Applicability of Quality 4.0 Characteristics in the Software Development Process

Kristian Petkoff Bankoff✉, Rocío Muñoz, Ariel Pasini, and Patricia Pesado

Institute for Research in Computer Science LIDI (III-LIDI), Faculty of Computer Science, National University of La Plata, Argentina
{kpb,rmunoz,apasini,ppesado}@lidi.info.unlp.edu.ar

Abstract. This paper explores the integration of Quality 4.0 into software engineering, showcasing how its frameworks enhance software development. It discusses 11 key Quality 4.0 elements—from data management to skill improvement—and their importance in software projects. The analysis suggests that DevOps and Agile boost Quality 4.0's data, analytics, collaboration, and connectivity aspects, crucial for creating an adaptable and collaborative software environment. Traditional quality models, however, still support management, scalability, compliance, and leadership effectively. It also emphasizes the essential role of app development in software engineering, regardless of the quality approach used.

Keywords: Quality 4.0, TQM, Software Engineering, DevOps, Agile Methodologies

1 Introduction

Quality 4.0 marks a major evolution in quality management by integrating traditional practices with the innovative technologies of Industry 4.0. This approach stems from the ongoing Fourth Industrial Revolution, noted for merging physical, digital, and biological technologies[11].

The concept of Quality 4.0 derives from the broader idea of Industry 4.0, initially introduced at the 2011 Hannover Fair. It highlighted how these technologies are transforming manufacturing[4]. In quality management, Quality 4.0 involves not only adopting new technologies but also transforming organizational cultures and aligning quality goals with digital transformation strategies.

Central to Quality 4.0 is the incorporation of digital technologies into quality management. IoT devices are crucial as they collect data directly from manufacturing equipment, enabling real-time monitoring and control that were once impossible. This data is analyzed using big data analytics to provide predictive insights on quality and maintenance, helping to prevent defects and failures, thereby reducing waste and enhancing efficiency[2].

AI and machine learning expand these capabilities by facilitating sophisticated data analysis and decision-making without human intervention. These

technologies detect patterns and insights from large data sets to enhance quality and optimize production processes[12].

The adoption of Quality 4.0 has significant implications for quality assurance. It supports improved product quality through continuous monitoring and feedback, allows for greater product customization, and enables quicker responses to quality issues. Moreover, Quality 4.0 can enhance customer satisfaction by ensuring higher product standards and faster service[9].

2 Traditional Software Product Quality

Traditional software quality concepts have always focused on ensuring that software products meet specific requirements, are free from defects, and perform reliably. These concepts are crucial in software development and cover a wide range of practices, from defining initial requirements to providing maintenance and support after the software is deployed[5].

Software quality can be seen through several lenses, including correctness, maintainability, efficiency, reliability, usability, integrity, and adaptability. This broad approach aims to ensure that software not only functions as intended under certain conditions but also meets wider performance criteria that enhance user satisfaction and operational efficiency[7].

In a traditional setting, software quality assurance (SQA) is about a systematic process to check the quality of software. This process includes development standards, code reviews, system testing, and performance evaluations, all designed to prevent defects. Quality control, however, focuses on finding defects in the finished products. It is reactive, addressing defects after they occur, unlike the preventive nature of SQA. Adherence to international standards such as ISO 9001 can help integrate these practices into a comprehensive quality management system, providing guidelines that ensure quality is maintained throughout software development.

3 Relation between Software and Quality 4.0

Software plays a vital role in applying Quality 4.0 across various industries. As Quality 4.0 focuses on data-driven decisions, real-time monitoring, and the use of new technologies, software offers the infrastructure needed to gather, process, and analyze vast amounts of data[8]. It also supports the connectivity and interoperability of devices and systems in the IoT framework, facilitating data exchange between the physical and digital realms[15]. Utilizing artificial intelligence and machine learning to detect patterns, predict defects, and refine processes in real-time significantly enhances operations[13].

Flexibility and adaptability are crucial for adopting continuous improvement, iterative development, and customer-focused strategies. A core aspect of Quality 4.0 involves creating tailored software applications to address an organization's unique needs[4]. Furthermore, the principles of Quality 4.0 deeply influence the

software industry, enabling software engineering teams to make informed decisions, spot defects early, and enhance software quality[1].

Quality 4.0 also complements agile methodologies, which support iterative development, continuous customer feedback, and team collaboration. These methodologies help deliver products that are more aligned with customer needs[1]. By focusing on customer-centric strategies and involving stakeholders throughout the development process, software engineering can more effectively meet user preferences, resulting in superior software products[5].

Quality 4.0 encourages software development to adopt data-centric practices, including real-time monitoring, predictive analytics, and error prediction models. These practices allow for ongoing monitoring of software systems and foster a culture of continuous learning and improvement[14].

4 Quality 4.0 in Software Development Process

The 11-axis model proposed by the LNS Research Group provides a comprehensive framework for implementing Quality 4.0 within organizations. This model is designed to guide companies in integrating modern digital technologies with traditional quality management systems, aligning them with the requirements of Industry 4.0[6].

Such axis are: sophisticated data management tecnologies for data-driven decision making; analytics for more complex predictive and prescriptive analytics using big data and machine learning technologies; connectivity to enable integration of information technology and operational technology; collaboration to focus on enhancing cooperation across various functional areas; app development to facilitate the execution of Quality 4.0 processes; scalability to address the capability of quality management systems to expand and adapt to the scope of data and operations; management systems that automate workflows and consolidate data and processes; compliance to meet regulatory and industry standards, facilitated through advanced technologies that automate compliance processes; quality-centric organizational culture that encourages continuous improvement; leadership to drive the adoption and implementation of Quality 4.0 initiatives; competency to enhance the skills and knowledge base of employees to effectively utilize Quality 4.0 technologies and practices.

DevOps, a compound of development and operations, inherently supports Quality 4.0 by fostering a culture of continuous integration and continuous deployment (CI/CD). This approach emphasizes automation, monitoring, and collaboration between software developers and other IT professionals. By automating repetitive tasks and integrating various stages of the software development lifecycle, DevOps facilitates a seamless flow of work, thereby enhancing productivity and ensuring more reliable software releases[3, 10].

Agile methodologies complement DevOps in enabling Quality 4.0 by providing the framework for adaptability and customer-focused development. Agile's iterative process allows for regular reassessment of development projects to align closely with customer requirements and market changes. This adaptability is cru-

cial for Quality 4.0, which must be flexible enough to respond to the dynamic nature of digital markets.

5 Conclusions

The integration of Quality 4.0 within the software engineering domain is significantly facilitated through the adoption of DevOps and agile methodologies.

As shown in Figure 1, while DevOps and agile methodologies enable and enhance the implementation of several key axes of Quality 4.0 in software engineering, such as Data, Analytics, Collaboration, and Connectivity, traditional quality models continue to robustly support Management Systems, Scalability, Compliance, Culture, Leadership, and Competency. The development of applications, while crucial, is a standard practice in software engineering and intrinsic to the industry itself, suggesting a holistic approach is needed to fully realize Quality 4.0 in software development. This integration across methodologies and models ensures a comprehensive alignment with the digital transformation goals of Industry 4.0, enhancing software quality and operational efficiency across the board.

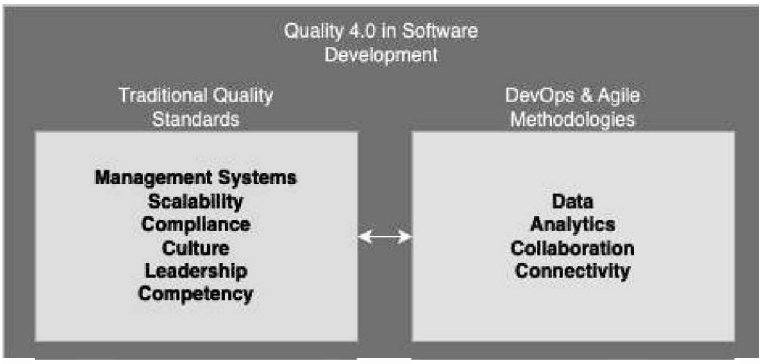

Fig. 1. Holistic view of Quality 4.0 in Software Development

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