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Improvement Product Design Quality to Reduce Warranty Cost in Aftermarket Sales for OEM's Customer

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ABSTRACT

Improving product quality and reducing warranty costs are critical objectives for Original Equipment Manufacturers (OEMs) and their aftermarket sales operations. For automotive component suppliers, analysing warranty claims is a standard practice to identify and mitigate product defects. Effective warranty cost management demands robust internal processes, innovative product designs, and early defect detection mechanisms. This study addresses the critical role of warranty claim analysis in mitigating warranty costs for automotive component suppliers, particularly in OEM aftermarket sales. Accurate warranty data analysis is pivotal for identifying defect root causes and implementing effective corrective actions. However, challenges such as incomplete data, like missing vehicle delivery dates, introduce uncertainty in forecasting and reliability assessments. This research proposes a systematic methodology to enhance vehicle warranty data analysis, focusing on reliability and robustness improvements to reduce warranty costs. The methodology consists of three phases. Phase 1 involves collecting and analysing warranty claims data from two batches: historical claims (2016–2020) and new claims (2021). Phase 2 investigates root causes using Original Failure Part (OFP) data and conducts diagnostic studies through in-person or remote assessments. Phase 3 introduces a component repair strategy aimed at reducing warranty claims by ensuring accurate fixes and improved service parts management. Results demonstrate the effectiveness of this approach, particularly in alternator component repairs, achieving a significant cost saving of RM 68,000 and a 73% reduction in warranty claims. These findings underscore the potential for enhanced profitability, strengthened customer trust in products and services, and minimized downtime for end-users. This research offers a practical framework for improving quality management and operational efficiency, contributing to sustainable growth in the automotive industry.

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INTRODUCTION

Challenges such as incomplete data, like missing vehicle delivery dates, often hinder accurate warranty analysis and market forecasting. The variability and complexity of warranty data formats further compound the issue, introducing uncertainty in predicting defect trends over time (Chang et al., 2012). This study explores design-centric strategies for enhancing product quality and mitigating warranty costs, addressing data reliability challenges, and improving the efficiency of corrective actions. The project's main aim is to reduce high warranty claims related to design issues by introducing component repair in OEM's car aftermarket and improving product design issues by creating an aftermarket component repair process and conducting a feasibility study to minimize warranty claim cost.

The Malaysian automotive market demonstrated robust growth in 2023, with new motor vehicle sales rising by 11%, driven predominantly by the passenger car segment. According to the Malaysian Automotive Association (MAA), this expansion was fueled by a resilient domestic economy, stable socio-political conditions, and strategic initiatives, such as tax-free car bookings and the introduction of affordable electric vehicles (EVs). The Total Industry Volume (TIV) peaked at 799,731 units, marking a significant recovery from the Covid-19 pandemic's downturn (Malaysia Automotive Association, 2025). This resurgence was further supported by government policies and incentives, alongside the launch of diverse vehicle models, including EVs that resonated with environmentally conscious consumers. Customer P represents one local automotive customer company, a leading player with the largest market share in Malaysia, that conducts annual vendor briefings to communicate key performance indicators and strategies for warranty claim reduction. In 2021, one of Malaysia's automotive vendors and known as Company XYZ, was identified as one of the top four suppliers contributing to warranty claims related to design issues. Customer P urged swift, proactive measures to identify root causes for each product while promoting cost-sharing models for warranty repairs. Suppliers were tasked with evaluating repair costs and exploring reduction strategies without compromising end-user satisfaction. The conceptual model for warranty cost reduction shared by Customer P underscores the importance of collaborative efforts to address warranty challenges, improve quality, and enhance customer trust in a highly competitive automotive market (Muhamad Lutfi, 2023).

This study focuses on optimizing the design of the market-available alternator housing in order to lower the product's noise output while simultaneously improving its functional requirements, such as the performance of the housing area for achieving a better charging value, as well as boosting manufacturing feasibility and incorporating uniform durability to lessen the likelihood of casting defects (Prabhakaran et al., 2021). Recent remanufacturing repair and restoration trends indicate a growing interest in additive manufacturing technology for metals (Alqahtani & Gupta, 2017). To increase the efficiency of additive manufacturing for automated repair and restoration, it is essential to optimize the core design (Ben Mabrouk & Chelbi, 2022). Remanufacturing is recognized as one of the most effective green strategies for achieving sustainable manufacturing because it renews the product's life cycle (He et al., 2018). The purpose of this paper is to examine the current challenges facing Malaysian remanufacturing industries as well as their future prospects (Saidin et al., 2018; Akbar et al., 2018; Rashid & Aslam, 2012).

METHODOLOGY

This study employs a structured, phased methodology to systematically assess and solve problems linked to the Alternator Assembly under the warranty claim. The methodology targets enhancing the precision in the data, revealing root causes, and developing effective corrective strategies to enhance product dependability. The methodology comprises three major phases, including: (1) Warranty claim data collection and analysis, in which the warranty data are gathered and assessed to reveal patterns and abnormalities; (2) Investigation and root cause analysis, in which cooperative inspection, failure evaluation,

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and comparative investigations are conducted to determine root failure mechanisms; and (3) Feasibility and implementation of component repairs, in which the cost-effectiveness, risks, and training courses are assessed to offer long-term and quality-based repair solutions. Through the employment of data-driven methodology, diagnostic tests, and improvement techniques, the methodology targets optimal warranty control, minimization in expenditures, and overall quality control practices in the automotive market.

Phase 1: Warranty Claim Data Collection and Analysis

Warranty represents the contractual terms under which suppliers repair, replace, or compensate for defective products. These costs encompass parts, labor, and taxes associated with addressing product defects. Company XYZ manages warranty claims received monthly from OEM car assemblers through the Global Warranty Analysis Management System (GWAMS), ensuring timely, accurate, and global data sharing. Analysis of warranty claims revealed a significant abnormality in the Alternator Assembly, particularly excessive noise during idling conditions. Following Customer P's vendor briefing in 2021, Company XYZ initiated a detailed analysis of the Alternator Assembly to address these issues (Muhamad Lutfi, 2023).

The increasing trend in the case of the Alternator Assembly warranty claims greatly impacted overall market-based expenditure in terms of warranty claims. However, a lack of detailed and accurate warranty data presents challenges in identifying the root cause accurately, assessing market conditions, and starting effective problem-solving. The failure to provide detailed and accurate information inhibits proper failure analysis and the generation of corrective strategies. Bridging the gaps using data-driven techniques and diagnostic evaluation assists in the improvement of product dependability, reducing the expenditure in the domain of the warranty, and overall quality control practices in the automotive industry.

Phase 2: Investigation and Root Cause Analysis

Root cause investigations involve collaborative training and joint inspections with OEM car assemblers and service centers. This process includes direct end-user complaint evaluations via online platforms or face-to-face consultations (Arokiasamy & Tat, 2014). Original Failure Parts (OFP) are collected biweekly from customers and sent to Quality Assurance (QA) plants for detailed examination, with a target lead time of 30 days for fault identification. QA teams utilize tools such as Fault Tree Analysis (FTA) and comparative data from complaint-free vehicles to uncover potential failure mechanisms. In cases of unresolved issues, joint verification activities on actual vehicles are conducted to enhance data accuracy and understanding of contributing factors (Theissler et al., 2021). Creativity techniques are employed to develop innovative strategies and resolve product quality issues within stipulated timelines. Comparative studies between failed and functional parts further facilitate failure mechanism analysis (Ucar et al., 2024). Once the root cause is identified, feasibility studies are undertaken to evaluate the viability of implementing component repair strategies, ensuring alignment with Customer P's expectations and other OEM requirements (Chi et al., 2020).

Phase 3: Feasibility and Implementation of Component Repairs

The feasibility of component repairs is evaluated through an in-depth cost analysis that considers factors such as child parts, profit margins, and applicable taxes to determine project viability. A comprehensive risk assessment is conducted to identify potential financial risks and ensure sustainable profitability. To maintain repair quality comparable to new Alternator Assemblies, specialized training programs are developed for mechanics and technicians. Collaboration with the QA team plays a pivotal role in creating visual repair guides and hands-on training sessions. Video-based training methods are preferred over traditional manuals due to their clarity and effectiveness in conveying repair procedures. To

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ensure consistency and quality, all repair processes and Standard Operating Procedures (SOPs) are meticulously documented and standardized.

A feasibility study, based on data from Customer P's Warranty Department, reveals substantial cost savings, with an average reduction of 78% achieved by replacing only the failed component instead of the entire assembly. This strategic approach enhances product reliability and strengthens customer confidence in post-service performance. Upon approval from Company XYZ's management, the next phase involves developing detailed repair procedures that align with company standards and specifications. Additionally, comprehensive training initiatives for Customer P's mechanics are implemented to ensure strict adherence to repair protocols.

To drive continuous improvement, robust monitoring and evaluation mechanisms are put in place. Future-oriented planning and goal setting are critical to optimizing management outcomes. Stakeholder engagement, facilitated through a structured induction process, is essential before full-scale implementation (Fadda et al., 2022). The active phase of the project focuses on designing strategic steps to achieve objectives, with continuous improvement methodologies such as kaizen, promoting process standardization, and corrective actions. Furthermore, knowledge-sharing initiatives, supported by efficient document management systems, contribute to operational excellence (Scherpen et al., 2018). As part of its long-term strategy, Company XYZ aims to solidify its market position by reorganizing operations to remain competitive and responsive to evolving industry demands. Fig 1 presents the flowchart outlining the phased approach for conducting warranty claim reduction activities.

RESULTS AND DISCUSSION

Warranty Data Collection

Customer P, a high-priority customer for Company XYZ, has become the focus of a comprehensive warranty claim analysis for the Fiscal Year (FY) 2020 market claims. The objective of this initiative is to identify potential products suitable for component repair and to develop a viable business model for selected customers. The warranty claim contributions for FY 2020 are illustrated in Fig 2.

Based on the analysis, the Alternator Assembly (Alternator Assy) has emerged as a promising product for further research and potential component repair. The Alternator Assy aligns with Company XYZ's goal of reducing warranty claim costs due to its repair feasibility. It is designed for disassembly and reassembly using standardized procedures and guidelines provided by the QA Department. The alternator's primary function is to generate electricity by converting the engine's power and regulating the output to supply energy to the vehicle's battery and electronic components.

To ensure the success of this repair initiative, a detailed Root Cause Analysis (RCA) is necessary. This analysis helps identify and address potential risks, such as secondary defects, that may arise during the repair process. The RCA guides accurate decision-making, aiming to enhance both the reliability and cost-effectiveness of the Alternator Assy repair. This structured approach not only focuses on reducing warranty claim costs but also ensures that the repair process maintains product integrity and customer satisfaction. By pursuing this data-driven strategy, Company XYZ seeks to strengthen its relationship with Customer P, improve operational efficiency, and provide a business model that emphasizes sustainable, high-quality repair processes. This initiative reflects the company's commitment to delivering innovative solutions that align with customer expectations while reinforcing long-term market competitiveness.

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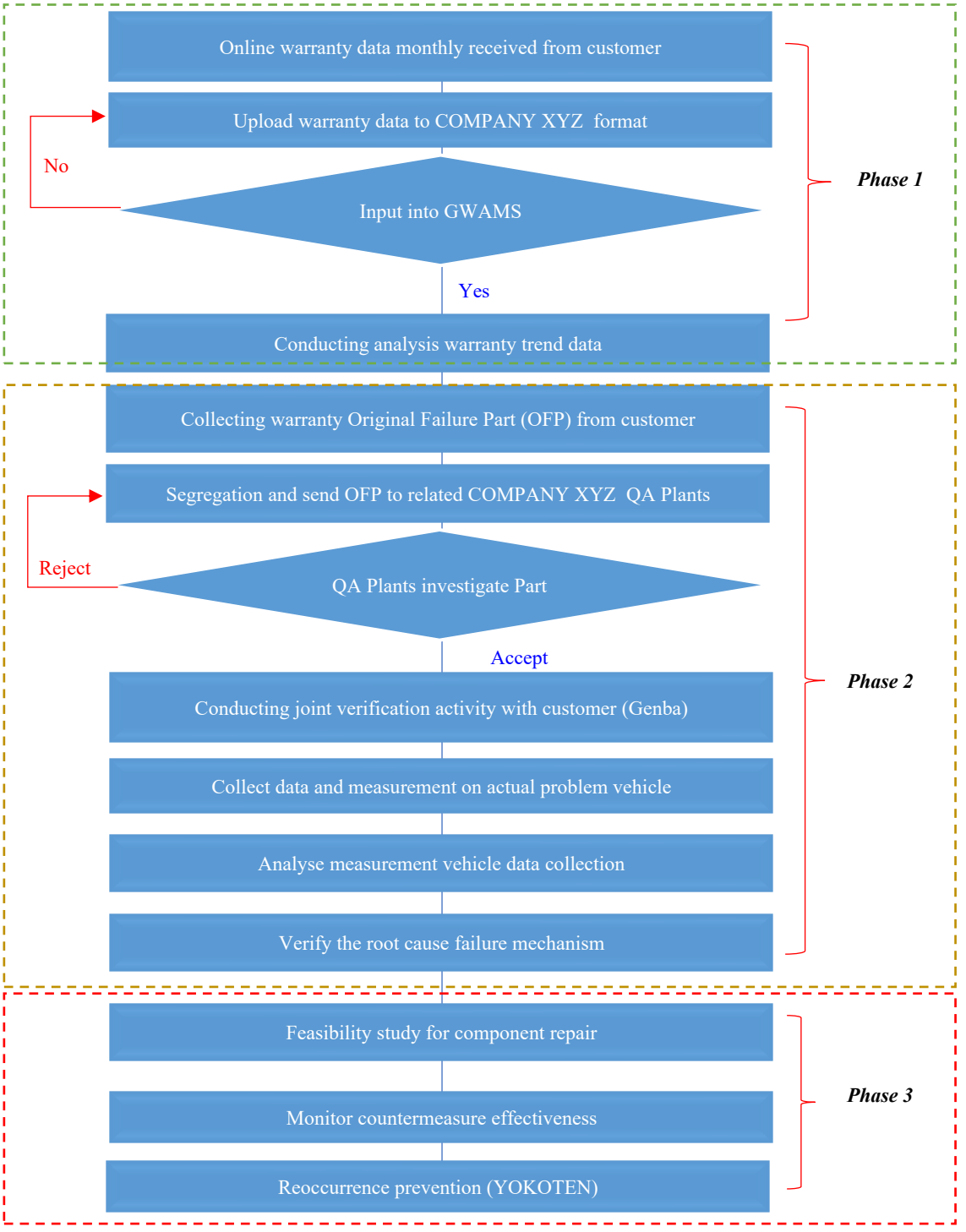

Fig. 1. Flowchart for conducting warranty reduction activity.

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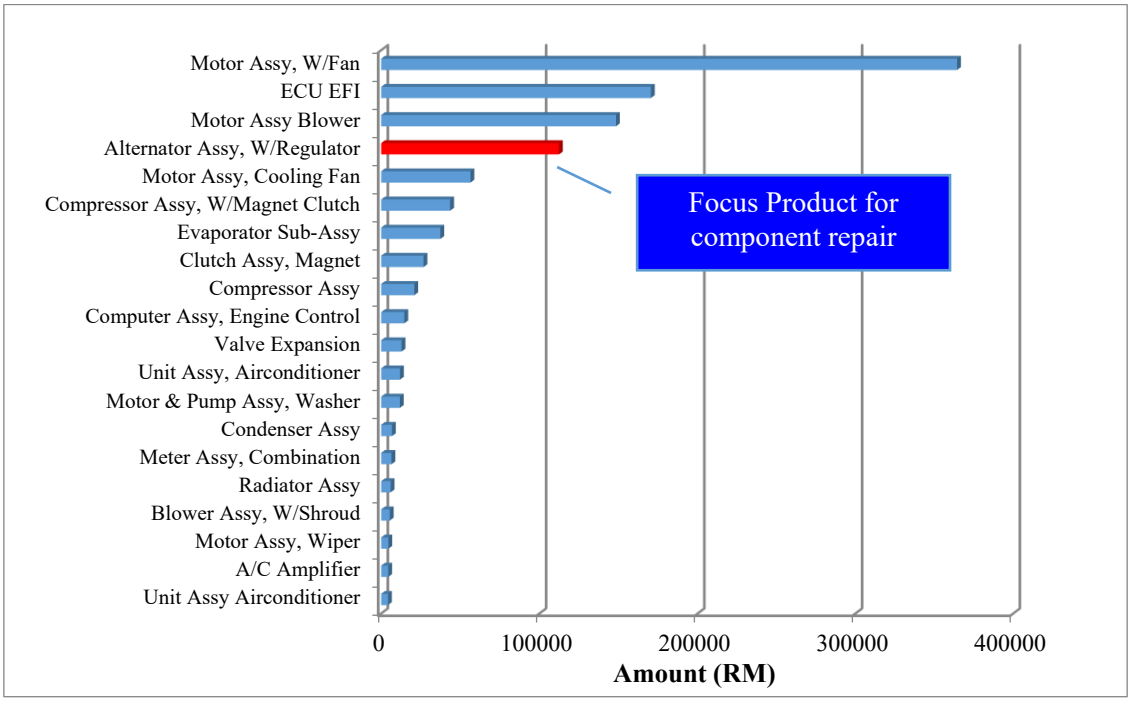

Fig. 2. Warranty claim amount by parts.

Investigation and Determine Root Cause

Company XYZ received an official response from the manufacturing plant confirming that no changes had occurred in the 4M1E factors—Man, Method, Material, Machine, and Environment. Following an in-depth investigation of the OFP, Company XYZ consolidated all findings and conducted a comprehensive FTA to systematically identify potential root causes and focus on key areas requiring resolution (Itoh et al., 2018).

The analysis identified abnormal noise emission as the primary root cause of the front alternator bearing failure (Xu et al., 2023). The contributing factors behind this failure were classified into three main categories: the bearing itself, the alternator, and vehicle conditions. After thorough evaluation, it was determined that no abnormalities were present in either the bearing or alternator components. However, further data collection and analysis of vehicle conditions were deemed necessary to accurately identify the definitive root cause, as depicted in Fig 3.

Company XYZ, in collaboration with the Regional Headquarters, QA plants, and Customer P's Warranty Department, conducted a joint verification activity known as the Go and Study initiative at the Customer P Service Center. The primary objective was to collect comprehensive vehicle data and compare it with well-functioning vehicles to identify the root cause of the reported issue.

To validate the issue further, data was analyzed using an FFT analyzer, with information extracted from the vehicle's data logger. While the estimated failure analysis is illustrated through FTA in Fig 3. Findings from the Go and Study initiative led Company XYZ to suspect that the issue originated from the auto belt tensioner's condition, prompting further verification of belt tension across both in-market and newly manufactured vehicles.

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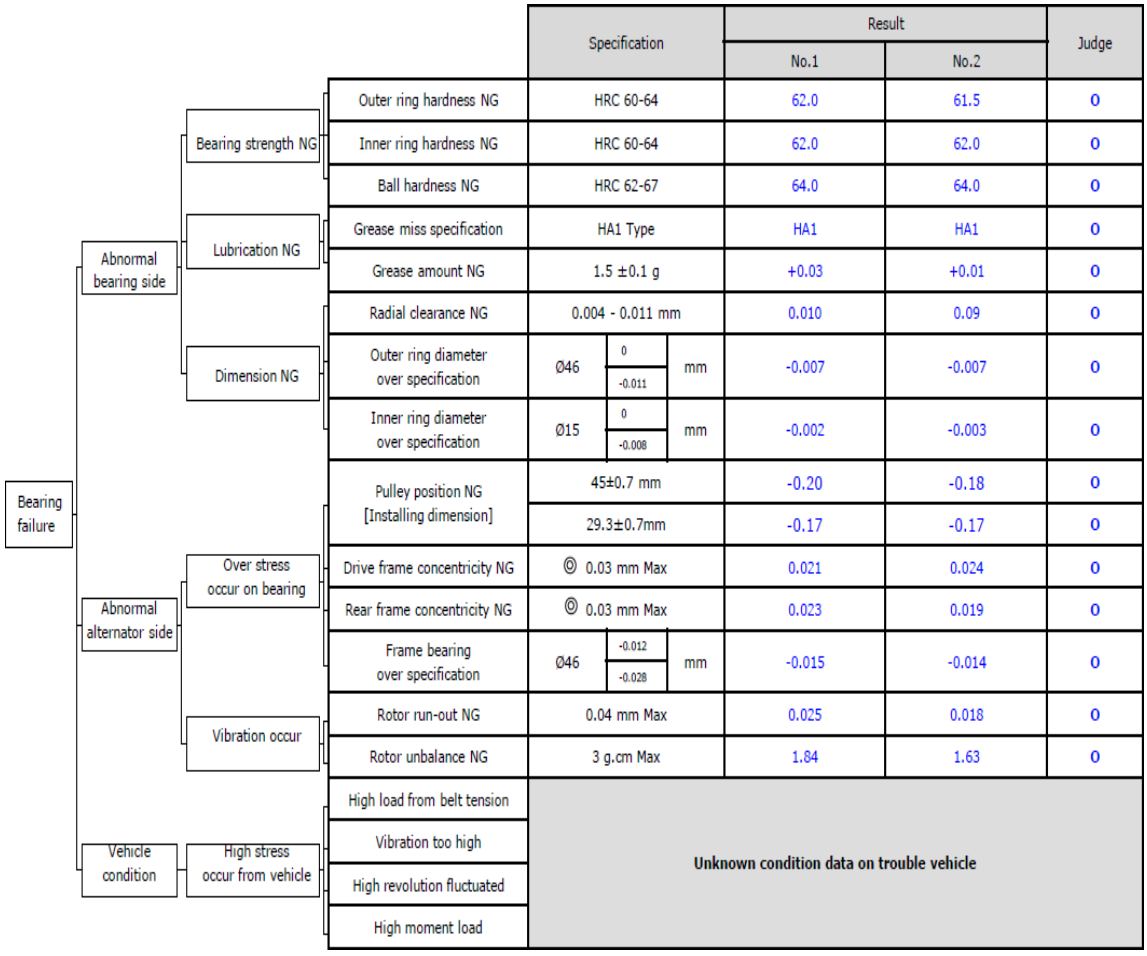

Fig. 3. Fault Tree Analysis [FTA] – Bearing failure.

A total of forty-nine (49) vehicles, including market vehicles and newly produced units from Customer P's manufacturing plant after passing Quality Control (QC) inspections, were examined to assess belt tension consistency. The detailed findings are presented in Table 1 and visualized in Fig 4, Fig 5, and Fig 6. Ultimately, the Quality Information Department of Customer P officially documented the conclusions in Fig 4, confirming that the primary cause of the bearing failure was inconsistent or excessive belt tension, leading to abnormal noise.

Table 1. Belt tension confirmation from good vehicles and new vehicles

Target	Good vehicle (used) (Using in market from end user)	New vehicle (After QC passed check)
Allowed quantity	Twenty-one (21) units of vehicle	Twenty-eight (28) units of vehicles
Analyzer	DNMY Quality Assurance (QA) staff	Customer P (Not allow outside persons)
Tools	CLAVIS Belt Tension meter	CLAVIS Belt Tension meter

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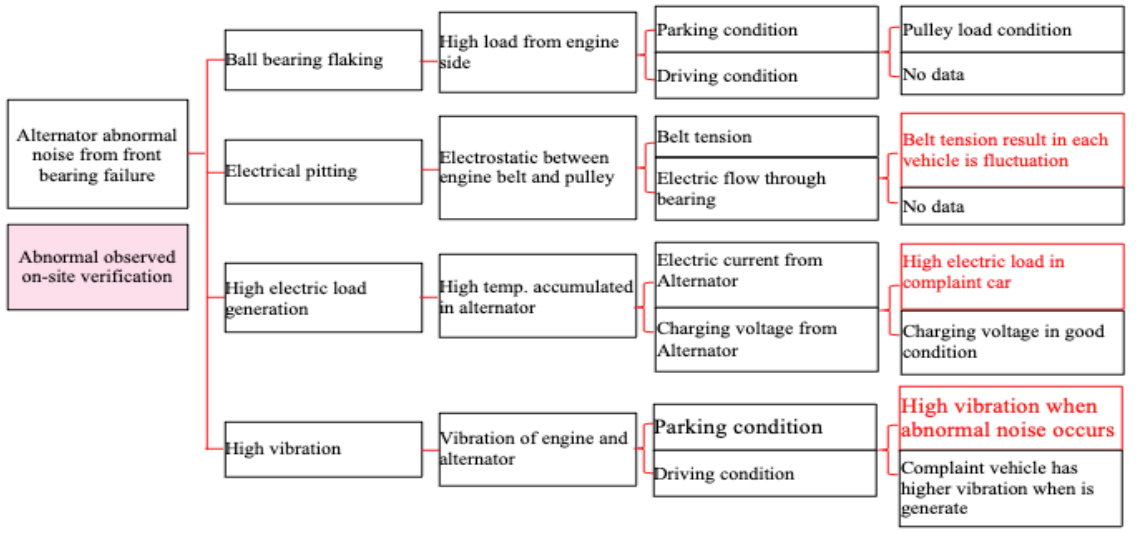

Fig. 4. Estimate failure analysis by Fault Tree Analysis.

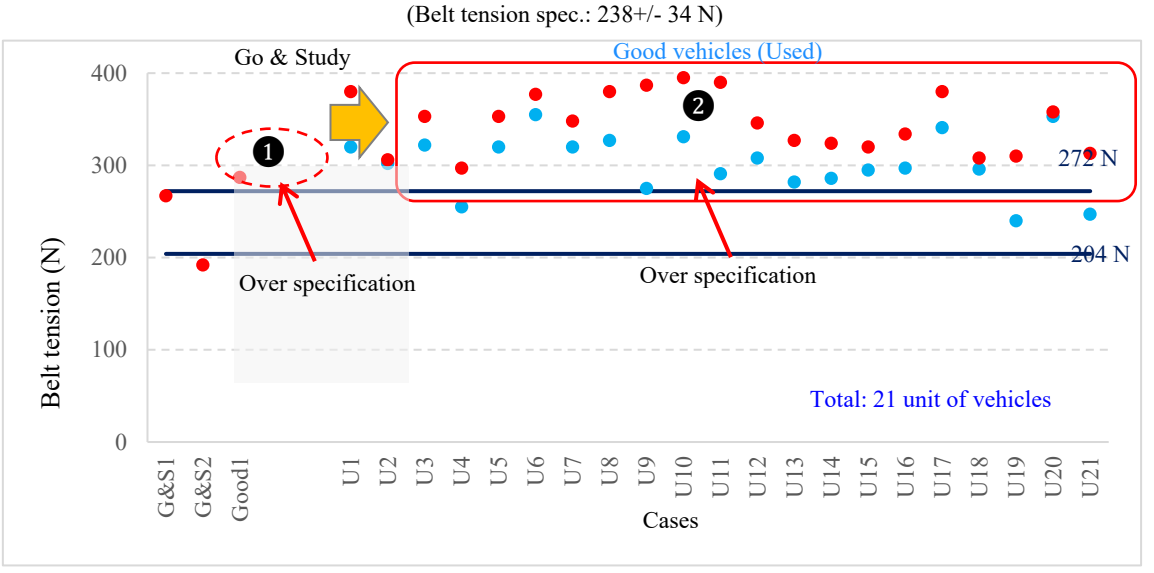

Fig. 5. Complained and good vehicles (used).

Note: ❶ Go and Study found over belt tension of complained and good vehicle (used).
❷ Further check of good vehicle (used) from market, found over belt tension.

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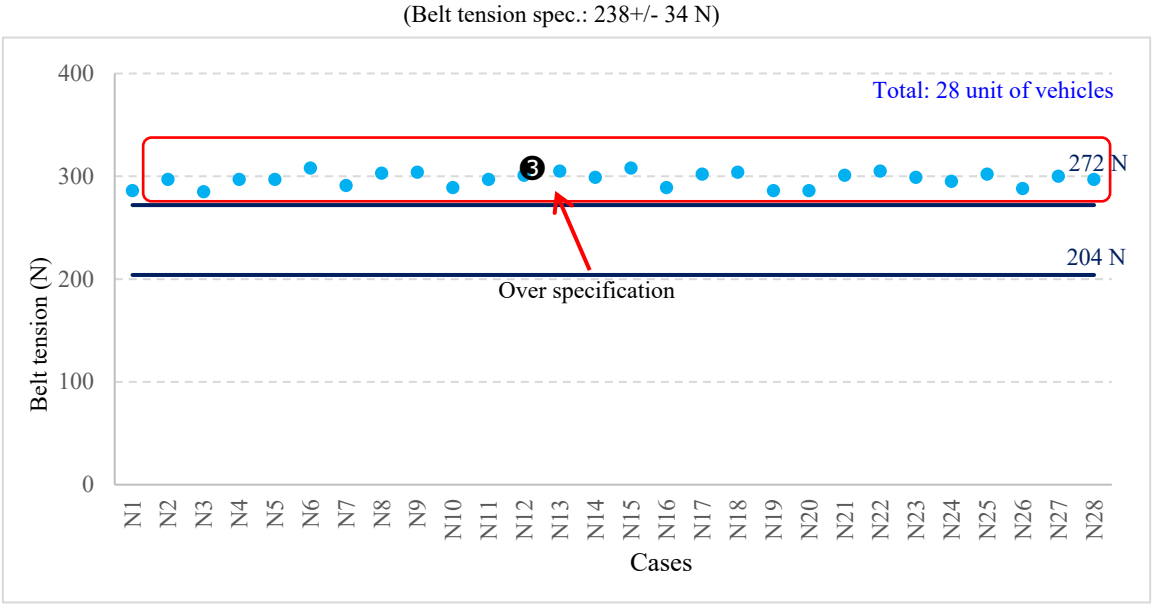

Fig. 6. New vehicles after quality control check by customer P Manufacturing.

Note: ❸ Belt tension of new vehicle has over spec.
Remark: Customer P allowed to check only cold condition due to new vehicle

Conduct Component Repair

Following a thorough investigation, Company XYZ determined that external factors were the primary contributors to noise emissions, ultimately leading to ball-bearing flaking. The root cause of the issue was attributed to a design-related shortcoming, as Customer P had not fully validated the alternator design during the initial Research and Development (R&D) phase. This gap in validation, particularly in relation to actual vehicle conditions and end-user usage, resulted in unforeseen failures in the field. To mitigate warranty claim costs and enhance product reliability, Company XYZ is working closely with Customer P to implement a field fix activity aimed at effectively addressing the issue. As part of the cost reduction strategy, Company XYZ proposed an alternative repair solution by replacing the Front Frame Assembly (Front Frame Assy) instead of the entire Alternator Assy at Customer P's authorized service dealers. This targeted approach is expected to yield significant benefits, including lower warranty costs, reduced repair lead times, and improved end-user satisfaction.

The Alternator Assy is composed of multiple child components, one of which is the Front Frame Assy, as depicted in Fig 7. The Front Frame Assy has been identified as a replaceable child component at Customer P's service centers, allowing for cost-effective repairs. However, to ensure accuracy in addressing the issue, mechanics are required to verify and confirm that the abnormal noise originates from the front bearing (Xu et al., 2023). This step is crucial to prevent misdiagnosis and avoid unnecessary costs for Company XYZ. To facilitate the implementation of this repair initiative, Company XYZ has introduced a new part number for the child component repair kit, complete with specialized packaging. This packaging solution has been designed to support efficient ordering and inventory management at Customer P's Part Center and Service Centers, ensuring smooth logistics and availability (Hatcher et al., 2013).

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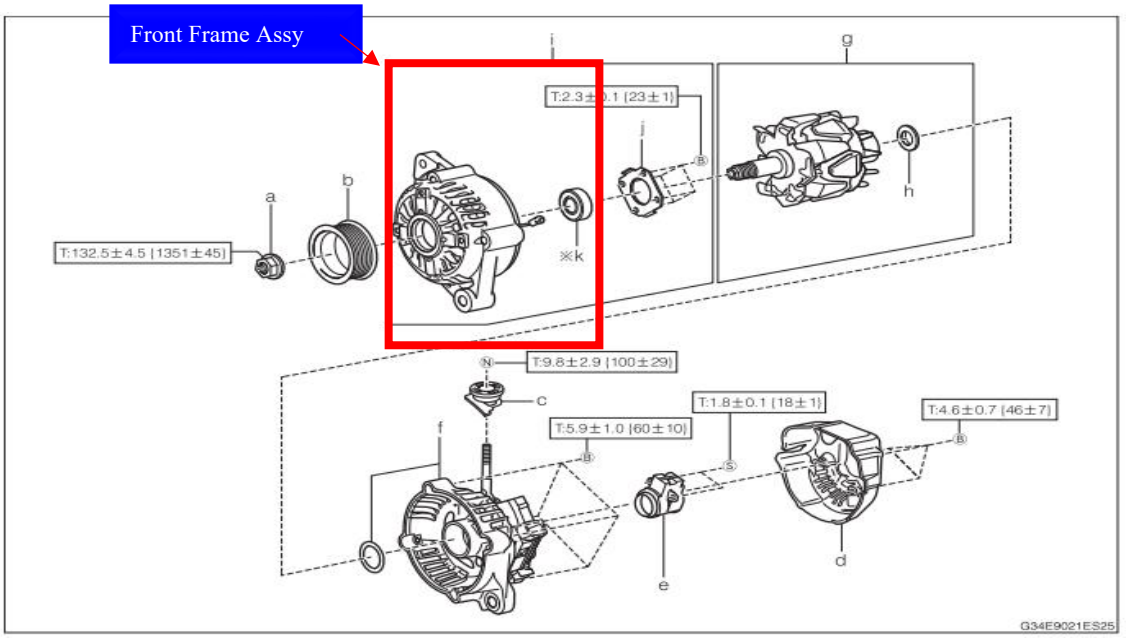

Fig. 7. Alternator Front Frame Assy for component replacement.

Alternator Component Repair Cost

The results of the component cost analysis conducted by Company XYZ, in collaboration with Customer P's Warranty Department, are summarized in Table 2. The analysis highlights significant cost savings achieved by replacing only the original failed part rather than the entire assembly unit. The findings indicate that the alternator component repair cost minimization resulted in an average savings of 84%. However, with the implementation of a cost-sharing strategy, the savings were adjusted to 36%, ensuring a balanced and sustainable approach to cost reduction that benefits both parties.

The cost-effectiveness of alternator component repair has exceeded expectations, safeguarding Company XYZ's profitability beyond the projections outlined in the feasibility study conducted before the project's initiation. The substantial savings achieved through this initiative reaffirm the feasibility of component-level repairs as a strategic approach to mitigating warranty costs (Oncioiu et al., 2019).

Table 2. Result alternator component repair cost

No	OEM P/No.	Component P/No.	Before (RM)	After (RM)	Cost saving
1	27060-BZ260	27310-BZ170	264	42	▲84%
2	27060-BZ381	27310-BZ140	259	43	▲84%
3	27060-BZ400	27310-BZ170	217	42	▲81%
4	27060-BZ440	27310-BZ140	305	43	▲86%

Guideline for Conduct Repair

In compliance with Company XYZ's quality standards and criteria, the repair manual has been successfully provided to Customer P. To ensure effective implementation, Company XYZ continues to deliver in-person training sessions for mechanics, equipping them with a thorough understanding of the repair process and the ability to apply their knowledge in real-world scenarios. For Customer P Service

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Centers unable to attend the in-person training, Company XYZ offers comprehensive support through instructional repair videos and remote diagnosis assistance via online platforms. This approach ensures that all service personnel gain a comprehensive understanding of the repair procedures, regardless of their ability to attend physical training sessions. Upon completion of both in-person and online training, all Customer P Service Centers are equipped with the necessary skills and knowledge to conduct repairs that meet the OEM standards of quality and reliability. To further support this initiative and ensure consistent compliance across all service centers, Customer P has issued a technical bulletin, outlining the standardized procedures and guidelines. This bulletin serves to prevent any procedural infractions and mitigate potential penalties from Customer P Headquarters, reinforcing adherence to the established repair protocols.

Countermeasure Effectiveness

According to Fig 8, Company XYZ observed a significant reduction in the total number of warranty claims from FY 2018 to FY 2022. However, the decline in claims during FY 2020 and FY 2021 was influenced by unusual circumstances, primarily due to the nationwide lockdowns imposed by the government in response to the COVID-19 pandemic. During the Movement Control Order (MCO) period, Customer P and other service centers experienced operational shutdowns, resulting in a temporary reduction in reported warranty claims. This decline, therefore, did not accurately reflect actual product improvements but rather the impact of restricted service availability (Kurilova-Palisaitiene et al., 2018; Hisham et al., 2023).

Despite these anomalies, Company XYZ's strategic initiatives, including targeted quality improvement measures and component repair programs, have contributed to a sustained downward trend in warranty costs. Through proactive efforts in addressing design issues and implementing efficient repair solutions, the company has been able to achieve meaningful cost reductions while maintaining product reliability (Li et al., 2022; Yunus et al., 2025). Based on current projections, warranty costs are expected to continue declining through FY 2024, with an anticipated reduction of approximately 20% compared to FY 2022 levels. This projected decrease underscores the effectiveness of proactive measures undertaken by Company XYZ, focusing on design enhancements, improved service center support, and strengthened collaboration with Customer P to mitigate warranty-related expenses and enhance overall customer satisfaction. The ongoing commitment to continuous improvement and collaboration positions Company XYZ as a leader in optimizing warranty management within the automotive industry.

CONCLUSION

The project was successfully completed within a three-year timeframe, beginning in January 2020 and concluding in December 2022. It comprised five key activities aimed at achieving the project's goals and objectives within the established deadlines. These activities included warranty claim analysis, collection of OFPs, Go and Study activities, feasibility studies for component repairs, and field repair activities. Implementation officially commenced in April 2022, with its effectiveness monitored over a six-month period, concluding in December 2022. The feasibility study results demonstrated that Company XYZ successfully met Customer P's expectations by effectively mitigating warranty costs and addressing design-related concerns. The internal component exchange project marked the first initiative undertaken for Customer P to resolve the identified design issue and ensure project completion within the specified timeline.

Company XYZ successfully achieved Objective 1 (Phase 1 and Phase 2), which involved a detailed analysis of warranty claims based on data received from OEM car manufacturers and other sources. The root cause of the alternator noise issue was confirmed to be a design issue, specifically due to high belt tension, which led to bearing ball flaking and electrical pitting. Additionally, Company XYZ accomplished

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Objective 2 (Phase 3), which focused on improving product design by developing an aftermarket repair process. A comprehensive feasibility study was conducted to minimize warranty claim costs, leading to the selection of Customer P's Service Dealer network to implement the Field Fix activity. These efforts have resulted in significant cost savings and improved overall product reliability, ensuring higher customer satisfaction and reinforcing long-term operational efficiency (Teplická et al., 2023; Kumar et al., 2017; Wahab et al., 2008).

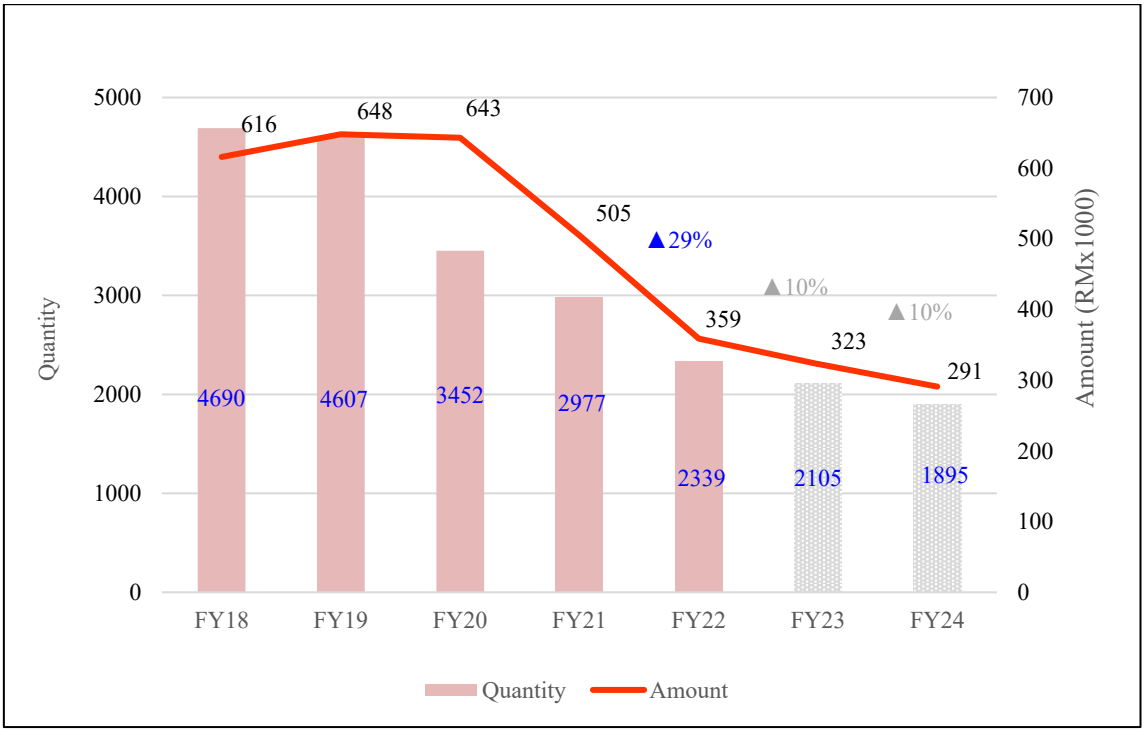

Fig. 8. Total warranty claim based on quantity vs paid amount.

In the Malaysian automotive industry, a groundbreaking initiative titled "Improvement on Product Quality (Design Aspect) for Warranty Cost Mitigation in OEM's Customer Aftermarket Sales" is being implemented for the first time. Company XYZ has pioneered this initiative as the first supplier to introduce child part repairs and replacements, focusing on addressing design issues and reducing warranty-related expenses. Despite initial resistance during the project's inception, Company XYZ successfully adhered to the implementation schedule set by Customer P, ensuring timely execution and delivering significant benefits. Customer P has acknowledged and highly valued the collaborative efforts and innovative solutions provided by Company XYZ, which have played a crucial role in cost reduction and sustaining profitability. The success of this initiative has encouraged Customer P to further adopt and promote similar quality improvement activities, aiming to enhance market value and strengthen its competitive position within the industry.

As a result of the project's achievements, Customer P now plans to expand the initiative to other suppliers, encouraging them to embrace the component repair approach with a strong emphasis on design enhancements. This strategic expansion highlights the importance of proactive quality management in the automotive aftermarket sector and sets a new benchmark for warranty cost optimization across the industry.

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Through its pioneering efforts, Company XYZ has demonstrated leadership in driving innovation and efficiency, establishing a model that aligns with evolving market demands and customer expectations.

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CONFLICT OF INTEREST STATEMENT

The authors agree that this research was conducted in the absence of any self-benefits, commercial or financial conflicts and declare the absence of conflicting interests with the funders.

AUTHORS' CONTRIBUTIONS

The authors confirm their contribution to the paper as follows:

Study conception and design: Nor Hissham Abdul Hamid, Nor Fazli Adull Manan; **data collection**: Nor Hissham Abdul Hamid, Mohd Fauzi Ismail; **analysis and interpretation of results**: Nor Hissham Abdul Hamid, Nor Fazli Adull Manan, Abdul Malek Abdul Wahab; **draft manuscript preparation**: Nor Hissham Abdul Hamid, Nor Fazli Adull Manan.

All authors reviewed the results and approved the final version of the manuscript.

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