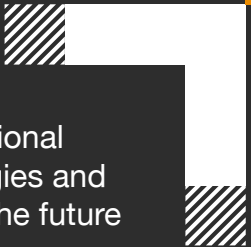![pwc]

The future of quality in manufacturing

In today's rapidly changing landscape, the quest for quality has gone beyond traditional bounds, evolving into a multifaceted concept that incorporates emerging technologies and shifting consumer expectations. As we approach a new era known as Quality 5.0, the future of excellence looks more dynamic and interconnected than ever before.

In the twenty-first century, Quality 4.0 has integrated Industry 4.0 technologies such as the internet of things (IoT) and artificial intelligence (AI) to optimise processes and ensure customer centricity. As quality continues to evolve, businesses have begun to reconsider whether their current quality systems will suffice. In addition to the existing Quality 4.0 systems, businesses may require a more comprehensive approach to meet the needs of various stakeholders such as customers, suppliers, employees, investors, and the community at large.

This article discusses the evolution of quality, the growing importance of Quality 5.0 and its implications for modern business practices. It looks into the skills needed by professionals to effectively navigate this transformation. It also outlines the key elements defining Quality 5.0 and provides insights into how these elements will influence organisational success. Finally, the article discusses the challenges associated with its implementation and makes recommendations to mitigate them.

Evolution of quality

To understand the implications of Quality 5.0, we must first examine how the concept of quality has changed over time. From the early days of industrial standards to today's sophisticated, technology-driven approaches, each phase has been built on the previous one, setting the stage for the innovations and strategies that define Quality 5.0.

Figure 1: Evolution of quality
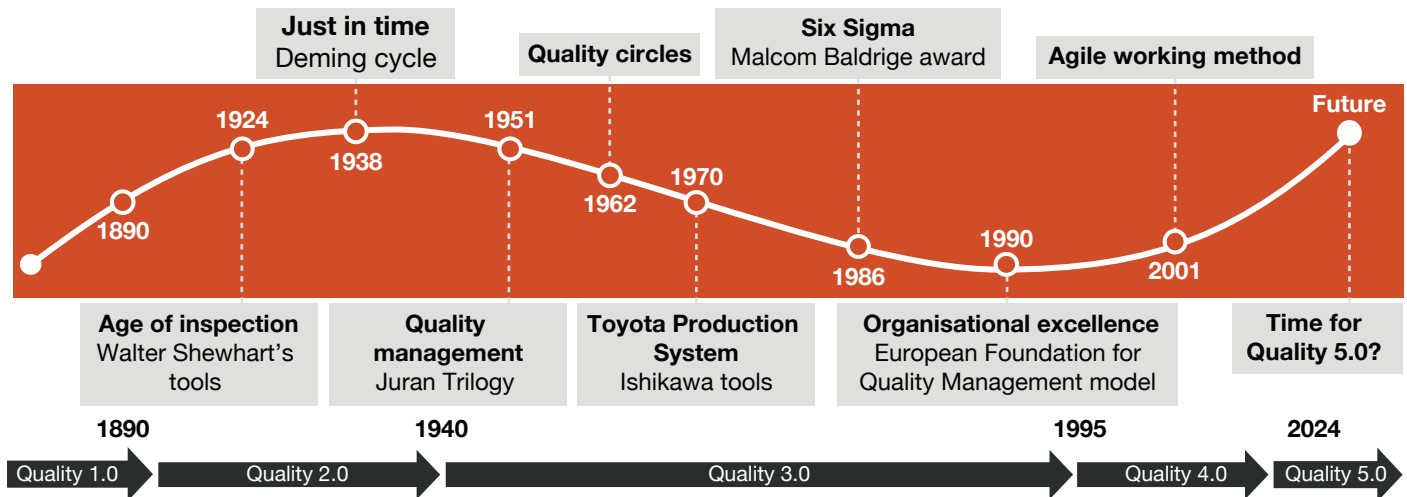
Source: PwC analysis

In Quality 1.0 (prior to 1890), quality was ensured through inspection. However, it focused primarily on achieving better productivity while neglecting cost reduction, waste elimination and worker safety.

Quality 2.0 (1891–1940) witnessed the implementation of quality management systems and statistical quality control methods. However, the emphasis was primarily on internal indicators such as rework and scrap, rather than on customer satisfaction.

The Third Industrial Revolution (Industry 3.0) introduced digital computers and automation, paving the way for Quality 3.0 (1941–1995), which began to use data to analyse costs and customer complaints and to incorporate consumer feedback into product development. The Juran Trilogy, quality circles, total quality management and Six Sigma are examples of key developments from this period.

Quality 4.0 saw a shift towards a more dynamic, real-time, data-driven and technology-enabled approach that incorporated digital technologies such as IoT, advanced analytics and automation into manufacturing processes with the goal of improving product quality, reducing defects, increasing efficiency and ensuring compliance with standards.[1]

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1. American Society of Quality. [Online] https://asq.org/quality-resources/history-of-quality?srsltid=AfmBOooIaI_y8RVjhUL6Jqeu2oZXLSpRTXO-crK6Ig3RN3u3bYJuS4PQA

Quality 5.0

Quality 5.0 is a transformative approach that combines technological innovation and human insight to improve the overall standards of products and processes. It focuses on improving system adaptability to changing demands and market conditions by combining technology with human creativity and intelligence. It goes beyond traditional efficiency metrics to focus on employee satisfaction, creativity and workplace humanisation. It also emphasises sustainable practices and social responsibility, with the goal of improving quality of life for both employees and consumers while promoting a more sustainable and socially responsible future.

Adopting Quality 5.0 improves companies' adaptability to changing market conditions and production demands. It increases employee satisfaction by creating a more engaging and human-centred working environment. Quality 5.0 ensures long-term viability and positions businesses for continued success in an increasingly dynamic marketplace by improving product quality and aligning with contemporary customer values and regulations.

Shifting skill sets and focus areas

Quality is evolving into a multifaceted discipline that encompasses many aspects of business. As these elements advance, the skill sets required of quality professionals shift. Professionals must focus on several key areas, including understanding business goals, improving collaboration and soft skills, and cultivating a continuous learning mindset.

Proficiency in emerging quality technologies, advanced data analytics and cybersecurity is becoming more valuable. On the other hand, dedicating a substantial amount of time to data management, data cleaning and filing regulatory compliances are becoming less important.

These changes will undoubtedly have an impact on employee engagement, and it is the duty of management to map the skills required for the future of quality and assist employees in upskilling themselves.
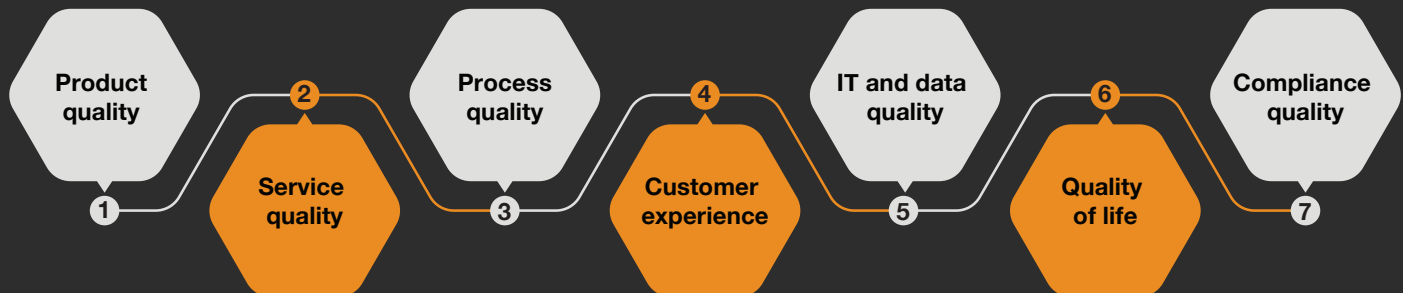
Figure 2: Skills required by the quality function

Skill required by quality function	Then	Now	Future
Understanding business goals	◔	◑	●
Dedicating time to data handling and cleaning	◕	◑	◔
Collaboration and boosting soft skills	◔	◑	◕
Advanced data analytics	○	◔	◕
Cross-departmental expertise	○	◔	◑
Emerging quality technology proficiency	○	◑	◕
Problem identification	◕	◑	◔
Continuous learning mindset	◔	◑	●
Knowledge of compliance environment	◑	◑	●
Filing regulatory compliances	●	◕	◔
Cybersecurity	○	○	◑

Source: PwC analysis

Seven key elements shaping Quality 5.0

In order to remain competitive and satisfy changing expectations, companies must adopt a multidimensional approach to quality. To help companies with this process, we've identified seven important aspects that will shape Quality 5.0. Improving these areas will better prepare organisations for upcoming challenges:

| Product quality (1) | Service quality (2) | Process quality (3) | Customer experience (4) | IT and data quality (5) | Quality of life (6) | Compliance quality (7) |

1. Product quality

Ensuring good product quality is critical for customer satisfaction, brand reputation and operational success. A complete approach to product quality entails incorporating key interventions throughout a product's lifecycle, from design to manufacturing to final inspection. Three key strategies in this aspect are design for quality (DfQ), real-time quality monitoring and predictive quality analytics.

DfQ: It prioritises quality considerations throughout the product design phase, emphasising issues such as reliability, manufacturability, ease of inspection, usage and maintenance. In the context of Quality 5.0, DfQ also embeds sustainability considerations and resource efficiency. This involves choosing materials with a lower environmental impact, using more efficient production methods, and planning for minimal energy consumption and waste generation throughout the product's lifecycle. This proactive strategy improves overall product quality, lowers manufacturing costs, increases customer happiness and promotes environmental friendliness.

Real-time quality monitoring: Embedded sensors and data analytics allow for continuous monitoring of performance measures, helping early detection of quality concerns and permitting timely interventions.

Predictive quality analytics: It involves predicting and preventing quality concerns by analysing historical data and monitoring real-time performance. With the help of machine learning, this approach identifies patterns and abnormalities early on, allowing for proactive modifications to minimise faults and optimise production, ultimately lowering costs and improving product quality.

2. Service quality

Service quality is defined as the capacity to meet or exceed client expectations by providing efficient and effective service. Today, this extends into elements such as personalised emotional engagement which foster a strong customer connection and satisfaction, as well as AI integration, which uses technologies such as robotic process automation (RPA), virtual assistants and chatbots to provide quick and accurate responses to customer requests. As a result, any approach to service quality must take into consideration these factors so as to provide a service experience that consistently satisfies client requests and increases overall satisfaction.

3. Process quality

Process quality now covers not just product performance, but also the environmental and social effect of the production or service delivery processes. With growing customer demand for sustainability and more environmental restrictions, firms are turning to environmental, social and governance (ESG) principles to decrease waste and carbon footprints in their processes.

By incorporating these concepts into their operational plans and decision-making processes, businesses can attempt to match their processes with sustainability goals while retaining high quality and efficiency.

4. Customer experience

The idea of customer experience has shifted from simply the purchasing experience to focusing on the overall user experience across the customer lifecycle. This starts from the point when the potential customer first learns about the product or service, evaluates the offerings, decides to make the purchase, and ends with keeping the customer satisfied and engaged post purchase. In this regard, immersive experiences such as virtual, augmented and mixed reality environments that provide spatial presence and sensory feedback are becoming increasingly important.

Furthermore, data privacy and responsible use of personal information are also increasingly important aspects in creating a high quality of experience (QoE).

5. IT and data quality

This entails utilising innovative technologies and processes to ensure the correctness, reliability and integrity of data across systems. This technique consists of several critical components:

Big data and cloud systems provide scalability and flexibility, making them suitable for managing, storing and processing large amounts of data. Cloud solutions allow for complete data quality checks across different and massive datasets that are not limited by physical infrastructure such as capacity of storage servers. These solutions also ensure access is restricted to authorised users and that the same data is consistently visible to all of them.

Automated data quality assurance uses machine vision and other AI-powered inspection tools and testing equipment to improve quality control operations. These tools allow for precise and efficient data gathering and validation, which reduces the chances of recording incorrect data and thus improves overall quality.
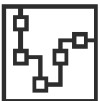
Blockchain can be used by organisations to dramatically improve their quality assurance methods due to its transparency, immutability and decentralisation. A blockchain creates a clear, visible record of every stage in the manufacturing or service delivery process, fostering responsibility and trust among stakeholders. Its immutability ensures that all data linked to quality checks and compliance is kept intact and tamper proof, resulting in a credible audit log. Furthermore, the decentralised structure of blockchain decreases the danger of single points of failure while increasing security by dispersing data across a network of nodes. These characteristics allow organisations to more efficiently evaluate and validate quality assurance processes, track and trace items across the supply chain, and maintain correct compliance records, thus increasing overall quality control.

6. Quality of life

To remain competitive, businesses must take a holistic approach that connects system and process changes with the goal of improving quality of life not only for their employees, but also for their customers and the community in general. This includes investing in employee well-being to increase job satisfaction and overall happiness, as well as ensuring that their products and services meet functional requirements as well as provide increased comfort, simplicity of use and hassle-free ownership. As customers begin to appreciate these additional benefits, organisations must adjust their strategy to this new dimension to create a more positive environment, increase customer loyalty and have a significant impact on the community.

7. Compliance quality

Compliance quality has shifted from a focus on simply meeting regulatory requirements to incorporating regulatory technology (RegTech) solutions. Emerging technologies and a commitment to sustainable practices have driven this shift by making possible advanced automation, real-time monitoring and risk management. RegTech tools help monitor regulatory changes, ensuring compliance with evolving standards by automating compliance procedures and reducing human error.
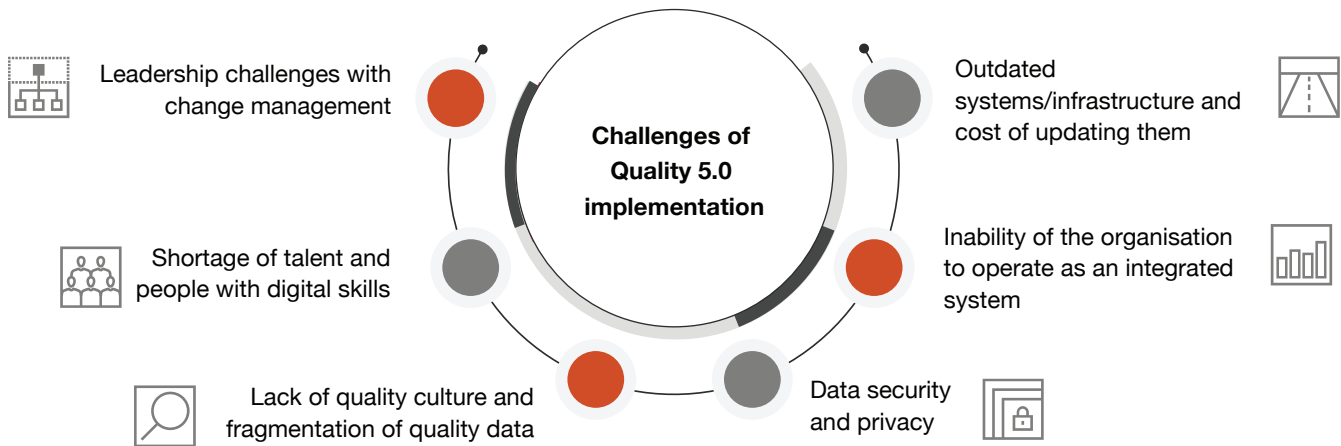
As a result, organisations can not only streamline their compliance activities, but also improve their overall efficiency, agility and resilience in an increasingly complex regulatory landscape, thus paving the path for long-term success.

Challenges in implementation

Adopting Quality 5.0, which integrates advanced technologies while focusing on a human-centric approach to quality management, poses several challenges.
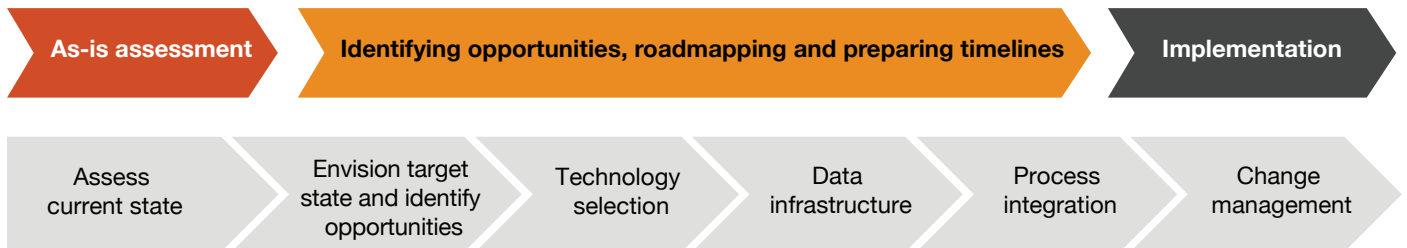
Figure 3: Challenges in implementing Quality 5.0

Leadership challenges with change management

Outdated systems/infrastructure and cost of updating them

Shortage of talent and people with digital skills

Inability of the organisation to operate as an integrated system

Lack of quality culture and fragmentation of quality data

Data security and privacy

Challenges of Quality 5.0 implementation

To address these challenges, organisations can:

- create a clear strategy roadmap, including implementation phases and regular reviews to manage the transition

- use change management principles to support the organisation and its people through the transition

- develop user-friendly solutions that fit with current skill levels and invest in training to effectively utilise data to generate better insights

- build a strong quality culture with buy-in from all levels of the organisation and address quality concerns by developing data enablers for successful compilation and analysis

- conduct frequent security assessments and apply data protection procedures to identify and address system vulnerabilities and operational hazards

- encourage collaboration among stakeholders across the value chain through open communication, knowledge exchange and collective problem solving to overcome interoperability concerns

- begin by identifying and testing small, cost-effective use cases, then scale up with more customised solutions as needed.

Recommendation: Follow a bottom-up approach to ensure successful adoption and employee buy-in.

PwC India assists clients in adopting innovative methods to implement Quality 5.0. This approach begins with assessing the current state, envisioning the desired future state, identifying opportunities, selecting appropriate technologies, establishing data infrastructure, integrating processes, and finally managing the change effectively.

Figure 4: PwC's approach for successful implementation

As-is assessment	Identifying opportunities, roadmapping and preparing timelines	Implementation
Assess current state	Envision target state and identify opportunities	Technology selection	Data infrastructure	Process integration	Change management

- As-is assessment: This involves evaluating existing quality management systems through stakeholder interviews, site visits (sampling and testing processes, integration with enterprise resource planning [ERP] system) and data analysis, thus setting the baseline for future comparison.

- Envisioning target state: During this phase, the emphasis shifts to imagining the future state of the quality management system. This includes establishing target states in Quality 5.0, ranging from foundational to advanced and best-in-class. Initiatives are then developed to bridge the gap between the existing situation and the intended future state.

- Technology selection: Here, we discuss how various Industry 4.0 technologies, such as IoT, AI and cloud computing, can be improved by including human, environmental and societal factors, and assist in selecting the best options.

- Data infrastructure: During this phase, we work towards ensuring a robust data infrastructure is in place to collect, store and analyse quality-related data.

- Process integration: To ensure seamless data flow and operational efficiency, quality processes must be integrated with other operational systems. This involves aligning quality management systems with ERP, customer relationship management (CRM), and other supply chain management systems, enabling data to move seamlessly across different functions. Such integration facilitates real-time updates, reduces manual data entry and enhances overall process efficiency.

- Change management: Successful implementation of new quality management principles necessitates effective change management. This includes designing communication strategies for employees, providing training and support to help them adjust to new systems and processes, and garnering employee buy-in through participation and feedback. Change management ensures that the transition to the new quality management system is smooth and that staff are engaged and motivated to accept the improvements.

PwC, with its proprietary quality management framework, is uniquely positioned to combine traditional quality management methods with Industry 5.0 tools to enhance operational efficiency, drive innovation, and achieve sustainable and superior quality outcomes, thereby enabling businesses to gain a competitive edge in today's evolving market.

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