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**FIELD: ENGINEERING AND MANAGEMENT**

# RESEARCH ON CONTROLLING NON-CONFORMITIES IN QUALITY MANAGEMENT SYSTEMS IN THE AUTOMOTIVE INDUSTRY

## SUMMARY

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**TÂRGU MUREŞ**

**2024**

## Introduction

This paper focuses on research regarding the control of non-conformities in quality management systems in the automotive industry. This field is of the utmost importance in the context of the stringent standards and rigorous requirements of this industry, where quality and compliance are essential for long-term success. The research comprehensively addresses the methods by which QMS can be optimized to reduce defects, improve customer satisfaction, and keep costs under control.

## Chapter 1: Scientific fundamentals of the research topic

Quality management systems (QMS) are essential to ensuring compliance with international standards, minimizing non-conformities, and preventing defects in industrial production, especially in the automotive sector. In the context of digitization and Industry 4.0, integrating advanced technologies into these systems allows for real-time monitoring and predictive quality analysis, enabling rapid and precise interventions. In a competitive global environment, operational efficiency and cost optimization are crucial, making the reduction of non-conformities a priority for maintaining competitiveness and reputation.

The research topic "Research on Controlling Non-Conformities in Quality Management Systems in the Automotive Industry" is motivated by the critical importance of quality in this sector. The automotive industry requires strict standards to ensure safe and reliable products, and defects can have severe financial and reputational consequences. The paper aims to make a significant contribution to understanding the relationship between QMS and non-conformities, offering practical recommendations for optimizing these systems.

The automotive industry is characterized by intense competition and strict regulations, making an efficient QMS vital to maintaining product quality. ISO 9001:2015 and IATF 16949 standards are widely adopted to ensure quality and continuous improvement. The research aims to analyze how the implementation of QMS influences product quality, identifying factors that contribute to the success of these systems and providing practical solutions for companies in this sector.

The research objectives include evaluating the effectiveness of QMS in reducing non-conformities, identifying the main types of non-conformities and their causes, analyzing the impact of QMS on the studied company, and formulating recommendations for improving these systems. The goal is to propose new solutions and methods for optimizing QMS adapted to the requirements of Industry 4.0.

The research methodology will combine quantitative and qualitative methods, including case studies, data collection and analysis from within the company, and the review of existing internal documents. Statistical analysis and qualitative methods will be used to interpret the data and develop new methods for identifying and addressing non-conformities.

The thesis is structured into 7 chapters, covering theoretical foundations, the analysis of the current state of QMS, identification of non-conformities through non-destructive control methods, statistical analysis of complaints, product audit contributions, self-developed methods of calculation and implementation of an efficient audit system, and final conclusions.

**Chapter 2: Analysis of the current state of quality management systems in the automotive sector**

This chapter defines and explains the fundamental concepts of a quality management system (QMS) in the automotive industry. QMS is a set of policies, processes, and procedures that ensure product and service compliance with customer requirements and specific sector regulations. The main concepts include quality, quality policy, quality objectives, quality planning, quality control, quality assurance, continuous improvement, and customer satisfaction.

International standards ISO and IATF regulate quality management systems in the automotive industry, with ISO 9001:2015 as the basic standard, and IATF 16949 adding industry-specific requirements. These standards promote continuous improvement, defect prevention, and operational efficiency, while emphasizing the importance of internal quality auditing, risk-based approaches, and the critical role of leadership in the effective implementation of these standards.

The evolution of quality management systems in the automotive industry is moving towards the integration of advanced technologies and the digitalization of production processes. The concept of "Quality 4.0" is central to this transformation, involving the use of artificial intelligence and data analysis to improve product quality. Additionally, the Advanced Product Quality Planning (APQP) standards and the Production Part Approval Process (PPAP) play a crucial role in maintaining high standards in the face of global challenges.

Non-conformities represent deviations from established specifications or standards and can significantly impact organizational performance, customer satisfaction, and the company's reputation. This section explores the causes of non-conformities, such as design errors, supply chain issues, and deficiencies in manufacturing processes. Efficient management of these non-conformities is vital to maintaining competitiveness in the market.

Complaints are a crucial indicator of the quality of products and services offered. This subsection discusses the importance of efficiently managing complaints, using methods such as CRM, QRQC, and FMEA. Complaints are classified into two main categories: "0 km" (issues identified before the vehicle leaves the factory) and "field" (problems discovered after the vehicle has been delivered to the consumer). Efficient management of these complaints is essential for maintaining quality and customer satisfaction.

The 8D (8 Disciplines) method is a structured approach to problem-solving, widely used in the automotive industry. It consists of eight steps that ensure the identification, correction, and prevention of recurring problems, thereby contributing to the continuous improvement of product and process quality.

**Chapter 3: Analysis of the current state of non-destructive control methods for identifying non-conformities in production processes and defects reported by customers**

Chapter 3 details the essential methods used to ensure the quality of automotive components and systems, focusing on various inspection and testing techniques. Visual inspection is one of the fundamental methods, used to evaluate product conformity and integrity by detecting visible defects, such as scratches or cracks, ensuring consistency and objectivity in evaluations. Dimensional examination is also crucial, utilizing advanced technologies like coordinate measuring machines (CMM) and 3D laser scanning for precise measurements, thus preventing manufacturing defects. Another important aspect is the unlocking of the electronic module, which involves using specialized software for its functional analysis and testing before integration into vehicle systems.

Functional testing, conducted on specialized benches and through advanced methods, ensures that all components and systems operate according to specifications. For internal inspection of critical components, X-ray examination plays an essential role, allowing the detection of hidden defects without damaging the product. Electrical measurements are fundamental for testing and calibrating electrical components, using precise instruments such as multimeters and oscilloscopes. Additionally, step temperature tests and thermal shock tests are used to ensure the performance and durability of components under extreme climatic conditions, identifying and preventing defects caused by thermal variations.

Oil environment tests are critical for evaluating the durability of components that interact with lubricants, simulating real operating conditions. Additionally, vibration tests simulate actual road conditions to assess the durability of components and prevent mechanical failures. The quality of electrical connections is verified through soldering tests, which include visual inspections and mechanical and thermal tests to ensure their durability.

Finally, the push and pull force test evaluates the resistance of components to specific mechanical forces, ensuring their mechanical integrity and performance under tension and compression. These methods and tests are essential for ensuring the quality and reliability of products in the automotive industry.

**Chapter 4: Statistical analysis of data from customer complaints and non-conformities identified in production**

Chapter 4 delves into the use of Statistical Process Control (SPC) as an essential preventive method for ensuring quality in the automotive industry. SPC allows for continuous monitoring and oversight of complex technological processes, contributing to the identification of systematic deviations and ensuring compliance with specifications.

The chapter also details the process of analyzing data from customer complaints using various statistical methods, such as descriptive analysis, hypothesis testing, regression analysis, and predictive modeling. A specific example is the analysis of complaints within Bosch, which involved 368 statistical observations to identify the most frequent non-conformities, such as issues with the "pressure sensor." Frequency analysis revealed that these defects are predominant, requiring interventions to reduce them.

Additionally, the $\chi2$ test was applied to evaluate the relationship between categorical variables, showing a significant connection between certain components and the types of associated defects, such as the susceptibility of integrated transmission processing units to functional defects. Furthermore, the "Crosstabs" analysis investigated the responsibility for defects, highlighting those issues with the "pressure sensor" are often attributed to the customer, while problems with the "position sensor" are the manufacturer's responsibility.

The chapter concludes with findings and improvement proposals, emphasizing the need for corrective and preventive measures, such as enhancing manufacturing processes, conducting extensive testing before delivery, and closely collaborating with suppliers to ensure the quality of components.

## Chapter 5: Product audit for identifying non-conformities and defects using reliability tests

The product audit is an essential process in quality management systems, ensuring that products comply with technical specifications and customer requirements. It involves evaluating finished products to identify non-conformities before they reach customers, and in the automotive industry, the VDA 6.3 and VDA 6.5 standards set the guidelines for conducting these audits.

Reliability tests play a crucial role in evaluating the durability and performance of products under extreme conditions, using methods such as temperature tests, high voltage, and mechanical shock tests, all designed to detect potential failures in a short period. Audit planning is essential, involving the definition of objectives, selection of products to be audited, and allocation of necessary resources. Coordination between departments, such as development and production, is vital for the audit's success and for promptly addressing non-conformities.

The audit process includes several stages: planning, preparing documentation, conducting the audit, documenting the results, and implementing corrective measures, with each stage being essential for evaluating and improving product quality. The audit program is planned annually, including defining the test density (PPM) and types of tests (quality and reliability). The program is adjusted throughout the year based on changes in production and customer requirements.

A case study conducted at Bosch Romania on electronic control modules for automatic transmissions showed that after two years of testing without major non-conformities, reducing the test density from 100 PPM to 50 PPM did not lead to an increase in complaints. This demonstrated the correctness and benefits of the decision in optimizing costs and resources.

In conclusion, product audits combined with rigorous reliability testing are essential for maintaining quality in the automotive industry. Reducing test density, based on risk analysis, can optimize processes without compromising reliability or customer satisfaction.

## Chapter 6: "Smart" product audit

The "smart" product audit in the automotive industry is an advanced methodology that integrates cutting-edge technologies such as the Internet of Things (IoT), Big Data, and machine learning algorithms to monitor and assess product quality in real-time. This revolutionary approach combines traditional quality control techniques with innovative digital solutions, enabling the early detection of non-conformities and the prevention of defects that could lead to costly recalls.

An innovative aspect of the "smart" audit is data-based sampling, which replaces traditional random sampling methods with a methodology that uses real-time data to identify critical parts with a high risk of non-conformity. This approach allows for rapid and precise corrective intervention, contributing to increased product reliability and operational cost optimization. Machine learning algorithms play a central role, analyzing large volumes of data collected from production processes and generating predictive models that identify and anticipate quality issues, thereby reducing complaints and optimizing costs.

The implementation of the "smart" product audit involves continuous monitoring of production processes and the collection of standardized data to analyze anomalies and non-conformities. Advanced algorithms are used to identify critical parts by analyzing standardized deviations from the process mean. In this context, the "Z-Score" methodology is employed to objectively evaluate the characteristics of the parts, allowing for a rigorous comparative analysis of deviations. Parts with significant deviations are directed to additional reliability tests, ensuring stricter quality control.

The benefits of the "smart" product audit are numerous, including continuous improvement of product quality through real-time monitoring and analysis of production data, reduced time required to identify and resolve issues, and optimized production processes through precise sample selection based on interpreted data. The implementation of this methodology has shown a significant positive impact, contributing to a reduction in the number of audited parts and customer complaints, as well as substantial cost and time savings.

Although the implementation of the smart audit presents challenges, such as integrating technological platforms and initial investments in IT infrastructure and staff training, the long-term benefits are considerable. These include continuous improvement of processes and products, reduction of non-conformities, and enhanced operational performance. A concrete example of success is the 83.6% reduction in the number of audited parts achieved through the application of an advanced algorithm for identifying critical parts.

The "smart" product audit represents an essential solution for optimizing quality control processes in the automotive industry, contributing to more efficient production by reducing costs and improving product quality.

## Chapter 7: Conclusions and personal contributions

The research clearly demonstrates that integrating advanced technologies into Quality Management Systems (QMS) is essential for the continuous improvement of quality in the automotive industry. Implementing a "smart" product audit based on predictive analysis and real-time monitoring enables companies to anticipate and address problems at an early stage, thereby reducing non-conformities and increasing customer satisfaction.

The paper makes a significant contribution to both theoretical and practical knowledge in the field of quality management, offering innovative solutions that can be practically applied by companies in the automotive industry. These solutions not only improve product quality but also enhance process efficiency, reduce costs, and help maintain control over product defects and non-conformities.

### Theoretical personal contributions

This research has allowed me to explore the impact of quality management systems on product non-conformities and how they can be effectively controlled by applying these systems in a way that is optimized to the company's needs.

I established a robust theoretical framework through a comprehensive analysis of the specialized literature and international standards, such as ISO 9001:2015 and IATF 16949, providing a critical perspective on the implementation and evolution of these norms.

I used a rigorous research methodology, combining both qualitative and quantitative approaches to evaluate the effectiveness of existing quality management systems (QMS) and to identify common non-conformities in the automotive industry.

I conducted a detailed analysis of the ISO 9001:2015 and IATF 16949 standards, highlighting the differences and similarities between them. I emphasized the importance of these standards in ensuring quality and continuous improvement in automotive production processes.

I developed a methodology for conducting product audits, which includes detailed stages such as planning, documentation preparation, execution, results documentation, and the implementation of corrective measures.

I conceptualized a "Quality 4.0" approach by integrating digital technologies and predictive analysis into quality control, enabling real-time monitoring and proactive identification of non-conformities before they escalate into critical issues.

**Experimental personal contributions**

I managed "0 km" and "field" complaints through a systematic approach, utilizing root cause analysis and implementing quick solutions to address the issues. I developed processes for the analysis and evaluation of returned parts, ensuring that all defects were correctly identified and resolved.

I optimized the audit process by reducing the test density from 100 PPM to 50 PPM, based on a detailed risk analysis. This led to cost reduction and increased audit efficiency, without compromising product quality.

I proposed and defined a calculation algorithm that utilizes process data to identify critical parts in a production line. The implementation of this algorithm led to a significant reduction in the number of parts selected for product audits, from 2,416 parts per year to 397 parts per year.

I contributed to reducing the number of customer complaints by approximately 60% through the implementation of a proactive method for identifying and preventing defects, thereby improving customer satisfaction and the company's reputation.