

Data-Driven Compliance Assessment of IATF 16949:2016 Operational Requirements: A Case Study in Automotive Manufacturing

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Abstract: This study proposes a computational framework for assessing operational compliance with the IATF 16949:2016 automotive quality management standard. A case study was conducted at the State Company for Automotive Industry and Equipment (Iraq), focusing on a car battery manufacturing facility. The framework integrates structured operational data with machine learning-assisted gap analysis to quantify deviations between actual practices and standard requirements. Key operational domains - including operational planning, control of externally provided processes, production and service provision, product release, and non-conformity management - were evaluated using weighted scoring models and statistical inference. Compliance levels were expressed through normalized conformity indices, enabling the identification of critical process deficiencies. The results indicate an overall compliance level of 55%, corresponding to a 45% operational gap relative to IATF 16949:2016 requirements. The findings demonstrate that data-driven compliance assessment enhances diagnostic accuracy and supports decision-making in quality management systems. The proposed approach contributes to the advancement of digital quality assurance, predictive compliance monitoring, and Industry 4.0-oriented manufacturing systems.

1 INTRODUCTION

Quality management systems (QMS) have become a critical component of organizational competitiveness, particularly in the automotive industry, where product reliability, safety, and regulatory compliance are essential. The increasing complexity of automotive supply chains requires standardized frameworks capable of ensuring consistent product quality and process reliability across all production stages.

The IATF 16949:2016 standard represents a globally recognized quality management framework specifically developed for the automotive sector. It extends the principles of ISO 9001:2015 by incorporating additional requirements related to risk management, defect prevention, and continuous improvement within automotive production and supply chains [1]–[3]. Unlike ISO 9001, which primarily focuses on customer satisfaction, IATF

16949 emphasizes defect reduction, process standardization, and strict compliance with customer-specific requirements.

Despite its importance, the implementation of IATF 16949:2016 remains challenging for many manufacturing organizations, particularly in developing economies. These challenges include limited technical expertise, insufficient process standardization, weak documentation practices, and the absence of data-driven decision-support systems. As a result, organizations often exhibit partial compliance, leading to operational inefficiencies and increased risk of non-conformities.

Recent studies highlight the growing role of digital technologies in enhancing quality management practices. Artificial intelligence (AI) and machine learning techniques enable real-time analysis of production data, facilitating early detection of process deviations and improving

resource allocation [4]. However, the application of computational methods for systematic compliance assessment with IATF 16949 remains limited in the literature.

This study addresses this gap by proposing a data-driven analytical framework for evaluating operational compliance with IATF 16949:2016. The research focuses on the "Operation" clause, which represents a core component of the standard and directly affects production performance and product quality.

A case study is conducted at the State Company for Automotive Industry and Equipment (SCAEI) in Iraq, specifically within a car battery manufacturing facility. The study aims to quantify the level of compliance, identify operational gaps, and provide a structured assessment of strengths and weaknesses across key operational processes.

The main contributions of this work are as follows:

- development of a computational framework for compliance assessment;
- integration of statistical and machine learning techniques for gap analysis;
- empirical validation through an industrial case study;
- identification of critical deficiencies in operational quality management.

The results provide insights into the practical challenges of implementing IATF 16949:2016 and demonstrate the potential of data-driven approaches to support digital transformation in quality management systems.

2 RESEARCH METHODOLOGY AND PREVIOUS STUDIES

2.1 Research Method

The research arises from the State Company for Automotive and Equipment Industry's (SCAEI) need to adopt internationally recognized standards in the manufacturing of vehicles and related products. Through a field visit conducted by the researcher to the company's factories under study, the Car Battery Factory was chosen as a sample for the research. This is due to problems affecting the quality of their production resulting from the factory management's failure to keep pace with the development of adopted international standards and weak knowledge of the nature of the specification (IATF 16949:2016).

Due to the numerous requirements of the studied specification, the "Operation" clause was used in its quality management system. Accordingly, the research problem can be formulated in a set of questions determined as follows:

- What is the operation clause's application level according to the specification (IATF 16949:2016) in the General Company for the Automotive and Equipment Industry?
- Is there a gap between the actual reality and the operation clause according to the specification (IATF 16949:2016) in the General Company for the Automotive and Equipment Industry?

The research objectives are derived from the questions raised by the research problem and are determined as follows:

- Diagnosing the actual reality of the operation clause according to the specification (IATF 16949:2016) in the General Company for the Automotive and Equipment Industry.
- Measuring the size of the gap between the actual reality and the operation clause according to the specification (IATF 16949:2016) in the General Company for the Automotive and Equipment Industry.
- Identifying the strengths and weaknesses of the operation clause according to the specification (IATF 16949:2016) in the General Company for the Automotive and Equipment Industry.

The importance of the research lies in its contribution to creating a qualitative shift in industry and production in one of the most important national industries in the Iraqi environment, represented by (the Car Battery Factory affiliated with the SCAEI, one of the formations of the Ministry of Industry and Minerals), which is in dire need of following international standards in the automotive industry and related products.

2.2 Research Limitations

Spatial limitations: The SCAEI, represented by the Battery Factory (research sample), one of the formations of the Iraqi Ministry of Industry and Minerals, was chosen to apply the practical aspect of the research. Temporal limitations: The period during which the researcher conducted field visits to identify the actual reality in the SCAEI, represented by the Battery Factory (research sample), from 30/11/2022 until 20/04/2023.

2.3 Data Analysis Methods

In this research, several formulas were used, as follows [5]:

- Weighted arithmetic mean = $\frac{\text{requeancies} \times \text{weights}}{\text{Sum of frequencies}}$ to calculate the approximate rate.
- The percentage of matching = $\frac{\text{Arithmetic mean}}{(\text{highest score on the scale})(6)} \times 100\%$
- The highest weight on the seven-point scale is (6).
- Gap size = 1 - Percentage of compliance.
- 7- sacale Likert according as shown in Table 1 to diagnose the possibility of applying the operation clause according to the specification (IATF16949:2016). Checklists were prepared for the operation clause and included (6) checklists and (104) axes. The seven-point Likert scale was used to determine the relative weights to know the operation clause's application level according to the standard specification (IATF16949:2016), as shown in Table 1.

Table 1: The seven-point scale [6].

Fully applied, fully documented	6
Fully applied, partially documented	5
Fully applied, undocumented	4
Partially applied, fully documented	3
Partially applied, partially documented	2
Partially applied, undocumented	1
Not applied, undocumented	0

3 THEORETICAL ASPECTS OF THE RESEARCH

The (IATF) consists of a group of Original Equipment Manufacturers (OEM) and national automotive industry associations [7]. Since the 1990s, automotive industry suppliers have been subject to complex national standards in industrialized countries, including North America, Germany, France, and Italy [8]. As a result, the IATF was established, which merged national quality management system standards in the automotive industry, including the North American Quality Standard (QS9000), German standards (VDA6.1), French standards (EAQF), and Italian standards (AVSQ) into a single standard, IATF16949, to eliminate the cost, administrative burdens, and audits imposed by the multiple standards previously

enforced in different geographical regions [9]. IATF's joint third-party registration system to provide appropriate training to support IATF16949 specification requirements and IATF registration requirements [10], [11]. IATF 16949 standard as follows [12]:

First Edition (ISO/TS 16949: 1999) titled "Quality Systems - Automotive Suppliers - Special Requirements for the Application of ISO 9001: 1994": Developed based on ISO 9001: 1994, the goal of this edition was to unify the quality management system worldwide in the automotive industry.

The Second Edition (ISO/TS 16949: 2002), titled "Quality Management Systems - Special Requirements for the Application of ISO 9001: 2000 for Automotive Production and Relevant Service Part Organizations": Resulted from updating the central systems, feedback, previous experiences, and comments from other participants on the last edition (ISO/TS 16949: 1999).

Third Edition (ISO/TS 16949: 2009) titled "Quality Management Systems - Special Requirements for the Application of ISO 9001: 2008 for Automotive Production and Relevant Service Part Organizations" includes meeting specifications according to customer requirements.

Fourth Edition: The standard's name was changed to IATF 16949: 2016, titled "Quality Management System Requirements for Automotive Production and Relevant Service Parts Organizations" Published by the (IATF), it is considered the first edition and replaces the third edition (ISO/TS16949: 2009) [13], [14].

From the above, the researcher adds that the organization's adoption of IATF16949 specification achieves many benefits by increasing employees' awareness of quality improvement tools used in the automotive industry and related products, as well as simplifying work procedures and improving its reputation, thereby increasing confidence in its products (goods or services) and increasing profits and market share and reducing production costs by reducing waste and defects in the supply chain. Most researchers agreed that the IATF 16949 specification achieves a set of objectives. The new version of the IATF 16949:2016 specification came with seven basic requirements and three definitional ones. Both [15] and [16] classified these requirements into three levels:

- First level. General requirements in ISO 9001 (understanding the organization's context, top management involvement, planning, support, etc.).

- Second level. Specific requirements from the (IATF) in the automotive industry.
- Third level. Represents customer-specific requirements.

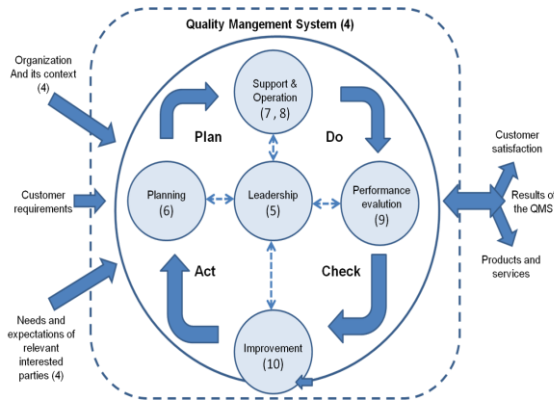


Figure 1: IATF16949:2016 specification requirements according to the PDCA methodology [17].

Figure 1 shows that the quality management system approach consists of four stages to ensure the effectiveness of the system based on the PDCA cycle (Plan, Do, Check, Act), which begins with leadership requirements (Clause 5), planning (Clause 6), support (Clause 7), operation (Clause 8), performance evaluation (Clause 9), and finally the requirements dedicated to improvement processes (Clause 10) [17]-[19]. This cycle enables automotive companies and their suppliers to ensure that their processes are provided with the required resources and managed efficiently and identify and address improvement opportunities. Figure 1 illustrates the requirements of the IATF 16949:2016 specification according to the PDCA methodology [19].

4 THE PRACTICAL ASPECT OF THE RESEARCH

This section presents the analysis of checklist-based assessment results derived from data collected through structured interviews with managers and employees, as well as a review of organizational records and documentation related to the State Company for Automotive Industry and Equipment (SCAEI), specifically the Battery Factory selected as the case study.

The analysis aims to quantify the level of compliance with the requirements of Clause 8 (Operation) of the IATF 16949:2016 standard. Compliance levels were calculated using weighted

arithmetic means, enabling the estimation of both implementation levels and corresponding gaps for each sub-clause. Clause 8 is further divided into seven operational sub-clauses, which are analyzed individually in the following subsections.

4.1 Operational Planning and Control

The evaluation of the “Operational Planning and Control” requirement yielded a mean score of 2.42 out of 6, corresponding to a compliance level of 40% and a non-compliance gap of 60%. This indicates a low level of implementation.

From a strengths perspective, the organizational structure includes a dedicated administrative unit reporting directly to top management, responsible for maintaining the confidentiality of contractual information, including product specifications and customer-related data associated with ongoing and future projects.

However, several critical limitations were identified. The factory lacks structured mechanisms for identifying and managing risks and opportunities that may affect the effectiveness of the quality management system. In addition, insufficient process control practices limit the organization’s ability to enhance desired outcomes, mitigate undesirable effects, and ensure continuous improvement. These deficiencies indicate weak alignment between operational planning activities and the broader requirements of quality management system implementation.

4.2 Requirements for Products (Goods or Services)

The assessment of the “Requirements for Products and Services” clause resulted in a mean score of 3.28 out of 6, corresponding to a compliance level of 55% and a non-compliance gap of 45%. This reflects a moderate level of implementation.

From a strengths perspective, product specifications are primarily defined based on customer requirements in accordance with established technical standards adopted by the factory. Customer requests are processed through the marketing division, and management conducts pre-contract reviews to ensure the organization’s capability to meet specified requirements. These practices contribute to structured requirement definition and planning processes.

Nevertheless, several limitations persist. The absence of systematic communication mechanisms, such as regular meetings between the marketing

division and customers, restricts the organization's ability to capture customer feedback and identify emerging issues. Furthermore, the factory does not maintain adequate documented evidence regarding customer-authorized deviations from ISO 9001 requirements, despite partially relying on this standard without formal certification. In addition, deficiencies in documenting requirement reviews and new product specifications reduce traceability and weaken overall process control.

4.3 Design and Development of Products (Goods or Services)

Requirement Design and Development of products (goods or services) was excluded from the factory's quality management system scope because the company relies on fixed standard designs as documented in (Car Battery Factory Quality Manual, p.7).

4.4 Control of Externally Provided Processes, Products (Goods or Services)

The evaluation of the requirement for controlling externally provided processes, products, and services yielded a mean score of 3.53 out of 6, corresponding to a compliance level of 59% and a non-compliance gap of 41%. This indicates a moderate level of implementation.

From a strengths perspective, the factory has established clear specifications for procured materials to ensure continuity of production processes. Externally supplied raw materials are defined in accordance with technical standards provided by Sovema Group (Italy), ensuring consistency with required specifications. Conformity verification is conducted through inspection and receiving procedures, where incoming materials are systematically checked against approved technical requirements. In addition, suppliers are required to provide authenticated certificates of origin in compliance with applicable regulations in the Republic of Iraq and relevant organizational requirements.

However, several limitations were identified. The factory lacks structured supplier development programs related to battery products and associated production processes. Furthermore, second-party audits conducted by qualified and certified auditors are not implemented, limiting objective evaluation of supplier risks, monitoring practices, and quality management system maturity. In addition, the

absence of documented procedures for supplier development restricts the organization's ability to enhance the performance of strategically important suppliers.

4.5 Production and Service Provision

The assessment of the requirement for production and service provision resulted in a mean score of 2.82 out of 6, corresponding to a compliance level of 47% and a non-compliance gap of 53%. This indicates a relatively low level of implementation compared to other operational requirements.

From a strengths perspective, the factory demonstrates the existence of structured production planning practices. The planning department develops operational plans, and management ensures the availability of resources required for production processes. Manufacturing activities are conducted in accordance with defined work procedures, instructions, and technical specifications. In addition, periodic engineering inspections are carried out to maintain equipment performance, and the organization ensures the preservation of customer and supplier property.

Nevertheless, significant weaknesses remain. The factory has not established a formal control plan governing production processes, which limits process standardization and consistency. In addition, insufficient attention is given to the preparation and management of critical operational conditions, such as initial setup, material changes, and process transitions. The absence of appropriate protective measures for equipment and measurement instruments further exposes operations to environmental influences, potentially affecting measurement accuracy and overall process reliability.

4.6 Release of Products (Goods or Services)

The evaluation of the requirement for the release of products and services yielded a mean score of 3.92, corresponding to a conformity level of 65% and a non-conformity gap of 35%. This indicates a relatively higher level of implementation compared to other operational requirements.

From a strengths perspective, the factory has established structured procedures for product release, ensuring that all planned operational activities are completed and that product requirements are satisfied prior to release. The Quality Control Division maintains documented information confirming product conformity, including records identifying the

authorized personnel responsible for product approval through standardized control and measurement forms. In addition, inspection and testing procedures are systematically applied to verify functional performance and compliance with specified standards.

However, several limitations were identified. Suboptimal working conditions, particularly inadequate lighting in production areas, may negatively affect worker performance and operational efficiency. Furthermore, the factory does not utilize statistical data provided by external suppliers to assess and monitor the quality of supplied products and processes. Quality verification primarily relies on internal inspection committees using sampling-based approaches, without the support of accredited external laboratories. This limitation reduces the robustness and objectivity of quality assurance for externally provided products.

4.7 Control of Non-Conforming Outputs

The assessment of the requirement for controlling non-conforming outputs yielded a mean score of 3.76, corresponding to a conformity level of 63% and a non-conformity gap of 37%. These findings indicate a moderate level of implementation, which can be interpreted in terms of the following strengths and limitations.

From a strengths perspective, the factory demonstrates structured practices for identifying non-conforming products through systematic quality inspection procedures. Non-conforming items are effectively isolated in designated areas to prevent unintended use. In addition, the factory adheres to control procedures established by Sovema Group (Italy), ensuring that non-conforming processes and products are managed in accordance with defined

requirements. Disposal procedures for irreparable products are also clearly established.

However, several limitations remain. Although a documented procedure exists for handling non-conforming sub-components, including classification as second-grade products, its implementation is inconsistent. Furthermore, the lack of specialized training programs for production personnel limits the effectiveness of containment and handling of suspected or non-conforming outputs.

Table 2 summarizes the overall evaluation results for the Operation clause. The total compliance level was estimated at 55%, indicating a 45% implementation gap. The highest conformity level was observed for the “Release of products and services” requirement (65%), reflecting relatively strong control over final product verification and release procedures.

In contrast, “Operational planning and control” exhibited the lowest compliance level (40%), highlighting deficiencies in process planning and insufficient alignment with quality management system requirements. These shortcomings also indicate limited adoption of risk-based approaches in operational processes.

The remaining requirements demonstrated moderate levels of implementation. “Control of non-conforming outputs” achieved a conformity level of 63%, reflecting effective but not fully optimized control mechanisms. “Production and service provision” showed a lower compliance level (47%), indicating weaknesses in process execution and control practices. “Control of externally provided processes” reached 59%, suggesting that supplier selection is prioritized, although documentation and supplier development practices remain insufficient. Finally, “Requirements for products and services” achieved a compliance level of 55%, indicating partial effectiveness in requirement definition and review processes.

Table 2: Overall results for the operation item, prepared by the researcher based on practical data.

#	Total results for the operational item		Evaluation scores for actual application & documentation		
	Req. number	Req name	Weighted arithmetic mean	Compliance %	Gap size
1	6.8	Release of products (goods or services)	3.92	%65	%35
2	7.8	Control of non-conforming outputs	3.76	%63	%37
3	4.8	Control of externally provided processes and products (goods or services)	3.53	%59	%41
4	2.8	Requirements for products (goods or services)	3.28	%55	%45
5	5.8	Production and service provision	2.82	%47	%53
6	1.8	Operational planning and control	2.42	%40	%60
Total matching percentage and size of the gap				%55	%45

5 CONCLUSIONS

This study presented a data-driven framework for assessing operational compliance with the IATF 16949:2016 standard, with empirical validation conducted at a car battery manufacturing facility within the State Company for Automotive Industry and Equipment (Iraq). The analysis focused on the “Operation” clause and quantified the level of alignment between implemented practices and standard requirements.

The results indicate a moderate compliance level of 55%, corresponding to a 45% operational gap. This gap reflects systemic deficiencies in several critical areas, including operational planning, risk-based process control, supplier quality management, and production process standardization. In contrast, relatively higher compliance was observed in product release and non-conformity control, suggesting that downstream quality assurance practices are more mature than upstream process management.

The findings demonstrate that partial implementation of structured quality management practices limits the effectiveness of the overall system and increases the risk of process variability and non-conformities. Moreover, the absence of integrated data-driven monitoring mechanisms constrains the organization’s ability to proactively identify and mitigate operational risks.

From a practical perspective, the results highlight the necessity of strengthening risk-based thinking, improving supplier integration mechanisms, and enhancing documentation and process control practices. The adoption of digital quality management tools, including AI-supported analytics and real-time monitoring systems, can significantly improve compliance levels and support continuous improvement initiatives.

The proposed framework contributes to the field by providing a systematic and quantifiable approach to compliance assessment, bridging the gap between standard requirements and operational execution. It also offers a scalable methodology applicable to other manufacturing environments seeking alignment with IATF 16949:2016 within the context of Industry 4.0 transformation.

Future research should focus on large-scale multi-site validation, integration of real-time industrial data streams, and the development of adaptive compliance models capable of handling dynamic production environments.

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