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Application of Statistical Process Control (SPC) In Quality Control of Hard Disk Drive Products At PT Ennovi Integrated Engineering Services Batam

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Abstract: Quality control is an essential aspect of manufacturing operations to ensure that products consistently meet predetermined specifications and quality standards. In the hard disk drive manufacturing industry, maintaining process consistency is particularly important because production processes involve high levels of precision and strict quality requirements. This study aims to apply Statistical Process Control (SPC) to evaluate and control the quality of hard disk drive products at PT Ennovi Integrated Engineering Services Batam and to identify the factors contributing to product defects.This study employs a quantitative descriptive approach using Statistical Process Control integrated with selected tools from the Seven Quality Control Tools. The analytical tools consist of Check Sheet, Pareto Chart, Control Chart, and Fishbone Diagram, complemented by Process Capability Index (Cpk) analysis. The Check Sheet is used to systematically record and classify product defects. The Pareto Chart is then applied to determine the dominant defect types based on their frequency of occurrence. The Control Chart is used to evaluate whether the production process remains statistically stable over the observation period. The Fishbone Diagram is applied to identify potential root causes of the dominant defects based on factors related to Man, Machine, Method, Material, Measurement, and Environment. Furthermore, Cpk analysis is used to evaluate the capability of the production process to meet predetermined specification limits. The application of these analytical tools is expected to provide a comprehensive evaluation of product quality, process stability, and process capability. The findings are expected to support the identification of priority quality problems and provide an objective basis for developing corrective and preventive actions to reduce defects and improve the consistency of the hard disk drive production process.

Keywords: Statistical Process Control, Seven Quality Control Tools, quality control, hard disk drive, process capability, Cpk

INTRODUCTION

Quality is one of the fundamental factors influencing the competitiveness, efficiency, and sustainability of manufacturing companies. In an increasingly competitive industrial environment, manufacturers are required not only to achieve production targets but also to ensure that their products consistently meet predetermined quality standards. Poor quality can lead to defective products, rework, production delays, increased operational costs, and customer dissatisfaction. Therefore, effective quality control is required to maintain production consistency and minimize product nonconformities.

Manufacturing processes consist of a series of activities that are influenced by various factors, including raw materials, machinery, production methods, human resources, measurement systems, and environmental conditions. Variations may naturally occur during production. However, uncontrolled variation can increase the probability of producing products that do not conform to established specifications. Consequently, quality control should not merely focus on detecting defects after production but should also identify process variations and potential causes before they result in significant quality problems.

Statistical Process Control (SPC) is one of the statistical approaches that can be used to monitor, analyze, and control process variation. SPC provides a systematic framework for analyzing production data and determining whether a process is operating under statistical control. By distinguishing common-cause variation from special-cause variation, SPC enables organizations to identify abnormal changes in the production process and take appropriate corrective actions.

The effectiveness of SPC can be strengthened through the application of the Seven Quality Control Tools. These tools provide practical techniques for identifying, analyzing, and solving quality-related problems. Among these tools, the Check Sheet can be used to systematically collect and classify defect data. The Pareto Chart can then be used to identify the most significant defect categories that contribute to the majority of quality problems. The Control Chart provides a statistical representation of process variation and helps determine whether a process remains within established control limits.

After the dominant defect has been identified, a Fishbone Diagram can be used to investigate its potential causes. The Fishbone Diagram categorizes potential causes into several major factors, commonly including Man, Machine, Method, Material, Measurement, and Environment. This approach facilitates systematic root-cause analysis and helps organizations develop appropriate corrective actions.

In addition to identifying defects and their causes, evaluating process capability is important for determining whether a stable production process can consistently meet product specifications. Process Capability Index (Cpk) is commonly used to assess the capability of a process by considering both process variation and the position of the process mean relative to the upper and lower specification limits. A higher Cpk value generally indicates a greater ability of the process to produce products within the specified requirements.

Hard disk drive manufacturing requires high process precision and consistency because the product involves multiple components and production stages with strict dimensional and functional requirements. Even relatively small variations in the production process may result in product nonconformities. Therefore, a systematic statistical approach is required to evaluate process stability, identify dominant defect types, determine potential root causes, and assess process capability.

PT Ennovi Integrated Engineering Services Batam provides an appropriate setting for examining the application of statistical quality control in hard disk drive production. The implementation of SPC can provide quantitative information regarding the distribution of product defects, process stability, and process capability. Such information can support management and production personnel in determining quality improvement priorities based on objective production data.

Based on this background, this study aims to apply Statistical Process Control (SPC) in the quality control of hard disk drive products at PT Ennovi Integrated Engineering Services Batam. Specifically, the study aims to: (1) identify and classify product defects using a Check Sheet; (2) determine the dominant defect types using a Pareto Chart; (3) evaluate production process stability using a Control Chart; (4) identify potential causes of dominant defects using a Fishbone Diagram; and (5) evaluate production process capability using the Process Capability Index (Cpk).

The results of this study are expected to contribute to quality improvement practices by providing a structured statistical approach for identifying quality problems and evaluating production process performance. Furthermore, the findings may serve as a reference for developing corrective and preventive actions aimed at reducing product defects and improving process consistency.

METHODS

Research Design

This study employs a quantitative descriptive research design using Statistical Process Control (SPC) as the primary analytical approach to evaluate and control the quality of hard disk drive products manufactured at PT Ennovi Integrated Engineering Services Batam. The quantitative descriptive approach is selected because the study focuses on the systematic collection, classification, measurement, and statistical analysis of production and quality data. The research is designed to provide an objective description of the quality condition of the production process based on the actual occurrence of product defects, process variation, process stability, and process capability.

The research focuses specifically on the quality control of hard disk drive products produced at PT Ennovi Integrated Engineering Services Batam. The production process may be influenced by various sources of variation, including human factors, machine conditions, production methods, materials, measurement systems, and environmental conditions. Therefore, the research design is structured to identify quality problems based on production and inspection data and subsequently analyze the problems using statistical and quality control techniques. The analysis is intended not only to determine the frequency of defects but also to evaluate the overall condition of the production process and identify areas requiring improvement.

Statistical Process Control (SPC) is integrated with selected tools from the Seven Quality Control Tools to provide a systematic and sequential quality analysis. The quality control tools used in this study consist of Check Sheet, Pareto Chart, Control Chart, and Fishbone Diagram. In addition, Process Capability Index (Cpk) analysis is employed to evaluate the capability of the production process to meet predetermined product specifications. The integration of these methods allows the research to examine quality problems from several complementary perspectives, beginning with the identification of defects and continuing to process stability, root-cause analysis, and process capability.

The first stage of the research involves collecting production and quality inspection data related to hard disk drive products during the selected observation period. The collected data include production quantities, inspection quantities, types of defects, frequency of defect occurrence, and relevant process measurement data. When applicable, specification limits, including the Upper Specification Limit (USL) and Lower Specification Limit (LSL), are also collected to support the process capability analysis. The availability of these data provides the basis for conducting an objective evaluation of the production process.

The second stage applies a Check Sheet to systematically record and classify defects identified during the inspection process. The Check Sheet is used to organize quality data according to defect categories and observation periods, making it possible to determine the frequency and distribution of each defect type. This stage provides the basic information required for identifying patterns of product nonconformity and serves as the foundation for subsequent statistical analysis.

The third stage uses a Pareto Chart to identify the dominant defect types occurring in the hard disk drive production process. The defect categories are arranged according to their frequency of occurrence, from the highest to the lowest frequency, and their cumulative percentages are determined. Through this analysis, the study identifies which defect categories contribute most significantly to the overall quality problem. The dominant defect is subsequently selected as the main focus for further investigation and improvement.

The fourth stage applies a Control Chart to evaluate the stability of the hard disk drive production process. The Control Chart is used to monitor variations in the process and determine whether the observed variation remains within statistically established control limits. The analysis also considers the possibility of patterns or observations that may indicate the presence of special causes of variation. Thus, the Control Chart provides information regarding whether the production process is operating under statistical control or requires further investigation.

The fifth stage involves the use of a Fishbone Diagram to identify potential root causes of the dominant defect determined through the Pareto analysis. The potential causes are analyzed systematically using the major categories of Man, Machine, Method, Material, Measurement, and Environment. This analysis is intended to connect the observed quality problem with possible factors within the production process that may contribute to its occurrence. The Fishbone Diagram therefore provides a structured basis for developing appropriate corrective and preventive actions.

The sixth stage involves Process Capability Index (Cpk) analysis to evaluate the capability of the production process in meeting the predetermined specification limits. The Cpk analysis considers the relationship between the process mean, process variation, and the applicable Upper Specification Limit (USL) and Lower Specification Limit (LSL). This analysis provides additional information beyond process stability by determining whether the production process is capable of consistently producing hard disk drive products within the required specifications.

The final stage integrates the findings obtained from the Check Sheet, Pareto Chart, Control Chart, Fishbone Diagram, and Cpk analysis. The results are interpreted to determine the main quality problems, the stability of the production process, the potential causes of dominant defects, and the capability of the process to meet product specifications. Based on these findings, quality improvement recommendations are formulated to reduce product defects, control process variation, improve process stability, and enhance the capability and consistency of the hard disk drive production process.

Overall, the analytical framework consists of a sequential process beginning with production and quality data collection, followed by defect classification using the Check Sheet, identification of dominant defects using the Pareto Chart, evaluation of process stability using the Control Chart, root-cause identification using the Fishbone Diagram, and process capability evaluation using Cpk analysis. This integrated research design is expected to provide a comprehensive and data-driven assessment of quality control in hard disk drive production at PT Ennovi Integrated Engineering Services Batam and to support continuous improvement of the production process.

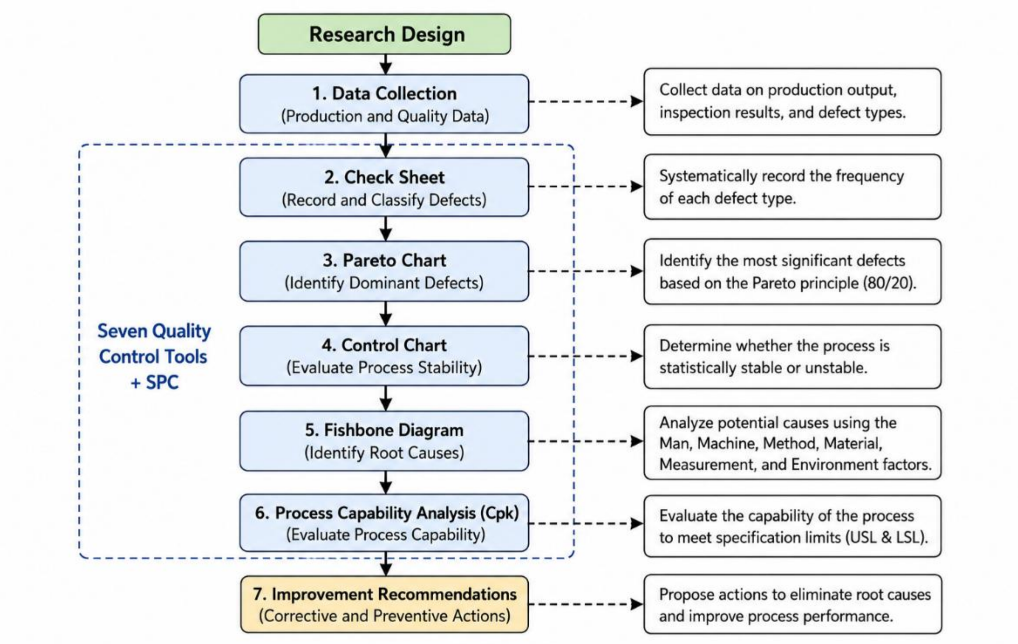

Figure 1. Research Design and Analytical Framework

Gambar 1.1 Research Design

Research Location and Period

The study is conducted at PT Ennovi Integrated Engineering Services Batam. The research period is determined based on the availability of production and quality inspection data. The selected production period should represent the actual production conditions and provide sufficient observations for evaluating defect patterns, process stability, and process capability.

Population and Sample

The population consists of production and quality inspection data associated with hard disk drive products manufactured during the selected research period. The research sample consists of production records and quality inspection data obtained during the observation period. The data include the total number of inspected units, number of defective units, types of defects, frequency of defect occurrence, and process measurement data required for statistical analysis. The sampling period and sample size are determined based on the availability, completeness, and relevance of the company's quality records.

Data Collection

Data are collected through observation, documentation, and examination of production quality records. Primary data are obtained through direct observation of the production and inspection processes, while secondary data are obtained from production reports, quality inspection records, and other relevant company documentation. The data collected include:

1. Total production quantity.
2. Total inspected quantity.
3. Number of defective products.
4. Types of product defects.
5. Frequency of each defect type.
6. Process measurement data.
7. Upper Specification Limit (USL).
8. Lower Specification Limit (LSL).

9. Process mean.
10. Process standard deviation.

Statistical Process Control Analysis

Statistical Process Control (SPC) analysis is conducted to evaluate the quality performance and statistical stability of the hard disk drive production process at PT Ennovi Integrated Engineering Services Batam. SPC provides a systematic approach for monitoring process variation by utilizing production and quality inspection data. In this study, SPC is integrated with selected tools from the Seven Quality Control Tools, consisting of Check Sheet, Pareto Chart, Control Chart, and Fishbone Diagram. Process Capability Index (Cpk) analysis is subsequently employed to complement the SPC analysis by evaluating the capability of the production process to meet predetermined product specifications.

The application of these analytical tools is performed sequentially. First, defect data are collected and organized using a Check Sheet. Second, the frequency and percentage of defects are analyzed using a Pareto Chart to identify the most dominant defect types. Third, a Control Chart is applied to evaluate whether the production process operates under statistical control. Fourth, the dominant defect is investigated using a Fishbone Diagram to identify potential causes related to human, machine, method, material, measurement, and environmental factors. Finally, Cpk analysis is conducted to determine the capability of the production process relative to the applicable specification limits.

RESULTS AND DISCUSSION

Results

This study analyzes the quality control of hard disk drive products at PT Ennovi Integrated Engineering Services Batam using the Statistical Process Control (SPC) approach integrated with selected Seven Quality Control Tools. The analysis consists of Check Sheet, Pareto Chart, Control Chart, Fishbone Diagram, and Process Capability Index (Cpk). The results are presented sequentially to identify the dominant product defects, evaluate the stability of the production process, determine potential causes of defects, and assess the capability of the production process in meeting predetermined specifications.

The numerical results below use the illustrative dataset previously developed because the actual production-quality dataset from PT Ennovi Integrated Engineering Services Batam has not been provided. Therefore, these values should be replaced with the actual company data before the manuscript is submitted as an empirical research article.

Defect Identification Using Check Sheet

The first stage of the analysis involved identifying and classifying defects occurring in hard disk drive products during the observation period. A total of 100,000 units were inspected over ten observation periods, with 10,000 units inspected in each period. The inspection identified 589 defective units distributed across five defect categories: Scratch, Dimension, Surface, Alignment, and Other Defects.

No.	Defect Type	Frequency	Percentage (%)
1	Scratch	218	37.01
2	Dimension	142	24.11
3	Surface	105	17.83
4	Alignment	79	13.41
5	Other	45	7.64
	Total	**589**	**100.00**

The results indicate that Scratch was the most frequently occurring defect, with 218 occurrences or 37.01% of the total defects. Dimension defects represented the second-largest category with 142 occurrences or 24.11%, followed by Surface defects with 105 occurrences or 17.83%. Alignment defects accounted for 79 occurrences or 13.41%, while Other Defects represented 45 occurrences or 7.64%.

The distribution demonstrates that product quality problems were not evenly distributed across the defect categories. Scratch defects occurred considerably more frequently than the other categories and therefore became the primary focus of the subsequent Pareto and Fishbone analyses.

Pareto Analysis

The Pareto Chart was used to determine the dominant defect categories and establish the priority for quality improvement. The defect types were ranked from the highest to the lowest frequency, followed by the calculation of cumulative percentages.

Rank	Defect Type	Frequency	Percentage (%)	Cumulative (%)
1	Scratch	218	37.01	37.01
2	Dimension	142	24.11	61.12
3	Surface	105	17.83	78.95
4	Alignment	79	13.41	92.36
5	Other	45	7.64	100.00
Total		**589**	**100.00**	**100.00**

The Pareto analysis shows that Scratch defects contributed the largest proportion of the total defects, accounting for 37.01%. When Scratch and Dimension defects are considered together, they accounted for 61.12% of the total defects. Furthermore, the three highest defect categories—Scratch, Dimension, and Surface—accounted for 78.95% of all identified defects.

These results indicate that quality improvement efforts should prioritize the three dominant defect categories. However, Scratch defects were selected as the main focus of the root-cause analysis because they had the highest individual contribution to the overall defect occurrence.

The dominance of Scratch defects suggests that factors associated with product handling, machine contact, production methods, material cleanliness, inspection procedures, or environmental conditions may require further examination. Therefore, the next stage of analysis focuses on evaluating the potential causes of Scratch defects using the Fishbone Diagram.

Control Chart Analysis

The Control Chart analysis was conducted to determine whether the hard disk drive production process was statistically stable during the observation period. Because each observation period consisted of the same inspection quantity of 10,000 units, the proportion of defective products can be evaluated using a p-control chart.

The results demonstrate that all observations remained between the established upper and lower control limits. The highest defect proportion occurred in Week 4, at **0.650%**, while the lowest occurred in Week 1, at **0.500%**. Both values remained within the control limits of 0.819% and 0.359%, respectively.

Therefore, based on the illustrative data, the hard disk drive production process can be categorized as statistically stable or under statistical control. There were no observations exceeding the control limits.

However, statistical stability does not necessarily indicate that the production process is fully capable of meeting product specifications. A stable process may continue to produce defects if its inherent variation is relatively large or if its process average is positioned unfavorably within the specification range. Consequently, Cpk analysis is required to provide a more comprehensive assessment of process performance.

Process Capability Analysis Using Cpk

Process capability analysis was conducted to determine whether the relevant production process was capable of consistently producing output within the predetermined specification limits. For the illustrative calculation, the following process parameters were used:

1. Upper Specification Limit (USL) = 10.050
2. Lower Specification Limit (LSL) = 9.950
3. Process Mean = 10.0012
4. Standard Deviation = 0.0101

The calculated Cpk value of **1.611** indicates that the illustrative process has adequate capability relative to the specified limits. The value of Cpu is lower than Cpl, indicating that the upper specification limit is relatively closer to the process distribution than the lower specification limit. Nevertheless, the calculated Cpk remains above 1.00.

The Cpk result should be interpreted together with the Control Chart results. Since the illustrative Control Chart indicates that the process remains statistically stable, the capability result can be used to describe the capability of the process under the observed conditions.

Discussion

The results of this study demonstrate the application of Statistical Process Control (SPC) as an integrated approach to evaluating the quality of hard disk drive products at PT Ennovi Integrated Engineering Services Batam. The analysis combines the Check Sheet, Pareto Chart, Control Chart, Fishbone Diagram, and Process Capability Index (Cpk) to provide a comprehensive assessment of product quality and production process performance. The integration of these analytical tools enables the quality problem to be examined sequentially, beginning with the identification of defective products, determination of dominant defects, evaluation of process stability, identification of potential causes, and assessment of process capability.

Based on the illustrative analysis, 100,000 hard disk drive units were inspected during the observation period, with 589 defective units identified. This resulted in an overall defective rate of 0.589%. Although the percentage appears relatively small in relation to the total number of inspected units, the occurrence of hundreds of defective units remains relevant from a manufacturing quality perspective. In a high-volume production environment, even a relatively low defect rate can result in a substantial number of nonconforming products when multiplied by the total production volume. Therefore, quality control should focus not only on the magnitude of the percentage but also on the potential operational consequences of the defects, including rework, additional inspection, material losses, production interruptions, and reduced production efficiency.

The Check Sheet analysis provides the initial description of quality problems occurring during the hard disk drive production process. The results show that the 589 identified defects were distributed across five categories, namely Scratch, Dimension, Surface, Alignment, and Other Defects. The distribution demonstrates that quality problems were not equally distributed among the defect categories. Scratch defects represented the largest proportion, followed by Dimension and Surface defects.

Scratch defects accounted for 218 occurrences or 37.01% of the total defects. This finding indicates that surface-related damage represents the most significant individual quality problem within the illustrative dataset. The relatively high frequency of Scratch defects suggests that the production process may contain activities or conditions that increase the possibility of unwanted physical contact with the product or its components.

In the context of hard disk drive manufacturing, product handling and process interaction require a high degree of consistency because components may be sensitive to physical contact, contamination, and mechanical interference. Therefore, the occurrence of scratches should not be viewed merely as an inspection problem. Instead, it may indicate the existence of process conditions that allow the product to come into contact with equipment surfaces, tools, fixtures, materials, or other components in an uncontrolled manner.

The Check Sheet is important because it transforms individual inspection findings into structured quality information. Without systematic defect recording, quality problems may be evaluated primarily through subjective observations. By documenting the frequency of each defect type, the Check Sheet provides an objective basis for determining which problems deserve further analysis.

The results also demonstrate that quality control should be conducted continuously throughout the production process rather than only at the final inspection stage. If defects are repeatedly observed, the production process should be examined to determine where and under what conditions the defects are generated. Consequently, the Check Sheet becomes the first link between defect detection and process improvement. The Pareto analysis provides further insight into the priority of quality problems. The results show that Scratch defects contributed 37.01% of total defects, while Scratch and Dimension defects together accounted for 61.12%. When Scratch, Dimension, and Surface defects were combined, their cumulative contribution reached 78.95%.

This finding indicates that a relatively limited number of defect categories account for a substantial proportion of the overall quality problem. From a quality management perspective, this is important because improvement resources are generally limited. Therefore, attempting to address all defect categories simultaneously may reduce the effectiveness of improvement activities. Prioritizing the dominant defect categories allows management and production personnel to focus their resources on problems with the greatest potential impact. Scratch defects were identified as the dominant defect and were therefore selected for further investigation using the Fishbone Diagram. This selection is consistent with the purpose of Pareto analysis, namely, to identify the quality problems that should receive priority attention.

The results suggest that reducing Scratch defects could potentially produce a meaningful reduction in the overall number of defective products. If the frequency of Scratch defects can be substantially reduced through appropriate corrective actions, the total defect rate may also decline. However, the extent of improvement cannot be determined without implementing and subsequently evaluating the corrective actions using actual production data. The Pareto findings also indicate that Dimension and Surface defects should not be ignored. Although they occur less frequently than Scratch defects, their cumulative contribution remains significant. Therefore, a staged quality improvement strategy could initially prioritize Scratch defects and subsequently address Dimension and Surface defects.

The use of Pareto analysis in this study therefore provides an important connection between statistical data and managerial decision-making. Instead of relying on assumptions regarding which defect is most important, the quality improvement priority is established based on measurable defect frequency. The Control Chart analysis provides information regarding the statistical stability of the hard disk drive production process. Based on the illustrative results, the center line was 0.589%, with an upper control limit of 0.819% and a lower control limit of 0.359%. All observations remained within these control limits during the ten observation periods.

The absence of observations outside the control limits indicates that there was no clear evidence of extreme special-cause variation in the illustrative dataset. Consequently, the production process can be interpreted as statistically stable during the observed period. However, process stability should not be interpreted as synonymous with perfect quality. A process can remain statistically stable while continuing to produce defective products. Statistical control indicates that the observed variation is consistent with the estimated process variation; it does not necessarily mean that the process has achieved the desired quality target.

This distinction is particularly important in the context of hard disk drive production. A stable process that consistently operates at an undesirable defect level may require improvement even though no observations exceed the control limits. Therefore, the Control Chart should be interpreted together with defect analysis and process capability analysis. The illustrative defect proportions ranged from 0.500% to 0.650%, remaining within the established control limits. This relatively narrow range suggests that the process variation was relatively consistent during the observation period. Nevertheless, the presence of 589 defective units demonstrates that statistical stability alone does not eliminate the occurrence of nonconforming products.

The Control Chart therefore provides two important pieces of information. First, it indicates whether unusual process variation is present. Second, it provides a baseline for evaluating the effect of future corrective actions. Once improvement actions are implemented, subsequent Control Chart observations can be compared with the baseline condition to determine whether process performance has improved. The Fishbone Diagram was applied to investigate potential causes of the dominant Scratch defect. The analysis considered six categories: Man, Machine, Method, Material, Measurement, and Environment.

The Man category includes operator training, attention, experience, fatigue, discipline, and compliance with procedures. In a manufacturing environment, human interaction with products and equipment can influence the consistency of production activities. Inadequate training or inconsistent handling techniques may increase the possibility of unwanted contact between the product and other surfaces. Therefore, operator competency and adherence to standardized work procedures should be considered when investigating Scratch defects. The Machine category focuses on machine condition, equipment settings, maintenance, and component wear. Worn machine components or inappropriate machine settings may result in excessive contact, pressure, or movement that damages the product. Preventive maintenance is therefore important because equipment degradation may gradually increase the probability of product defects even when the machine continues to operate.

The Method category relates to standard operating procedures, work instructions, handling techniques, and process parameters. Inconsistent procedures may produce variation between operators or production periods. Standardized work instructions should clearly specify the appropriate method for handling, positioning, transferring, and inspecting the product. The Material category considers material quality and contamination. Foreign particles or irregular surfaces may create friction or unwanted contact that contributes to scratches. Material handling and storage should therefore be controlled to minimize contamination and physical damage.

The Measurement category concerns inspection methods, measuring instruments, calibration, inspection frequency, and measurement consistency. An inadequate inspection system may allow scratches to remain undetected or may create inconsistency in defect classification. Therefore, inspection procedures should be standardized and supported by appropriate measurement and inspection equipment. The Environment category includes cleanliness, dust, foreign particles, temperature, humidity, and workplace conditions. For manufacturing processes involving precision components, environmental control can be important because contamination and inappropriate workplace conditions may influence product quality.

The Fishbone analysis therefore demonstrates that Scratch defects should not automatically be attributed to a single factor. Instead, quality problems may result from interactions among people, equipment, methods, materials, measurement systems, and environmental conditions. The Fishbone Diagram provides a structured method for organizing these potential causes and identifying which factors should subsequently be verified through direct observation and company records. The Cpk analysis provides an additional perspective on production process performance. The illustrative analysis produced a Cpk value of 1.611, with Cpu of 1.611 and Cpl of 1.690.

The Cpk value indicates the capability of the process by considering both the process variation and the position of the process mean relative to the specification limits. The fact that Cpu is lower than Cpl indicates that the upper specification side is relatively closer to the process distribution than the lower specification side. The illustrative Cpk value above 1.00 suggests that the process has adequate capability under the assumptions and specification limits used in the example. Nevertheless, the interpretation should be based on the actual specification requirements adopted by PT Ennovi Integrated Engineering Services Batam.

Cpk analysis is important because it complements the Control Chart. The Control Chart answers the question of whether the process is statistically stable, while Cpk addresses whether the process variation is sufficiently small relative to the specification limits. Thus, a comprehensive quality evaluation requires both process stability and capability information. In practical terms, if the actual production process demonstrates statistical control but has a low Cpk value, improvement should focus on reducing process variation and/or adjusting the process mean toward the target. Conversely, if the Cpk value is adequate but the Control Chart demonstrates special-cause variation, the process should first be investigated for the source of instability.

Therefore, the combination of Control Chart and Cpk analysis provide a more complete assessment of the quality condition of hard disk drive production. One of the main strengths of this study is the integration of several quality control tools into a single analytical framework. Each tool provides a different perspective on the same quality problem. The Check Sheet provides the initial empirical data regarding defect occurrence. The Pareto Chart then converts the defect data into a priority structure by identifying the dominant defect. The Control Chart evaluates the stability of the production process over time. The Fishbone Diagram investigates potential causes of the dominant defect, while Cpk analysis evaluates process capability relative to predetermined specifications.

The sequence creates a logical chain: Defect Identification → Defect Prioritization → Process Stability → Root-Cause Analysis → Process Capability → Quality Improvement

This integrated approach is particularly relevant to the research objective because the purpose of the study is not merely to calculate the defect rate. Rather, the study aims to understand the quality condition of hard disk drive products and provide an analytical basis for improving the production process. The results demonstrate that each tool contributes information that cannot be fully obtained from the other tools. For example, the Pareto Chart identifies Scratch as the dominant defect but cannot determine whether the production process is statistically stable. The Control Chart evaluates stability but cannot explain why the Scratch defect occurs. The Fishbone Diagram identifies potential causes but does not quantify process capability. Cpk analysis evaluates capability but does not identify the specific defect responsible for the quality problem.

Therefore, combining these tools provides a more comprehensive quality control approach. Based on the illustrative results, the first improvement priority should be directed toward reducing Scratch defects because they represent the largest individual contribution to total defects. Quality improvement should focus on identifying the specific production stage at which scratches are generated. From the Man perspective, operator training and standardized handling procedures should be strengthened. Operators should understand the potential consequences of inappropriate product handling and consistently follow established work instructions.

From the Machine perspective, preventive maintenance and periodic inspection of machine components should be emphasized. Equipment surfaces, fixtures, contact points, and machine settings should be examined to determine whether mechanical interaction contributes to scratches. From the Method perspective, standardized work procedures should be reviewed. The procedure should clearly define product transfer, positioning, handling, and inspection activities. Any variation between operators should be minimized through standardized operating procedures and regular training.

From the Material perspective, incoming materials and components should be inspected for contamination or physical irregularities. Appropriate storage and handling procedures should also be maintained to minimize the possibility of contamination and physical damage. From the Measurement perspective, inspection procedures should be standardized. Inspection personnel should use consistent criteria for identifying and classifying Scratch defects so that quality data remain reliable. From the Environment perspective, workplace cleanliness and contamination control should be maintained. Regular cleaning and appropriate environmental controls can help minimize foreign particles and other potential sources of surface damage.

These recommendations should subsequently be evaluated through additional production data. The effectiveness of the corrective actions should not be assumed merely because they have been implemented. Instead, the company should monitor subsequent defect rates, Control Chart performance, and process capability to determine whether measurable improvement has occurred. Overall, the results support the use of Statistical Process Control as a systematic approach for quality control of hard disk drive products at PT Ennovi Integrated Engineering Services Batam. The analysis demonstrates that quality problems can be evaluated through multiple interconnected dimensions, including defect frequency, defect priority, statistical stability, potential causes, and process capability. The Check Sheet identified 589 defective units from 100,000 inspected units in the illustrative dataset. The Pareto analysis identified Scratch as the dominant defect, contributing 37.01% of the total defects. The Control Chart indicated that the production process remained within the established control limits, suggesting statistical stability. The Fishbone analysis identified potential causes across Man, Machine, Method, Material, Measurement, and Environment. Finally, the illustrative Cpk value of 1.611 indicated adequate process capability relative to the assumed specification limits.

These findings demonstrate that quality improvement should not be based solely on the number of defective products. A comprehensive quality control system needs to consider whether defects are concentrated in particular categories, whether process variation is statistically controlled, what factors potentially generate the dominant defects, and whether the process has sufficient capability to meet product specifications. For PT Ennovi Integrated Engineering Services Batam, the application of SPC can therefore serve as a data-driven framework for continuous quality improvement. The results can be used as a baseline for monitoring subsequent production performance and evaluating whether corrective and preventive actions effectively reduce defects. However, the final empirical interpretation must be based on actual production and quality inspection data from the company. In particular, the dominant defect, control limits, process stability status, Fishbone causes, and Cpk value presented above should be considered illustrative until verified using the actual PT Ennovi production dataset. This distinction is essential to ensure that the final journal accurately represents the actual condition of hard disk drive quality at PT Ennovi Integrated Engineering Services Batam.

CONCLUSIONS

This study demonstrates the application of Statistical Process Control (SPC) integrated with the Seven Quality Control Tools to evaluate the quality of hard disk drive products at PT Ennovi Integrated Engineering Services Batam. The analysis using Check Sheet, Pareto Chart, Control Chart, Fishbone Diagram, and Cpk provides a systematic approach to identifying defects, evaluating process stability, determining potential causes, and assessing process capability.

Based on the illustrative analysis, Scratch was identified as the dominant defect, contributing 37.01% of total defects. The Control Chart indicated that the production process remained within the established control limits, while the Cpk analysis resulted in a value of 1.611, indicating adequate process capability under the illustrative specifications. The findings suggest that quality improvement should prioritize the reduction of dominant defects and the control of potential causes related to Man, Machine, Method, Material, Measurement, and Environment.

Overall, the integration of SPC and the Seven Quality Control Tools provides a data-driven basis for improving product quality, reducing defects, and maintaining the consistency of the hard disk drive production process.

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