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Review

THE ROLE OF THE PARETO PRINCIPLE IN QUALITY MANAGEMENT WITHIN INDUSTRY 4.0: A COMPREHENSIVE BIBLIOMETRIC ANALYSIS

Aleksy Kwilinski, and Maciej Kardas

Abstract. Quality is a fundamental aspect of the management of almost every area of a company, directly influencing the efficiency of its processes. The increased importance of quality, as well as advances in industrialisation methods and computerisation, has stimulated the development of a new generation of technologies, leading to the fourth industrial revolution known as Industry 4.0. In addition to new technologies, the Pareto principle plays an important role in quality management, enabling the identification of the key factors that influence quality, emphasising that 20% of causes are responsible for 80% of quality problems. Its importance has been highlighted by the American Society for Quality (ASQ), which recognises the Pareto principle as one of the seven basic tools used in the area of process improvement. The purpose of this study is to identify the impact of the Pareto principle on quality management on the basis of a bibliometric analysis carried out to characterise the evolutionary aspects of the development of key terms specific to the area under consideration. The analysis focuses on a sample of 8002 items, and the data collected come from the extensive Scopus database of scientific articles, covering the years 1990-2024. VOSviewer software was used as a tool. On the basis of the empirical data, the exponential growth of the number of publications was confirmed in terms of the relationship between the Pareto principle and quality management. On the basis of the resulting visualisation maps, five areas (clusters) were identified and characterised in terms of keyword coincidence, and their evolutionary natures were described. This publication can serve as a basis for further considerations in the impact layer of the Pareto principle in terms of quality management.

Keywords*:* quality; Industry 4.0; artificial intelligence; machine learning; Pareto principle; quality management; sustainable management; development management

Authors:

Aleksy Kwilinski
The London Academy of Science and Business, 120 Baker St, London W1U 6TU, UK;
Institute for Sustainable Development and International Relations, WSB University, 41-300 Dabrowa Gornicza, Poland
E-mail: a.kwilinski@london-asb.co.uk
https://orcid.org/0000-0001-6318-4001

Maciej Kardas
Faculty of Applied Sciences, WSB University, 41-300 Dabrowa Gornicza, Poland
E-mail: kardas.maciej@wp.pl
https://orcid.org/0009-0008-9910-7380

Corresponding author: Maciej Kardas, kardas.maciej@wp.pl

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1. Introduction

The multidimensionality of quality precludes the possibility of defining the concept unambiguously, assigning it a plane in the area between subjectivity and objectivity. On the basis of the semantic relationship and its holistic understanding, the solution becomes the equal juxtaposition of both qualitative and quantitative aspects that build global quality, emphasising, at the same time, their immanent character [1–4]. The concept of quality in philosophy is multifaceted and includes prioritisation of the customer position, continuous improvement and employee empowerment [5]. It is also influenced by ethical principles, especially the concept of accountability [6]. Quality should not be considered a static concept. It is accompanied by a continuous evolution, the focus of which has moved away from meeting specifications to now focus on minimising losses to society. This evolution has led to a greater emphasis on functionality and cost-effectiveness in achieving quality [7].

Quality is a fundamental aspect of the management of almost every area of a company, directly influencing the increase in the efficiency of its processes. The simplest definition classifies it as a set of characteristics and properties of products, processes and services that meet specific guidelines and potential needs [8,9]. The dynamics of the increase in the importance of quality, as well as advances in industrialisation and computerisation methods, have spurred the development of next-generation technologies, leading to the fourth industrial revolution known as Industry 4.0. It encompasses a set of technologies, such as autonomous mobile robots (AMRs), artificial intelligence (AI), big data analytics, machine learning (ML), and the internet of Robotic Things (IoRT), focused on improving productivity and efficiency and maintaining highquality products and services [10–12]. In the context of Industry 4.0 technologies, it is important to note their integral impact on sustainability while highlighting the difficulties of parallel implementation, which is a significant challenge [13,14]. The main difference between the ideas of the Industry 3.0 approach and those of Industry 4.0 is the mutual integration of technological solutions in a network, which significantly increases efficiency and facilitates the control and monitoring of processes in management [15].

In addition to the development of new technologies and the emergence of Industry 4.0, a tool whose roots date back to the 19th century played a key role in quality management. Vilfredo Pareto introduced and developed economic concepts that later became the basis of the Pareto principle. He noted that wealth in a society is distributed unequally, with 80% of the wealth reaching 20% of the population [16,17]. This principle, referred to as the 20/80 rule, makes it possible to distinguish important issues from trivial ones [18]. Juran (1998) introduced the Pareto principle to quality management, which provided an opportunity to identify key factors affecting quality, noting that 20% of causes are responsible for 80% of problems [19]. Its importance has been highlighted by the American Society for Quality (ASQ), which recognises it as one of the seven basic tools used in the area of process improvement [20]. In the context of quality management of production processes, the implementation of the Pareto principle makes it possible to analyse product defects and identify the main sources of errors. It is also important to focus on the analysis of production machine downtimes.

With the Pareto principle, a key aspect is to prioritise corrective and optimisation actions by focusing on the most important causes of problems. In addition, it allows for more efficient management, which consequently leads to the minimisation of waste [21].

In quality management, the Pareto chart, which is directly based on the Pareto principle, plays an important role and is widely used in design engineering. It allows unique groups of data to be examined on the basis of the variability of their frequency values; data analysis focuses on the combination of frequency distribution models together with the cumulative frequency distribution [22–24].

In addition to the Pareto principle, which is considered a fundamental tool in process improvement, there are other theories, such as the law of diminishing returns and the principle of equal distribution, which offer different perspectives on the distribution of efforts and results in quality management.

The law of diminishing returns, which is the inverse of the Pareto principle, assumes that a smaller proportion of results require more effort. In quality management, this means that achieving specific, smaller quality goals may require disproportionately more resources and effort [25–29].

The principle of equal distribution suggests that efforts and results are distributed equally, indicating that each input produces a proportional result. In the context of quality management, this principle implies that each unit of effort invested in improving production or service processes yields an equivalent increase in quality.

The principles described here offer a unique approach to quality management. The Pareto principle identifies and focuses on the key areas of greatest benefit, which is particularly useful in the initial stages of process optimisation. The Law of Diminishing Returns highlights the challenges of eliminating specific, smaller quality problems that may require disproportionate resources. The principle of equal distribution is most appropriate in the context of continuous, even process improvement, where each action has predictable and proportional benefits.

2. Literature Review

Norland et al. [30], in their publication, highlighted the importance of the Pareto principle, noting that it is commonly known as the 20/80 rule. Notably, Joseph Moses Juran is considered a pioneer of the implementation of the Pareto principle in the field of quality management [31].

Zhang et al. [32] described the Pareto principle as a tool for identifying the factors that most influence the results obtained, allowing a focus on areas of greatest importance. A similar message comes from an article [33], which recognises the principle as a valuable quality management tool, emphasising its role in prioritising efforts and resources towards areas requiring significant improvement.

According to research by Norland et al. [30], a minority of causes are often responsible for the majority of problems, suggesting that companies seeking to improve process quality can effectively focus on key issues, ultimately improving overall quality. In the service industry, the Pareto principle has been used to identify key success factors within total quality management (TQM) [20,34]. Research also indicates that the principle contributes positively to business performance, particularly in the service sector, through its focus on continuous improvement, employee engagement and process orientation [35].

The authors of the publication [36] emphasise that the Pareto principle is in line with the general tenets of TQM, which leads to the continuous improvement of both processes and products to meet customer expectations [37].

An important statement remains the article [38], in which Knoth noted that the Pareto principle in parallel application with statistical tools makes it possible to exclude intuition-based decision-making on the basis solely of process data.

Notably, in terms of the literature review, the Pareto principle is applicable to a broad view of quality management. It is used, for example, in the layer of analysis of critical success factors for service industries, drawing attention to their adaptability in different sectors [39]. A large body of research has been devoted to evaluating the implementation of this principle in terms of optimising resource allocation in the medical field [40].

The above applications highlight the versatility of implementing the Pareto principle to increase operational efficiency. Importantly, its influence extends significantly beyond the standards of traditional quality management, as has been recognised in many other industries, such as food safety, where the Pareto principle is credited with a key role in identifying factors during the implementation of hazard analysis and critical control points (HACCP) systems, which translates into a parallel increase in standards both in terms of safety and in terms of food production [41]. In addition, in academia, the relationship between the Pareto principle in terms of leadership effectiveness at the nonacademic level has been analysed, highlighting its strong importance in implementation for organisational success [42].

In the context of this study on quality management processes, in addition to recognising the importance of digitalisation as a critical factor for development [43–59], it is also necessary to consider the impact of various aspects of entrepreneurial motivation [60–79]. Entrepreneurial motivation facilitates the identification of opportunities, innovations, and the application of strategic approaches, which are key in the modern business environment. Moreover, understanding the essence, forms, and directions of development in the context of sustainable development management is vital both in principle and in practice [80–89].

The literature review highlights the robust integration of the Pareto principle with statistical process control tools in various fields, which interact to directly increase the effectiveness of quality management systems. Furthermore, it has a significant impact on process efficiency and optimisation. The general area of research is the evolution of the Pareto principle in the context of quality management through the analysis of key words (patterns) in the scientific literature.

3. Materials and Methods

This publication is based on bibliometric analysis in terms of assessing the impact of the Pareto principle on quality management. The range of the analysis is focused on mathematical graph theory, clustering and scientific visualisation methods [90]. Bibliometric analysis is characterised as a method for exploring and analysing large amounts of scientific data, enabling the study of the subject in the sphere of its evolution [91].

Bibliometric analysis leads to increased rigour, with a concomitant mitigation of researcher bias within the literature review, providing fulfilment within the meta-analysis layer [92]. It is also defined as a knowledge synthesis methodology that focuses on the quantitative analysis of large bibliometric datasets while pointing to the essences derived from the assumed framework of the subject matter under study.

The PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines were used to facilitate and ensure an unbiased approach to the search and further classification of literature sources. This set of guidelines enables a systematic and unbiased approach to the literature data selection, which is crucial for assessing the reliability and concordance of studies (Figure 1).

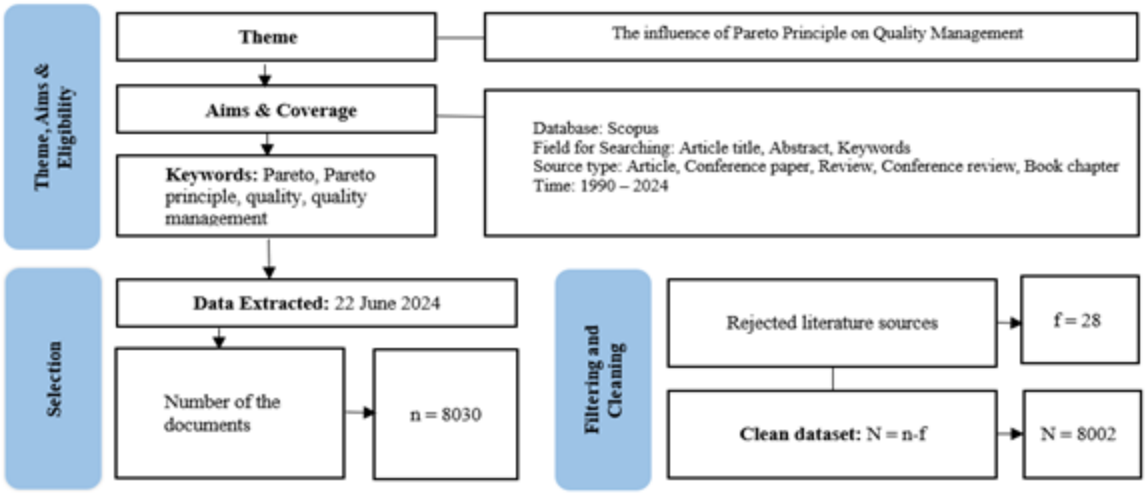

Figure 1. PRISMA Guidelines for Investigating the Influence of the Pareto Principle on Quality Management
Source: own elaboration.

In the initiating stage of the process (identification), criteria for data search and selection are established. A key element is the definition of databases, keywords, timeframes and publication types. The extracted data are methodically assessed to determine their relevance according to the agreed-upon inclusion and exclusion criteria (review).

The next stage focuses on a detailed evaluation of the extracted studies for completeness. The analysis included verification of the included content, methodology and quality of the studies (qualification assessment). Studies meeting the established assumption are subjected to further review. The aim of this stage is to confirm that the dataset is representative of the research area (Inclusion).

The final stage focuses on defining patterns and networks of interrelationships on the basis of the data selected in the previous stages (data analysis). The final element is the preparation of a report summarising the methodology and the final results obtained through the implementation of the PRISMA guidelines (Reporting) [93].

The research methodology includes the following stages: data collection and analysis, selection of a visualisation tool, graphical representation of the identified relationships and interpretation of the obtained results. The tool used to analyse the data in terms of this article is VOSviewer v.1.6.19, a freely available computer program that allows the creation and review of bibliometric maps. Unlike most bibliometric mapping tools, it places particular emphasis on their graphical presentation. The program's functionality is particularly useful for displaying large maps, allowing them to be easily interpreted [94]. Notably, VOSviewer provides the possibility of creating visualisation maps of keywords on the basis of data on the co-occurrence of author relationships, countries, etc., in relation to, for example, the number of citations [90].

The quality of the analysed data is a key element for proper interpretation. The data collected in this publication come from Scopus, an extensive database of scientific articles indexing content from various scientific fields, such as science, technology, medicine, and social sciences. The range of data analysis was set from 1990-2024. The search results include phrases and keywords such as ‘Pareto’, ‘Pareto principle’, ‘quality’ or ‘quality management’. With respect to the above assumption, the population of publications generated from the Scopus database was 8030. In terms of the analysis conducted, items assigned to the categories letter (1), undefined (1), erratum (2), short survey (3), note (4), editorial (5), retracted (5) and book (7) were discarded. Data extraction limited the analysis to 8002 indices (Figure 1).

4. Results and Discussion

A quantitative analysis of the sample within the impact of the Pareto principle on quality management revealed that there was an exponential increase in the number of studies between 1990 and 2023 (Figure 2).

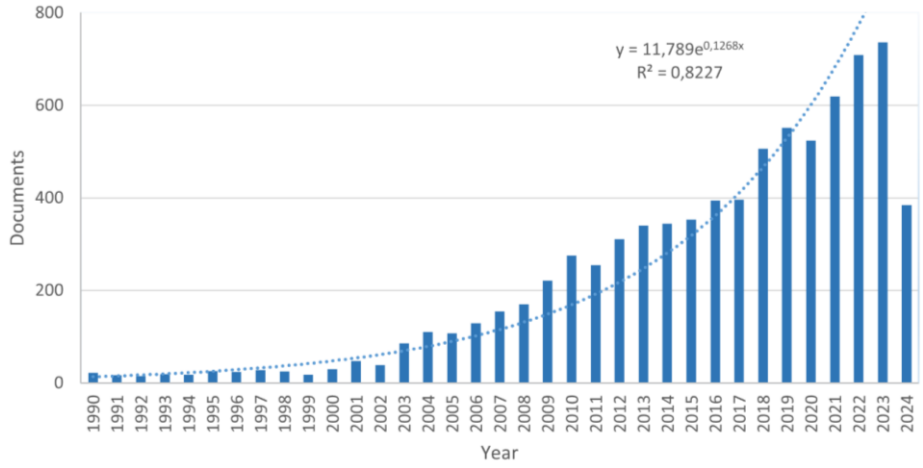

Figure 2. Number of Publications Covering the Pareto Principle and Quality Management from 1990 to 2024, Based on the Scopus Database
Source: own elaboration.

Considering the number of publications in terms of 2024 – 384 documents for only 1/2 of its part, assuming a parallel current growth rate, a record value is to be expected compared with previous periods. Nevertheless, the year-to-year growth rate for the previous two years (2022-2023) indicates some deceleration of the trend – 3.8%.

Figure 3 shows the distribution of the indices by organisation and by programmes funding research focusing on the area of the analysed theme of combining the Pareto principle with quality management. Notably, the National Natural Science Foundation of China is dominant, with 857 items. The second place is occupied by the National Science Foundation with 151 indices. The third place is completed by the Fundamental Research Funds for the Central Universities (138). The first European organisation with the highest number of papers is the European Commission (79).

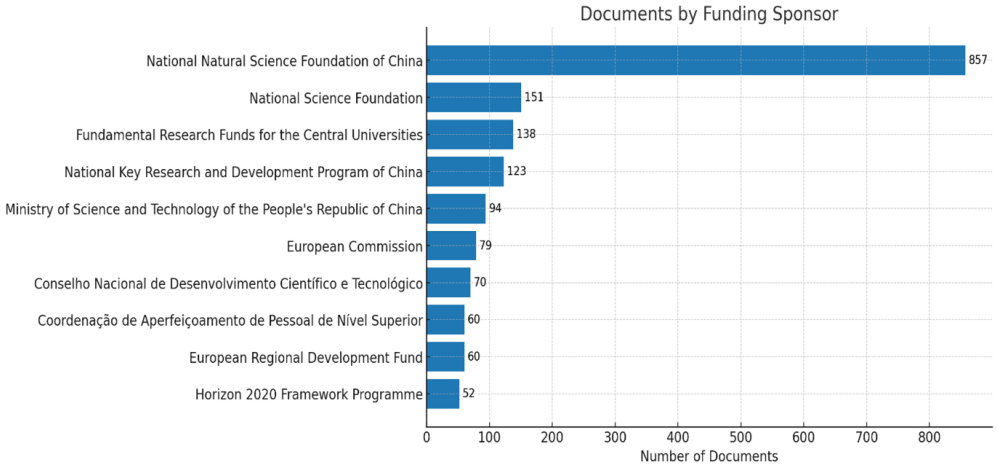

Figure 3. Documents by Funding Sponsor – Top 10 Organisations/Program
Source: own elaboration.

In further bibliometric analysis, relating the number of publications to their origin remains an important aspect. The visualisation (Figure 4) shows the number of publications as the point size, and the average number of citations is the fill colour.

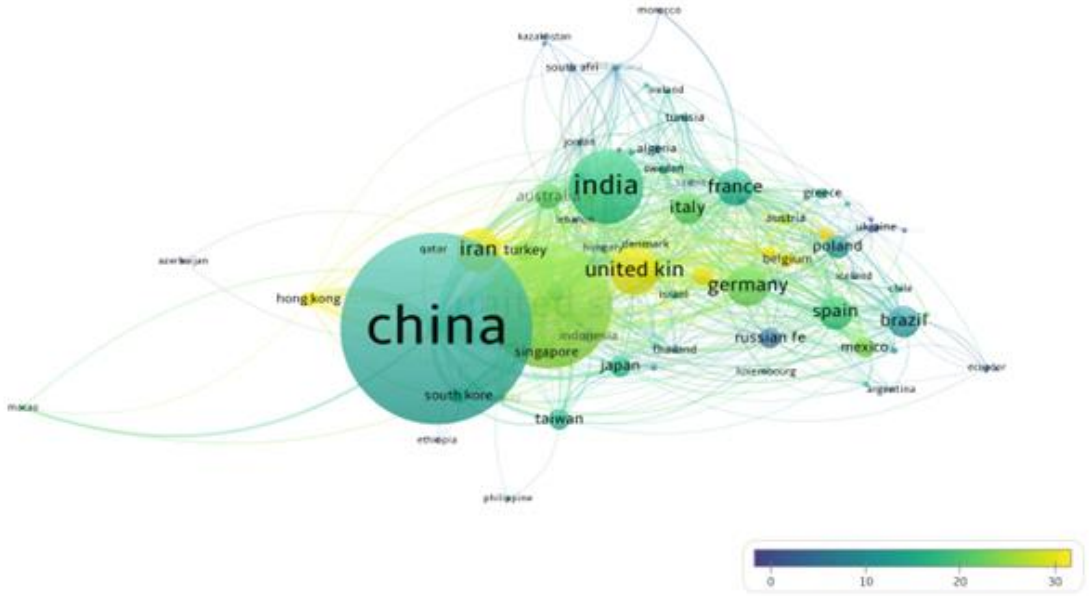

Figure 4. Number of Publications in Relation to Country of Origin: Taking into Account the Accepted Keywords for the Period 1990 to 2024
Source: own elaboration.

The highest number of articles is attributed to authors from China, with 2118 papers, followed by researchers from the USA, with 1275 publications, while India is in third place, with 682 publications. An important parameter worth noting is also the average citation level. Despite having the highest number of publications originating from China, the average citation level is 13. For the USA, the value is close to 24, whereas for India, the index level is slightly above 17.4. The highest average citation level is for researchers from Switzerland, bove 107.

An analysis of the data presented in Table 1 concerning the authors with the highest number of publications on the link between the Pareto principle and quality management shows that Jin Y. is dominant in terms of the h index, which is 90. The high value of this index suggests that his work is frequently cited, even though he has a lower total number of publications (619) than Wang X. (982) and Xin Y. (1054). Huang M. has the most publications directly related to the subject matter under analysis (35), whereas Coello C.A. has published a total of 27 items. The third place goes to Wang X., with 20 publications.

Table 1. Top 10 Leading Authors on Topics Covering Aspects of the Pareto Principle and Quality Management

Authors	Affiliation	h-Index	Number of Documents	
			Total	Related to Pareto Principle and Quality Management
Huang M.	Northeastern University, Shenyang, China	38	672	35
Coello C.A.	Centro de Investigacion y de Estudios Avanzados del Instituto Politécnico Nacional, Mexico, Mexico	79	631	27
Wang X.	College of Computer Science and Engineering, Northeastern University, Shenyang, China	41	982	20
Li M.	University of Birmingham, Birmingham, United Kingdom	31	115	19
Mitra K.	Indian Institute of Technology Hyderabad, Kandi, India	29	160	19
Ishibuchi H.	Southern University of Science and Technology, Shenzen, China	75	690	17
Yen G.G.	Oklahoma State University, Stillwater, United States	59	388	17
Gao L.	Huazhong University of Science and Technology, Wuhan, China	85	1054	15
Jin Y.	University of Surrey, Guildford, United Kingdom	90	619	15
Talbi E.G.	Faculte de Medecine de Tunis, Tunis, Tunisia	49	422	15

Source: own elaboration.

The analysis of these data highlights the authors' diverse approaches to the issues of the Pareto principle and quality management while also highlighting the importance of citation metrics, such as the h-Index, in assessing the scientific impact of individual researchers.

The analysis of the proximity and interconnectedness between keywords in the selected set of publications is an important element of the bibliometric analysis (Figure 5). On the basis of the data obtained, five main areas were selected and characterised.

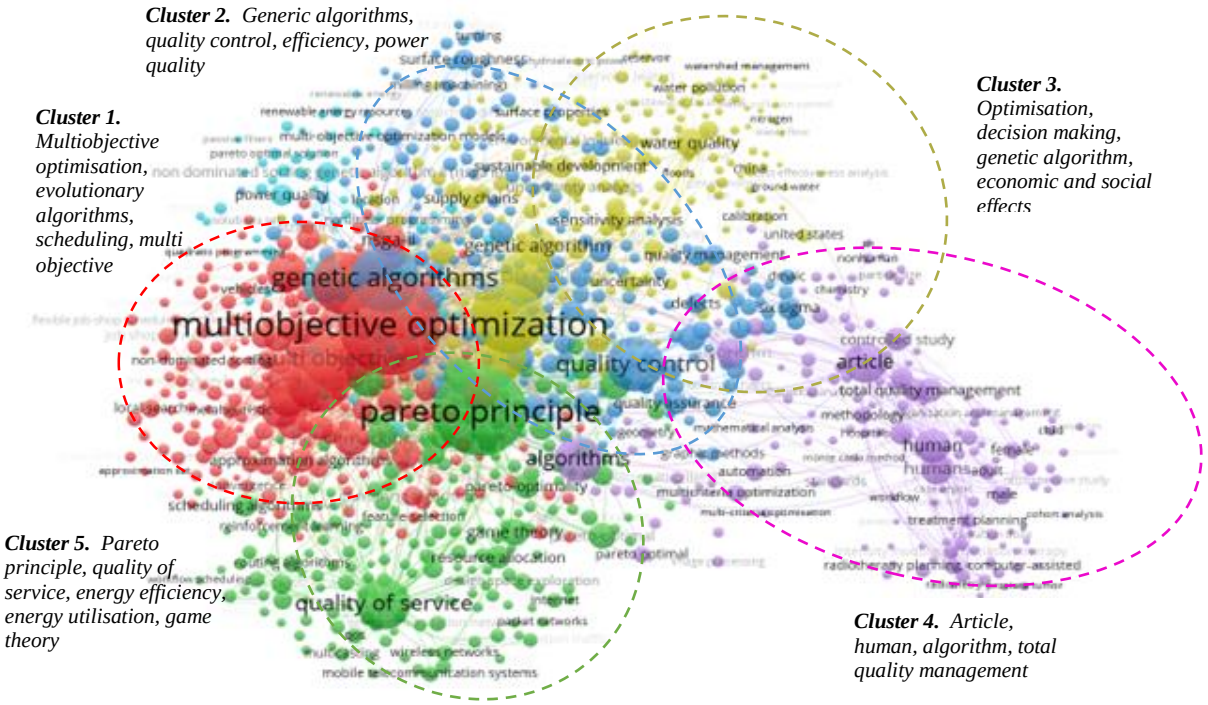

Figure 5. Analysis of Interdependence within the Highlighted Keywords
Source: own elaboration.

In terms of the analysis performed, the most numerous cluster is the area highlighted in red (cluster 1), containing 210 records in the set. Extending the analysis within the obtained data, the keyword multiobjective optimisation appears 2869 times, whereas the total strength of the connection is 27,860. The general assumption of multiobjective optimisation is to determine an optimal solution, taking into account multiple objectives that may compete with each other in parallel. Other keywords included evolutionary algorithms, scheduling, multiple objectives, particle swarm optimisation, and heuristic algorithms.

The third area in terms of numbers is blue, with 195 items (cluster 2). The dominant keyword that appears 1266 times in the sample analysed is genetic algorithms (total link strength – 12,335). Genetic algorithms are responsible for analysing potentially alternative solutions to a problem to find the best one. Another key word for this area is quality control, which appears in number – 842. In addition to these expressions, the following should be distinguished: efficiency, power quality, quality assurance, quality, and mathematical models.

The fourth area is the yellow area (cluster 3). It contains 178 keywords. The dominant one is optimisation, which has a count of 1405, while the total strength of the link is 1477. Within this area, it is important to note the other keywords that directly influence its essence: decision making, genetic algorithms, economic and social effects, and sensitivity analysis.

In the area marked in purple, there are 159 records (cluster 4). The most frequently occurring keywords are algorithms (557). The strength of the link is 6105. In addition, the following terms should be distinguished: algorithm, human, human, and total quality management. The next area on the neural network map is the green area (cluster 5), with 199 records. The leading

keyword is the Pareto principle, which appears 2410 times, for which the total connection strength is 21,525. The most frequent keywords are quality of service, energy efficiency, energy utilisation, game theory, and optimisations.

An important element of the bibliometric analysis in the layer of research carried out is the evolutionary aspect, which focuses on the interplay between the Pareto principle and quality management over time (Figure 6). To this end, the criteria underpinning Figure 5 have been retained to best illustrate the various relationships.

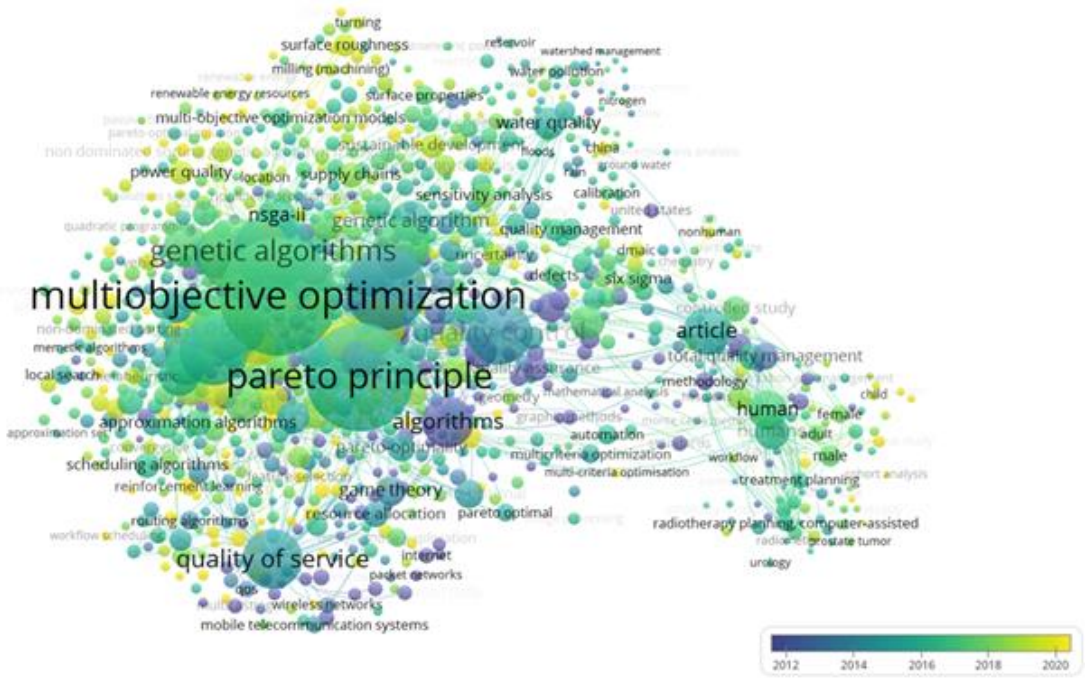

Figure 6. Analysis of the Interdependence within the Keywords Used—An Evolutionary Aspect
Source: own elaboration.

Within the analytical framework, five main time periods were distinguished, illustrating the evolutionary aspect of the interdependence of the Pareto principle and quality management and their multidimensional interrelationships with key terms in the layer of the relationship under study. An important element of the analysis is to understand the cross-fertilisation of the expressions identified in the time period—a synergistic implementation of the analytical tools in the quality management (continuous improvement) layer.

The first period, from 2012 to 2014, focused on keywords such as algorithms, computer simulations, mathematical models, priority journals, quality assurance, and total quality management. The next area defines the period from 2014 to 2016. The dominant keywords are the Pareto principle, genetic algorithms, quality control, and evolutionary algorithms. A characteristic element of this period is the implementation of optimisation methods aimed at both the identification and simultaneous elimination of quality problems. The third area covers the years 2016 to 2018. The main keywords for the analysed period are multiobjective

optimisation, decision-making, particle swarm optimisation, human, human, and benchmarking. They are characterised by their relationship in the area of optimisation, or multicriteria problem solving. The period from 2018 to 2020 represents the fourth area. It is characterised by the following keywords: efficiency, forecasting, economic and social effects, optimisation algorithms, and energy utilisation. The terms listed interrelate, enabling improvements in the layers of resource management, increased efficiency and organisational sustainability. The fifth area covers the period from 2020 to 2024 and focuses on optimisations, multiobjective optimisations, and machine learning. The terms listed highlight modern data analysis techniques in terms of optimisation, multiobjective optimisation and machine learning, highlighting significant developments in technology.

5. Discussion

This publication is a valuable source of information in the area of multifaceted analysis, defining the impact and interplay of the Pareto principle in terms of quality management. Notably, the observations and conclusions of the study may contain limitations and shortcomings, resulting in a lack of objectivity in the area studied. Oke et al. (2008) noted the validity of applying the Pareto principle in the context of defining key factors for the proper implementation of TQM, among other factors, for the service industry. A previous study [95] highlighted the relevance of this principle in the area of quality management by identifying the most influential factors. The indications from the publication [95] were confirmed in the bibliometric analysis carried out, which indicates a strong correlation in terms of the implementation of the Pareto principle.

There are several scientific publications that highlight the importance of the Pareto principle and its impact on quality management through process optimisation. Anguelov et al. (2018) focused on the implementation of the principle in terms of multiagent optimisation, highlighting business interactions in a manufacturing cluster [96], whereas [97] focused on the use of parametric optimisation to solve multiagent problems. The cited contents of the articles clearly indicate the intertwining of the Pareto principle and terms strongly associated with the quality management layer in many areas. The fundamental importance of this phenomenon

6. Conclusions

The bibliometric analysis carried out provides a wealth of information on the multidimensional impact of the Pareto principle in terms of quality management. Notably, the number of publications containing the keywords studied has been increasing exponentially, with the highest growth occurring between 2002 and 2010. Over time, the growth rate has slowed. An increase in the number of publications can lead to qualitative changes, resulting in complementarities between the different solutions and a better understanding of the relationships in terms of identifying key factors for building quality in different economic areas. In this study, the philosophical question of Hegel's dialectic on the interrelationship between quantity and quality is also addressed. The research demonstrates that an increase in the number of publications on the Pareto principle in quality management leads to qualitative changes. This is expressed in a deeper understanding of the interrelationships between the various factors influencing quality systems and in the emergence of new solutions and approaches. This study reflects a dialectical process in which a gradual increase in the number of publications and

research interest eventually generates new qualitative changes in the methodology and practical approaches to quality management.

This publication provides an analysis of the impact of the Pareto principle on quality management. It presents the interrelationships between key terms associated with the described issue. In the course of the conducted research, the VOSviewer program was used to generate a visualisation map of neural network matches on the basis of a collection of publications indexed in the Scopus database, covering the period from 1990 to 2024. The scheme presented in Figure 4 highlights the fact that China significantly leads in the number of publications (2118 documents), whereas the USA, with 1275 publications, occupies the second position. Special attention should be given to the parameter of the average citation level. Although China and the United States lead in the number of published scientific articles on the analysed topic, Switzerland is characterised by the highest citation level. This may result from several independent factors, such as the reputation of the authors or the quality of the conducted research. The clusters highlighted in Figure 5 illustrate the interrelationships between the key terms. The obtained results indicate a strong connection between the Pareto principle and terms related to tools and methods used in the analysis of factors influencing the quality of processes, as well as directly with quality itself. On the basis of the bibliometric analysis focused on evolutionary characteristics (Figure 6), continuous growth in the importance of quality should be emphasised. Initially, efforts were concentrated on individual factors in the context of improving process quality. Currently, publications focus on their multilevel analysis leading to process optimisation and technological development (multiobjective optimisation, machine learning).

The results obtained from the conducted analysis contribute to a fuller understanding of the interrelationships between the Pareto principle and quality management. As a perspective for further scientific research on the basis of the conclusions of this publication, one can point to how new technologies (machine learning, multiobjective optimisation) influence the application of the Pareto principle in quality management. The use of these technologies could lead to new qualitative changes in the field, allowing for process optimisation and improving quality management outcomes across various economic sectors.

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References

1. Reeves, C., & Bednar, D. (1994). Defining quality: Alternatives and implications. *Academy of Management Review, 19*(3), 419-445. https://doi.org/10.5465/AMR.1994.9412271805.
2. Kemenade, E., Pupius, M., & Hardjono, T. (2008). More value to defining quality. *Quality in Higher Education, 14*(3), 175-185. https://doi.org/10.1080/13538320802278461.
3. Smith, G. (1993). The meaning of quality. *Total Quality Management & Business Excellence*, *4*(3), 235–244. https://doi.org/10.1080/09544129300000038.
4. Anand, K. (1997). Quality: An evolving concept. *Total Quality Management & Business Excellence*, *8*(2-3), 195–200. https://doi.org/10.1080/0954412979622.
5. Kenyon, G. N., & Sen, K. C. (2015). The philosophy of quality. In G. N. Kenyon & K. C. Sen (Eds.), *The perception of quality: Mapping product and service quality to consumer perceptions* (pp. 29-40). Springer. https://doi.org/10.1007/978-1-4471-6627-6.
6. Freiesleben, J., & Pohl, T. (2004). Quality: An ethical inquiry. *Total Quality Management & Business Excellence*, *15*(9–10), 1209–1216. https://doi.org/10.1080/1478336042000255587.
7. Anand, K. N. (1997). Quality: An evolving concept. *Total Quality Management, 8*(4), 195–200. https://doi.org/10.1080/0954412979622.
8. Anguo, X. (2004). The conception of quality in marketing. *Journal of Gansu Radio & TV University, 4*, 23–26.
9. Meng, F., & Yang, J. (2023). Process capability analysis of Taguchi index Cpm based on generalized p-value. *Quality and Reliability Engineering International, 39*(6), 2311–2329. https://doi.org/10.1002/qre.3344.
10. Topczewska, J., & Krupa, S. (2022). Zrównoważona logistyka żywności a technologie przemysłu 4.0. *Polish Journal for Sustainable Development, 26*(1), 43–50. http://dx.doi.org/10.15584/pjsd.2022.26.1.5.
11. Dalenogare, L. S., Benitez, G. B., Ayala, N. F., & Frank, A. G. (2018). The expected contribution of Industry 4.0 technologies for industrial performance. *International Journal of Production Economics, 204*, 383–394. https://doi.org/10.1016/j.ijpe.2018.08.019.
12. Xu, L., Xu, E., & Li, L. (2018). Industry 4.0: State of the art and future trends. *International Journal of Production Research, 56*(8), 2941–2962. https://doi.org/10.1080/00207543.2018.1444806.
13. Bai, C., Dallasega, P., Orzes, G., & Sarkis, J. (2020). Industry 4.0 technologies assessment: A sustainability perspective. *International Journal of Production Economics, 229*, Article 107776. https://doi.org/10.1016/j.ijpe.2020.107776.
14. Frank, A. G., Dalenogare, L. S., & Ayala, N. F. (2019). Industry 4.0 technologies: Implementation patterns in manufacturing companies. *International Journal of Production Economics, 210*, 15–26. https://doi.org/10.1016/j.ijpe.2019.01.004.
15. Rane, S., Shah, P., & Sekhar, R. (2022). Survey of technologies for Industry 4.0. In *2022 6th International Conference on Computing, Communication, Control and Automation (ICCUBEA)* (pp. 1-6). IEEE. https://doi.org/10.1109/ICCUBEA54992.2022.10010837.
16. Sanders, R. (1987). The Pareto principle: Its use and abuse. *Journal of Services Marketing, 1*(2), 37–40. https://doi.org/10.1108/EB024706.
17. Pareto, V. (1897). The New Theories of Economics. *Journal of Political Economy*, *5*(4), 485–502.
18. Shabrawy, A. (1986). The application of Pareto distribution principle to quality control in repair workshops. *Arab Academy for Science, Technology and Maritime Transport Journal*, *1*, 31–39. https://doi.org/10.21608/amme.1986.52558.
19. Juran, M., & Godfrey, A. (Eds). (1998). *Juran's quality handbook* (5th ed.). McGraw-Hill Companies, Inc.
20. Alkiayat, M. (2021). A practical guide to creating a Pareto chart as a quality improvement tool. *Global Journal on Quality and Safety in Healthcare*, *4*(2), 83–84. https://doi.org/10.36401/JQSH-21-X1.
21. Radson, D., & Boyd, A. (1997). The Pareto principle and rate analysis. *Quality Engineering*, *10*(2), 223–229. https://doi.org/10.1080/08982119708919129.

22. Nicolae, R., Nedelcu, A., & Dumitrascu, A. (2015). Improvement of the quality of industrial products by applying the Pareto chart. *Scientific Bulletin of Naval Academy, 13*(3), 169–172. https://doi.org/10.19062/1842-9238.2015.13.3.29.
23. AnilKumar, S. (2016). Knowledge-based selection in soft computing models using Pareto charts and Pareto principle. *International Journal of Research in Engineering and Technology, 5*(19), 1–10. https://doi.org/10.15623/IJRET.2016.0531001.
24. Roriz, C., Nunes, E., & Sousa, S. (2017). Application of lean production principles and tools for quality improvement of production processes in a carton company. *Procedia Manufacturing, 11*, 1069–1076. https://doi.org/10.1016/J.PROMFG.2017.07.218.
25. Shephard, R., & Färe, R. (1974). The law of diminishing returns. *Zeitschrift für Nationalökonomie/Journal of Economics, 34*, 69–90. https://doi.org/10.1007/BF01289147.
26. Brue, S. (1993). Retrospectives: The law of diminishing returns. *Journal of Economic Perspectives, 7*(3), 185–192. https://doi.org/10.1257/JEP.7.3.185.
27. Fogarty, G., & Stankov, L. (1995). Challenging the 'law of diminishing returns'. *Intelligence, 21*(2), 157–174. https://doi.org/10.1016/0160-2896(95)90024-1.
28. Liang, X. (2023). Research on the influence of the law of diminishing marginal returns in agriculture. *Advances in Economics, Management and Political Sciences, 8*, 262–267https://doi.org/10.54254/2754-1169/8/20230323.
29. Ahmad, A., Subramanian, T., Panteliadis, P., Wilson-Macdonald, J., Rothenfluh, D., & Nnadi, C. (2017). Quantifying the 'law of diminishing returns' in magnetically controlled growing rods. *Spine Deformity, 5*(5), Article 452. https://doi.org/10.1016/j.jspd.2017.09.028.
30. Norland, J. E., Dixon, C., Larson, D. L., Askerooth, K., & Geaumont, B. A. (2018). Prairie reconstruction unpredictability and complexity: What is the rate of reconstruction failures? *Ecological Restoration, 36*(4), 263–266. https://doi.org/10.3368/er.36.4.263.
31. Filho, W. M. M., Gonçalves, C. A., Rodrigues, H. L. d. N., & Coelho, I. (2023). Applying the seven basic quality tools to solve a quality issue in the manufacturing of electronic switches. *Journal of Engineering Research, 3*(20), 1–22. https://doi.org/10.22533/at.ed.3173202307061.
32. Zhang, J., Ding, X., Zhou, X., Chen, W., Yao, J., Guo, Z., Chen, L., Xia, Y., & Fan, Q. (2021). Performance of HIV detection in Zhejiang Province in China: The Pareto principle at work. *Journal of Clinical Laboratory Analysis, 35*(6), Article e23794. https://doi.org/10.1002/jcla.23794.
33. Karuppusami, G., & Gandhinathan, R. (2006). Pareto analysis of critical success factors of total quality management. *The TQM Magazine, 18*(4), 372–385. https://doi.org/10.1108/09544780610671048.
34. Talib, F., Rahman, Z., & Qureshi, M.N. (2010). Pareto Analysis of Total Quality Management Factors Critical to Success for Service Industries. *International Journal for Quality Research*, 4(2), 155–168.
35. Rönnbäck, Å., & Witell, L. (2008). The impact of quality management principles on business performance–A comparison between manufacturing and service organisations. *Managing Service Quality*, 18(6), 577–598.
36. Yousef, N., & Yousef, F. (2017). Using total quality management approach to improve patient safety by preventing medication error incidences. *BMC Health Services Research, 17*(1) Article 621. https://doi.org/10.1186/s12913-017-2531-6.
37. Li, Q., Liu, Z., Hu, N., Zhong, S., & Cheng, K. (2022). A new method for quality analysis of multi-process manufacture. In *2022 IEEE 22nd International Conference on Software Quality, Reliability, and Security Companion (QRS-C)* (pp. 776-777). IEEE. https://doi.org/10.1109/QRS-C57518.2022.00130.
38. Knoth, S. (2005). *Statistical process control* [Unpublished doctoral dissertation]. Humboldt-Universität zu Berlin, Wirtschaftswissenschaftliche Fakultät.
39. Ahuja, V., Akhtar, A., & Wali, O. P. (2019). Development of a comprehensive model of social entrepreneurial intention formation using a quality tool. *Journal of Global Entrepreneurship Research, 9*, Article 41. https://doi.org/10.1186/s40497-019-0164-4.
40. Khan, A., Biggs, T. C., & Faoury, M. (2018). Improving the allocation of junior doctor resources using a pareto analysis of pager activity. *International Journal of Otorhinolaryngology and Head and Neck Surgery, 5*(1), 1–4. https://doi.org/10.18203/issn.2454-5929.ijohns20184676.
41. Fotopoulos, C., Kafetzopoulos, D., & Gotzamani, K. (2011). Critical factors for effective implementation of the haccp system: a pareto analysis. *British Food Journal*, 113(5), 578–597. https://doi.org/10.1108/00070701111131700.
42. Khan, A. R. A. M. (2023). An empirical examination of relationship between pareto principle and stages of leadership at university level. *PJE, 35*(3). https://doi.org/10.30971/pje.v35i3.914.

43. Khan, A. A., Laghari, A. A., Shaikh, Z. A., Dacko-Pikiewicz, Z., & Kot, S. (2022). Internet of Things (IoT) security with blockchain technology: A state-of-the-art review. *IEEE Access, 10*, 122679–122695. https://doi.org/10.1109/ACCESS.2022.3223370.
44. Kwilinski, A., Szczepańska-Woszczyna, K., Lyulyov, O., & Pimonenko, T. (2024). Digital public services: Catalysts for healthcare efficiency. *Journal of Open Innovation: Technology, Market, and Complexity, 10*(3), Article 100319. https://doi.org/10.1016/j.joitmc.2024.100319.
45. Infante-Moro, A., Infante-Moro, J. C., Gallardo-Pérez, J., & Martínez-López, F. J. (2022). Key factors in the implementation of e-proctoring in the Spanish university system. *Sustainability, 14*(13), Article 8112. https://doi.org/10.3390/su14138112.
46. Climent, R. C., Haftor, D. M., & Staniewski, M. W. (2024). AI-enabled business models for competitive advantage. *Journal of Innovation and Knowledge, 9*(3), Article 100532. https://doi.org/10.1016/j.jik.2024.100532.
47. Infante-Moro, A., Infante-Moro, J. C., & Gallardo-Pérez, J. (2022). Key factors to raise cybersecurity awareness among employees [Factores claves para concienciar la ciberseguridad en los empleados]. *Revista de Pensamiento Estratégico y Seguridad CISDE, 7*(1), 69-79.
48. Kwilinski, A. (2024). Understanding the nonlinear effect of digital technology development on CO2 reduction. *Sustainable Development, 32*(5), 5797–5811. https://doi.org/10.1002/sd.2964.
49. Kwilinski, A. (2019). Implementation of blockchain technology in accounting sphere. *Academy of Accounting and Financial Studies Journal, 23*(SI2), 1–6.
50. Nguyen, T.-L., Infante-Moro, A., & Infante-Moro, J. C. (2024). Generation Z's followers on hotel social networking sites: Motivational factors from a theory of planned behavior approach [Seguidores de la generación Z en los sitios de redes sociales del hotel: Factores motivacionales desde el enfoque de la teoría del comportamiento planificado]. *RISTI - Revista Iberica de Sistemas e Tecnologias de Informacao*, 2024(E66), 340–354.
51. Kwilinski, A., Trushkina, N., Birca, I., & Shkrygun, Y. (2023). Organizational and economic mechanism of customer relationship management under the era of digital transformations. *E3S Web of Conferences, 456*, Article 05002. https://doi.org/10.1051/e3sconf/202345605002.
52. Infante-Moro, J. C., Infante-Moro, A., Garrido, Y. C., & Segura, R. I. (2023). Indicators to measure competence "2.3. Engaging with citizens through digital technologies" of the DigComp model in the context of active aging. In *2023 XIII International Conference on Virtual Campus (JICV)* (pp. 1–4). Porto, Portugal. https://doi.org/10.1109/JICV59748.2023.10565636.
53. Ayala-Mora, J., Infante-Moro, A., & Infante-Moro, J. C. (2023). Electronic administration in the Council of the Judiciary of Ecuador [La administración electrónica en el Consejo de la Judicatura de Ecuador]. *RISTI - Revista Iberica de Sistemas e Tecnologias de Informacao*, 2023(E60), 511–523.
54. Kwilinski, A., Merritt, P., & Wróblewski, Ł. (2024). Advancing Sustainable Development Goals through Digital Culture: A Global Research Overview. *Cultural Management: Science and Education, 8*(1), 61–80. https://doi.org/10.30819/cmse.8-1.04.
55. Lis, M. (2021). Shaping relations between higher education institutions and the enterprise world in the age of digital transformation. *Polish Journal of Management Studies, 23*(1), 294–314. https://doi.org/10.17512/pjms.2021.23.1.18.
56. Kwilinski, A. (2023). E-commerce and sustainable development in the European Union: A comprehensive analysis of SDG2, SDG12, and SDG13. *Forum Scientiae Oeconomia, 11*(3), 87–107. https://doi.org/10.23762/FSO_VOL11_NO3_5.
57. Kwilinski, A., Lyulyov, O., & Pimonenko, T. (2023). The coupling and coordination degree of digital business and digital governance in the context of sustainable development. *Information, 14*(12), Article 651. https://doi.org/10.3390/info14120651.
58. Lyulyov, O., Pimonenko, T., Saura, J. R., & Barbosa, B. (2024). How do e-governance and e-business drive sustainable development goals? *Technological Forecasting and Social Change, 199*, Article 123082. https://doi.org/10.1016/j.techfore.2023.123082.
59. Acheampong, S., Lyulyov, O., & Pimonenko, T. (2023). Digital marketing and sustainable economic development trends in developed and underdeveloped countries: A bibliometric analysis. *E3S Web of Conferences, 456*, Article 02002. https://doi.org/10.1051/e3sconf/202345602002.
60. Zimbroff, A., Schlake, M. R., Anderson-Knott, M., Eberle, N., & Vigna, D. (2017). Beyond lemonade stands to main street business development: A youth entrepreneurship curriculum. *Journal of Extension, 55*(3), Article 3IAW9.

61. Szczepańska-Woszczyna, K. (2018). Strategy, corporate culture, structure and operational processes as the context for the innovativeness of an organization. *Foundations of Management*, *10*(1), 33–44. https://doi.org/10.2478/fman-2018-0004.
62. Ismail, N., Kot, S., Abd Aziz, A. S., & Rajiani, I. (2020). From innovation to market: Integrating university and industry perspectives towards commercialising research output. *Forum Scientiae Oeconomia*, *8*(4), 99–115. https://doi.org/10.23762/FSO_VOL8_NO4_6.
63. Dacko-Pikiewicz, Z. (2019). The selected aspects of strategic management in the city divided by the border in the context of the development of the cross-border market of cultural services. *Polish Journal of Management Studies*, *19*(1), 130–144. https://doi.org/10.17512/pjms.2019.19.1.10.
64. Szczepańska-Woszczyna, K., & Gatnar, S. (2022). Key competences of research and development project managers in high technology sector. *Forum Scientiae Oeconomia*, *10*(3), 107–130. https://doi.org/10.23762/FSO_VOL10_NO3_6.
65. Zimbroff, A., & Jorgensen, J. J. (2019). An assessment of young adult perceptions towards entrepreneurship in Bangladesh using a mixed methods approach. *International Journal of Entrepreneurship*, *23*(4), 1–18.
66. Zane, L. J., & Zimbroff, A. (2018). New product development: A prototyping experiential exercise using Human Centered Design methodology. In S. Hoskinson & D. F. Kuratko (Eds.), *Annals of entrepreneurship education and pedagogy – 2018* (pp. 293-300). Edward Elgar Publishing. https://doi.org/10.4337/9781788114950.00030.
67. Rajiani, I., & Kot, S. (2020). Javanese Indonesia: Human resource management issues in a uniquely collectivist culture. *Cultural Management: Science and Education*, *4*(2), 9–21. https://doi.org/10.30819/cmse.4-2.01.
68. Khalid, B., & Kot, M. (2021). The impact of accounting information systems on performance management in the banking sector. *IBIMA Business Review*, *2021*, Article 578902. https://doi.org/10.5171/2021.578902.
69. Dacko-Pikiewicz, Z. (2019). Building a family business brand in the context of the concept of stakeholder-oriented value. *Forum Scientiae Oeconomia*, *7*(2), 37–51. https://doi.org/10.23762/FSO_VOL7_NO2_3.
70. Szczepańska-Woszczyna, K., & Muras, W. (2023). Shareholders and the long-term ability of a company to value creation: The case of the IT sector. *Polish Journal of Management Studies*, *28*(2), 323–348. https://doi.org/10.17512/pjms.2023.28.2.19.
71. Wróblewski, Ł., Dacko-Pikiewicz, Z., & Cuyler, A. (2017). The European Union consumer behaviour in the festivals market in Poland. *Polish Journal of Management Studies*, *16*(2), 302–314. https://doi.org/10.17512/pjms.2017.16.2.26.
72. Zimbroff, A. (2023). The future of extension programming post-pandemic: The need for diverse approaches. *The Journal of Extension*, *61*(2), Article 6. https://doi.org/10.34068/joe.61.02.06.
73. Wróblewski, Ł., & Dacko-Pikiewicz, Z. (2018). Sustainable consumer behaviour in the market of cultural services in Central European countries: The example of Poland. *Sustainability*, *10*(11), 3856. https://doi.org/10.3390/su10113856.
74. Zimbroff, A., Jorgensen, J. J., & Callan, J. (2021). Assessment of regional entrepreneurship ecosystems in Australia: A mixed methods approach. *International Journal of Entrepreneurship*, *25*(8), 1–19.
75. Baldi, N. (2020). Management of innovations in public governance: Quality management system, management controlling and internal auditing appropriation. *Marketing and Management of Innovations*, *2*, 95–107. https://doi.org/10.21272/mmi.2020.2-07.
76. Zatar, T. (2022). Achieving firm financial performance through the just-in-time supply chain, quality management, and supply chain integration: The moderating role of IT advancement. *Marketing and Management of Innovations*, *4*, 136–151. https://doi.org/10.21272/mmi.2022.4-13.
77. Erden Ayhun, S., Usta Kara, I., & Cavusgil Kose, B. (2024). Quality management research in tourism literature: A bibliometric analysis approach. *Marketing and Management of Innovations*, *15*(2), 55–74. https://doi.org/10.21272/mmi.2024.2-05.
78. Nadason, S., Vasudevan, H., & Yee, C. M. (2024). The mediating effect of customer loyalty on the relationship among supply chain performance, inventory management and quality management. *Marketing and Management of Innovations*, *15*(1), 67–79. https://doi.org/10.21272/mmi.2024.1-06.
79. Chygryn, O., Shevchenko, K., & Tuliakov, O. (2024). Neuromarketing as a mechanism of communication with the consumer: Case for small business. *Marketing and Management of Innovations*, *15*(2), 26–38. https://doi.org/10.21272/mmi.2024.2-03.
80. Kwilinski, A., Lyulyov, O., & Pimonenko, T. (2024). The role of country's green brand and digitalization in enhancing environmental, social, and governance performance. *Economics and Environment*, *87*(4), Article 613. https://doi.org/10.34659/eis.2023.87.4.613.

81. da Silva Tomadon, L., do Couto, E. V., & de Vries, W. T. (2024). Smart city and sustainability indicators: A bibliometric literature review. *Discovery Sustainability, 5*, Article 143. https://doi.org/10.1007/s43621-024-00328-w.
82. Kwilinski, A., & Kardas, M. (2024). Efficiency of Full and Fractional Factorial Designs in Quality Management: A Case Study on Identifying Key Adhesion Factors. *Forum Scientiae Oeconomia, 12*(3), 138–158. https://doi.org/10.23762/FSO_VOL12_NO3_7.
83. Chen, Y., Lyulyov, O., Pimonenko, T., & Kwilinski, A. (2024). Green development of the country: Role of macroeconomic stability. *Energy & Environment, 35*(5), 2273–2295. https://doi.org/10.1177/0958305X231151679.
84. Lyulyov, O., Chygryn, O., Pimonenko, T., Zimbroff, A., Makiela, Z., & Kwilinski, A. (2024). Green competitiveness forecasting as an instrument for sustainable business transformation. *Forum Scientiae Oeconomia, 12*(2), 8–20. https://doi.org/10.23762/FSO_VOL12_NO2_1.
85. Mlaabdal, S. M. A., Kulish, A., Kwilinski, A., & Chygryn, O. (2024). Sustainable energy policy and environmental responsibility: Clustering of key development patterns. *Journal of Sustainability Science and Management, 19*(8), 132–148. http://doi.org/10.46754/jssm.2024.08.010.
86. Lyulyov, O., Pimonenko, T., Chen, Y., Kwilinski, A., & Us, Y. (2024). Countries' green brands within the context of sustainable development goals. *Journal of Innovation & Knowledge, 9*(3), Article 100509. https://doi.org/10.1016/j.jik.2024.100509.
87. Kwilinski, A., Lyulyov, O., Pimonenko, T., & Pudryk, D. (2024). Competitiveness of higher education systems: Exploring the role of migration flow. *Journal of Infrastructure, Policy and Development, 8*(2), Article 2839. https://doi.org/10.24294/jipd.v8i2.2839.
88. Kwilinski, A., Lyulyov, O., & Pimonenko, T. (2023). Environmental sustainability within attaining sustainable development goals: The role of digitalization and the transport sector. *Sustainability, 15*(14), Article 11282. https://doi.org/10.3390/su151411282.
89. Kwilinski, A., & Trushkina, N. (2023). Green investments as tools for stimulating the sustainable financing of logistics systems development. *E3S Web of Conferences, 456*, Article 01003. https://doi.org/10.1051/e3sconf/202345601003.
90. Kwilinski, A. (2023). The Relationship between Sustainable Development and Digital Transformation: Bibliometric Analysis. *Virtual Economics*, 6(3), 56–69. https://doi.org/10.34021/ve.2023.06.03(4).
91. Donthu, N., Kumar, S., Mukherjee, D., Pandey, N., & Lim, W. (2021). How to conduct a bibliometric analysis: An overview and guidelines. *Journal of Business Research, 133*, 285–296. https://doi.org/10.1016/J.JBUSRES.2021.04.070.
92. Zupic, I., & Čater, T. (2014). Bibliometric Methods in Management and Organization. *Organizational Research Methods, 18*, 429–472. https://doi.org/10.1177/1094428114562629.
93. Kwilinski, A. (2024). Mapping Global Research on Green Energy and Green Investment: A Comprehensive Bibliometric Study. *Energies*, *17*(5), Article 1119. https://doi.org/10.3390/en17051119.
94. Eck, N., & Waltman, L. (2009). Software survey: VOSviewer, a computer program for bibliometric mapping. *Scientometrics*, *84*, 523–538. https://doi.org/10.1007/s11192-009-0146-3.
95. Oke, S. A., Ofiabulu, C. E., Banjo, A. A., Akanbi, O. G., & Oyawale, F. A. (2008). The combined application of quality function deployment and Pareto analysis for hotel services improvement. *International Journal of Productivity and Quality Management*, 3(2), 183–197. https://doi.org/10.1504/IJPQM.2008.016567.
96. Anguelov, K., Stoyanova, T., & Hristov, M. (2018). Model for multi-objective optimization according to Pareto principle of business interactions in a production cluster composed by participant organizations with the same business activities. *AIP Conference Proceedings*, *2048*(1), Article 060030. https://doi.org/10.1063/1.5082145.
97. Romanko, O., Ghaffari-Hadigheh, A., & Terlaky, T. (2012). Multiobjective optimization via parametric optimization: Models, algorithms, and applications. In T. Terlaky & F. Curtis (Eds.), *Modeling and optimization: Theory and applications* (Vol. 21, pp. 73-95). Springer. https://doi.org/10.1007/978-1-4614-3924-0_5.