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QUALITY MANAGEMENT STANDARDS IN THE CONTEMPORARY AEROSPACE SECTOR: EMERGING TRENDS IN QUALITY DEFINITION

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Rezumat. *ISO și IAQG stabilesc standardele de calitate care sunt utilizate în industria aviației, spațiului și apărării și oferă contribuții în politicile, standardele și practicile de îmbunătățire a calității. Scopul studiului este de a identifica instrumentele și metodele necesare pentru îmbunătățirea calității, ce sunt utilizate de către companiile din industria aerospațială. Analiza din cadrul studiului este realizată prin prisma metodologiei dezvoltate de către cele două organizații de standardizare. Implementarea standardelor de calitate asigură sprijin în dezvoltarea inițiativelor globale, printr-o abordare holistică a managementului organizației, care se concentrează pe îmbunătățirea continuă a calității.*

Abstract. *The International Organization for Standardization (ISO) and the International Aerospace Quality Group (IAQG) define the quality standards applied within the aviation, space, and defence industries. These organizations contribute significantly to the formulation of policies, standards, and best practices aimed at continuous quality enhancement. The objective of this study is to identify the key tools and methodologies employed by aerospace companies to improve quality performance. The analysis is conducted in alignment with the methodological frameworks established by the aforementioned standardization bodies. The implementation of quality standards provides strategic support for the advancement of global initiatives, through a holistic approach to organizational management that emphasizes continuous quality improvement.*

Keywords: ISO, IAQG, standardization, quality, aerospace industry

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1. Introduction. Current trends in Defining Quality.

A study of antiquity or ancient history would begin with the emergence of the first civilizations around 3500 BCE, some of the most representative being the Sumerian, Babylonian and Egyptian civilizations, followed by the Indian and Chinese civilizations. Eventually, the cultures of Classical Greece, Hellenistic Greece, and Rome also become noteworthy. Examining various ancient societies

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and their management practices shifts the dialogue beyond the origins of scientific management towards a more holistic understanding of current management theories and practices. In the context of antiquity, “management” can be defined as the production of goods and services within a hierarchically structured society. The term *“quality”*, derived from the latin word *“qualis”*, meaning “the way of being”, represents a complex concept that defines the degree of perfection or the state of being free from defects, deficiencies, and significant variations. [1]

Although the need to define the concept of quality truly emerged only in the second half of the 20th century, the necessity of applying product quality principles and quality standards has since ancient times. Quality management has a much longer history than previously assumed, and such a history offers valuable lessons for modern management.

The contemporary quality management system is strongly influenced by the concept of Japanese management, which originated in the early post-war period and has continuously evolved ever since. The unique management practices used in Japanese companies might have gone unnoticed were it not for James C. Abegglen, who can confidently be regarded as the father of a remarkable body of work on the Japanese management system. Abegglen was one of the first Western scholars to dedicate himself to studying the management practices of Japanese companies. His central message was that Japan’s industrialization process is deeply rooted in its unique social and cultural conditions and is therefore fundamentally different from that of the United States of Europe. Abegglen was the first to identify three defining characteristics of management in Japanese companies at the time-features that continue to constitute the core of the classical definition of Japanese management today. The first component of the classical is lifetime employment *(shūshin koyō).* Abegglen emphasized the commitment of Japanese workers to dedicating their entire careers to a single company. From the employers perspective, the desire to stabilize employment stemmed from the shortage of skilled labour during Japan’s rapid economic growth and the widespread adoption of new technologies. Since its inception, lifetime employment has remained one of the most closely studied aspects of Japanese management. Subsequent research revealed that his practice has no formal or legal basis, is limited to a group of large companies, and applies to only about 20% of the workforce. Abegglen defined the second characteristic as seniority-based wage and promotion systems *(Nenko joretsu chingin gata)* forms the third pillar of the classical Japanese management model described by Abegglen. He particularly emphasized the harmonious cooperation between union members and management, as well as the inclusion of middle manager within the union structure.[2]

Japanese management is governed by a set of principles that emphasize human resources, collaboration, continuous improvement, and decision-making through consensus. [3] These principles are reflected in international standards such as ISO 9001:2015, AS 9100D, and the core tenets of LEAN Manufacturing, as outlined in Tabel 1.

Tabel 1) Analysis of Japanese principles reflected in international standards such as ISO 9001, AS9100, and the core tenets of LEAN manufacturing.

No.	*Japanese Management Principle*	*International Standard*	*Comparative Commentary*
1.	Kaizen *(continuous improvement)*	ISO 9001:2015 (Clause 10.3) AS9100 Rev. D	*"Kaizen"* is formally integrated into the requirement for continual improvement of the quality management system.
2.	Hansei *(reflection on mistakes)*	ISO 9001 (Clause 10.2) Corrective Actions	In Japanese management, *"Hansei"* is deeply cultural, whereas in standards it is formalized.
3.	Genchi Genbutsu *(go to the source)*	SAE AS 9145 (APQP) – Product Management	Modern standards encourage periodic verification during product development, but it is not as culturally embedded as in Japan.
4.	Jinponshugi (respect for people)	AS 9100 – Leadership and commitment	Implicitly present in standards, yet not always culturally emphasized to the same extent as in Japanese systems.
5.	Obeya *(rapid decision-making)*	Not formally required; applied in Lean Product Development processes	*"Obeya"* is practiced by companies like Airbus and Boeing, though not officially mandated by standards.
6.	Gemba *(the actual place/ origin of action)*	Root Cause Analysis (RCA) in standards	Similar in intent; *"Gemba"* implies a continuous physical presence, not officially mandated by standards.
7.	Hoshi Kanri *(strategic alignment)*	Balanced Scorecard, AS 9100-Context of the Organizational	*"Hoshi Kanri"* provides a clearer top-down alignment model compared to the general requirements in ISO/AS standards.

2. Quality Standards in the Aviation, Space and Defence Sectors

In the current industrial context, quality is no longer perceived solely as the responsibility of organizations, but is increasingly acquiring a social and educational dimension, becoming an integral part of both individual and collective culture. This trend reflects a paradigm shift wherein education for quality and awareness of its value contribute to shaping a society oriented toward excellence, sustainability, and accountability.

Consequently, the effective implementation of the quality requires not only specific tools and methods, but also an integrative vision grounded in ethical, economic, and socio-cultural principles. In the aerospace industry, state-of-the-art technologies and QMS are complementary: the former enabling innovation and efficiency, while the latter ensure safety and compliance with regulations.

According to SR EN ISO 9000:2015, quality is defined as the degree to which a set of inherent characteristics of an object fulfills requirements. [4] In reference to ISO 9001:2015 and AS9100, quality in production is defined by the strict and consistent conformity to measurable and verifiable standards, aiming to achieve uniform outcomes that meet the specific requirements of customers or end-users.

As aerospace enterprises expand and globalize, and as technology evolves and manufacturing environments shift, quality management systems are also evolving – reaching new heights through the development of specialized monitoring, evaluation, and performance improvement practices. Quality has thus moved beyond the technical domain of product conformity and has become a strategic management element and a key indicator of competitiveness.

3. The Quality 4.0. Evolution of the Concept

Industrial revolutions marks a paradigm shift in manufacturing, characterized by the integration of advanced technologies designed to meet increasingly stringent quality and performance requirements. Foundational technologies of this industrial transformation include the IoT, the digital thread, AR, and predictive analytics – tools that collectively enable smarter, more efficient and responsive production systems. [5]

Within this context, Quality 4.0 emerges as a data-centric, digitally enhanced approach to quality management that operates throughout the production lifecycle. Rather than replacing traditional quality methodologies, Quality 4.0 enhances them by incorporating cutting-edge technologies such as machine learning, cloud computing, digital twins and networked sensors. This convergence facilitates the transformation of quality management systems into proactive, real-time frameworks that can anticipate, detect, and eliminate potential product or process nonconformities. [6]

A defining feature of Quality 4.0 is its ability to embed QA and operational insights from the earliest stages of product development, including conceptual design and engineering. Despite the advancement of manufacturing technologies, many organizations still rely on manual design transfer processes, which are prone to error-both internally and in communications with external supply chain partners. Quality 4.0 addresses this challenge by enabling automated, error-resistant design flows, thus reducing risk and enhancing consistency.

Beyond the design phase, Quality 4.0 leverages process-oriented machine learning algorithms to minimize rework, reduce material waste and optimize production parameters in real time. It also extends beyond the factory floor by facilitating post-delivery performance monitoring and remote updates to embedded software, which enhance customer satisfaction and foster long-term client relationships. The new domains and principles of the Quality 4.0 concept are highlighted in Fig. 1.

Fig. 1. Principles of a new concept of quality. [5], [6]

In essence, Quality 4.0 is not a peripheral initiative but a core enabler of Industry 4.0. Its holistic approach ensures that quality becomes an embedded function across all domains of manufacturing-design, planning, production, and service.

Importantly, Quality 4.0 promotes a closed-loop quality management system, wherein each stage of the manufacturing process is tightly integrated with real-time quality feedback mechanisms. These systems have the capacity to autonomously pause, continue, or adjust production processes based on quality data, thereby eliminating reliance on human intervention and minimizing the risk of error. This capability is particularly vital in aerospace manufacturing, where the implementation of such systems is key to improving production cycle times, achieving elevated levels of quality, and ensuring compliance with rigorous standards, such as AS 9100D.

Finally, the inclusive and organization-wide scope of quality 4.0 cultivates a culture of quality, where data-driven decision-making becomes a standard practice, and compliance is viewed not just as a requirement, but as a strategic asset. This culture enhances overall operational resilience, aligns with sustainability goals, and strengthens long-term competitiveness in a rapidly evolving industrial landscape.

The quality 4.0 principle emerged in response to the integration of advanced equipment and technologies into aerospace manufacturing.

4. Standards used in the Aerospace Industry

The International Aerospace Group (IAQG) is the reference organization for setting quality standards applicable to the aviation, space and defence industries. IAQG plays an active role in defining policies, standards and best practices aimed at the continuous improvement of global quality performance. Since 2016, the entire AS9100 series of standards has undergone substantial revision. [7]

The IAQG developed standards offer a technical and methodological reference framework that supports organizations in the establishment, optimization and enhancement of QMS, as well as associated operational processes and activities. These auxiliary standards do not impose from certification requirements, but rather provide guidance and recommendations for the implementation of best practices within the aviation, space, and defence industries.

The AS9100D standard and its Romanian version SR EN 9100:2018, titled *"Quality management systems. Requirements for aviation, space and defence organizations"* [8], fully incorporates the requirements of SR EN ISO 9001:2015 *"Quality management systems. Requirements"* [9] and adds aerospace-specific requirements, clearly distinguished in the text for differentiation from general requirement.

5. Relationship Between Total Quality Management, Lean Manufacturing, Six Sigma and SR EN 9100:2018 Standard

AS9100D nationally adopted as SR EN 9100:2018 is specifically designed for organizations engaged in the design, development, production or maintenance of products within the aerospace, space and defence sector.

The ensure the full integration of quality throughout the aerospace supply chain, complementary standards are also required:

- SR EN 9110:2018 „Quality Management System – Requirements for Aviation Maintenance Organizations" [10] and
- SR EN 9120:2018 „Quality Management Systems – Requirements for Aviation, Space and Defence Distributors". [11]

Although TQM is not explicitly mandated by SR EN 9100:2018 its application is not restricted. On the contrary, the standard includes clear requirements regarding continuous improvement within the QMS. In this context, TQM principles and methodologies can be strategically integrated to support organizational excellence and enhance global process performance.

The complementary use of Lean manufacturing and Six Sigma principles for process optimization typically results in, but is not limited to:

- Reduction or elimination of waste;
- Increased process capability;
- Ongoing process improvement.

AS 9100D / SR EN 9100:2018 is based on the PDCA cycle, providing a systematic and iterative framework for managing process performance. It aligns the organization's efforts with structured planning, implementation, monitoring and continuous adjustment of its QMS. The seven quality management principles – as illustrated in figure 2 – serve as the conceptual pillars supporting a robust and effective QMS.

Following a thorough analysis of bibliographic sources, along with the review of best practices set forth in established application guides such as SR EN ISO 9004:2015, SR EN ISO 27002, and others, several key directions for improving and optimising organisational processes have been identified. These improvements can be achieved through the strategic implementation of well-known methodologies such as Lean Manufacturing and Six Sigma, which focus on enhancing efficiency, reducing waste, and increasing overall process quality. The effectiveness of these approaches is clearly illustrated in Fig. 2, which summarises the findings and outcomes of the analytical studies conducted.

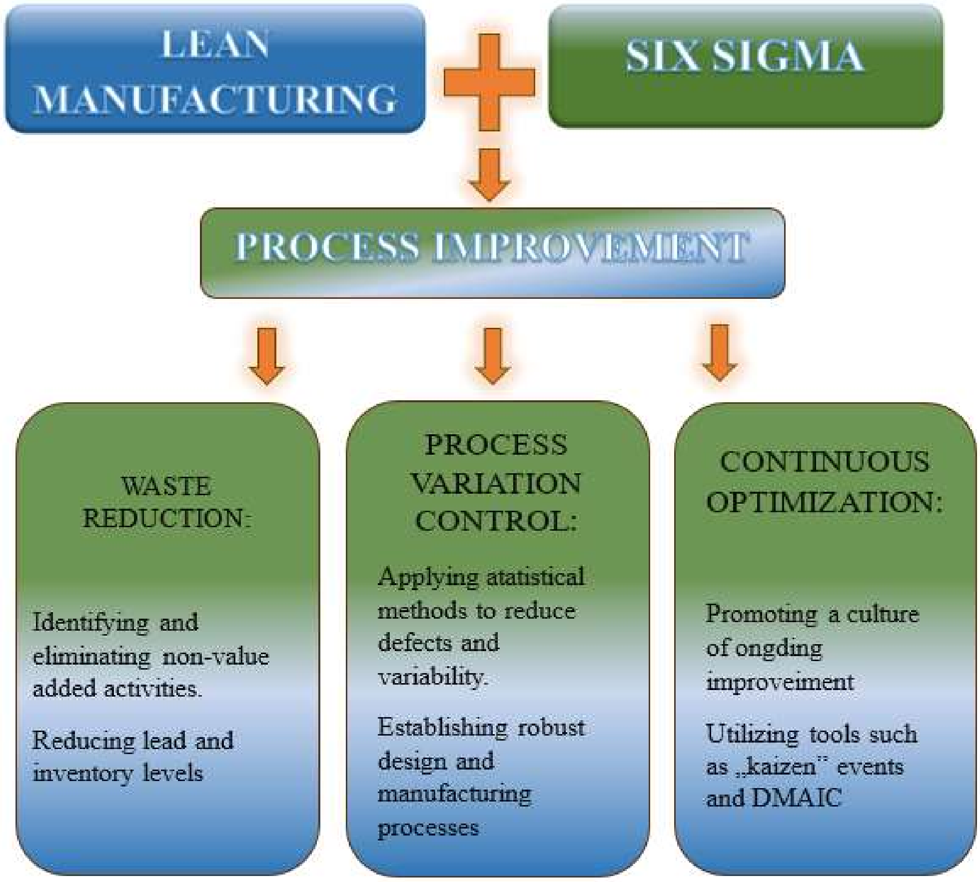

Fig. 2. The results of Lean manufacturing and Six Sigma implementation in industry.

Lean manufacturing is a systemic operational model focused of efficiency, based on the principle that any activity not adding value as perceived by the customer is considered waste (referred to in Japanese as *muda*) and should be eliminated or, at the very least, minimized. Within the specific terminology of the Lean philosophy, the term Kaizen is also frequently used, denoting the process of continuous improvement. According to this paradigm, value is defined as any activity or process for which the customer is willing to pay. By systematically eliminating non-value-adding activities, Lean manufacturing enables the preservation of added value while simultaneously reducing resource consumption and operational effort. [13]

Thus, as can be seen from Table 2, various standardisation and regulatory entities issue standards and regulations specifically intended for the aerospace sector, as outlined below:

Table 2) Quality Standards and Legislative Framework in the Modern Aerospace Sector

Category	Standard/ Regulation	Issuing Body	Application Domain	Purpose/ Main Benefits	Notes
General Quality Standard	ISO 9001:2015	ISO	All industries, including aerospace	Ensure process compliance with customer and legal requirements. Serves as the foundation for more industry-specific standards.	Baseline standard that is extended by aerospace specific standards such as AS9100.
Aerospace Specific Standard	AS9100D/ AS 9110D, AS 9120D, SR EN 9100:2018	IAQG/ ISO/ SAE	Design, development, manufacturing and maintenance of aerospace and defence products	Extends ISO 9001 by adding aerospace-specific requirements for traceability, safety, configuration control and risk management.	Requires certification; critical for aerospace supply chain participants.
Special Process Audit	NADCAP	PRI	Special processes: heat treatment, welding, coatings, NDT, etc.	Accredits special processes to ensure technical compliance in critical aerospace and defense operations.	NADCAP accreditation is often required in parallel with AS9100 certification.
Design Quality Planning	AS9145	IAQG	Quality planning in product design and development	Helps identify and mitigate risks in early design and preproduction phases. Promotes validated quality prior to production launch.	Adapted from automotive APQA standards for the aerospace industry.
Risk Managemen t	ISO 31000:2018	ISO	Enterprise risk management across sector	Provides principles and guidelines for risk management. Useful in aligning quality and safety goals within aerospace operations.	Supports implementation of AS9100 and related standards.
European Regulation	Regulation (EU) 2018/1139	European Commiss ion/	Civil aviation safety in the EU	Establishes rules for aircraft certification, operational	Legal foundation for EASA regulatory

Category	**Standard/ Regulation**	**Issuing Body**	**Application Domain**	**Purpose/ Main Benefits**	**Notes**
		EASA		requirements, pilot licensing, and safety infrastructure across EU member states.	framework in European aerospace.
Product Certification	CS-25, CS-27, CS-E, etc.	EASA	Type certification of aircraft and aerospace components	Provides detailed technical requirements for certifying the airworthiness of aircraft and systems.	Equivalent to FAA's FAR Part 25, 27, etc.
US Regulation	FAR/ CFR Title 14	FAA	Civil aviation operations in the United States	Includes comprehensive rules for aircraft design, manufacturing, maintenance and operation within U.S. airspace.	Aligned with EASA regulations through bilateral agreements (e.g.,BASA).
Information Security	AS9115/ ISO 27001	IAQG/ISO	Design and development of aerospace software systems	Ensures data protection, secure configuration management, traceability, and cybersecurity in critical systems.	Critical for companies involved in software development for flight and control systems.
Quality & Sustainability	ISO 14001:2015	ISO	Industries seeking sustainability integration	Provides a framework for managing environmental responsibilities. Applicable in aerospace for sustainable fuels, emissions reduction, and circular economy practices.	Complementary to quality standards, especially in the context of sustainable aviation initiatives.

Conclusions

The integration of new manufacturing technologies and principles requires the establishment of updated control criteria and the adoption of modern inspection and quality control frameworks. The internationally recognized AS9100 series, developed by IAQG, provides the standardized foundation to ensure interoperability, safety and efficiency within automated aerospace systems.

Quality and risk management represent fundamental components throughout the design, development, manufacturing and maintenance of aerospace systems. These elements significantly impact the overall performance and competitiveness of organizations in the aerospace sector.

The quality standards and regulatory frameworks governing the modern aerospace sector form a multi-layered, interdependent system that ensures safety, traceability, legal compliance and operational excellence.

Concurrent implementation of standards like AS9100, NADCAP and ISO 9001, alongside compliance with EASA and FAA regulations, is mandatory for global competitiveness in aerospace markets.

In the context of digital transformation (Industry 4.0 and Quality 4.0), these standards are increasingly integrated with advanced technologies (e.g., Digital Twins, AI, Blockchain), enabling greater efficiency, transparency and real-time compliance in global aerospace supply chains.

Notations and/or Abbreviations

AR – Augmented Reality, **EASA** – European Aviation Safety Agency, **FAA** – Federal Aviation Administration, **IAQG** – International Aerospace Quality Group, **IoT** – Industrial Internet of Things, **ISO** – International Organization for Standardization, **NADCAP** – National Aerospace and Defence Contractors Accreditation Program, **PDCA** – Plan-Do-Check-Act, PRI – Performance Review Institute, **TQM** – Total Quality Management, **QA** – Quality Assurance, **QMS** – Quality Management System

R E F E R E N C E S

[1] Morariu C. O., Quality management System, “Transilvania” University Publishing, Brasov, 2006;

[2] T. Olejniczak, „Japanese Management: 50 Years of Evolution of the Concept,” ResearchGate, 2013.

[3] A. M. Whitehill, Japanese Management. Tradition and Transition, Routledge Revivals, First published in 1991.

[4] SR EN ISO 9000:2015 Quality management Systems. Fundamental principles and vocabulary,” Romanian standardization Association (ASRO), 2015. [Interactive]. Available: https://www.asro.ro/familia-sr-en-iso-9000/.

[5] Ines Guyon, Rachid Amine, Simon Tamayo, Frederic Fontane "Analysis of the opportunities of industry 4.0 in the aeronautical sector", The 10th International Multi-Conference on Complexity, Informatics and Cybernetics: IMCIC 2019, March 12 - 15, 2019 ~ Orlando, Florida, USA

[6] Aleksandr Korchagin, Yury Deniskin, Irina Pocebneva, Olga Vasilyeva, "Lean Maintenance 4.0: implementation for aviation industry", Transportation Research Procedia 63 (2022) 1521–1533, Moscow Aviation Institute 2022

[7] International Aerospace Quality Group, accessed 2025, https://iaqg.org/sectors/

[8] "SR EN 9100: 2018 Quality management Systems. Requirements of organizations for aviation, space and defense," Romanian standardization Association (ASRO), 2018. [Interactive]. Available: https://magazin.asro.ro/ro/standard/267027.

[9] "SR EN ISO 9001: 2015 Quality management Systems. Requirements, " Romanian standardization Association (ASRO), 2015. [Interactive]. Available: https://magazin.asro.ro/ro/standard/237762.

[10] 9110 QMS – Requirements for Aviation Maintenance Organizations, https://iaqg.org/standard/9110-qms-requirements-for-aviation-maintenance-organizations/

[11] 9120 QMS – Requirements for Aviation, Space and Defense Distributors, 9120 Quality Management Systems – Requirements for Aviation, Space and Defense Distributors – IAQG

[12] Total Quality Management (TQM)," [Accessed12 05 2025], Available: https://www.techtarget.com/searchcio/definition/Total-Quality-Management

[13] Aicha Amrani and Yves Ducq, „Lean practices implementation in aerospace based on sector characteristics: methodology and case study", Production Planning & Control, The Management of Operations, https://doi.org/10.1080/09537287.2019.1706197

[14] "SR EN ISO 9001: 2015 Quality management Systems. Requirements, " Romanian standardization Association (ASRO), 2015. [Interactive]. Available: https://magazin.asro.ro/ro/standard/237762.

[15] "SR EN ISO 14001:2015 Environmental management systems - Requirements with guidance for use". Romanian standardization Association (ASRO), 2015. [Interactive]. Available: https://e-standard.eu/en/standard/238864

[16] "SR EN ISO/IEC 27001:2023 Information security, cybersecurity and privacy protection - Information security management systems - Requirements" Romanian standardization Association (ASRO), 2023. [Interactive]. Available: https://e-standard.eu/en/standard/281430

[17] "9115 Quality Management Systems – Requirements For Aviation, Space And Defense Organizations – Deliverable Software" International Aerospace Quality Group (IAQG) , 2015. [Interactive]. Available: https://iaqg.org/standard/9115-qms-requirements-for-aviation-space-and-defense-organizations-deliverable-software/

[18] "SR ISO 31000:2018 Risk management -- Guidelines" Romanian standardization Association (ASRO), 2028. [Interactive]. Available: https://e-standard.eu/en/standard/261581