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REDUCING QUALITY COSTS THROUGH THE INTEGRATION OF SIX SIGMA, PFMEA, AND THEORY OF INVENTIVE PROBLEM SOLVING (TRIZ) IN MASS PRODUCTION ELECTRONICS MANUFACTURING

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ABSTRACT

This thesis proposal outlines a study aimed at reducing quality costs through the integration of Six Sigma, Process Failure Mode and Effects Analysis (PFMEA), and the Theory of Inventive Problem Solving (TRIZ) within the context of electronics manufacturing at PT X. NQC, which refers to costs incurred from products failing to meet established quality standards, has emerged as a critical concern for the company due to its substantial impact on overall expenditures. The primary objective of this research is to identify the underlying factors contributing to elevated NQC and to develop effective solutions through a comprehensive, integrated approach. The research methodology will encompass a thorough analysis of the production process, the identification of potential failure modes, and the application of TRIZ methodology to reduce subjectivity in the PFMEA analysis. By synthesizing these three methodologies, it is anticipated that actionable recommendations will be generated to improve product quality and enhance operational efficiency. This research is expected to yield practical solutions for PT X while also contributing to the advancement of theories and practices in quality management within the manufacturing sector. The outcomes of this study will serve as a valuable reference for other organizations encountering similar challenges in their efforts to enhance quality and cost efficiency. Product A is one of the main products of PT X, but after doing some data collection it was found that the cost of quality was very high in product A, the problem of product A is the frequent occurrence of defects that exceed the Company's target on quality costs. To reduce the cost of quality is to control quality, so this study uses six sigma as a tool for improvement with the DMAIC stage, where the define stage includes identifying problems, introducing the Operation process chart, and also determining CTQ in each process, then the Measurement stage includes the calculation of DPMO, sigma level and process capability, followed by the Analysis Stage including RPN identification with PFMEA and fishbone diagrams to analyze problems from each aspect. The next stage is Improve which uses TRIZ to provide innovative solutions, and the last stage is the control stage where the appropriate control mechanism is given. The results showed that the existing process in Product A has a CP < 1.33 which indicates a poor process. The PFMEA results are caused by the lack of pressure during overlay installation, due to excessive pressure during LCD installation, lack of pressure during cable installation, non-standardized torque, and also the large variation in tolerance on the bezel. Based on the contradiction matrix analysis and the 40 inventive principles, the improvement recommendations for the overlay process are. .... LCD Process is, Touch panel Process is... Process Bezel is, and Process PCBA is.

Keywords: Quality Cost, Six Sigma, PFMEA, TRIZ, Electronic Manufacturing

INTRODUCTION

In the manufacturing industry, one of the sectors experiencing the most rapid growth is the electronics sector. There are several key factors that can determine the success of an electronics manufacturing company, namely the quality of raw materials, production process efficiency, and product quality control (Kumar et al., 2021). The electronics manufacturing process in Indonesia generally consists of several stages, starting from product planning, raw material procurement, production processes that include assembly and testing, to product distribution to customers (Talenta, 2023). One of the key players in this sector is PT X, a factory engaged in the electronics industry. PT X operates two production systems: custom engineering and custom manufacturing. Custom engineering refers to the production of products based on customer specifications, while custom manufacturing refers to the production of goods according to the company's catalog. The catalog includes various electronic devices produced by PT X.

Product manufacturing at PT X involves two main processes, namely assembly and testing, both of which greatly affect production efficiency. Due to the importance of these two processes, PT X collects internal data that affects production efficiency, in the form of quality costs. Quality costs are expenses incurred due to products or services that fail to meet established quality standards. The quality cost data collected indicates that in 2024, quality costs were one of the company's largest expense contributors. Further research identified that among all products sold, as shown in Figure 1, Product A was the primary contributor to quality cost expenses.

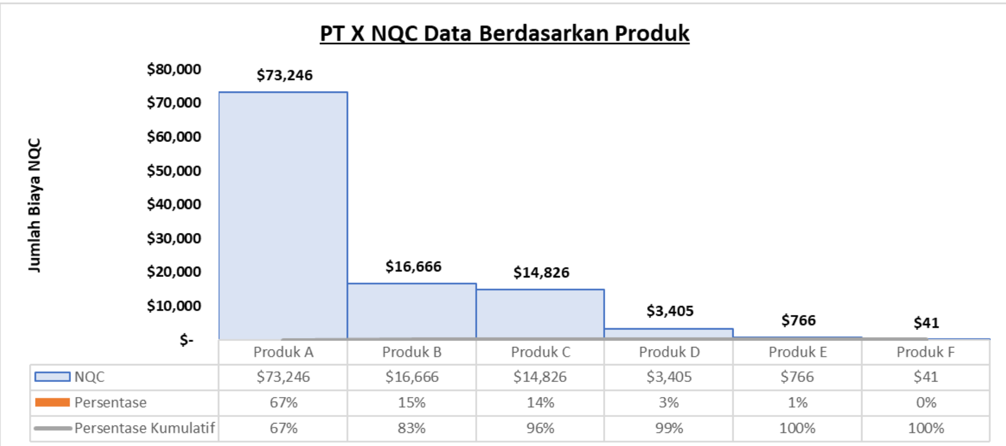

Figure 1. Pareto diagram of quality costs for each

Therefore, a comprehensive approach is needed to identify and reduce the main sources of quality costs in order to improve product quality and process efficiency at PT X. One method that can be used to solve problems is FMEA. In addition to the FMEA approach, another commonly used methodology for improving process flow is Six Sigma. Six Sigma focuses on reducing variation and improving quality. Various studies have integrated FMEA to further enhance the Six Sigma method (Hidayat et al., 2021; Ishak et al., 2019; Mansur et al., 2016; Jirasukprasert et al., 2014).

The integration of FMEA with the Six Sigma method is not new, but the integration of PFMEA (Process Failure Mode and Effects Analysis) and Six Sigma specifically for manufacturing processes has rarely been investigated. This study integrates PFMEA with the Six Sigma method.

Another methodology that will be applied in this study is TRIZ (Theory of Inventive Problem Solving). One of the problems with PFMEA is its subjectivity (Andrejić et al, 2020). TRIZ is an innovative and structured method for inventive problem solving, enabling it to be applied to minimize the subjectivity of the PFMEA method. The combination of these three methods—Six Sigma, PFMEA, and TRIZ—is aimed at achieving continuous quality improvement, enhancing operational efficiency, and offering more competitive product pricing.

RESEARCH METHODS

This research began with a literature study and field observation at PT X to map the theoretical gap while confirming the high quality cost of Product A. All workflow process data, defects, quality costs, SIPOC, and Voice of Customer are collected and processed through the Six Sigma-DMAIC framework: the Define phase maps the problem and the flow process chart; Measure collects and verifies production data; Analyze uses Pareto, fishbone, and PFMEA to trace the root cause; Improve synthesizes solutions based on the integration of Six Sigma, PFMEA, and TRIZ; while Control is designed as a continuation monitoring plan. Technical analysis evaluates the reduction of defects and process efficiency; economic analysis assesses the impact of quality cost savings on profitability; and organizational analysis to assess the readiness of human resources and management support. The main findings are summarized as evidence that the combination of Six Sigma–PFMEA–TRIZ is effective in reducing quality costs, improving quality, and improving productivity, along with implementation recommendations, continuous monitoring, and advanced research agendas to expand the application of the methodology in other lines and industries.

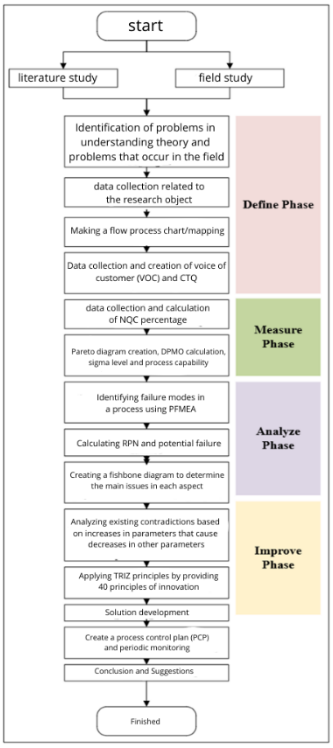

Figure 1. Research flow

RESULTS AND DISCUSSION

Define

The define stage is the first step in the Six Sigma approach which aims to clearly identify the main problems that occur in a business process. In this phase, the project team maps customer needs, process boundaries, and sets improvement goals to be achieved (Tampubolon & Purba, 2021). The output of this stage is a thorough understanding of the process to be analyzed, both in terms of inputs, internal processes, and outputs received by customers.

This research focuses on the Product A line at PT X, which accounts for 67% of the total quality costs by 2024 (≈ 73 k USD). Observation began with a detailed mapping of the assembly process through a flow-process-chart of five stations: touch-panel and front-cover unification, LCD & dust-foam assembly, module cleaning & unification, chassis-PCBA assembly & connectors, and rear-cover closure ended in pre-test, 5-hour burn-in, final-test, and packing. The SIPOC diagram then maps the supply chain: key suppliers (materials, maintenance, methods, facilities, human resources), six input categories (raw material, sub-assembly, tools & jigs, test-equipment, operator-skills, OWS), eight process steps, four key outputs (conformance assembly & functional, high-performance product, efficient production), and three types of customers (in-house production, distribution center, scrap).

Voice of Customer (VoC) affirms the core goal of the research: lowering the cost of product quality 1 through critical-to-quality (CTQ) control in the four input elements of the test equipment (SGEP cleanliness, dust count accuracy), material (component dimensions and cleanliness), jig & fixtures (precision, torque, preventive-maintenance), and operator (competence & defect awareness). Furthermore, total quality costs are grouped into five categories: Non-Quality Internal (NQI: scrap & rework), Non-Quality External Return (NQER: returns & warranty), Time-to-2.4 Sigma (T2.4: capability enhancement investment), Non-Quality Inspection Service (NQIS: inspection & calibration), and Non-Quality External (NQE: reputation/market loss). Pareto analysis shows NQI dominates 95% of spending; in line A, Product 1 alone costs 19.272 USD.

Defect decomposition identifies five critical processes (overlay, LCD, touch-panel, PCBA, front-bezel) and groups them into six defect classifications Visual, Functional, Mechanical, Assembly-Error, Contamination, and Orientation-Error. The 2023 data shows the highest defects in shifted overlays (1,639 cases) as well as tilted panels (976 cases), followed by loose connectors, loose bolts, and dust on LCDs. These findings confirm that quality costs are rooted in material control, cleanliness, jig tuning methods, and operator skills. The results of process mapping, VoC-CTQ, and defect priority are then the basis for designing Six Sigma-PFMEA-TRIZ integrated improvement to reduce scrap/rework and improve PT X's cost-quality performance in a sustainable manner.

Measure Stage

The Measure Stage aims to measure the actual performance of the ongoing process as well as identify and quantify the types of defects that occur in the production process (Tampubolon & Purba, 2021). In this study, data collection was focused on the type and number of defects from each product component assembly process such as Overlay, Touch Panel, PCBA, LCD, and Front Bezel. This process is carried out with a data-driven approach to support the objectivity of the analysis. In the Six Sigma approach, one of the important stages in analyzing the performance of a production process is to calculate the value of DPMO

(Defects Per Million Opportunities) and estimate the capabilities of the process. DPMO provides quantitative information on the number of chances of defects occurring per million occasions, while process capabilities reflect the extent to which the process can produce products according to specifications with high consistency.

1. DPMO and Sigma Level Calculation

In the Six Sigma approach, the measurement of the performance of the production process is carried out by statistical method that refers to the number of defects that occur compared to the total chance of defects occurring. One of the performance measures used is Defects Per Million Opportunities (DPMO), which is the number of defects per million chance of error. DPMO provides a more in-depth picture than simply calculating the defect percentage, as it takes into account the complexity of the process through the number of defect opportunities in each product unit (Setiawan et al., 2021). The DPMO is designed to measure how often errors or nonconformities appear in a process based on production volume and the chance of possible defects. By knowing the value of the DPMO, companies can measure how well a process is going and how much opportunity it has to make improvements. In general, the DPMO calculation formula is as follows:

$$DPMO = \left(\frac{Number\ of\ Defects\ Found}{Number\ of\ Products\ Inspected}\right) \times 1.000.000$$

As an illustration of the calculation of Defects Per Million Opportunities (DPMO), the following is explained in detail the use of the DPMO formula on one of the types of defects found in the overlay installation process, namely air bubbles. In this process, it is known that the number of units produced is 44,721 units, while the number of units that have defects in the form of air bubbles is recorded as 132 units. Thus, the DPMO value for this type of defect can be calculated using the following formula:

$$DPMO = \left(\frac{132}{44721}\right) \times 1.000.000 = 2951{,}63$$

From these results, it can be concluded that for every one million opportunities in the overlay installation process, it is estimated that there are around 2,951 errors in the form of air bubbles. This value can then be used as the basis for conversion to sigma-level values, reflecting the process's ability to avoid production errors. The lower the DPMO value, the higher the sigma level and the better the performance of the process (Setiawan et al., 2021). Next, the calculation of the indigo sigma level is carried out with the following formula:

$$Level\ Sigma = normsinv\left(\frac{1000000 - DPMO}{1000000}\right) + 1{,}5$$

The following is an example of calculating the sigma level calculation on one of the types of defects found in the overlay installation process, namely air bubbles. This type of defect has a DPMO value of 2951.63, so the results of the sigma level calculation are as follows:

$$Level\ Sigma = normsinv\left(\frac{1000000 - 2951{,}63}{1000000}\right) + 1{,}5 = 4{,}25$$

Based on the results of conversion into sigma level, which is an indicator of the level of process capability, it is obtained that this process has a sigma level of 4.25. The sigma level of 4.25 indicates that the overlay installation process for air bubble defects is quite good, although there is still room for further improvement and quality improvement. With the sigma level being above four, it can be said that the error frequency is relatively low and the process is running quite stable. After measurements of these types of defects, a similar approach is then applied to all other types of defects recorded during the production process, as listed in table 1 as follows:

Table 1. DPMO and Sigma Level

Process	Types of Defects	Number of Defects	Production Quantity	DPMO	Level Sigma
Overlay Installation	Air bubbles	132	44721	2951,63	4,25
	Doesn't stick flat	465	44721	10397,80	3,81
	Overlay bergeser	1.639	44721	36649,45	3,29
Touch Panel Installation	Loose flexible cable	122	42484	2871,67	4,26
	Connector not full	300	42484	7061,48	3,95
	Tilt panel	976	42484	22973,35	3,50
PCBA Installation	Loose bolts	136	41086	3310,13	4,22
	Incorrect connector	101	41086	2458,26	4,31
	Loose soldering components	718	41086	17475,54	3,61
LCD Mounting	Dust sticks	90	40131	2242,66	4,34
	Cracked LCD	50	40131	1245,92	4,52
	LCD unlocked	520	40131	12957,56	3,73
Front Bezel Mounting	Loose bezel	53	39471	1342,76	4,50
	Bezel doesn't fit	32	39471	810,72	4,65
	Incorrect orientation of the installation	420	39471	10640,72	3,80

The results of the DPMO calculation and sigma level show that the capabilities of the production process vary, with sigma values ranging from 3.29 to 4.65. Defects such as snug bezels and cracked LCDs have high sigma levels, indicating good process quality, while defects such as shifted overlays and tilted panels indicate lower sigma levels, indicating the need for process improvements. These findings help identify critical points in the production line that need improvement so that product quality can be consistently improved.

2. Process Capability Measurement

Process capability measurement is carried out to evaluate how well each production stage is able to produce output according to the set quality standards. Through the DPMO approach and conversion to the sigma level, it can be known the level of stability and reliability of each process against the possibility of defects. A high sigma value indicates a controlled process and has a low potential for failure, while a low sigma value indicates a more frequent mismatch that needs to be followed up on (Setiawan et al., 2021). With this method, the production process can be analyzed quantitatively to support efforts to improve quality and efficiency in a sustainable manner. The calculation of the process is carried out with the following formula:

$$Process\ Capability\ Index\ (Cp) = \frac{Level\ Sigma}{3}$$

Based on the calculation results, the sigma level value for the type of air bubble defect in the overlay installation process is 4.25. Using a simple estimation formula, the Cp value can be calculated as follows:

$$Process\ Capability\ Index\ (Cp) = \frac{4{,}25}{3} = 1{,}42$$

A Cp value of 1.42 indicates that the process is capable, because the value is higher than the minimum standard of Cp = 1.33 which is usually used as the lower limit for a stable process that is able to meet quality specifications. Similar calculations are applied to other types of defects to assess the capabilities of each process. The full calculation results for other types of defects can be seen in the following table.

Table 2. Process Capability Index

Process	Types of Defects	DPMO	Level Sigma	Cp
Overlay Installation	Air bubbles	2951,63	4,25	1,42
	Doesn't stick flat	10397,80	3,81	1,27
	Shifted overlay	36649,45	3,29	1,10
Touch Panel Installation	Loose flexible cable	2871,67	4,26	1,42
	Connector not full	7061,48	3,95	1,32
	Tilt panel	22973,35	3,50	1,17
PCBA Installation	Loose bolts	3310,13	4,22	1,41
	Incorrect connector	2458,26	4,31	1,44
	Loose soldering components	17475,54	3,61	1,20
LCD Mounting	Dust sticks	2242,66	4,34	1,45
	Cracked LCD	1245,92	4,52	1,51
	LCD unlocked	12957,56	3,73	1,24
Front Bezel Mounting	Stretchy bezels	1342,76	4,50	1,50
	Bezel doesn't fit	810,72	4,65	1,55
	Incorrect orientation of the installation	10640,72	3,80	1,27

Based on the calculation results, the process capability index (Cp) value for each type of defect shows that most processes are at a good level of capability, with a Cp value above 1.33. Some processes even reach Cp > 1.5, such as improper bezel defects (Cp = 1.55) and cracked LCDs (Cp = 1.51), which indicate the process performance is highly capable. However, there are also processes with Cp below ideal standards, such as shifted overlays (Cp = 1.10) and slanted panels (Cp = 1.17), which need to be the focus of improvement. Overall, this analysis provides a quantitative picture of the capabilities of each process and helps identify critical areas for improving production quality.

Analyze Stage

At the analysis stage, the risk of failure in the process was identified using the Process Failure Mode and Effect Analysis (PFMEA) method. This technique aims to determine the potential failure in each process, its impact on the product, and determine improvement priorities based on the Risk Priority Number (RPN) value (Huang et al., 2020). The data used included flow process charts, direct observation results, and interviews with operators and production line supervisors. At this stage, the analysis is carried out using the following approach:

1. Process Failure Mode and Effect Analysis (PFMEA)

   PFMEA is prepared based on actual process maps and simulations of process conditions in the field. Assessment is carried out on each stage of the process by considering three main factors, namely Severity (S), Occurrence (O), and Detection (D). The RPN value is calculated using the formula:

   $$RPN = S \times O \times D$$

   The results of the PFMEA analysis are compiled in the form of a table that shows the failure mode, causes, impacts, and recommendations for corrective actions. The focus is directed to the failure mode with the highest RPN to follow up on at the improve stage.

2. Fishbone Diagram

   Fishbone diagrams are utilized to group the root causes of defects based on key factors such as Human, Machine, Material, Method, Environment, and Measurement. With the combination of these two methods, the analysis can uncover the hidden root of the problem and identify the critical points in the production process that contribute the most to defects, so that corrective actions can be designed that are more targeted and have a significant impact on quality improvement.

   Add the table below as the conclusion of the analysis stage.

Failure Mode	**Failure Effect**	**RPN**	**Priority**
LCD cracks during installation	Product total failure	273,38	1
Air bubbles appear during installation	Visual display is disturbed	266,89	2
Flexible cable is loose	Unit does not respond to touch, malfunction	241,72	3
Bolts are loose / not properly torqued	PCBA shake, product malfunction	230,56	4
Bezel does not fit into housing	Reject due to visual or open gap	224,00	5

The Improve stage in the Six Sigma methodology is a critical step in designing and implementing improvement solutions based on the results of the identification of the root of the problem that has been carried out previously (Setiawan et al., 2021). In this context, the TRIZ (Theory of Inventive Problem Solving) approach is used to overcome technical contradictions in the production process that cause high cost of quality. The resulting solution not only aims to reduce defects, but also prevent increased costs due to inefficient corrective actions.

1. Contradictions of Defects

In the production process of product A at PT. X, various types of defects are found at critical stages such as LCD installation, overlays, touch panels, PCBAs, and front bezels. Each of the defects has complex and conflicting root causes. Efforts to improve one aspect often lead to a decline in other aspects. This situation is referred to as a technical contradiction, where an increase in the performance of one parameter can lead to a loss in the other. For example, to prevent LCD cracking during installation, a pressure drop provided by the auxiliary tool is required. However, pressure reduction can actually slow down installation time or decrease efficiency. The same applies to the overlay installation process, where the effort to produce perfect adhesion actually adds to the complexity of the tool and the cost. By identifying and analyzing these technical contradictions, we can formulate innovative approaches that not only solve the problem on the surface, but also eliminate the root of the problem by considering the balance between parameters.

2. Application of TRIZ's Inventive Principles Based on Contradictions

Once technical contradictions have been identified in each defective installation process, the next approach is to determine the inventive principles of the relevant TRIZ (Theory of Inventive Problem Solving) method to resolve the conflict. These principles not only offer technical solutions, but also aim to eliminate compromises between two conflicting parameters (Malvik, 2025)

Failure Mode	Principles of Contradiction	Improvements that can be made
LCD cracked during installation	Principle 10 (Prior Action)	Repair the jig and adjust the jig surface when installing the LCD.
	Principle 3 (Local Quality)	Add CTP to the Work Instruction and add sampling checks during the first production run.
	Principle 28 (Mechanical Substitution)	Replace manual processes with automated machines.
Air bubbles appeared during installation	Principle 3 (Local Quality) and Principle 19 (Periodic Action)	Use a press designed to apply pressure gradually or from one side to the other.
	Principle 27 (Cheap Short-Lived Objects)	Break down the overlay installation process into several small, clearly defined, standardized steps.
	Principle 10 (Prior Action)	Use a thin intermediate layer temporarily placed between the overlay and the pressing tool
Flexible cable loose	Principle 17 (Another Dimension), and Principle 25 (Self-Service)	Create guides or jigs around the connector slots to ensure flexible cables can only be inserted with the correct orientation and depth

	Principle 23 (Feedback), and Principle 28 (Mechanical Substitution)	Apply a color-coding system or visual markers on connector pins and flexible cables
	Principle 19 (Periodic Action), and Principle 40 (Composite Materials)	Use pneumatic or simple mechanical pressing tools designed to apply consistent force and duration when pressing connectors
Failure Mode	Principles of Contradiction	Improvements that can be made
Screws loose / incorrect torque	Principle 19 (Periodic Action) and Principle 25 (Self-Service)	Replace manual screwdrivers with electric or digital torque screwdrivers that can be programmed.
	Principle 6 (Universality)	Standardize torque screwdrivers that can be adjusted for torque settings and are compatible with various types of screwdriver bits.
	Principle 14 (Curvature)	Ensure that torque screwdrivers have ergonomic handles and that workstations are properly configured.
Bezel does not fit properly with housing	Principle 3 (Local Quality) and Principle 14 (Curvature)	Design locking clips with geometry that allows for minimal movement.
	Principle 32 (Color Change)	Place simple visual markers, such as colored lines or dots
	Principle 5 (Merging), 34 (Discarding and Recovering)	No solution can be implemented due to the significant effort required

Control Stage:

After identification, analysis, and improvement using the Six Sigma and TRIZ approaches, the last stage in the DMAIC methodology is the Control phase. The main objective of this stage is to ensure that the improvements that have been implemented can be maintained consistently and do not regress over time (Hameed et al., 2022). For this reason, it is necessary to develop a systematic control mechanism, such as a process control plan (Control Plan) and a layered process audit (Layered Process Audit / LPA). The Control Plan is focused on the important elements in the production process that directly affect quality (CTQ). Meanwhile, LPA is a visual and operational audit system that is carried out regularly and in stages, to ensure the discipline of implementing standards at the shopfloor level, from operators to management. The following is presented a draft Control Plan for five priority processes based on the results of the previous PFMEA and TRIZ.

Table 3. Control Plan Design

Process	CTQ	Control Method	Freq.	Control Tools	PIC	Reaction If It Doesn't Fit
LCD Mounting	LCD does not crack, pressure ≤ 2 N	Visual check and pressure sensor	Every 10 units	Tools and sensors	QA In-line	Pull the unit, check the aids, retrain
Overlay Installation	No air bubbles	Visual inspection of adhesive	Every 20 units	Jig overlay	Operators and QA	Re-clean, evaluation of adhesive patterns
Touch Panel Installation	Perfectly locked flexible cable	Check snap sounds and indicators	Every 10 units	Snap lock check	QA and Technicians	Replace cables, evaluate locking clips
PCBA Installation	Torque Conforming Bolts	Digital torque meter	Each unit	Automatic torque screwdriver	Operators and Leaders	Stop line, recalibration of tools, SOP evaluation
Front Bezel Mounting	Bezel fits and doesn't stretch	Visual dimension inspection	Every 15 units	Jig bezel	QA In-line	Double-check housing, save visual evidence

This table contains complete information about the quality variables that must be monitored, the measurement or inspection methods used, the frequency of inspections, the aids used, the person in charge (PIC), and corrective actions if deviations from the standard are found. This control plan is expected to be the main reference for the production and quality team in maintaining the stability of the post-repair process. After the Control Plan is prepared, the control stage is strengthened by the implementation of routine audits in the form of Layered Process Audit (LPA). This audit is preventive and involves various levels of the organization, from operators to supervisors and managers, with the aim of ensuring that daily activities on the shopfloor run according to procedures and the changes that have been implemented remain consistent.

Table 4. Layered Process Audit

Yes	Questions / Checklist	Yes	Not	Notes/Corrective Actions
1	Are LCD mounting aids SOP compliant and clean?			
2	Is the mounting pressure of the LCD measured and recorded?			
3	Is the adhesive overlay even and does not create bubbles?			

4	Do touch panel flexible cables lock with clicks?			
5	Does PCBA bolt torque use a calibration torque screwdriver?			
6	What are the attached bezels without gaps/stretches?			
7	Does the operator understand the latest SOP from the TRIZ results?			
8	Are there any recurring defects from the last 3 days?			

The LPA checklist is designed to verify the implementation of work standards and the sustainability of repair results in areas with a high risk of defects. The questions in this audit refer to the key factors causing failures that have been identified in the Define and Analyze stages, as well as the solutions that have been implemented in the Improve stages. The results of the audit are the basis for taking corrective action and coaching personnel if discrepancies are found. By implementing a multi-layered process control and audit plan, companies can minimize the possibility of defects or non-conformities reappearing. This is important to maintain the sustainability of repair results and improve efficiency and customer satisfaction in the long term. In addition, the control stage is clear evidence of commitment to a sustainable quality culture in the manufacturing environment.

Conclusion

This study identified that PT X's quality costs for product A reached $73,246, contributing 67% of the company's total quality costs. The analysis showed that five material categories—Overlay, Touch Screen, PCBA, LCD, and Front Bezel—had a significant impact on these costs. The performance of Product A is deemed unsatisfactory with a Cp value < 1.33, indicating the need for further improvements. The PFMEA results identified several defect-causing factors, with the highest priority on the LCD and overlay assembly processes. Improvement recommendations based on the integration of PFMEA and TRIZ include developing jigs, using automated machines, and standardizing tools to enhance efficiency and reduce defects.

Recommendations

1. Implementation of Recommendations: The company is advised to implement the analysis and improvement recommendations that have been generated to reduce quality costs for product A.
2. Further Analysis: More in-depth analysis is needed to determine improvement principles that are in line with the company's budget.
3. Monitoring and Evaluation: This research needs to be continued after the recommendations have been implemented to evaluate the effectiveness and impact of the changes.

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