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Capítulo 15 | Quality 4.0: using text mining to reveal trending topics

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Abstract:

The pursuit of quality and operational excellence is an ongoing journey for organisations seeking sustainable success in today's dynamic business environment. This chapter explores the latest trends shaping the field of quality management and operational excellence by focusing on Quality 4.0, a concept that embodies the pervasive integration of digital technology into quality management practices. To understand the most prominent topics surrounding Quality 4.0 within the literature spanning from January 2016 to December 2023, this study employs a text mining technique known as Latent Dirichlet Allocation (LDA), which, to the best of the authors' knowledge, has not been previously utilized for this purpose. The LDA algorithm identified twenty-two distinct topics, which were broadly grouped into four main categories: Historical Aspects, Human Factors, Implementation, Literature Analysis, and Technological Applications. These subjects highlight several facets of this subject, including the uncertainties regarding the skill set needed for quality professionals to embrace novel approaches, as well as the absence of clearly defined implementation roadmaps. The use of a powerful and data-oriented technique to explore Quality 4.0 perfectly fits with the essence of this novel concept. In conclusion, through the utilization of a state-of-the-art text mining technique to explore an emergent concept within the realm of Quality and its practical applications, this chapter provides readers with invaluable insights to effectively navigate the dynamic landscape of Quality 4.0.

Keywords: quality, operational excellence, Latent Dirichlet Allocation, quality 4.0.

15.1 Introduction

In today's rapidly evolving business landscape, pursuing quality and operational excellence has become imperative for organisations seeking sustainable success. The relentless drive to meet and exceed customer expectations, coupled with the need for optimised processes and resource utilisation, compels businesses to constantly seek ways to enhance their performance and competitiveness. With technological advancements, shifts in consumer preferences, and increasing global interconnections, traditional approaches to quality management and operational excellence are undergoing transformative changes (Antony et al., 2023b).

Scholars have extensively explored the concept of quality that has evolved over time, adjusting to new realities (Garvin, 1984; Reeves and Bednar, 1994). Initially, quality was primarily associated with ensuring that products or services meet specified standards. Over time, the definition of quality has expanded to encompass a more comprehensive perspective called Total Quality, which considers the entire organisation and its processes.

The advent of Industry 4.0, characterised by integrating cyber-physical systems, the Internet of Things (IoT), and data analytics, marks a significant turning point in manufacturing and service industries. Industry 4.0 has given rise to smart factories and supply chains interconnected and driven by real-time data. Aligned with this transformation, quality management has been adapting its core concepts and practices, leading to the emergence of the concept of Quality 4.0.

To gain deeper insights into how these new technological advances are reflected in quality management literature, this chapter employs a text mining method called Latent Dirichlet Allocation (LDA) (Blei et al., 2003) to analyse the existing literature on Quality 4.0. LDA is a statistical model in topic modelling that identifies prevalent topics in a given body of text. It relies on probabilistic word vectors to assess word relevance. Through an iterative process, LDA assigns words to topics, calculating scores based on the likelihood of a word belonging to a specific topic across documents. After multiple iterations, the model generates lists of words for each topic with probabilities. Selecting the top words with the highest probabilities for each topic provides a concise and accurate description of each respective topic.

LDA offers several advantages over a systematic literature review. First, it allows for unsupervised screening of retrieved documents, providing an objective and data-driven approach. Additionally, it eliminates subjective judgement present in manual screening, which may potentially introduce bias. Second, LDA can efficiently analyse large document collections, making it suitable for handling massive amounts of data (Hoffman et al., 2010) even though its reliability and validity can be affected by challenges such as text pre-processing, model parameter selection, and topic interpretation (Maier et al., 2018). Despite its challenges, LDA remains a powerful technique in text mining and topic modelling (Jelodar et al., 2017).

The relevance of this research is underscored by the transformative impact of Quality 4.0 on quality management and the need for a better understanding of this innovative paradigm. Quality 4.0 stands as a prevailing framework in contemporary quality management. Through an approach that allows the literature to speak for itself and identify the key topics in Quality 4.0, our goal is to highlight the major trends in the field and pave the way for new research directions. Besides that, this chapter delves into the transformative influence of Quality 4.0 on quality control and quality management. By facilitating proactive decision-making, it sets the stage for improved operational outcomes.

The employment of LDA aligns with the essence of Quality 4.0, as it represents a digitised and technologically advanced method for analysing literature. Unlike traditional bibliometric reviews, the use of LDA reflects a proactive engagement with the digitisation inherent in Quality 4.0, highlighting the exploration of this transformative paradigm with state-of-art methodologies.

This chapter is structured as follows: Section 15.2 introduces the concepts of Industry 4.0 and Quality 4.0. Section 15.3 outlines the evolving literature on Quality 4.0 and the application of LDA to analyse it. Following that, Section 15.4 presents the methodology used to analyse data using the LDA technique. Section 15.5 then demonstrates the practical application of LDA within the selected dataset. The results are discussed in Section 15.6, and the conclusions are presented in Section 15.7.

15.2 Industry 4.0 and Quality 4.0

The term Industry 4.0 originated from the German Government in 2011 as part of its high-tech industrial strategy, and it has since then become widely used to describe the ongoing fourth industrial revolution. Industrial revolutions are characterised by significant shifts in industrial practices that have a profound impact on society as a whole.

The first industrial revolution, known as Industry 1.0, took place before the 1890s and was characterised by the widespread adoption of steam and water powered machinery, which revolutionised manufacturing by greatly increasing production outputs. Industry 2.0, spanning from 1890 to 1940, was initiated by introducing electricity-powered automated machines and assembly lines. This period witnessed mass production and the expansion of transportation infrastructure. From 1940 to 1995, the industrial era that followed was referred to as Industry 3.0. This period saw the rise of digital computing, programmable controllers, and other technological innovations that propelled industrial productivity to unprecedented levels.

Industry 4.0, also known as I4.0, represents the most recent manufacturing paradigm, built upon the principles of decentralised decision-making, connectivity, information transparency, intelligence, and interoperability. It is a transformative concept that embraces emerging technologies to redefine industrial processes and systems. Industry 4.0 leverages advanced technologies such as the Internet of Things (IoT), artificial intelligence, robotics, and data analytics to enable interconnected and intelligent manufacturing systems (Prashar, 2023).

The technologies used in I4.0 provide real-time information for monitoring and reporting at both internal and external levels within an organisation. Internally, they enable the monitoring of operational units, such as inventory-related parameters, setup time and use of automated visual inspection. Externally, they capture data on factors like demand, lead time, order size, and transport handling. The control of operations is facilitated through application software deployed at both internal and external levels, which may include cloud-based enterprise resource planning (ERP) systems equipped with inventory management modules. To optimise operations, these systems employ algorithms that can streamline and enhance efficiency within the system. Moreover, they can adapt to the environment, thereby improving performance autonomously (Dev et al., 2020). In the context of I4.0, the concept of Open Manufacturing has emerged to create a Collaborative Manufacturing Network. This network facilitates the sharing of product information among various stakeholders within the production supply chain (Li et al., 2020).

By embracing the principles of Industry 4.0 organisations can achieve increased efficiency, agility, and innovation, while enabling seamless collaboration and communication across the entire value chain. This paradigm shift can potentially revolutionise industries and drive economic growth in the digital age.

During the first industrial revolution (Industry 1.0), quality management activities primarily centred around inspections, measurements, and statistical quality control. In the second revolution, quality management shifted its focus to quality assurance, aiming to maintain a minimum acceptable level of quality from suppliers. Throughout the third revolution, the primary goal of quality management became customer satisfaction, leading to a strong emphasis on continuous process improvement and the emergence of operational excellence practices. Various approaches for continuous improvement, such as Total Quality Management programs, Lean Manufacturing, Six Sigma, and Lean Six Sigma, emerged during this era (Prashar, 2023; Radziwill, 2018).

With the advent of Industry 4.0, the existing approaches for quality management needed to adapt to the new environment. The term Quality 4.0 has been coined to describe the future of these practices within the Industry 4.0 paradigm. It refers to the digitisation of quality in design, conformance, and performance using modern technologies (Sony et al., 2020). In Quality 4.0, it is crucial, for example, to develop expertise in managing data throughout its lifespan, beyond the lifespan of the organisation that gathers that data. The concept of the voice of the customer evolved, encompassing not only human feedback but also insights gathered from interconnected objects in the customers' environment. These and other initiatives can contribute to expanding intelligence to manage operations, including enabling remote monitoring to enhance productivity. These advancements have the potential to revolutionise the way organisations gather and utilise data, leading to improved operational efficiency and customer satisfaction (Radziwill, 2018). Table 15.1 displays the major features of each industrial era and the corresponding characteristics of quality management.

The connectivity within Collaborative Manufacturing Networks (CMN) under the Open Manufacturing approach presents an opportunity to enhance and expand quality management practices throughout the supply chain. This approach involves active involvement and integration of upstream and downstream partners, who play vital roles in the dynamic and complex global sourcing environments (Li et al., 2020). By leveraging the power of connectivity, CMN enables seamless communication and information sharing among manufacturers, suppliers, distributors, and other stakeholders. This real-time collaboration fosters a proactive approach to quality management, as all participants can contribute their expertise, insights, and best practices to ensure high standards throughout the production process.

Table 15.1. Evolution of industrial paradigms and corresponding features of quality management (adapted by the authors, using (Prashar, 2023).

Industrial Era	Industry Highlights	Quality Management Features
Industry 1.0	- Development of steam-and water-powered machines - Production volume increase - Production location expansion	- Inspections - Measurements

Industry 2.0	- Application of electricity - Mass production - Expansion of transportation infrastructure	- Quality assurance - Supplier confidence - Statistical quality control
Industry 3.0	- Rise of digital computing - Development of programmable controllers	- Rise of operational excellence - Continuous improvement - Lean, Six Sigma - Total quality management - ISO 9000
Industry 4.0	- Smart manufacturing - Robust Connectivity - Decentralised decision making - Artificial intelligence - Robotics - IoT - Data analytics - Open Manufacturing	- Information quality in smart manufacturing - Increased customer participation - Emphasis on continuous learning and adaptation - Quick analysis from enhanced data sources - Supply chain quality management - Predictive quality

In an Open Manufacturing framework, upstream partners such as raw material suppliers and component manufacturers can provide valuable input on product specifications, quality standards, and potential improvements. This early involvement helps streamline the production process and ensures that the end product meets the desired quality criteria. Similarly, downstream partners like distributors and retailers can share valuable customer feedback, market insights, and performance data, which can inform and guide quality management efforts.

This holistic approach to quality management, involving all stakeholders in the supply chain, helps identify and address potential issues or inefficiencies, ultimately leading to improved product quality, customer satisfaction, and overall supply chain performance. Furthermore, the Open Manufacturing approach encourages a culture of transparency, trust, and collaboration among all participants. By establishing open networks, manufacturers can establish strong partnerships based on shared goals, fostering a sense of collective responsibility for quality and driving continuous improvement initiatives across the supply chain.

Quality 4.0 offers organisations numerous benefits by leveraging advanced technologies to enhance the performance of employees, projects, and products. The potential capabilities of Quality 4.0, extensively discussed by Prashar (2023) and Radziwill (2018), are depicted in Figure 15.1.

One of these benefits is expanded workforce intelligence, which empowers employees to remotely monitor processes and generate proper prescriptive analytics. This capability enables organisations to identify potential failure modes in their products or processes and take informed actions to alter the outcomes.

Another advantage of Quality 4.0 is improving the speed and quality of decision-making. By providing real-time visibility of key quality metrics, such as the ones related to internal performance, supplier performance, and customer service, organisations can make accurate and tactical decisions promptly. This timely decision-making contributes to improved efficiency and effectiveness in organisational processes.

Fig.15.1. Capabilities of Quality 4.0

Quality 4.0 also enables enhanced transparency, traceability, and auditability of data. By effectively integrating fragmented data sources, processes, and systems, organisations can achieve greater visibility of those parts and generate comprehensive data across their supply chains. This comprehensive visibility allows for efficient tracking and monitoring of products throughout their life cycle, enhancing operational efficiency and facilitating compliance with quality standards.

Anticipating and adapting to changes is another competency facilitated by Quality 4.0. Organisations equipped with Quality 4.0 initiatives can foresee emerging business trends and align their quality objectives, processes, and skills accordingly. By staying ahead of market changes, organisations can proactively adapt their quality management practices, ensuring continued relevance and effectiveness.

Quality 4.0 also generates new opportunities for continuous improvement through seamless knowledge sharing. By leveraging advanced networking capabilities in Open Manufacturing environments, organisations can share knowledge with their suppliers, manufacturers, distributors, and customers. This exchange of information leads to a more accurate understanding of processes, fostering collaboration and innovation, and ultimately driving continuous improvement throughout the value chain.

Cultivating self-awareness is another crucial aspect of Quality 4.0. Quality management systems within this framework can automatically configure and reconfigure themselves based on different circumstances. This self-awareness allows quality management systems to continuously gather and analyse data, identify patterns, and extract valuable insights to enhance their own performance. By learning from past experiences and adjusting their strategies accordingly, quality management systems can proactively adapt and optimise operations, ensuring maximum efficiency and effectiveness in diverse scenarios. The ability to learn and improve autonomously is a key characteristic of Quality 4.0, enabling organisations to stay agile and responsive in an ever-changing business landscape. Ultimately, organisations can embrace the concept of "learning to learn" as they harness the power of self-aware quality management systems that continuously evolve and grow through iterative learning processes.

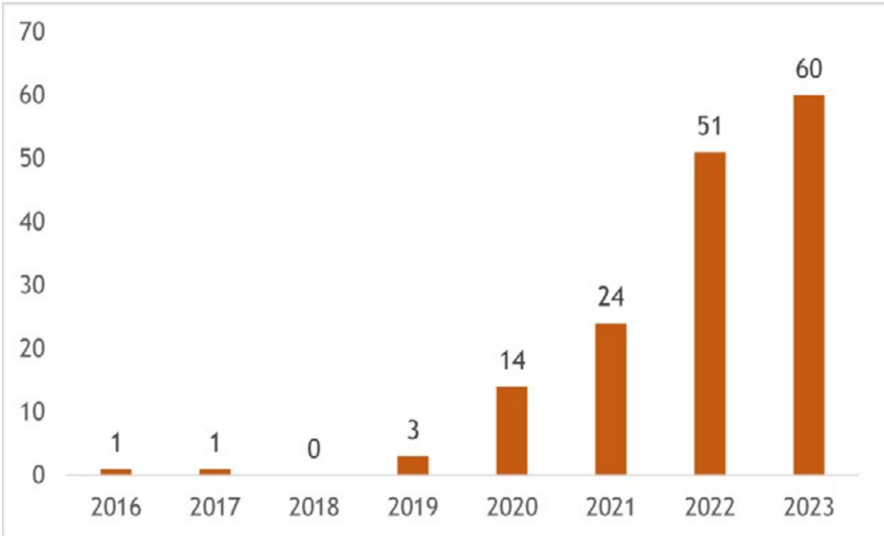
By embracing these aspects of Quality 4.0, organisations can drive operational excellence, enhance customer satisfaction, and gain a competitive edge in the marketplace.

More recently, discussions have emerged regarding the incorporation of new components into Quality 4.0 in alignment with the evolution of a human-centred society. These components include sustainability, well-being, and quality of life, and are now being considered under a novel concept termed Quality 5.0 (Saraiva, 2023).

15.3 Literature content analysis in Quality 4.0

The literature on Quality 4.0 has seen significant growth in recent years. Examining the Scopus database, it is noted that the first article introducing this concept appeared in 2016, with the count growing to 60 articles in 2023, as outlined in Figure 15.2. This upward trajectory in publications signals an increasing interest within the academic community regarding this subject. Although the volume of literature on Quality 4.0 is not extensive, the challenge lies in thoroughly analysing the content of the numerous papers available. To address this challenge, a more structured and efficient approach is chosen by employing text mining techniques that can automate the extraction of content information from a large collection of documents.

Fig.15.2. Number of articles about Quality 4.0 issued per year (Source: Scopus Database)



Text Mining is a branch of data mining that involves a computer-based approach to create new information by automatically extracting data from various written sources (Hearst, 2003). One type of information that can be extracted from texts are their main topics, and this activity is commonly referred to as topic modelling. Topic modelling stands out as a potent text mining technique, offering robust capabilities for data mining, latent data discovery, and uncovering relationships within data and textual documents. Numerous researchers have contributed to this field, producing many articles applied across diverse domains such as software engineering, political science, medicine, and linguistics. Among the various methods employed for topic modelling, the LDA algorithm, introduced by Blei et al. (2003), is the most widely used. Several researchers have proposed models based on LDA for topic modelling, making it a prevalent approach (Jelodar et al., 2019). LDA has found application in various domains, including the identification of scientific topics (Griffiths and Steyvers, 2004), prediction of software failures (Liu et al., 2015), drug repositioning (Bisgin et al., 2014), selection and recognition of features (Bregonzio et al., 2010), segmentation of stories in broadcast news (Chen et al., 2016), and the evaluation of disease similarity (Frick et al., 2015).

According to Blei (2012), in LDA, the data is treated as comprising observed variables (the words in the text) and hidden variables (the text topics). The text topics are considered hidden variables because they are not explicitly stated. They represent latent themes within the text, and the models aim to uncover these themes. As a probabilistic model, the algorithm analyses the text data by computing the conditional distribution of the hidden variables given the observed variables. This distribution, known as the posterior distribution, is utilised by the model to infer the topic structure.

By employing the LDA text mining approach to the Quality 4.0 literature, the objective is not only to offer insights into the current state of the field but also to gain a more in-depth understanding of the prevalent topics within the domain of Quality 4.0

15.4 Methodology

The methodology for implementing topic modelling in the literature initiates with the collection and systematic organisation of data sourced from chosen databases. This gathered data subsequently acts as the input for the LDA model. The outputs of the LDA model are also leveraged to present other relevant information regarding the extracted topics.

The LDA modelling process was performed employing the R programming language. The data, sourced from the database, was read and prepared for processing by the LDA algorithm. This preparation phase ensures the data is formatted and structured appropriately to be effectively utilised through the LDA model.

Creating an LDA model involves three essential steps. Initially, you define the number of topics and assign a topic to each term in every document. The subsequent step employs the Gibbs sampling algorithm, which iteratively assigns new topics to each term until convergence is reached. The final step involves generating the topic-word co-occurrence frequency matrix, summarising the learned relationships between topics and words, and ultimately constituting the completed LDA model.

The decision about the number of topics to be assessed is based on a performance metric that indicates the optimal number of topics. In this work, we used the metric Griffiths2004 developed by Griffiths and Steyvers (2004). The goal is to maximise this metric, as it indicates how well a model can predict new data.

The LDA model produces probabilities for words within topics and probabilities for topics within documents. These probabilities establish distributions that facilitate the identification of the most representative words for each topic and assess the likelihood of documents aligning with specific topics (Karami et al., 2020). Furthermore, LDA enables the extraction of prevalent topics across an entire set of documents, providing insights into the dominant themes permeating the collection of documents.

Following the generation of a list of topics and their association with the most representative words, the analysis involves examining the list of words for each topic and the order of their calculated probabilities. This process allows for the definition of a topic name that effectively represents the uncovered topic. The choice regarding naming a given topic is then performed by analysing the most common words for each topic according to the order of magnitude of their calculated probabilities. Particularly, the words with the highest probabilities better represent a given topic, which indicates the underlying subject discussed in them. Subsequently, topics can be categorised into broader groups, providing an overview of the literature.

The distribution of the extracted topics will also be analysed to determine their popularity and relevance in the given context. The gamma values of the model, representing the proportion of each topic within a document, were then agglomerated to instead identify which topics are more popular or frequently discussed. In other words, topics with consistently high gamma values will likely be prevalent across all documents. Additionally, the gamma values help determine the most relevant documents in each topic. By uncovering the documents that are more aligned with each topic, better and more relevant insights can be extracted. Moreover, examining documents in the context of a single topic and analysing their common characteristics can support the choice of the topic designation.

15.5 Topic modelling and content analysis

This section outlines the process employed for conducting topic modelling in the literature on Quality 4.0, divided into three subsections: In Section 15.1, the steps to collect and organise data from the literature are presented. Section 15.2 covers the outputs of the LDA model.

15.5.1 Data collection and pre-processing

Information pertaining to studies on Quality 4.0 was gathered from the Scopus database. A search was conducted within article titles, abstracts, and keywords using the specific expression Quality 4.0. The search timeframe was limited to entries up to December 31, 2023, and the language parameter was restricted to English. This initial search identified 202 documents. In a more detailed analysis, 41 documents were excluded from the search for not being related to the field of quality management. Thus, a set of 161 was considered.

After, as part of the preprocessing step, documents that did not have information regarding their abstract or their keywords were also removed from the analysis, leaving 154 documents to be considered hereinafter. The outcomes of this search were then exported to a data file in CSV format containing the following fields: author, year, title, abstract, and author keywords.

The next preprocessing phase was performed in R language to prepare the collected data for the LDA model. This involves refining the data to include only pertinent words for LDA processing. Consequently, words that start or end with numbers, hyphens between words, and punctuation characters were eliminated. All the words with two or fewer characters were also removed. An essential aspect of this process was to consider only the relevant parts of words for analysis.

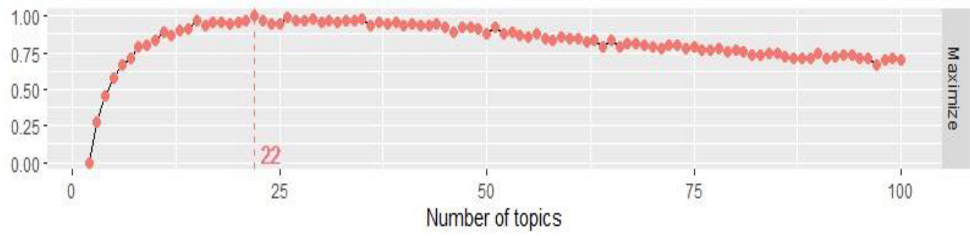
For instance, words like "qualities" and "quality" or "practicing" and "practice" were reduced to their root form "qualiti" and "practic", respectively, since they convey the same idea for topic modelling. This transformation was achieved through a method known as stemming, a text normalisation process that reduces words to their root or base form. The R function "stemDocument()" was employed to perform stemming on the document. This function is part of the tm (text mining) R package (Feinerer and Hornik, 2023).

The most frequent words are shown in Figure 15.3. From a total of 2,235 unique words in the data set, the word "qualiti", root form of "quality" or "qualities", is the most prevalent, appearing 1405 times.

Fig.15.3. Word cloud for the most frequent words

The final stage of preprocessing the data is to determine the optimal number of topics using the Griffiths2004 metric. This task is accomplished through the application of the "FindTopicsNumber()" function, which is part of R package ldatuning. The exploration spans a range of topics from 2 to 100, and based on the Griffiths2004 metric, the optimal number of topics was identified as 22, as seen depicted in Figure 15.4 wherein the values were normalised to be between 0 and 1.

Fig.15.4. Optimal number of topics to adopt



15.1.2 LDA model processing

The LDA model is constructed using the topicmodels package in R. By setting the number of topics to 22, the documents were processed, and 22 topics were extracted from them. These should significantly differ between themselves and represent the subjects discussed in the different documents.

The LDA model also presents the most relevant words for a given topic. From these, it is possible to assign a meaningful name that represents the essence of that specific topic, making it easier to understand the subjects present in the field of Quality 4.0. To this end, the most relevant words in a given topic and the documents that better represent them provide support for determining the meaningful name for the topic.

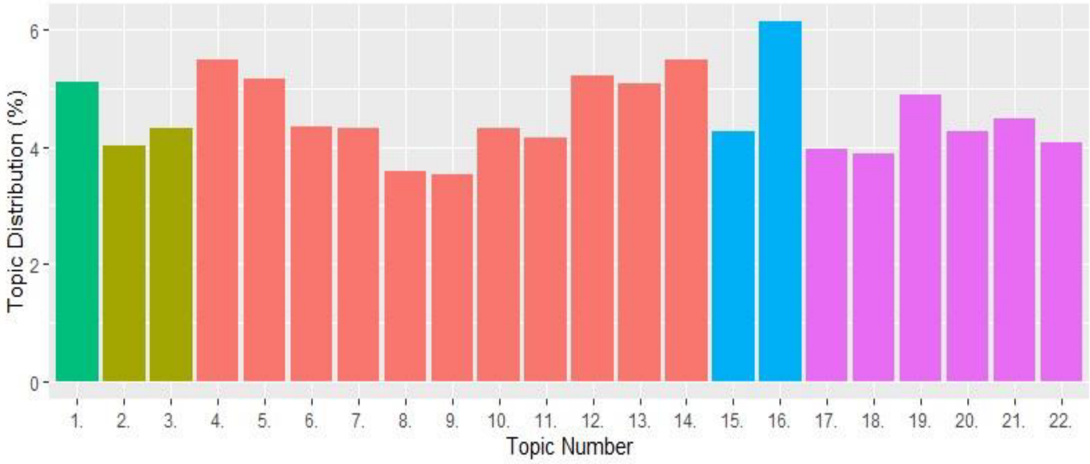
Following the name assignment for the topics, they can be grouped into broader categories to provide a more cohesive overview of the underlying themes and patterns. The name given to the topics, their corresponding top 10 words, as well as the categories they correspond to is shown in Table 15.2.

To provide an objective overview of the topic distribution, the topic prominence, represented via the average gamma values discussed in Section 15.4, is drawn in Figure 15.5. These probabilities refer to the average proportion in which each topic appears in the set of documents. The bar colours in the graph represent the category that the topics correspond to, as seen in Table 15.2. Overall, the presence of the 22 topics is mostly equalised, oscillating between 3.5 and 6.1 %, meaning there is no dominant topic within the field of Quality 4.0.

Table 15.2. Topic groups, topics and words in LDA analysis

Category	Topic Name	Top 10 words
A) Historical aspects	1) Evolution of quality concepts	qualiti; industri; approach; revolut; data; challeng; fourth; manag; support; advantag
B) Human Factors	2) Analysis of the organisational culture	manag; tqm; practic; total; industri; effect; result; context; role; cultur
C) Implementation	3) Impacts and effects on employee performance	perform; studi; practic; employe; sustain; organiz; variabl; empir; methodolog; employ
	4) Success factors for change	studi; factor; readi; success; profession; implement; understand; organis; adopt; benefit
	5) Effective change management	qualiti; manag; custom; chang; indic; compani; achiev; process; import; accord
	6) Measurement model for implementation	model; system; measur; paper; propos; main; author; compani; inform; efqm
	7) Establishment of roadmaps for implementation	qualiti; oper; focus; technolog; transform; ensur; contribut; import; era; follow
	8) Stakeholder identification and engagement	manag; project; stakehold; phase; resourc; compani; digitalis; cycl; purpos; plan
	9) Industry cases of implementation	food; iso; lean; lss; sigma; standard; artifici; includ; technolog; tradit
	10) Advantages and opportunities	qualiti; improv; busi; process; competit; provid; signific; dure; innov; effici
	11) Frameworks for acessing maturity level	framework; digit; matur; aim; transform; develop; dimens; educ; adopt; base
	12) Key success aspects for implementation	qualiti; implement; organ; improv; key; digit; level; continu; term; practic
	13) Integration in industrial practices	industri; technolog; integr; paper; concept; enabl; howev; discuss; aspect; reserv
	14) Impact on management systems	industri; develop; qualiti; manag; enterpris; author; signific; sustain; base; innov
D) Literature analysis	15) Bibliometric analysis	analysi; paper; qualiti; articl; identifi; public; trend; bibliometr; studi; emerg
	16) Systematic literature reviews	research; review; literatur; qualiti; purpos; limit; manag; publish; originality; valu; futur
E) Technological applications	17) Mining digital content	approach; topic; studi; result; digit; servic; valid; determin; applic; propos
	18) Machine learning	data; learn; machin; detect; defect; advanc; algorithm; predict; analyz; process
	19)Process monitoring in manufacturing	manufactur; product; control; digit; process; smart; monitor; achiev; potenti; key
	20) Intelligent machine-based methods	intellig; develop; system; increas; industri; artifici; process; process; product; qms
	21) Predictive fault models and maintenance	system; industri; predict; fault; build; mainten; research; studi; water; paradigm
	22) Reality augmentation systems	solut; method; applic; sector; develop; map; time; consid; softwar; comprehens

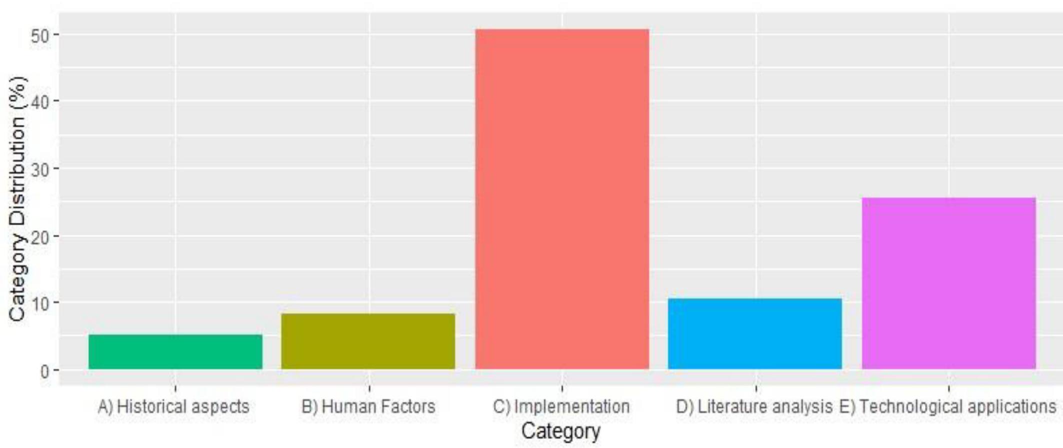
Fig.15.5. Average gamma factor by topic



Regarding the encompassing categories, the topics were classified according to five categories. These were A) Historical aspects, B) Human Factors, C) Implementation, D) Literature analysis, and E) Technological applications.

Although the topics themselves have similar popularity, the same is not true for the category prevalence, as shown in Figure 15.6 that displays the sum of the average gamma factors for the topics within each category. Category C) Implementation is clearly more extensively discussed in the literature compared to the others. This could be attributed to the larger number of topics falling under this category, which were manually categorized after automated topic addressing. Nonetheless, it's noteworthy the prevalence of discussions concerning Quality 4.0 implementation issues in the literature.

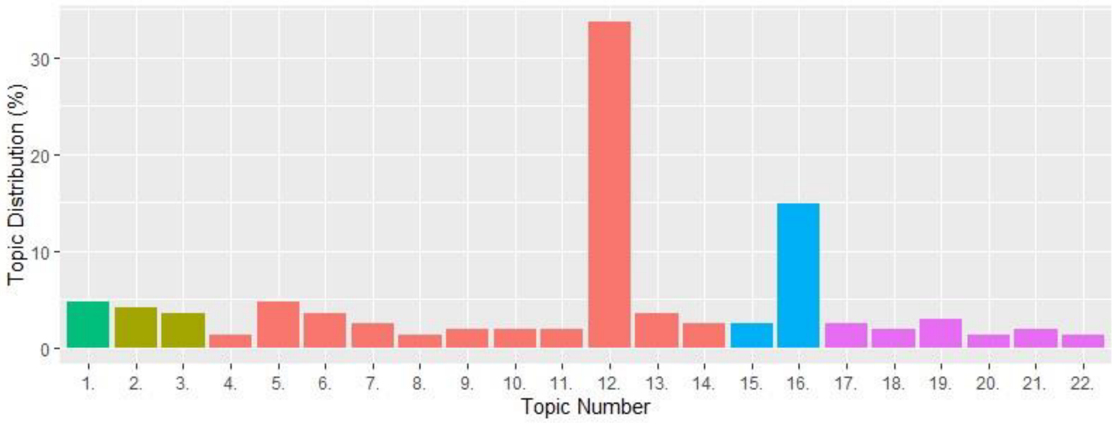
Fig.15.6. Average gamma factor by topic grouped by category



On the other hand, in terms of individual documents, their gamma values can also be extracted, expressing the probability that it correlates with a given topic For each document, the sum of its 22 gamma values adds up to 100%, indicating that for a given document, the topics with the highest gamma value are the ones that better represent the subject they discuss.

Thus, it is important to notice that individual papers are not strictly assigned to specific topics. Instead, they exhibit a correlation between multiple topics and different probabilities. For instance, the distribution of the topics discussed in Sony et al. (2020) are drawn in Figure 15.7. In its majority, topics 12 and 16 are the more prominent ones in this paper. However, in small proportions, all the other topics are addressed in the paper as expected.

Fig.15.7. Distribution of topics for Sony et al. (2020)



15.6 Discussion of results

By employing LDA, 22 different topics were extracted from a set of selected papers which were then grouped into 5 categories for visibility and readability. As expected, since Quality 4.0 was the expression used for the query, "qualiti" was the most popular term in all documents. Other prevalent terms are also "industri" and "manag", which are also at the core of the theme under examination.

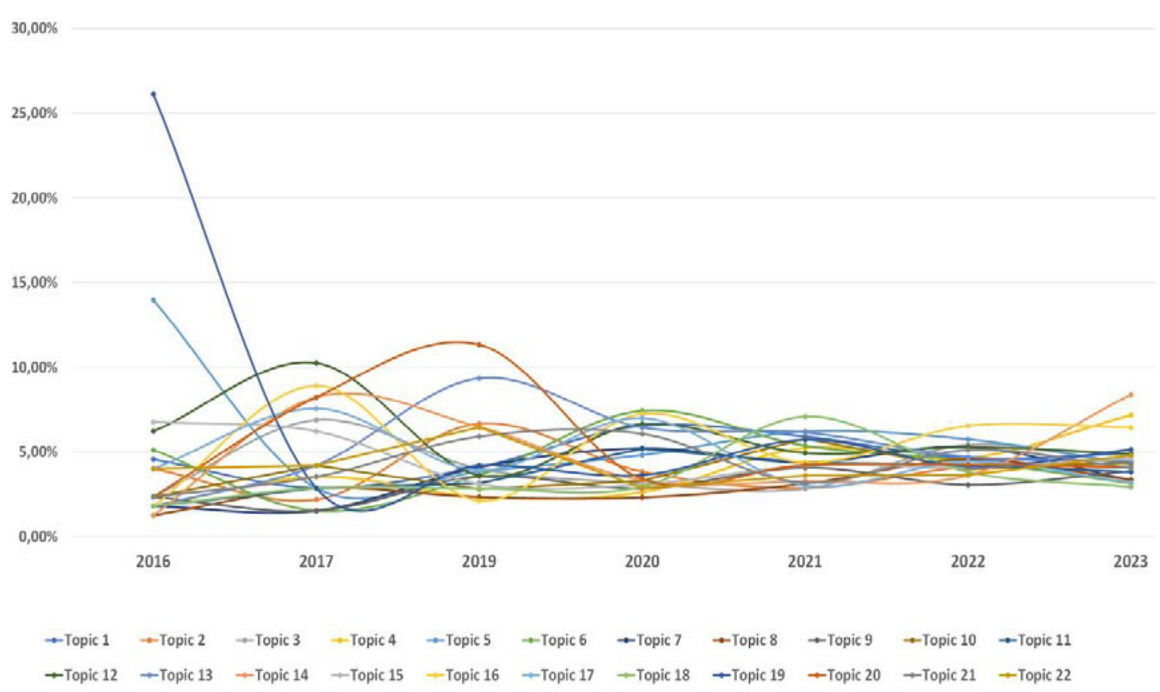
The distribution of the topics themselves is well-matched, with no significant differences between them. Nonetheless, 16) Systematic literature reviews is the most prevalent topic among the documents considered.

When considering the evolution of topic popularity throughout the years, Figure 15.8 illustrates the evolution of the average probabilities of each topic's occurrence by year. Notably, no single topic predominates. It's worth mentioning that 2016 and 2017 stand out as special cases due to the publication of only one paper during each of those years. Additionally, there are also no articles for the year 2018. Generally, all topics appear to be evenly distributed across all years. Despite the analysis covering only an eight-year period, no discernible trends are observed.

As previously discussed, in the field of Quality 4.0, there is a greater tendency for articles to focus on practical solutions that are synthesised in the category C) Implementation. Given that this category appears to be prevalent in the literature, the subsequent paragraphs explore the various topics within this category to provide a brief overview of the content found in papers with the highest alignment to the topic under consideration. As mentioned earlier, this alignment is quantified by the gamma factor associated with each article and topic. The aim here is not to conduct an exhaustive literature review but rather to demonstrate how analysing the results of the LDA technique can facilitate identifying trends and insights in the literature. The category C) Implementation is used as an illustrative example.

To better understand how the LDA model has clustered ten words under each topic and assess the accuracy of the attributed Topic Name, we delve deeper into the papers showing higher gamma values under each topic. This analysis also has the added benefit of quickly perceiving the "hot" subjects in terms of the grand theme of Quality 4.0 and avenues of future research.

Fig.15.8. Distribution of topics by years



Starting with Topic 4, which deals with the understanding of what are the successful factors for a Quality 4.0 deployment, all the papers that show a high alignment with Topic 4 (ranging from 35.8 to 48.5%) share a common approach to the problem, targeting common goals of understanding what are the motivations, barriers and organisational readiness factors for a successful Quality 4.0 implementation, as well as the skills required by quality professionals (Sony et al., 2021; Antony et al., 2022, 2023c,a). The time span of these papers spreads between 2020 to 2023, and it is curious that some authors participated in all the studies. The methodologies used were typically based on online surveys targeting senior quality professionals working in leading companies in Europe and America, typically in countries that dominate Industry 4.0 research and implementation. Another noteworthy trend observed across the time frame covered by these papers is the gradual emergence of clarity regarding the essential skillset for future quality professionals. As stated by Antony et al. (2023a), a proposed curriculum for these professionals should encompass six key areas of knowledge: statistics, quality management, manufacturing processes, programming, continuous learning methodologies, and optimisation techniques. However, it is pertinent to note that the development of the future curriculum remains an ongoing process, subject to evolution and refinement (Antony et al., 2023a). Finally, also worth mentioning is the fact that the most recent works under this topic address application examples of Quality 4.0 in various companies. Among these applications, automated inspection utilising advanced vision systems emerges as a prevalent theme, attributed to its ability to enhance inspection accuracy, and eliminate non-value-added human inspection, thus substantially reducing associated costs.

Topic 5, labelled "Effective change management", explores the underlying process of change management that needs to be put in place towards Quality 4.0. Jamkhaneh et al. (2022), showing the highest gamma factor of the papers in this cluster (38.02%), propose the identification and evaluation of Quality 4.0 indicators that enable the outline of a road map for companies to align Quality 4.0 management with Industry 4.0 technologies. Another proposal to enable this process of change management is offered by Dror (2022), using well-renowned quality tools, such as Quality Function Deployment to facilitate the translation of desired improvements in quality objectives into core Quality 4.0 technologies (gamma factor of 15.65%).

Concerning the topic related to the depiction of assessment/measurement models to evaluate Quality 4.0 completion (Topic 6), diverse proposals are held, using as a basis either i) the adaptation of well-known standards, i.e., ISO standards (Glogovac et al., 2022; Antonino et al., 2022), ii) mature excellence models, as is the case of EFQM model (Nenadál, 2020; Fonseca et al., 2021), or even iii) new conceptual measurement models (Sureshchandar, 2023). As an example of the utilisation of ISO standards, Glogovac et al. (2022) proposes a ISO 9004:2018 guidance as a possible basis for assessment of the maturity level of quality in Industry 4.0/Quality 4.0, with the end goal of developing a basis for a sustainable Quality 4.0 system roadmap. Antonino et al. (2022) has used a refined version of ISO 25010, a standard that provides guidelines and recommendations for evaluating software product quality, as a method to support the identification and specification of quality attributes that are relevant to I4.0 systems. The EFQM model is also a topic of analysis due to its potential to provide an integrated business excellence framework for Quality 4.0, supporting a successful digital transformation within the I4.0 paradigm (Fonseca et al., 2021; Nenadál, 2020). In the third approach to the theme, i.e., novel frameworks and methodologies to assess and measure the maturity level for the implementation of Quality 4.0, Nenadál et al. (2022) has proposed and tested a specific proposal to evaluate the readiness to adopt Quality 4.0 practices. In this case, the authors validated the framework with a set of Czech production companies showing promising results. A more ambitious proposal has attempted to identify the 12 Axes of the multidimensional construct related to Quality 4.0 (Sureshchandar, 2023). One of the most interesting conclusions of this study is the argument that, in contrast to the most announced belief that technological dimensions are the rudiments of a Quality 4.0 implementation, the authors demonstrate that both traditional quality factors and technological factors are fundamental for the Quality 4.0 journey. Thus, an all-inclusive approach is needed, focusing both on the traditional aspects of quality (leadership, culture, customer centricity, quality systems, metrics, data analysis, etc.), as well as on the more technological aspects of quality (data governance, innovation, advanced analytics, etc.).

Under Topic 7, labelled “Establishment of roadmaps for implementation”, papers with the highest gamma factor (between 16.5% and 45.7%) express concern in clarifying further the definition of Quality 4.0, going beyond the most accepted technology perspective to a perspective encompassing the human factors (Dias et al., 2022), paving the way to the Quality 5.0 concept. A case study in an automotive factory, Zulqarnain et al. (2022) reinforce this view of combining smart technologies with a human-centred and user-friendly perspective, contributing to employees’ involvement on the shop floor.

Topic 8, “Stakeholder identification and engagement”, grouped papers that address the key stakeholders involved in the Quality 4.0 transformation. Recognising company employees as key company stakeholders, the study developed by Balouei Jamkhaneh et al. (2022) based its analysis in an in-depth literature review on the challenges of human aspects and quality management developments in Industry 4.0. Alongside interviews with recognised experts of knowledge intensive business service companies, the authors identified twenty-nine Quality 4.0 drivers of readiness and workforce ability at different stages of the production cycle. A prevailing theme spanning multiple topics is unequivocally the revitalisation and empowerment of human resources for the digital era, constituting one of the toughest challenges for quality professionals. The paper that has the highest gamma value (38.5%) under Topic 8, conducts a case-study analysis to propose a novel framework to integrate Quality 4.0 to facilitate social interactions for remote work labour during and after the global pandemic (Tran et al., 2022).

When discussing the implementation of Quality 4.0 principles within the industry (Topic 9), several distinct themes emerge. These range from assessing the quality management practices of Indian Small and Medium-sized Enterprises (SMEs) within the context of I4.0, evaluating their readiness to embrace Quality 4.0 (Biswas et al., 2023), to examining the critical success factors for Lean Six Sigma in the Quality 4.0 environment, aimed at facilitating a smoother adoption of Industry 4.0/Quality 4.0 by organizations (Yadav et al., 2021). In the end, identifying these critical success factors will empower workers to remain employable, thus facilitating a successful transition.

Notably, the papers showing higher gamma values under this topic (25.6% and 21.1%) are related to the food industry. Traditionally, food quality is determined using various destructive and time-consuming approaches with modest analytical performance, underscoring the urgent need to develop novel analytical techniques (Hassoun et al., 2023). "Food Quality 4.0" is a new concept that uses Industry 4.0 technologies in food analysis to achieve rapid, reliable, and objective assessment of food quality. This recent development builds on previous stages of quality management in the food industry, aiming to integrate digital technologies and data analytics into the existing quality management systems, enabling real-time monitoring, traceability, transparency, and optimisation of food quality throughout the value chain (Djekic et al., 2023). Artificial Intelligence (AI) is recognized as a pivotal component, leveraging machine learning and deep learning techniques to advance the food industry, enhancing food quality and safety standards, promoting good hygiene practices, and optimising production processes. In summary, Food Quality 4.0 is characterised by growing digitalisation and automation of food analysis using the most advanced technologies in the food industry (Hassoun et al., 2023).

In Topic 10, the discourse revolves around the advantages and opportunities inherent in implementing Quality 4.0 practices. Among the academic works that strongly resonate with this subject, Haleem et al. (2021) delves into the possibilities of leveraging these innovative practices to bolster healthcare quality, particularly amidst the challenges posed by the COVID-19 pandemic. This paper exhibits a 38.3% alignment with Topic 10. Conversely, Yanamandra et al. (2023), with a 21.2% alignment, offers valuable insights for industrial managers regarding the application of Quality 4.0 to enhance competitive advantages within the food industry.

Continuing the discussion, Topic 11 explores frameworks aimed at assessing maturity levels for the implementation of Quality 4.0. Three papers closely aligned with this theme are Alzahrani et al. (2021), Sutoová et al. (2020), and Zulqarnain et al. (2022). The first study, exhibiting a gamma factor of 28.0%, furnishes insights tailored for higher education institutions, presenting a framework to evaluate their preparedness for the Quality 4.0 journey. Similarly, the second paper, aligning at 26.5%, introduces a method designed to gauge maturity levels and technology adoption within the automotive industry. Lastly, the third study, with a 23.6% alignment, presents a maturity level framework applicable across various industries, even though its eleven-dimension model is primarily intended for use in developing countries.

Under the Topic 12 related to the establishment of key aspects for implementation, a range of studies aimed at uncovering its motivations, barriers, and readiness factors for the effective implementation of Quality 4.0 (Sony et al., 2021, 2020; Thekkoote, 2022; Wawak et al., 2023) were held. In Sony et al. (2020), a narrative literature review revealed eight essential ingredients for effective Quality 4.0 implementation, worth mentioning, namely: (1) handling big data, (2) improving prescriptive analytics, (3) using Quality 4.0 for effective vertical, horizontal and end-to-end integration, (4) using Quality 4.0 to achieve strategic advantage, (5) fostering leadership in Quality 4.0, (6) training in Quality 4.0, (7) nurturing organisational culture, and (8) securing top management support. This work aligns 33.7% with Topic 12. The same authors collaborated in another study (Sony et al., 2020) with presents a 21.3% alignment with Topic 12, revealing readiness factors for Quality 4.0 implementation including: (1) top management support, (2) organisational culture, (3) leadership, (4) vision and strategy, (5) knowledge and awareness on Quality 4.0, (6) customer centeredness, (7) supplier centricity, and (8) training and rewards. With a gamma factor of 20.0% in Topic 12, Wawak et al. (2023) identified barriers to Quality 4.0 implementation such as: time and investment requirements, lack of financial resources, absence of a long-term strategy, the necessity of new knowledge and skills, a passive approach of top management or owners, and difficult cooperation of quality management professionals with information technology specialists.

Topic 13 primarily delves into the integration of Quality 4.0 within industrial practices. The study conducted by Emblemsvag (2020) demonstrates the highest alignment with this topic, presenting a gamma factor of 26.4%. This paper focuses on specific aspects within project-based industries, an area relatively underexplored in quality management literature. It examines how the enhanced credibility and transparency of Quality 4.0 can support contracting practices in this business. With a gamma factor of 16.7%, Ammar et al. (2022) investigates Quality 4.0 practices within manufacturing industries. This study explores the integration of digital tools, smart materials, and analytics to develop advanced quality management systems. Additionally, it addresses various error detection methods during manufacturing, along with corresponding problem-solving strategies facilitated by advanced Quality 4.0 practices. Similarly aligned with Topic 13, Efimova and Bris (2021) presents a gamma factor of 15.2%. This paper analyses industrial companies' adaptation to Industry 4.0's influence on quality management and its impact on customer satisfaction. It concludes that the advent of new technologies benefits quality management processes and enhances customer satisfaction, particularly emphasising the significant role played by the vast amount of data now available for analysis.

Topic 14 focuses on how the implementation of Quality 4.0 impacts the management systems of organisations. Among the LDA outcomes, seven studies stand out with stronger alignment to this topic, presenting gamma factors exceeding 40%.

As expected, quality management systems emerge as the primary focus within this topic. Bogoviz et al. (2023), Popkova et al. (2023), and Tolmachev et al. (2023) discuss the integration of quality management systems with sustainability, displaying gamma factors of 52.9%, 45.3%, and 44.7% respectively. Conversely, Nosirov et al. (2023) (gamma of 47.4%) delve into the impact of export issues on quality management systems within the framework of Quality 4.0, while Akhmedova et al. (2023b) (gamma of 45.0%) explore the general evolution of those quality management systems.

Other management systems under Quality 4.0 are also addressed in the literature associated with this topic. For instance, information management systems are discussed by Karbekova et al. (2023) (gamma of 52.6%), and environmental management systems are tackled by Akhmedova et al. (2023a) (gamma of 43.4%). Additionally, this study proposes a new dimension for product quality in Industry 4.0: "Green 4.0". It's evident that the alignment of Quality 4.0 with environmental concerns is a recurring theme in many articles within this topic.

15.7 Conclusions

Although there are already a significant number of literature reviews exploring the concept of Quality 4.0, none, as to the authors knowledge, have explored in full the more advanced text mining potentialities that have emerged recently. The use of Latent Dirichlet Allocation (LDA) has proven valuable in identifying the key topics within the domain of Quality 4.0. Twenty-two distinct topics were identified by the LDA algorithm, which were broadly grouped into four main categories. Notably, half of these topics revolved around issues related to implementation, highlighting their significance in the debate around Quality 4.0.

In essence, employing LDA provided an unbiased and insightful overview of Quality 4.0, revealing its core concepts and challenges. Beyond its accuracy, this method aligns well with the principles of Industry 4.0 and Quality 4.0, reflecting their innovative and data-oriented nature. The full potential of LDA awaits further exploration as the number of documents increases, which will naturally occur as more aspects of these novel approaches are more discussed in the literature. Our review of the literature indicates that considering the number of studies published so far, many aspects of Quality 4.0 remain relatively unexplored.

This study took advantage of the manageable size of the document set to delve into specific contents within individual papers, illustrating their alignment with the topics generated by LDA. While this approach yielded nuanced insights, it also underscored the time-consuming nature of such detailed examination, especially on a per-article basis. With a larger document set, typical of LDA analysis, such detailed scrutiny would be feasible for only a restricted sample of papers.

Throughout our study, certain recurring themes emerged, representing prevalent challenges in the realm of Quality 4.0. These include the ambiguity surrounding the required skill set for quality professionals to tackle new approaches, as well as the lack of clearly defined implementation roadmaps. Addressing these challenges is crucial for advancing and effectively implementing Quality 4.0 principles across different organizational contexts and to move further towards Quality 5.0.

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