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Mapping the Evolution of Management Engineering: Bibliometric Insights into Social and Conceptual Structures (1928–2025)

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ABSTRACT

The purpose of this study is to contribute to the identification of "Management Engineering" (ManagEng) as a distinct scientific field but also as a professional field, providing a comprehensive overview of existing scientific research. In particular, we map the social and conceptual structure of ManagEng, the evolution of scientific research and the trends of scientific research. We performed bibliometric analysis using performance analysis and scientific mapping with Biblioshiny and VOSviewer software. The Scopus database was used according to the PRISMA methodology. After a thorough examination, a significant number of papers (334) were considered to be unrelated to ManagEng even though they met the inclusion criteria set. In the end, 525 papers were studied, covering the period from 1928 to 2025. The main results of the study are: a) scientific production is dominated by the USA and China, although a large number of countries (47) have published 1/3 of the articles. There is also a significant divergence between countries in the conceptualization and research areas of ManagEng, b) ManagEng is often identified with Industrial engineering, especially in the health sector and is often mistakenly confused with engineering management. c) Scientific research at ManagEng focuses mainly on decision making and project management. d) At the same time, a significant part of the literature comes from the USA and hospital management (economic aspects-optimization). (e) Artificial intelligence and risk management are also an important part of the literature as well as the management of the environment and natural resources. Academic staff, ManagEng alumni/students, and career counselors can recognize the different conceptualizations between countries and ManagEng's prospects in the future

Keywords: Bibliometric Analysis; Biblioshiny; Conceptual Structure; Industrial Engineering; Management Engineering; PRISMA; Scientific Mapping; Social Structure; Thematic Maps; VOSviewer.

1.0. Introduction

Management Engineering (ManagEng) is characterized as the discipline of constructing mathematical models of real systems and then analyzing them to formulate informed management decisions [1, p.4]. Management engineers possess the knowledge, abilities, and analytical methodologies to understand the impact of new technologies on organizations and society. They are able to design integrated management systems and innovation processes, taking into account the user's perspective, while understanding environmental changes and market interconnections [2, 3].

Management engineers are professionals who possess the necessary skills and competencies to improve organizational performance [4]. As suggested by researchers, the methodologies applied by industrial engineers (IEs) in the manufacturing and processing industries can be adopted by various public and private sector organizations through the "servitisation" process [2]. This is precisely when a ManagEng perspective is required in many service industries [3]. Management engineers utilize engineering methodologies or tools (e.g., Lean and Six Sigma) to achieve a sustainable change by having a holistic view of the social and technical characteristics of management systems [2, 4].

However, it is important to note that the "Management Engineer" is not included in the taxonomies of occupations established by international or national labor organizations as a distinct occupation, such as: a) the International Standardized Classification of Occupations (ISCO-08) by the International Labour Organization [5], b) O*NET

Online by the U.S. Department of Labor [6], and (c) ESCO, the European Classification of Skills, Competences, Qualifications and Occupations [7].

Bibliometric analysis is one of the most useful tools for mapping the evolution of scientific knowledge over time, contributing to greater clarity and reliability of research findings [8]. Bibliometric data are increasingly applied to issues of broader social significance, such as environmental concerns and the adaptation of engineering practice to the Sustainable Development Goals (SDGs) [9, 10]. Bibliometric analyses have also been conducted on the integration of SDGs into engineering curricula [11], as well as on the accreditation of higher education in engineering disciplines [12].

The absence of consensus on the conceptual content of ManagEng, as well as the lack of reference to the international occupational classifications regarding the field of ManagEng, leads to the conclusion that a thorough investigation of the coherence and special characteristics of this field is required, both conceptually and socially.

1.1. Study Objectives

The purpose of this paper is to record the fundamental bibliometric characteristics of the existing literature and to capture the conceptual and social structure of the scientific field of ManagEng as well as the relevant profession. The aim is to present a comprehensive picture of the scientific field and the professional prospects of the graduates, as recorded in the literature. The primary goals of this research include:

1) Recording the fundamental bibliometric characteristics of ManagEng literature.
2) Mapping the conceptual and social structure of the scientific field and the profession.
3) Presenting a comprehensive picture of professional prospects for graduates.
4) Investigating the evolution of scientific production and key research indicators.
5) Identifying the most productive and highly funded countries in the field.
6) Highlighting future trends such as Artificial Intelligence and the green economy.

The following research questions will be addressed. The first two research questions provide a descriptive bibliometric overview of the existing literature, and the next two questions focus on mapping the social and conceptual structure of scientific research in ManagEng.

RQ1. How is scientific production evolving at ManagEng and what are the key bibliometric indicators of the research?

RQ2. Which countries have the highest number of publications on ManagEng and which countries fund scientific research the most?

RQ3. What is the social structure of scientific research in ManagEng?

RQ4. What is the conceptual structure of scientific research in ManagEng?

The structure of the paper is as follows: the literature and methodology are presented in the next sections. The results and discussion are then presented according to the research questions. Then the conclusion is provided.

2.0. Literature Review

In the literature, there is often limited clarity in the use of the terms "Management Engineering" (ManagEng) and "Engineering Management" (EngManag). Although both disciplines serve as conduits between the fields of engineering and management, they approach the subject from different perspectives [3, 13, 14]. EngManag is defined as the set of knowledge, skills, and general management responsibilities that engineers acquire as they progress in their careers and are assigned managerial responsibilities [15]. The role of engineering managers includes the application of engineering principles and technical competences, alongside the cultivation of managerial and leadership skills [15, 16].

In contrast, ManagEng is viewed as a multidisciplinary field that integrates a wide range of academic disciplines, including operations research, industrial and production engineering, human factor engineering, financial engineering, quality management, computer science, general engineering disciplines as well as social and behavioural sciences [17, p. 27]. It represents a modern form of industrial engineering applied to both industrial and service-related sectors [2, 3]. In the healthcare sector, the terms "industrial engineers" and "management engineers" are often used interchangeably [4]. ManagEng is also known in North America as "industrial engineering for healthcare" [1, 18, 19], using specialized methodologies to improve the efficiency and productivity of the system [18].

From a professional standpoint, management engineers frequently undertake the role of an internal improvement consultant, assuming responsibilities that necessitate the cultivation of a comprehensive and holistic perspective [4].

Bibliometric methods of analysis are a form of quantitative analysis used to evaluate the literature in a systematic and objective way [20]. A bibliometric analysis involves the exploration and analysis of large amounts of scientific data [21]. It is considered an inherently quantitative analytical technique [22] which offers new opportunities to study and understand a research area [23]. As it is based on algorithms, it is considered objective and reproducible [22, 24]. A bibliometric analysis can be conducted via performance analysis [20, 25, 26] and scientific mapping of conceptual, social, and intellectual structures [20, 22, 26].

Reviewing the existing literature, we observe a plethora of bibliometric analyses for EngManag. These have encompassed topics such as the evolution of research during the period 2014-2023 [27], the maturity of the research area [28], the distinction between EngManag and technology management [29], author collaboration [30], and the business mindset in the field [31]. In contrast, there is no relevant research on ManagEng as a distinct scientific field or much less on any sub-topic of this field.

3.0. Methodology

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) methodology was followed for the survey [32], which includes a 27-item checklist and a flowchart (Fig. 1). The flowchart helps to capture the process followed in identifying the results studied, selecting and evaluating them as well as to the composition of the studies. The data was retrieved from the Scopus database on June 15, 2025, and the following inclusion and exclusion criteria were established:

a) The title, abstract, or keywords of the document must contain the term 'management engineer*'.

b) The type of the document is limited to articles and conference proceedings.

c) The source type is limited to journals or conference proceedings.

d) The language of publication is set to English.

The wildcard character (*) used is instrumental in broadening the scope of the research findings to include all possible variations of the term under consideration, including the terms "management engineering" and "management engineer", together with their derivatives. In the search for results, no specific time frame is defined, in order to capture and map the overall scientific production over time from the first papers to the present day.

We use two software programs to provide an integrated approach to research questions, covering both performance analysis as well as scientific mapping methodology: a) Biblioshiny [33] is a web-based application, which is part of the Bibliometrix package (R 4.3.1 software) and b) VOSviewer [34]. VOSviewer and Biblioshiny are recommended for conducting bibliometric analysis and are used in a significant number of bibliometric analyses, for scientific mapping and visualization of data [20], [23], [25].

According to the original criteria, a total of 892 documents were recovered (see Fig. 1). Following a review, 17 duplicate documents and 16 unauthored documents were removed, resulting in a total of 859 documents for analysis. A thorough examination of document titles and summaries revealed that a significant number of papers focused on other disciplines rather than "management engineering". As a result, an additional 334 documents were removed. The process resulted in 525 documents, a significantly reduced percentage (58.9%) of the original 892 documents recovered, focusing exclusively on "management engineering" (Fig. 1).

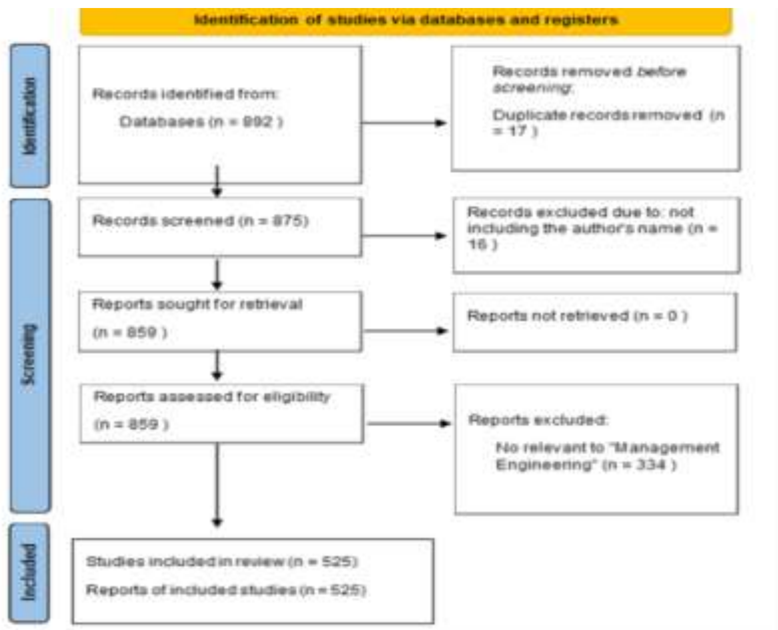

Figure 1. PRISMA methodology data flowchart illustrating the study selection process.

Bibliometric methods make it easier for scientists to draw conclusions about the structure of a scientific field through the use of aggregated bibliographic data generated by other scientists in that field [20]. Co-authorship analysis studies the social networks of researchers, organizations, and countries based on the number of publications [24]. It reveals the collaborative networks of authors and the social structures of the field [23]. Co-word or co-occurrence analysis is a linguistic technique that identifies keywords in summaries, titles, and articles to reveal connections between topics [23], [24]. The words collected represent a common theme [25]. Co-word analysis identifies dominant concepts or themes, how they evolve, and their relationships to each other [26].

In order to enhance the reliability of the results, it is recommended to use multiple approaches [22], [25], [26]. Co-phrase analysis has been shown to map the relevant conceptual structure, while co-authorship analysis of the social structure of a field [20].

4.0. Results and Discussion

4.1. RQ1. How is scientific production evolving and what are the main bibliometric indicators of research?

As shown in Fig. 2, a total of 525 papers from 354 sources have been published from 1928 to 2025. The majority of these are articles (317) and 208 are conference papers. While the annual increase appears modest at 2.03% (see Fig. 2), it is important to note that 2025 is only calculated for the first six months. The data in Fig. 2 on scientific output growth, authors, and keywords are detailed in the following sections.

Figure 2. Summary of key bibliometric indicators for ManagEng research from 1928 to 2025.

In Fig. 3 it is observed that between 1928 and 2010 (a period of 83 years), a total of 250 articles were published. For this reason, the average age of publication (20.9 years) is comparatively increased (Fig. 2). However, there were extensive periods during which no relevant document was published, such as: a) from 1930-1946, b) the period 1956-1964, and c) the years 1948, 1952, 1954 and 1968.

In Fig. 4, the scientific output over the next 15 years, from 2011 to 2025, is depicted. In particular, we observe that the number of publications increased to 275, representing 52.4% of the total scientific output. The most productive years of this period are 2022 (31 documents), 2020 (26), 2023 (24) and 2024 (23). By comparison, in the previous period (1928-2010), the years in which there was a significant number of operations were: 1978 (12), 1980 (17), 2006 (11) and 2010 (14).

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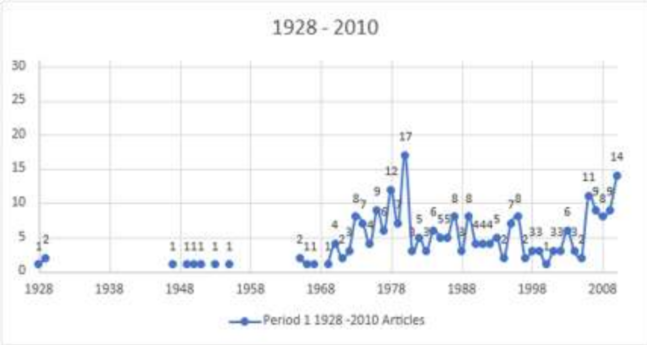

Figure 3. Annual scientific production 1928-2010

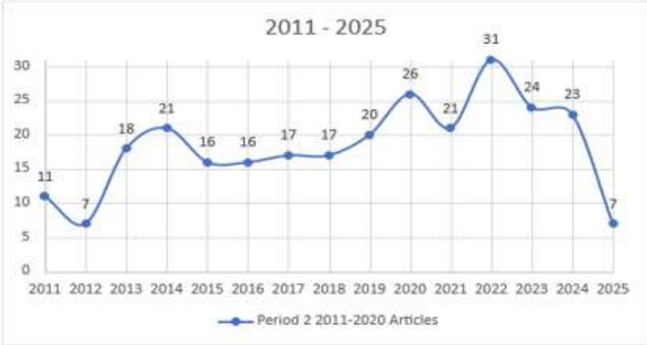

Figure 4. Annual Scientific production 2011-2025

4.2. RQ2. Which countries have the highest number of publications and which funds the most scientific research?

As shown in Fig. 5, the most productive countries are the United States, which accounts for 28% of documents (147 documents), and China, with 94 documents (17.9%). The literature under review contains a total of 525 documents from 71 countries, indicating a significant degree of geographical diversity. It is worth noting that the category entitled "OTHER" is the largest in Fig. 5, with a total production of 157 papers from 47 countries, representing 29.9% of the total scientific output. The next countries with the most relevant scientific papers are: Italy (39 papers, 7.4%), Japan (28, 5.3%), Canada (18, 3.4%), Saudi Arabia and the United Kingdom (11 papers each, 2.1%) and Brazil and Spain (with 10 papers, 1.9%). It is characteristic that countries with significant Gross Domestic Product (GDP) have a very small number of publications, e.g. Germany (8 publications, 1.5%), Australia (6 publications, 1.1%) and France (2 publications, 0.4%).

A total of 128 papers were published between 1928 and 1987, with the majority coming from the United States or Canada. In contrast, in the 21st century, the majority of published scientific research on the SCOPUS basis comes from China. During 2011 and 2025, China led in terms of publication production, with a total of 75 publications, accounting for 27.3% of the total. The United States followed by contributing 29 publications, which account for 10.5% of global production.

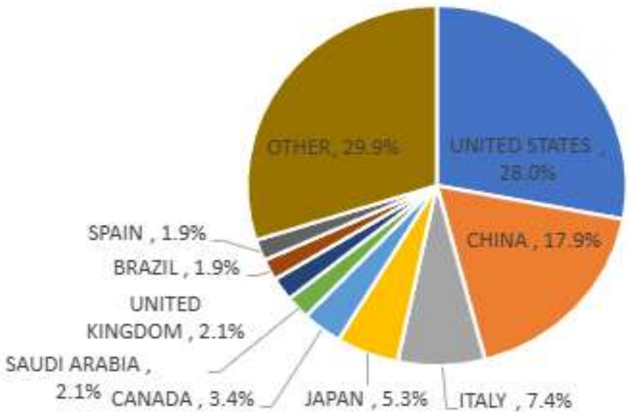

Figure 5. Distribution of scientific production by country.

A significant percentage of the total scientific output at ManagEng has been funded by institutions and organizations (18.3% or 96 papers out of 525 in total). The majority of the funded publications come from China, with 35 papers, followed by the US with 15 studies and Brazil with 9 papers. As a share of each country's own output, however, the funding rate is highest in Brazil (90%), followed by China (37.3%) and the US (10.2%). Finally, there was limited funding for international cooperation, with cooperation between the US and China dominating (4 papers).

4.3. RQ3. What is the social structure of ManagEng?

The total number of authors for the 525 papers under study is 1,227 (Fig. 2), with an average of 2.67 co-authors per paper. A significant 29.5% of papers (155 out of 525 papers) had only one author. This finding demonstrates that for the remaining articles, the average number of co-authors is significantly higher. International cooperation in scientific production for ManagEng is also limited, accounting for only 7.81% of papers.

The VOSviewer app was used to perform the co-authoring analysis. The country of origin of the institutions with which the authors collaborate was chosen to be used as the unit of analysis because the available results for the authors were limited. Fractional counting was used, with at least three documents required for each country and without a minimum number of references per country. Out of a total of 71 countries, 30 met the above-mentioned exclusion criteria. The largest set of connections that can be captured according to the VOSviewer software consists of 22 countries, which have been divided into six groups (see Fig. 6). The following section describes clusters. For each cluster, the following are listed: a) in brackets, the country(s) with the largest total connection capacity b) the countries with the largest number of documents and references.

Cluster 1, (in red), includes the largest number of countries (five): the United Kingdom (9), Saudi Arabia, Norway, Greece and Taiwan. The United Kingdom and Saudi Arabia each have 11 papers with 153 and 143 references, respectively. Cluster 2 (green) is far from the center of the map and includes four countries from Asia and Africa: Hong Kong (5), Malaysia, Nigeria and South Africa. As shown on the map, cluster 3 is located in the center of the map, in blue. It contains the United States (3) with 147 documents and 901 citations, Spain (4) with 10 documents and 133 citations, Canada with 18 documents and 166 citations and Jordan. Cluster 4, represented by the color yellow, includes three countries from different continents: China has 94 documents and 810 references and the highest total binding power (15). There are also Australia and Italy (with 39 documents and 641 references). Cluster 5, with the purple color, is placed at a significant distance from the center of the map. This cluster includes three countries: Brazil (2) which has a total of ten documents and 132 citations, Germany and Denmark.

Figure 6. Social network analysis of international co-authorship by country

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Finally, the sixth cluster, which is located in the center of the map and is represented by the color light blue, includes three countries. Japan (4) has 28 documents and 187 citations, Russian Federation (4) and Mexico.

4.4. RQ4. What is the conceptual structure of ManagEng?

A co-word analysis of the conceptual structure of scientific research in ManagEng has been conducted using the Biblioshiny application. The analysis is implemented at four levels.

RQ4.1. First, we present a Sankey chart about the most common words in Summaries and Titles and their correlations with countries.

RQ4.2. A thematic map for the entire study period (1928-2025) is presented based on the Keywords Plus occurrences.

RQ4.3. Depicts thematic progression, based on Keywords Plus, for three periods: 1928-2010, 2011-2020 and 2021-2025. The evolution of the most frequent terms of these periods is presented. Also, the thematic maps for each period are depicted, with the most frequent terms and at least one characterized document of each cluster.

RQ4.4. A factorial analysis based on author keywords is presented.

4.4.1. RQ4.1. Most frequent words in Abstracts and Titles

The initial exploration of the ManagEng branch conceptual framework involves a 3D Sankey diagram depicting countries and word occurrences in Abstracts and Titles (Fig. 7). As shown in Fig. 7, the 10 most frequent words in Abstracts are (in parentheses, the occurrences for each word): management (936), engineering (585), system (340), paper (261), study (260), data (253), model (248), systems (197), analysis (193), and results (192). Also, in document titles, the most common terms are (in parentheses, appearances for each word when they are more than a hundred): management (198), engineering (128), study, system, analysis, base, design, hospital, approach and engineers.

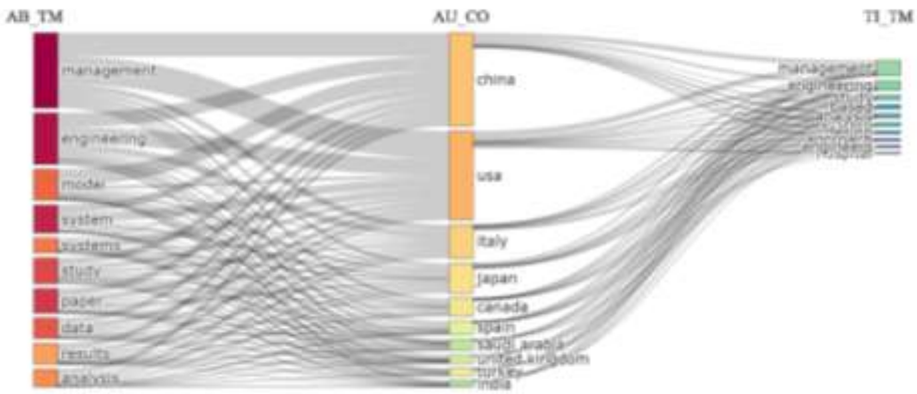

Figure 7. Sankey Diagram – Top producing countries and word co-occurrences in Abstracts and Titles.

We emphasize the presence of the word "system" in both the Abstracts and the Titles, as well as the word "systems" in the Abstracts. These findings suggest the importance of systems, and are an initial indication of the importance of a systemic approach. In addition, the terms "design" and "hospital" in the Titles as well as in Abstracts (171 and

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144 appearances respectively), demonstrate two other perspectives for the ManagEng literature. Although all words are associated with all countries, the word "hospital" (in the Titles) has limited or no connections to countries other than the U.S. and Canada.

4.4.2. RQ4.2. Thematic map (1928-2025)

The next step involves conducting thematic analysis using KeywordsPlus. We use KeywordsPlus instead of Author Keywords, because we take into account the limited frequency of Author Keywords per document (see Fig. 2) in relation to index keywords. The total number of Author Keywords is 1,170, with an average of 2.23 keywords per document. In contrast, a total of 3,459 index keywords has been identified, with an average of 6.59 keywords per document.

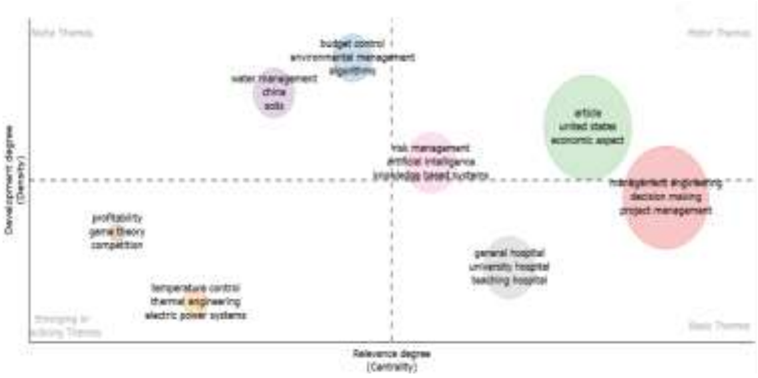

Figure 8. Thematic map of KeywordsPlus (1928-2025)

We conduct a co-word analysis, using Biblioshiny to map the conceptual structure of ManagEng's scientific field. We have set the following parameters: 250 words, 20 documents per thousand as the minimum cluster frequency, and the Walktrap algorithm. The map is divided into four quadrants that contain varying degrees of density and centrality: motor themes, niche themes, emerging or declining themes, and basic themes. Each cluster is identified on the thematic map based on its degree of density and centrality. Below are the clusters that are depicted in the Thematic Map (Fig. 8) and are mentioned a) the most frequently occurring terms in each cluster (in parentheses the occurrences for the most common term of each cluster) and b) at least one document that characterizes each cluster.

As shown in Fig. 8, there are 8 clusters in the Thematic map of scientific research for ManagEng. Cluster 1, "Management Engineering" which is considered as both a basic theme and a motor theme, has the second highest clustering frequency (850 occurrences) and includes 101 different keywords (the largest number of terms of each cluster) as well as 190 assigned documents (190). Here we find many terms that focus on specific tasks of "management engineering (133 occurrences) such as: "decision-making", "project management", "information management", "planning", "risk assessment" and "optimization". Also, there are terms that focus on educational topics such as: "students", "engineering education", "curricula" and "teaching". Notable work is [35] for a predictive model that estimates the performance of centrifugal pumps, [36] for reliable measurements of the quality of education in Italian higher education, and [37] for large language models in engineering education. Cluster 2 is a niche topic linking budget control (7 occurrences), algorithms, and environmental management. For example, the study on machine learning approaches to geoenvironmental engineering [38] is a prime example.

Cluster 3, titled "article" (61 occurrences) is the main motor theme, has the highest frequency (963) and the second highest number of terms (92) and documents (140) present in all clusters. It captures the strong connection between ManagEng and healthcare in the US, including terms such as: "United States", "economic aspect", "hospital management "human", "methodology", "organization and management", "hospital administration", "hospital", "engineering", "efficiency", "systems analysis", "education", "productivity", "human engineering", "management" and "personnel management". Two examples that illustrate this point are the work of [39], which focuses on techniques for predicting and simulating traffic behavior on the Internet, and [40], which examines interdisciplinary experiential learning in biomedical engineering education to improve healthcare systems.

Another niche topic, present in Cluster 4, focuses on 'water management' (11 appearances) and 'soils' in research produced mainly in 'China', as shown in the study by [41] on agricultural ecological efficiency in China over the past 40 years.

As emerging or declining topics we can find two groups. Cluster 5 focuses on "temperature control" (6 appearances) and "thermal engineering" as well as "electricity systems", as [42] on high-beneficiary solar cells. Cluster 6 has a more economic perspective, connecting "profitability" (5 appearances), "game theory" and "competition". Typical is the work of [43] for a centralized multi-criteria business ManagEng model.

The third motor theme of the map (Cluster 7) can be seen as the most innovative, linking "risk management" (17 incidents), "artificial intelligence", and "knowledge-based systems". This theme is characterized by [44] the work of Liu (2010) on knowledge systems of service science and [45], [46] on the mail order industry and payment methods.

Cluster 8 forms the main basic theme of the map and refers to different types of hospitals, such as "general hospitals" (15 appearances), "university hospitals", and "teaching hospitals". All documents in this cluster were published in the 1970s, including the [47] study on optimal hospital staffing.

4.4.3. RQ4.3. Thematic Evolution of Scientific Research

As shown in Fig. 9, the main terms for the period 1928-2010 are as follows: "management engineering," "engineering education," and "United States" indicating the dominance of educational research and the U.S. in scientific production up to that point. In addition, the term "management engineering" is the only one that persists in all periods, indicating that it is a separate scientific discipline. At the same time, we note that from 2011 to 2020, the term "students" emerged, taking flows from all the terms of the initial period. The prevalence of the term "students" during this period reflects an increase in educational research as well as a greater focus on the individual, as opposed to the general term "engineering education". In addition, we observe that during this period, the term "knowledge-based systems" appears, indicating a new approach to research due to technological advancements. After 2021, we can assume that there is a greater synthesis in the production of the prevailing terms. In the period 2021-2025, there are four conditions, two that are a continuation of the previous period and two new terms. The terms "students" and "management engineering" remain as a continuation of the previous period. The term "management engineering" specifically receives additional flows from both other terms of the previous period

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("students" and "knowledge-based systems"). The new terms for the period 2021-2025 are "project management" and "efficiency". The first appeared with flows from both the term "students" and the term "knowledge-based systems" while the second term comes from the term "management engineering". These transformations indicate a shift in research towards the ManagEng profession and specific tasks and responsibilities.

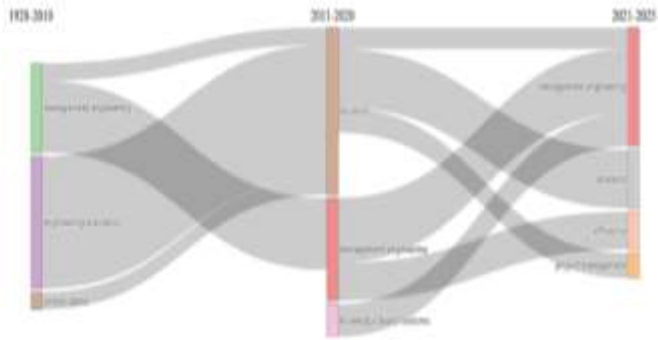

Figure 9. Thematic evolution of KeywordsPlus across 1928-2010, 2011-2020, and 2021-2025.

- **1928 - 2010**

The first period (1928 to 2010) includes four (4) clusters (Fig. 10). The main term of each cluster (in parentheses the frequency of cluster terms), terms with more than 12 occurrences, as well as the primary documents of each cluster, are described below.

The cluster with the largest number of terms and the highest overall frequency is cluster 3, in gray, named "United States". As cluster 3 in the main Thematic map, it is a motor theme at this period, includes 33 terms with terms such as: "United States" (55), "article", "hospital management”, “methodology", "human", "hospital administration", "organization and management”, “systems analysis”, “engineering”, “efficiency”, “human engineering”, “management”, “personnel management”, “productivity”, “system analysis”, “bioengineering”, “personnel staffing” and “scheduling”, “task performance", and “ Another motor theme of this period is the studies on the “economic aspects” (41) of the 'hospital', which also included topics related to different dimensions of the healthcare sector, such as: general hospital”, “university hospital”, “teaching hospital”, “public hospital”, “home for the aged”, “nursing”, “mental 'health center” and “mental hospital”. 'psychiatric hospital'. The study of [19] Gilbreth (1950) examining the relationship between management, engineering and nursing is considered groundbreaking by largely representing clusters 3 and 8 on the main thematic map.

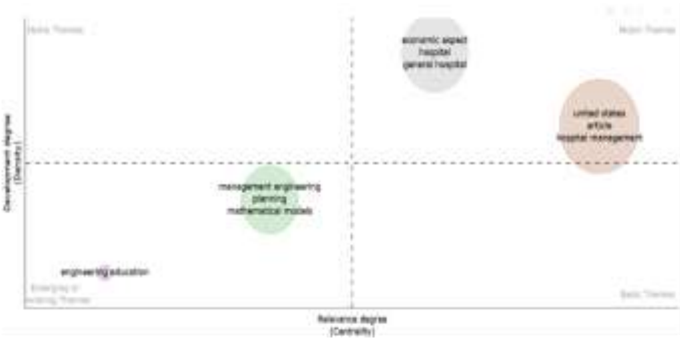

Figure 10. Thematic map for the period 1928-2010: healthcare management in U.S.

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During this period, two emerging (or declining) topics have also been identified. As we have seen in the evolution of the terms, both topics will dominate scientific research in the coming decades. The first topic is "management engineering" (39 appearances), which is linked to "planning" and "mathematical models". [48] provide an example for internal competence modeling. The second area of focus is "engineering education" (8 appearances), which includes the work of [39] on the knowledge system of service science.

- **2011 - 2020**

Figure 11. Thematic map for 2011-2020: emergence of information management and educational perspectives

In the period 2011-2020 (Fig. 11), "management engineering" (58 occurrences) prevails as a basic theme, encompassing different themes, such as "information management" and "water management" e.g. the study [49]. During this period, the educational perspective emerges as a motor theme, with the terms: “students” (11 occurrences), “engineering education" and "teaching". The study on the impact of integrated work-based learning on engineering education is an example [50].

A cluster between motor and niche themes is the cluster titled "knowledge-based systems" (9 appearances) linked to concepts such as "integrative Artificial Intelligence" and "risk management". Typical is the study of [40] as mentioned above (cluster 7 in the main thematic maps) and [51].

As emerging or declining themes during this time period, there are two groups of topics with limited frequency: One topic refers to "engineers" (5 appearances) e.g. the research of [51] on training in reservoir management engineering work. Another group of topics focuses on "profitability" (5 appearances) with a typical example being the work of [43] (group 6 in the main thematic maps as mentioned above).

2021 - 2025

The thematic map for the period 2021 to 2025 (Fig. 12) includes the largest number of cluster topics (10), compared to other periods. The following is a detailed overview of each cluster, including its terms and its primary document. Next to each term there are (in parentheses) the corresponding number where it appears. In the area of basic themes, there is only one cluster (cluster 3), which includes work related to four terms: "budget control", "machine learning", "disasters" and "environmental management". An example is [38] on machine learning approaches to geoenvironmental engineering.

Cluster 1 reflects the basic term of the survey ("management engineering" with 36 occurrences) and has the highest frequency overall (17 terms with a total frequency of 114 occurrences). Cluster 1 is considered both a basic theme

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and a motor theme. It focuses on both professional and educational aspects. Professional aspects include “decision making”, “information management”, “risk assessment”, “case studies”, “risk management”, and educational aspects include “engineering education”, “curricula”, “higher education”, and 'learning systems'.

Typical examples can be found in his work [37] on the use of large language models in engineering education and [3] on the new perspective offered by ManagEng to the extent that it integrates engineering and management knowledge.

Another motor theme that is also relevant for management engineers is cluster 4, on the topic of "project management" (8 appearances). This is the second largest cluster for this time period with a number of conditions (10) and frequency (42). It covers topics such as "construction industry”, “surveys”, “construction," "construction projects," "cost engineering," "artificial intelligence," and "decision theory." Typical are the studies by [52] on the multi-criteria portfolio selection and [53] the energy and cost optimization of building material in construction management.

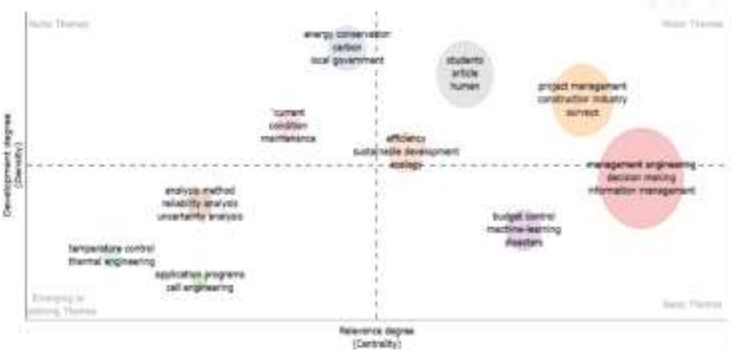

Figure 12. Thematic map for 2021-2025: rise of green economy, project management, and AI topics

An additional motor theme that emphasizes the educational aspect of the research is cluster 7, which focuses on “students” (9), “article”, “human”, “education”, “humans”, “student” and 'teaching'. [54] for example link sustainable education to young people's confidence in the future of civil society. The topic in Cluster 9 includes terms such as "efficiency" and "sustainable development" (4 appearances), "ecology" and "rivers". A relevant case study is that of [55], which focuses on agricultural ecological efficiency in areas that are rapidly urbanizing. This approach is seen as the motor theme of research, offering a new perspective.

Relevant, but more specific, is the theme of cluster 10 (a niche theme), which emphasizes 'energy saving' (4), 'carbon' and 'local government'. An illustrative example is the work of [56] on land ManagEng.

It is noted that the following clusters (6, 2 and 5) have a limited number of occurrences (only 3) for all relevant terms. Cluster 6 is another niche topic that includes terms like: "current", "condition", and "maintenance." The work of [57] is a prime example. Groups 2 and 4 are considered as emerging or declining themes. Cluster 2, with only two terms: "application programs" and "cell engineering", focuses on solar energy as [42] Çetinkaya (2022) on solar cells. Similarly, in Cluster 5, the terms "analysis method", "reliability analysis" and "uncertainty analysis" are covered and the research conducted by [58] on reliability management in social network and uncertainty environments is a prime example.

Finally, as an emerging or declining theme it is cluster 8 on "temperature control" (4 appearances) and "thermal engineering" and thermal management, as [59].

4.4.4. RQ4.4. Factorial Analysis – Author's Keywords

We performed factorial analysis using Biblioshiny based on the author's keywords. Multiple resolution was selected and set to have 3 clusters (Fig. 13).

The first cluster, in red, includes a wide variety of dimensions of ManagEng (97 terms) such as: "color rendering index", "light management engineering", "translucent organic solar cells", "value management engineering", "additive manufacturing", "agricultural management engineering", "artificial intelligence", "decision support system", "risk assessment", "risk analysis", "emergency management engineering", "industrial engineering", "systems engineering", "thermal management", "Industry 4.0", "Sustainability", "Virtual reality", "Creativity", "Optimization", "Intellectual property" and "Supply Chain Management". Works [35, 36, 37, 41] mentioned above are a few examples.

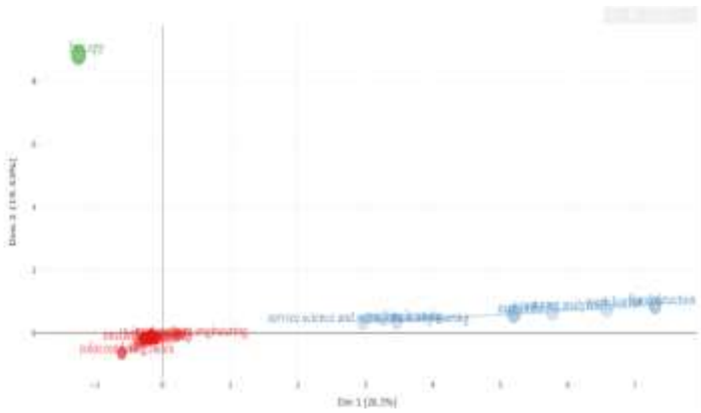

Figure 13. Factorial analysis of author keywords: three primary clusters

Cluster 2 focuses on services and includes 8 terms such as: "machine learning", "mail order", "risk management", "customer analyses," and "service science and management engineering". [44] and [45], [46]. The works mentioned above are the most characteristic.

Cluster 3 finally includes 5 terms such as "bus app", "influence index," and "performance evaluation matrix", such as his work [60].

5.0. Conclusion and Future Recommendations

A combination of bibliometric techniques is used to provide a comprehensive overview of ManagEng's social and conceptual map. A total of 525 papers were analyzed by the Scopus database, following the PRISMA methodology. Although ManagEng's literature begins in 1928, there are extensive periods during which no relevant scientific work is published.

In the US, the terms "industrial engineering" and "management engineering" are used interchangeably, especially in the healthcare sector. In addition, there seems to be some confusion between the terms ManagEng and EngManag.

The social structure of the research presented in the study helps to capture the social/geographical context within which scientific research is formed in ManagEng and to distinguish it from other scientific disciplines. We observe scientific production from 71 countries with different conceptualizations for ManagEng depending on the geographical area. The USA was the leading country in terms of scientific production until 2010. China and Italy, however, have experienced significant increases in recent decades. In contrast, countries with high GDP, such as Germany and France, have demonstrated limited scientific output in this field.

The period up to 2010 is associated with healthcare in the US, a perspective that began with Gilbreth (1950) and focuses on "hospital administration" and the "economic aspects" of hospital administration. In addition, during this period, the concepts of "design" and "mathematical models" are studied, with the aim of optimizing productivity. As part of this approach, topics such as 'profitability' and 'risk management' came to the fore in 2011-2020 and in 2021-2025, “budget control”, “efficiency”, “uncertainty analysis' and “reliability analysis”, with a focus on specific areas.

The concept of "engineering education" has also evolved steadily over time, with the 2021-2025 period marked by a focus on "learners" (a humanitarian perspective). The integration of "information management" and "decision management" is a key feature in ManagEng. In addition, research in the current period is focused on "project management", particularly in the "construction industry".

The areas that are considered to have a future in ManagEng's scientific research are the green economy and Industry 4.0 technologies. The concepts of "green economy" and "energy" issues have been developed in recent decades, with the terms "water management", "soils", "energy conservation" and "carbon" being used in the period 2011-2020 and "sustainable development", "ecology", "thermal engineering" and "temperature control" in the period 2021-2025. The majority of these studies have been conducted in China, with a particular focus on agricultural efficiency analysis.

Also, Industry 4.0 technologies have been studied in ManagEng either as "Additive Manufacturing", "artificial intelligence" or as "machine learning". It is important to note the need for a multidisciplinary approach that characterizes ManagEng, indicating a wide range of sectors, beyond Manufacturing, such as Service Management. Also, several studies emphasize a holistic, systemic approach. From a professional standpoint, management engineers frequently undertake the role of an internal improvement consultant, assuming responsibilities that necessitate the cultivation of a comprehensive and holistic perspective [4].

As with all studies, this one is subject to restrictions. After manual examination, 334 surveys were deemed irrelevant to the subject and excluded from further study. However, the application of stricter exclusion criteria would result in an even greater reduction in the number of studies to be studied. Instead, incorporating additional databases, such as Web of Science, could increase the number of publications examined. Furthermore, the inclusion of grey literature, such as books, alongside non-English publications could provide a more balanced geographical representation of the field; however, this approach would introduce linguistic complexities in the standardized evaluation of terminology.

An important element to complete this work would be the study of the intellectual structure of ManagEng's scientific field, which would contribute to the emergence of the most important publications that shape this field.

In this paper, a thorough bibliometric analysis of scientific research in Management Engineering (ManagEng) is presented, mapping the conceptual and social structures of the scientific field. As an industry, ManagEng combines engineering and management, offering an engineering perspective on management. Due to the close relationship between the terms "Industrial Engineering" and "Management Engineering" (ManagEng), as well as confusion with "Engineering Management" (EngManag), it is necessary to distinguish between these terms, and this work contributes to this direction.

We observe that there are different perceptions between countries where different research topics and areas in which a management engineer could develop his career emerge. It is important for ManagEng graduates and engineers aspiring to pursue a career in this field, particularly in a global context, to be aware of these accolades. The fact that the profession of management engineer is not classified in the international classifications of professions further underlines the need for this work.

The rapid development of the service sector, energy and environmental issues and the emergence of Industry 4.0 technologies create new perspectives and opportunities for management engineers as well as in research at ManagEng.

Although the findings of this research offer a comprehensive overview of the scientific landscape in ManagEng by combining systematic literature review and bibliometric analysis, this study—like any research design—is subject to certain limitations. These limitations, however, provide valuable pathways for future research endeavours. Specifically, future studies could focus on the following:

1. Expansion of Database Sources: Future research should include additional databases beyond Scopus, such as Web of Science and Google Scholar. This would increase the volume of results under study and lead to a more precise mapping of scientific activity in the field.

2. Analysis of Intellectual Structure: A detailed bibliometric analysis focused on the intellectual structure of the field is recommended. This would help identify the most influential papers, seminal books, and core theoretical foundations that have shaped ManagEng.

3. Qualitative Academic Research: Implementing qualitative research methods, such as personal interviews with academic staff in ManagEng departments, could provide deeper insights into the current state and future direction of the scientific field.

4. Quantitative Attitudinal Surveys: Quantitative research using multiple-choice questionnaires could be conducted among faculty members to capture a broader consensus on the challenges and evolution of the discipline.

5. Involvement of Professional Stakeholders: Future research designs should involve practicing Management Engineers and representatives from professional engineering bodies. Their practical perspective would be invaluable in bridging the gap between academic research and industry requirements.

6. Integration of Emerging Technologies: Further investigation into how emerging trends like the Green Economy and Industry 5.0 are being integrated into the ManagEng curriculum and professional practice would provide a forward-looking perspective on the profession's evolution.

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Consent for publication

All authors have read and approved the final version of the manuscript and have given their explicit consent for its submission and publication in this journal.

Availability of data and material

The raw bibliometric data (bibliographic records in .csv format) are available from the corresponding author upon reasonable request. The analysis was performed using the software Biblioshiny (Bibliometrix R-package v.4.3.1) and VOSviewer (v.1.6.20), both of which are freely accessible at https://www.bibliometrix.org and https://www.vosviewer.com, respectively.

Authors' Contributions

All authors contributed equally to the conceptualization, design, data collection, analysis, and writing of this manuscript. All authors have read and approved the final version.

Informed Consent

Not Applicable.

Institutional Review Board Statement

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Declaration of Artificial Intelligence

The authors declare that no Artificial Intelligence (AI) tools were used in the conception, design, data collection, analysis, or writing of this manuscript. All intellectual contributions are solely those of the authors.

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