Total Quality Management Assignment

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A paper presented to

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June 19, 2023

Contents

Introduction and Justification of Papers Chosen

The pace of technological advancement and the surge in new and disruptive technologies have led to significant changes in how Total Quality Management is practiced. The topic has garnered much academic attention in recent years. This paper will review relevant academic literature of recent years in order to get an insight into the most recent developments and discussions on the topic.

1.1 Theoretical background

1.1.1 Quality 4.0

Industry 4.0 (first coined in 2011 at the Hannover Fair [29]) is the term used to describe the fourth industrial revolution, brought about by the technological advancements of the past decade, which has seen an exponential surge in the number of disruptive technologies, such as AI, IoT, robots, cobots, 3D printing, cloud computing and advanced data analytics, to name but a few, and by changes these have brought to workplaces, markets and, naturally, to quality. [28][27].

Quality 4.0 is an extension of these technological advancements into the realm of quality processes and organizational excellence in the context of Industry 4.0. It focuses on the technological aspects and capabilities provided by the fourth industrial revolution to enhance quality control, assurance, and improvement. It aims for continuous monitoring, predictive maintenance, and data-informed decision-making to improve on quality management processes. By automating quality checks and using data analysis for ongoing improvements, it also improves efficiency and reduces costs. It is essentially a shift from reactive to a proactive quality approach, via integrating digital technologies with quality management systems [13].

TQM 4.0 (Total Quality Management 4.0) is Total Quality Management in a Quality 4.0 context. In fact, Carvalho at al. [6] described Quality 4.0 in their 2021 paper as 'the digitalization of TQM', a holistic management approach that aims to maximize organizations competitiveness for long-term success with a focus on customer satisfaction, through the involvement of all members of an organization in the continual improvement of the quality of their processes, goods, services, people and environments, including the culture in which they work [11, p. 4]. It is often depicted by a three-legged stool, having customer focus in the centre, and measures/tools, people and processes as the three legs on which the concept 'rests' [24]. TQM aims to deliver superior value (cost, services and quality). This is increasingly more important in order to remain competitive in the rapidly changing world of globalization. TQM 4.0 extends these principles into the digital age, harnessing the power of new technologies, but also keeping the focus on customer satisfaction and continuous improvement among others.

1.1.2 Quality 5.0

Quality 5.0 represents a vision for the future of industrial innovation that prioritizes societal goals beyond jobs and growth, putting the wellbeing of industry workers and green initiatives at the core and, by extension, TQM 5.0 represents a further evolution of Total Quality Management that incorporates these principles [8].

In this evolution, Quality 5.0 recognizes the power of industry to achieve societal goals beyond jobs and growth. It emphasizes human-centricity, sustainability, and resilience in the manufacturing and service industries, as referenced in Figure 2.3. It complements Industry 4.0's digital and technological advances by encouraging research and innovation that drive transitions to sustainable, human-centric, and resilient industries [8].

The benefits of this approach are manifold and include attracting and retaining talents, ensuring resource efficiency for sustainability and competitiveness, and increasing resilience. Making Quality 5.0 a reality requires a focus on human-centricity, sustainability, and resilience [8].

1.2 Research questions

1. What is Quality 4.0, and how does it relate to the concept of Industry 4.0? What are the key principles and technologies associated with Quality 4.0?
2. What is Quality 5.0, and how does it differ from Quality 4.0? What are the core elements of Quality 5.0, including human-centricity, sustainability, and resilience?
3. What are the implications of Quality 4.0 and Quality 5.0 on quality management practices, such as Statistical Process Control (SPC) and lean methodologies?
4. How do these approaches impact the workforce in digital organizations?

1.3 Literature reviewed

After formulating the research questions, a comprehensive list of search terms and keywords related to these questions was developed to guide the literature search, as per table A.1.
Limo, the online library platform of KU Leuven, was used for the search.
In order to focus on the most current and relevant information, only peer-reviewed articles published from 2018 onwards were considered.
The articles were screened and selected based on their titles and abstracts. Only the ones that appeared to closely relate to the research questions were kept, as summarized in figures A.3 to A.9.
Upon further inspection, the following seven articles were retained in a somewhat ad hoc manner, based on their perceived relevance and the author's preference.

1. "Quality 4.0: leveraging Industry 4.0 technologies to improve quality management practices – a systematic review" (2021) by Afef Saihi, Mahmoud Awad, and Mohamed Ben-Daya [28]. This systematic review provides a broad overview of how Industry 4.0 technologies have impacted TQM practices and an insight into what principal technologies are associated with Quality 4.0.
2. "A review of quality 4.0: Definitions, features, technologies, applications, and challenges" (2022) by Sami Sader, István Huszti, and Miklós Daróczi [27]. This is another comprehensive research paper on Quality 4.0.
3. "Towards societal satisfaction in a fifth generation of quality – the sustainability model" (2020) by Mats Deleryd and Anders Fundin [9]. This paper suggests that societal satisfaction would be a more appropriate way of measuring sustainable success and proposes a generic model for sustainable development.
4. "The evolution and future of lean Six Sigma 4.0" (2023) by Jiju Antony et al. [1]. This paper outlines the evolution of Six Sigma and, as such, is crucial to answering the research question about implications to quality management practices, such as Statistical Process Control (SPC) and lean methodologies.

5. "Lean Six Sigma tools and sustainable performance measurments: A Review" (2022) by Ikram Ait Hammou and Salah Oulfarsi [12]. This paper reviews the tools and performance measures of Lean Six Sigma. Again, a paper crucial to answering the research question on the implications to quality management practices.

6. "Psychosocial Impact of Collaborating with an Autonomous Mobile Robot: Results of an Exploratory Case Study" (2021) by Nicole Berx, Liliane Pintelon, and Wilm Decré [4]. This paper provides insight into human-robot interactions and their impact on human workforce.

7. "Rethinking companies' culture through knowledge management lens during Industry 5.0 transition" (2022) by Valentina Cillo et al. [7]. This article provides an insight into how organizations and the workforce benefit from certain transformations relating to organizational culture, policies and Industry 5.0.

Discussion

2.1 Quality 4.0

2.1.1 Key Principles

According to Sader et al. [27], Quality 4.0 (Q4.0) is an evolution of traditional quality management, incorporating recent technological advancements to enhance these practices. This extended approach suggests Q4.0 evolved not only in response to Industry 4.0, but also in parallel with it, both influenced by the same technological advancements, as per figure 2.1.

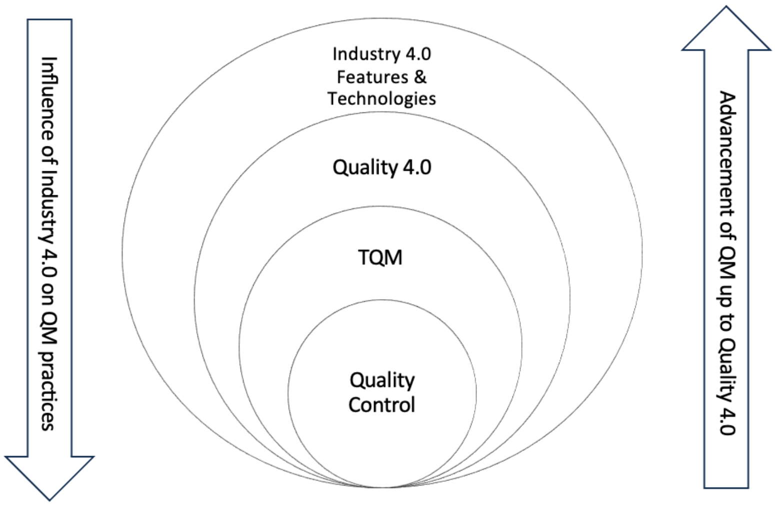

Figure 2.1: Industry 4.0 as supporting incubator for quality management practices. Figure adapted from Sader et al. (2022)[27]

Saihi et al. [28], drawing on the work of Armani et al. [2], describes Quality 4.0 is the digitalization of quality, aligning TQM practices with the capabilities of Industry 4.0.

The growth of Industry 4.0 has resulted in more sophisticated products which, in turn, demanded advanced measurement and correction tools for quality assurance and control. The integration of traditional quality management practices with modern technology is at the heart of Quality 4.0 [27].

Sader et al. [27] outline Quality 4.0 as the latest development phase in quality management, following major progressions in the 1970s and 1980s that lead from inspection or Statistical Quality Control by Shewhart, to process control or Quality Assurance (QA) inspired by Deming to the holistic approach of Total Quality Management (TQM), and more recently, as a result of intelligent environments and instant data processing, to Quality 4.0.

Quality 4.0 emphasizes the use of advanced process monitoring and big data for real-time feedback at various levels. It involves customers in the value chain through feedback and customization, aligns defects to their relative root causes, and utilizes integrated systems for enhanced connectivity. This enables automated quality tuning and real-time integration, synchronization and analysis of manufacturing process data, fostering a proactive rather than reactive approach which enables predictive process control, immediate 'in situ' intervention to/correction of the process and zero defects [27] [28].

Although technology plays a significant role in Q4.0, its scope goes beyond that. It is one facet of a broader approach to quality management. Q4.0 transforms the customer from a receiver to a contributor in the product value chain, the operator to decision-maker and uses quality to drive the production process. The result is higher-quality products at a lower cost, improved responsiveness, and greater competitiveness [27].

Sader et al. [27] states, referring to the ASQ, that Quality 4.0 requires higher levels of quality professional competence than Industry 4.0 in order to know what kind of data is needed and how to obtain and utilize it.

Sader et al. [27] concludes that the key features of Q4.0 are automation of inspection, facilitating lean quality methods, predictive analysis and zero waste production, analysis of results and integration which enables the product value chain to adjust immediately responding to quality issues. Vertical, horizontal, and end-to-end integration enable suppliers as well as different departments to partake in performance improvement [27][28].

Saihi et al. [28] cite the work of Radziwill [26], who outlined the possible advantages of Quality 4.0 initiatives within a value proposition. Radziwill suggested that these initiatives typically offer one or more of the following benefits: augmenting human intelligence, improving the quality and pace of decision-making processes, increasing traceability and transparency, forecasting changes and adjusting to new scenarios, identifying continuous improvement opportunities, and fostering a culture of learning.

2.1.2 Associated technologies

Quality 4.0 leverages a myriad of digital technologies reflective of the Industry 4.0 era. As highlighted by Saihi et al. [28] and Sader et al. [27], the principal technologies associated with Quality 4.0 span various domains. These include:

- *Artificial Intelligence (AI)* and *Machine Learning (ML)*: These technologies help in automating quality control processes, analyzing data, predicting outcomes, and optimizing decision-making.
- *Internet of Things (IoT)* and *Industrial Internet of Things (IIoT)*: IoT technologies facilitate interconnectivity and data exchange between physical devices and systems, providing real-time information about product performance and aiding in root cause analysis.
- *Big Data Analytics*: Handles large volumes of real-time data, extracting valuable insights for quality management.
- *Cloud Computing (CC)*: Provides the infrastructure necessary for data collection, storage, and analysis, enhancing connectivity and collaboration.
- *Cyber-Physical Systems (CPS)*: Integrate computation with physical processes for automation and virtualization of quality management processes.
- *Robotics*: Assist in automating repetitive tasks and improving precision in quality control.
- *Networking*: Facilitates communication and data exchange, supporting integrated and collaborative quality management.
- *Augmented Reality (AR)* and *Virtual Reality (VR)*: These technologies aid in data visualization, enhancing user interaction and informed decision-making.
- *Enabling technologies*: Including sensors, actuators, and RFID that facilitate data collection and automation.
- *Blockchain*: Allows tracking of product history in versatile environments, enhancing transparency and accountability.

Figure 2.2: Key technologies associated with Quality 4.0

- *Deep Learning, neural networks*: A subset of machine learning that mimics the workings of the human brain to process data patterns, contributing to improved quality prediction and decision-making processes.

Additionally, Sader et al. [27] adds connectivity, collaboration and data-presentation to their Quality 4.0 technologies. Connectivity via smart devices that can aid with training and transmitting information, RFID that can store data on the processes a product went through, IPv6, which allows for more devices to be connected online, self-reporting products can all help in different or collective ways to improve quality,e.g., via root cause analysis.

Collaborative channels, via social media, customer feedback channels, and smart devices involve customers in the value chain, driving Quality 4.0 towards higher product quality, greater competitiveness, and improved responsiveness [27].

Saihi et al. elaborates on the opportunities provided by smart glasses, smart gloves and AR in the QC process [28] and by smart products, e.g., vehicles in the Quality Planning and Quality Assurance context.

2.1.3 Challenges

Applications of Q4.0 span across sectors like manufacturing, RD, procurement, sales, after-sales, logistics and decision-making processes, ranging from predicting process and product quality issues, reaching higher levels of manufacturing visibility, extending the scope of RD, utilizing new collaboration platforms, integrating the entire value chain to aid procurement functions, and so on [27]. Challenges of Q4.0 are multi-faceted and include HR-related issues, such as the need for higher qualifications and talent and specifying the nature of these skills and ways to acquire them. Organizational challenges include resistance to change and the need and importance of creating a quality culture. Technological challenges include the readiness of the company, such as whether they have reliable data sources and appropriate infrastructure. Furthermore, substantial required investment, lack of interoperability and cybersecurity and data protection concerns also often pose as barriers [27].

Table 2.1: A comparison of traditional Quality Management versus Quality 4.0. Adapted from Sader et al.(2022) [27]

Traditional QM	Quality 4.0
Statistical quality control and sampling inspection	Instant, real-time, and in-process inspection and monitoring systems
Utilisation of statistical analysis and regular data gathering and analysis techniques	Utilisation of big-data systems and AI techniques, predictive instead of proactive or reactive quality methods
Paper, or paperless, or electronic format in the form of documents format or slides presentation of data	Utilisation of smart devices and shop floor smart and dynamic screens, real-time flow of information
Inspection and other quality techniques and methods results are transferred manually to stakeholders	Results are being transferred in the form of knowledge to all stakeholders including other units or suppliers
Quality experts are at the centre of quality management	Quality experts remain the central role player in the quality management supported by Quality 4.0 technologies
Supplier quality is based on reporting of quality issues when occurred	Suppliers are involved in the quality of their supplies and can contribute to solving production issues from their location
Involvement of customers in production is limited to service after sales	Customers are quality contributors and involved in the manufacturing process, products are able to transmit quality-related data to the manufacturer

2.2 Quality 5.0

As mention earlier, the European Commission and Directorate-General for Research and Innovation described Industry 5.0 as "putting research and innovation at the service of the transition to a sustainable, human-centric and resilient European industry", by placing the well-being of workers, economic and environmental sustainability at the heart of production processes. Whereas Industry 4.0 focused more on digitalization and AI-driven technologies, Industry 5.0 focuses more on social fairness and sustainability [8], as depicted in Figure 2.3.

The shift in paradigm and the underlying drivers (societal changes, globalization, etc.) naturally influence the way Quality Management (QM) should be approached in the future. Drawing on the works of Porter Kramer [25], Deleryd and Fundin [9] highlight that Corporate Social Responsibility (CSR) is becoming increasingly more important in today's society (Society 5.0), partially driving the evolution of the quality paradigm. These changes have an impact on the requirements, necessitating the accommodation of different needs in order to align with the evolving landscape. It is crucial to adapt QM practices intelligently and thoughtfully in response to these shifts.

Deleryd and Fundin [9] assert that the fifth generation of QM, Quality 5.0 has a predominant focus on sustainability, claiming that the latest paradigm shift revealed differing needs of customers and stakeholders, proposing 'societal satisfaction' as a new, more appropriate means of measuring sustainable success. They claim, that organizations should aim to contribute to Total Sustainable Development through business practices that benefit society. They define sustainable development within three areas of concern: environmental, social and economic sustainability,

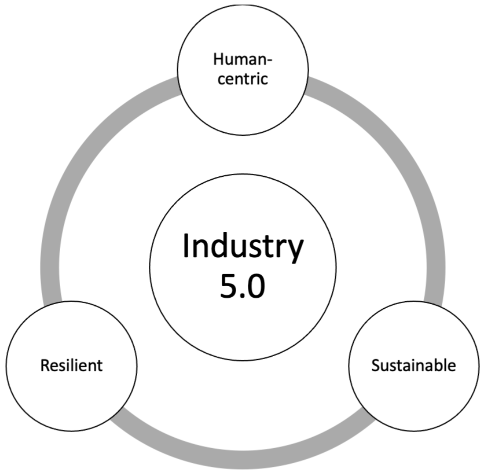

Figure 2.3: Industry 5.0. Figure adapted from the European Commission and Directorate-General for Research and Innovation (2021) [8, p.13]

as per figure 2.4, in particular, "The fifth generation of QM, Quality 5.0, broadens the definition of stakeholder satisfaction to include societal satisfaction with sustainability perspectives—that not only consider environmental and economic needs, but also critical societal needs — where future generations are viewed as today's customers" and emphasise the importance of increasing satisfaction and loyalty both externally and internally. Recent QM research reflects this and calls for redefinition of stakeholder characterizations. There is clear connection between customer satisfaction, financial performance and economic sustainability. As organizations are becoming more differentiated and increasingly more international, taking all stakeholders'/societal needs into consideration becomes a necessity [9].

Furthermore, they point out that current industrial market leaders are those organizations that have already embarked on this trajectory [9, p.8.].

Sustainability programs to enhance CSR already exist (OHSAS 18001, ISO 14001, EU Green Deal, etc.). In today's fast-paced environment, what is sustainable may quickly change though, highlighting yet again, the importance of Change Management. Deleryd and Fundin [9] proposed a conceptual sustainability model for companies to help further discourse regarding the topic. Certain tools to assess CSR efforts are already in place, such as the Dow Jones Sustainability Index, that evaluates public companies based on a combination of business performance related metrics, economical factors, environmental and social responsibility factors relevant for CSR.

2.3 Implications on quality management practices

Quality management practices evolved closely parallel to industrial revolutions. Quality Inspection and Quality Control were the earliest stages of Quality Management, , with the first control charts being developed by Juran [23]. With the advent of serial production, in this era the primary focus was on inspepction and statistical methods to separate/estimate bad products from the rest [27]. Quality Assurance (Dahlgaard) is a process-oriented approach, with a focus on standardization and consistency. TQM, a comprehensive managerial approach that integrates all organizational functions, overarching the entire organization and beyond, emerged in the 1980's at the advent of digital technology. Key proponents of this approach include Deming with his 14 points, Juran with his 10 steps, and Crosby with his 14 points [23]. More recently, boosted by the ongoing development in communication and IT technologies, the forth phase of quality development, Quality 4.0 emerged, shifting the focus to predictive process control, predicting

Figure 2.4: Core elements of Quality 5.0

and preventing defects in real-time and striving for zero-waste [27] [28].

Statistical Process Control (SPC), developed by Shewhart, serves as a statistical method for separating special-cause variation from natural variation, eliminating the special cause and establishing consistency, thereby enabling process improvement. The goal is to achieve higher quality at lower costs to compete successfully in world markets. In the past, western companies often overlooked this method, while Japan embraced it and integrated it into their TQM approach [21] [11, p.8].

In SPC, the control charts for variables and attributes are essential tools. Variables refer to measurements (such as size or time), while attributes refer to countable items (such as accepted products). The charts' upper control limit (UCL) and lower control limit (LCL) represent the process boundaries within which 99.7% of the data should ideally fall in a stable process. The goal is to maintain a normal distribution curve (assumtion) without bimodality and other distortions, which might indicate the presence of special causes of variation. Common causes represent predictable, recurrent variations, while special causes are uncommon, unpredictable, and sporadic. Continual improvement of processes, elimination of special causes of variation, and reduction of waste are all critical aspects of this approach [21] [11, p.329-331].

In contrast to traditional Statistical Quality Control (SQC), which relied on samples and statistical inference, current quality control employs advanced technologies for automatic real-time process monitoring and alerting, early failure detection and prediction, automated sensors, including x-rays, CT's, etc. aiming for 100% accuracy and zero waste. Quality 4.0 thus elevates SQC to Predictive Quality Control (PQC) [27] [28].

The ISO 9000 family introduced a new approach to TQM, providing a good starting point for implementation in any organization [17]. Its fundamental principles include: customer focus, leadership, engagement of people, process approach, continual improvement, evidence-based decision making/factual approach, relationship management, for example mutually beneficial supplier relationships and a systems approach to management" [14] [28] [27][18]. Saihi et al. highlighted the need for further studies in relation to the mapping and integration of ISO 9001 with Quality 4.0 features [28]. Similarly, Sader et al. mentioned the need for further studies about the applications of the ISO 9000 family as a whole in a Quality 4.0 context.

Saihi et al. found that six sigma, lean manufacturing, and lean six sigma had been most frequently associated with Continuous Improvement in Quality 4.0 in the literature they reviewed, citing that advanced data analytics aid these programs, allowing for even more reliable and faster decision making [28].

Lean Six Sigma (LSS) is a powerful methodology that combines the systematic elimination of waste through lean manufacturing with the reduction of process variability using Six Sigma [1]. The synergistic effect between Lean and Industry 4.0 [1] improves operational performance by enhancing process flows and reducing bottlenecks [15]. Nonetheless, LSS 2.0 already incorporated "Green" as of 2002 and as a result of recent technological advancements, LSS 4.0 has become even more powerful and technologically enabled to meet the needs of a circular economy by enhancing resource efficiency and environmental performance. Furthermore, Antony et al [1] concludes that lean Concepts, such as TPM, Kanban, production smoothing, JIT (Just-in-time), Jidoka, waste elimination can all be improved by integrating technologies associated with I4.0 and hence Q4.0. They claim, that LSS will help with forecasting and demand management over time, improve KPI's (Key Performance Indicators) and with Big Data integration benefit in all phases of the DMAIC cycle (Define, Measure, Analyze, Improve, and Control), including real-time quality control, event-based inspection and predictive maintenance [1].

In practice, implementing LSS with JIT pull system can be tricky, lead to unpredictable work schedules, occasional overtime [19] and if not done optimally, may actually lead to longer lead times. Therefore, Heijunka might be a better alternative, particularly when some of the standard parts have longer lead times, then keeping extra stock of those might be a good idea.

On the other hand, some of the challenges they highlighted were the lack of a framework for integration, changes in operating procedures without clear guidelines, emergence of new types of waste like non-utilized talent and poor information management, and potential conflicts between lean-induced socio-cultural changes and I4.0's high-tech demands.

Hammou et al. [12] attempted to summarize and synthesize existing literature on the impact of LSS tools on companies sustainable performance pillars. They found that the most used LSS tools in the sustainability context were VSM, Cause and effect diagrams, Pareto analysis, 5S, DoE, DMAIC and 5 why analysis. They found that Lean, Six Sigma, Lean Six Sigma, all have positive environmental impacts through resource efficiency, reduced defects, i.e., less rework needed and energy saving nature, all of which result in higher profitability. Nonetheless, they note that concluding these strategies appeared not to be beneficial for SME's (small and medium sized businesses) with limited resources. In addition, they refereed to the work of Ben Ruben et al. [3] which identified 5S and the Kaizen tools as most efficient in reducing environmental and social waste and confirmed that implementing LSS practices enhancing the competitiveness of organizations processes. They highlighted the lack of research relating to the human-factor and also presented a service sector example of a U.S. tax firm, where as a result of successful LSS implementation, service quality, financial results and working conditions had all improved. Table 2.2 summarizes the main sustainable performance measurements proposed in the paper.

Economic	**Social**	**Environmental**
Increased profitability	Equity	Waste reduction
Cost reduction	Education	Environmental impact
Product marketability	Social cohesion	Resource efficiency
ROI	Job satisfaction	Reuse and recycling
Financial savings	Health and safety	Pollution and emission
Smart growth	Stakeholder trust	Hazardous materials
Revenue	Standard of living	CO_2 emission
R&D	Diversity and Equity	Energy efficiency

Table 2.2: Proposed Sustainability Measurements [12]

The effects of Quality 5.0 on Quality Management practices is less defined based on the literature reviewed, but Deleryd and Fundin [9, p.12] proposed 4 areas of concern. First, the changing role of quality managers, in terms of facilitators of change. Second, the changing role of management teams, many of whom will need to become collaborators and co-creators of value with competitors, customers and other stakeholders. Third, adapting measurements to accurately capture quality criteria, e.g., societal satisfaction, as proposed in the literature. And last, but not at least, managing this transition. This will require new management models, active change management, adopting and internalizing new principle values, investigating how this transition in principal values affect all stakeholders, etc. More research need to be conducted on how these could be incorporated into current QM practices, including new constructs to measure societal satisfaction from different sources [9, p.13].

2.4 Implications on the workforce

The implications of these advancements impact the workforce as well. There are certain challenges that arise, such as the need for higher and/or different qualifications and talent. This raises human resource issues and emphasizes the need for training and learning and instating a quality culture [27]. In training scenarios, for instance, managers must consider what to teach, whether training should be voluntary or mandatory, and if assessments can accurately measure training outcomes. Feedback becomes crucial in this process, serving as a leading and lagging indicators of performance [16].

Saihi et al. [28] suggested that Industry 4.0 technologies like smart devices and Augmented Reality (AR), provide new ways to educate operators and customers alike and can enhance the capabilities of the workforce.

Berx et al. (2021) [4] found that working with Autonomous Mobile Robots did not lead to extra psychosocial workload on the operators in the study and that in general they were very open to the experience and had positive to very positive attitudes towards working with AMRs. Robotics are one of the enabling technologies of Industry 4.0 and in recent years there has been a surge in their application in plants. Nonetheless, as mentioned before, empirical studies are still scarce on the topic.

In the face of changing demographics (growing but aging population of Belgium for example [5]), it's increasingly challenging to find employees who are both digitally literate and adaptable to rapid learning. Functional illiteracy can result in equipment damage and employee dissatisfaction, leading to a decline in quality. To mitigate these risks, organizations need to ensure that employees have a clear purpose and regularly check their progress, in line with Duran's Plan-Do-Check-Act (PDCA) cycle [22]. To foster such culture, Lewin's Participative Decision-Making Model, which advocates for involving employees in the decision-making process, aligns best with the principles of Total Quality Management (TQM). For effective implementation of TQM, consensus is crucial, but it must be achieved in a structured manner (PDCA) [20].

Human-centricity, a core concept of Industry 5.0, emphasizes elements like diversity, equity, and employee satisfaction, which are also pivotal in fostering social sustainability a key feature of Quality 5.0. Within this context, Cillo et al. [7] investigated the influence of diversity, inclusion, and people empowerment policies on company performance. Data from international public companies during five years showed that these human-centric policies enhanced profitability and investor appeal. Furthermore, shared purpose, interactions and a friendly working environment promoted knowledge sharing, which is a fundamental asset to TQM, promoting collaboration, engagement and innovation.

2.5 Gaps and limitations

The following are identified gaps in the current literature and research: Definitions of Quality 4.0 are ambiguous [27] [28]. Quality Assurance (QA) and Quality Planning (QP) have received less attention than other aspects of Quality 4.0 [28]. There are no studies comparing Industry 4.0 to the capabilities of Total Quality Management (TQM) [28]. Current research lacks exploration into how the ISO 9000 family integrates with Quality 4.0 [27, 28]. There is a call for more practical, hands-on research that includes clear guidance for companies, use-cases, and case studies [27, 28]. Few studies have conducted cost-benefit analysis or economic evaluations related to Quality 4.0 [27, 28]. Research focusing on Quality 4.0 in the service industry, including sectors such as healthcare and finance that rely heavily on information systems, is scarce [28]. There's a shortage of studies on Quality 4.0 technologies like Augmented Reality (AR), smart products, Virtual Reality (VR), and simulation [28]. Longitudinal case studies, particularly those observing the evolution of Quality 4.0 implementation and results, are absent [28]. There's a noticeable lack of maturity models in Quality 4.0 research [27][28]. More attention should be given to aspects of change management, culture creation, and human factors within Quality 4.0 [28]. Literature specifically addressing Quality 5.0 is scarce. The reviewed literature that was related to this topic primarily approached it from the perspective of Industry 5.0 [7], with a particular focus on the human aspect [4] or in the form of a concept paper [10]. Although the paper of Deleryd and Fundin [9] is recent (2020), the data they draw on is limited (two Delhi studies) and relatively old (conducted between 2012 and 2018). Further research is required to fully understand the readiness factors and critical success factors for the integration of LSS and I4.0 [1] Empirical and longitudinal studies and research on the impact of Lean Six Sigma 4.0 on corporate performance are lacking entirely. These effects also may vary across sectors, it would be beneficial to study these separately. Same applies to the Quality 5.0 context [1]. The study of Hammou et al. indicated that there is a lack of research on the integration of Lean, Six Sigma, lean Six Sigma and sustainability concepts with the human-factor having garnered the least amount of academic attention so far[12].

Some of the limitations of the current assignment include, researcher's lack of experience, limited time frame and resources, the novelty of the topic and hence the relatively little literature available, the somewhat ad-hoc paper selection, and the low number of papers reviewed.

Critical Reflection and Future Outlook

Quality 4.0 and Quality 5.0 represent the present and the future of quality management in a digitized human and sustainability-centric industrial landscape. They bring opportunities for increased efficiency, improved customer satisfaction, and better organizational performance. However, they also present challenges and potential pitfalls.

Quality 4.0 leverages digital technologies like AI, IoT, Big Data, to name but a few, for predictive quality control and real-time monitoring. However, it might increase complexity, require significant investments, and bring about data security and privacy concerns. Furthermore, organizations may struggle with lack of skilled labour and resistance to change.

Quality 5.0, focusing on social, environmental and economic sustainability, presents the opportunity to enhance employee satisfaction, collaboration, and innovation. Yet, it also calls for a cultural shift towards values like empathy, inclusiveness, and ethical consciousness in an increasingly polarized world. Additionally, quantifying and measuring the impact of such qualitative factors can be challenging.

The successful transition to Quality 4.0 and 5.0 requires a balanced data-based approach. Organizations need to effectively integrate technology and human elements, foster a culture of continuous learning and adaptability, and develop a strategic plan to manage the change, highlighting the continued importance of Quality Management tools and practices.

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Appendix

a Keywords and search terms

Table A.1: Research Questions and Search Terms

R.Q.	Search Terms
1	Industry 4.0, Fourth industrial revolution, Quality control in Industry 4.0, Key principles of Quality 4.0, Quality assurance in Industry 4.0, Digital quality management in an Industry 4.0 context, Technological advancements in quality management, Quality 4.0 and Industry 4.0 relationship, Quality 4.0 and Industry 4.0 comparison, Quality 4.0 technologies
2	Industry 5.0, Fifth industrial revolution, Human-centric quality, Sustainable quality, Resilient quality, Quality management in Industry 5.0, Quality 4.0 and Quality 5.0 comparison, Quality 5.0 technologies, Quality 5.0 core elements
3	Statistical Process Control (SPC) in Industry 4.0/5.0, Lean methodologies in digital organizations, Quality improvement in the digital age, Data-driven quality management, Automation and quality control, Future outlook Quality 4.0, Future outlook Quality 5.0, Challenges, pitfalls, Quality 4.0/5.0, Opportunities Quality 4.0/5.0, Kaizen in Quality 4.0/5.0, Six sigma in Quality 4.0/5.0, Quality function deployment in Quality 4.0/5.0, TQM tools in Quality 4.0/5.0, Implications of statistical quality control in Quality 4.0/5.0, Quality 4.0/5.0 case study
4	Workforce transformation in Industry 4.0/5.0, Human-machine collaboration in quality management, Skills and competencies for quality professionals in the digital era, Employee engagement in Quality 4.0/5.0, Workforce adaptation to technological changes

b Preliminary literature review

Year	Author(s)	Title	Institutional affiliation	Abstract	Keywords	Research Method	CAT1	CAT2	CAT3
2022	Enrique Coronado, Takuya Kiyokawa, Gustavo A. Garcia Ricardez, Ixchel G. Ramirez-Alpizar, Gentiane Venture, Natsuki Yamanobe	Evaluating quality in human-robot interaction: A systematic search and classification of performance and human-centered factors, measures and metrics towards an industry 5.0	Department of Mechanical Systems Engineering, Tokyo; University of Agriculture and Technology, Tokyo, Japan; National Institute of Advanced Industrial Science and Technology (AIST), Tokyo, Japan; Department of Systems Innovation, Graduate School of Engineering Science, Osaka University, Osaka, Japan; Division of Information Science, Graduate School of Science and Technology, Nara Institute of Science and Technology (NAIST), Nara, Japan; Ritsumeikan University, Shiga, Japan	Industry 5.0 constitutes a change of paradigm where the increase of economic benefits caused by a never-ending increment of production is no longer the only priority. Instead, Industry 5.0 addresses social and planetary challenges caused or neglected in Industry 4.0 and below. One relevant the most relevant challenges of Industry 5.0 is the design of human-centered smart environments (i.e., that prioritize human well-being while maintaining production performance). In these environments, robots and humans will share the same space and collaborate to reach common objectives. This article presents a literature review of the different aspects concerning the problem of quality measurement in Human-Robot Interaction (HRI) applications for manufacturing environments. To help practitioners and new researchers in the area, this article presents an overview of factors, metrics, and measures used in the robotics community to evaluate performance and human well-being quality aspects in HRI applications. For this, we performed a systematic search in relevant databases for robotics (Science Direct, IEEE Xplore, ACM digital library, and Springer Link). We summarize and classify results extracted from 102 peerreviewed research articles published until March 2022 in two definition models: 1) a taxonomy of performance aspects and 2) a Venn Diagram of common human factors in HRI. Additionally, we briefly explain the differences between often confusing or overlapped concepts in the area. We also introduce common human factors evaluated by the robotics community and identify seven emergent research topics which can have a relevant impact on Industry 5.0.	Human-robot interaction Human-robot collaboration Metrics Robotics Industry 5.0 Society 5.0	Literature review	Quality 5.0	Human-robot	HR, well-being
2020	Peter Chemweno, Liliane Pintelon, Wilm Decre	Orienting safety assurance with outcomes of hazard analysis and risk assessment: A review of the ISO 15066 standard for collaborative robot systems	Department of Design, Production and Management, University of Twente, Drienerlolaan 5, 7522 NB Enschede, the Netherlands; Department of Mechanical Engineering, KU Leuven, Celestijnenlaan 300A, 3001 Heverlee, Belgium; Division RAM, Robotics Research Group, and Flanders Make@KU Leuven, Core Lab ROB, Celestijnenlaan 300A, 3001 Heverlee, Belgium	Close interactions with a human operator are an important safety concern for collaborative robot systems. For safety assurance, robot integrators are required to demonstrate that they have taken steps to identify potential hazards, which may be embedded in collaborative tasks, or embedded within the collaborative workspace. Consequently, design safeguards are developed to mitigate unintended contact, which may be hazardous to the human co-worker, while performing cooperative or collaborative tasks. The ISO 15066 standard proposes guidelines, which designers, integrators, and users need to consider when embedding passive and active safeguards on the robot system, or while designing collaborative workspaces. Importantly, the standard premises such safeguards on structured hazard analysis and risk assessment processes. However, from studies in literature, it is often unclear how designers, integrators or users can orient design safeguards to outcomes of hazard analysis and risk assessment. Often it is unclear which steps designers need to follow, or which methods they can use to analyze hazards and assess risks, which may occur when robot systems and human co-worker perform collaborative/cooperative manufacturing tasks. Consequently, verifying the sufficiency of design safeguards to mitigate hazardous interactions in a manufacturing cell is challenging. This article reviews requirements for safety assurance of collaborative robot systems discussed in the recent ISO 15066 standard for collaborative robots and how such safeguards are realized in studies discussed in literature. The review explores gaps and propose a framework based on the ISO 31000 for orienting design safeguards for collaborative robots to outcomes of hazard analysis and risk assessment.	Collaborative robots Hazard analysis Risk assessment Safety assurance	Literature review	Quality 5.0	Human-robot	Safety
2021	Ana Margarida Dias, André M. Carvalho, Paulo Sampaio	Quality 4.0: literature review analysis, definition and impacts of the digital transformation process on quality	School of Engineering, University of Minho, Guimaraes, Portugal; EIGeS - Research Centre in Industrial Engineering, Management and Sustainability, Universidade Lusofona, Lisboa, Portugal and Production and Systems Engineering, University of Minho, Braga, Portugal; Department of Production and Systems, University of Minho, Braga, Portugal	Purpose – The changes brought forth by the Digital Transformation have an impact on the way we think, assess and manage Quality. While the concept of Quality 4.0 has resulted from these changes, there is still limited understanding and unclear definitions in this new era of Quality Management. Design/methodology/approach – There is a clear opportunity to review and analyze the state-of-the-art of Quality 4.0, its main research efforts, topics and directions. To do so, a bibliometric analysis and descriptive/ mapping literature review were performed. Findings – There is a clear focus on the implications of technology for Quality, but other relevant topics include business management and strategy models and systems, as well as human or soft factors. Results reveal an increasing interest in Quality 4.0 as well as a link between topics. Originality/value – Together with the review, analysis and digest of the literature, we offer our own contribution to a commonly accepted definition Quality 4.0.	Quality 4.0, Technology, People, Business management	Literature review	Quality 4.0	Impact of Technology	Business management, strategy

Figure A.1: Preliminary literature review

2021	Afef Saihi, Mahmoud Awad and Mohamed Ben-Daya	Quality 4.0: leveraging Industry 4.0 technologies to improve quality management practices – a systematic review	Industrial Engineering Department, American University of Sharjah, Sharjah, United Arab Emirates	Purpose – Quality 4.0 is an emerging research topic concerned with rethinking how quality management needs to be adopted in the digital era. The purpose of this research is to conduct a systematic review on the state of the research in the field of Industry 4.0 impact on improving quality management aspects and how technology can be leveraged to enhance its practices. Design/methodology/approach – A systematic review of the literature published in the last 5 years is conducted. 52 papers were selected, mapped based on the technology they focused on and categorized based on the addressed quality aspects. Findings – The review revealed various areas where quality management can benefit from Industry 4.0 technologies, identified several research gaps and suggested new directions for future research. Firstly, the literature provided some insights about industry 4.0 potential contributions but lacks further detail on the exact applications and solutions through use cases and case studies. Secondly, there has been a focus on the potential benefits provided for quality control while there is a clear scarcity in terms of the other quality management tools and methodologies. Thirdly, there is a lack of studies on economic analysis or detailed impacts on quality costs that justifies the substantial investments needed. Finally, there is a need for including more studies about the mapping and integration of ISO 9001 requirements and Industry 4.0 features. Originality/value – This is the first attempt to conduct a comprehensive review on the ways industry 4.0 technologies can be leveraged for the field of quality management. Based on this review, several directions for further research in this area are identified.	Quality 4.0, Industry 4.0, Quality management, Internet of things, Big data, Machine learning, Quality control, Predictive quality, Decision making	Literature review	Quality 4.0	Impact of Technology	TQM tools, quality control
2022	Valentina Cillo, Gian Luca Gregori, Lucia Michela Daniele, Francesco Caputo and Nathalie Bitbol-Saba	Rethinking companies' culture through knowledge management lens during Industry 5.0 transition	Valentina Cillo is based at the Business Administration, Roma Tre University, Roma, Italy. Gian Luca Gregori is based at the Department of Management, Universita` Politecnica delle Marche, Ancona, Italy. Lucia Michela Daniele is based at the Department of Economics, University of Campania Luigi Vanvitelli, Capua, Italy. Francesco Caputo is based at the Department of Economics, Management and Institutionster Systems and Communications, Faculty of Informatics, University of Naples Federico II, Naples, Italy. Nathalie Bitbol-Saba is based at the Global Monetary & Financial Dynamics, Paris School of Business, Paris, France.	Purpose – Through the human resources (HR) and knowledge management (KM) perspective as human-centric processes, the aim of this study is to explore how companies' engagement in diversity (DIV), inclusion (INC) and people empowerment (PEMP) policies influences companies' organizational performance, to support organizations in the shift to the Industry 5.0 framework. Design/methodology/approach – Combining the HR management and the KM-driven organizational culture, a conceptual model is proposed for explaining companies' higher organizational performance. Proposed hypotheses are tested with reference to a set of listed international companies traced by Refinitiv on a five-year time horizon (2016–2020) through 24,196 firm-year observations. Findings – This research shows that companies engaged in DIV policies, INC practices and PEMP through education have higher profitability and are more valued by capital markets' investors. Originality/value – This paper draws attention to the need to overcome the reductionist view of HR and rethink KMarchitecture to cope with the growing challenge of HR integration according to the Industry 5.0 paradigm.	Sustainable development, Knowledge management, Human resource management, Companies' culture, Companies' performance-driven culture	Quantitative analysis using secondary data	Quality 5.0	Dievrsity, inclusion	Profitability
2022	Jiju Antony, Olivia McDermott, Daryl Powell, Michael Sony	The evolution and future of lean Six Sigma 4.0	Industrial and Systems Engineering, Khalifa University, Abu Dhabi, United Arab Emirates; College of Science and Engineering, National University of Ireland, Galway, Ireland; SINTEF Manufacturing AS, Horten, Norway; WITS Business School, University of Witwatersrand, Johannesburg, South Africa	Purpose – This purpose of this study is to provide an overview of the current state of research on Lean Six Sigma (LSS) and Industry 4.0 and the key aspects of the relationships between them. The research analyses LSS's evolution and discusses the future role of LSS 4.0 in an increasingly digitalized world. We present the benefits and motivations of integrating LSS and Industry 4.0 as well as the critical success factors and challenges within this emerging area of research. Design/methodology/approach – A systematic literature review methodology was established to identify, select and evaluate published research. Findings – There is a synergistic nature between LSS and Industry 4.0. Companies having a strong LSS culture can ease the transition to Industry 4.0 while Industry 4.0 technologies can provide superior performance for companies who are using LSS methodology. Research limitations/implications – One limitation of this research was that as this area is a nascent area, the researchers were limited in their literature review and research. A more comprehensive longitudinal study would yield more data. There is an opportunity for further study and analysis. Practical implications – This study reviews the evolution of LSS and its integration with Industry 4.0. Organisations can use this study to understand the benefits and motivating factors for integrating LSS and Industry 4.0, the Critical Success Factors and challenges to such integration. Originality/value – This is the first systematic literature review on LSS 4.0 and can provide insight for practitioners, organisations and future research directions.	Lean six sigma, Industry 4.0, Continuous improvement, Lean and green	Literature review	Quality 4.0/5.0	Lean Six Sigma	Green, transition
2021	Nicole Berx, Liliane Pintelon, Wilm Decré	Psychosocial Impact of Collaborating with an Autonomous Mobile Robot	Mechanical Engineering, KU Leuven	The study was part of a confidential pilot project concerning the introduction of Autonomous Mobile Robots (AMRs) in an order picking process. The study assesses the impact of working with an AMR on logistics workers (hereinafter referred to as 'operators'). Two research questions were investigated. First, does working with an AMR lead to increased psychosocial workload? And second, what is the perception of the operators working with an AMR? Very little research, outside a lab context, has been done so far on the impact of working with an AMR. This study contributes to the understanding of the impact of working with robots, outside the lab in an industrial setting. The results of this study can be summarized as follows: 1) working with an AMR does not lead to extra psychosocial workload and 2) there is a positive perception and attitude versus working with an AMR.	Human Robot Interaction, Autonomous Mobile Robots, Warehouse Automation	Exploratory Case Study	Quality 5.0	Human-robot	Impact of working with an AMR

Figure A.2: Preliminary literature review

2020	Ocident Bongomin, Aregawi Yemane , Brendah Kembabazi, Clement Malanda, Mwewa Chikonkolo Mwape, Nonsikelelo Sheron Mpofu, and Dan Tigalana	Industry 4.0 Disruption and Its Neologisms in Major Industrial Sectors: A State of the Art	Department of Manufacturing, Industrial and Textile Engineering, School of Engineering, Moi University, P.O. Box 3900-30100, Eldoret, Kenya Department of Industrial Engineering, Mekelle University, P.O. Box 231, Mek'ele, Ethiopia Department of Animal Science, Faculty of Agriculture, Egerton University, P.O. Box 536-20115, Nakuru, Kenya Department of Applied Studies, Malawi University of Science and Technology, P.O. Box 5196, Limbe, Malawi Department of Mechanical, Production and Energy Engineering, School of Engineering, Moi University, P.O. Box 3900-30100, Eldoret, Kenya Department of Renewable Energy, Zambia Electricity Supply Corporation Limited (ZESCO), P.O. Box 33304-10101, Lusaka, Zambia Department of Fibre, Polymer and Materials Engineering, P.O. Box AC939, Bulawayo, Zimbabwe Department of Polymer, Industrial and Textile Engineering, Faculty of Engineering, Busitema University, P.O. Box 236, Tororo, Uganda	Very well into the dawn of the fourth industrial revolution (industry 4.0), humankind can hardly distinguish between what is artificial and what is natural (e.g., man-made virus and natural virus). Thus, the level of discombobulation among people, companies, or countries is indeed unprecedented. The fact that industry 4.0 is explosively disrupting or retrofitting each and every industrial sector makes industry 4.0 the famous buzzword amongst researchers today. However, the insight of industry 4.0 disruption into the industrial sectors remains ill-defined in both academic and nonacademic literature. The present study aimed at identifying industry 4.0 neologisms, understanding the industry 4.0 disruption and illustrating the disruptive technology convergence in the major industrial sectors. A total of 99 neologisms of industry 4.0 were identified. Industry 4.0 disruption in the education industry (education 4.0), energy industry (energy 4.0), agriculture industry (agriculture 4.0), healthcare industry (healthcare 4.0), and logistics industry (logistics 4.0) was described. The convergence of 12 disruptive technologies including 3D printing, artificial intelligence, augmented reality, big data, blockchain, cloud computing, drones, Internet of Things, nanotechnology, robotics, simulation, and synthetic biology in agriculture, healthcare, and logistics industries was illustrated.The study divulged the need for extensive research to expand the application areas of the disruptive technologies in the industrial sectors.	Industry 4.0, Quality 4.0, disruptive technologies, 3D printing, artificial intelligence, augmented reality, big data, blockchain, cloud computing, drones, Internet of Things, nanotechnology, robotics, simulation, etc.	Literature review	Quality 4.0	Tecnology	Applications
2019	Guilherme Luz Tortorella, Matteo Rossini, Federica Costa, Alberto Portioli Staudacher & Rapinder Sawhney	A comparison on Industry 4.0 and Lean Production between manufacturers from emerging and developed economies	Universidade Federal de Santa Catarina, Florianópolis, Brazil; Management, economics and industrial engineering, Politecnico di Milano, Milan, Italy; University of Tennessee, Knoxville, TN, USA	This study examines the differences in implementation level of both Industry 4.0 (I4.0) and Lean Production (LP), whose integration is denoted here as Lean Automation (LA), between manufacturers located in emerging and developed economies. A survey-based research was carried out with a total of 249 Brazilian (emerging economy) and Italian (developed economy) companies that are implementing LP and have initiated the adoption of I4.0 technologies. Collected data was analysed through multivariate data techniques. Results indicate that the socio-economic context where companies are located does influence the extension of LA implementation. However, they also suggest that, if properly managed, a high level of LA implementation is feasible regardless the socio-economic barriers and challenges that manufacturers may face. Further, companies' characteristics that favour higher LA levels might also vary between emerging and developed economies, emphasising the importance of a clear understanding of the socio-economic specificities of the contexts. This study sheds light on how pervasive LA implementation can be in manufacturers from both socioeconomic contexts. Moreover, these outcomes demystify assumptions related to management approaches that may only prevail if certain socio-economic conditions are present. This evidence is especially important for multinational companies that seek for highly competitive standards across all their sites.	Lean automation; Industry 4.0; Lean Production; developed economies; emerging economies; lean manufacturing	Survey research	Quality 4.0	Lean	Impelemntation in different socio-economic contexts
2021	Sami Sader, Istvan Husti & Miklos Daroczi	A review of quality 4.0: definitions, features, technologies, applications, and challenges	Doctoral School of Mechanical Engineering, Szent Istvan University, Godollo, Hungary; Institute of Engineering Management, Szent Istvan University, Godollo, Hungary	Quality 4.0 is a new term representing a new featured approach to quality management. The recent development in information and communication technologies resulted in a great leap in Industry, causing the emergence of what is called 'Industry 4.0'. The term '4.0' has been attached to other fields such as Quality 4.0, Agriculture 4.0, Agribusiness 4.0, Service 4.0, Logistics 4.0, Health 4.0. etc., all representing the impact of Industry 4.0 on these terms. In the meanwhile, Quality 4.0 hasn't been adequately discussed from a scientific perspective; few journal articles pointed out 'Quality 4.0' but without a comprehensive interpretation for the scientific foundations behind it. Therefore, this paper suggested a comprehensive, hybrid and balanced definition for Quality 4.0. The paper suggested that Quality 4.0 is an extended approach to quality management, where recent technologies are being integrated with traditional quality practices (QC, QA, TQM) to expand the quality management scope and to improve quality activities. The paper also identified Quality 4.0 features, technologies, and applications. Moreover, the paper highlighted the challenges and future research topics in the context of Quality 4.0.	quality 4.0; industry 4.0; quality management; TQM; big data; intelligent quality	Literature review	Quality 4.0		

Figure A.3: Preliminary literature review

2023	Tim Komkowski, Jiju Antony, Jose Arturo Garza-Reyes, Guilherme Luz Tortorella & Tanawadee Pongboonchai-Empl	A systematic review of the integration of Industry 4.0 with quality-related operational excellence methodologies	Edinburgh Business School, Heriot-Watt University, Edinburgh, UK; Industrial and Systems Engineering, Khalifa University, Abu Dhabi, UAE; Centre for Supply Chain Improvement, University of Derby, Derby, UK; Department of Management Studies, Graphic Era Deemed to be University, Dehradun, India; Department of Mechanical Engineering, The University of Melbourne, Melbourne, Australia	This study examines the common themes for integrating Industry 4.0 with quality-related operational excellence methodologies to provide a comprehensive overview of "what" and "how" to combine them in an initial integration process. In addition, the gaps in the present literature are aggregated, and a research plan for the future is proposed. The study is based on a systematic review of 37 papers published in academic journals between 2015 and 2021. Unlike previous reviews, this study concentrates on the "what" and "how" level of total quality management, Lean Six Sigma, and business process management as quality related operational excellence methodologies integrated with Industry 4.0 to provide a practical perspective when executing their integration and implementation. Findings indicate a strong technical and data-driven integration focus across the three themes. Furthermore, modes of action as moderators of success were derived as initial variables to be included in quality-driven Industry 4.0 transitions. Identifying gaps in the present literature and defining a research agenda centered on operational principles opens up opportunities for future study with significant practical value.	business process management; Industry 4.0; integration; Lean Six Sigma; systematic literature review; total quality management; transformation	Literature review	Quality 4.0	Lean Six Sigma, TQM	Implementation
2022	Marina Crnjac Zizic, Marko Mladineo, Nikola Gjeldum and Luka Celent	From Industry 4.0 towards Industry 5.0: A Review and Analysis of Paradigm Shift for the People, Organization and Technology	Faculty of Electrical Engineering, Mechanical Engineering and Naval Architecture, University of Split, Croatia; School of Mechanical and Design Engineering, University of Portsmouth, Portsmouth PO1 3DJ, UK	The industry is a key driver of economic development. However, changes caused by introduction of modern technologies, and increasing complexity of products and production, directly affect the industrial enterprises and workers. The critics of the Industry 4.0 paradigm emphasized its orientation to new technologies and digitalization in a technocratic way. Therefore, the new industrial paradigm Industry 5.0 appeared very soon and automatically triggered a debate about the role of, and reasons for applying, the new paradigm. Industry 5.0 is complementing the existing Industry 4.0 paradigm with the orientation to the worker who has an important role in the production process, and that role has been emphasized during the COVID-19 pandemic. In this research, there is a brief discussion on main drivers and enablers for introduction of these new paradigms, then a literature-based analysis is carried out to highlight the differences between two paradigms from three important aspects—people, organization, and technology. The conclusion emphasizes the main features and concerns regarding the movement towards Industry 5.0, and the general conclusion is that there is a significant change of the main research aims from sustainability towards human-centricity. At the end, the analysis of maturity models that evaluates enterprises' readiness to introduce features of new paradigms is given as well.	4.0; Industry 5.0; people; Operator 5.0; organization; technology; COVID-19	Literature review	Quality 5.0	Human-centricity, sustainability	Organizational rediness
2022	Dimitris Mourtzis, John Angelopoulos and Nikos Panopoulos	A Literature Review of the Challenges and Opportunities of the Transition from Industry 4.0 to Society 5.0	Laboratory for Manufacturing Systems and Automation, Department of Mechanical Engineering and Aeronautics, University of Patras, 26504 Rio Patras, Greece	In the era of Industry 4.0, manufacturing and production systems were revolutionized by increasing operational efficiency and developing and implementing new business models, services, and products. Concretely, the milestone set for Industry 4.0 was to improve the sustainability and efficiency of production systems. By extension, the emphasis was focused on both the digitization and the digitalization of systems, providing room for further improvement. However, the current technological evolution is more system/machine-oriented, rather than human-oriented. Thus, several countries have begun orchestrating initiatives towards the design and development of the humancentric aspect of technologies, systems, and services, which has been coined as Industry 5.0. The impact of Industry 5.0 will extend to societal transformation, which eventually leads to the generation of a new society, the Society 5.0. The developments will be focused on the social and human-centric aspect of the tools and technologies introduced under the framework of Industry 4.0. Therefore, sustainability and human well-being will be at the heart of what comes next, the Industry 5.0, as a subset of Society 5.0. Industry 5.0 will build on the foundations laid during Industry 4.0 by emphasizing human-centered, resilient, and sustainable design. Consequently, the authors in this research work, through a critical literature review, aim to provide adequate reasoning for considering Industry 5.0 as a framework for enabling the coexistence of industry and emerging societal trends and needs. The contribution of this research work extends to the provision of a framework to facilitate the transition from Industry 4.0 to Society 5.0.	Industry 5.0; Society 5.0; human-centricity; resilience; sustainability	Literature review	Society 5.0	Challanges, opportunities	Human-centred, resilient, sustainable
2023	Phuoc-Luong Le & Duy-Tan Nguyen	Exploring Lean Practices' Importance in Sustainable Supply Chain Management Trends: An Empirical Study in Canadian Construction Industry	Ho Chi Minh City University of Technology (HCMUT, Vietnam National University (VNU-HCM), HEC Montréal, Canada	To contend with the current economic conditions, construction managers are recommended to identify sustainable construction supply chain management (CSCM) trends over the forthcoming years and adopt suitable techniques to manage construction projects strategically, tactically, and operationally. However, there is a shortage of studies exploring Lean Construction (LC) practices' contributions to sustainable CSCM trends in the forthcoming years. Thus, this paper applies the integrated fuzzy AHP–Delphi approach to identify key sustainable CSCM trends and uses them as strategic evaluation criteria to assess and rank LC techniques. The evaluation was done by 28 experts having more than four years' experience and expertise in lean construction and sustainable CSCM. This work also provides managerial implications by proposing a framework for LC techniques to advance sustainability throughout construction project phases.	Supply Chain Management, Construction Industry, Lean Construction, Sustainable Construction, Sustainability Trends	Integrated fuzzy Analytic Hierarchy Process (AHP)–Delphi approach	Quality 4.0/5.0	Sustainability, lean, supply chain management	Construction industry

Figure A.4: Preliminary literature review

2022	Jože M. Rožanec, Inna Novalija, Patrik Zajec, Klemen Kenda, Hooman Tavakoli Ghinani, Sungho Suh, Entso Veliou, Dimitrios Papamartzivanos, Thanassis Giannetsos, Sofia Anna Menesidou, Ruben Alonso, Nino Cauli, Antonello Meloni, Diego Reforgiato Recupero, Dimosthenis Kyriazis, Georgios Sofianidis, Spyros Theodoropoulos, Blaž Fortuna, Dunja Mladenić & John Soldatos	Human-centric artificial intelligence architecture for industry 5.0 applications	Jožef Stefan International Postgraduate School, Ljubljana, Slovenia; Qlector d.o.o., Ljubljana, Slovenia; German Research Center for Artificial Intelligence (DFKI), Kaiserslautern, Germany; Department of Informatics and Computer Engineering, University of West Attica, Egaleo, Athens, Greece; Digital Security & Trusted Computing Group, Ubitech Ltd., Athens, Greece; gR2M Solution Srl, Pavia, Italy; Department of Computer Science, University of Cagliari, Cagliari, Italy; Department of Digital Systems, University of Piraeus, Piraeus, Greece;Department of Electrical and Computer Engineering, National Technical University of Athens, Athens, Greece; Intrasoft International, Peania, Greece	Human-centricity is the core value behind the evolution of manufacturing towards Industry 5.0. Nevertheless, there is a lack of architecture that considers safety, trustworthiness, and human-centricity at its core. Therefore, we propose an architecture that integrates Artificial Intelligence (Active Learning, Forecasting, Explainable Artificial Intelligence), simulated reality, decision-making, and users' feedback, focussing on synergies between humans and machines. Furthermore, we align the proposed architecture with the Big Data Value Association Reference Architecture Model. Finally, we validate it on three use cases from real-world case studies.	Smart manufacturing; explainable artificial intelligence (XAI); active learning; demand forecasting; quality inspection	Conceptual framework development, architectural design, and validation through real-world case studies	Quality 5.0	Human-centricity, safety, trustworthiness	AI architecture
2022	Maja Glogovac, Jelena Ruso & Milica Maricic	ISO 9004 maturity model for quality in industry 4.0	Department of Quality Management and Standardization, Faculty of Organizational Sciences, University of Belgrade, Belgrade, Serbia; Department of Operations Research and Statistics, Faculty of Organizational Sciences, University of Belgrade, Belgrade, Serbia	It is believed that Industry 4.0., as an integration of business and technologies, can significantly improve companies' process performances and their innovation. However, most companies are not aware or not capable of assessing their Industry 4.0 maturity level. Since many considerations on Industry 4.0 successfulness include elements of the quality management system, ISO 9004:2018 guidance for achieving sustained success is considered in this paper as a possible basis for assessment of maturity level of quality in Industry 4.0, framed as Quality 4.0. The questionnaire with a sample size of 335 companies is used to explore the topic. Confirmatory factor analysis (CFA) and Structural equation modelling (SEM) were used to verify the ISO 9004:2018 model potential to be used for assessing Quality 4.0 maturity level. Results show that the Context of an organisation positively impacts the Identity of an organisation and Leadership. Therewithal, the Identity of an organisation is recognised to be a positive influencing predictor of Leadership that is proved to be a positive predictor of Process management and Resource management. Furthermore, Resource management is proved to have a positive impact on Performance analysis and evaluation as well on Improvement, learning and innovation construct. The findings indicate the model is usable in the context of Quality 4.0. Such a model could be utilised as a basis for developing a sustainable Quality 4.0 system roadmap.	Industry 4.0; Quality 4.0; maturity level; ISO 9004:2018; structural equation modelling; conceptual model; quality management system roadmap	Questionnaire-based survey	Quality 4.0	Organizational rediness, maturty level	Sustainable quality roadmap development
2022	Ikram Ait Hammou, Salah Oulfarsi	Lean Six Sigma tools and sustainable performance measurments : A Review	National School of Commerce and Management, Chaouaïb Doukkali University, El Jadida, Morocco	In today's highly competitive business world, firms are constantly trying to rethink their processes in order to attain customer satisfaction and thus the highest levels of profitability. However, the increasingly high requirements of customers, the government, and other stakeholders have led to new hurdles in achieving more sustainable operations that incorporate social and environmental issues into production processes, while also achieving high levels of profitability. Lean Six Sigma (LSS) is a method that has been proven to be effective for companies in order to attain sustainable performance goals. However, few studies have been devoted to reviewing the literature in order to identify the most commonly used LSS tools in the context of sustainability, as well as the different measures used to assess the economic, social and environmental outcomes that result from the use of the LSS approach. Thus, the objective of this paper is to conduct an in-depth literature review to present and synthesize the main results of previous studies on the impact of LSS tools on companies' sustainable performance pillars. The main finding of this literature review was that there are four categories of studies that have presented the relationship between the LSS approach and the concept of sustainability. Furthermore, the most used LSS tools in the context of sustainability have been identified, among which VSM, Cause and effect diagram, Pareto analysis, 5S, DoE, DMAIC and 5 why analysis. In addition, some of the least used LSS tools in the literature are TQM, Process Sigma Calculation, Consumption analysis, Cost-benefit analysis, SOPs and JIT. We also concluded that among the three dimensions of sustainable performance, the number of social performance measurements used is the highest.	Lean Six Sigma, tools, sustainable performance, measurements	Literature review	Quality 4.0/5.0	Lean Six Sigma	VSM, Cause and effect diagram, Pareto analysis, 5S, DoE, DMAIC and 5 why analysis, TQM, Process Sigma Calculation, Consumption analysis, Cost-benefit analysis, SOPs and JIT.

Figure A.5: Preliminary literature review

2023	Jakub Pizon and Arkadiusz Gola	Human–Machine Relationship—Perspective and Future Roadmap for Industry 5.0 Solutions	Department of Enterprise Organization, Faculty of Management, Lublin University of Technology, ul. Nadbystrzycka 38, 20-618 Lublin, Poland; Department of Production Computerization and Robotization, Faculty of Mechanical Engineering, ul. Nadbystrzycka 36, 20-618 Lublin, Poland	The human–machine relationship was dictated by human needs and what technology was available at the time. Changes within this relationship are illustrated by successive industrial revolutions as well as changes in manufacturing paradigms. The change in the relationship occurred in line with advances in technology. Machines in each successive century have gained new functions, capabilities, and even abilities that are only appropriate for humans—vision, inference, or classification. Therefore, the human–machine relationship is evolving, but the question is what the perspective of these changes is and what developmental path accompanies them. This question represents a research gap that the following article aims to fill. The article aims to identify the status of change and to indicate the direction of change in the human–machine relationship. Within the framework of the article, a literature review has been carried out on the issue of the human–machine relationship from the perspective of Industry 5.0. The fifth industrial revolution is restoring the importance of the human aspect in production, and this is in addition to the developments in the field of technology developed within Industry 4.0. Therefore, a broad spectrum of publications has been analyzed within the framework of this paper, considering both specialist articles and review articles presenting the overall issue under consideration. To demonstrate the relationships between the issues that formed the basis for the formulation of the development path.	Human–machine relationship; human–machine collaboration; human-orientedmanufacturing; Industry 5.0; human factor		Quality 5.0	Human-machine	Status of change, direction of change, future roadmap
2023	Pavel Klaput, Radim Hercik, Zdeněk Macháček, Darja Noskievičová, Vladimír Dostál & David Vykydal	Mutual combination of selected principles and technologies of Industry 4.0 and quality management methods - case study	Faculty of Materials Science and Technology, VSB-TUO, Ostrava, Czech Republic; Faculty of Electrical Engineering and Computer Science, VSB-TUO, Ostrava, Czech Republic; cIdeaHub, z. s., the shared development center in Science and Technology Park, Ostrava-Pustkovec, Czech Republic	In this paper, the application of Failure Mode and Effects Analysis (FMEA) on the testbed "Smart Factory Line" is described. The study aims to verify the feasibility and applicability of FMEA on complex technical systems and demonstrate the integration of Industry 4.0 principles and technologies with quality management methods. The paper includes an extensive literature review of related topics such as mass customization, individualization, Industry 4.0, Quality 4.0, and fault management. Emphasis is placed on the team cooperation of experts from different specializations. The importance of testbeds as platforms for bridging academia and practice is also highlighted. The practical integration of the smart factory testbed design and its products with a new FMEA approach, based on the harmonized AIAG and VDA manual, provides insights into the realization of smart factories and the significance of building Quality 4.0. Additionally, it emphasizes the need for interdisciplinary education of technicians and quality specialists for Industry 4.0.	Industry 4.0; fault management; FMEA; Quality 4.0; testbed	Literature review and case study	Quality 4.0/5.0	FMEA	Interdisciplinary education
2022	Bas van Oudenhoven , Philippe Van de Calseyde , Rob Basten and Evangelia Demerouti	Predictive maintenance for industry 5.0: behavioural inquiries from a work system perspective	School of Industrial Engineering, Eindhoven University of Technology, Eindhoven, Netherlands	Predictive Maintenance (PdM) solutions assist decision-makers by predicting equipment health and scheduling maintenance actions, but their implementation in industry remains problematic. Specifically, prior research repeatedly indicates that decision-makers often refuse to adopt the data-driven, system-generated advice in their working procedures. In this paper, we address these acceptance issues by studying how PdM implementation changes the nature of decision-makers' work and how these changes affect their acceptance of PdM systems. We build on the human-centric Smith-Carayon Work System model to synthesise literature from research areas where system acceptance has been explored in more detail. Consequently, we expand the maintenance literature by investigating the human-, task-, and organisational characteristics of PdM implementation. Following the literature review, we distil ten propositions regarding decision-making behaviour in PdM settings. Next, we verify each proposition's relevance through in-depth interviews with experts from both academia and industry. Based on the propositions and interviews, we identify four factors that facilitate PdM adoption: trust between decision-maker and model (maker), control in the decisionmaking process, availability of sufficient cognitive resources, and proper organisational allocation of decision-making. Our results contribute to a fundamental understanding of acceptance behaviour in a PdM context and provide recommendations to increase the effectiveness ofPdMimplementations.	Behavioural operations management; decision support systems; human–computer interaction; human factors; predictive maintenance; Industry 5.0	Literature review and interviews	Quality 5.0	Predictive maintanance	Acceptance, effectiveness, attitudes

Figure A.6: Preliminary literature review

2022	Shuki Dror	QFD for selecting key success factors in the implementation of quality 4.0	Department of Industrial Engineering and Management, ORT Braude College, Karmiel, Israel	Industry 4.0 technological advancements over the last few years have generated a variety of interchangeable methods for achieving quality objectives. The present study seeks to create a framework that will facilitate the selection of key success factors in the implementation of Quality 4.0. Since the ways in which Quality 4.0 technologies can interact present a new industrial reality, our prioritization program addresses the synergy that can exist between technologies. The current study presents the development of a Quality Function Deployment (QFD) methodology for the effective implementation of Quality 4.0. The methodology extracts the desired improvements in quality objectives and translates them into the important Quality 4.0 technologies and, ultimately, into core implementation barriers that need to be reduced, ranked by importance. Normalized improvement scores were calculated at each of three hierarchical levels: quality objectives, Quality 4.0 technologies, and implementation barriers. The components to be improved at each level were selected using the Mean Square Error (MSE) criterion. The methodology was implemented in a food processing company. The vital few quality objectives to be improved were found to be stable quality, equipment reliability, customer satisfaction, and product related complaints. The most important technologies to be considered are big data, enabling technologies, statistics and datamining, and artificial intelligence. Concerns regarding cyber security and outdated systems/infrastructure are the most significant barriers to Quality 4.0 implementation.	QFD, Quality 4.0, quality objectives, technology implementation		Quality 4.0	QFD	Effective implementation of Quality 4.0
2020	Anders Fundin, Johan Lilja, Yvonne Lagrosen & Bjarne Bergquist	Quality 2030: quality management for the future	SIQ – The Swedish Institute for Quality, Drakegatan 6, SE 412 50, Gothenburg, Sweden; Department of Quality Management and Mechanical Engineering, Mid Sweden University, Östersund, Sweden; School of Innovation, Design and Engineering, Mälardalen University, Eskilstuna, Sweden; Business Administration and Industrial Engineering, Luleå University of Technology, Luleå, Sweden	Quality management (QM) has shown an impressive ability to update and evolve. The purpose of this paper is to highlight themes that have been identified as vital and important for research projects within QM during the coming decade. The paper is also an attempt to initiate research for the emerging 2030 agenda for QM, here referred to as 'Quality 2030'. This article is based on extensive data gathered during a workshop process conducted in two main steps: (1) a collaborative brainstorming workshop with 22 researchers and practitioners (spring 2019) and (2) an appreciative inquiry summit with 20 researchers and practitioners (autumn 2019). The process produced five collectively elaborated and designed future research themes for QM: (a) systems perspectives applied, (b) stability in change, (c) models for smart self-organising, (d) integrating sustainable development, and (e) higher purpose as QM booster. The process also identified a positive core of QM, defined as core values and aspects in the field and practice that need to be preserved and nurtured in the future.	Quality management; Agenda 2030; sustainable development; complex systems; higher purpose; self-organisation; systems theory; Quality 5.0	A collaborative brainstorming workshop and an appreciative inquiry summit	Quality 5.0	Future	Trends
2022	Parkash Tambare, Chandrashekhar Meshram, Cheng-Chi Lee, Rakesh Jagdish Ramteke and Agbotiname Lucky Imoize	Performance Measurement System and Quality Management in Data-Driven Industry 4.0: A Review	Water Resources & Applied Mathematics Research Lab, Nagpur 440027, Maharashtra, India; Department of Post Graduate Studies and Research in Mathematics, Jaywanti Haksar Govt. Post-Graduation College, College of Chhindwara University, Betul 460001, Madhya Pradesh, India; Department of Library and Information Science, Research and Development Center for Physical Education, Health, and Information Technology, Fu Jen Catholic University, New Taipei 24205, Taiwan; Department of Computer Science and Information Engineering, Asia University, Wufeng Shiang, Taichung 41354, Taiwan; School of Computer Sciences, KBC North Maharashtra University, P.B. No.80, Umavinagar, Jalgaon 425001, Maharashtra, India; Department of Electrical and Electronics Engineering, Faculty of Engineering, University of Lagos, Akoka, Lagos 100213, Nigeria; Department of Electrical Engineering and Information Technology, Institute of Digital Communication, Ruhr University, 44801 Bochum, Germany	The birth of mass production started in the early 1900s. The manufacturing industries were transformed from mechanization to digitalization with the help of Information and Communication Technology (ICT). Now, the advancement of ICT and the Internet of Things has enabled smart manufacturing or Industry 4.0. Industry 4.0 refers to the various technologies that are transforming the way we work in manufacturing industries such as Internet of Things, cloud, big data, AI, robotics, blockchain, autonomous vehicles, enterprise software, etc. Additionally, the Industry 4.0 concept refers to new production patterns involving new technologies, manufacturing factors, and workforce organization. It changes the production process and creates a highly efficient production system that reduces production costs and improves product quality. The concept of Industry 4.0 is relatively new; there is high uncertainty, lack of knowledge and limited publication about the performance measurement and quality management with respect to Industry 4.0. Conversely, manufacturing companies are still struggling to understand the variety of Industry 4.0 technologies. Industrial standards are used to measure performance and manage the quality of the product and services. In order to fill this gap, our study focuses on how the manufacturing industries use different industrial standards to measure performance and manage the quality of the product and services. This paper reviews the current methods, industrial standards, key performance indicators (KPIs) used for performance measurement systems in data-driven Industry 4.0, and the case studies to understand how smart manufacturing companies are taking advantage of Industry 4.0. Furthermore, this article discusses the digitalization of quality called Quality 4.0, research challenges and opportunities in data-driven Industry 4.0 are discussed.	4.0; Internet of Things;Quality 4.0; performancemeasurement system; cyber–physical production system	Literature review and case studies	Quality 4.0	Current methods, industraial standards, KPI's	Challanges and opportunities

Figure A.7: Preliminary literature review

2022	Alessandro Massaro	Advanced Control Systems in Industry 5.0 Enabling Process Mining	LUM Enterprise S.r.l., S.S. 100-Km.18, Parco il Baricentro, 70010 Bari, Italy; Dipartimento di Management, Finanza e Tecnologia, LUM—Libera Università Mediterranea "Giuseppe Degennaro", S.S. 100-Km.18, Parco il Baricentro, 70010 Bari, Italy	This paper merges new research topics in Industry 5.0 using the Business Process Modeling and Notation (BPMN) approach able to integrate Artificial Intelligence (AI) in production processes. The goal is to provide an innovative approach to model production management in industry, adopting a new "proof of concept" of advanced Process Mining (PM) automatizing decisions and optimizing machine setting and maintenance interventions. Advanced electronic sensing and actuation systems, integrating supervised and unsupervised AI algorithms, are embedded in the PM model as theoretical process workflows suggested by a Decision Support System (DSS) engine enabling an intelligent decision-making procedure. The paper discusses, as examples, two theoretical models applied to specific industry sectors, such as food processing and energy production. The proposed work provides important elements of engineering management related to the digitalization of production process matching with automated control systems setting production parameters, thus enabling the self-adapting of product quality supervision and production efficiency in modern industrial systems.	Process Mining; Industry 5.0; self-adaptive machine parameter setting; BPMN process workflows; Artificial Intelligence	Conceptual approach and theoretical modeling	Quality 5.0	Automated Control Systems	Engineering management
2022	Kashif Ali & Satirenjit Kaur Johl	Soft and hard TQM practices: future research agenda for industry 4.0	Management sciences, Universiti Teknologi PETRONAS, Seri Iskandar, Malaysia	The primary objective of this study is to examine the present literature of Total Quality Management (TQM) and its connection with industry 4.0. The author tried to understand what subject and problems might be deemed more relevant, referring to the so-called Quality 4.0, which is absent from the literature to open avenues for further research. To achieve the primary objective, the author reviewed the literature on TQM from the objective (soft) and subjective (hard) perspectives, followed by identifying the critical success factors and future research avenues for researchers. A total of 87 empirical studies from 1987–2019 were studied. The descriptive and thematic analysis identified the soft and hard total quality management practices. A quality tool, 'Pareto Analysis', was applied to soft and hard TQM practices. The comprehensive review identified 23 soft and 15 hard TQM practices in the manufacturing and services sectors. The findings revealed four soft dimensions for the effective implementation of Quality 4.0 in business: Top management commitment, customer focus, training and learning, and quality of big data and analysis. Furthermore, three hard dimensions revealed the effective implementation of Quality 4.0: process management, continuous improvement, and product/service design.	Hard total quality management; soft total quality management; Quality 4.0; critical success factors; industry 4.0	Literature review	Quality 4.0	Soft and hard factors for effective implementation	Top management commitment, customer focus, training and learning, quality of big data and analysis, process management, continuous improvement, and product/service design
2023	Bojana Bajic, Nikola Suzic, Slobodan Moraca, Miladin Stefanovi´c, Milos Jovicic and Aleksandar Rikalovic	Edge Computing Data Optimization for Smart Quality Management: Industry 5.0 Perspective	Department of Industrial Engineering and Management, University of Novi Sad, 21000 Novi Sad, Serbia; Institute for Artificial Intelligence Research and Developments of Serbia, 21000 Novi Sad, Serbia; Department of Industrial Engineering, University of Trento, 38123 Trento, Italy; Center for Quality, Faculty of Engineering, University of Kragujevac, 34000 Kragujevac, Serbia	In the last decade, researchers have focused on digital technologies within Industry 4.0. However, it seems that the Industry 4.0 hype did not meet industry expectations due to various implementation challenges. In response, Industry 5.0 proposes a human-centric approach to implementing sustainable digital technologies for smart quality improvement. One crucial aspect of digital sustainability is reducing the energy consumption of digital technologies. This can be achieved through optimizing energy efficiency and addressing data center power consumption. Building upon the features of Industry 4.0, this research develops a conceptual model to promote Industry 5.0. The model aims to optimize data while retaining significant information contained in big data. It leverages edge computing, which serves as an enabler for Industry 5.0, providing timely and meaningful insights into the system for real-time decision-making. The model also strives to optimize data storage and create conditions for rationalizing power and processing resources. Additionally, the proposed model contributes to Industry 5.0 from a social aspect by considering not only the knowledge of experienced engineers but also the insights of workers operating the machines. The research conducted a proof-of-concept industrial application using manufacturing data from the process industry. Through this application, the amount of data was reduced by 99.73% without losing significant information contained in big data.	Human-cyber-physical systems (HCPS); big data analytics (BDA); Industrial Internet of Things (IIoT); smart quality management; digital sustainability; data optimization	Conceptual model development, proof-of-concept industrial application	Quality/Industry 5.0	Edge computing, data optimization	Human-centred

Figure A.8: Preliminary literature review

2023	Marta Christina Suciu, Doru Alexandru Plesea, Adrian Petre, Adrian Simion, Mircea Ovidiu Mituca, Decebal Dumitrescu, Ana Maria Bocaneala, Ramona Madalina Moroianu and Diana Florentina Nasulea	Core Competence—As a Key Factor for a Sustainable, Innovative and Resilient Development Model Based on Industry 5.0	Economics I Doctoral School, The Bucharest University of Economic Studies, 010374 Bucharest, Romania; Interdisciplinary Research Group, Romanian Academy, Calea Victoriei 129, 010071 Bucharest, Romania; Complexity Research Center, National Institute of Economic Research, 13 Septembrie 13, 050711 Bucharest, Romania; Romanian Academy of Scientists, Ilfov 3, 050094 Bucharest, Romania; Business Administration Doctoral School, The Bucharest University of Economic Studies, 010374 Bucharest, Romania	The main objective of this paper is to highlight the importance of core competences as an important catalyst to enable a sustainable transition of business models to Industry 5.0. According to our research based on a scientific methodology, we illustrated that Industry 4.0 might greatly affect the labor market by introducing ITC, AI, IR, and AR that will change many jobs in most areas of activity. One alternative solution to diminish these negative effects is to accommodate and prepare the shift to a more human-centric approach. In order to better implement this alternative solution and generate mid- to long-run positive effects from economic, social, and environmental perspectives, we consider it imperative for human resources to be prepared to understand and use new technologies. Our research focused on European countries and found that only a part of the European Union Member Countries benefit from the use of human resources with advanced digital skills. Consequently, only some countries will be able to face the challenges generated by the transition to Industry 5.0. On the other hand, emergent countries like Romania will need to intensify the complex process of designing competitive and coherent strategies and implement a more efficient and effective mix of policies. This will help them capitalize on the potential sustainable competitive advantage of industries 4.0 and 5.0.	Industry 5.0; Industry 4.0; human capital; core competences and high skills; sustainability; long-term sustainable; innovative and resilient development model	Mixed, literature review, secondary data analysis	Quality 5.0	HR	Evolution of jobs, digitally literacy
2020	Mats Deleryd & Anders Fundin	Towards societal satisfaction in a fifth generation of quality – the sustainability model	SIQ – The Swedish Institute for Quality, Gothenburg, Sweden; School of Innovation, Design and Engineering, Mälardalen University, Eskilstuna, Sweden	The quality concept has developed over many generations. The purpose of this article is to review and describe how the quality movement developed through four sequential generations and how a fifth generation is upcoming. Building on the different generations of quality, the fifth generation reveals differing needs between customers and stakeholders. In the new generation of quality, societal satisfaction would be a more appropriate way of measuring sustainable success. Consequently, and to support societal satisfaction, additional quality management models that complement current approaches are needed. For organizations to manage current, fast-changing environments successfully, existing management models need to be further developed. Hence, to support decision-makers in the fifth generation of quality, Quality 5.0, achieve societal satisfaction, this paper proposes a generic model for sustainable development based on a longitudinal trend analysis of two sequential Delphi studies conducted in 2012 and 2018. The sustainability model supports all organizations—private or public, large or small—on their pathway towards sustainable organizational success and a sustainable future.	Customer satisfaction; quality management; societal satisfaction; environmental care; economic performance; sustainability; sustainable success; Quality 5.0	Longitudinal trend analysis of two sequential Delphi studies	Quality/Industry 5.0	Societal satisfaction as measurement criteria, sustainability model	
2022	Foivos Psarommatis, João Sousa, João Pedro Mendonça & Dimitris Kiritsis	Zero-defect manufacturing the approach for higher manufacturing sustainability in the era of industry 4.0: a position paper	ICT4SM Group, École Polytechnique Fédérale de Lausanne – EPFL, Lausanne, Switzerland; MEtRICs Research Centre, University of Minho, Guimarães, Portugal	For manufacturing companies, quality management is a key feature for increasing the competitiveness, productivity, profitability, and sustainability of their systems. Quality improvement (QI) methods aim to achieve high-quality parts without reducing performance. The Industry 4.0 framework brought technological developments that cannot be used by traditional QI methods, such as Six Sigma, Lean, Lean Six, the Theory of Constraints, and Total Quality Management, which are widely used in manufacturing companies. The need for higher manufacturing sustainability and market requirements has led to the search for alternative QI methods with superior performance to traditional QI methods, such as Zero-Defect Manufacturing (ZDM). The current paper is a position paper with a goal to present the ZDM approach and provide a clear definition of ZDM to align everyone in one common understanding of ZDM. Many researchers and manufacturers are skeptical about ZDM; therefore, numerous argumentative questions have been created and answered to convince them why they should migrate from traditional QI methods to ZDM. The migration to ZDM has already started, and to support this statement, numerous facts from the literature have been presented. Finally, several directions were identified, demonstrating that there is still plenty of room for research in several domains.	Zero-defect manufacturing (ZDM); quality assurance; quality improvement; quality management; sustainable manufacturing; Industry 4.0	Literature review	Quality 4.0	QI methods	Zero-Defect Manufacturing (ZDM)

Figure A.9: Preliminary literature review