Quality 5.0: A Paradigm Shift Towards Proactive Quality Control in Industry 5.0

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Received: May 28, 2023 Accepted: June 20, 2023 Online Published: June 28, 2023

doi:10.5430/ijba.v14n2p51 URL: https://doi.org/10.5430/ijba.v14n2p51

Abstract

Industry 5.0, the latest wave of industrial revolution, is redefining the traditional manufacturing and production landscapes by leveraging advanced technologies, promoting sustainability, and fostering a human-centric approach. An inevitable consequence of this progression is Quality 5.0, the next phase of quality control and assurance. Quality 5.0 aims to transcend the limitations of conventional quality control techniques, which are typically reactive, by adopting a proactive stance towards defect prevention and process optimization. This paper elucidates the concepts of Quality 5.0, discussing its principles, benefits, and potential challenges in the context of Industry 5.0.

Keywords: Quality 5.0, Industry 5.0, proactive quality control, manufacturing, industrial production

1. Introduction

The manufacturing industry is in the midst of a technological transformation, known as Industry 5.0. This revolution emphasizes the collaboration between humans and advanced technologies, such as artificial intelligence, machine learning, and the Internet of Things, to achieve sustainable and high-quality production. As a natural extension of this, Quality 5.0 integrates quality control into the entire production process, focusing on proactive measures to prevent defects and inefficiencies.

The main objective adopted by the authors of this article is a synthetic presentation of the Quality 5.0 concept as an effect of economic and social changes in the world, against the background of the evolution of the approach to the quality category over the last 130 years.

Quality 5.0, as its name suggests, is the fifth evolution of quality management principles, reflecting the transformative impact of emerging technologies and holistic quality concepts on industrial processes. This paradigm shift emphasizes not just product or service quality in isolation, but a holistic view encompassing sustainability, customer satisfaction, employee engagement, and social responsibility.

One of the key features of Quality 5.0 is the use of advanced technologies, such as artificial intelligence, machine learning, and the Internet of Things (IoT), to gather and analyze data in real-time. By monitoring and analyzing data from various sources, including sensors, cameras, and other connected devices, Quality 5.0 can identify potential defects or quality issues before they occur, allowing manufacturers to take corrective action proactively. Another important aspect of Quality 5.0 is the emphasis on collaboration and communication between humans and machines. This involves empowering workers with the knowledge and tools they need to identify and address quality issues, as well as using automation and robotics to streamline and optimize production processes. This paper is based upon a course development “Quality Improvement” which is an EEA funded collaboration project Edu4QI between Poland and Norway.

Overall, Quality 5.0 represents a significant shift in how quality is managed and achieved in manufacturing and industrial production. It integrates advanced technologies with human-centered approaches to create a more proactive, collaborative, and efficient quality control system that benefits both manufacturers and customers.

However, as with any paradigm shift, Quality 5.0 also presents its own set of challenges, such as data privacy, skill requirements, and technology dependency. Addressing these will be key to its successful implementation. Moreover, further research is needed to clarify its implications for leadership, existing quality methodologies, standards, and

quality assurance mechanisms.

Ultimately, as we stand on the precipice of this new era, the key question is not if, but how Quality 5.0 will redefine our understanding of quality – potentially co-creating a new paradigm for quality of life. As we delve deeper into this exciting new frontier, the promise of a more sustainable, inclusive, and efficient industrial landscape lies tantalizingly within our grasp. (Chehri et al 2023)

2. Evolution of Quality

The understanding of Quality and how to improve quality have developed much during the last century. Many companies in Europe and US developed a special quality department early, and it was in most cases located as the last activity before shipping. It contained specialists and developed many good procedures for inspection. The downside was that finding fault in the last minute generated a lot of rework and extra cost. This developed from quality control focus into quality assurance focus during the sixties and seventies. Japan after WW2 could not afford this and generated the opposite approach. All operators should be responsible to check the parts they receive and output of their own work. Then problems could be detected and corrected as soon as possible. (Hauser 2014) This developed into the Total Quality Management, TQM, approach. (Talha 2004) During the last 20 years there have been an increasing focus on use of new technologies into the Quality work. This makes use of the Industry 4.0 technologies and methods into Quality improvement. We call this use of sensors, communication, Big Data, Machine Learning, etc, for Quality 4.0. Quality 4.0 enables automated detection and analysis of Quality and can provide priorities for improvement in processes and products. (Mehran 2013)

Quality 1, as it was referenced before 1890, is a concept that primarily revolved around the inherent characteristics or attributes of a particular item, product, or service.

- The concept of Quality 1 was predominantly focused on craftsmanship, raw material, and functionality.
- In this context, a high-quality item was usually one that was skillfully made using high-grade materials, and that performed its function well and reliably.
- Distinctive features, unique design, and durability were also common components of the perceived quality.
- Notably, this early understanding of quality was less standardized and more subjective, varying considerably depending on the specific cultural, geographical, or individual perceptions.

Quality 2, used in the period between 1890 and 1940, was significantly influenced by the Industrial Revolution and the advent of mass production.

- During this time, the concept of quality began to shift from purely craftsmanship and individuality of a product to include consistency and uniformity in mass-produced goods.
- Quality control processes were introduced in factories, focusing on detecting and eliminating defects. Thus, a quality product during this era was one that met a certain standard, had fewer defects, and was reliably replicated on a large scale.
- This period marked the beginning of a more systematized and standardized approach to quality, paving the way for more sophisticated quality management systems in the decades to come.

Quality 3, encompassing the period from 1940 to 1995, saw a significant evolution in the concept of quality due to advancements in technology, increased global competition, and the influence of quality gurus like W. Edwards Deming and Joseph Juran.

- During this period, quality became an all-encompassing organizational philosophy, moving beyond mere defect detection to proactive quality assurance and continuous process improvement, often encapsulated in methodologies like Total Quality Management (TQM). (Talha 2004)
- Emphasis was placed on preventing defects at the source, incorporating customer feedback into product development, and embedding quality in every step of the production process.
- The customer's perception of quality also grew in importance, with a focus on meeting and exceeding customer expectations. Quality during this time was associated with reliability, durability, functionality, and value for money.

Quality 4, from 1995 to 2020, is characterized by a shift towards total customer satisfaction and experience, innovation, and sustainability. (Koc 2007)

- Quality, in this context, is not just about a product or service meeting its intended function, but also about

exceeding customer expectations in every possible way. This includes the overall user experience, convenience, after-sales service, and even the impact on the environment. (Chiarini A. and Kumar M. 2022)

- High-quality products or services are those that not only provide superior performance and durability but also create a positive customer experience and adhere to ethical and sustainable practices. With the proliferation of the internet and e-commerce, transparency and access to information have become integral to perceptions of quality.
- Customer reviews and ratings often drive perceptions of quality, and companies are increasingly reliant on data analysis and feedback to monitor and improve quality.
- Quality 4 also sees the rise of quality standards like ISO 9001, as well as practices such as Six Sigma and Lean Manufacturing, which aim at reducing waste and improving efficiency. (Koc 2007)

Quality 5, starting from 2020 and projected into the future, reflects a new era marked by digital transformation, increasing automation, and a growing awareness of environmental and societal impacts. (Arsovski, 2019). This is based upon Industry 5.0 (Nahavandi 2019)

- The concept of quality is becoming more intertwined with innovation, technology, and sustainable practices.
- In this context, high-quality products and services are expected to provide exceptional user experiences, enhanced by digital interfaces and artificial intelligence, while also being sustainable and contributing positively to society.
- Companies are using advanced technologies like AI and data analytics to predict customer needs and personalize experiences, thereby enhancing quality.
- At the same time, quality is also being redefined by the principles of the circular economy, with a focus on reducing waste, recycling, and creating products that have minimal impact on the environment.
- Thus, in the era of Quality 5, quality transcends traditional boundaries to incorporate a holistic approach that considers customer satisfaction, innovation, societal impact, and sustainability.

3. Quality 5.0: From Reactive to Proactive

Quality 5.0 represents a shift from the traditional reactive model of quality control, which focuses on identifying and addressing defects post-production, to a proactive approach (Arsovski, 2019). This shift includes continuous monitoring, predictive analytics, and real-time adjustments to prevent defects before they occur. (Mills 2020) Quality 5.0 leverages advanced technologies to embed quality control into every step of the manufacturing process, from design to delivery, enhancing product reliability and customer satisfaction (Campagne 1995).

4. Principles of Quality 5.0

The central principles of Quality 5.0 include real-time monitoring, predictive analytics, AI-driven process optimization, and human-machine collaboration (Arsovski, 2019). These principles are designed to enable a thorough understanding of production processes, anticipate potential issues, optimize operations, and facilitate collaborative decision-making to maximize product quality and operational efficiency.

It is the integration of digital technology and the traditional quality methods to ensure product reliability and enhance customer satisfaction.

Components of Quality 5.0:

1. **Design**: With the aid of advanced design software, manufacturers can create virtual prototypes of their products, conduct stress tests, and identify potential flaws before a physical prototype is even built. This allows for more accurate and efficient quality control during the design phase.
2. **Production**: Advanced technologies such as Internet of Things (IoT) devices, automation, robotics, and AI can be used to constantly monitor the production process, identifying and correcting errors in real-time. This helps to minimize waste, reduce downtime, and ensure that the final product meets the highest quality standards.
3. **Inspection**: AI-powered computer vision systems can be used for automated inspection, identifying defects with greater accuracy than human inspectors. Machine learning algorithms can learn from each inspection, continually improving the accuracy and reliability of quality control.
4. **Data Analysis**: Advanced data analytics and machine learning can be used to analyze vast amounts of data generated throughout the manufacturing process. This can identify patterns and trends that might indicate underlying quality issues, allowing for proactive quality control.

5. **Delivery**: IoT-enabled supply chains allow for real-time tracking and monitoring of products throughout the delivery process, ensuring they reach the customer in perfect condition.
6. **Feedback**: Feedback systems using AI can process customer feedback more efficiently and effectively, identifying trends, and implementing improvements based on this feedback, further enhancing product quality and customer satisfaction.

In essence, Quality 5.0 represents a comprehensive, end-to-end approach to quality control that leverages the latest technologies to ensure the highest standards of quality, reliability, and customer satisfaction. It's a proactive rather than a reactive approach, which is a shift from traditional quality management methodologies. (Mills 2020)

5. The Potential of Quality 5.0

Quality 5.0, when integrated into the Industry 5.0 framework, offers a multitude of benefits. It enables faster detection and resolution of quality issues, minimizes waste, improves operational efficiency, and promotes a culture of continuous improvement. In addition, it enhances transparency in the production process, which boosts customer trust and loyalty.

Quality 5.0 refers to the next evolution in quality management systems. While traditional quality management focuses on improving products or services to meet customer expectations and regulatory requirements, Quality 5.0 brings a wider lens to these concepts. It introduces a focus on aspects like sustainability, environmental impact, employee engagement, and corporate social responsibility. (Sannö 2016)

Here's how profit, the environment, and employees might benefit from Quality 5.0:

1. Profit:
    - Enhanced Customer Satisfaction: Better quality management results in superior products or services, leading to increased customer satisfaction. Happy customers can lead to repeat business, positive word-of-mouth, and new customer acquisition, thus increasing profits.
    - Improved Operational Efficiency: Quality 5.0 emphasizes the elimination of waste and inefficiencies. This can result in cost savings in terms of reduced rework, fewer defects, and improved resource utilization, which all positively impact the bottom line.
    - Future-proofing: The forward-thinking nature of Quality 5.0 can help a company stay ahead of regulatory changes, avoid fines and penalties, and be prepared for shifts in consumer demand, all of which can protect and increase profits.
2. Environment:
    - Sustainability Focus: Quality 5.0 puts a strong emphasis on environmental stewardship. This involves reducing waste, minimizing energy consumption, using sustainable resources, and more, which all contribute to environmental protection and sustainability. (Sannö 2016)
    - Reduced Waste: Better quality management means fewer defects and less waste. This not only saves money but also reduces the environmental impact of the business.
    - Compliance with Environmental Regulations: Companies embracing Quality 5.0 are likely to be ahead of the curve in terms of meeting or exceeding environmental regulations.
3. Employees:
    - Employee Engagement: Quality 5.0 places high importance on employee engagement and empowerment. Employees who are engaged are more likely to be productive, innovative, and committed to the organization.
    - Skill Development: Implementation of Quality 5.0 involves training and education, providing employees with opportunities to learn and grow. This can lead to skill enhancement and career progression.
    - Better Work Environment: By focusing on aspects like workplace safety, wellness, diversity, and inclusion, Quality 5.0 can contribute to a better work environment for employees. This can improve job satisfaction, reduce turnover, and attract talent.

N. Radziwill [2018] indicated the features and competencies that should be possessed by specialists carrying out the transformation of the organization from the current state of quality solutions to the state characterized by Quality 5.0. These are:

1. system thinking,
2. making decisions based on evidence,
3. leadership in organizational learning,
4. establishing continuous improvement processes,
5. understanding how decisions affect people: lives, relationships, communities, well-being, health, and society.

6. Challenges and Future Directions

Despite the promise of Quality 5.0, there are potential challenges associated with its implementation, including data privacy concerns, the need for a skilled workforce, and the risk of technology dependency. However, as Industry 5.0 continues to evolve, it is expected that these challenges will be addressed, paving the way for the widespread adoption of Quality 5.0 principles. (Chehri et al 2023)

In order to help leaders meet the challenges posed by the contemporary paradigm of quality, it is necessary to find answers to the following questions through appropriate research:

• What leadership characteristics does Quality 5.0 require?

• In what directions will the concepts of TQM, Lean Management and Six Sigma develop, and will these names remain valid?

• What changes need to be made to balance the involvement of all employees of private and public organizations in relation to disruptive new technologies and organizational solutions?

• What should be the new standards related to the target level of quality and the new synonym for excellence (7σ?) and how should quality assurance mechanisms be transformed?

• Are new methods needed to capture emerging quality challenges such as new risks and opportunities, security, trust, and compliance globally?

• Will the concept of Quality 5.0 integrate the concepts of excellence, security, trust, credibility or social responsibility — co-creating the quality of life paradigm?

7. Conclusion

Quality 5.0 represents a significant leap forward in quality control and assurance, promising to revolutionize manufacturing processes in the context of Industry 5.0. By shifting from a reactive to a proactive approach, Quality 5.0 can lead to more efficient production, higher quality products, and improved customer satisfaction. The challenges that lie ahead should be considered opportunities for further research and innovation, ensuring that the potential of Quality 5.0 is fully realized.

Acknowledgments

This research was supported as part of Education for Quality Improvement (Edu4QI), an EEA project supported by the Iceland, Lichtenstein, Norway Grants ‘EDUCATION’ program of the European Economic Area Fund of the European Union.

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