

Contemporary challenges to quality management in the context of the competitiveness of industrial enterprises

Ivan Genov

Technical University of Sofia, Branch Plovdiv, Bulgaria

E-mail: i.genov@std.tu-plovdiv.bg

Abstract: Quality management is an often-overlooked business factor that represents a strategic pillar for industrial enterprises that aim to strengthen their competitiveness in the national and global markets. This paper examines the contemporary challenges faced by quality management systems in industrial settings, considering digital transformation and integration with Industry 4.0. Key impediments and opportunities are identified, and recommendations for enhancing quality practices are proposed.

KEYWORDS: QUALITY MANAGEMENT, COMPETITIVENESS, INDUSTRIAL ENTERPRISES, INDUSTRY 4.0, DIGITALIZATION, STRATEGIC DEVELOPMENT

1. Introduction

The rapid changes in the national and global markets, as well as the external and internal factors of the economy, form the features that ensure the competitiveness of enterprises [3].

The general definition for an industrial enterprise describes it as a large-scale business focused on manufacturing goods or providing industry-related services, characterized by machines and devices, technology, mass production and transition from manual labor to factory systems [13].

The key characteristics of industrial enterprises describe them as focused on the manufacturing aspect of the economy, typically large by scale, with significant influence on the country's gross domestic product (GDP). They operate by utilizing machines, designed mostly for mass production, and are organized by a traditional, top-down structure, defining clear levels of authority, ensuring a strict chain of decision making, communication and control [13]. These business entities are critically important for national and regional economic prosperity, involving operations like resource conversion (coal, gas, oil) or high-tech production and are refined by their production scale, impact and often a distinct structure with specialized labor. This also involves sophisticated management, supply chain optimization, global collaboration, as well as aim for a boost of competitiveness through strategic planning and investments [15].

Flexible quality management systems (QMS) allow companies to adapt quickly to changing market demands and technological shifts. The core principles of ISO 9001 (Fig. 1) and recent developments in QMS also play a role in the vitality of the industrial enterprises, but the general understanding for a company's quality is often limited to simple inspections and aim for reduction of the rejected pieces during the production cycle.



Figure 1. The 7 principles of ISO 9001 [2]

Apart from the cost reduction aspect, quality management drives competitiveness through customer satisfaction and loyalty, market differentiation, product superiority, efficiency and innovation.

Quality management tools (e.g. Root Cause Analysis) improve product and service performance, reliability and durability, creating a strong competitive edge [5,11].

Industrial enterprises operate in an increasingly competitive global environment where the ability to deliver superior quality products and services constitutes a fundamental determinant of performance and market position [15].

In modern contexts, digital transformation and Industry 4.0 affect competitiveness drivers such as productivity, product quality and innovation through coordination with the quality management within the organization [2,10,14].

2. Impact of quality management in economic processes

2.1. Quality management systems and international standards

QMS represents an organized set of policies, procedures and processes aimed at continuously improving the quality of products and services, satisfying customer requirements and stimulating the efficiency of organizational processes. The most widely applied international standard for QMS, in its current revision, is ISO 9001:2015. It is based on the *Plan-Do-Check-Act* (PDCA) cycle and defines the requirements for QMS and the principles that must be followed by any organization, regardless of its size or economic sector. This standard emphasizes customer focus, leadership, a process approach and continuous improvement (Fig. 2), which are key to sustainable development and economic competitiveness [2].

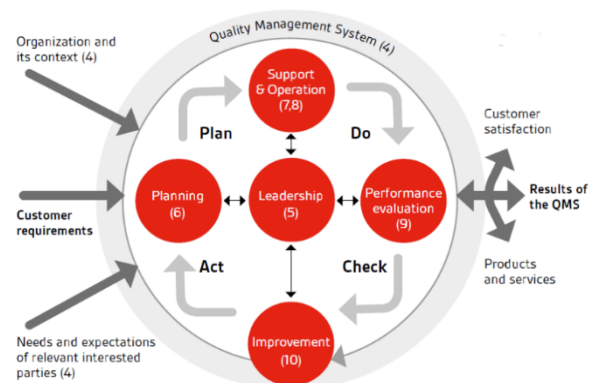


Figure 2. Structure of ISO 9001 and the PDCA (continuous improvement) approach [2]

2.2. Quality management in the context of digital transformation

With the development of new technologies and industrial automation, quality management cannot be considered only as a mechanical set of documented procedures and inspections. This allows quality to be integrated with modern digital practices and the Industry 4.0 paradigm. This leads to the concept of Quality 4.0, which is a digitalization of traditional QMS by implementing tools such as Internet of things (IoT) for real-time quality tracking, machine learning, big data analysis for predicting quality deviations, and automated process control mechanisms [15].

Digital QMS (Fig.3) allow for more precise measurements, better control of production processes and faster response to market changes [15].

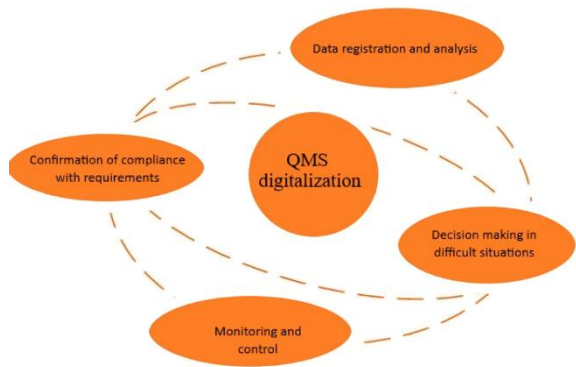


Figure 3. The Digital QMS [15]

The integration between QMS and Industry 4.0 supports the creation of adaptive and flexible processes, which are important for competitiveness in conditions of unstable markets and intense technological dynamics [1].

2.3. Organizational and strategic preconditions

For a QMS to be effective and contribute to competitiveness, it needs to be supported by an organizational strategy and involvement of the top management. Systematic and sustainable quality management results often depend on:

2.3.1. Commitment of the top management to set quality objectives that are in line with the strategic goals and interests of the enterprise. According to ISO 9001, leadership is a key factor in providing resources, communicating and taking strategic decisions, which in themselves contribute to competitive advantage [4,6].

2.3.2. Training and development of personnel, which ensures that employees understand their roles in the context of the QMS and can contribute to continuous improvement [2].

2.3.3. Internal organization and cultural development including the adoption of the principles of continuous improvement and customer focus [1].

2.4. Economic preconditions

2.4.1. European programs to support innovation, digitalization and quality

Bulgarian industrial enterprises operate within the framework of European Union policies that are related to continuous improvement, digitalization, implementation of modern technologies and improving the standards of products and services.

2.4.1.1. The "Competitiveness and Innovation in Enterprises" Program provides grants for the introduction of technologies in the field of Industry 4.0 and digitalization of enterprises, which also supports the modernization of quality processes and increased productivity. This support is part of the European Union's (EU) policy to accelerate the technological transformation of the industrial base and improve the competitiveness of companies from the Bulgarian manufacturing sector [8].

This operational program also supports the development of quality laboratory services and conformity assessment bodies, which are a key element of the quality management infrastructure, including certification, metrology and assessment services, which companies adapt to comply with increased market requirements [9].

These tools help companies not only to modernize their technologies, but also to develop quality systems that are more adaptable, traceable and compatible with European standards – a factor that strengthens their competitive presence in foreign markets.

2.4.2. Competitiveness and digital transition policies

The European Commission clearly places competitiveness, digitalization and innovation at the heart of its economic strategy for the 2024-2029 period that includes stimulating investment in AI and digital technologies and reducing the administrative burden for

small and medium enterprises (SMEs) for access to growth measures within the operational program [8].

2.4.3. Institutional factors for quality

2.4.3.1. Regulations and standards:

External regulatory requirements, including European directives and standards (such as ISO, CE marking and other harmonised rules) set specific quality management requirements that companies must meet in order to participate freely in the single market. This creates an institutional framework that incentivises businesses to invest in QMS and certification [9].

2.4.3.2. Innovation funding:

Competitiveness programmes provide funds for the deployment of technologies, digital systems and tools that help automate and track quality through Industry 4.0 approaches [9].

2.4.3.3. Market competitiveness:

Support for exports, marketing campaigns and participation in international exhibitions increases the quality of products. Companies meet higher market standards and expand their competitive advantages on foreign markets [14].

2.4.4. Influence over Bulgarian industrial enterprises

Bulgarian enterprises, especially SMEs, operate in an economic environment where the implementation of Industry 4.0 technologies and digital solutions is considered part of the strategy for increasing quality and competitiveness, including through access to European funding programs (e.g. procedures under the CPIP 2021–2027). This supports their technological improvement and adaptation to the requirements of international markets.

3. Opportunities for strategic implementation of QMS

3.1. Adoption of QMS in SMEs

A fundamental step for Bulgarian industrial enterprises seeking enhanced competitiveness is the adoption of formal QMS, mostly based on ISO 9001. It is perceived not only as a compliance tool, but also as a strategic mechanism for improving competitiveness, especially when applied in an integrated manner with the management objectives of the enterprise [16].

In the context of Bulgarian economics, an empirical study among manufacturers in the manufacturing sector shows that managers evaluate QMS as a factor for competitiveness by reducing defects, optimizing costs and increasing market presence, including in foreign markets. As part of the strategic implementation, enterprises should involve leadership and top management in setting strategic quality objectives, integrate different functions (production, quality control, logistics) under a common monitoring and accountability system and use QMS data to support strategic management decisions [17].

3.2. Integration with Industry 4.0 – Approaches to Quality 4.0

In today's industrial environment, traditional quality management is evolving towards Quality 4.0 — an approach that combines the principles of classic QMS with digital technologies and real-time data. Quality 4.0 is not just the digitalization of procedures, but a conceptual framework that unites people, processes and technologies to achieve higher value, transparent analysis and sustainable improvement. Table 1 represents key research deficiencies and future directions for advancing the Quality 4.0 approach, with focus on integrating Industry 4.0 technologies [12].

Table 1. Key Research deficiencies and Future research directions for Quality 4.0 [12].

№	Research Area	Gaps	Future Research Directions
1	Human factors and workforce	Insufficient focus on workforce skills and engagement	Investigate strategies for employee training, engagement and role transformation
2	Lean Practices Integration	Lack of focus on managing change during adoption.	Explore methods to overcome resistance and facilitate organizational

			transformation.
3	Change Management	Lack of focus on managing change during adoption.	Explore methods to overcome resistance and facilitate organizational transformation.
4	Real-Time Decision-Making & Automation	Insufficient exploration of real-time decision-making.	Research AI, IoT, and real-time analytics for enhanced process optimization.
5	Standardization	Absence of standardized frameworks for Quality 4.0 adoption.	Create universal frameworks for consistent Quality 4.0 implementation.
6	Cross-Industry Applications	Limited cross-industry research.	Conduct cross-sector studies to understand best practices for Quality 4.0 adoption.
7	AI, IoT, Big Data Integration	Underexplored integration of digital technologies.	Investigate AI, IoT, and Big Data for quality control and operational efficiency.
8	Sustainability	Limited research on sustainability in Quality 4.0.	Explore the role of Quality 4.0 in promoting sustainability in business practices.
9	Supply Chain Integration	Lack of focus on Quality 4.0's role in supply chain management.	Research the impact of Quality 4.0 on supply chain optimization and resilience.
10	Predictive Analytics	Limited use of predictive analytics in quality improvement.	Develop predictive models to prevent quality issues and improve processes.
11	Cybersecurity	Unexplored cybersecurity risks in Quality 4.0.	Research strategies for securing Quality 4.0 systems and data from cyber threats.
12	Customer-Centricity	Insufficient focus on customer-oriented strategies.	Explore how Quality 4.0 technologies can enhance customer satisfaction and engagement.
13	Data Interoperability	Challenges in seamless data interoperability.	Investigate solutions for improved data sharing and system integration.
14	Performance Metrics	Lack of comprehensive performance metrics for Quality 4.0.	Develop new metrics to assess the impact of Quality 4.0

Quality 4.0 includes [5]:

- Using IoT, sensors and automated measurements to monitor quality in real time;
- Applying big data and analytical platforms for predictive control and optimization of production processes;
- Building a digital culture and training that allow employees to work effectively with new tools and data;

Research shows that Quality 4.0 can significantly speed up deviation response processes, reduce delays and improve the quality

of products and services, which brings competitive advantages to companies that adopt it adequately [12].

3.3. Organizational and Human Factors in Quality Transformation

The implementation and successful operation of QMS and Quality 4.0 require not only technologies, but also organizational culture, competencies and leadership commitment.

Key social and management factors include:

3.3.1. Leadership and strategic vision

Effective leadership is key to creating an environment that supports innovation, quality and flexibility. The level of commitment from top management determines the adoption, resources and integration of QMS into the strategic goals of the company [15].

3.3.2. Training and competencies

The transition to digital and integrated quality practices requires specific skills - from data and analytics to process management - that are not always available in the traditional workforce. This creates a need for continuous training and development of human capital [16].

3.3.3. Culture of continuous improvement and collaboration

Organizations that manage to achieve successful transformation build a culture of transparency, cross-departmental collaboration and knowledge sharing. This is particularly important for the application of interdisciplinary digital tools and analyses in quality.

3.4. Overcoming Barriers and Enhancing Competitiveness

For Bulgarian enterprises, barriers to integrating modern quality management approaches often include a lack of digital readiness, financial constraints and insufficient strategic planning. Studies show that among industrial companies in Bulgaria, initiatives to implement Industry 4.0 technologies to improve quality and competitiveness are being adopted by an increasing number of organizations, but there is a significant lag compared to the EU average, which requires targeted investment and training efforts [7].

To overcome the obstacles, enterprises can:

- Develop a strategic digital transformation plan integrating elements of Quality 4.0;
- Build an information infrastructure to support data exchange and analysis;
- Stimulate internal leadership and training to increase digital and quality competence.

4. Results and discussion

The literature indicates that a well-functioning QMS correlates positively with competitive outcomes such as customer satisfaction, process efficiency and market performance. ISO 9001 certification has been shown to drive enhanced competitiveness and improved company image, which are particularly important for Bulgarian firms operating in transitional economies.

However, certain challenges persist. Many enterprises still treat QMS primarily as a certification exercise rather than a strategic initiative, which limits the system's potential impact on competitiveness. Additionally, digitalization adoption rates vary across sectors, with barriers including financial constraints, technological readiness, and workforce skills gaps [17].

The integration of quality management with digital strategies is gaining attention in academic and industrial circles as a path toward sustainable competitiveness, requiring new competencies and organizational flexibility [18].

5. Conclusion

Quality management is an essential driver of competitiveness for Bulgarian industrial enterprises. Effective implementation of QMS according to international standards such as ISO 9001 - coupled with a strategic orientation toward continuous improvement and integration with digital transformation - enhances operational performance, product quality and market responsiveness. Embracing quality management as a core strategic objective, rather

than a mere compliance requirement, supports long-term competitiveness and organizational resilience.

Future research should further investigate the impact of emerging quality paradigms on competitive outcomes, and empirical studies should explore sector-specific dynamics in Bulgarian industry to enable tailored strategies.

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