Advanced and Sustainable Technologies
ASET
E-ISSN 2976-2294
Volume 4, No 1, June 2025 [43-51]

Enhancing Quality Control in Automotive Reconditioning: A Case Study of Carsome Certified Lab

Muhammad Naufal Aqil Bin Daud[1], Suhaimi Shahrin[1*], Muhammad Aiman Bin Ahmad Fozi[1] and Muhammad Lutfi Bin Abd. Latif[1]

[1]Faculty of Mechanical Engineering & Technology, University Malaysia Perlis, 02600 Arau, Perlis, Malaysia.

Received 24 December 2024, Revised 13 January 2025, Accepted 4 February 2025

ABSTRACT

This study examines quality control (QC) practices at Carsome Certified Lab (CCL), focusing on the reconditioning of pre-owned vehicles. Employing a mixed-methods approach, the research integrates analysis of internal QC records, interviews with CCL staff, and customer satisfaction surveys. Findings highlight significant inconsistencies, especially in aesthetic evaluations, with about 30% of vehicles requiring rework due to initially missed defects. Customer surveys indicate a high overall satisfaction rate (75%), yet 20% report dissatisfaction linked primarily to aesthetic issues. Statistical analysis reveals a strong correlation ($p < 0.05$) between the thoroughness of QC checks and customer satisfaction levels. The study advocates for more rigorous, standardized QC protocols and the adoption of advanced technologies (digital tools, artificial intelligence, imaging technologies, etc.) to improve evaluation precision and consistency. These enhancements are projected to boost customer satisfaction and operational efficiency, serving as a model for similar reconditioning facilities and contributing to industry-wide standards improvement.

Keywords: Quality Control, Automotive Reconditioning, Industry Standards, Case Study, Carsome, Process Improvement.

1. INTRODUCTION

In the context of the rapidly transforming automotive industry, the reconditioning of pre-owned vehicles represents a pivotal process that bridges the divide between used and new cars. This process ensures that pre-owned vehicles meet the elevated aesthetic and performance expectations of contemporary consumers. As a prominent entity in the domain of automotive reconditioning, the Carsome Certified Lab (CCL) upholds rigorous quality control standards to preserve the integrity and market value of reconditioned vehicles. However, the sector at large grapples with substantial challenges in standardizing these quality measures, which ultimately influence customer satisfaction and the long-term sustainability of the business. At CCL, similar to other facilities of its kind, inconsistencies in the application of quality control protocols have been observed. These variations are primarily attributed to the absence of a universally accepted framework tailored to the unique demands of automotive reconditioning. Notably, existing practices at CCL, while extensive, exhibit deficiencies in the consistent definition and enforcement of quality benchmarks, particularly concerning aesthetic attributes such as panel alignment and overall vehicle presentation—factors critical to consumer approval and regulatory adherence.

Aesthetic quality control (QC) is crucial in automotive repair and restoration for several reasons, emphasizing both functional and perceptual aspects. Foremost, aesthetic QC is important to achieve customer satisfaction. Automotive customers often evaluate the success of repairs and

*Corresponding author: suhaimishahrin@unimap.edu.my

restorations based on the vehicle's appearance. Even minor imperfections can negatively impact satisfaction. High aesthetic quality conveys a sense of meticulous craftsmanship and professionalism, enhancing the perceived value of the repair or restoration. Indirectly, the quality of work may increase brand reputation and customer trust by delivering aesthetically superior results building trust, and strengthening their reputation. A single subpar aesthetic outcome can tarnish their image and reduce repeat business. Aesthetics play a significant role in determining a vehicle's resale value. Paint quality, panel alignment, and interior detailing are crucial for ensuring the car retains or increases its market worth. In a competitive market, businesses that maintain strict aesthetic QC standards differentiate themselves from competitors. This attention to detail attracts discerning clients who prioritize visual perfection alongside mechanical soundness. Aesthetic issues, such as uneven paint application or misaligned body panels, may indicate underlying technical problems or rushed work. By addressing aesthetic flaws during QC, businesses can also ensure technical robustness. A visually flawless car can evoke pride and emotional satisfaction for the owner. Automotive aesthetics are intertwined with identity, making them crucial for customer contentment.

This research endeavors to critically analyze and enhance the quality control mechanisms employed at CCL, with the overarching objective of formulating a comprehensive, standardized framework for automotive reconditioning quality assurance. By addressing both technical and aesthetic parameters, the study aims to identify key areas for optimization that align with prevailing industry standards and bolster customer satisfaction. Enhanced quality control protocols not only elevate consumer confidence but also position facilities like CCL as frontrunners in the domain of automotive quality assurance. The findings of this investigation are intended to enrich the broader academic and professional discourse on quality control in automotive reconditioning. Moreover, this work aspires to offer a replicable model that can be adopted by similar facilities worldwide. By instituting more robust quality control standards, CCL can also address critical issues related to vehicle safety and regulatory compliance, thereby mitigating potential legal and financial risks. This study underscores the strategic importance of quality assurance in advancing the operational efficacy and market leadership of automotive reconditioning enterprises.

2. Quality Control (QC)

Quality control (QC) within the automotive reconditioning industry is a critical mechanism for ensuring that vehicles meet not only regulatory requirements but also the elevated expectations of consumers regarding performance, safety, and aesthetics. The importance of robust QC processes has been emphasized by Ishikawa (1990) and Mitra (2016) [1] [2], who contend that stringent QC measures are integral for sustaining competitive advantage in an industry marked by rapid technological innovation and growing consumer demand for high-quality pre-owned vehicles. The implementation of effective QC protocols directly impacts the reliability, safety, and market appeal of reconditioned automobiles. However, a persistent challenge highlighted in the literature is the inconsistent application of QC standards across the automotive reconditioning sector. Msakni et. Al. (2023) noted the absence of comprehensive, industry-wide frameworks, which leads to significant disparities in quality control practices among reconditioning centers. These inconsistencies not only affect the uniformity of vehicle quality but also undermine consumer trust and erode brand equity [3].

A further complication arises from the subjective nature of aesthetic improvements, such as paint correction, panel alignment, and interior refinements, which are often governed by vague and non-quantifiable criteria. Mould (2016) and Zhang (2021) argue that the lack of standardized benchmarks for aesthetic quality exacerbates variability and hinders the establishment of universally accepted QC protocols [4] [5]. This challenge underscores the need for a more

nuanced approach that integrates both technical and aesthetic dimensions into quality assurance frameworks.

The role of technology in addressing these challenges has been increasingly recognized in recent scholarship. For instance, automated systems and digital tools have emerged as pivotal in enhancing the precision, efficiency, and consistency of QC processes [6]. Wang et. Al. (2024) demonstrated that the integration of technology minimizes human error, facilitates standardized inspections, and enables real-time tracking of compliance and quality metrics. These advancements have the potential to bridge existing gaps in QC practices, particularly by ensuring greater adherence to defined standards [7].

The economic and reputational implications of effective QC practices are well documented. Mahmood et. Al. (2014) underscores that higher quality standards not only elevate customer satisfaction but also lead to increased resale values for reconditioned vehicles, thereby enhancing the financial performance of reconditioning businesses [8]. Moreover, stringent QC measures are instrumental in reducing the frequency of customer complaints and returns, which are both financially burdensome and damaging to organizational credibility [9].

Despite these advancements and insights, notable gaps persist in the literature. Limited research has been conducted on the integration of aesthetic quality controls into the broader QC framework, particularly in the context of the automotive reconditioning industry. Furthermore, the development of industry-specific QC guidelines that holistically address both technical and aesthetic aspects remains largely unexplored. This research gap underscores the necessity for a more comprehensive approach to quality control, one that not only leverages technological innovations but also establishes a harmonized set of standards tailored to the unique challenges and demands of automotive reconditioning. Such efforts could significantly enhance the uniformity, reliability, and market competitiveness of reconditioned vehicles, while also advancing the theoretical and practical discourse in this critical area of the automotive industry.

3. METHODS

This study adopts a mixed-methods research design to systematically analyze and refine the quality control (QC) standards at the Carsome Certified Lab (CCL). By integrating both qualitative and quantitative approaches, the research ensures a holistic examination of the existing QC processes, identifies critical gaps, and proposes actionable improvements. The mixed-methods approach is particularly suited to this study, as it combines the depth of qualitative insights with the breadth and generalizability offered by quantitative data, thereby enabling a nuanced understanding of both operational challenges and customer perspectives.

3.1 Data Collection

The data collection strategy is multi-dimensional, leveraging diverse sources to ensure a comprehensive evaluation of QC practices:

i. *Internal QC Records*: Historical QC data from CCL is analyzed to uncover trends, recurring non-compliance issues, and failure points. This analysis provides a foundational understanding of systemic challenges within current QC processes.
ii. *Technician and Manager Interviews:* Semi-structured interviews are conducted with technicians and managerial staff directly involved in reconditioning operations. These interviews offer detailed insights into practical challenges, operational constraints, and perceptions regarding existing QC practices.
iii. *Customer Surveys*: Structured surveys are distributed to customers who have purchased vehicles from CCL. These surveys are designed to gauge satisfaction levels, collect

feedback on specific QC attributes, and assess perceptions of quality and value in reconditioned vehicles.

iv. *Focus Groups*: Focus group discussions with technicians and managers provide a platform for collective brainstorming and the identification of shared concerns or areas for improvement, adding depth to the individual interview findings.

3.2 Sampling

The study employs distinct sampling techniques tailored to the participant groups to ensure representativeness and relevance:

i. *Technicians and Managers*: A purposive sampling method is used to select participants with direct involvement in QC processes. This targeted approach ensures that the interviewees possess relevant expertise and operational knowledge to provide meaningful insights. Three technicians and two shift managers of QA departments were selected as part of the interview and focus group discussion.

ii. *Customers*: A random sampling technique is applied to select survey participants from the pool of recent CCL customers. This approach ensures diversity in customer experiences and opinions, enhancing the reliability of the findings. A total of 16 respondents responded to the survey, consisting of 75% male and 25% female respondents.

3.3 Data Analysis

The data analysis process employs rigorous methodologies to derive actionable insights from both qualitative and quantitative datasets:

i. *Qualitative Data Analysis*: Responses from interviews and focus groups are subjected to thematic analysis. This process involves coding the data to identify recurring themes, patterns, and outliers that reveal challenges and opportunities in QC practices.

ii. *Quantitative Data Analysis*: Statistical methods, including descriptive statistics and regression analysis using an ordinal regression model, are applied to survey data and internal QC records. These analyses quantify customer satisfaction levels, identify correlations between specific QC practices and satisfaction outcomes, and evaluate the effectiveness of existing standards.

Customer surveys may be subjected to response bias, as participants might overstate or understate their satisfaction levels. To mitigate this, triangulation is employed by cross-referencing survey responses with internal QC records and qualitative data. As the study is confined to CCL operations within a specific region, the findings may have limited generalizability. However, due to the confidentiality of this study, some of the data may not be displayed in the results. To address this, the research emphasizes the development of adaptable QC frameworks that can be modified to suit diverse contexts. Time and resource limitations may restrict the depth of qualitative data collection. To counterbalance this, interviews and focus groups are carefully structured to maximize the relevance and richness of insights within the available period.

4. RESULTS & DISCUSSIONS

The comprehensive analysis of qualitative and quantitative data from Carsome Certified Lab (CCL) provided significant insights into the efficacy of current quality control (QC) practices while identifying critical areas for improvement. These findings are systematically categorized into three domains: internal QC records, interviews with technicians and management, and customer survey responses. Each domain offers unique perspectives that collectively inform the development of a more robust and standardized QC framework.

4.1 Internal Quality Control Records

The analysis of historical QC data from CCL revealed notable inconsistencies in the implementation and effectiveness of quality checks across various vehicle components (Table 1). A pronounced disparity was observed between the handling of aesthetic and mechanical defects, with aesthetic issues emerging as a primary challenge. Figure 1 shows a sample of quality checks throughout to track the progress of each staff in a single day. Approximately 30% of vehicles required rework due to deficiencies initially overlooked during QC inspections. This rework percentage indicates a significant gap in the effectiveness of the initial QC processes. Cosmetic defects, such as inconsistencies in paintwork, panel misalignments, and minor surface imperfections, accounted for most of the rework cases. In contrast, mechanical defects represented a smaller proportion of identified issues, suggesting that the technical evaluation procedures are more robust than their aesthetic counterparts. The prevalence of rework for aesthetic defects has a cascading effect on operational efficiency, increasing turnaround times and resource utilization. This underscores the need for enhanced QC protocols tailored to the aesthetic evaluation of vehicles. The data revealed a lack of standardized criteria for assessing aesthetic quality, leading to subjective interpretations by QC personnel. This inconsistency not only affects the reliability of QC outcomes but also undermines customer satisfaction and brand reputation.

Table 1: Quality Check Throughout.

Name	9AM	10AM	11AM	12PM	1PM	2PM	3PM	4PM	5PM	6PM	Total
Afiq	P	P	RW	P	-	RW	RW	RW	P	RW	
Mustaqim	RW	RW	P	RW	-	P	RW	P	RW	P	
Souffi	RW	RW	RW	P	-	RW	RW	RW	RW	RW	
Adha	P	RW	P	-	RW	P	P	P	RW	RW	
Loges	P	RW	RW	-	RW	RW	RW	RW	RW	RW	
Fathi	RW	RW	P	-	RW	P	RW	P	P	RW	
Iqbal	P	P	P	-	RW	RW	P	RW	RW	RW	
QC-Pass (P)	**4**	**2**	**4**	**4**	**-**	**3**	**3**	**3**	**2**	**1**	**26**
Rework (RW)	**3**	**5**	**3**	**1**	**4**	**4**	**4**	**4**	**5**	**6**	**39**

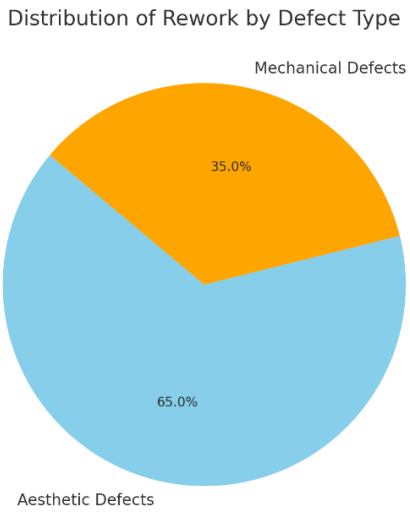

Figure 1: Distribution of Rework by Defect Type.

Figure 1 illustrates the rework distribution by defect type at Carsome Certified Lab (CCL). It shows that 65% of the reworks are due to aesthetic defects, while 35% are attributed to mechanical defects. This visualization effectively highlights the predominant area of concern in the quality control processes. The findings from internal QC records point to several critical areas that warrant immediate attention.

i. **Enhanced Aesthetic QC Standards:** The predominance of cosmetic issues highlights the urgent need to establish rigorous, quantifiable criteria for evaluating aesthetic quality. Standardized guidelines can reduce variability in assessments and ensure uniformity across reconditioned vehicles.
ii. **Training and Calibration of QC Personnel:** To address inconsistencies in the application of QC standards, targeted training programs should be implemented for QC personnel. These programs should emphasize objective evaluation techniques, particularly in areas prone to subjective interpretation, such as paint finishes and panel alignment.
iii. **Integration of Technology:** Leveraging advanced digital tools, such as AI-driven inspection systems and imaging technologies, could significantly enhance the precision and consistency of aesthetic evaluations. Automated systems could also reduce reliance on manual assessments, minimizing human error and bias.
iv. **Reduction of Rework Rates:** By addressing the root causes of aesthetic defects during initial inspections, CCL can substantially decrease the incidence of rework. This would not only improve operational efficiency but also reduce costs and enhance customer satisfaction.

These findings provide a critical foundation for developing a standardized and holistic QC framework at CCL. By prioritizing the identified areas for improvement, the lab can enhance the quality of reconditioned vehicles, strengthen consumer trust, and solidify its leadership position in the automotive reconditioning industry.

4.2 Interviews with Technicians and Managers

Interviews conducted with technicians and management at Carsome Certified Lab (CCL) provided valuable insights into the challenges and perceptions associated with the quality control (QC) processes. These findings highlight critical issues in operational practices, particularly concerning the subjective nature of aesthetic quality assessments and the need for enhanced training and standardization. The perspectives of staff members underscore both the strengths and the areas requiring immediate intervention to improve QC outcomes. One of the most prominent challenges highlighted by staff was the subjective nature of aesthetic quality evaluations. Unlike mechanical inspections, which are guided by clear, objective metrics, assessments of cosmetic features such as paint finishes, panel alignments, and interior detailing often rely on individual judgment. This subjectivity leads to inconsistencies in evaluations and contributes to variability in reconditioning outcomes. The lack of specific, universally accepted standards for aesthetic quality assessments further exacerbates subjectivity. Without clearly defined criteria, technicians face difficulty ensuring uniformity across inspections, negatively impacting operational efficiency and customer satisfaction.

Most participants expressed a degree of confidence in the overall effectiveness of existing QC protocols. They acknowledged that these processes are well-structured for technical inspections and have successfully mitigated major mechanical issues in reconditioned vehicles. Despite this positive perception, staff members identified significant opportunities for enhancement. They emphasized the importance of addressing deficiencies in aesthetic quality evaluations and improving the consistency of inspections. A recurring theme in the interviews was the need for more robust and structured training programs, particularly for newer and less experienced

technicians. Participants observed that these individuals often lack the skills and confidence required for accurate and consistent QC evaluations, especially for aesthetic components. This gap in training was seen as a critical area for improvement to ensure the reliability of QC practices across all levels of expertise.

4.3 Focus Group with Technicians and Managers

The findings underline the urgent need to establish clear, quantifiable criteria for aesthetic evaluations. A standardized framework would minimize subjectivity and enhance the consistency of assessments, fostering greater reliability in QC outcomes. Structured and comprehensive training initiatives should be developed to address skill gaps among newer and less experienced staff. These programs should include practical workshops, standardized evaluation protocols, and case studies to simulate real-world challenges. Periodic assessments and refresher courses can further ensure the alignment of all staff with updated QC standards. Incorporating digital tools, such as AI-powered inspection systems and imaging technologies, could supplement human evaluations and reduce reliance on subjective judgments. Such tools can serve as a valuable aid in achieving more objective and precise aesthetic assessments.

The findings from staff interviews provide critical insights into the challenges and perceptions of QC processes at CCL. Addressing these issues through targeted interventions in training, standardization, and technology integration can significantly enhance the quality, consistency, and efficiency of QC practices. These improvements will not only strengthen operational performance but also contribute to higher levels of customer satisfaction and trust in CCL's reconditioned vehicles.

4.4 Customer Survey Responses

Customer satisfaction surveys conducted at Carsome Certified Lab (CCL) provided critical insights into the influence of quality control (QC) practices on customer perceptions and experiences with reconditioned vehicles. The results underscore the effectiveness of current QC measures while highlighting key areas for improvement, particularly in addressing aesthetic inconsistencies. A significant proportion of respondents (75%) expressed high satisfaction with the quality of their reconditioned vehicles, reflecting the effectiveness of many of CCL's QC protocols. This demonstrates that, in general, the lab's quality assurance measures align with customer expectations regarding vehicle performance and presentation. Despite the high overall satisfaction rate, 20% of customers reported dissatisfaction, citing aesthetic defects such as paint mismatches and misaligned panels as primary concerns. These issues were frequently mentioned as detracting from the perceived value and quality of the reconditioned vehicles. This feedback underscores the critical role of consistency in QC standards and the potential business risks associated with unmet customer expectations in aesthetic quality. Customer feedback strongly indicated that inconsistencies in aesthetic quality could lead to reputational risks and customer attrition. The data suggests that addressing these shortcomings is essential for maintaining CCL’s competitive edge and fostering long-term customer loyalty. Overall customer satisfaction is illustrated in Figure 2.

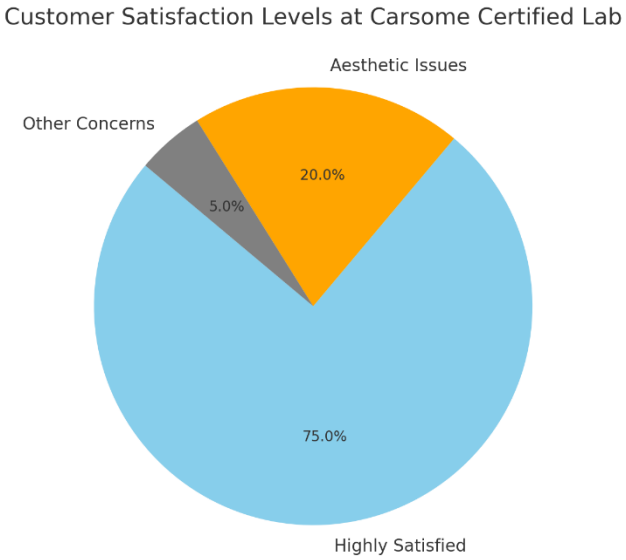

Figure 2: Customer Satisfaction Levels.

Further quantitative analysis, employing regression models, reinforced the survey findings by establishing a significant statistical correlation between the thoroughness of QC processes and customer satisfaction. The regression analysis revealed a robust positive association between detailed defect identification and customer satisfaction scores, with a p-value less than 0.05. However, the author is unable to share further statistics from raw data since the author is bound to the confidentiality of Carsome's customer feedback. Nevertheless, this statistical significance confirms that meticulous QC practices, including comprehensive rework processes, directly enhance customer satisfaction. The data showed that approximately 30% of vehicles required rework after the initial QC checks, with most rework cases attributed to aesthetic inconsistencies. These findings emphasize the need for more stringent QC standards in evaluating aesthetic components to reduce rework rates and enhance customer experiences. Despite the challenges, the high overall satisfaction rate of 75% illustrates that CCL's QC practices are effective. However, the 20% dissatisfaction rate among respondents due to aesthetic issues highlights a key area where targeted interventions could significantly improve customer perceptions and trust.

The findings from the customer satisfaction surveys, supported by statistical analysis, underscore the critical importance of rigorous and consistent QC practices in driving customer satisfaction and maintaining competitive advantage. By addressing the identified gaps, particularly in aesthetic evaluations, CCL can enhance operational efficiency and customer trust, ensuring sustained success in the reconditioning industry.

5. CONCLUSION

The study's findings highlight the urgent need for more rigorous and standardized QC measures, particularly in evaluating aesthetic quality. By implementing clear, objective criteria for assessing components such as paint finishes, panel alignment, and interior detailing, CCL can reduce subjectivity and variability in QC outcomes. This approach will ensure greater consistency and reliability across all inspections, addressing key gaps identified in the research. The insights from this study have implications beyond CCL, offering a potential benchmark for other reconditioning facilities grappling with similar challenges. The integration of enhanced QC processes, robust training programs, and advanced technological tools can foster industry-wide improvements in vehicle quality, customer satisfaction, and business sustainability. Adopting advanced digital tools, such as AI-driven defect detection systems and automated inspection technologies, presents a promising avenue for future improvement [10]. These tools can provide more

objective, repeatable, and precise assessments of reconditioned vehicles, reducing human error and enhancing the efficiency of QC processes.

Further research should investigate the implementation and effectiveness of cutting-edge digital tools in automotive reconditioning. This could include studying their impact on the accuracy, efficiency, and consistency of aesthetic and technical quality assessments. Long-term studies tracking the effects of improved QC processes on customer satisfaction, rework rates, and business performance would provide valuable insights into the sustained benefits of enhanced QC protocols. Such research could inform industry best practices and guide the strategic development of reconditioning facilities. Comparative studies examining QC processes across different reconditioning facilities and industries could provide a broader perspective on best practices and innovative solutions, offering further opportunities for improvement and standardization.

ACKNOWLEDGEMENTS

This paper is created from the Final Industrial Project under Work-Based Learning between Universiti Malaysia Perlis and Carsome Academy Sdn Bhd.

REFERENCES

[1] Ishikawa, K., & Loftus, J. H. Introduction to quality control. Tokyo: 3A Corporation, vol 98, (1990) p. 31.
[2] Mitra, A. Fundamentals of quality control and improvement. John Wiley & Sons, (2016).
[3] Msakni, M. K., Risan, A., & Schütz, P. Using machine learning prediction models for quality control: a case study from the automotive industry. Computational Management Science, vol 20, issue 1 (2023) p.14.
[4] Mould, D., & Rosin, P. L. A benchmark image set for evaluating stylization. In Expressive (2016) pp. 11-20.
[5] Zhang, J., Miao, Y., & Yu, J. A comprehensive survey on computational aesthetic evaluation of visual art images: Metrics and challenges. IEEE Access, vol 9, (2021) pp. 77164-77187.
[6] Kimball, D. A. (Ed.). Citrus processing: quality control and technology. Springer Science & Business Media. (2012).
[7] Wang, P., Tao, H., Qi, J., & Li, P. Machining quality prediction of complex thin-walled parts using multi-task dual domain adaptive deep transfer learning. Advanced Engineering Informatics, vol 62, (2024) p. 102640.
[8] Mahmood, S., M. Ahmed, S., Panthi, K., & Ishaque Kureshi, N. Determining the cost of poor quality and its impact on productivity and profitability. Built Environment Project and Asset Management, vol 4, issue 3 (2014) pp. 296-311.
[9] Anthony, K. A., Damaro, A. O., & Ngozi, M. O. G. B. O. L. U. Sustaining Organizational Profitability Through Enhanced Quality Control Practices In Manufacturing Businesses. International Journal of Management & Entrepreneurship Research, vol 5, issue 6 (2023) pp. 373-385.
[10] Ghelani, H. AI-Driven Quality Control in PCB Manufacturing: Enhancing Production Efficiency and Precision. Valley International Journal Digital Library, (2024) pp. 1549-1564.

Conflict of interest statement: The authors declare no conflict of interest.

Author contributions statement: Conceptualization, Muhammad Naufal Aqil Bin Daud & Suhaimi Shahrin; Methodology, Muhammad Aiman Bin Ahmad Fozi and Muhammad Lutfi Bin Abd. Latif; Writing & Editing, Muhammad Naufal Aqil Bin Daud & Suhaimi Shahrin.