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Quality 4.0: An Overview

Adriana Ventura Carvalho[a], Daisy Valle Enrique[a,b], Amal Chouchene[a,c], Fernando Charrua-Santos[a,*]

[a]*C-MAST. University of Beira Interior, Covilha, Portugal*
[b]*Department of Industrial Engineering, Federal University of Rio Grande do Sul Porto Alegre, Brazil*
[c]*Université de Tunis El Manar, Research Team SIIVA, Laboratoire de recherche en Informatique, Modélisation et Traitement de l'Information et de la Connaissance (LIMTIC), Tunisia*

Abstract

Quality management practices are widely implemented by companies, as they constitute a competitive advantage. Nowadays it is almost mandatory to follow quality standards, in order to make a product available on the market. However, facing new production paradigms, such as Industry 4.0, questions arise about how quality management processes could benefit and adapt in the era of digital technologies. Following a literature review approach, this paper lead to the development of a table that links the relationship between quality management practices and Industry 4.0 technologies that improve quality, as it aimed.

Keywords: digital technologies; Industry 4.0; quality management; quality 4.0

* Corresponding author. Tel.: +351 275 319 700, ext. 3955
E-mail address: bigares@ubi.pt

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1. Introduction

Quality management (QM) plays a fundamental role within the production processes, since it guarantees the reliability of products/services according to customers' requirements [1]. It is a topic widely addressed in the literature, beginning in the 80s and 90s, mainly focusing on the analysis of non-conformities, philosophies such as Total Quality Management (TQM) and Lean Six Sigma, tools and methodologies for quality control and inspection, as well as the impact of quality on company performance [2] [3].

According to [4] the traditional methods and tools of quality management enable the detection of errors and improved decision making, but with delay in the execution of corrective actions. In addition, the growing model of mass production and mass customization brings new complexities in the production processes, requiring new approaches in quality management. In this sense, information and communication technologies allow the integration of quality management into technological processes and managing quality in real-time [4].

Currently, Industry 4.0 (I4.0) technologies, such as the Internet of Things (IoT), Big Data, Cloud Computing, Visual inspection, have been improving the digitization of the factory with several advantages in terms of production efficiency, product quality and cost reduction [5] [6]. In this sense, it is of central importance for understanding how to manage and improve quality processes in the era of Industry 4.0. In addition, research addressing the role of QM in digital transformation is scarce [7]. Based on this, this article aims to identify, based on the literature review, what are the new technologies in industry 4.0 that directly link to quality management improvements.

The current manuscript is organized as follows. In Section II the methodology used is described. In Section III the authors analyzed the literature on Quality Management and Industry 4.0 and the relationship between these concepts. To conclude the paper, the principal conclusions of the study are made known, followed by acknowledgments and references.

2. Methodology

Bibliographic research was conducted following the 3 main stages adapted from the study by [8]: (i) Research planning, (ii) Research execution, and (iii) Summary of results.

A. Research Planning

In the research-planning phase, the research objective and data sources that will be used in the execution stage were defined. The goal defined in this stage was to analyze the relationship between the different technologies of Industry 4.0 and the quality processes. For this, two recognized databases with many indexed articles were chosen to search, Scopus and Science Direct. Magazines and books related to the subjects were also analyzed.

B. Research Execution

In the execution phase, the keywords were defined, and the definition of criteria for inclusion and exclusion of articles. The keywords defined for the search were: (quality management OR quality control OR quality inspection) AND (Industry 4.0 OR digital technologies). The search was conducted based on the title, abstract (abstract), and keywords. The search was also limited to studies in English. In order to include relevant articles in the sample, the "Snowballing" technique was applied. A literature review was carried out briefly selecting papers focusing only on digital transformation in the quality management process.

C. Summary of Results

This step corresponds to the content analysis of the articles and aims to summarize and connect the data according to the objectives of the study.

3. Quality Management in the Fourth Industrial Revolution

A. Quality Management Overview

Quality management is an approach to achieve and sustain high-quality results. Quality management is seen as an element of an integrated approach supported by just in time (JIT), human resource management, top management support, technology management, and strategic management [9]. Controlling and managing the critical characteristics of the product and services is a fundamental task of the quality measurement system and, therefore, of the quality management system [10]. QM improves customer satisfaction and, at the same time, reduces non-quality costs [1], this is due to high-quality impacts and other competitive advantages, such as cost, delivery, cycle time, flexibility and sustainability [11] [12] [13].

The specific requirements of the quality management system are described in the international standard ISO 9001: 2015 [10]. In addition, different tools and approaches such as TQM, Lean Six-Sigma, failure mode and effect analysis (FMEA), quality function deployment (QFD), benchmarking have been implemented by many organizations to improve quality performance [1]. Moreover, for a successful implementation of quality management, several practices must be conducted in the factories, such as process management, customer focus, involvement in the quality of supply, and small group activity [13]. Table 1 shows the principle quality management practices adapted from [13] and [2].

Table 1. Quality Management Practices

Dimensions	Quality Management Practices
Behavioral Aspects	Management Commitment
	Customer Involvement
	Supplier Involvement
	Employee involvement
Technical Aspects	Benchmarking techniques
	Process Management
	Information and Analysis
	Formal strategic planning

Management Commitment is considered as being the commitment and involvement of managers to actively encourage change and implement a culture of trust, and commitment to change to "best practice." Customer Involvement and Supplier Involvement are related to keeping a straight relationship with these two stakeholders through different practices and tools. Employee Involvement is related to employee flexibility, multi-skill, training, and employee capacity to solve problems. Through the Bench Marketing techniques, the company knows its position in the market based on cost and operation processes. Process Management comprises statistical process control. Nowadays the cross-functional product design and production are an important approach to improve quality too. Information and Analysis are related to the collection and analysis of new product information and product and process quality information. Last, the Formal Strategic Planning refers to the quality aims of the company short and long terms and the formal planning to achieve them and how they are communicated to all employees [13]; [2].

B. Industry 4.0 concept

Industry 4.0 refers to the fourth industrial revolution, in which the production technique has to be defined in a global and decentralized way [14] using a fully-integrated collaborative manufacturing system [19].

This integration serves the concept of globalization which may help to handle, not only the production inside the manufactory itself but also to deal with the quick change of costumer demands [19]. Besides, a keynote technology for this revolution is the adoption of Cyber-Physical Systems (CPS) ensuring the full communication between humankind and machinery [25].

The main interest behind emerging towards smart manufacturing is that all industries seek to boost their productivity while trying, at the same time, to minimize the waste of production, which denotes the concept of Lean Production [20]. In fact, the term Industry 4.0, or the industry of the future, was firstly introduced in 2011 by the

German Hannover Fair [27] and aims to enable real-time communication between the physical and digital areas [24].

In addition to opting for the CPS, which is considered as the main pillar, in the literature too many technologies have been cited that contribute to serving the Industry 4.0 concept. Among them, we cite: Internet f Things (IoT), Big data, Cloud Computing, Artificial Intelligence (AI), Augmented Reality (AR) and Virtual Reality (VR). IoT enables the manufacturing network (including intelligent sensors and human) a better global visualization plus taking actions in real-time based on the data understanding [24].

Inside a smart industry, the data understanding can be managed using Big Data cooperating with CPS. Big data analytics play a key role in assisting early failure detection during the production process, which supplies pertinent insight into manufactory management such as increasing productivity [22].

Furthermore, AI has gained a growing interest in manufacturing environments throughout the past years. In general, AI is defined in the literature as the ability of computer-based solutions to mimic human intelligence. Later, AI was related to the concept of "Big Data" and "data-analytics" since it serves to reveal the hidden structure between processing conditions and outputs providing relevant decisions without human intervention [24].

The application of AI inside industries is generally related to the visual inspection of products toward quality-control evaluation. The ability to visually detect the quality of a product is one of the most important issues for the manufacturing field [21].

In the literature, AI approaches (Machine Learning techniques) prove its accuracy to assist the inspection based on data analyzing. This latter, are frequently gathered inside manufactory environments as images that are collected from sensors (cameras). Inhere, comes AR or VR technologies to cooperate in the inspection process. Indeed, AR/VR denotes a set of techniques enabling to display the real environment with the addition of information generated by a computer [16]. The surrounding environment displaying is although insured by the visualization device which could be Head-Mounted Displays (HMDs), Hand-held Devices (HHDs), statistic devices, and projectors [23].

The above-mentioned technologies contribute all to serve the concept of Industry 4.0 without denying the importance of one technology over another. A well-designed industry conception where all of these technologies can work together consistently will undoubtedly bring many benefits that deepen the goal of industry 4.0.

C. Quality 4.0

The traditional meaning for Quality has of late gotten a larger role. Quality 4.0 (Q4.0) can be characterized as the digitalization of TQM and its effect on quality technology, processes, and individuals [18] just as it can be defined as the application of I4.0 technologies to quality [17]. The aptitudes to decide how and why information ought to be utilized are essential for Quality professionals, since the utilization of information must be directed by the process, and not the other route around [15].

Having this in mind, a table (table 2) was designed to link the relationship between the Quality Management practices that were previously identified, and seven tools and technologies that can be used to improve quality.

This table was developed based on the description of the I4.0 tools and technologies provided by [26], that stated the following:

- Data science and statistics: Data collection and classification that prompts critical thinking;
- Enabling technologies: developments in sensors, mobile devices, networks, IoT, IIoT, Integrated systems, VR, AR, cloud computing. How to manage documentation;
- Big Data: Analysis and management of massive data sets;
- Blockchain: Transactions happen only if quality objectives are met;
- Artificial Intelligence (AI): complex decisions (computer visions, chatbots, and robotics);
- Machine Learning (ML): When heuristics are utilized for decision making, forecasting, filtering the information;
- Neural Networks and Deep Learning: Forecasting and complex pattern recognition.

Based on this information and previous knowledge about Quality Management Practices (section A of the current chapter), the table below was developed.

Management must always have a commitment to all decisions concerning any change/improvement within the organization.

Table 2. Quality Management Practices and Industry 4.0 Technologies Relationship

	Quality Management Practices							
I4.0 Tools and Technologies	Management Commitment	Customer Involvement	Supplier Involvement	Employee involvement	Benchmarking techniques	Process Management	Information and Analysis	Formal strategic planning
Data science and statistics	X					X	X	X
Enabling technologies (IoT, IIoT, Integrated systems, VR, AR, cloud computing	X	X	X	X	X	X	X	X
Big Data	X	X	X			X	X	
Blockchain	X			X		X		X
AI	X			X			X	
ML	X						X	X
Neural Networks and Deep Learning	X					X	X	

To analyse the quality of the results obtained from the table above, the available literature on the subject was reviewed [15] [26] , the results obtained from the table allows the user to make informed decisions on what tools and technologies to apply when facing different quality management practices, in order to use the information through I4.0 technologies available in favor of the process, reduzing the time wasted looking for the best suited technologies and/or tools.

4. Conclusion

This manuscript aimed to analyze the relationship between the different practices of quality management and the new technologies of Industry 4.0, which might lead to an improvement of QM.

Through a literature review, this research leads to the development of a table that links the relationship between quality management practices and Industry 4.0 technologies that improve quality, as it aimed.

As future research, the authors highlight the importance of developing empirical and quantitative studies that demonstrate the influence of Industry 4.0 on quality management practices and the company's overall performance.

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