Quality Control Analysis in the E-Bike Assembly Process Using Six Sigma and Kaizen Methods

Raden Danang Aryo Putro Satriyonoa) and Alzura Ryanda Fadly Radiansyahb)

Faculty of Engineering, Universitas Muhammadiyah Surakarta, Surakarta, Indonesia

a) Corresponding author: mailto:rda715@ums.ac.id

b) D600200021@ums.ac.id

**Abstract.**  PT. Roda Pasifik Mandiri is a manufacturing company engaged in the production and assembly of bicycles of various types and sizes. In addition to bicycles, this company also produces electric motorcycles. In maintaining customer comfort and satisfaction, the company must provide quality according to customer demand. To maintain quality, it is necessary to control the quality of each production process. Quality control is very important in influencing the quality of products that will be distributed to customers. The six sigma method is a quality control method, using six sigma with the DMAIC (define, measure, analyze, improve, and control) approach. This approach is supported by SIPOC diagrams, diagrams that explain the flow from suppliers to customers. The data processing uses a p-chart to determine the control limits for product defects, a Pareto chart to determine the highest defects, and a fishbone diagram to see cause-effect caused by humans, machines, materials, methods, and the environment. The last data processing is using the kaizen method which functions to provide suggestions regarding the cause-effect defects that occur in each assembly.

**Keywords:** Quality Control, Six Sigma, Defect, Kaizen, E-Bike

# INTRODUCTION

Quality is the characteristic possessed by a product or service, and these characteristics are related to one or more other characteristics. Quality becomes one of the assessment and decision factors for consumers in the competition between products and services. Quality is based on the actual experience of customers with the product and service, measured according to customer requirements and demands [1]. Meanwhile, according to Kusumawati and Fitriyeni [2], quality is a standard characteristic of a product or service aimed at satisfying customer demands and needs [3]. Good quality has a consistent goal and benefits. Generally, quality is very important for a product or service to gain customer trust. Customers certainly expect products or services of good quality [4]. Therefore, companies must create quality products or services to compete effectively and understand customer satisfaction more deeply and the concept of improving the quality of the products or services produced [5]. To improve and maintain good quality, quality control is needed [6].

Quality control is a control system from the beginning of the process to the finished product, even up to distribution to customers [6]. Quality control is crucial to maintaining and improving the quality of the products produced. If the quality is good and meets the standards, the product can proceed to the next process. Conversely, if the quality does not meet the standards, the product will not proceed to the next process, which will be detrimental to the company [6]. Meanwhile, according to Zulaikha [3], quality control is an activity closely related to the production process. Quality control is essentially a system of inspection and maintenance of a certain quality level of the product or process through careful planning, appropriate equipment use, continuous inspection, and corrective actions if needed. The goals of quality control include reducing defective products in the company because if there are many defective products, it will impact the quality cost, company image, and customer satisfaction [4]. Problems with many defective products can be analyzed first by understanding the types of defects and then identifying the causes of recurring defects. Identifying defect types and impacts can use the Six Sigma method [5] [6].

Six Sigma is a comprehensive, flexible, and systematic problem-solving method using the DMAIC (Define, Measure, Analyze, Improve, and Control) standard process. Six Sigma aims to improve quality in meeting customer needs, with successful quality improvement starting with accurately identifying defect types and influencing factors [4]. Tools required in problem identification include Pareto diagrams, fishbone diagrams, p-charts, and other statistical tools [6]. Six Sigma translates into a measurement process using statistical tools and techniques to reduce defects to no more than 3.4 defects per million activities or opportunities. DPMO (Defect Per Million Opportunities) focuses on achieving customer satisfaction. Before and after improvements, this measurement compares the percentage of defects, which determines the sigma level.

Kaizen is a term for (kai) change and (zen) improvement, meaning continuous improvement involving everyone. This method significantly influences workers' attitudes and the results created, making the products more quality and increasing production productivity. Kaizen implementation can use the five-step plan (5S): Seiri (Sorting), Seiso (Cleaning), Seiton (Organizing), Seiketsu (Standardizing), and Shitsuke (Sustaining) [6].

# METHODS

Initial Step of the Research

The initial step of the research involves observing the assembly process on line 2 at PT. Roda Pasifik Mandiri Semarang. The observation was conducted from July 3 to July 28, 2023. The purpose of the observation is to study the events and processes within the company, focusing on familiarizing and understanding the company's conditions [1].

1. Field Study and Literature Study The field study was conducted on line 2 of the e-bike assembly process at PT. Roda Pasifik Mandiri. This activity aims to understand the assembly process on line 2 and gather data directly or through interviews with the operators. The literature study was conducted to obtain theoretical information and material that supports solving the problems related to the practical work research [3]. The literature study was done by reading journals, articles, and e-books on the internet.
2. Problem Identification and Formulation The problem identification involves observing the assembly process and analyzing and identifying the causes of frequent problems. The formulation of the defect problem aims to identify the factors and impacts on the e-bike [5].
3. Determining the Research Method The method used in this research is the Six Sigma method. Six Sigma is an improvement method that emphasizes continuous improvement, consisting of five stages known as DMAIC (Define, Measure, Analyze, Improve, Control) [6].
4. Defect Data Collection The data collection stage involves gathering necessary defect data and production data of the Groza RX, Groza X3.5, Groza X4, Groza X5, Groza X6, and Groza RX e-bike models, which will be used in data processing [6].
5. Data Processing The data processing in this practical work research uses the DMAIC stages in the e-bike assembly of the Groza model at PT. Roda Pasifik Mandiri. The data processing begins with creating a SIPOC diagram to describe the assembly process of the Groza e-bike at the Define stage [7]. The creation of a p-chart and the DMAIC process in determining the number of defects occurring during the line 2 assembly process is conducted at the Measure stage [8]. Identifying the causes of problems involves analyzing the factors causing assembly nonconformities based on defects using Pareto diagrams and fishbone diagrams [9]. Preventing product defects using the Kaizen method is conducted at the Improve stage [10]. The next stage is control to manage the improvements made and implemented at the Improve stage [11].
6. Conclusion The conclusion includes the goals to be achieved and the results of the data analysis performed [12].

# RESULTS AND DISCUSSION

## Data Collection

Data collection is conducted to analyze product defects at PT. Roda Pasifik Mandiri. Poor product quality will lead to defects. A high number of product defects will disrupt the production process due to the necessary rework activities. This data serves as supporting information for the research and consists of data on the Groza e-bike types, including Groza X4, Groza X5, Groza X6, Groza 3.5, Groza MX, and Groza RX. The following is the table of Production Data for Groza E-Bike Types from January to July 2023.

**TABLE 1**. Data Recapitulation of Groza Type E-Bike Defect Categories

|  |  |  |
| --- | --- | --- |
| **Defect Category** | **Total Defect** | **Percentage of Defect** |
| Cover Body Defect | 297 | 19% |
| Wiring Defect | 412 | 27% |
| Frame Defect | 211 | 14% |
| Cover Battery Defect | 456 | 30% |
| Rantai Defect | 157 | 10% |
| Total | 1533 | 100% |

Based on the data above, the most dominant or highest defects are found in the battery cover defects, followed by electrical defects, body cover defects, frame defects, and lastly, chain defects.

## Data Processing

Data Processing is carried out using the Six Sigma method through the DMAIC phases (Define, Measure, Analyze, Improve, Control).

**a. Define Stage** The Define stage is used to identify and define the e-bike production process from start to finish. Below is a SIPOC diagram that helps to understand the production flow of the e-bike product

*.*

**Suppliers**

**Inputs**

**Process**

**Outputs**

**Customers**

**PT Energy China Tianjin Indonesia PT Tianfu**

**Sparepart E-Bike**

**E-Bike Tipe Groza**

**Seluruh Indonesia**

**± 80 Distributor**

**Assembly Part Quality Control**

**Electrical Assembly**

**Electrical Quality Control**

**Packaging**

**E-Bike Defect**

**Revision**

**FIGURE 1.** SIPOC Diagram

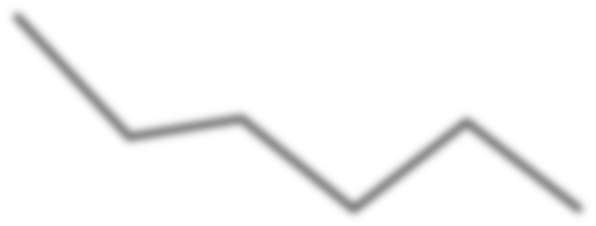
Description:

1. **Suppliers** Suppliers are individuals, organizations, or systems that provide the resources needed by the company to produce goods or services. The suppliers for PT. Roda Pasifik Mandiri include major Chinese companies such as PT. Energy China Tianjin Indonesia and PT. Tianfu.
2. **Inputs** Inputs are materials, information, or other resources provided by suppliers to the company for consumption or transformation during the production process. Inputs in the e-bike production process include spare parts such as frames, body covers, brakes, chains, battery covers, batteries, lights, tires, cables, etc.
3. **Process** The Process refers to transforming inputs into outputs. All inputs go through several stages:
   * The first process involves assembling visual components such as lights, tires, brakes, chains, body covers, batteries, etc.
   * The second process is quality control, where a visual inspection is performed to determine if the product can proceed to the next stage.
   * The third process involves assembling and installing electrical components such as cables, lights, signal lights, horns, and speedometers.
   * The fourth process is electrical quality control, which checks if all electrical components function properly.
   * The fifth process is e-bike packaging.
   * The sixth process involves re-checking the e-bike to identify and address any remaining defects.
4. **Outputs** Outputs are the goods or services produced by the process for use by customers. The output produced from this process is the Groza e-bike.
5. **Customers** Customers are individuals, organizations, or systems that receive the output from the process. Customers of PT. Roda Pasifik Mandiri include several distributors in Indonesia.

**b. Measure Stage** The Measure stage involves collecting and calculating data on production quantities and defect proportions using a p-chart, as well as measuring process performance with DPMO and sigma values. In statistics, a p-chart is used to monitor the proportion of defective products within control limits. Below is the Table of p-Chart Calculations for Defects Before Improvement from January to July 2023 and the p-Chart Graph Before Improvement

**TABLE 2.** Calculation of P Control Map for Number of Defects Before Improvement for January - July 2023.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Period** | **Production Quantity** | **Number of Defects** | **Defect Proportion** | **CL** | **UCL** | **LCL** |
| January | 2859 | 374 | 0,13 | 0,077 | 0,092 | 0,062 |
| February | 3751 | 270 | 0,07 | 0,077 | 0,090 | 0,064 |
| March | 5695 | 461 | 0,08 | 0,077 | 0,088 | 0,067 |
| April | 1044 | 38 | 0,04 | 0,077 | 0,102 | 0,053 |
| May | 3596 | 285 | 0,08 | 0,077 | 0,091 | 0,064 |
| July | 1925 | 297 | 0,04 | 0,077 | 0,092 | 0,062 |
| **Total** | 19804 | 1533 |  | | | |



P-Chart Before Revised

0,14

0,12

0,10

0,08

0,06

0,04

0,02

1

2

3

4

5

6

Defect Proportion

CL

UCL

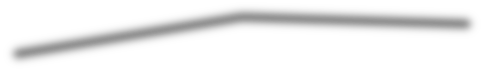
LCL

**FIGURE 2.** P-Chart Chart Before Improvement

Next, the following is the Calculation Table for the P-Chart for the Number of Defects After Improvements from January to July 2023 and the P-Chart Graph After Improvements.

**TABLE 3.** Calculation of P Control Map for Number of Defects after Improvement for January - July 2023.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Period** | **Production Quantity** | **Number of Defects** | **Defect Proportion** | **CL** | **UCL** | **LCL** |
| February | 3751 | 270 | 0,07 | 0,078 | 0,091 | 0,065 |
| March | 5695 | 461 | 0,08 | 0,078 | 0,089 | 0,067 |
| May | 3596 | 285 | 0,08 | 0,078 | 0,091 | 0,064 |
| **Total** | 13042 | 1016 |  | | | |



*P-Chart* After Revised

0,10

0,09

0,08

0,07

0,06

0,05

0,04

1

2

3

Defect Proportion

CL

UCL

LCL

**FIGURE 3.** P-Chart Graph After Improvement

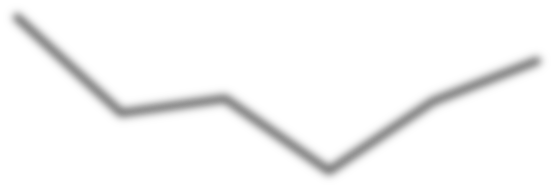
The control chart used is the p-chart, which functions to determine whether quality control in the company is already under control or not through the proportion of defects in production. From the above calculations, the values of CL, UCL, and LCL before and after improvements have been determined. The control chart above shows that there are three values outside the control limits, namely numbers 1, 4, and 6, so improvements are needed by removing these numbers. After removing data numbers 1, 4, and 6, it can be seen that all data in the control chart are within the control limits.

The next step is to measure process performance using DPMO and the sigma level of the determined CTQs. There are 5 CTQs in this study, namely cover body defect, battery cover defect, chain defect, electrical defect, and frame defect. The following is Table X.X Calculation of DPMO and Sigma Values.

**TABLE 4.** Calculation of DPMO and Sigma Value

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Period** | **Production Quantity** | **Number of Defects** | **CTQ** | **DPMO** | **Sigma Value** |
| January | 2859 | 374 | 5 | 26162,99 | 3,44 |
| February | 3751 | 270 | 5 | 14396,16 | 3,69 |
| March | 5695 | 461 | 5 | 16189,64 | 3,64 |
| April | 1044 | 38 | 5 | 7279,69 | 3,94 |
| May | 3596 | 285 | 5 | 15850,95 | 3,65 |
| July | 2859 | 297 | 5 | 20776,50 | 3,54 |
| Average | | | | 100655,93 | 2,78 |

From the results of the DPMO calculations and sigma values above, a graph can be created to clearly see the differences in values for each sample and the values for the production process. The following are the DPMO Graph and the Sigma Value Graph.



DPMO Chart

30000,00

25000,00

20000,00

15000,00

10000,00

5000,00

0,00

1

2

3

4

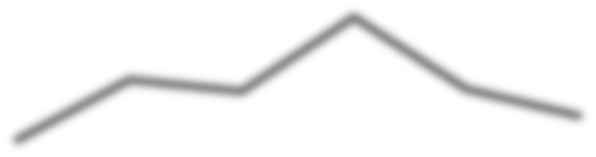
5

6

DPMO

DPMO Average

**FIGURE 4.** DPMO Chart



**Sigma Value Chart**

4,00

3,80

3,60

3,40

3,20

3,00

1

2

3

4

5

6

Sigma Value

Sigma Average

**FIGURE 5**. Sigma Value

Based on the calculations and graphs above, it is found that the DPMO pattern and sigma values of the production process for the Groza type e-bike at PT. Pasifik Mandiri are not consistent, as the patterns in the graph fluctuate throughout the production period, indicating that the production process is not well managed. If the process is well controlled, the quality of the products produced will improve, marked by a continuous decrease in DPMO and an increase in sigma values.

* + 1. **Analyze Stage** The analyze stage is the stage of identifying and analyzing the cause-effect of defective products during the production process. The following is the table of the Number of Defective E-Bike Products and the Recapitulation Data of Defective E-Bike Products.

**TABLE 5**. Data on the number of E-Bike Defect Products

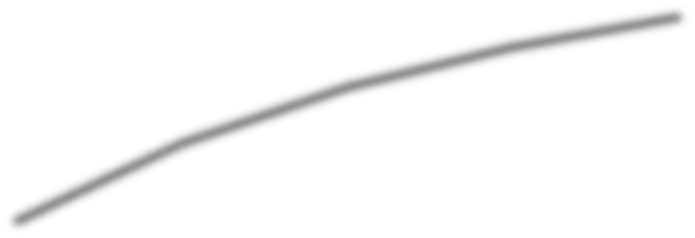
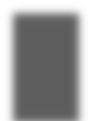
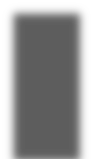
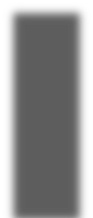
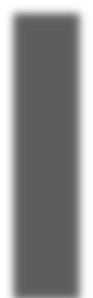
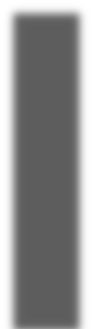
|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Period** | ***Cover Body***  ***Defect*** | **Electrical Defects** | ***Frame***  ***Defect*** | ***Cover Battery***  ***Defect*** | **Defect Chain** | **Number of Defects** |
| January | 15 | 73 | 134 | 132 | 20 | 374 |
| February | 32 | 72 | 24 | 134 | 8 | 270 |
| March | 144 | 92 | 36 | 106 | 83 | 461 |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| April | 8 | 28 | 0 | 7 | 1 | 38 |
| May | 90 | 102 | 3 | 83 | 7 | 285 |
| July | 8 | 45 | 14 | 0 | 38 | 105 |
| Total | 297 | 412 | 211 | 456 | 157 | 1533 |

**TABLE 6.** E-Bike Product Defect Recapitulation Data

|  |  |  |  |
| --- | --- | --- | --- |
| **Defect** | **Number of Defects** | **Cumulative Count** | **Cumulative %** |
| Cover Body Defect | 297 | 297 | 19% |
| Electrical Defects | 412 | 709 | 46% |
| Frame Defect | 211 | 920 | 60% |
| Cover Battery Defect | 456 | 1376 | 90% |
| Defect Chain | 157 | 1533 | 100% |

The type of defect data that is most dominant or frequently occurring can be seen either through data or visually using a Pareto diagram. The following is the Pareto diagram of defects.



**Pareto Diagram**

500

450

400

350

300

250

200

150

100

50

0

120%

100%

80%

60%

40%

20%

0%

Cover Battery Electrical

Defect Defect

Cover Body Frame Defect

Defect

Chain Defect

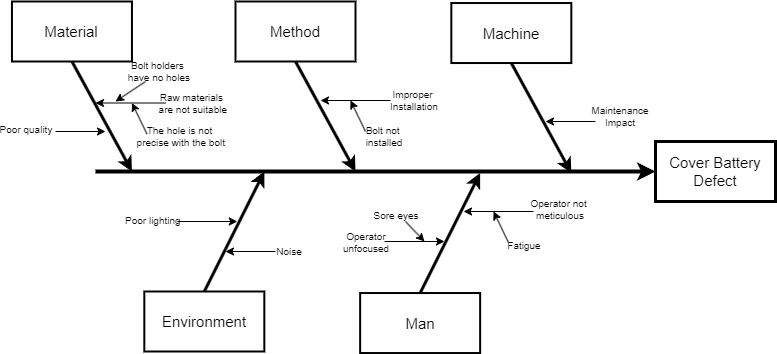
Number of Defect

Cumulative %

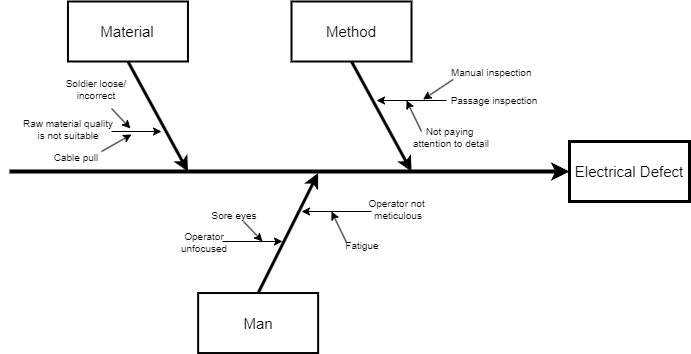
**FIGURE 7.** Pareto Diagram

Based on the Pareto diagram above, it is known that the highest number of defects is in the battery cover. The next highest number of defects is in the electrical system, followed by the cover body, frame, and chain.

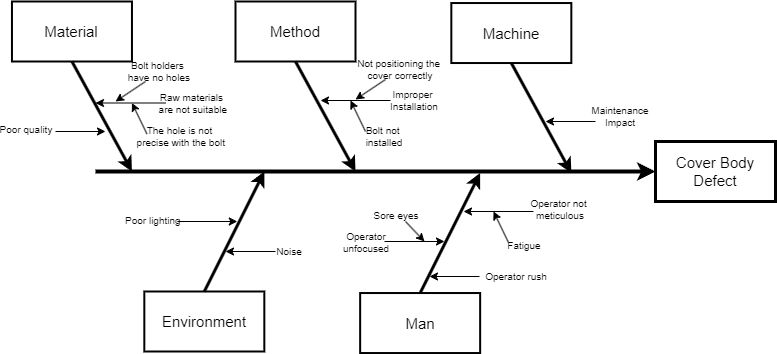
The next step is to use the fishbone diagram to identify the causes of the five types of product defects, which consist of human, machine, method, material, and environment factors. The fishbone diagram is designed based on direct observation and interviews. The following is the Fishbone Diagram.



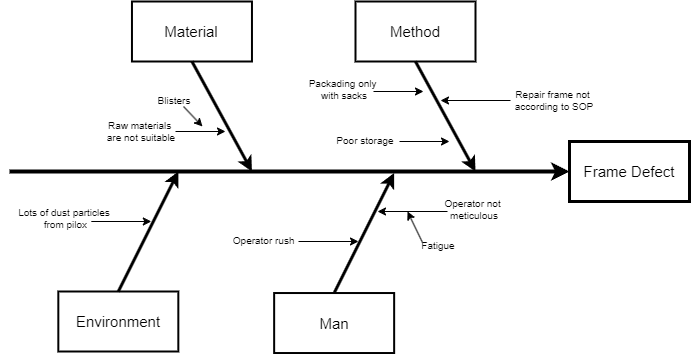
**FIGURE 7**. Fishbone Diagram of Cover Battery Defect

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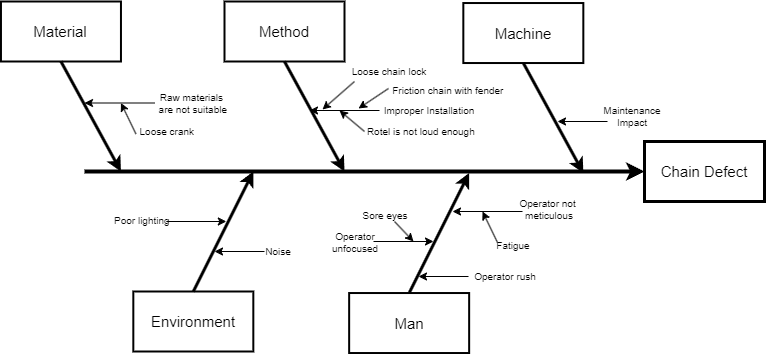
**FIGURE 8**. Fishbone Diagram of Electrical Defect

**

**FIGURE 9.** Fishbone Diagram of Cover Body Defect



**FIGURE 10**. Fishbone Diagram of Frame Defect

**

**FIGURE 11**. Fishbone Diagram of Chain Defect

Based on the above image, there are 5 factors causing defects in a product, namely, man, machine, method, material, and environment factors. The man factor is caused by operators being less meticulous, unfocused, and in a hurry. The machine factor is caused by the machine used, which is an impact machine, experiencing issues. The method factor is due to improper installation and storage of spare parts. The material factor is due to raw materials or spare parts that are ordered not meeting specifications. The environment factor is due to inadequate lighting in the production line and a high noise level.

**d. Improve Stage** The improve stage is carried out to provide suggestions or recommendations for improvements to the company based on the causes or identification of defects in the e-bike products to reduce the number of product defects. After calculating the CTQ and DPMO values as well as the sigma values, the analysis is done using a pareto diagram and a fishbone diagram. In this improve stage, defective product improvements are made using the Kaizen method, specifically the Five-M Checklist

**TABLE 8**. Five-M Ceklist

|  |  |  |  |
| --- | --- | --- | --- |
| **No** | **Factors** | **Problem** | **Troubleshooting** |
| 1. | Man | 1. Less thorough and unfocused | 1. Regular training to utilize rest time and evaluate working time and workload. |
| 2. Operator rush | 2. Review conveyor speed so as not to rush tasks at workstations |
| 2. | Machine | 1. Impact machine maintenance | 1. Checking every time it will be used and periodic machine maintenance |
| 3. | Method | 1. Improper installation | 1. Provide SOPs and periodic training at each work station. |
| 2. Passage inspection | 2. Provide SOPs and checklists for each electrical component that has passed the check. |
| 3. Repair frame not according to SOP | 3. Provide regular training so that when repairing there are no defects that are |
| 4. | Material | 1. Raw materials (spare parts) are of poor quality and not up to standard | 1. Ensure from the beginning the supplier's commitment to provide raw materials in accordance with (standard spare parts |
| 2. Poor bolt quality | 2. Ensure from the outset the bolt supplier's commitment to provide sturdy bolts |
| 5. | Environment | 1. Noise | 1. Provide PPE such as earplugs to minimize the effects of noise |
| 2. Less lighting | 2. Add or replace sufficient lighting, not too bright and not too dim |
| 3. Presence of dust particles | 3. Providing PPE such as masks to minimize inhalation of particulate dust |

**e. Control Stage** The control stage is the final stage in DMAIC, aimed at controlling and monitoring the production process improvements based on the given recommendations to achieve the desired results. Successful improvements in the process are standardized and used as standard work guidelines. This stage is the last in problem-solving using the Six Sigma methodology. In this stage, all improvement efforts are technically controlled and documented, and disseminated to all company employees so that everyone understands good quality practices. The quality control department must be meticulous in checking products to prevent a high number of defects. Additionally, the quality control department records data on improvements based on the types of defects that occur, and the company should routinely update guidelines such as SOPs and Work Instructions.

# CONCLUSIONS

The following are the conclusions drawn from the research at PT. Roda Pasifik Mandiri:

1. The assembly process of e-bike line 2 has several common defects, namely cover body defects at 19%, electrical defects at 27%, frame defects at 14%, battery cover defects at 30%, and chain defects at 10%. These percentages indicate that the most frequent defect in the assembly process is the battery cover defect, with the highest percentage of 30%.
2. Defects in e-bikes at PT. Roda Pasifik Mandiri occur due to 5 factors: man, machine, method, material, and environment. The causes for these factors are as follows:

Man: Operators are rushing and not meticulous during the assembly process.

Machine: Lack of maintenance on the impact machine before production activities.

Method: Incorrect installation of e-bike parts, errors in passing inspection, and frame repairs not following SOP.

Material: Raw materials from the supplier do not meet standards.

Environment: Noise, insufficient lighting, and airborne dust particles.

1. Actions that PT. Roda Pasifik Mandiri can take to improve product quality include increasing supervision during the production process and providing training to operators outside production hours to avoid disrupting production. Operators are required to perform maintenance on the impact tools before production to prevent issues during production. Additionally, the quality control process needs to be enhanced, and checksheet reports must be thorough to avoid rework processes. The company should regularly update SOPs and work instructions to serve as guidelines for both new and existing employees, ensuring adherence to SOPs and work instructions to reduce product defects.

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