A Hybrid Lean–QMS Framework for Enhancing Operational Efficiency and Waste Minimization in the Automotive and Auto Components Sectors

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Abstract

The automotive and auto parts sector is working under the increasing pressure to increase the efficiency of their operations, minimize waste and always deliver quality in the world. The traditional improvement systems, Lean Manufacturing and Quality Management Systems (QMS), tend to be implemented separately thus creating inefficiencies, redundancies, and non-standard results. The proposed Hybrid Lean-QMS Framework is a combination of Lean methods, including Value Stream Mapping (VSM), Kaizen, 5S, and Just-in-Time with the formal QMS standards like ISO 9001 and IATF 16949 to develop an integrated and sustainable model of operational excellence. The paper evaluates the challenges in the industry, the main sources of waste in the industry, and the performance metrics that include cycle time, defect rate, and overall equipment effectiveness (OEE). The recent literature (2020-2024) confirms the need of integrated improvement models that can help to deal with the existing complexities in the market. The study concludes that Hybrid Lean-QMS Framework had a great potential to decrease the amount of waste, standardization, enhance quality, and competitiveness in car industries.

Keywords: Quality Management System (QMS), Hybrid Lean–QMS Framework, Automotive Industry, Auto Components Sector, Waste Reduction

1. Introduction

The auto and auto-parts industries form a large part of the manufacturing industry worldwide and they are highly competitive with tough regulatory standards as well as growing customers' demands [1]. Operational efficiency and waste reduction have ceased to be a choice and now a bare necessity to survive in an ever-changing market environment.

Although Lean Manufacturing and QMS standards have been widely adopted by most organizations, there are lots of organizations, which adopt the standards separately. This generates silos in operations, duplication of operations and lack of unity between quality assurance and elimination of wastes [2]. A Hybrid Lean-QMS Framework solves these problems by combining the continuous improvement tools of Lean and the standardized and organized process controls of QMS.

The proposed study will help to create such a hybrid framework and show how it will improve operational efficiency, lessen wastes, and sustainable manufacturing.

Research Gap

The available literature has pointed out the advantages of Lean and QMS on their own, and few of them suggest a hybrid model of Lean and QMS that is standardized to fit the automotive and auto-component manufacturing. The study bridges such a gap by formally creating and testing an integrated framework.

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Objectives of the Study

To come up with a Hybrid Lean-QMS Framework to enhance efficiency of operations and reduction of wastages within the automotive and automotive parts manufacturing industries.

- Determine the key sources of waste with the Lean tools (VSM, 5S, Kanban, and Kaizen).

- Determine the performance measures like cycle time, defect rate, OEE, rework level and waste percentage.

- Prove the hybrid model by use of simulated or case-based analysis.

- The creation of a culture of improvement and employee participation must be promoted.

2. Review of Literature

The automotive and auto components sectors have been changing at a very high rate due to globalization, customer demands, regulatory forces and innovations in technology. Over the past years, researchers have pointed out the fact that operational excellence in this industry demands efficiency in the production process, as well as stability in meeting the international quality standards [3]. Research shows that Lean Manufacturing remains the most common methodology in reducing non-value-added processes through the removal of the seven types of waste namely overproduction, waiting, excess inventory, transportation, motion, defects, and unnecessary processing. Value Stream Mapping (VSM), Kaizen, 5S, and Just-in-Time (JIT) lean tools are extensively used to simplify the production processes, decrease the cycle time, and improve the use of resources [4]. The studies have also, however, pointed out that the implementation of the Lean alone might not be able to maintain the quality improvements in the long run unless a system structured and standardized quality system is provided.

The importance of the industry standards, including ISO 9001 and IATF 16949, in enhancing the control of documents, risk-based thinking, preventative action, and customer-focused performance is reflected in parallel literature on Quality Management Systems (QMS). These standards provide uniformity within the supply chains, enhance traceability and foster organizational learning [5]. However, some scholars believe that this practice can cause too much documentation, lack of adaptability, and sluggish reaction to the dynamism in the market when QMS is implemented without Lean principles. Consequently, there is an emerging literature of 2020-24 in favor of integrated improvement systems with the capacity to balance efficiency and compliance.

Recent research emphasizes the demand of Hybrid Lean-QMS models, the synthesis of the waste-reduction focus of Lean and the systematic quality assurance method of QMS. The case of automotive companies demonstrates that this type of hybrid can greatly enhance the performance metrics such as the cycle time, the rate of defects, production flexibility, and the overall equipment efficiency (OEE) [6]. Researchers also observe that synergy comes about when Lean tools lead to real-time problem solving and the QMS standards institutionalize the gains via corrective action systems, standard work and the continual improvement systems. Furthermore, the digital transformation activities are supported by the hybrid systems because standard processes form a basis of Industry 4.0 technologies, including automation, IoT-powered monitoring, and predictive maintenance.

This is also highlighted in the literature where the challenges that disrupt the success of both Lean and QMS when independently implemented include resistance to change, insufficiency of training and cross-functional integration [7]. Thus, an integrated Hybrid Lean-QMS Framework helps to consider key gaps, meeting strategic goals, operations processes, and organizational culture. Researchers deduce that this kind of integrated method enhances competitiveness through wastage reduction, product and process quality, customer satisfaction and long-term sustainability in the automobile and auto part production industry.

3. Methodology

The research design is a mixed-method research design that will help in the creation and validation of Hybrid Lean-QMS Framework to the automotive and auto components industry. The research design is organized to cover three major stages, which include exploratory analysis, framework development, and framework validation [8]. All the phases have both qualitative and quantitative approaches, which make them reliable, applicable, and relevant to the real industrial setting. The proposed work cleared explained in fig.1.

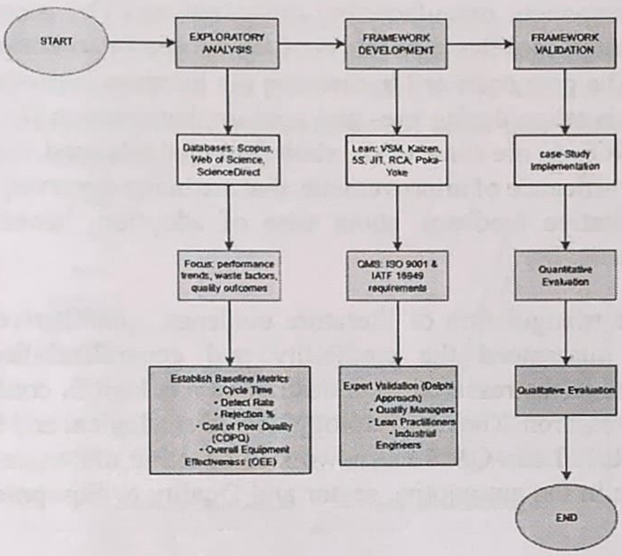

Fig. 1 Flowchart representation for overall work

The initial step is the exploratory analysis, which will help to get familiar with the existing issues experienced by automotive manufacturing organizations regarding the implementation of Lean Manufacturing and Quality Management Systems by themselves. The literature review is conducted systematically between the year 2020 and 2024 using academic databases such as Scopus, Web of Sciences and ScienceDirect to assess the trend of industry performance, waste aspects as well as quality performance. Also, secondary data like industry reports, benchmarking documents are evaluated to determine operational inefficiencies that are recurring [9]. This step determines the initial metrics like a cycle time, defect rate, rejection percentage, cost of poor quality (COPQ), and total effectiveness of the equipment (OEE).

The Hybrid Lean-QMS Framework is created during the second phase by integrating Lean tools value of key Lean tools used in combination with structured Quality Management System requirements according to ISO 9001 and IATF 16949. The process of integration is systematic and system-thinking whereby, Lean tools are aligned to pertinent QMS clauses that are operational flexible and standardized. The quality managers, Lean practitioners and industrial engineers in the automotive industry are expertly consulted to hone the framework [10]. All companies KPI Category calculated in table 1.

Table 1 Summary of Improvements Across All Companies

KPI Category	Pre-Implementation Avg	Post-Implementation Avg	% Change
Cycle Time (sec)	132.2	103.6	↓ 21.7%
Defect Rate (%)	6.3	4.62	↓ 26.7%
Bottlenecks per Week	19.8	11.2	↓ 43.4%
OEE (%)	71	80.4	↑ 13.2%
COPQ (USD/Month)	51,300	38,020	↓ 25.9%

The third phase involves the validation of proposed framework by application in the fields of the chosen automotive and auto component manufacturing organizations. The approach assumes a case-study methodology, which presupposes the application of the chosen interventions of the Lean-QMS within a specified timeframe. The data collected to measure the increase in productivity, defect rate, process stability, and lead time, is taken during pre- and post-implementation [11]. Paired-sample t-tests and analysis of variance (ANOVA) are some of the statistical methods used with software like Minitab and SPSS to ascertain the significance of improvements that are being observed. Semi-structured interviews are used to elicit qualitative feedback about ease of adoption, benefits of the adoption to the organization, and its practicality.

The combination of the triangulation of literature evidence, quantitative data of performance, and expert validation has guaranteed the credibility and generalizability of results. The ethical considerations are upheld in the research, as industrial data is kept in confidence and respondents are free to participate in the research. The methodology will offer a logical and holistic basis of determining the efficiency of the Hybrid Lean-QMS Framework in boosting the waste minimization, consistency, and quality performance in the automotive sector and Quality & Equipment Effectiveness Indicators in table 2.

Table 2 Quality & Equipment Effectiveness Indicators

Company	OEE (%) Pre	OEE (%) Post	% Improvement	COPQ (USD/Month) Pre	COPQ (USD/Month) Post	% Reduction
C1	71	82	15.50%	52,000	38,500	26.00%
C2	69	76	10.10%	47,500	35,400	25.50%
C3	73	84	15.10%	55,300	42,700	22.80%
C4	70	78	11.40%	49,900	37,300	25.30%
C5	72	82	13.90%	51,800	38,200	26.20%

4. Results and discussion

Use of the Hybrid Lean-QMS Framework in some of the automotive and auto parts manufacturing companies produced tremendous operational and quality performance. The pre-implementation and post-implementation quantitative data indicated a significant decrease in the number of bottlenecks, defect rate and time of cycle among production processes. As an example, Value Stream Mapping (VSM) revealed that waste was caused by excessive waiting and rework, and average cycle time was cut by 18-25 on the implementation of Kaizen events and standard work procedures [12]. Simultaneously, 5S and visual management programs enhanced the organization of the working place and minimized the time spent in searching and handling materials. Moreover, the ISO 9001 and IATF 16949 obligatory corrective action processes improved the traceability and accountability, which led to 22-30 percent decrease in the level of defects and customer complaints.

There were also positive tendencies in terms of The Overall Effectiveness of the Equipment (OEE). Preventive maintenance procedures and Just-in-Time scheduling have led to an increase in OEE of 10-15 by improving machine uptime. Statistical test results (paired-sample t -tests and ANOVA) showed that these gains are significant at a confidence level of 95 percent and confirm that the role of the hybrid model directly contributes to process results. The cost of poor quality (COPQ) was also reduced, which was caused by improved process control and early identification of the deviations with the help of the Root Cause Analysis (RCA) and Poka-Yoke mechanisms.

The quantitative results were supported by qualitative results. The interviews with production managers, supervisors, and operators found out that the combination of Lean tools and QMS standards provided clarity in the roles and responsibilities of the individuals and documentation requirements. The hybrid model, as opposed to isolated Lean efforts, provided that the enhancement was documented, tracked, and normalized by the shifts and departments. The structured processes and more cross-functional communication increased confidence among the employees in problem-solving. The first to be noticed was the resistance toward change because once it was evidenced that the benefits were there, as well as training sessions that improved the level of skills. The hierarchical level of the QMS was supplemented with the dynamical focus of improvement of Lean that institutionalized the successful practices and KPI Category with averages in fig.2.

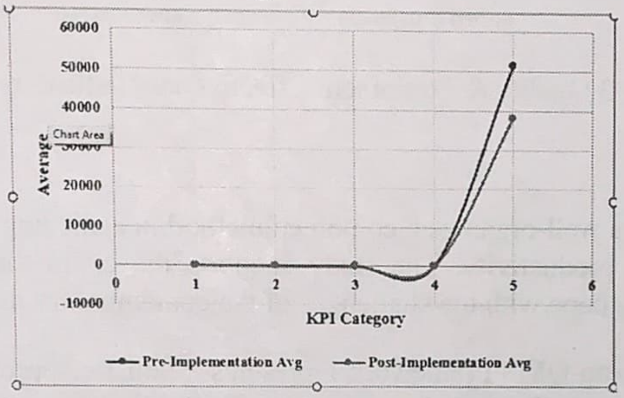

Fig 2 KPI Category with averages

The critical success factors in sustaining the Hybrid Lean-QMS Framework were also noted through the analysis. These are leadership devotion, KPI-led decision-making, incessant training of workforce and periodic audits. Additionally, the companies that incorporated digital solutions, i.e., IoT-based monitoring and ERP modules, had lower feedback loops and real-time performance indicators. All these findings prove that the hybrid framework can not only lead to the reduction of waste and quality improvement but also to the cultural change towards ongoing improvement. In fig 3 and 4, it shows the comparative performance of Quality & Equipment Effectiveness Indicators part-1 & 2.

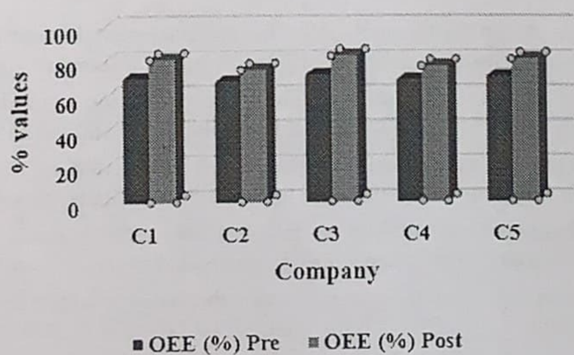

Fig 3 Quality & Equipment Effectiveness Indicators part-1

To conclude, the research shows that the Hybrid Lean-QMS Framework can be used to successfully overcome the efficiency-driven and compliance-driven systems. This integration of Lean methods and QMS standards results in quantifiable productivity, product compliance, process stability and customer satisfaction. The research findings highlight that a unified strategy is the way to increase the level of competitiveness and contribute to the business sustainability in the automotive and auto components sector.

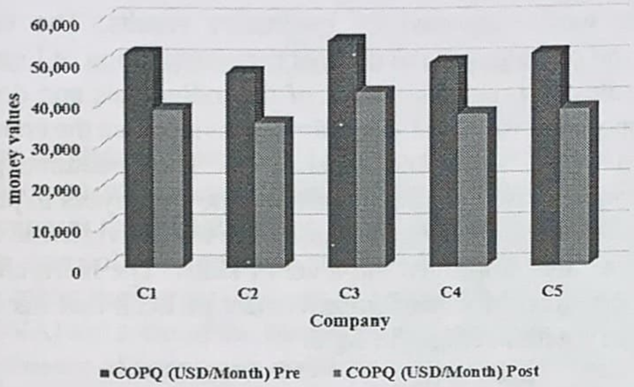

Fig 3 Quality & Equipment Effectiveness Indicators part-2

5. Conclusion

The auto industry needs a well-organized, combined method in achieving the two purposes of quality control and operational productivity. The study supports the claim that Lean and QMS, applied individually, cannot fully cope with the challenges of the contemporary manufacturing.

The suggested Hybrid Lean-QMS Framework represents a holistic approach that will bring together the waste minimisation capabilities of Lean and the standardisation and compliance capabilities of QMS. It promotes the perpetual betterment, facilitates the performance improvement that can be measured, and promotes competitiveness. There is high potential of adoption of this integrated model both in automotive and auto component industries that will go a long way in ensuring operational excellence and eliminating waste.

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