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Quality Management Practices in the Context of Industry 5.0

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Abstract

Though Quality 4.0 promised a future for enhanced sustainability, and even though it is evident in some micro cases, macro benefits are still shortcoming, as the broader impact Quality 4.0 on sustainability is still missing on energy consumption, inequality, unemployment issues, and the preservation of nature. This motivated the transition and talks around Industry 5.0. This study aims to explore the integration of quality management practices with Industry 5.0's core features, focusing on human-centric technological advancement and addressing life value threatening challenges. The study follows designs a Quality 5.0 framework by evaluating the impact of Industry 5.0 core features and concepts on quality management practices to ethically enhance quality while preserving the environment and showing social responsibility. The study, through a rigorous systematic literature review, discovered that Quality 5.0 is an attempt to address the constraints of Quality 4.0, putting an emphasis on industry and the use of modern technology, mostly in manufacturing processes. The study developed a framework for Quality 5.0, which extends quality management practices by including an equally strong human and social dimension. This work emphasizes that quality management systems in the era of Industry 5.0 should extend beyond profit making and competitiveness for individual organisations but should seek to promote social responsibility, resilience and sustainability. This study is in line with the United Nations' Concept for Sustainable Development Goals (SDGs).

Keywords
Industry 5.0, Quality 5.0, Human-centricity, Sustainable manufacturing, resilience

1. Introduction
The 21st century has seen significant technological, economic, and social advancements, which have caused a rapid process of change around the world (Arıcı and Kitapci, 2021). These changes brought forth the concept of Industry 4.0, which emerged because of combining information and communication technologies, artificial intelligence, and the Internet of Things with industrial operations to create what was then called the cyber-physical environment (Mhlongo and Nyembwe, 2024). The rapid developments in how processes were handled caused changes in many sectors, particularly the manufacturing sector. Businesses have been able to more effectively, quickly, and affordably integrate global or scattered production/service lines and streamline their business operations because of these technical advancements (Arıcı and Kitapci, 2021). Some of the pros that came with Industry 4.0 developments were the shortened operational processes in businesses, significant reduction in production costs, and the improvement in efficiency and quality (Sader, Husti and Daróczi, 2019; Arıcı and Kitapci, 2021; Sader, Husti and Daroczi, 2021). This era also enabled innovative solutions in several sectors and economic growth.

However, developments in Industry 4.0 technology were not without flaws. Some workers were unable to keep up with or satisfy the expectations of Industry 4.0, and as a result, they lost their jobs owing to a lack of skills or because the innovations of this new period destroyed various business lines (Arıcı and Kitapci, 2021). This generated an

enormous disruption and resulted in numerous technological advances and ideas to be treated with criticism on a social scale, either by employees or society. The ensuing chaos has resulted in several countries sinking back into high unemployment rates and experiencing substantial societal ills. According to Fukuda (2020), it is vital to protect society from these and comparable threats and to introduce new practices through regulations. Furthermore, mass production, a product of heavy digitization has been found to use half of the world's energy which eats greatly at the sustainable manufacturing goals. In addition to using a lot of fresh water and other natural resources, mass manufacturing produces a lot of waste. Given that mass manufacturing methods have such a significant impact on the environment as a whole, they must be made more efficient if the world is to have a sustainable future (Sukdeo and Mothilall, 2023).

Industry 5.0 aims to address the faults of the 4th industrial revolution by reconstructing societies, enhancing human-machine interaction, and integrating technology to prioritize humans. The concept of Industry 5.0 is rooted in integrating new innovative ideas with human-oriented studies (Fukuda, 2020; Arıcı and Kitapci, 2021). This will ensure that challenges faced in this century and the next are addressed by ensuring digital transformations are beneficial to all demographics. Furthermore, Ohiomah and Sukdeo (2022) claim that the global shift to a circular economy is being hailed as a way to maintain economic growth without endangering non-renewable resources and natural ecosystems. Furthermore, Industry 5.0 is meant to transform the world into a human-centric, sustainable, automated, virtual, and flexible environment, resulting in a worldwide competition for jobs requiring specialist considerations and abilities for the digital, responsible, ethical, and sharing economies (Keenavinna and Wickramarachchi, 2024; Lei *et al.*, 2024). Organisations that adopt Industry 5.0 technologies and features operate in a digitized and networked workplace that encourages engagement with algorithms and cobotics, as well as in a virtual environment (Frick and Grudowski, 2023; Keenavinna and Wickramarachchi, 2024; Kovari, 2024).

The transition to Industry 5.0 then necessitates a new quality management regime which addresses the challenges posed by rapid Industry 4.0 adoptions and new production challenges happening in the new industrial era, and authors have named this new quality regime Quality 5.0 (Arsovski, 2019; Arıcı and Kitapci, 2021; Frick and Grudowski, 2023; Fiałkowska-Filipek and Dobrowolska, 2024). Quality 5.0 so far, is defined as an advanced approach that merges traditional quality management practices with digital transformation and sustainability principles (Arsovski, 2019; Arıcı and Kitapci, 2021; Frick and Grudowski, 2023; Fiałkowska-Filipek and Dobrowolska, 2024). Quality 5.0 enables organizations to enhance product quality while simultaneously minimizing environmental impact, thereby aligning with global sustainability goals and strengthening their market position (Frick and Grudowski, 2023; Fiałkowska-Filipek and Dobrowolska, 2024; Grabowska *et al.*, 2024; Narkhede *et al.*, 2024).

By embracing Quality 5.0, manufacturers can not only fulfil regulatory requirements and customer expectations but also secure a competitive advantage in an era where sustainability is becoming a key business imperative (Frick and Grudowski, 2023; Fiałkowska-Filipek and Dobrowolska, 2024). According to Kovari (2024), companies that transition to Industry 5.0 and incorporate their concepts into their legacy processes will achieve both their sustainable development goals and gain competitive advantage against their rivals. Be that as it may, Quality 5.0 is a new concept and still needs to be studied and conceptualized to bring an understanding so that industry decision makers and policymakers may make informed decisions on whether or not to adopt it. This research conducts a systematic literature review to synthesize literature on the impact of Industry 5.0 features on quality management practices, to identify benefits and requirements of Quality 5.0.

1.1 Objectives

The main objectives of this study are as follows:

- To investigate the impact of Industry 5.0 features on quality management practices
- To conceptualize Quality 5.0

2. Theoretical Background: Quality Management Practices, Industry 5.0 and Quality 5.0

Quality refers to the extent to which a product or service meets customer requirements, remains defect-free, and supports continuous improvement. It is commonly defined as "conformance to requirements," where these requirements are based on fulfilling customer needs (Saxena and Srinivas Rao, 2019; Santos *et al.*, 2021). Quality management is a systematic strategy to ensure that products and services are delivered consistently and match set standards and customer expectations (Sader, Husti and Daroczi, 2017; Arıcı and Kitapci, 2021). Core Quality Management practices are structured around seven key principles:

a) **Customer Focus** – Emphasizes the importance of understanding and fulfilling customer needs to build long-term, sustainable relationships.
b) **Supplier Relationship Management** – Recognizes the role of suppliers in consistently meeting customer demands, highlighting the need for integrated collaboration across the value chain.
c) **Employee Engagement** – Stresses the involvement of all stakeholders, including employees, in quality initiatives to align internal processes with customer expectations (Rawashdeh, 2018; Sader, Husti and Daróczi, 2019; Chiarini, 2020).
d) **Leadership** – Involves visionary guidance that motivates employees, fosters innovation, and ensures alignment with organizational goals (Sader, Husti and Daroczi, 2017; Arıcı and Kitapci, 2021)
e) **Process Approach** – Advocates for clearly defined and consistently applied processes to achieve reliable outputs in products and services.
f) **Evidence-Based Decision Making** – Encourages the use of accurate, reliable data to inform objective and effective business decisions.
g) **Continual Improvement** – Promotes a culture of ongoing enhancement, which is critical for maintaining competitiveness and innovation.

2.1 Industry 5.0

Industry 5.0 is bringing about a paradigm shift in the manufacturing sector by making production processes more sustainable, individualized, and efficient. The integration of cutting-edge technologies like artificial intelligence (AI), robotics, and the Internet of Things (IoT) defines this evolution, enabling machines to assist human creativity and decision-making instead of merely automating tasks (Leng *et al.*, 2022; Frick and Grudowski, 2023; Kovari, 2024). In order to create an agile production line that satisfies customized client requests while cutting waste and increasing resource efficiency, the primary goal is to improve human-machine collaboration. As a result, this synergy creates a more responsible and responsive manufacturing environment that meets the growing need for sustainability (Arıcı and Kitapci, 2021; Fiałkowska-Filipek and Dobrowolska, 2024).

2.2 Quality 5.0

According to Fiałkowska-Filipek and Dobrowo (2024), the correct adoption of Quality 5.0 practices would not only have monetary benefits for individual organisations but would also contribute to the triple bottom line of sustainability which looks at people, planet and prosperity, through value co-creation, problem-solving, cooperation, and innovation. According to Arıcı and Kitapci (2021), Fukuda (2020) and Ziatdinov et al. (2024), Quality 5.0 innovations should also aim to improve technological literacy to society, promote technology use across all demographics, and raise awareness of rapidly evolving technology. This will ensure that the entire society is in support of the growing adoption of technology as they will understand the benefits it has for them, not just those in power.

3. Methods

The shortcomings of conventional quality management techniques were previously resolved by the methodical implementation of advancement in industrial revolutions. This study therefore adopted a Systematic Literature Review (SLR) to collect relevant data from global literature on the impact of this current 5th Industrial Revolution on quality management. Figure 1 displays the SLR approach proposed by Albliwi et al. (2014), which directed this study process. Following that, there are detailed steps that facilitate this process.

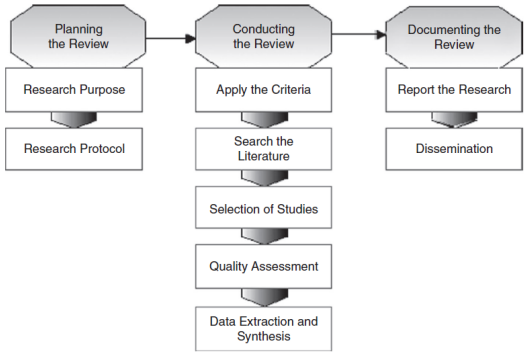

Figure 1. Methodology (Adapted from Albliwi et al (2014))

3.1 Step 1 - Develop a research purpose

The purpose of this study was to gather and synthesise the available academic work . This review allowed us to assess the impact of 5IR on QM practices and identify whether they address previous shortcomings brought forth by innovations in the 4th Industrial revolution, find similar trends, consensus, and gaps in the literature.

3.2 Step 2 - Develop a research protocol

Table 1 shows the research protocol developed for this study.

Table 1. Study review protocol

Purpose of the study	• To gather, arrange and synthesize data on Industry 5.0 technologies and leading concepts and their impact on quality management practices- Quality 5.0
Inclusion criteria	• Literature that contains “Quality 5.0” OR “Industry 5.0” AND “Quality Management” in the title, abstract or keywords • Literature that discusses the definition, enablers and benefits of Quality 5.0/ Industry 5.0 in manufacturing quality.
Exclusion criteria	• Papers published in any other language besides English • Studies focused on Industry 4.0, Quality 4.0 and any other earlier quality management regimen.
Search databases	• This study scoped papers from Emerald Insight, Scopus, Science Direct and Web of Science.
Keywords	• “Quality Management” AND “Industry 5.0” AND “Quality 5.0”
Quality assessment criteria	• Removing duplicates • Check for relevance. • Ensure appropriate interpretation of Quality 5.0 concepts. • Studies should be scientific. • Data collection in studies should be transparent.

3.3 Step 3 - Establish relevance criteria

When this study was conducted, the body of knowledge on Industry 5.0 and Quality 5.0 was limited and only spanning from 2021. To widen the search, the following criteria was followed:

- Only literature containing the term "Industry 5.0" AND/OR “Quality 5.0” in its title, abstract, or keywords will be considered for inclusion.
- The scope of selected literature will be restricted to studies that comprehensively address the definition, related benefits and impact of Industry 5.0 on quality practices.
- To ensure consistency, studies conducted in other languages besides English will be omitted from the review.
- Research concentrating on specific other quality control regimes prior the 5th Industrial Era will be omitted. This decision is based on the distinct nature of their applications and the emergence of their own Industry 5.0-aligned subgroups which fall outside the immediate focus of this study.

3.4 Step 4 - Search and retrieve the literature

In the 4th step, the search and retrieval of relevant literature was executed utilising the databases specified in Table 1, yielding a total of 350 papers. The 'Identification' section of Figure 2 illustrates the detailed breakdown of papers acquired during this phase.

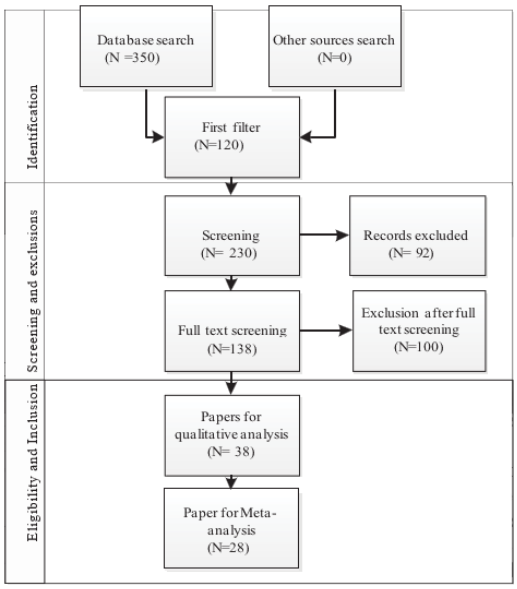

Figure 2. Prisma Diagram

3.5 Step 5 - Selection of studies

During the 5th step, duplicates were removed, leaving a refined set of 120 papers. The papers were screened in full and additional papers were omitted for various reasons, including instances where they did not adequately discuss the definitions, benefits, technologies and features and issues pertinent to Quality 5.0, or explored the historical aspects of quality management without specific details on Quality 5.0. Furthermore, non-English studies were excluded. This step identified 38 papers that would be included in the qualitative analysis where recurring themes would be identified to assist with the quantitative analysis of this study. Only 28 of those papers made it to the final quantitative analysis.

3.6 Step 6 - Quality assessment for relevant studies

All 28 selected studies underwent a rigorous quality assessment, utilising the criteria presented in Table 1, and successfully met the requirements for inclusion in the SLR , as illustrated in Figure 3. This quality assessment was based on several key factors: ensuring the removal of all duplicate literature, verifying the relevance of each piece of literature, confirming the accurate understanding and interpretation of Quality Management, ascertaining that all studies were scientific in nature, and validating that transparent data collection methods were employed.

4. Results and Discussion

4.1 Step 7 – Data extraction

This section outlines the results of the systematic literature review (SLR), which was conducted in June 2025. As illustrated in Figure 3, the distribution of publications by year spans from 2021 to 2025, with the highest number of studies published in 2024. This trend highlights the increasing scholarly interest in Industry 5.0 and quality management during this period. Figure 4 displays a keyword word cloud generated from the reviewed literature, with prominent terms including *Artificial Intelligence, Big Data and Analytics, Industry, Quality, Sustainability, Resilience, and Human-Centricity*. These keywords provide insight into the key themes and focus areas emerging from the SLR, indicating the direction and scope of current research in the field.

4.1.1 Evolution of Publications

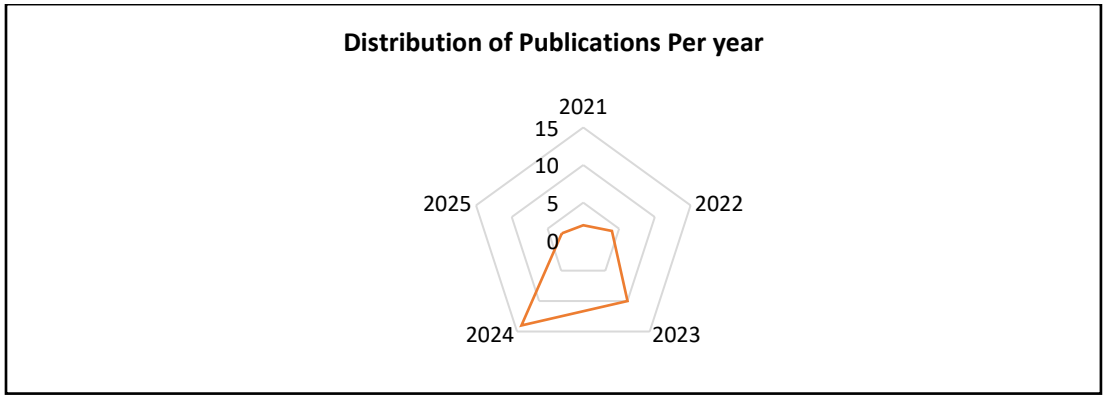

Figure 3. Evolution of publications

4.1.2 Industry 5.0 Features and Technologies

Table 2 shows the results of Industry 5.0 technologies and features covered by the different publications. The results show that all the publications analyzed emphasized human-centricity in Industry 5.0 which highlights the complete transformation from the automation-driven era of the fourth industrial revolution to one which uses technology to enhance human potential and allows for collaboration between humans and intelligent systems ensuring that humans aren't replaced by systems but are augmented by it. This finding is noteworthy and validates the claims in literature that I5.0 represents a shift away from the automation-centric logic of Industry 4.0 and toward one that uses technology to augment rather than replace human potential. While this unanimity indicates widespread acceptance of human-centricity as a defining principle, it also risks oversimplifying the problem. Some researchers, such as Rijwani et al. (2024) and Narkhede et al. (2024), view human-centricity as fundamentally value-driven, while others warn that without systemic worker reskilling and organizational redesign, such ambitions may stay rhetorical (Liu et al., 2024; Rame et al., 2024). Thus, while there is agreement in discourse, there is still question about the practical viability of implementation.

Table 2. Summary of Identified Publications

Study Title	*Human-Centricity*	*Resilience*	*Sustainability*	*Edge Computing*	*BDA*	*IoT*	*Blockchain*	*6G and beyond*	*Cobots*	*Digital Twins*	*AI*	*Bioinspired Technologies & Smart Material (3G/4G)*	*Main Focus*
"Edge Computing Data Optimization for Smart Quality Management: Industry 5.0 Perspective"	✓	-	✓	✓	✓	-			-	-	-		It emphasizes the evolution from Industry 4.0's data-intensive systems toward Industry 5.0's human-centred and sustainable model, with the goal to use edge computing not only to optimize production efficiency but also to empower workforce collaboration with machines and robots in flexible and green environments (Bajic *et al.*, 2023)
"Quality 5.0: A Paradigm Shift Towards Proactive Quality	✓	-	-	✓	✓	-			-		-		Discusses the evolution from Quality 4.0 to 5.0, focusing on proactive quality control and digital transformation (Frick and Grudowski, 2023)
"Future of Industry 5.0 in Society: Human-Centric Solutions,	✓	-	-	✓	✓	-	✓	✓	-		-		Highlights human-centric approaches in Industry 5.0, emphasizing collaboration between humans and smart systems (Adel, 2022).

"Industry 5.0: A Review of Emerging Trends and Transformative	.	,	✓	✓	,	✓	✓	,		,	✓	Reviews transformative trends and key technologies driving Industry 5.0 (Rijwani *et al.*, 2024a).
"From Food Industry 4.0 to Food Industry 5.0: Identifying	.	,	✓	✓	,	✓	✓	,		,		Investigates how Industry 5.0 principles can be applied to sustainable food production (Hassoun *et al.*, 2024).
"The Convergence of Blockchain, IoT and 6G: Potential,	.	,	✓	✓	,	✓	✓	,		,		Explores the convergence of blockchain, IoT, and 6G technologies within Industry 5.0 (Jahid, Alsharif and Hall, 2021).
"Editorial: Human-Centred Artificial Intelligence in Industry 5.0"	.	,		✓						,		Discusses the role of AI in fostering human-centred Industry 5.0 transformations (Mentzas *et al.*, 2024).
"Mist and Edge Computing Cyber-Physical Human-Centered	.	,	✓	✓	,			,	,	,		Examines the importance of mist and edge computing in cyber-physical human-centred systems (Fraga-Lamas *et al.*, 2022).
"Industry 5.0 is Coming: A Survey on Intelligent NextG Wireless	.	,	✓	✓	,	✓	✓	,	,	,		Surveys the role of next-generation wireless networks in enabling Industry 5.0 applications (Zeb *et al.*, 2022).
"Promoting Sustainable and Human-Centric Industry 5.0: A	.	,	✓	✓	,	✓	✓	,		,		Provides a thematic analysis of sustainable and human-centric practices in Industry 5.0 (Rajumesh, 2024).
"The Role of the Quality Management Process within Society	.	,		✓						,		Analyses the integration of quality management principles within Society 5.0 (Maljugić *et al.*, 2024).
"Technological Modernizations in the Industry 5.0 Era"	.	,	✓	✓	,	✓	✓	,		,		Covers the latest technological innovations shaping Industry 5.0 (Alojaiman, 2023).
"Industry 5.0: Research Areas and Challenges with Artificial	.	,	✓	✓	,	✓	✓	,		,		Focuses on AI-driven advancements in Industry 5.0 and associated challenges (Dimitrakopoulos *et al.*, 2024)
"The Era of Industry 5.0: An Overview of Technologies,	.	,	✓	✓	,	✓	✓	,	,	,	✓	Explores key technologies enabling Industry 5.0 and their applications in various industries (Bazel *et al.*, 2024).
"Quality 5.0: Towards Sustainable Quality Improvement in	.	,		✓						,		Investigates how Quality 5.0 can drive sustainable quality improvement through data-driven decision-making (Fiałkowska-Filipek and Dobrowolska, 2024).
"Behind the Definition of Industry 5.0: A Systematic Review"	.	,	✓	✓	,	✓	✓	,		,		A comprehensive literature review outlining the defining principles and technologies of Industry 5.0 (Ghobakhloo *et al.*, 2023).

Total % of Publications Covering the subject	*A Framework for Sustainable Manufacturing: Integrating Industry 4.0 Technologies with Industry 5.0 Values*	*Industry 5.0: Generalized Definition, Key Applicati*	*A Systematic Review of Emerging Industry 5.0 Technologi*	*Industry 5.0 and sustainable manufacturing: a systematic literature review*	*"Resilient Supply Chains in Industry 5.0"*	*"A Review of 4IR/5IR Enabling Technologies and Their Linkage to*	*"Industry 5.0 and Sustainable Manufacturing: A Systematic Review"*
100%							
100%	ˏ	ˏ	ˏ	ˏ	ˏ	ˏ	ˏ
100%	ˏ	ˏ	ˏ	ˏ	ˏ	ˏ	ˏ
79%	✓	✓	✓	✓	✓	✓	✓
100%	✓	✓	✓	✓	✓	✓	✓
86%	ˏ	ˏ	ˏ	ˏ	ˏ	ˏ	ˏ
68%		✓	✓	✓	✓	✓	✓
71%		✓			✓	✓	✓
86%		ˏ	ˏ	ˏ	ˏ	ˏ	ˏ
21%	ˏ						
100%	ˏ	ˏ	ˏ	ˏ	ˏ	ˏ	ˏ
29%		✓	✓	✓		✓	✓
Total % of Publications Covering the subject	Evaluates key Industry 5.0 enabling across the three pillars of sustainability, economic, environmental, and social—to determine how well each supports sustainable outcomes, and develops a conceptual framework (Martín-Gómez, Agote-Garrido and Lama-Ruiz, 2024)	Investigates the key definitions of Industry 5.0, its applications, strengths and threats in different industries. (Kovari, 2024)	Conducts a structured review to gather and analyze academic publications on emerging Industry 5.0 technologies (Pant *et al.*, 2025)	Examine the relationship between Industry 5.0 and Sustainable manufacturing, particularly through the lens of triple-bottom-line along with added dimensions of resilience, human wellbeing, and societal benefits (Narkhede *et al.*, 2024)	Discusses how Industry 5.0 improves supply chain resilience using smart technologies and automation (Ejjami and Boussalham, 2024).	Examines how Industry 4.0 and 5.0 technologies impact supply chains, focusing on digital transformation and sustainability (Fanoro, Božanić and Sinha, 2021).	Systematic review analysing Industry 5.0 and its role in sustainable manufacturing, emphasizing circular economy models (Narkhede *et al.*, 2024).

The publications also unanimously covered the feature sustainability, which illustrates the commitment Industry 5.0 has on environmental responsibility and ethical industrial practices. This is a huge step forward from 4IR which was criticized to neglecting ethical practices in AI models and production practices. This supports Ghobakhloo et al. (2024), who found that Industry 5.0 will enhance the use of Industry 4.0 technologies and ensure their ethical and sustainable usage, saving humankind and the environment. Although this may be enticing, this optimism might overlook the ongoing contradictions between economic expansion and environmental responsibility. For example, while Artificial Intelligence and Internet of Things offer increased efficiency, their energy intensity raises concerns about whether they can negatively impact sustainability (Liu et al., 2024). This demonstrates an unsolved conflict between the technological enablers of I5.0 and its sustainability claims. All the publications also covered resilience, which indicates the growing need for adaptive, crisis-resistant, and future-proof systems, reinforcing 5IR's role in addressing economic, environmental, and technological disruptions. Revolutionized (2024) and Hickey (2023a) found that Industry 5.0 practices will ensure close-loop supply chains ensuring that industries can withstand global disruptions and still operate should the world face disruptions as we did with COVID-19.

Figure 4. Word cloud of keywords

However, literature diverges on what resilience entails. While some studies emphasize digital redundancy and technological robustness (Hickey, 2023b; Grabowska et al., 2024; Mhlongo and Nyembwe, 2024; Revolutionized, 2024), others focus on socioeconomic resilience, such as equal access and worker adaptation (Adel, 2022; Mentzas et al., 2024; Rane et al., 2024). This diversity implies that, despite widespread support, resilience remains conceptually fractured across scholarly communities. Other features that were covered unanimously by all publications are artificial intelligence and big data and analytics. The need for data-driven industries makes for these two to be more than tools but essential backbones of 5IR, driving smart decision-making, automation, and optimization. Mentzas et al. (2024) found that AI can be used to enhance human intelligence, working hand in hand with humans to efficient and defect free processes. Outside of production, AI in Industry 5.0 will also be used to aid human comfortability and fairness ensuring that recruitment processes are fair and just, ergonomics data will be analysed to ensure comfortability and safety in the workplace (Chen, 2023; Rane, Kaya and Rane, 2024). Yet, the assumption that AI will naturally enhance human well-being is contested. Concerns persist regarding algorithmic bias and the potential to reinforce inequalities (Drage and Mackereth, 2022; Mujtaba and Mahapatra, 2024; Revolutionized, 2024). This signals that while AI is universally viewed as indispensable, its role in enabling human-centricity is not uncontested but shaped by ongoing ethical debates.

Other Industry 5.0 features gaining traction include IoT, edge computing, cobots, and '5G, 6G, and Beyond', which are covered by 70-79% of publications. Their partial coverage suggests strong momentum but also indicates variability in perceived maturity and adoption readiness across industries. Blockchain was covered by 64% of publications, indicating a mixed reception and highlighting unsolved debates. While proponents emphasize its potential for secure, transparent supply chains, critiques emphasize scale restrictions, high energy usage, and the lack of defined regulatory frameworks (Alam *et al.*, 2021; Srivastava, Mahara and Yadav, 2021). This divergence reveals that blockchain's role in I5.0 is far from settled, hinging whether these technical and governance barriers can be overcome. Digital Twins (14%) and Bioinspired Technologies (25%) have minimal coverage, indicating that they are still in the early stages of integrating into I5.0 discussions, though this could also be due to a research lag rather than technological irrelevance. Given the increased industrial interest in modelling and simulation, these could be future research areas that the literature has yet to address.

These findings highlight the reality that 5IR is a value-driven, AI-powered, and sustainability-oriented shift. These highlight the importance of aligning technological adoptions with ethical, environmental, and human-centric factors, ensuring that 5IR promotes responsible and inclusive innovation.

4.2 Impact of industry 5.0 on improving quality management practices

a) Customer Relationships

According to Hickey (2023), organizations will gain customers by preparing for their future expectations by leveraging AI to provide predictive demand forecasting, ensuring that present customer demands are met and exceeded by eliminating design and production defects and also facilitating rapid shipping (Sukdeo and Mothilall, 2023). According to authors Sader et al. (2017), Corti et al. (2021) and Mhlongo and Nyembwe (2023), consumer demands and rivalry frequently drive organizations' quality initiatives. According to Grabowska et al. (2024) and Revolutionized (2024), more customers want green economy products, and Quality 5.0 characteristics promote environmental consciousness, influencing customer decisions. Organisations will use Industry 5.0 technologies such as big data and analytics, as well as advanced sensors, to track products even at customer bases, not only to view user experience in order to improve next products, but also to recycle and reuse the product after use to support circular

economy initiatives for planet sustainability, and to ensure closed loop supply chains to ensure resilience (Hickey, 2023b; Grabowska *et al.*, 2024; Revolutionized, 2024). Organisations in Industry 5.0 will exploit the circular economy to attract customers which will lead to prosperity, while promoting resilience and sustainability.

b) Supplier Relationship Management

According to Rijwani et al. (2024), the use of BCT for transparent supplier collaboration will help prevent counterfeiting, ensure compliance, and streamline supplier audits by providing an immutable digital record of transactions. According to Hickey (2023b), blockchain and artificial intelligence (AI) can trace goods and materials across the supply chain, guaranteeing ethical and sustainable production and raw material sourcing. Fanoro et al.(2021), found that the use of IoT and Blockchain Technology enables real-time monitoring of supplier production processes and enforce compliance with predefined quality standards. Furthermore, with the use of AI driven analytics, supply chain risks will be predicted by analysing past supplier performance and real-time operational data (Frederico *et al.*, 2020; Fanoro, Božanić and Sinha, 2021; Narkhede *et al.*, 2024; Pant *et al.*, 2025). AI helps choose environmentally sustainable suppliers, which enhances brand perception and supplier relationships (Hickey, 2023b). According to Hickey (2023a), artificial intelligence will also be used to ensure sustainable supply chains and supplier relationships. They foresee that AI capabilities will also be used to analyse large volumes of data to precisely forecast future material and product demand. This minimizes waste and maximizes sourcing.

c) Employee Engagement

Industry 5.0 uses AI and analytics to assess and then allows for improved working conditions, prioritizing flexible work arrangements, improved ergonomics and safe environment for shop floor workers. This is possible through the human-robot collaborations which ensure that robots take care of all the monotonous, physically strenuous and dangerous duties while collaborating with humans for their potential (Hassoun *et al.*, 2024; Martini, Bellisario and Coletti, 2024; Mentzas *et al.*, 2024; Rijwani *et al.*, 2024b), creativity and critical thinking, guaranteeing improved efficiency and continual improvement which in turn improves product quality and improves productivity, and they are thus engaged and satisfied with their work which ensures retention of employees (Maljugić *et al.*, 2024; Rajumesh, 2024; Rane, Kaya and Rane, 2024). Furthermore, even while workers are aware of the advantages of PPE, they occasionally choose not to wear it.

Sukdeo and Mothilall (2023) discovered that the manufacturing industry may enhance worker safety and ensure that all workers are wearing personal protective equipment (PPE) in compliance with rules to prevent safety accidents and excessive fines in the plant by utilizing AI models. AI can also forecast machine and line failures and this may also help reduce accidents in the workplace. Ensuring that production processes are safe. Although some feared job displacement due to digitization, Sukdeo and Mothilall (2023) asserted that AI would only augment human potential and eliminate human errors from the production process, and humans would have to receive advanced training to handle critical thinking roles. Furthermore, personalized learning platforms powered by AI and augmented reality (AR) contribute to bridging the skills gap, ensuring that workers from diverse backgrounds have access to upskilling opportunities (Adel, 2022).

d) Leadership

Leaders must balance digital transformation with ethical and environmental considerations. Cobots (Collaborative Robots) and Human Augmented Intelligence (HAI) allow leaders to focus on employee development, well-being, and engagement while ensuring quality standards are maintained(Frick and Grudowski, 2023; Narkhede *et al.*, 2024; Rijwani *et al.*, 2024a; Ziatdinov, Atteraya and Nabiyev, 2024). Rijwani et al. (2024) discuss how Big Data and AI enable quality leaders to analyse massive datasets for proactive decision-making in Industry 5.0. Mhlongo and Nyembwe (2023) emphasize that advanced and modern technologies improve leadership effectiveness by leveraging real-time analytics and automation for strategic quality control. Furthermore, Industry 5.0 promotes human-centric leadership where leaders empower employees with smart tools, leading to higher job satisfaction and quality improvements (Grabowska *et al.*, 2024; Narkhede *et al.*, 2024; Rijwani *et al.*, 2024a; Ziatdinov, Atteraya and Nabiyev, 2024). Research also highlights how blockchain enhances traceability and accountability, ensuring quality leaders maintain compliance and prevent defects (Fanoro, Božanić and Sinha, 2021; Frick and Grudowski, 2023; Narkhede *et al.*, 2024). Leaders also use feedback from the entire supply chain and from customers to focus their production lines effectively (Sukdeo and Mothilall, 2023).

e) Process Approach

In Industry 5.0, organisations will design their products with circularity in mind(Narkhede *et al.*, 2024; Revolutionized, 2024). This will ensure that their parts are either reusable or recyclable. According to Ohiomah and Sukdeo (2022), one way to apply the circular economy is through remanufacturing, which turns broken, outdated, and end-of-life objects into "a new condition." An end-of-life product or its components can have their useful lives extended through remanufacturing. This will aid in resilience in cases of world disruptions that disturb supply chains and contribute to the green economy. Businesses will use technologies such as artificial intelligence and digital twins, organisations will be able to simulate different process scenarios, for quality, resilience and sustainability and choose the best one to go into production with (Hickey, 2023b, 2023a; Revolutionized, 2024).

Organisations will further use technology like blockchain technology to allow process transparency of processes, including the supply chain process, this will ensure that they are all trustworthy and defect free (Leng *et al.*, 2020; Jahid, Alsharif and Hall, 2021). The use of internet of things in conjunction with sustainable practices in Industry 5.0 will promote sustainable consumption and improved distribution of resources throughout the production process (Hickey, 2023b, 2023a; Narkhede *et al.*, 2024; Revolutionized, 2024). Industry 5.0 will also use BDA to encourage continuous feedback collection from customers which will ensure next products are improved. This will not only forecast demand and satisfaction but will also ensure companies focus their production lines effectively (Sukdeo and Mothilall, 2023).

f) Evidence-based decision making

In 5IR, technologies such as BDA, AI and digital twins will be employed to improve decision making all throughout the production process through real-time analytics of quality metrics and deviations throughout the process, predictive insights and simulation of process scenarios and selecting the best one with less or no defects before the actual production (Bazel *et al.*, 2024; Dimitrakopoulos *et al.*, 2024; Rajumesh, 2024). This evidence informed decisions will minimize variability and enhance consistency and standardization in quality processes. As per Frick et al. (2023), blockchain technology will be leveraged to ensure the integrity of quality records, making it easier to track and validate compliance.

a) Continual Improvement

According to Narkhede et al. (2024), AI-powered systems detect inefficiencies in real time and provide recommendations for process optimizations. Rijwani et al. (2024) and Narkhede et al. (2024) assert that human centric AI enhances the collaboration between humans and machines, leading to continuous innovation and improvements in quality systems. Augmented AI is considered the next generation for the future and will significantly drive change. According to Narkhede et al. (2024), Ziatdinov et al. (2024) and Fiałkowska-Filipek et al. (2024), Bio-Inspired Manufacturing encourages sustainable innovations, reducing material waste while improving process efficiency. This comes in time when consumers continue to demand green products, forcing businesses to continue with their pursuit to ensure sustainable production processes.

4.3 Quality 5.0 Conceptual Framework

Figure 5 is the conceptual framework of Quality 5.0 based on the impact that Industry 5.0 has on quality management practices.

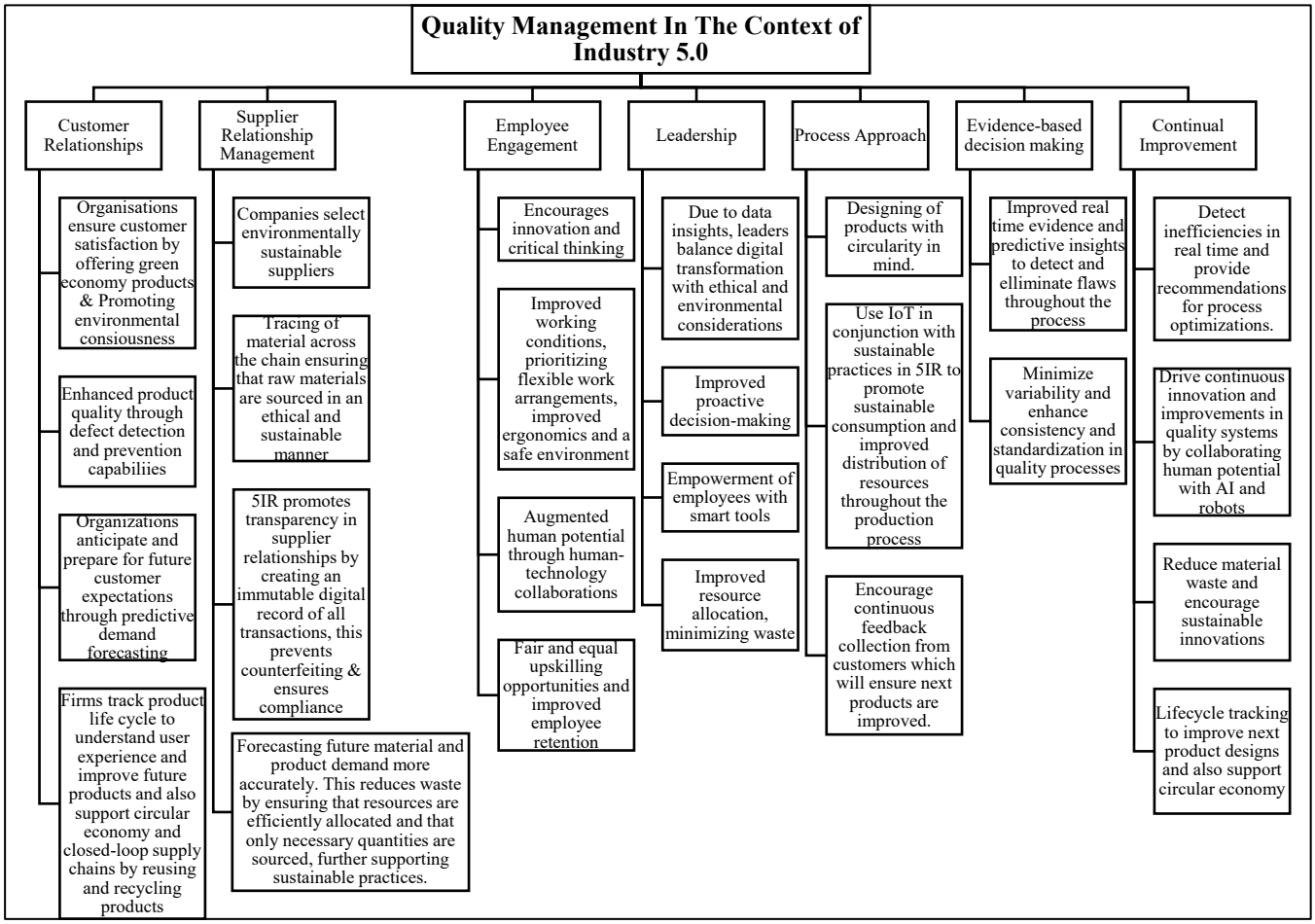

Figure 5 Quality 5.0 framework

5. Conclusion

Industry 4.0, which includes technologies such as AI, BDA, CPS, robotics, and IoT, has rapidly digitized production processes, ensuring efficiency and self-healing. However, the period had limitations in assuring sustainability and social responsibility, which Industry 5.0 aims to remedy. Industry 5.0 does not necessarily replace the Fourth Industrial Revolution, but rather operates alongside it, addressing its inadequacies. The study adopted a SLR and researched the impact of Industry 5.0 on quality management practices to ensure that quality regimes address previous shortcomings of Quality 4.0 and others prior to that. Findings revealed that Industry 5.0 features have great impact on quality management ensuring ethically digitized and sustainable processes that emphasize social responsibility together with process optimization. The study found that correct adoption of Quality 5.0 practices would not only have monetary benefits for individual organisations but would also contribute to the triple bottom line of sustainability which looks at people, planet and prosperity, through value co-creation, problem-solving, cooperation, and innovation. Moreover, a framework for Quality 5.0 was developed using the findings of this study.

6. Literature Gaps and Future Recommendations

The reviewed literature highlights the significant potential of Industry 5.0 in advancing quality management practices through its emphasis on human-centricity, sustainability, and resilience. Key contributions include the sustainable and ethical development of intelligent, real-time quality control systems, advanced defect prediction mechanisms, and data-driven decision-making frameworks enabled by extensive data collection and analysis. These capabilities have shown promise in enhancing customer satisfaction, improving end-to-end integration, and reducing quality-related costs by enabling early detection and elimination of defects.

The findings also revealed that, while I5.0 is commonly described as value-driven, human-centred, and sustainability-oriented, fundamental inconsistencies exist. These include concerns over whether ethical values can endure economic and technical constraints, how resilience is understood in multiple contexts, and unresolved disputes over specific technologies such as blockchain, digital twins, and bioinspired techniques. The findings imply that I5.0 is a growing framework with broad acceptance but divergent views on specific enablers, implementation methods, and trade-offs.

Future research should prioritize the documentation of real-life use cases and pilot implementations to illustrate the tangible benefits and contextual nuances of Industry 5.0-enabled quality management. Moreover, although a few studies attempt to conceptualize this emerging term, their definitions lack depth and consistency. As the field evolves, it is imperative for scholars to collaboratively develop a comprehensive and theoretically grounded definition of Quality 5.0 that captures its unique attributes, distinguishing it from Quality 4.0 and earlier paradigms. The literature on this field is still in its infancy and lacks cost–benefit analyses that evaluate the financial implications of implementing Industry 5.0 technologies for quality management. While qualitative benefits such as sustainable manufacturing, augmented human intelligence and employee satisfaction, improved responsiveness and defect reduction are frequently discussed, there is limited evidence quantifying these outcomes in monetary terms. Most studies provide a generic overview of enabling technologies, yet few examine how particular technologies are best suited to distinct quality management practices within the manufacturing sectors. Research is needed to map these linkages to guide firms in selecting and customizing Industry 5.0 tools based on their unique operational needs.

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