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Intelligent Systems applied to Quality Management

Henrique Pulido Freire de Andrade Barrosa

MSc in Management

Supervisor:
MSc António Ângelo Machado Matos Pereira, Invited Lecturer
ISCTE – Instituto Universitário de Lisboa

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BUSINESS
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Department of Marketing, Strategy and Operations

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Resumo

A integração de Sistemas Inteligentes e Inteligência Artificial na Gestão da Qualidade tem um enorme potencial para revolucionar o setor ao oferecer oportunidades significativas de evolução num futuro próximo. Este estudo visa esclarecer os principais benefícios e desafios associados à implementação dessas mesmas tecnologias nos processos de gestão da qualidade. Através de uma pesquisa qualitativa, foram realizadas 15 entrevistas semiestruturadas com profissionais da área de qualidade, predominantemente diretores de qualidade, que compartilharam as suas perspetivas sobre o tema.

A análise dessas entrevistas revelou, na maioria dos casos, uma convergência de opiniões com a literatura existente, particularmente em relação às vantagens que se obtêm ao nível da eficiência e automação de processos oferecidos pelos Sistemas Inteligentes e pela IA. No entanto, o estudo também destacou desafios únicos, especialmente no contexto da gestão da qualidade. Questões éticas, como a eventual substituição das pessoas em determinadas tarefas e o ritmo desequilibrado da adaptação regulamentar em comparação com os avanços tecnológicos, foram alguns dos problemas relevantes identificados. Apesar desses desafios, as entrevistas indicaram uma visão equilibrada entre os vários profissionais, que expressaram tanto entusiasmo pela tecnologia quanto cautela em relação aos seus impactos mais amplos.

Esta pesquisa contribui para o estudo de dois tópicos raramente correlacionados, Sistemas Inteligentes e Gestão da Qualidade, fornecendo conclusões diretamente relacionadas com as perceções de profissionais do setor, oferecendo assim uma compreensão mais profunda da dicotomia entre o avanço tecnológico e o movimento da qualidade, enquanto se aborda também as suas implicações sociais.

Palavras-chave: Sistemas Inteligentes, Inteligência Artificial, Gestão da Qualidade, Eficiência, Eficácia, Preocupações Éticas

Classificação JEL:

O320 - *Management of Technological Innovation and R&D*

L150 - *Information and Product Quality; Standardization and Compatibility*

Abstract

The integration of Intelligent Systems and Artificial Intelligence (AI) within Quality Management has enormous potential to revolutionize the field, offering significant opportunities for evolution in the near future. This study aims to clarify the primary benefits and challenges associated with implementing these advanced technologies in quality management processes. Through qualitative research, 15 semi-structured interviews were conducted with quality professionals, predominantly quality directors, who shared their perspectives on the topic.

The analysis of these interviews revealed, in most cases, a convergence of opinions with existing literature, particularly regarding the efficiency gains and process automation offered by Intelligent Systems and AI. However, the study also highlights unique challenges, especially within the context of quality management. Ethical concerns such as potential job displacement and the unbalanced pace of regulatory adaptation when compared to technology advancements, were some of the relevant issues identified. Despite these challenges, the interviews indicated a balanced outlook among professionals, who expressed both enthusiasm for the technology and caution regarding its broader impacts.

This research contributes to the study of two rarely correlated topics, Intelligent Systems and Quality Management, by providing conclusions directly related to insights from industry professionals. It offers a deeper understanding of the dichotomy between technological advancement and the quality movement, while also approaching its social implications.

Keywords: Intelligent Systems, Artificial Intelligence, Quality Management, Efficiency, Effectiveness, Ethical Concerns

JEL Classification:

O320 - Management of Technological Innovation and R&D

L150 - Information and Product Quality; Standardization and Compatibility

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List of Abbreviations

AI – Artificial Intelligence
EFQM – European Foundation for Quality Management
FAQ – Frequently Asked Questions
GDPR – General Data Protection Regulation
HITL – Human in the Loop
IoT – Internet of Things
IQ – Interview Questions
ISO – International Organization for Standardization
ROI – Return on Investment
RQ – Research Question
SDG – Sustainable Development Goals
TQM – Total Quality Management

Chapter 1 – Introduction

1.1. Theme Framework

If there ever was, there is no longer any doubt that we live in a digital era. What seemed to be a distant reality years ago is now a very clear one. Nowadays we hear terms like Industry 4.0, Big Data or Internet of Things (IoT) and we are no longer strangers to them.

The same happens when referring to intelligent systems. Their application covers various areas and has been growing in number, with some examples being factory automation, finance, military applications, healthcare, education, entertainment, or human identification through biometric modalities. When we refer to these systems, we are inevitably including Artificial Intelligence (AI) in the discussion since both terms are intertwined. The concept of intelligent systems has emerged in information technology as a type of system derived from successful applications of AI and its development also usually requires the combination of several AI methods (Molina, 2020).

The attention given to this type of system has been growing since they have been proving to have a positive impact on business performance, while also becoming truly relevant and beneficial for various organizations. Some even consider that they might have a crucial role in enhancing economic growth and innovation. For instance, Peres et al. (2020) approach their use in the manufacturing industry, fundamentally stating that they enable a dynamic response to variable product demand, assist manufacturers in tackling the challenges associated with the systems' digital transformation, and redefine the way manufacturing processes, and business models are structured. It is important not to forget that digital transformation processes involve multidisciplinary activities, which require the existence of specialists in various areas, a scenario that does not occur in all companies (Pereira et al., 2023).

In the context of this technological evolution, it is still crucial to recognize the pivotal role of quality management. It dedicates itself to ensuring products or services consistently meet or exceed customer expectations and takes center stage in the proliferation of intelligent systems. It serves as an organizational excellence enabler by encouraging the pursuit of superior outcomes across various industries. The integration of quality management practices becomes the bedrock upon which intelligent systems contribute to operational efficiency, business performance, and innovation. Afterall, companies' reputation largely depends on this sector. If the product lacks its standards, it drastically affects the company and, hopefully, through the usage of these systems, the ability to analyze and monitor the process and product quality at key points in the manufacturing processes and identify when products are under the

required standards or their attributes deviate from requirements, one can obtain substantial cost savings (Ammar et al., 2021).

1.2. Research Problem

The field of quality management has historically relied on established theories and concepts, with the likes of Deming, Shewhart, Juran, and Ishikawa being some of the authors highlighted in the movement's theory (Dahlgaard & Anninos, 2022). Despite the universal pursuit of high-quality standards in the business world, the absence of contemporary contributions raises concerns about the potential obsolescence of existing quality frameworks. That absence suggests that there has been a decline in the development and interest in quality models and practices in recent years (Zonnenshain & Kenett, 2020).

In this context, Zonnenshain & Kennet (2020) also highlight that there is a clear opportunity for quality to be renewed and increasingly continue to be used as a factor of competitive advantage within organizations since the integration of Intelligent Systems and AI into quality management emerges as a promising avenue for transformative advancements. The traditional paradigms may benefit from the infusion of intelligent technologies, leading to novel approaches in the quality movement. It is all about the balance achieved by companies on the combination of new technologies and human expertise (Urban, 2023). However, the current state of research lacks comprehensive insights into the synergies between Intelligent Systems, AI, and quality since this relation between the concepts is still a potentiality, hence Rashid & Kausik (2024) referral to quality control as a potential area for the application of AI. Plus, most literature majorly focuses on AI when approaching the current state of quality management, and it is important to have a more holistic vision on the topic, including a vast quantity of Intelligent Systems instead of only focusing on one.

In that sense, this dissertation aims to explore and analyze what type of impact intelligent systems and AI have on quality management, with a special focus on innovating, overcoming challenges, and maximizing effectiveness. By investigating the applications of these tools in quality, this study seeks to identify gaps in existing quality theories. The research problem will also center on the need to delineate how intelligent systems can be successfully incorporated into quality management frameworks (regardless of the industry) to optimize processes, mitigate quality-related issues, and achieve sustainable improvements in organizational performance, customer satisfaction, and stakeholder satisfaction (Ahmad et al., 2016).

In some way, this research will end up helping to understand how these systems have been applied in quality management, while also analyzing where their application would be

beneficial for quality within organizations since the quality concept is everywhere, which means that it is general to all sectors. Ultimately, one hopes to show how can intelligent systems allow companies to perform at their maximum capacity, while also helping the quality movement to regain its relevance. There is still some discussion on whether the implementation of these systems will be beneficial for organizations or not, mainly because of the ethical problems they can generate (Dwivedi et al., 2021). Through the literature review inserted in this dissertation, various points and findings will be considered and analyzed, with the ultimate aim being to come to a conclusion on that matter as well.

1.3. Objectives and Research Questions of the Dissertation

The primary aim of this investigation is to explore and evaluate the integration of intelligent systems in the domain of quality management and try to understand how advancements in AI and related technologies can enhance and optimize quality management processes within diverse organizational contexts. Synthesizing, the objectives will be the following:

i) Evaluate the role of intelligent systems in enhancing quality control, emphasizing their potential for automation and real-time decision-making.

ii) Assess the benefits and opportunities derived from the adoption of intelligent systems in quality management and demonstrate how can intelligent systems and AI serve as a tool for quality to gain visibility again, while also having in mind the obstacles that can appear from that adoption.

Having all these objectives in mind, it is crucial for the development of the dissertation to be centered around the following research questions:

RQ1) How do intelligent systems contribute to the enhancement of quality control processes in various industries?

RQ2) What are the main benefits and opportunities associated with the adoption of intelligent systems in quality management?

RQ3) What obstacles and challenges might organizations face when adopting intelligent systems for quality management, and how can these be addressed?

RQ4) What are the potential implications of widespread adoption of intelligent systems in quality management for various stakeholders, including employees, management, and customers?

1.4. Structure of the Dissertation

This dissertation will be structured around 6 chapters, each one being instrumental in its own way.

To start off, Chapter 1 was separated into four different parts, more specifically the already approached theme framework, research problem, objectives of the dissertation and finally its structure. After that, a thorough literature review was developed in Chapter 2, to delve into the current level of research on themes like Intelligent Systems, AI, Quality, and Total Quality Management (TQM), as well as trying to discover possible interrelations between the various concepts for later usage. Further down the line, the concept of Quality 4.0 will also be vital to connect the two realities in this dissertation, which will allow me to approach the theme of the dissertation with a different view. Chapter 3 will be key in explaining some of the thoughts and processes behind the research questions' development. Chapter 4 will be designed to base itself off the methodology being applied, including the explanation behind the strategy being adopted, more specifically the adoption of semi-structured interviews. Chapters 5 and 6 will be of the upmost importance to complete the ideas shared in the previous chapters, with the first being crucial to combine the whole research, from objectives, passing through the research questions developed, and finally the findings obtained via the semi-structured interviews, allowing then for the data analysis and discussion keeping in mind the existent literature. After the main conclusions in Chapter 6, it is also relevant to expose some of the investigation's limitations and give out some suggestions for future research.

Chapter 2 - Literature Review

2.1. Intelligent Systems

Computer-based solutions continue to be developed in this digital age to automate jobs that need mental effort. These instruments can now accomplish tasks that demand ever-higher levels of intelligence thanks to their ever-expanding capabilities. Intelligent systems appeared exactly from this progression in time as a disruptive form of tool (Molina, 2020). According to Molina (2020), an intelligent system is an artificial system that: (1) functions as an agent, meaning it interprets and responds to its environment and interacts with other agents; and (2) demonstrates rational behavior, meaning it acts rationally and engages in rational thought (justifies beliefs through reasoning).Some examples are autonomous robots, first generation expert systems, and management support systems.

This wide variety means there is a requirement for companies to analyze which is the best fit for them among the vast options available. A company must be able to identify and understand its characteristics and resources and, only then, predict and decide which intelligent system will bring the most value. To take suitable decisions, businesses need to be fully aware of their digitalization degree and willingness to evolve in that direction (Javaid et al., 2022). Additionally, Yaremko et al. (2021), add that the adoption of intelligent systems for business process modeling and activity forecasting enables management to obtain pertinent and necessary information for the implementation of effective management decisions and the development of a strategic plan. Additionally, the competitiveness of enterprises increasingly depends on effective management efforts to react quickly to changes in the external environment in addition to their existing production capabilities.

2.1.1. Artificial Intelligence

According to Haenlein & Kaplan (2019), AI consists in a system's ability to interpret data, learn from it, and use it to achieve specific goals. It can be classified by the types of intelligence it exhibits or by its evolutionary stage. Still, as mentioned by Peres et al. (2020), there is not yet any generally accepted, unambiguous, and exact definition of the term. Various definitions of AI have been proposed in the literature with all of them capturing the essential ideas of non-human intelligence that has been taught to carry out particular tasks. The increasing ability of these tools to carry out certain responsibilities and functions now undertaken by humans in the workplace and society ends up uniting these definitions (Dwivedi et al., 2021).

Haenlein & Kaplan (2019) make an interesting analogy when referring to AI's past by allocating each of the concept's eras to a season and by doing so, helping to understand how far this area has evolved:

i) AI Spring: This season refers to the birth of the concept in the 1940s and 1950s. Starting with the importance of Alan Turing (considered by many 'the father of AI') during World War II derived from his work on the code breaking machine 'The Bombe' for the British government, which was crucial to decipher the 'Enigma' code used by the Germans. Later, the term AI was coined at the Dartmouth Conference in 1956 (with the credit being given to the computer scientist John McCarthy) where pioneers of the field gathered to create a new research area aimed at building machines that could simulate human intelligence.

ii) AI Summer and Winter: Depicts the ups and downs of AI in the 1960s to 1980s, marked by some successes and failures of Expert Systems, which are collections of rules that try to formalize human intelligence in a top-down approach. The funding and enthusiasm for AI research fluctuated depending on the expectations and criticisms of the field, which means it was an inconsistent era.

iii) AI Fall: Driven by the rise of big data, computing power, and statistical methods such as artificial neural networks and deep learning, the attention given to AI has risen since the 1990s. The methods mentioned above allow AI systems to learn from data and adapt to new situations, enabling applications such as image recognition, speech recognition, and self-driving cars.

As we can see, AI has been present for many years and is no longer just linked to futurology because it is an essential part of many companies' business models and a crucial strategic component of plans for numerous industries. Productivity and performance are impacted when AI can overcome some of the cognitive, creative, and computationally demanding limits of humans, opening up new application domains within those diverse sectors (Dwivedi et al., 2021):

i) Education: AI can aid the learning process and assist educators in their interaction with students.

ii) Healthcare: AI can improve medical diagnosis and treatment, as well as support health and well-being.

iii) Finance: AI can enhance financial services and security, as well as enable new business models and opportunities.

iv) Manufacturing: AI can increase productivity, efficiency, and innovation, as well as create new products and markets. Peres et al. (2020) add up to this sector by

mentioning that AI can assist manufacturers in tackling the challenges associated with the digital transformation of cyber-physical systems and enable systems to perceive their environment, process the data they acquire and solve complex problems, as well as to learn from experience to improve their capability to solve specific tasks. Also, AI is one of the key technologies to achieve self-capabilities and disruptively redefine the way manufacturing processes, and business models are structured, while also creating added value for companies.

v) Government: AI can improve public services and governance, as well as foster public awareness and education.

A study predicted that AI technologies would drive economic growth and innovation while also creating 133 million new jobs globally by 2022, however it is also mentioned that AI systems are expected to reach the level of overall human capability by 2075, and some experts believe that further advancements toward superintelligent AI could pose risks to humanity (Dwivedi et al., 2021). This creates a conflict: whilst the benefits of greater levels of AI adoption within many sectors of the global economy are felt in the context of greater efficiency, improved productivity and reliability, the picture of positive innovation is not universally welcomed. Automation-related job displacement estimates indicate that by 2030, up to one-third of present labor activities may be affected. Many repetitive and rule-based tasks could be replaced by AI, which could result in the loss of a sizable number of jobs that were previously performed in emerging market economies (Dwivedi et al., 2021).

Haenlein & Kaplan (2019) add to the topic by mentioning that AI also poses significant ethical, legal, and social challenges that need to be addressed as it requires regulation to ensure the safety, fairness, accountability, and transparency of AI systems, as well as to balance economic growth and personal privacy. Regulation should be based on commonly accepted standards, best practices, and international coordination and should also consider the specific characteristics, applications, and impacts of AI in different domains and levels. The biggest concern is discovering how to regulate a technology that is constantly evolving by itself (Haenlein & Kaplan, 2019). Rashid & Kausik (2024) also contribute with some challenges, including the bias in business models, lack of transparency, job displacement, ethical concerns, security concerns, data privacy, and regulation and control. Rashid & Kausik (2024) proceed by presenting some potential solutions for each challenge, as followed: improved data collection and algorithm design; increased transparency and explainability in AI; investment in education and job training programs; development of ethical frameworks and regulations; development of more secure AI systems; increased data privacy regulations and standards; development of regulatory frameworks for AI.

According to Dwivedi et al. (2021), there will be winners and losers in the social/economic construction of AI and its effects on people and society, hence decision-makers need to strive for strategic decision-making and think about the future. The way forward is not clear and, although there may be numerous benefits accruing from AI, there are also significant risks that could arise from its implementation, meaning that decisions made within the next few years are likely to have an impact on all our lives and the lives of future generations.

2.2. Quality Management

2.2.1. Quality

Quality is an important aspect of products and processes, and it is thought to give businesses and organizations a competitive edge in the global market, according to Zonnenshain & Kenett (2020). As to its general definition, quality is a natural property or condition of a person/thing that distinguishes it from others. There is also the definition from the International Organization for Standardization (ISO), that considers quality to be the degree to which a set of inherent characteristics of an object fulfills requirements. Garvin (1984) presents us with five definitions of the concept:

Table 2.1 - Definitions of Quality

Transcendent Approach	“Quality is viewed as absolute and universally recognizable, yet difficult to define objectively. It is often associated with excellence or innate superiority in products or services, and is primarily subjective, based on personal experience or perception” (Garvin, 1984)
Product-based Approach	“Quality is seen as a measurable characteristic. Differences in quality are directly linked to the quantifiable attributes of a product, such as features, performance, or durability. The more of these desired features a product has, the higher its quality” (Garvin, 1984)
User-Based Approach	“Quality is determined by how well a product or service meets the needs and preferences of the user. It is subjective and varies according to the consumer’s expectations—quality is essentially "fitness for use"” (Garvin, 1984)
Manufacturing-based Approach	“Quality is defined as conformance to specifications. The focus is on ensuring that products are made according to design standards with minimal defects or variations. High quality is achieved when products are produced correctly the first time, with efficiency and consistency” (Garvin, 1984)

Value-based Approach	Quality is considered a function of price. A product is seen as high-quality if it offers value for money, balancing performance or features with cost. This approach emphasizes achieving the desired level of quality at a reasonable price (Garvin, 1984)

Source: Self-elaborated

ISO's definition ends up being the one that minimizes ambiguity regarding the concept hence its importance. ISO aims to help organizations meet their customers' and stakeholders' needs and it's the international reference in terms of quality management systems certification. ISO's standards have undergone several revisions since their creation in the 1940s and the number of ISO 9001 certified organizations has increased considerably, as well as the number of standards related to quality management and other subjects (Rogala & Wawak, 2021). Nonetheless, not everything is perfect according to some experts in the sector, as perceived in a research and survey carried out by Rogala & Wawak (2021), whom after obtaining their findings, concluded that experts in the area generally accept the ISO 9000 series of standards but rate their quality of elaboration as low or average. Some components that needed improvement were identified: definitions, guidelines explaining the requirements for a quality management system, the necessity of a self-assessment tool, and guidelines concerning quality management in relation to chosen forms of activity.

When it comes to historical context regarding quality management, Durakovic & Halilovic (2023) identify four stages:

i) Craftsmanship Era: Infers that quality was maintained by skilled masters through inspections before sales (until early 19th century).
ii) Industrial Revolution: Takes us to the growing importance of mechanization and standardization starting in the 1750s, which reflected in the substitution of traditional craftsmanship for the steam engine and mass production systems.
iii) 20th Century Developments: Introduction of assembly lines, statistical process control, and quality assurance concepts (a phase where some of the most important authors regarding quality emerged).
iv) Modern Quality Management: Appearance of terms like TQM, Six Sigma, and Lean manufacturing, which focus on continuous improvement and customer satisfaction.

Synthesizing, each industrial revolution brought significant changes, from mechanization and standardization to automation, plus quality management has evolved from traditional craftsmanship to modern concepts like TQM and customer experience management (Durakovic & Halilovic, 2023).

There are various relevant figures in the quality movement, each of them with its contribution and vision regarding the concept. On one hand we have western authors like Shewhart, Deming, and Juran. On the other hand, Japanese authors with the likes of Ishikawa being truly important for the concept in his own way (Dahlgaard & Anninos, 2022). For the authors, all the definitions provided by these figures are valid since quality can have distinct expressions and meanings depending on the context surrounding it, as previously defended by Garvin (1984). According to Dahlgaard & Anninos (2022), these are some of the main faces that will always be connected to the concept of quality:

i) Walter A. Shewhart (1891-1967) was responsible for the development of Statistical Control Charts and laid the foundation for understanding, measuring, and controlling product quality, which gave him the honor of being perceived as the father of modern quality control. He defined quality in his doctoral thesis as having two dimensions: objective quality (product attributes independent of consumer desires) and subjective quality (customer requirements, expectations, experiences). His work emphasized the importance of understanding customer needs and expectations to define quality.

ii) W. Edwards Deming (1900–1993) gave special attention to the dynamic nature of quality in the sense that it constitutes a challenge for translating future user needs into measurable characteristics since what constitutes good quality today may not be the same tomorrow. Deming's philosophy centered on the continuous improvement of products and services to meet the ever-changing customer needs.

iii) Joseph Moses Juran (1904–2008) defined quality as “fitness for use” and emphasized that quality comprises two dimensions: product features that meet customer needs and freedom from deficiencies. Juran's work aimed to provide a comprehensive definition of quality that would aggregate customer satisfaction and product excellence.

iv) Kaoru Ishikawa’s (1915–1989) work highlighted the idea that quality is related to everything within a company (work, processes, and people). His approach emphasized a very complete perspective on quality management that extended beyond just the product itself and contributed greatly in the context of the Japanese way of quality management.

It is important to emphasize that quality seems to have stopped in time, with no presentation of new relevant quality models in recent years. This is corroborated by the fact that the most relevant figures for the concept date back to decades ago, as seen above. Research even concluded that interest in quality engineering has fallen by 70% since 2004 in

Google searches (Zonnenshain & Kenett, 2020). In that sense, the fourth industrial revolution can be seen as an opportunity for quality to have visibility again. As Broday (2022) points out, the stagnation within the sector of quality plus the advancements in technology at a global level mean that there is an opportunity for quality to be renewed and increasingly continue to be used as a factor of competitive advantage within organizations.

Before implementing any kind of system and diving into a much more holistic approach on quality, Durakovic & Halilovic (2023) set out an alert regarding the current trends in quality control. Those are key for the previously mentioned customer experience management, which shows there has been a shift towards managing the overall customer experience to ensure satisfaction and loyalty. In their work, Durakovic & Halilovic (2023) point out that there has been a focus on identifying and fulfilling needs that customers are unaware of, which can lead to major innovations. This is correlated with the emphasis on creating products that evoke strong positive emotional responses, such as joy or surprise in the search for the much desired "customer delight". Not only that, but also the search for an innovative and attractive design, which is now linked to quality.

Quality control's importance for organizations is the main idea to retain. It will always be a fundamental aspect for business operations, regardless of its terminology or the methods used to implement it. Whether labeled as quality assurance, TQM, or any other term, the underlying principle remains the same: companies must consistently ensure the quality of their products and services. Despite the evolution of literature and the emergence of new approaches, the need for rigorous quality control remains unchanged. Organizations that prioritize quality are better positioned to thrive in competitive markets, address customer needs, and drive continuous improvement, which is exactly what is defended by Kareska (2023). The author refers to quality control as an essential piece of the puzzle, not only for the survival and future development of any organization, but also for its ability to gain a competitive advantage in an increasingly dynamic market. Furthermore, Kareska (2023) argues that success is achieved by organizations with professionally trained management teams that implement necessary structural changes and continuously follow customer needs, while also choosing optimal product quality characteristics to meet buyer needs.

2.2.2. Total Quality Management

The evolution of quality management has taken us to a phase where we cannot refer to the topic without mentioning TQM. The term was first suggested and led by the previously

mentioned Deming, who traveled from the United States of America to Japan to help the Japanese industrial firms to recover from the World War II (Sader et al., 2019).

Understanding the past is crucial for gaining a complete view of any subject since historical insights reveal the evolution of ideas and practices. By studying the development of concepts, we can better understand their origins, recognize patterns of change, and anticipate future trends. This awareness is essential for informed decision-making and innovation in any field. Having that in mind, Chen et al. (2022) point out that quality control began in the 1920s with statistical methods and evolved into TQM in the 1950s (corroborating what is mentioned in the paragraph above), emphasizing comprehensive quality management in production. In their work, Chen et al. (2022) and Durakovic & Halilovic (2023) also point out that in the late 1980s, TQM influenced service quality, focusing on customer satisfaction and loyalty, with various models and tools developed to measure and improve service quality. Chen et al. (2022), continue their line of thought by explaining the path from service quality to service science, which happened due to criticisms of service quality models.

TQM involves the application of quality management principles throughout the whole organization, which implies that everyone is supposed to seek improvement on a continuous basis. According to Porter & Parker (1993, as referenced in Al-Sabi et al., 2023), it is a holistic approach to quality management that incorporates the entire organization in a continuous improvement effort. In addition to optimizing organizational performance and customer satisfaction, TQM unifies all quality management processes, tools, and procedures into a unified system (Al-Sabi et al., 2023). It brings numerous benefits with it, from greater customer satisfaction to the already mentioned continuous improvement, which means that everyone must be involved in continuously improving the processes under their control, while also taking responsibility for their own quality assurance. Additionally, given that various technological disruptions are challenging organizations' performance more than ever these days, continuous innovation in products, services, and processes with TQM applications is crucial for an organization to survive and perform better during this difficult period (Bhandari, 2024, as cited in Sahoo, 2019).

As defended by Hitka et al. (2020) and reiterated by Bhandari (2024), an employee should be the center of attention. Employee motivation can enhance output, efficacy, and quality, all of which contribute to the success of the company (Hitka et al., 2020). Moreover, this supportive organization culture is essential for effective TQM implementation and to achieve the organization's goals. It consists of core assumptions, values, and norms developed through solving external and internal problems, which are communicated to employees (Kareska, 2023). The author continues by exposing its impact on TQM, arguing that a

successful implementation depends on compatibility with the existing organizational culture since, if compatible, TQM becomes integrated into it. When approaching the implementation of new technologies within companies, change and resistance are also truly relevant since changing organizational culture is crucial for TQM success and said resistance to change can occur due to fear, ignorance, or lack of resources, ultimately compromising companies' goals (Kareska, 2023).

Kareska (2023) also approaches continuous improvement and innovation. The author reiterates the idea that those are vital for achieving TQM goals and competitive advantage. Continuous improvement involves ongoing efforts to enhance all aspects of operations, both externally (better products/services, market position, higher income) and internally (efficient resource use, fewer errors, lower costs). Another crucial point is the employees' involvement to bet on their continuous learning, incremental improvements, and taking corrective actions. Lastly, Kareska (2023) praises the importance of quality improvement programs, which include training employees to use tools and techniques for continuous improvement, monitoring quality costs, and analyzing customer feedback.

To embrace TQM and achieve it, ISO 9000:2015 has highlighted seven principles: customer focus, leadership, engagement of people, process approach, improvement, evidence-based decision making, and relationship management (Sader et al., 2019). Dahlgaard & Anninos (2022) have a simpler approach, stating that TQM is based on only five of those seven principles. The first one has to do with the focus on the customers' needs, followed by the importance of guaranteeing everybody's participation within the organization. The authors also mention that the company should put a strong emphasis on evidence-based management, while also fostering continuous improvement. Lastly, leadership appears as the last principle as it must be committed to the other principles as well as to their integration into the organization's climate. If this is successfully perceived, companies should find it easier to achieve excellence.

The concept of excellence is introduced as a concept closely related to TQM and their interrelationship is explored in the work of Dahlgaard & Anninos (2022). To transform this relation into something more palpable, the authors developed a thorough analysis on how a company like LEGO has achieved high standards of quality in its products and processes, starting by pointing out that the Danish company has implemented a quality management system that covers all aspects of its business, from design and production to distribution and customer service. Said system is based on the ISO 9001 standard and is certified by external auditors. Dahlgaard & Anninos (2022) proceed by emphasizing LEGO's quality culture, where continuous improvement, innovation, and learning are encouraged throughout the whole

organization with a quality policy that defines the company's quality objectives and values, as well as a quality vision that guides its strategic direction. LEGO has also adopted various quality tools to ensure the quality of its products and processes, which will be key in identifying and eliminating waste, defects, and errors, while also optimizing performance. The company's efforts have been recognized by being awarded several quality prizes, which are the ultimate proof of LEGO's commitment to quality. This is exactly what TQM is about, with the company applying quality management principles throughout the whole organization.

2.3. Digital Transformation and Quality 4.0 – the "glue" between concepts

Throughout modern history, quality models and methods have evolved through several stages, including inspection, control, assurance, management, and quality by design. (Zonnenshain & Kenett, 2020) and now, with the fourth industrial revolution, Industry 4.0 has become part of the routine of organizations (Broday, 2022). Being based on advanced manufacturing and engineering technologies, massive digitization, Big Data analytics, advanced robotics, adaptive automation, additive and precision manufacturing, modelling and simulation, AI, and nano engineering of materials, this phenomenon is an opportunity for the quality movement to become a leading force (Zonnenshain & Kenett, 2020) since it allows for greater customization of processes and adaptation of products to the needs and demands of each consumer (Pereira et al., 2023).

One of the most relevant models is the European Foundation for Quality Management (EFQM) 2020 Model, which is highly related to the concept of TQM and has enough content to develop an entire paper around it, like it was demonstrated by Fonseca et al. (2021). In their work, the authors refer that this model is a comprehensive business model designed to enhance organizational performance and sustainability by integrating principles of TQM, Industry 4.0, and sustainability. Its relevance to Industry 4.0 has to do with its ability to support digital transformation through the combination of quality, excellence, and Industry 4.0 technologies, while also emphasizing the importance of managing knowledge, skills and capabilities to successfully adopt Industry 4.0. The model provides a strategic, technologically unbiased perspective, helping organizations align their operations with the United Nations' Sustainable Development Goals (SDG) and European business ethics (Fonseca et al., 2021). Finally, Fonseca et al. (2021) allude to the fact that this model's holistic approach ensures a very complete overview of the reality mentioned and offers an integrated framework for Quality 4.0, focusing on transformation, innovation, and performance improvement. The model is adaptable to various organizational sizes and sectors and incorporates Quality 4.0 principles.

Both Sader et al. (2019) and Fonseca et al. (2021) have a similar vision regarding Industry 4.0, referring to the concept as the new technological development occurred at the industrial production systems. According to the authors, its evolution derives will allow acquiring new capabilities, and consequently, a higher level of business excellence, efficiency, effectiveness, enhanced connectivity and real-time communication. It can also have an impact by promoting new organizational business models and practices, aiming to improve efficiency, quality, and sustainability. Besides the technologies previously mentioned, Ammar et al. (2021), add to the matter by mentioning cyber security, advanced monitoring and maintenance, while Varriale et al. (2023) provides a list of emerging technologies where he mentions blockchain technology, computing, geospatial technologies, human-computer interaction, immersive environments, and robotics.

Pereira et al. (2023) also share their perspective on this matter by mentioning that Industry 4.0 is characterized by the application of technology in all the integral elements of the processes, resulting in more effective and distinctive control processes as well as more flexible and agile management. Pereira et al. (2023) elaborate on this further, pointing out that the human and organizational components are equally vital to the establishment and maintenance of the concept and methodology of these systems, as they are the only ones that can produce networks that are sustainable.

Naturally, this concept is presented with both barriers and benefits. Some of its barriers are related to the high investment costs, lack of qualified human resources, the eventuality of changing management, cybersecurity issues, among others. As to the benefits, the main ones identified are increases in productivity, quality, efficiency, and competitiveness, reduction of errors and costs in the production process, intensification of relationships between consumers, availability of information in a permanent and immediate way (resulting in faster and more accurate decision making), and optimization of resources through the flexibility and agility of employees (Pereira et al., 2023).

Quality 4.0 is considered one of the newest and trending terms for quality professionals (Sony et al., 2021). It infers the digitalization of quality management and consequent improvement within the culture, organization, skills, and leadership of organizations (Jacob, 2017, as cited in Broday, 2022). It is a digital transformation that aims to improve customer satisfaction and business performance by using advanced technologies (Su, 2022), while also combining quality management with technology to foster critical competencies for organizational success, hence its relevance in the Industry 4.0 era and, in order to succeed, one should integrate Quality 4.0 with Industry 4.0 to drive change and improvement. (Fonseca et al., 2021).

Instead of a concern with product quality, more emphasis will be placed on design and safety, as well as the quality of service, plus Quality 4.0 does not replace traditional quality but promotes improvements with Broday (2022) stating that the current phase of the industry should be viewed as a chance for quality to reinvent itself.

Not only does Quality 4.0 connect the two terms being approached in this dissertation, but it also carries significant benefits with it. According to Antony et al. (2022), some of the main benefits are increased efficiency (by streamlining manufacturing processes, leading to higher operational efficiency), improved product quality (by utilizing advanced analytics and machine learning to detect inconsistencies, predict quality issues, and recommend eventual corrective actions), enhanced risk management (by identifying potential issues earlier and providing solutions to mitigate or solve them), reduction in equipment breakdown (by minimizing equipment failures through predictive maintenance), improvements in safety (by identifying and addressing potential hazards), reduction in labor costs (through the automation of repetitive tasks, reducing the need for manual labor; the ethic side can also reveal a negative side to this aspect), reduction in setup time (decreases the time required to set up processes and machinery) and drastic reduction in repetitive errors (reduces human errors by automating quality checks and processes). Furthermore, Sony et al. (2021) conducted an online survey on senior quality professionals working in leading companies in Europe and America, with a total of 50 participants, aiming to discover the top five motivations and barriers for Quality 4.0 implementation. The results retrieved, registered that regarding the motivations to implement it, the participants felt that it could improve customer satisfaction and loyalty by delivering high-quality products and services, enhance operational efficiency and performance by reducing waste, defects, and costs, foster innovation and competitiveness by adopting new technologies and practices, comply with regulatory requirements and standards by ensuring quality compliance and governance, and achieve sustainability and social responsibility by minimizing environmental impact and improving social welfare.

On the other hand, the respondents felt that this implementation can also have its risks because of the lack of awareness and understanding of the concept and benefits among stakeholders also adding the resistance to change and culture issues that accompany the adoption of new technologies and practices, the insufficient skills and competencies of quality professionals and employees to deal with quality 4.0 challenges, the limited resources and budgets to invest in these technologies and initiatives, and the inadequate infrastructure and integration of Quality 4.0 technologies with existing systems and processes (Sony et al., 2021). Once again, Antony et al. (2022), also share some of their findings on the challenges inherent to the concept. Some of those are the high training costs,

the lack of top management support (crucial for a successful implementation) and cultural change since organizations need to foster a culture that embraces digital transformation and continuous improvement. The complexity of integration could also translate into a major challenge due to the necessity of integrating new technologies with existing systems, which can be complex and time-consuming. This concept translates in a need for a highly skilled workforce as well (in both quality management and digital technologies) and that takes us to another point: data management issues. Handling and analyzing large volumes of data can be challenging, which further accentuates the necessity to have a workforce with the specific skills mentioned previously. This means that this type of decision must be carefully considered by the ones responsible before adopting any kind of system, taking us once again to the idea shared by Javaid et al. (2022) regarding companies' capacity of analyzing themselves before committing to a decision.

The motivations for implementing Quality 4.0 are also important to mention and, according to Antony et al. (2022), include terms like competitive advantage (organizations aim to stay ahead of competitors by leveraging advanced technologies to improve quality and efficiency), customer satisfaction (enhancing product quality and consistency leads to higher customer satisfaction and loyalty), cost reduction (automating processes and improving efficiency can significantly reduce operational costs), regulatory compliance (meeting rigorous quality standards and regulations is easier with advanced quality management systems), innovation (embracing Quality 4.0 fosters a culture of innovation, enabling organizations to develop new products and services) and sustainability (implementing more efficient processes can reduce waste and energy consumption, contributing to sustainability goals).

Furthermore, if companies want to act, it is important to consider some critical success factors, namely the importance of having a well-defined vision and strategy since they will help guiding the organization through the incoming transformation and towards innovation. Afterall, emphasizing continuous improvement and innovation ensures that the organization remains competitive and adapts to changing market conditions (Antony et al., 2022).

Antony et al. (2022), also mention that leadership plays a pivotal role in guiding and supporting this type of transition since commitment from top management is crucial for Quality 4.0 implementation and leaders need to align their initiatives with the overall business strategy by ensuring resources (financial, human, and technological) are adequately allocated for these projects. In other words, Kareska (2023) states that management must influence factors that create and maintain organizational culture, ensuring they support TQM principles and practices.

At the end of the day, it is up to managers to analyze and decide what to do depending on the situation and reality of the organization they are inserted in (Javaid et al., 2022). Organizations should start by analyzing and assessing their capabilities, adapting strategies, and seeking to implement them in the intended scenarios. According to Pereira et al. (2023), many companies, when integrating a digital strategy into their overall strategy, tend to focus primarily on the technology itself, quickly moving to the technical and operational aspects of the solution. In doing so, they often overlook the necessary research into the company's broader purpose, objectives, impact on competitive advantage, and value chain gains, ultimately missing the comprehensive, integrated vision crucial for successful implementation.

As we can see through the way Quality 4.0 is perceived, the concept infers the strengthening of organizational capabilities with the use of technology to produce high performing products and service experiences which calls for new ways of managing organizations. This digital era we all live in demands not only the adoption of alluring technological innovations but also the combination of quality theories with creative leadership to support innovation and agility (Dahlgaard & Anninos, 2022). Despite still being at its early stages and needing more evidence and examples of successful implementation (Su, 2022), Quality 4.0 still is considered a promising direction for the future of quality and can serve as the point to connect intelligent systems and AI to quality management.

2.4. Intelligent Systems applied to Quality Management

The fourth industrial revolution has brought about a new world where physical and virtual production systems collaborate globally, improving productivity, process efficiency, and final product quality for businesses. This has increased global income levels, increased organizational competitiveness, and improved people's quality of life (Pereira et al., 2023).

It is easy to conclude that intelligent systems and AI are current themes, with real relevance and importance which can ultimately serve as valuable help for the quality movement to gain relevance again. With quality management aiming to optimize processes to guarantee quality within organizations, intelligent systems could be an enabler in reaching so. One example of the connection between both concepts has been approached by Peres et al. (2019) by presenting a case study of applying machine learning (branch of AI) techniques to predict dimensional defects in an automotive multistage assembly process. Said paper shows us how can machine learning improve quality control by enabling the early detection of defects, which would mean the reduction of scrap and repair costs. Despite the article being very technical, the main point to take away from it is the possibility of using intelligent systems to

enhance quality management in manufacturing by using data analysis, prediction, and supervision tools, which highlights the importance of innovating. Afterall, innovation is a key driver for companies striving to differentiate themselves from their competitors and ensure long-term success and improved performance (Farida & Setiawan, 2022).

In theory, the application of these systems in most sectors will have very positive repercussions, making processes more autonomous and allowing companies to save time and money by reducing errors and enhancing decision-making speed (Antony et al., 2022). All those aspects translate in a better quality overall within organizations. However, there is a delicate relationship between humans and machines, with a growing fear among the workforce to be replaced. Some of those concerns were already shared through the findings in Dwivedi et al. (2021). There are also those who consider machines will not substitute professionals, and the key is being able to properly combine the usage of both. This is exactly what is defended by Urban (2023), who assumes that AI can be a friend or foe, depending on how it is deployed, however her article mainly focuses on the fact that AI did not necessarily appear to substitute humans, and if applied in the right way, it can be a very powerful tool. Urban (2023) makes a series of very interesting points and starts by mentioning the rising concern on whether AI poses a threat to careers or not, following that by stating that the concept is still fairly away from being maximized in terms of development, which means it does not pose (for now) a real threat to people's careers.

In fact, for forward-thinking organizations, empowering quality assurance professionals and instigating the inclusion of AI as a useful tool in quality is a must. By doing so, professionals will be able to take advantage of the concept and consequently get valuable help to perform their function with distinction and make it possible for the business they are part of to execute high-quality plans more effectively (Urban, 2023). The author uses the fact that human-centered tasks like creating, implementing, maintaining, and enhancing quality programs and product quality continue to be crucial, even considering AI's significant involvement in automating some areas of quality assurance, to support her argument. The proper combination of the two would mean that, while AI automates repetitive and time-consuming tasks, analyzes large volumes of data to identify patterns, anomalies, and potential defects, professionals can focus on tasks that require human judgement and problem-solving skills (Urban, 2023). While humans are able to make subjective judgments, take into account aspects other than data analysis, and apply their experience to assure high-quality outcomes, AI may find it difficult to do complicated and nuanced quality assessments that call for contextual understanding or subjective judgment (Urban, 2023).

Urban (2023) ends up by mentioning that the main benefit of AI is that it can support and enhance the job of quality professionals, allowing them to manage the human side of quality while making better judgments and promoting continual improvement. When AI and human knowledge are properly balanced, superior results can be achieved while utilizing the advantages of cutting-edge technologies.

Chapter 3 - Theorethical Approach

This section builds on the insights from literature to outline the theoretical foundation for analyzing the impact of intelligent systems and AI on quality management. The goal is to establish a structured framework that directly informs the research questions and enables a deeper understanding of the role intelligent systems play in transforming quality management. This theoretical approach will contextualize how these systems contribute to quality control processes, explore the challenges in their adoption, and assess their implications for stakeholders.

Intelligent systems are increasingly recognized for their capacity to automate complex processes and optimize operations across various industries. These systems have a lot of potential in the sector, and in some cases, are already revolutionizing quality management. As highlighted in the existent literature, frameworks like Quality 4.0 merge traditional quality management practices with new technologies, allowing organizations to integrate advanced data-driven techniques into their operations (Sony et al., 2021; Antony et al., 2022; Broday, 2022; Su, 2022).

According to Javaid et al. (2022), robots in Industry 4.0 will carry out recurring tasks, reduce human error, and enhance quality assurance. By automating design and development models, intelligent systems improve organizational competence and help develop strategies for building automation, ensuring superior quality control and continuous process improvement. Similarly, Zonnenshain & Kenett (2020) emphasize that intelligent systems facilitate achieving the goals of TQM by enabling a more adaptive and responsive quality management structure, enhancing continuous improvement, and minimizing errors in production processes.

While intelligent systems offer these advancements, it is important to consider the ethical implications associated with AI and automation. One key concern is data privacy. As AI systems become more ingrained in quality management, they handle vast amounts of data, some of which may include sensitive customer or operational information. Organizations must ensure they are compliant with regulations such as the General Data Protection Regulation (GDPR) in Europe and seek to implement robust data security measures (Haenlein & Kaplan, 2019).

The integration of intelligent systems into quality management fundamentally transforms the way companies monitor, assess, and improve their production processes, which directly addresses the first research question:

RQ1: How do intelligent systems contribute to the enhancement of quality control processes in various industries?

Intelligent systems, including AI, can sense irregularities in production, analyze data in real-time, and manage massive data flows by passing crucial insights to cloud-based networks, as noted by Javaid et al. (2022). This capability leads to superior decision-making and optimized process management. In line with TQM principles, Kareska (2023) mentions the importance of a general alignment in the mindset of organizations by taking advantage of techniques for continuous improvement, monitoring quality costs, and analyzing customer feedback. These are all aspects that will be improved by these systems, which offer predictive insights and automate routine checks, as Urban (2023) points out. As a result, they contribute significantly to overall product quality improvement and operational efficiency in various industries (Antony et al., 2022).

Despite the capabilities of intelligent systems, human oversight remains critical, especially in industries where nuanced decision-making and ethical considerations are vital. Rather than replacing quality professionals, intelligent systems augment their capabilities, allowing them to focus on more strategic and value-adding tasks (Urban, 2023). For example, in the automotive industry, while robots handle repetitive tasks such as assembly line work, human workers oversee quality control and manage complex tasks that require experience and critical thinking. This combination ensures that automation increases productivity without sacrificing human judgment.

The second research question focuses on the benefits and opportunities that come with adopting intelligent systems:

RQ2: What are the main benefits and opportunities associated with the adoption of intelligent systems in quality management?

The benefits of adopting intelligent systems are various (Dwivedi et al., 2021; Pereira et al., 2023) and culminate in a notoriously improved product quality (Antony et al., 2022). Javaid et al. (2022) highlight that AI enables advanced analysis of individual components' performance, which improves overall facility output quality. This specific analysis allows businesses to better control and refine their processes continuously, leading to increased efficiency. Sony et al. (2021) add that Quality 4.0 amplifies customer satisfaction through high-quality outputs and optimizes resource usage through automation. The ability to move from reactive to proactive quality control provides organizations with the opportunity to anticipate issues before they arise, significantly enhancing operational outcomes (Javaid et al., 2021).

However, adopting intelligent systems does not come without some challenges, which leads to the third research question:

RQ3: What obstacles and challenges might organizations face when adopting intelligent systems for quality management, and how can these be addressed?

While the benefits are evident, organizations face challenges such as resistance to change, high implementation costs, and the need for skilled professionals. Rashid & Kausik (2024) identify these obstacles as some of the main barriers to successful implementation. Javaid et al. (2022) further emphasize that companies must be fully aware of their digitalization degree and Industry 4.0 readiness to make suitable decisions. Organizations can address these challenges by fostering a culture of adaptability and investing in proper training.

The adoption of intelligent systems has significant implications for different stakeholders. Urban (2023) suggests that AI can automate many quality-related tasks, but Dwivedi et al. (2021) raise concerns about job displacement, especially among employees whose roles may be affected by automation. For management, intelligent systems provide strategic insights that improve decision-making but also require adjustments in leadership approaches to accommodate these new digital tools. Customers benefit primarily from higher product quality and consistency, although ethical concerns around data privacy may arise, as Haenlein & Kaplan (2019) point out.

The conceptual framework guiding this study is built on the premise that intelligent systems, when integrated with traditional quality management models, have the potential to transform processes at both operational and strategic levels. Intelligent systems certainly don't lack the potential to act as enablers of continuous improvement, data-driven decision-making, and stakeholder engagement, all of which are central to the Quality 4.0 paradigm.

Looking ahead, the future of intelligent systems in quality management will likely be shaped by further advancements, with these tools becoming more autonomous, with less need for human intervention, while improving their ability to learn from data and make predictive decisions.

On a more holistic view, and on an end note, a fourth research question was found, in relation to the various implications for all the parts involved in an organization and whether a future where almost everyone wins with the implementation of this type of technology is foreseeable:

RQ4: What are the potential implications of widespread adoption of intelligent systems in quality management for various stakeholders, including employees, management, and customers?

Chapter 4 - Methodology

4.1. Research Approach

This research was supported by a qualitative approach, using semi-structured interviews as the method for data collection. This approach was ideal for exploring how intelligent systems are integrated into quality management, while also understanding the differing perceptions between interviewees, from the challenges to the opportunities inherent to the concept, always taking into consideration these professionals' experience in their respective sectors. This approach made it possible for participants to have a flexible but focused conversation, which provided in-depth insights that were in line with the research questions. This was truly effective, since it gave participants the opportunity to focus on certain points considered more relevant than others while giving me the ability to navigate through the various topics as I saw fit.

The study's goal was to gather experiential data from participants who hold important roles in quality management within their organizations, namely directors, thus providing understanding of the quality movement and hopefully the impacts of intelligent systems and AI in their companies or sectors.

To clarify the relationship between the objectives of this dissertation, the research questions, and the theoretical foundations derived from the literature, the following table provides a structured outline, which highlights the connections between the research objectives and the corresponding research questions, supported by some of the literature review.

Table 4.1 - Relationship between objectives, research questions and literature review

Objectives	Research Question	Literature Review
(O1) Evaluate the role of intelligent systems in enhancing quality control, emphasizing their potential for automation and real-time decision-making	(RQ1) How do intelligent systems contribute to the enhancement of quality control processes in various industries?	Broday (2022); Dwivedi et al., (2021); Javaid et al. (2022); Molina (2020); Pereira et al. (2023); Sader et al. (2019); Varriale et al. (2023); Zonnenshain & Kennett (2020)
(O2) Assess the benefits and opportunities derived from the adoption of intelligent systems in quality management and demonstrate how intelligent systems and AI can serve as tools for quality to gain visibility, while considering the obstacles to their adoption	(RQ2) What are the main benefits and opportunities associated with the adoption of intelligent systems in quality management?	Antony et al. (2022); Dahlgaard & Anninos (2022); Dwivedi et al. (2021) Fonseca et al. (2021); Javaid et al. (2021); Javaid et al. (2022); Kareska (2023); Pereira et al. (2023); Sader et al. (2019); Sony et al. (2021); Urban (2023)
	(RQ3) What obstacles and challenges might organizations face when adopting intelligent systems for quality management, and how can these be addressed?	Antony et al. (2022); Bhandari (2024); Dahlgaard & Anninos (2022); Dwivedi et al. (2021); Fadilasari et al. (2024); Hitka et al. (2020); Kareska (2023); Pereira et al. (2023); Rashid & Kausik (2024); Sony et al. (2021); Souza et al. (2022)

	(RQ4) What are the potential implications of widespread adoption of intelligent systems in quality management for various stakeholders, including employees, management, and customers?	Antony et al. (2022); Bhandari (2024); Broday (2022); Dahlgaard & Anninos (2022); Dwivedi et al. (2021); Farida & Setiawan (2022); Haenlein & Kaplan (2019); Su (2022); Urban (2023)

Source: Self-elaborated

The first objective of this research was to evaluate the role of intelligent systems in enhancing quality control, with a particular focus on their potential for automation and real-time decision-making. To address this, RQ1 investigates how intelligent systems contribute to the enhancement of quality control processes in various industries. This question directly aligns with the aim of understanding the specific contributions and mechanisms by which intelligent systems improve quality management.

The second objective of the study is to assess the benefits and opportunities related to the adoption of intelligent systems in quality management and demonstrate how these systems and AI can serve as tools for quality to regain visibility. Furthermore, this objective considers the obstacles that organizations might face during this transition phase.

RQ2, RQ3, and RQ4 are closely aligned with this objective. RQ2 seeks to identify the main benefits and opportunities that intelligent systems bring to quality management, while RQ3 explores the potential obstacles and challenges organizations face when adopting these systems. Lastly, RQ4 delves into the implications for stakeholders, including employees, management, and customers, offering insights into how the adoption of intelligent systems affects both organizational operations and professionals. Together, these research questions provide a comprehensive view of the opportunities, challenges, and impacts that intelligent systems may have on quality management in organizations.

Possible participants were intentionally selected and contacted to be part of this research, and the sample consisted of 15 quality directors from various industries, all of whom were directly involved in or responsible for the implementation and management of quality control processes within their organizations. The participants were chosen based on their expertise and experience in quality management, as distinguishing between who had experience in

implementing these tools, or not, in their companies would be focusing on a niche, and that was not what was intended. Having that in mind, various quality directors were contacted, purposefully expecting the answers and visions would differ from each other and, by doing so, enrich my research and ensure that participants met my expectations and were relevant to the research objectives, which was key (Yadav et al., 2021).

Most interviewees were contacted through LinkedIn or email, where they were provided with a detailed explanation of the purpose of the dissertation and what was being sought from the conversation. This allowed potential participants to have a clear understanding of the research objectives before agreeing to take part on this research. Most of the interviews were conducted via Microsoft Teams, though a small percentage were conducted via telephone, and one was conducted in person.

The interviews were conducted between April 17th and September 13th, as finding interested professionals was challenging. The decision to conduct 15 interviews was based on the concept of data saturation, which suggests that an adequate number of interviews is reached when no new themes or insights emerge (Yadav et al., 2021; Marshall et al., 2013). As noted by both Yadav et al. (2021) and Marshall et al. (2013), rich rigor in qualitative research is achieved not only through the number of participants but also by ensuring that the data collected provides thick descriptions and a comprehensive understanding of the subjects being studied. Thus, 15 interviews allowed for a balance between obtaining depth and variety of responses while ensuring manageable data analysis.

The diversity of industries represented in the sample ensured that the study captured a wide range of perspectives, allowing for the identification of both common themes and industry-specific challenges or benefits. This sampling approach was appropriate for addressing the research questions and exploring how intelligent systems are applied across different contexts, offering the possibility of depicting both shared ideas and incongruencies between the interviewees' shared ideas. Additionally, by selecting participants from varied industries, the study adhered to criteria for trustworthiness and credibility, ensuring that the findings could offer transferable insights (Yadav et al., 2021).

4.2. Data Collection

As previously mentioned, the data was collected through semi-structured interviews, each lasting between 25 and 35 minutes and being recorded and transcribed for accurate data analysis. To maintain ethical standards, all participants were informed about the purpose of the study and provided consent before the interviews began, with confidentiality being

guaranteed. Any identifying information was anonymized to protect the privacy of the participants and their organizations.

The interview guide was designed to align with the two objectives and the four research questions, ensuring that the questions asked during the interviews addressed the core themes of the study. Consequently, interview questions (IQ) were developed to explore the specific topics related to the RQ, with IQ1 and IQ2 addressing RQ1, focusing on examples and efficiency improvements from intelligent systems in quality control; IQ3 and IQ4 explored RQ2, focusing on benefits and opportunities linked to intelligent systems; IQ5 and IQ6 aligned with RQ3, examining challenges and obstacles in adopting intelligent systems, followed by possible solutions suggested by the interviewees; IQ7, IQ8, and IQ9 related to RQ4, investigating implications for stakeholders, including ethical concerns.

All interviews were manually reviewed without the usage of any software, ensuring that every one of them was carefully examined to the detail. This manual process was demanding but ensured that no key information was lost, preserving the full context of the respondents' answers. The semi-structured format allowed a guided conversation, while also offering the flexibility to delve deeper into unexpected areas that arose during the interviews. The chance to get human insights rather than simply corporate perspectives was one of the primary purposes of the interviews, which was good to see accomplished. Mainly RQ4 and its associated interview questions allowed participants to explore a more personal dimension, giving them the freedom to move beyond their formal organizational roles. This led to a rich variety of opinions being shared, offering a chance to explore a broader range of topics in this section.

Data was organized by categorizing the responses, which were coded and grouped according to themes that emerged during the interviews. This process involved analyzing the interview transcripts to identify patterns, similarities, and differences in the responses, which were then categorized based on their relevance to the research questions.

To facilitate the analysis, the responses were put into an Excel sheet. For each IQ, the corresponding answers were examined, and key themes were extracted. This process resulted in the creation of nine tables, each corresponding to one interview question, providing a clear overview of the topics discussed by the interviewees, and leading to the following categorization:

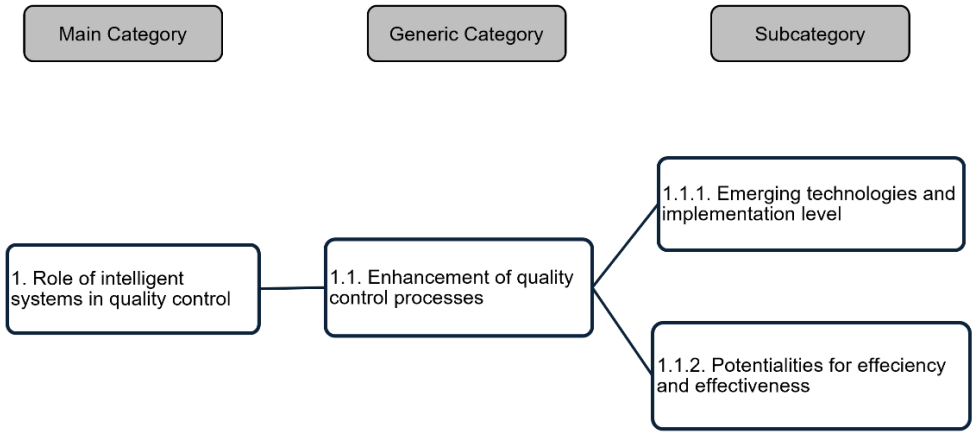

Figure 4.1. a): Categorization and codification of the interview for qualitative analysis. Source: Self-elaborated

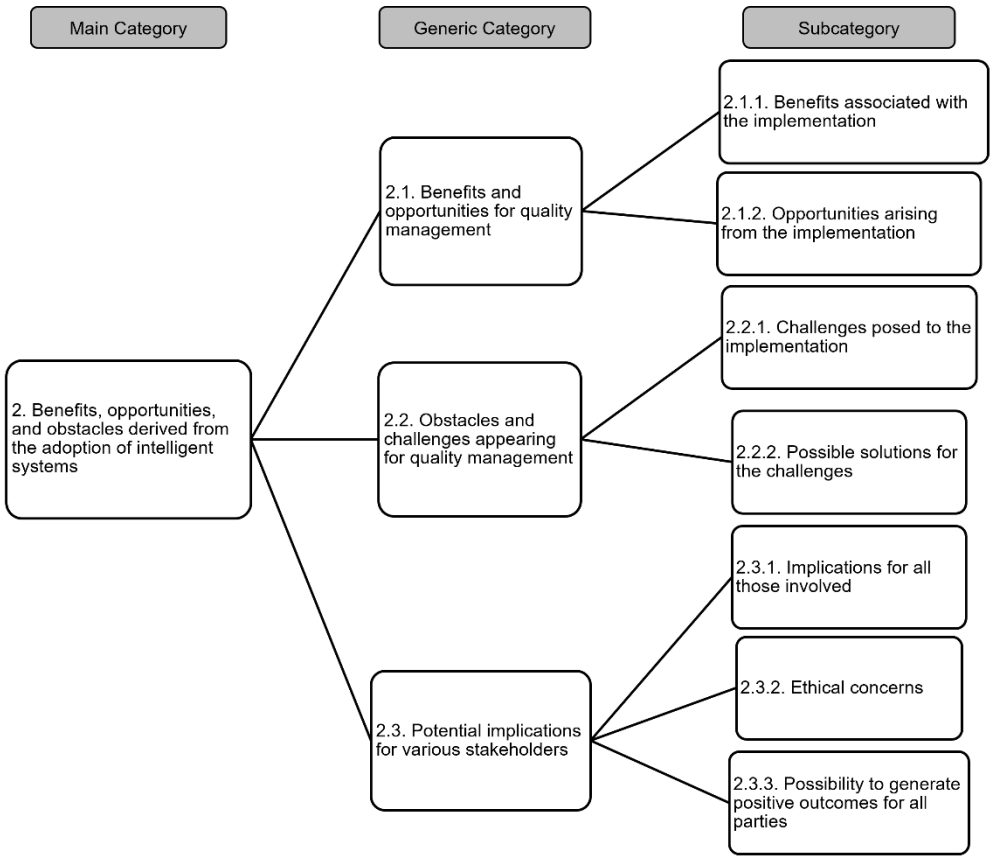

Figure 4.1. b): Categorization and codification of the interview for qualitative analysis. Source: Self-elaborated

The categorization of the interview data follows a clear structure in order to maintain coherence with the research framework. The Main Categories are based on the objectives of

the dissertation, which served as foundation for the interviews as well. Generic Categories reflect the RQ, which naturally were generated from the objectives. Each RQ provides a specific angle to assess the adoption and implementation of intelligent systems in quality management, ensuring that the analysis remains tied to the main purpose of the research.

Finally, Subcategories were designed to ensure a detailed and intuitive discussion of the results. These are directly linked to the interview questions and allow for the comparison of the insights obtained from the interviews with the theoretical concepts and findings explored in the literature review. These subcategories capture specific aspects such as the level of technology implementation, potential efficiency gains, opportunities, and stakeholder implications, ensuring a comprehensive understanding of the subject matter. This approach, commonly used in qualitative research, was guided by the work of Costa et al. (2017), who provide a clear and objective explanation of the categorization process applied to their research focus, despite approaching a totally different subject from the one in this research.

4.3. Sample Characterization

The sample for this study is characterized based on several demographic and organizational factors, providing the context for understanding the diversity of experiences and perspectives among the interviewees.

Most interviewees (73%) were “pure” Quality Directors, emphasizing that the primary focus was set on individuals who oversee quality management directly. A smaller portion (14%) represented specialized quality roles focused on specific areas, while 13% of participants held multiple responsibilities, combining quality with other roles like compliance or safety. This indicates the importance of quality management across a range of specialized and integrated functions, also reflecting the various ways organizations approach quality management.

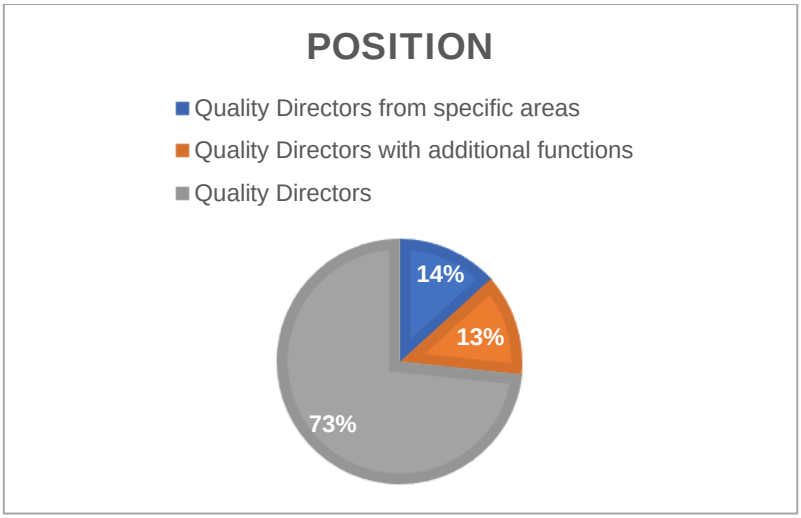

Figure 4.2: Interviewees' position. Source: Self-elaborated

The Food & Beverage industry was the most represented, with 33% of interviewees coming from this sector. Technology and Automotive followed, each contributing 13%, showing that precision, compliance, and product safety are equally critical in these high-tech, manufacturing-intensive sectors. Other industries, such as Luxury Goods, Aviation, and Consulting, were also represented. This industry distribution indicates that quality management tools and professionals are essential across a wide variety of sectors. Whether focusing on production, customer service, or regulatory compliance, these industries tend to rely on robust quality systems to maintain efficiency, safety, and customer satisfaction, showcasing the versatility and importance of quality management in both manufacturing and service-based industries.

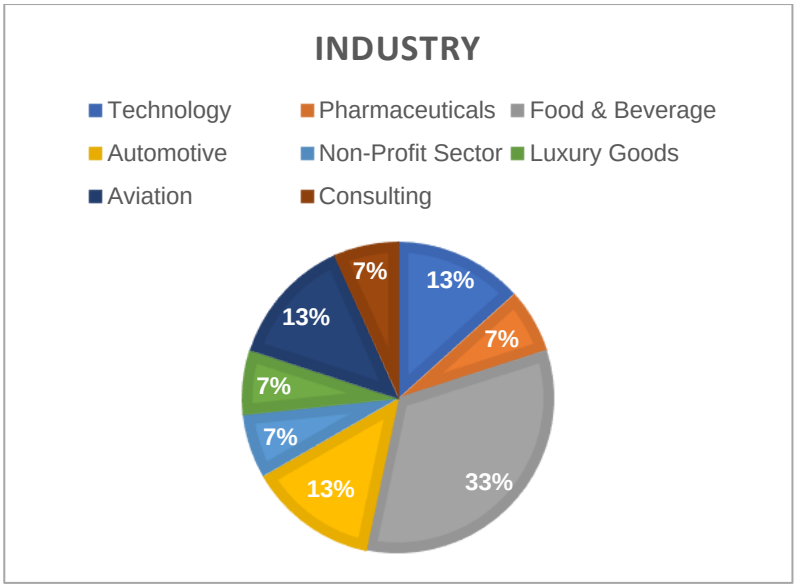

Figure 4.3: Interviewees' Industry. Source: Self-elaborated

The gender balance among the interviewees in Figure 4.4, showed a notable presence of women in quality management, with 60% female and 40% male. This gender distribution could reflect broader trends in workplace diversity, where women are increasingly occupying leadership positions.

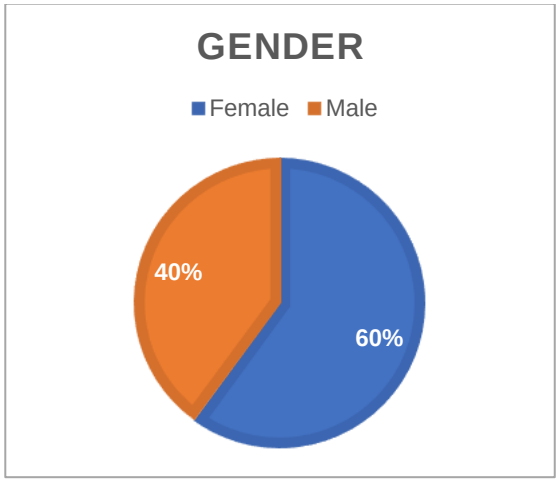

Figure 4.4: Interviewees' gender. Source: Self-elaborated

A significant portion of interviewees (80%) are from large enterprises, illustrating that larger organizations are more likely to have established dedicated roles for quality management due to the complexity and scope of their operations. Companies of smaller sizes are also represented, with 13% from medium-sized enterprises and 7% from small companies, indicating that quality management is crucial for companies of all sizes.

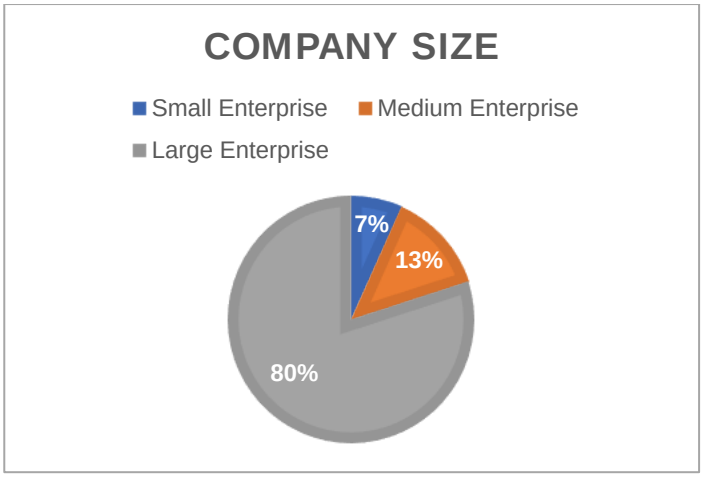

Figure 4.5: Company Size. Source: Self-elaborated

Nearly half (47%) of the interviewees' companies are between 21 and 50 years old, reflecting a stage where they are established but still evolving in their quality management processes. 20% of companies are relatively young (0-20 years), meaning they are likely to still be focusing on building robust quality systems to ensure long-term sustainability. The remaining 33% are older companies, over 50 years old, including legacy firms that have likely adapted their quality systems over time.

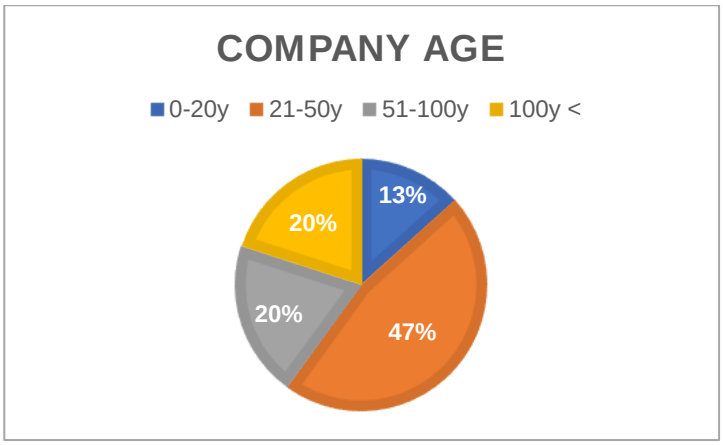

Figure 4.6: Company age. Source: Self-elaborated

Before delving into the interviewees' companies' geographical scope, it is important to begin by clarifying that all interviewees were from Portugal, and operating in the country, this chart simply shows that the companies where they work may operate at an international level. That was exactly the case for over half (53%) of them. The remaining 47% operate primarily within national borders, where the focus is on maintaining local regulatory compliance and optimizing internal processes.

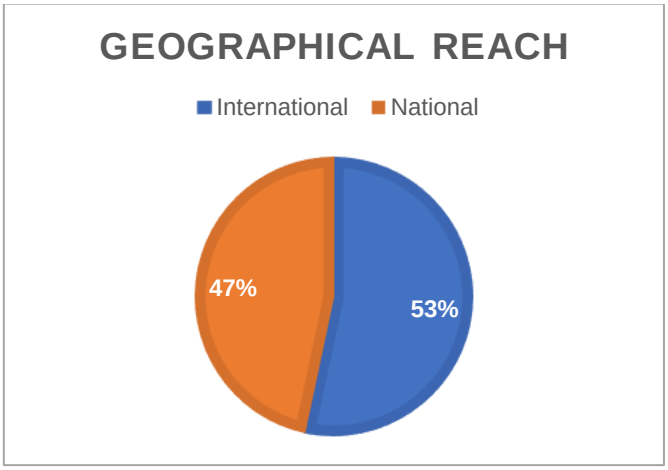

Figure 4.7: Companies' geographical reach. Source: Self-elaborated

Chapter 5 - Data Analysis and Discussion

This chapter will include a data analysis of the data collected from the interviews, followed by a comparison with the literature reviewed in Chapter 2 of this dissertation. The focus is clear: the implementation of intelligent systems in quality management. There will be various topics explored, including how said systems contribute to automation, decision-making, and process optimization within organizations, while also having in account the benefits, opportunities, challenges, and implications for all those involved, directly or indirectly, in this shift. The discussion in this chapter will connect the insights obtained via the interviews and provide a complete analysis on the important role performed by intelligent systems in enhancing the quality concept itself, but also the quality at every level within a company and show their potential for innovation and continuous improvement.

5.1. Enhancement of Quality Control Processes

The first research category in this investigation approaches the levels of interest and implementation from interviewees regarding the enhancement offered by intelligent systems for quality control processes. Having that in mind, various points from authors were considered and compared to some of the findings, in most cases serving as a tool to make them more palpable. Table 5.1 provides information about the realities faced by the organizations that the interviewees work for. This first section of the interviews gave them the opportunity to demonstrate their degree of application as well as their level of interest in the subject.

More than half of the interviewees answered affirmatively when asked if their company has some kind of intelligent system implemented within their company, which was frankly surprising, as Portugal is seen as a country at an early stage when it comes to implementing these technologies, as Pereira et al. (2023) defend.

Nevertheless, the idea that followed corroborates what Pereira et al. (2023) conclude in their work, since none of the interviewees revealed a very advanced level of technological advancement within their company. The areas of implementation by the interviewees' companies naturally varied from each other, given that they operate in different sectors. According to them, some of the examples collected were the usage of intelligent systems for automated testing related to software quality, usage of systems to comply with safety regulations, various functionalities related to the product itself, such as its identification, handling, inspection, and maintenance. Manufacturing, data collection and analysis were also mentioned.

Then, we entered onto the second dominium with the interviewees who revealed not having any system implemented within their company. Those were then divided into two groups, the ones who showed clear interest in this implementation and the ones who are already going through that process. There was one last group, not depicted in Table 5.1, related to the ones who lacked enthusiasm when referring to these tools. This seems to reflect well the way society sees these tools nowadays, with most people showing clear interest in them, but there is always a minority that goes against the masses.

The interview data showed certain companies were still at the early stages of intelligent system adoption. That reality must take into account the findings from Javaid et al. (2022), who highlight that for companies to implement intelligent systems successfully, they must first assess their internal resources and digital maturity. The fact that many of these companies showed clear interest in evolving in this direction suggests that there is a recognition of the need for proper assessment and planning to reap the benefits of these systems. In that sense, it is important to emphasize the importance of the progressive development of intelligent systems across sectors, which coincides with the perspectives from Molina (2020) and Dwivedi et al. (2021) regarding this topic, with the first citing examples like autonomous robots and management support systems and the data from the interviews corroborates this notion, as various sectors have been adopting these technologies. Broday (2022) and Zonnenshain & Kenett (2020) even highlight Industry 4.0 and its technological innovations as a crucial turning point for quality management, with Dwivedi et al. (2021), implying that AI improves productivity and performance in multiple sectors with the data retrieved from the interviews showing that professionals are becoming increasingly aware of these potentialities, hence the interest in this implementation. Independently of being at an introductory level in this process or not, companies are slowly, but promptly, starting to integrate such tools for operational improvements, betting on the incorporation of emerging technologies such as the ones depicted by Varriale et al. (2023) in his work, which can be essential for modern quality management practices.

Table 5.1 - Implementation and Interest Levels for Enhancing Quality Control Processes Across Various Industries

Text	Generic Category	Subcategory	Times mentioned	Interviewees
Already have some kind of system/technology implemented in the company	1.1	1.1.1.	8	1, 3, 6, 7, 8, 9, 10, 14
Still don't have any of these systems implemented within the company	1.1	1.1.1.	7	2, 4, 5, 11, 12, 13, 15

Despite not having any system, there is a clear interest from the professional and/or the company	1.1	1.1.1.	4	5, 11, 13, 15
Currently going through the process of implementing one of these tools	1.1	1.1.1.	2	2, 4

Source: Self-elaborated

Table 5.2 demonstrates the key contributions of intelligent systems in enhancing efficiency and effectiveness within quality control processes. These two concepts, by themselves, are significant benefits of implementing intelligent systems, making them directly related to the topic in Table 5.3, which focuses on identifying the advantages of these systems. For a start, it is crucial to focus solely on effectiveness and efficiency which were consistently highlighted by various authors, signaling their importance in the context of intelligent systems. Recognizing this, a question that asked participants to clarify how they believe intelligent systems contribute to efficiency and effectiveness within companies was deliberately included. By framing the interview question in this way, I guided the conversation to ensure that this topic was addressed, which increased the likelihood of the responses aligning with the existing literature. In summary, efficiency and effectiveness were seen as keyways through which intelligent systems enhance quality control processes and a must to mention during the interviews.

One of the main points highlighted by the interviewees was how these systems contribute significantly to task automation and process standardization, a point also supported by Broday (2022). Standardizing tasks ensures consistency, optimizes resources, and saves time across the board. Broday's view that the quality sector, coupled with the advancements in technology, creates an opportunity for intelligent systems to renew and improve operational processes aligns closely with the interviewees' perspectives on automation. The findings from Pereira et al. (2023), who discuss the flexibility and agility that intelligent systems bring to the management of processes perfectly reinforce the idea of time savings at every level.

The detection and reduction of errors and non-compliances was frequently mentioned as well, with interviewees stressing the importance of intelligent systems in identifying discrepancies and ensuring regulatory adherence. In that sense, Sader et al. (2019) emphasize how these systems not only increase operational efficiency but also lead to improvements in the overall quality control processes, aligning directly with interviewee feedback. By minimizing errors, organizations can streamline their quality control efforts, thereby increasing overall effectiveness.

The usage of efficiency and effectiveness as catalysts for differentiation was also briefly mentioned in one of the interviews, which I found interesting, since it aligns with Broday (2022), who mentions that these advancements create a competitive advantage for organizations.

Other points were mentioned by interviewees, with the likes of access to information exponentially improving with these systems, since we become much more efficient when searching for it, and effective when we get it, meaning that the information arrives to us with much more quality than prior to an eventual implementation. Reiterating the idea regarding efficiency, quality is always heavily regulated and with these systems we can navigate and understand those regulations much quicker.

Table 5.2 - Potential for Process Optimization, Efficiency, and Effectiveness by Enhancing Quality Control

Text	Generic Category	Subcategory	Times mentioned	Interviewees
Importance for task automation, facilitating process standardization, which leads to saving time, optimizing resources, and increasing consistency	1.1	1.1.2.	11	1, 2, 3, 5, 6, 7, 8, 10, 11, 12, 14
Reduction and detection of errors and non-compliances	1.1	1.1.2.	8	3, 4, 5, 6, 10, 11, 14, 15
Freeing up employees from certain tasks performed by tools and allocate them to others	1.1	1.1.2.	7	1, 3, 6, 7, 10, 13, 14
Control related tasks become much more efficient and objective	1.1	1.1.2.	5	8, 9, 11, 12, 13
Much better search and access to information, as the results will have much more quality	1.1	1.1.2.	2	2, 9
Better communication, which in turn leads to better quality results	1.1	1.1.2.	2	10, 14
Companies that know how to use these tools are more likely to differentiate themselves from their competitors by improving various areas	1.1	1.1.2.	1	5
Regulations can be navigated much more efficiently and understood more quickly	1.1	1.1.2.	1	10

Source: Self-elaborated

5.2. Benefits and Opportunities Arising from the Implementation of Intelligent Systems in Quality Management

It was already possible to get a first glance into what will be mentioned regarding the benefits of this implementation through the findings in Table 5.2. Initially, it was important to solely focus on efficiency and effectiveness as catalysts for improved quality through the usage of intelligent systems, nonetheless Table 5.3 offers a much broader view regarding the benefits mentioned by the interviewees, where we can start to see a tendency of repeating topics being approached by them. Reduction of errors was, once again, highly mentioned by the interviewees and the same happened regarding the possibility of employees focusing on tasks that require critical thinking. Two benefits that had much more adherence than before were the capabilities regarding access to information and the objectivity in the processes.

As Sader et al. (2019) and Fonseca et al. (2021) argue, intelligent systems are key to achieving higher levels of business excellence, efficiency, and effectiveness, which is also present in the interviewees' responses with various mentions to the optimization of processes and productivity gains. This is also consistent with the literature that suggests technology adoption fosters both operational and strategic gains, including enhanced communication and real-time responsiveness (Pereira et al., 2023).

The idea of reallocating employees to tasks requiring higher levels of critical thinking was also highly mentioned by the interviewees. On that note, Urban (2023) describes how AI enhances the capabilities of quality professionals by automating routine tasks, allowing them to focus on problem-solving and more complex responsibilities. The implementation of these systems not only reduces the burden on employees but also enables a more proactive management approach, as noted by Javaid et al. (2022), which is evident in the interviewees' mention to systems constituting an enabler for better decision-making.

The role of intelligent systems in reducing errors and enhancing data processing capabilities was frequently highlighted once again, being directly in line with the work of Pereira et al. (2023), who emphasized the ability of Industry 4.0 technologies to increase precision in manufacturing and operations, translating in a reduction of mistakes and an optimization regarding resource allocation. Antony et al. (2022) is also one the various authors reiterating these advancements' capacity to reduce errors and augment the speed in decision-making, which allows companies to automate processes, consequently allowing companies to save time and money. Curiously, there was one major topic missing in the interviews which was an integral part of the survey conducted by Sony et al. (2021) in which the author assessed the top five motivations for Quality 4.0 implementation. All those motivations were

mentioned in this study on a regular basis, except for one: the ability to achieve sustainability and social responsibility by minimizing environmental impact and improving social welfare which were notably absent from interviewees' responses, reflecting a gap between the interviews and literature, as interviewees largely concentrated on more immediate operational benefits. Additionally, considering this implementation could lead to an improvement in social welfare is at minimum debatable. On the contrary, various concerns are being lifted at an ethical level, both by interviewees and authors such as Dwivedi et al. (2021), with those concerns being analyzed further along the line.

Two points worth noting are the focus on proactive capabilities and data processing, both mentioned by Javaid et al. (2021) and highlighted in the table. Despite not being in its top half, they are still worth mentioning as systems' ability to not just react but to predict and address issues before they escalate provides a significant advantage, and interviewees acknowledged this proactive capacity. This aligns with Javaid et al. (2021), who puts his focus on predictive analytics, which focuses on how intelligent systems help organizations foresee and mitigate potential quality issues before they impact production.

Lastly, while the potential for labor cost reduction was mentioned by at least one of the interviewees, it certainly was not a dominant theme. This suggests that although cost savings are acknowledged, the emphasis remains on improving efficiency and operational effectiveness.

Table 5.3 - Benefits derived from the adoption of intelligent systems in quality management

Text	Generic Category	Subcategory	Times mentioned	Interviewees
Process optimization will help to skyrocket productivity levels	2.1	2.1.1.	10	1, 2, 3, 4, 5, 6, 8, 9, 13, 14
Less errors will be committed	2.1	2.1.1.	8	3, 4, 5, 6, 10, 11, 14, 15
Employees can focus on tasks that require critical thinking and have a say in decision-making processes	2.1	2.1.1.	8	1, 3, 6, 7, 10, 13, 14, 15
Quick and easy to access information, helping professionals save a lot of time and effort in the handling of documentation and other tasks	2.1	2.1.1.	7	2, 4, 7, 9, 10, 12, 13
Systems facilitate management by enabling more efficient decision-making and resource allocation	2.1	2.1.1.	5	4, 7, 9, 10, 14

Objectivity in processes is embraced	2.1	2.1.1.	5	8, 9, 11, 12, 13
Data processing benefits will be notable	2.1	2.1.1.	4	7, 9, 13, 14
Capacity to act proactively instead of waiting and only then reacting	2.1	2.1.1.	4	11, 13, 14, 15
Having a much more holistic view of the whole operation	2.1	2.1.1.	3	10, 11, 12
Some industries have been lacking specialized labor and these systems might mitigate that	2.1	2.1.1.	3	8, 11, 14
They will enable effective communication within the various departments	2.1	2.1.1.	2	10, 14
It will be easier to meet legislation requirements	2.1	2.1.1.	2	4, 14
Labor costs will be reduced	2.1	2.1.1.	1	3

Source: Self-elaborated

Table 5.4 delves into the interviewees' views on the potential opportunities that intelligent systems can provide in quality management. This was where many participants seemed the most uncertain, likely due to a limited level of literacy regarding intelligent systems and AI in quality management. This highlights a significant gap in knowledge and experience with these technologies. In many cases, interviewees had no implementations within their own companies, making it difficult for them to provide concrete opinions on potential opportunities. As a result, they often gave broad, generalized answers or reiterated points they had previously made. Despite that, several key opportunities were highlighted, showing that there is a general understanding of how these tools might positively impact their companies' quality management processes.

These findings are once again reinforced by Javaid et al. (2021) since there was one main interviewee who kept mentioning these systems' prediction capabilities for quality management. However, one of the most mentioned opportunities was the potential for enhanced service efficiency and personalization, which interviewees believe will lead to higher levels of product or service quality and customer satisfaction. This correlates with Kareska (2023), who implies that there is in fact an opportunity for companies to offer better products and services to their clients, nevertheless the technological advancements by themselves are not enough, since they require a much more holistic vision of the whole framework the company is inserted in. Quality itself is as important as these systems and an integrated approach combining technology, human expertise, and organizational alignment is essential

for sustainable success. Pereira et al. (2023) help this cause by raising the exact same point, which should not be overlooked. While intelligent systems offer great technological advancements, they cannot operate in isolation. The organizational and human components are just as essential for success. This is echoed in the interviews, with the most mentioned topic being the opportunity to reach an optimal combination of human skills and technological tools. Companies that focus solely on the technology itself without considering the human and organizational factors are likely to struggle in realizing its full benefits.

Said integrated approach by companies can be obtained if companies bet on continuous improvement which was something labeled as an opportunity by a small fraction of the interviewees. That is in line with the work of Dahlgaard & Anninos (2022). They argue that continuous improvement, combined with a focus on TQM, is key to achieving excellence within an organization. The responses from interviewees show that many are already aware of how intelligent systems could facilitate this process, but there is still room for growth in understanding how to fully implement these systems to their advantage.

Table 5.4 - Opportunities arising from the implementation for quality management

Text	Generic Category	Subcategory	Times mentioned	Interviewees
Opportunity for every company to obtain an optimal combination of human skills and technological tools	2.1.	2.1.2.	5	3, 7, 12, 13, 14
Enhanced service efficiency and personalization, leading to increased levels of product/service quality and customer satisfaction in the future	2.1.	2.1.2.	5	2, 6, 12, 14, 15
Legislative compliance and regulations will keep benefiting from these systems	2.1.	2.1.2.	4	4, 10, 13, 14
Opportunity to better manage generated knowledge within the company	2.1.	2.1.2.	3	2, 11, 13
Enable organizations to make more informed decisions by leveraging real-time data analytics and insights	2.1.	2.1.2.	3	9, 13, 15
Organizations will be able to monitor and assess product quality more effectively, ensuring consistent adherence to high standards	2.1.	2.1.2.	3	11,14, 15

There is still a lot of space for growth in non-conformity management	2.1.	2.1.2.	2	2, 14
Opportunities related to risk management, namely by understanding in more detail the impact of a change or a potential risk	2.1.	2.1.2.	2	2, 11
Certainly, more opportunities related to production and processing will continue to appear	2.1.	2.1.2.	2	3, 14
Potential to streamline processes, facilitating continuous improvement and optimization of quality control methods	2.1.	2.1.2.	2	9, 10
The predictive capabilities of intelligent systems will allow companies to anticipate potential issues and respond proactively	2.1.	2.1.2.	2	13, 15
The usage of this tools to answer to FAQs and complaints evidences a lot of potential	2.1.	2.1.2.	1	5
The need for skilled labor to manage new technologies offers opportunities for both individual learning and company innovation	2.1.	2.1.2.	1	8

Source: Self-elaborated

5.3. Obstacles and Challenges Derived from the Implementation of Intelligent Systems

The insights gathered from the interviews highlighted several critical challenges related to the implementation of intelligent systems in quality management. A primary comparison can be made with the findings from Fadilasari et al. (2024), which identify 13 major challenges against this study's 12. Gladly, most challenges identified were common to this study's, giving the following analysis more reasoning.

As outlined in Table 5.4, the primary concerns revolved around the need for specialized teams, resistance to change, and the necessity for human oversight, among others. One of the most frequent challenges identified was the need for specialized talent (mentioned by 7 interviewees), which was already highlighted in Table 5.4, initially viewed as an opportunity emerging from the implementation of intelligent systems. However, its mention in the challenges section suggests that this need is a double-edged sword. While it presents an opportunity, it also poses a significant concern: if companies struggle to find specialized talent,

companies may find the implementation of these systems ineffective or unsustainable. Still on the implementation topic, Antony et al. (2022), also expose one challenge which is only mentioned twice in the interviews, which is the necessity to overhaul or adjust existing tools to integrate these systems effectively. This aligns with Pereira et al. (2023) and Sony et al. (2021), who both emphasize the difficulty of finding qualified professionals with the necessary expertise to manage and optimize intelligent systems. In this sense, companies may struggle to fully integrate these systems if they do not invest in enhancing their workforce's capabilities.

Further complicating matters is the resistance to change, with 6 interviewees pointing out that companies often face internal pushback from employees who fear job loss due to automation. This issue is well-supported by Kareska (2023) and Dwivedi et al. (2021), who discuss the social and cultural resistance that often accompanies technological change, particularly when the workforce fears its future. This is an important topic for further discussion later, when the ethical concerns of this implementation are approached. Furthermore, the concern that intelligent systems may fall into the wrong hands was also mentioned by interviewees and it is a relevant aspect to consider from an ethical perspective as well. Dwivedi et al. (2021) and Rashid & Kausik (2024) also emphasize the risks of misuse and bias in AI models, which could lead to harmful applications. These ethical concerns emphasize the importance of implementing robust AI governance frameworks to mitigate such risks and ensure these tools are used responsibly.

Lastly, the necessary human oversight required to maintain accuracy and consistency in quality management was noted by 4 interviewees. This resonates with Antony et al. (2022) and Sony et al. (2021), who argue that human involvement remains essential in ensuring the effectiveness of intelligent systems, particularly in the context of complex decision-making processes. Additionally, Rashid & Kausik (2024) highlight the necessity of ensuring transparency and accountability in AI systems to avoid bias and errors, further reinforcing the point that human supervision is indispensable in these scenarios. Souza et al. (2022), also contribute to the idea of human supervision in their findings by mentioning the Human in the Loop (HITL) concept, which infers that human judgement is crucial even in the most automated environments.

Table 5.5 - Arising challenges from the implementation of intelligent systems

Text	Generic Category	Subcategory	Times mentioned	Interviewees
There is a need for a specialized team with the know-how to handle these systems	2.2.	2.2.1.	7	1, 2, 7, 12, 13, 14, 15

The mentality shift necessary for this implementation can be a challenge to overcome from a company's perspective, both internally and externally	2.2.	2.2.1.	6	1, 7, 9, 10, 11, 13
Resistance to change could emerge from within the own organization with rising concerns about job loss due to automation	2.2.	2.2.1.	6	1, 4, 8, 10, 11, 13
Employees may struggle to adapt to new technologies, especially long-term ones	2.2.	2.2.1.	6	7, 9, 10, 13, 14, 15
Human supervision is still necessary to ensure accurate results in quality management	2.2.	2.2.1.	4	3, 6, 11, 13
Ensuring compliance with evolving regulations, may slow down the adoption of intelligent systems in quality management	2.2.	2.2.1.	3	2, 9, 13
There is a danger that intelligent systems could fall into the wrong hands, leading to unethical or harmful applications	2.2.	2.2.1.	3	3, 5, 13
The high upfront investment required for intelligent systems can be a barrier for many companies	2.2.	2.2.1.	2	4, 6
Companies may need to overhaul or adjust existing tools to integrate systems effectively	2.2.	2.2.1.	2	9, 15
Systems may lack judgement that human experts bring to quality assurance decisions	2.2.	2.2.1.	2	11, 13
Organizations may struggle to adapt at the same pace as technological advancements	2.2.	2.2.1.	1	5
Companies may start losing their identity	2.2.	2.2.1.	1	8

Source: Self-elaborated

Although various challenges were raised by both interviewees and literature, there is a clear tendency to pair these difficulties with potential solutions. This proactive approach demonstrates that, despite the obstacles companies may encounter, quality professionals seem ready to tackle them promptly. The table illustrates a series of solutions proposed by them to address the eventual challenges appearing from the implementation of intelligent systems in quality management. 6 out of 15 interviewees highlighted the need for continuous training of professionals, while 4 of them mentioned the necessity to have realistic discussions within the company to raise awareness. As to the rest of the solutions mentioned, those only

had one or two respondents, this being explained by the fact that 4 of the interviewees had difficulties answering this question, thus not appearing in the table. It is not clear what this pattern infers, but basing ourselves on previous discussions, this could be another proof of most quality professionals' lack of maturity regarding these topics. This is also supported through one interviewee's mention of external guidance being a viable option for better informing companies about these advancements since it echoes what was previously highlighted in the analysis of Table 5.4, implying a general discomfort and knowledge gap among some professionals regarding intelligent systems.

Literature supports the main solutions highlighted in Table 5.6, particularly through Hitka et al. (2020) and Bhandari (2024), who emphasize employees and organizational culture as central topics. The continuous motivation and training of employees leads to higher performance and effectiveness, which aligns with the interviewees' concerns about keeping employees informed and aware. Kareska (2023) reinforces this by indicating that TQM should be compatible with existing organizational cultures for it to become an integrated part of the company and foster innovation. Rashid & Kausik (2024) also provide a list of possible solutions for various challenges regarding AI throughout their work, hence supporting some of the ones mentioned by interviewees. The authors mention the importance of investing in education and job training programs, supporting the interviewees' importance given to continuous training. Another topic mentioned by Rashid & Kausik (2024) is the increasement of transparency which complies with the need to have realistic discussions on the topic within companies. Lastly, the authors fully support the necessity of regulation playing a pivotal role in preventing these technological advancements from becoming a risk. Despite only being mentioned by one interviewee, leadership is pivotal in supporting the implementation of these technologies. The discrepancy between the interviewees' input and the rest of the literature, where authors such as Antony et al. (2022), Kareska (2023), and Dahlgaard & Anninos (2022) emphasize leadership's role, could indicate a gap in understanding or a lack of focus on leadership's involvement.

Table 5.6 - Solutions presented to mitigate the challenges in implementation

Text	Generic Category	Subcategory	Times mentioned	Interviewees
Betting on professionals' continuous training	2.2.	2.2.2.	6	5, 7, 8, 10, 14, 15
Having realistic discussions to raise awareness, mainly within the own company is very important	2.2.	2.2.2.	4	2, 5, 8, 10

Achieving a balanced combination of systems and employees	2.2.	2.2.2.	2	1, 3
Investing on a phased implementation	2.2.	2.2.2.	2	2, 15
Regulation plays a pivotal role in preventing these advancements from becoming a risk	2.2.	2.2.2.	1	5
Leadership must be aligned with the implementation	2.2.	2.2.2.	1	10
External guidance could be an option for companies to be better informed about these advancements and make choices on this regard	2.2.	2.2.2.	1	13
Making sure the company obtains specialized resources to soften the transition	2.2.	2.2.2.	1	15

Source: Self-elaborated

5.4. Implications for Everyone Involved

As shown in Table 5.7, the interviewees shared their thoughts on the various implications of intelligent systems in their organizations. This section of the interviews recorded highly varied responses, reflecting the diversity of opinions across different industries and roles. Despite not being mentioned the most, there were two themes that emerged from this section of the data where we can observe this divergence of ideas: the impact on communication within companies and concerns related to privacy and safety.

Regarding interdepartmental communication, three interviewees emphasized the potential improvement these systems could bring, facilitating information sharing. For these interviewees, the implementation of intelligent systems was seen as a key driver for improved communication processes across different departments, thus aligning with the organizational goals of continuous improvement. This aligns with the vision from Urban (2023), who mentions AI and systems as important support tools for quality professionals, allowing them to make more informed decisions. Nonetheless, not all interviewees shared this optimistic view. One participant noted that while these systems may improve communication, they also pose a threat to the depersonalization of relationships within the company, making interactions more robotic and less human which introduces an important consideration: while intelligent systems can streamline processes, they may also deteriorate human relationships within organizations, a factor that may impact organizational culture. Urban (2023) also discusses the importance

of human judgement and problem-solving skills, and this highlights the necessity of a balanced approach where human input is not entirely replaced by automated systems.

Another key concern mentioned had to do with the privacy and safety implications of intelligent systems. Several interviewees highlighted privacy risks, particularly regarding data integrity and confidentiality. Four respondents pointed out that the implementation of intelligent systems may expose organizations to privacy breaches or make sensitive data vulnerable. However, another interviewee noted that these systems bring greater control and safety, adding to the complexity of this debate. Privacy and data security remain highly contested topics (not only because of AI and other tools), and we can take the findings from Su (2022) into consideration since they state that despite Quality 4.0 being considered a promising path towards continuous quality enhancement, we can't forget this concept is at an early stage, meaning that it needs more evidence and examples to fundament its implementation at a larger scale.

Furthermore, implications like job displacement for less skilled workers and the reduction of human dependency were highlighted by four and three interviewees, respectively. This concern is also present in literature and will be later discussed in this chapter.

Broday (2022) emphasizes that the introduction of Quality 4.0 does not replace traditional quality management but enhances it, offering an opportunity for industries to reinvent and improve processes. The potential for professionals to work collaboratively with intelligent systems, as emphasized by seven interviewees, demonstrates a strong alignment with this notion of evolution rather than replacement. It shows that, while concerns persist, professionals can adapt and work together with technology, leveraging its benefits for greater organizational success.

Table 5.7 - Implications of the implementation of intelligent systems

Text	Generic Category	Subcategory	Times mentioned	Interviewees
Professionals will work together with systems/AI, using them as support tools and being liberated from repetitive tasks	2.3.	2.3.1.	7	1, 2, 3, 10, 12, 13, 14
Systems will contribute for continuous improvement throughout the whole organization	2.3.	2.3.1.	5	2, 6, 9, 11, 12
This implementation constitutes a threat for the less skilled employees	2.3.	2.3.1.	4	5, 7, 8, 11

Privacy/safety dilemma with some feeling there are privacy risks related to data integrity and confidentiality, while others feel safer	2.3.	2.3.1.	4	2, 4, 5, 10
Reduction of human dependency	2.3.	2.3.1.	3	6, 9, 10
Professionals will find it easier to handle data	2.3.	2.3.1.	3	10, 12, 15
Sharing of information and interdepartmental communication will improve	2.3.	2.3.1.	3	11, 12, 14
There is still some distrust from professionals and society as a whole	2.3.	2.3.1.	2	13, 14
Customers will have higher expectations	2.3.	2.3.1.	1	1
Introducing systems might deteriorate human relationships within companies	2.3.	2.3.1.	1	8

Source: Self-elaborated

Table 5.8 reflects a section of the interviews that was truly enriching, with various considerations being considered, with most interviewees showing agreement on key concerns related to job displacement and the fear that less-skilled employees may be at higher risk, echoing what Dwivedi et al. (2021) pointed out in their discussion on AI potentially replacing human workers, particularly in repetitive tasks. Contrarily there were 3 interviewees, which represents 20% of the sample, who did not share these concerns, presenting various reasons to justify so: (1) Complacency is what leads to being surpassed, not the tools by themselves; (2) Companies are created to generate profit; (3) With evolution, new functions and processes are also developed; (4) These tools create an opportunity to evolve at every level, including the chance to hire employees with more qualifications; (5) There is no necessity to reduce job positions, as people would simply perform their tasks more quickly. Following this idea, Urban (2023), acts as the "devil's advocate" by emphasizing that AI, if implemented correctly, is not necessarily a threat. Rather, it can complement human skills and support professionals. Urban (2023) also highlights that the threat is still not imminent due to the current stage of development of these systems.

Concerns about privacy and security also emerged in the interviews since implementation without adequate regulations, may pose data integrity and confidentiality risks. This debate mirrors the perspectives from Dwivedi et al. (2021) and Haenlein & Kaplan (2019) shared, with the second ones mentioning that while customers will benefit from better products, they too

might raise concerns around data privacy, which could become increasingly concerning as systems develop further.

Another recurring theme in the interviews was society's immaturity to deal with these systems at various levels: technological, regulatory, and social. This was mentioned by one of the interviewees that probably showed the highest level of literacy and passion for the topic. Said respondent added to the matter by mentioning that it is too early to consider these tools as replacements ones. Instead, we must use them as support for professionals, since it is still too dangerous and premature to give such high autonomy to this type of system. This has also been mentioned in literature, with Dwivedi et al. (2021) emphasizing that while AI offers many benefits, it needs to be carefully managed and regulated to avoid negative outcomes.

Finally, a regulated system is necessary to address these concerns, a sentiment supported by several interviewees who believe that AI systems need strict regulations to prevent misuse.

Table 5.8 - Ethical concerns accruing from the implementation of intelligent systems

Text	Generic Category	Subcategory	Times mentioned	Interviewees
There is a general concern related to human replacement and consequent unemployment	2.3.	2.3.2.	9	2, 3, 5, 7, 8, 9, 10, 11, 15
The immaturity revealed at various levels can be something dangerous	2.3.	2.3.2.	4	2, 4, 9, 13
Privacy issues	2.3.	2.3.2.	4	4, 13, 14, 15
There are no relevant ethical concerns	2.3.	2.3.2.	3	1, 6, 12
Difficulty and controversy on encoding moral principles into a system	2.3.	2.3.2.	2	2, 3
Leadership's sole focus on profit	2.3.	2.3.2.	2	3, 10
Systems clearly need to be used in a regulated system	2.3.	2.3.2.	1	2
These tools may lead to lack of mental exercise	2.3.	2.3.2.	1	9

Source: Self-elaborated

The responses in Table 5.9 indicate the most relevant steps companies must take to generate positive outcomes from the implementation of intelligent systems and AI. This topic gave interviewees a lot of freedom in their answers, in which they were expected to decide on whether it is possible to obtain a win-win situation in the future, with the increasing number of

intelligent systems and AI being implemented within companies. That is mirrored in the way answers are distributed. The most talked about matter was the importance of acceptance of these disruptions by both leadership and departments across companies, which is facilitated by a well-structured transformation plan, as this process has impacts at an organizational culture level. In that sense, Antony et al. (2022) highlights the necessity of a well-structured transformation plan, aligned with a clear vision and strategy, to guide organizations through technological advancements. This aligns with interviewees' emphasis on ensuring all departments are involved to avoid resistance and foster adaptation.

Capacity to adapt was another frequent response. Farida & Setiawan (2022) assert that innovation is crucial for companies aiming to differentiate themselves and stay competitive. With that in mind, adaptability plays a critical role in allowing companies to incorporate innovative strategies and solutions. Urban (2023) suggests that empowering professionals to work alongside AI, rather than seeing it as a threat, facilitates this adaptation, which means companies must manage these innovations in a way that supports continuous improvement while preserving human judgment for more complex tasks, which was also an idea repeated in the interviewees' opinions.

The possibility of handing over repetitive tasks to systems and take on others was something already mentioned throughout the whole analysis, nevertheless there were still 3 interviewees who made sure they mentioned this aspect again as an important tool to generate positive outcomes for all. Urban (2023) agrees by mentioning that AI is designed to automate repetitive and time-consuming tasks, enabling professionals to focus on problem-solving and other kinds of activities. This frees up resources and enhances overall productivity, as mentioned by interviewees who saw this as a key driver for generating positive outcomes.

Interestingly, interviewees also raised the need for independent voices or ethics committees to oversee the implementation of these technologies. This aligns with Haenlein & Kaplan (2019), who emphasize the importance of regulation and transparency to ensure the ethical use of AI. This showed that interviewees, at least the 3 mentioning this matter, kept showing enormous awareness regarding the ethical concerns previously highlighted.

Another significant point from the interviewees was the management of information, especially regarding what leaves the organization and what employees can access. Dwivedi et al. (2021) also highlight these and other matters, which was echoed by 3 of the interviewees.

There was a vast list of other answers which had a lot less adherence than others. The most surprising one was the assessment of the cost-benefit of the implementation and its return on investment, as it is something truly crucial for companies to assess if said implementation is even viable, otherwise they don't even need to check the other

requirements. This might be explained by the fact that this question followed one that centered around the ethical concerns of this reality, meaning interviewees still had their minds on that matter.

Innovation was cited as another key factor for generating positive outcomes. Bhandari (2024) reiterates the importance of continuous innovation in maintaining competitiveness, particularly in times of technological disruption. The interviewees mentioned that companies must seek innovation not only to stay competitive but also to ensure that systems are continuously optimized and aligned with evolving market demands. Additionally, the concept of ensuring the right human and technological resources was emphasized by both interviewees and literature, which takes us again to what was mentioned by Urban (2023), who argues that AI must support professionals, not replace them, with a need for balanced integration of human expertise and technology. Dahlgaard & Anninos (2022) support the notion that quality should be a key driver for companies, ensuring they stay on the right path when implementing disruptive technologies.

Table 5.9 - The path to generate positive outcomes for all

Text	Generic Category	Subcategory	Times mentioned	Interviewees
Importance of acceptance from leadership and all parties, facilitated with well-structured transformation plans involving all departments	2.3.	2.3.3.	5	1, 8, 13, 14, 15
Capacity to adapt	2.3.	2.3.3.	4	1, 5, 11, 13
Handing over repetitive tasks to systems and take on others	2.3.	2.3.3.	3	1, 5, 11
Need for independent voices or ethic committees to instill a sense of responsibility within companies	2.3.	2.3.3.	3	2, 3, 15
Manage information by controlling what leaves the organization and what each employee can access	2.3.	2.3.3.	3	4, 7, 12
Assess the cost-benefit of the implementation, as well as its return on investment (ROI)	2.3.	2.3.3.	2	1, 14
Seek innovation to stay competitive	2.3.	2.3.3.	2	2, 13
Ensure the right human and technological resources	2.3.	2.3.3.	2	2, 11
Manage supplier-client discrepancies when it comes to	2.3.	2.3.3.	2	7, 10

regulation and standards involved				
More transparency in processes	2.3.	2.3.3.	2	12, 15
Understand the tool prior to implementing it	2.3.	2.3.3.	2	14, 15
Quality as a key driver for companies to follow the right path	2.3.	2.3.3.	1	2
Create and update legislation so that these systems can be used in a controlled manner	2.3.	2.3.3.	1	3

Source: Self-elaborated

When analyzing the relationship between quality and the implementation of intelligent systems, the data from interviews might initially suggest a unidirectional connection where quality is solely enhanced by the integration of new technologies. However, upon further exploration, an interesting perspective emerged, one that indicated a mutually beneficial relationship between quality and technology.

Drawing on the insights provided by Bhandari (2024) and the responses from the interviewees, it becomes clear that while intelligent systems and new technologies offer significant benefits to quality management, quality itself plays a pivotal role in driving the adoption of these technologies in many organizations since the pursuit for higher quality standards and the need for continuous improvement at every level, act as the catalyst for innovation, attracting companies to invest in cutting-edge technological solutions.

This interdependence suggests that the relationship between quality and technology is not linear but rather cyclical. On one hand, quality management relies on intelligent systems to enhance process efficiency, minimize errors, and ensure consistency. On the other hand, the demand for superior quality motivates companies to push the boundaries of technological innovation, adopting new tools and systems to meet evolving customer expectations and regulatory standards.

Chapter 6 – Conclusion

6.1. Final Considerations

The concluding chapter of this research brings together the key insights derived from the interviews and analysis carried out on the implementation of intelligent systems in quality management. As industries increasingly turn to automation and data-driven technologies, the role of intelligent systems in enhancing quality control should increasingly come to the forefront. This research sheds light on how these technologies are being adopted, the benefits they bring, and the challenges organizations face. The findings offer a deeper understanding of how intelligent systems can be leveraged not only to improve quality processes but also to reshape the future of quality management. By revisiting the research questions, this chapter synthesizes the results gathered from the interviews and discusses their implications for both industry stakeholders and future developments in the field.

The first research question of this study was designed to explore how intelligent systems contribute to the enhancement of quality control processes across various industries, which led to two major questions for interviewees to answer, one related to levels of interest and implementation of said tools in their companies and the other requiring their vision on the potential of these systems for efficiency and effectiveness within companies by enhancing quality control. From the interviews, it was possible to gather that more than 50% of the interviewees (8 out of 15) indicated that their companies already have some form of intelligent system in place, while 7 answered contrarily. Out of those, 2 revealed being in the process of implementing these technologies, while 4 showed keen interest in their adoption, which demonstrates how professionals are becoming more conscious of these possibilities, thus demonstrating there is interest in this application. Whether or not they are just getting started, businesses are swiftly but steadily incorporating these technologies to enhance their operations. It was still possible to find that despite this current higher than expected adherence, none of the interviewees revealed to be working for a company at the forefront of technological advancements. When delving into the second interview question, and focusing on efficiency and effectiveness, participants noted that these systems play a crucial role in process automation and standardization, with 73,3% of them highlighting the optimization of time and resources as significant benefits. The systems' ability to detect and reduce errors was mentioned by 53,3% of respondents, showing that intelligent systems lead to enhanced product consistency and fewer non-conformities. Additionally, 7 interviewees noted that automating repetitive tasks enables employees to focus on more strategic functions. These

points underline the effectiveness of intelligent systems in streamlining quality control processes and optimizing organizational performance, mainly through the reduction in errors.

The second research question sought to address the main benefits and opportunities associated with the adoption of intelligent systems in quality management. The interviews revealed that process optimization is viewed as one of the greatest benefits, which would significantly boost productivity, as agreed upon by two thirds (66,6%) of the interviewees. Moreover, slightly over 50% of the participants mentioned that these systems enable employees to focus on tasks requiring critical thinking, thus improving overall decision-making and strategic management, with the same number being registered as to the benefit related to the reduction of errors at every level within the organization. Many interviewees also emphasized the increased ability to process data quickly and accurately, facilitating faster and better-informed decisions. These systems' role in embracing objectivity in processes was highlighted by 5 participants, while other benefits mentioned included the better handling of data and the prediction capabilities of some of these systems, enabling companies to act proactively (both with 33,3% adherence from interviewees). Having a more complete view of the operations and the capacity of these systems to mitigate labor shortages were mentioned by 20% of the respondents. When approaching the opportunities inherent to these tools, many interviewees recognized the potential of intelligent systems in improving quality management, however there was noticeable uncertainty among some participants due to a limited understanding and experience with these technologies. This first glance to a gap in knowledge led to several broad or generalized responses, particularly from those whose companies had not yet implemented intelligent systems. Among the opportunities mentioned, 5 interviewees noted the potential for companies to achieve a balance between human skills and technology, and five more noted the existing potentialities when it comes to enhanced product and service quality, followed by increasing customer satisfaction.

The third research question addressed the obstacles and challenges organizations might face when adopting intelligent systems for quality management, with a consequent focus on how those can be addressed. The interviews highlighted several barriers, with the need for specialized talent being the most frequently cited challenge. 46,7% of interviewees indicated that companies often struggle to find employees with the necessary expertise to manage these systems effectively, which shows once again that this aspect is two-faced. On one hand, being mentioned in the benefits for the previously mentioned reasons and being mentioned in the challenges as the skilled professionals may not be easy to find. There were two challenges related to this shift at an organizational level that were mentioned by 6 interviewees. One of them was the resistance to change mainly due to a shared fear of job displacement, with the

other challenge (with 40% of adherence) being the necessity for a mentality shift, which can be something difficult to overcome. With 6 respondents sharing this challenge, the difficulty for employees to adapt to these technological advancements was also mentioned. 4 interviewees mentioned human oversight as a challenge, in the sense that maintaining human involvement in quality control to ensure the accuracy and reliability of automated systems is needed. Despite these challenges, participants suggested solutions to mitigate them, with some demonstrating a hands-on approach to the matter. As to the others, there was another evidence of eventual lack of literacy on this topic, as 4 of the interviewees had difficulties answering the question related to potential opportunities for quality management. Six respondents emphasized the importance of investing in continuous training for employees, while 4 recommended holding realistic and honest discussions within the company to raise awareness about the potential benefits and challenges of these tools. Despite only being mentioned by 1 interviewee in this section of the interviews, the role of leadership cannot be underestimated, as it can act as a catalyst to help kick-start innovation throughout the whole organization.

The fourth, and last, research question focused on the potential implications of the widespread adoption of intelligent systems for various stakeholders, including employees, management, and customers. The interviews revealed that 7 participants believe professionals will collaborate with intelligent systems, using them as support tools to handle repetitive tasks while focusing on more critical functions. Furthermore, 33,3% of interviewees felt that these systems will substantially foster continuous improvement within their organizations. However, concerns regarding the impact on less-skilled employees were raised by 4 interviewees, who feared these systems might lead to job displacement. Later, as the interviews progressed, an eighth question led to 60% of interviewees mentioning once again this concern related to human replacement. The issue of privacy was also brought up, with 4 respondents highlighting potential risks to data integrity and confidentiality, and a truly interesting concern was shared by one of the respondents, by mentioning the existent society's immaturity in three domains when it comes to these advancements: technological, social, and regulatory. Despite these concerns, other interviewees saw intelligent systems as an opportunity to enhance data handling and improve communication within organizations. To generate positive outcomes, the interviewees stressed the importance of well-structured transformation plans that involve leadership and all relevant departments. Five respondents emphasized the need for transparency in processes, and 4 noted that adaptability is crucial for companies to manage this transition effectively. Additionally, ensuring that organizations maintain ethical guidelines and regulatory frameworks was highlighted as essential to mitigate

potential risks associated with these technologies. On a large scale, interviewees considered it challenging but possible to generate positive outcomes for almost everyone, mentioning various key enablers to do so, namely leadership (33,3%), capacity to adapt (26,7%), proper combination of professionals and systems (20%), the need for ethic committees (20%), proper information handling (20%), and others with a representation of mostly 13,3%, of which the return on investment deserves special attention, as it constitutes something that all successful companies calculate, and could be the difference between going forward with this implementation.

With an emphasis on how AI and other intelligent tools can improve quality control procedures, this study sought to address quality management's need for renewal and the role that intelligent systems play in it. Pereira et al. (2023), Antony et al. (2022), and Javaid et al. (2022) constitute some of the literature that has already addressed these disruptive advancements, which provide noteworthy advantages, including enhanced decision-making, optimized quality operations, and increased process efficiency. Nonetheless, it's crucial to approach these developments cautiously as Dwivedi et al. (2021) draw attention to the difficulties that may occur from implementing them and serve as a reminder of the possible obstacles that organizations may have to face. However, these difficulties can be mitigated with strategic planning and effective execution, enabling businesses to gain from intelligent systems for long-term development and enhancement.

In conclusion, the findings from this study indicate that while the adoption of intelligent systems in quality management offers significant benefits, it is not without challenges. Additionally, the relationship between quality management and technology appears to be cyclical: intelligent systems improve quality, but at the same time, the pursuit of higher quality standards drives companies to adopt further technological innovations. This research has successfully addressed its objectives by evaluating the role of intelligent systems in enhancing quality control and assessing the benefits, opportunities, and challenges associated with their adoption. Through a combination of theoretical insights and empirical data, it is clear that intelligent systems not only improve operational efficiency but also act as a catalyst for continuous innovation in quality management.

6.2. Contributions to the University and Corporations in the field of Quality Management

This dissertation provides valuable academic insights into a field with a lot of potential, one in which technology intercepts quality management. It highlights how these systems can

revolutionize traditional practices, offering improved efficiency, data-driven decision-making, and greater customer satisfaction. More specifically, the study aids organizations by identifying success factors, opportunities, and challenges in adopting these types of solutions.

For companies operating in diverse industries, this research serves as a blueprint for integrating intelligent systems into their quality control frameworks, offering a strategic approach to address challenges like resistance to change and high implementation costs. Additionally, it emphasizes the significance of human oversight in this deployment, reinforcing the value of collaboration between these systems and quality professionals to achieve organizational goals.

These contributions are especially critical for industries striving to stay competitive in an increasingly digital landscape, where it is important to remember that the relationship between quality management and technology appears to be cyclical: intelligent systems improve quality, but at the same time, the pursuit of higher quality standards drives companies to adopt further technological innovations.

Moreover, the findings encourage companies to pursue continuous improvement by aligning technological advancements with established quality management frameworks. As this transformation becomes increasingly integrated into operational processes, this research underscores the importance of preparing organizations, employees, while aiming for sustainable organizational performance.

6.3. Limitations

A total of 15 quality directors participated in semi-structured interviews as part of this study's qualitative research methodology. Although this approach generated insightful results, the study has some pitfalls. The main drawback is the small sample size, which can limit the range to which the results can be applied. While individuals from a variety of industries were included in the sample, it does not reflect all industries or geographic situations. As such, the research's outcomes should be interpreted cautiously, particularly in light of more expansive uses of intelligent systems in quality management. This study is exploratory in nature, and rather than offering conclusive answers, its findings are intended to offer a supplementary understanding of the subject.

6.4. Suggestions for Future Research

In line with the limitations of this study, future research could start by approaching a bigger sample, one that is not only richer in quantity, but also at geographical level. Future research could build upon the conclusions drawn here, particularly regarding the balance between the benefits and challenges of implementing intelligent systems in quality management. Should professionals in the field be open to it, and if companies have the necessary resources, it would be beneficial to identify an organization currently undergoing this implementation process and carry out a project or thesis within that context. Such a study could provide practical, real-time insights into the actual impact of intelligent systems, offering a valuable comparison between theoretical predictions and real-world outcomes.

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Annex A – Interview Script

(RQ1: How do intelligent systems contribute to the enhancement of quality control processes in various industries?)

1. Could you share examples of how intelligent systems have been implemented in quality control processes within your industry? If not, is that something your company has been considering?
2. In what ways do these systems improve the efficiency and effectiveness of quality control?

(RQ2: What are the main benefits and opportunities associated with the adoption of intelligent systems in quality management?)

3. From your experience, what are the key benefits that organizations obtain from implementing intelligent systems in quality management?
4. Could you provide examples of specific opportunities that arise from implementing intelligent systems in quality control, perhaps including ones that may not be immediately apparent?

(RQ3: What obstacles and challenges might organizations face when adopting intelligent systems for quality management, and how can these be addressed)

5. What are some common challenges or obstacles organizations encounter during the adoption process of intelligent systems for quality management?
6. How can these challenges be mitigated or overcome to ensure successful implementation?

(RQ4: What are the potential implications of widespread adoption of intelligent systems in quality management for various stakeholders, including employees, management, and customers?)

7. From your experience, what are the potential implications of widespread adoption of intelligent systems in quality management for various stakeholders such as employees, management, and customers?
8. Are there any potential concerns or implications that need to be addressed when implementing these systems?
9. How do you think organizations can effectively manage these implications to ensure positive outcomes for all stakeholders involved?