155 | 0.0000 | 0.0032 | 0.0040 | 0.0007 | 0.0014 | 0.0041 | 0.0006 | 0.0000 | | |
| 100 | 1 | 0.8123 | 0.0000 | 0.0000 | 0.0000 | 0.2121 | 0.5804 | 0.4706 | 0.0883 | 0.0606 | 0.7133 | 21.0143 |
| | 2 | 0.1304 | 0.0000 | 0.0000 | 0.5417 | 0.0000 | 0.0000 | 0.3235 | 0.0026 | 0.0000 | | |
| | 3 | 0.1457 | 0.0000 | 0.0194 | 0.0451 | 0.0069 | 0.0304 | 0.0891 | 0.0146 | 0.0000 | | |
| | 4 | 0.1458 | 0.0000 | 0.0000 | 0.2250 | 0.0000 | 0.1231 | 0.2471 | 0.0298 | 0.4000 | | |
| | 5 | 0.4275 | 0.0000 | 0.2000 | 0.3571 | 0.0000 | 0.1016 | 0.2521 | 0.7718 | 0.0000 | | |
| | 6 | 0.0783 | 0.0294 | 0.0294 | 0.0110 | 0.0049 | 0.0328 | 0.0467 | 0.0060 | 0.9314 | | |
| | 7 | 0.0146 | 0.0000 | 0.0032 | 0.0038 | 0.0007 | 0.0012 | 0.0031 | 0.0006 | 0.0000 | | |

| K = 9 | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Iteration | Cluster | Centroid | | | | | | | | | Silhouette Index | SSE |
| | | Lot Inspected | NRS A | NRS B | NRS C | QCI A | QCI B | QCI C | SAR | Demerit | | |
| | 8 | 0.1543 | 0.0000 | 0.5692 | 0.0673 | 0.0000 | 0.0355 | 0.0136 | 0.1370 | 0.0256 | | |
| | 9 | 0.5027 | 0.0000 | 0.0880 | 0.0900 | 0.1933 | 0.2492 | 0.1059 | 0.1675 | 0.0133 | | |

| K = 10 | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Iteration | Cluster | Centroid | | | | | | | | | Silhouette Index | SSE |
| | | Lot Inspected | NRS A | NRS B | NRS C | QCI A | QCI B | QCI C | SAR | Demerit | | |
| 5 | 1 | 0.0906 | 0.0000 | 0.0000 | 0.2396 | 0.0000 | 0.0128 | 0.0474 | 0.0036 | 0.0093 | 0.5741 | 23.7173 |
| | 2 | 0.4001 | 0.0000 | 0.0900 | 0.2375 | 0.1000 | 0.1500 | 0.2147 | 0.0630 | 0.0000 | | |
| | 3 | 0.4278 | 0.0000 | 0.1895 | 0.2632 | 0.0088 | 0.1235 | 0.2353 | 0.7057 | 0.0175 | | |
| | 4 | 0.1813 | 0.0000 | 0.0114 | 0.0107 | 0.0143 | 0.0407 | 0.1412 | 0.0286 | 0.0000 | | |
| | 5 | 0.1617 | 0.0000 | 0.0545 | 0.0682 | 0.0152 | 0.1154 | 0.1123 | 0.0250 | 0.5758 | | |
| | 6 | 0.0766 | 0.0000 | 0.0000 | 0.0000 | 0.0019 | 0.0063 | 0.0198 | 0.0011 | 0.0000 | | |
| | 7 | 0.0973 | 0.0000 | 0.3760 | 0.0400 | 0.0067 | 0.0262 | 0.0141 | 0.0428 | 0.0133 | | |
| | 8 | 0.0047 | 0.0000 | 0.0000 | 0.0006 | 0.0004 | 0.0006 | 0.0010 | 0.0003 | 0.0000 | | |
| | 9 | 0.0559 | 0.0370 | 0.0148 | 0.0093 | 0.0000 | 0.0171 | 0.0545 | 0.0029 | 1.0000 | | |
| | 10 | 0.7210 | 0.0000 | 0.0118 | 0.0147 | 0.2843 | 0.5090 | 0.3287 | 0.1179 | 0.0392 | | |
| 50 | 1 | 0.1349 | 0.0000 | 0.0000 | 0.5625 | 0.0000 | 0.0000 | 0.2745 | 0.0026 | 0.0278 | 0.6690 | 19.9232 |

| K = 10 | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Iteration** | **Cluster** | **Centroid** | | | | | | | | | **Silhouette Index** | **SSE** |
| | | **Lot Inspected** | **NRS A** | **NRS B** | **NRS C** | **QCI A** | **QCI B** | **QCI C** | **SAR** | **Demerit** | | |
| | 2 | 0.5249 | 0.0000 | 0.1000 | 0.1111 | 0.2500 | 0.2607 | 0.0621 | 0.0657 | 0.0000 | | |
| | 3 | 0.4254 | 0.0000 | 0.1810 | 0.2500 | 0.0159 | 0.1374 | 0.2325 | 0.6754 | 0.0159 | | |
| | 4 | 0.1165 | 0.0000 | 0.0111 | 0.0347 | 0.0093 | 0.0235 | 0.2941 | 0.0189 | 0.0000 | | |
| | 5 | 0.1617 | 0.0000 | 0.0545 | 0.0682 | 0.0152 | 0.1154 | 0.1123 | 0.0250 | 0.5758 | | |
| | 6 | 0.1415 | 0.0000 | 0.0150 | 0.0375 | 0.0042 | 0.0255 | 0.0228 | 0.0134 | 0.0000 | | |
| | 7 | 0.1484 | 0.0000 | 0.5667 | 0.0729 | 0.0000 | 0.0385 | 0.0098 | 0.0891 | 0.0278 | | |
| | 8 | 0.0101 | 0.0000 | 0.0034 | 0.0037 | 0.0007 | 0.0009 | 0.0037 | 0.0006 | 0.0000 | | |
| | 9 | 0.0559 | 0.0370 | 0.0148 | 0.0093 | 0.0000 | 0.0171 | 0.0545 | 0.0029 | 1.0000 | | |
| | 10 | 0.8123 | 0.0000 | 0.0000 | 0.0000 | 0.2121 | 0.5804 | 0.4706 | 0.0883 | 0.0606 | | |
| 100 | 1 | 0.0783 | 0.0294 | 0.0294 | 0.0110 | 0.0049 | 0.0328 | 0.0467 | 0.0060 | 0.9314 | 0.6688 | 19.7550 |
| | 2 | 0.1361 | 0.0000 | 0.0143 | 0.0000 | 0.0048 | 0.0236 | 0.0185 | 0.0141 | 0.0048 | | |
| | 3 | 0.0086 | 0.0000 | 0.0035 | 0.0000 | 0.0004 | 0.0008 | 0.0037 | 0.0005 | 0.0000 | | |
| | 4 | 0.4140 | 0.0000 | 0.2267 | 0.3333 | 0.0000 | 0.0949 | 0.2392 | 0.7678 | 0.0000 | | |
| | 5 | 0.1484 | 0.0000 | 0.5667 | 0.0729 | 0.0000 | 0.0385 | 0.0098 | 0.0891 | 0.0278 | | |
| | 6 | 0.0923 | 0.0000 | 0.0054 | 0.1757 | 0.0045 | 0.0187 | 0.0286 | 0.0035 | 0.0090 | | |
| | 7 | 0.1034 | 0.0000 | 0.0125 | 0.0234 | 0.0104 | 0.0216 | 0.2721 | 0.0000 | 0.0000 | | |
| | 8 | 0.4957 | 0.0000 | 0.0846 | 0.0865 | 0.1859 | 0.2544 | 0.1109 | 0.1667 | 0.0256 | | |
| | 9 | 0.8123 | 0.0000 | 0.0000 | 0.0000 | 0.2121 | 0.5804 | 0.4706 | 0.0883 | 0.0606 | | |
| | 10 | 0.1260 | 0.0000 | 0.0000 | 0.5875 | 0.0000 | 0.0000 | 0.4471 | 0.0033 | 0.1000 | | |

# BIOGRAPHY

The author named Anggi Prienda Sukma and was born in Jakarta, August 31st 1998. The author is the first child of three. Educational background of author are SDN Cempaka Putih Barat 05, SMP Negeri 99 Jakarta, SMA N 77 Jakarta and got bachelor degree in Department of Industrial Engineering of ITS Surabaya after going through 8 semesters from 2016-2020.

During college life, the author not only focused on academic activities but also organizational and professional experience. The author was a staff of PSDM BEM FTI ITS 2017/2018, which responsible in faculty-level events. Also, the author was a manufacturing system laboratory assistant from 2018-2020. As an assistant, the author responsible to held training, help lecturer conduct courses, assists in practicum and courses. For professional experience, the author was an Incoming Quality Control Department intern of OMRON Manufacturing of Indonesia from June 2019-August 2019. Besides organizational and professional experience, the author actively involved in several events, such as a volunteer of ITS community service that held by Manufacturing System Laboratory, Liaison Officer of IE Games 12th Edition, Steering Committee of IE Games 13th Edition, and participant of AutoCAD training.

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