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Business Intelligence Strategies, Best Practices, and Latest Trends: Analysis of Scientometric Data from 2003 to 2023 Using Machine Learning

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Abstract: The widespread use of business intelligence products, services, and applications piques the interest of researchers in this field. The interest of researchers in business intelligence increases the number of studies significantly. Identifying domain-specific research patterns and trends is thus a significant research problem. This study employs a topic modeling approach to analyze domain-specific articles in order to identify research patterns and trends in the business intelligence field over the last 20 years. As a result, 36 topics were discovered that reflect the field's research landscape and trends. Topics such as "Organizational Capability", "AI Applications", "Data Mining", "Big Data Analytics", and "Visualization" have recently gained popularity. A systematic taxonomic map was also created, revealing the research background and BI perspectives based on the topics. This study may be useful to researchers and practitioners interested in learning about the most recent developments in the field. Topics generated by topic modeling can also be used to identify gaps in current research or potential future research directions.

Keywords: business intelligence; topic modeling; text mining; trend analysis; machine learning

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1. Introduction

Business intelligence (BI) is a discipline that combines business analytics, data mining, data visualization, data reporting, data tools, infrastructure, and best practices to empower organizations to make more data-driven decisions. Business operations and processes can generate massive amounts of structured data, such as emails, memos, call center notes, news, user groups, chats, reports, corporate documentation, web pages, presentations, image files, video files, and marketing materials [1,2]. In practice, to have modern BI, organizations must have a comprehensive data infrastructure and be able to use this data effectively to drive development and competition, eliminate inefficiencies, and quickly adapt to market or supply changes [3,4]. Businesses and organizations have questions and goals. To answer these questions and define the roadmap towards these goals, they collect and analyze the necessary data using BI functions and determine what actions to take to achieve these goals [3,5–7]. One of the most important achievements of BI is to support the sustainable development of enterprises. The unequal distribution of resources creates a serious competitive inequality between large and small-scale enterprises in the context of sustainable development and makes it difficult to implement BI effectively in all enterprises [8].

Common functions of BI applications include data mining, data visualization and reporting, business performance metrics and benchmarking, online analytics processing,

descriptive analytics, dashboard development, and predictive analytics [1,9]. BI uses these processes to transform raw data into meaningful and valuable information to ensure more effective strategic, tactical, and operational insights and decision-making. BI can provide essential insights to support various business decisions, from operational to strategic [3,9].

Although BI has a very modern definition similar to the one above, it should be emphasized that BI, as a fashionable word, has a suppressed past. Traditional BI emerged in the 1960s as a system of information sharing between organizations. Luhn touched upon the need for BI systems, emphasizing the importance of automating information categorization, retrieval, and dissemination within the organization [10]. In 1989, Howard Dresner proposed the concept of BI as an umbrella term. He defined it as "concepts and methods for improving business decisions using information and information technology-based support systems" [11]. This definition has become increasingly common since the late 1990s. The rapid transformation in information and communication technologies in recent years has enabled businesses to adopt BI more [12].

Thus, services, tools, and BI applications are more frequently being used every day. With the spread of BI, the interest of researchers in this field has increased day by day. This increasing research interest in BI has also led to a significant increase in academic research in this field [12]. The number of publications, only 45 in 2003, has increased exponentially in recent years and will reach over 300 in 2022. Scientific literature is a rich source of information, especially for dynamic fields such as BI, where ever-changing research and applications are indexed. Analysis of the scientific literature can provide important insights to better understand the research background, implementations, scope, development, and future trends of the BI field. However, since there are many studies in the BI field, it is difficult to analyze all these studies and to create an epistemological research map of the field with traditional systematic review methods [5,12–14]. This situation is because there are thousands of field-specific studies in the literature. In this context, using automated text mining procedures based on machine learning can provide an effective methodology for analyzing the scientific literature in this field.

Several attempts to analyze BI studies using this approach have been made in the literature [12,15,16]. Despite these commendable efforts, machine learning-based topic modeling approaches are still in limited use to reveal a comprehensive map of the BI research landscape. This study aims to fill this gap in the literature through a semantic content analysis based on a topic modeling approach applied to 3749 peer-reviewed journal articles published in the last 20 years in the BI field between 2003 and 2022. Specifically, the methodology of this study is designed to seek answers to the following research questions (RQ) based on the previous 20 years of the BI field:

RQ1. What are the bibliometric features of BI research?
RQ2. What are the emerging topics in BI research?
RQ3. How have BI topics changed in the last 20 years?
RQ4. What is the taxonomy of BI topics?

2. Research Background and Related Work

The concept of "BI systems" was introduced by H. P Luhn in 1958 [10]. Luhn touched upon the need for these systems and the importance of automating the organization's sorting, retrieval, and dissemination of information. He also argued that systems could be developed that accepts information, promptly transmit data and information to users, and respond to related requests. However, he reported that the institution, with its communication infrastructure and input-output units, is a living system that focuses on solving all information-related problems [10]. Václav et al. stated that the primary purpose of BI systems is to obtain information that will help decision-making by filtering it from valuable data sets [17].

The perspective on BI systems in today's studies is also fed from previous studies. Chen & Lin consider BI systems as providing the transformation from data to information or knowledge to provide solutions for corporate applications [18]. At this point, these authors

reported that these systems could be advanced decision support systems. Combita Niño et al. stated that the primary purpose of BI implementations is to ensure the effectiveness of information in the strategies and targets to be followed in order to provide a competitive advantage [19]. Muntean et al. defined BI systems as tools used for processing raw data and information to make decisions about the future. They reported that BI is to turn to the future through the question, "What happened in the past?" [20].

Various studies have tried to identify BI research's bibliometric features and trends [12]. These studies are generally based on bibliometric analysis. For example, Purnomo et al. analyzed 244 studies published between 1975 and 2020 in the Scopus database and grouped BI research into six themes. They named their theme titles "Business analytics", "Element of marketing", "Competitive intelligence", "Intelligence system", "Industry", and "Business" [21]. In another study, Dorti & Akdemir discovered research trends by analyzing the keywords of articles on BI from the Web of Science database [22]. Similarly, Vanani & Jalali aimed to examine research trends by focusing on titles, abstracts, and keywords in BI research. For this purpose, they used the scientometric method "burst detection" algorithm to represent emerging and disappearing trends in the BI field between 1980 and 2014 [23]. In another study, Zou et al. [24] conducted a bibliometric analysis to evaluate the annual amount of publications, the trend in the research, and citation variables of BI research between 1997 and 2017. The results revealed that the "Expert Systems with Applications" journal stands out in BI research, and the United States of America leads in the number of publications. In addition, "cloud computing" is the main keyword in hot research topics. Today, BI software is used in almost all sectors, including finance, telecommunications, retail, energy, public, and health. Therefore, studies examining the use of BI in different sectors are also striking. For example, Brum et al. conducted a bibliometric analysis of studies investigating the current use of BI technologies in the agricultural sector [25]. There are also studies examining BI with different trends. For example, Liang & Liu used bibliometric analysis to explore research trends in "Big Data" and "BI" between 1990 and 2017. They also applied common word analysis on keywords to show the distribution of topics over time. The most used keywords were determined as "data mining", "social media", and "information system". However, the keywords "cloud computing", "data warehouse", and "knowledge management" were used more after 2016 [5].

Although bibliometric analysis studies provide the general lines of research, these studies are insufficient for machine learning-based semantic content analysis of extensive textual collections [26,27]. One way to solve this problem is to use topic modeling, a text-mining technique based on machine learning. Topic modeling analysis has been used effectively and widely in recent years to define the scope of a field [28]. It is noteworthy that there are few topic modeling studies on BI. For example, Gallinucci et al. [29] applied the topic modeling method to social BI research. However, this study was limited as it only included "social BI" research. In another study, Moro et al. [15] used the LDA method, a topic modeling approach, in 2019 research published between 2002 and 2013 to identify trends in BI applications in the banking sector. Although this study uses topic modeling, it does not reflect the holistic view of the BI field as it is directed toward BI implementations in the banking sector. Only one study focuses directly on BI research and applies the topic modeling method.

Previous BI research was generally examined through bibliometric methods. Although keyword analysis is often applied to reveal trends in BI research, this research offers a limited view of the field or analyzes different sub-contexts of BI. As far as we know, no study applied topic modeling to BI research except for [16]. Therefore, this study aims to analyze BI research by topic modeling to fill this gap in the literature and present a broader picture of research and applications in the field. Therefore, this study will contribute valuably to the BI literature.

3. Method

The study method is organized under three sub-headings: data collection, data preprocessing, and implementing topic modeling on the empirical corpus.

3.1. Data Collection

Creating an empirical corpus for a textual content analysis based on topic modeling is one of the most critical steps [26,30]. The operations applied during corpus creation directly affect the analysis performance [31]. First, to create an experimental corpus about BI, a query was made in the Scopus database in the form of "BI" in the title, summary, and keyword fields. Scopus is the most comprehensive bibliometric database covering more than 7000 publishers and 240 disciplines, including Elsevier, Emerald, IEEE, Sage, Springer, Taylor & Francis, and Wiley Blackwell [26,32]. Only research articles and review articles in English were included in the corpus of the studies filtered by this query. Other studies, such as editorial materials and book reviews, were excluded from the dataset. The filtered articles were extracted from the Scopus database, and an experimental data set was created that includes data such as bibliometric indicators, author keywords, abstract, and title of each article [26,32]. This empirical BI corpus includes 3749 peer-reviewed journal articles (3487 research papers and 262 reviews) published in the last 20 years between 2003 and 2022.

3.2. Data Preprocessing

Data preprocessing is a fundamental task that directly affects the success of the analysis, especially for text mining and natural language processing studies [33]. The data mining process does not proceed in a fixed order, and some processes go back and forth between each stage [13]. In the first step of data preprocessing, each word was converted to lowercase, and tags, web links, punctuation, publisher information, symbols, and numeric information in the dataset was deleted. In the second stage, the word tokenization was applied to decompose each article text into individual terms. In the third stage, all English stop words (how what, and, is, or, the, a, an, for, etc.) that made no sense on their own were deleted [34]. In the fourth stage, the remaining words were reduced from their derived form to their plain form by applying the Lemmatization process [26]. Finally, each article in the dataset was converted into a word vector using the "word bag" approach to provide a numerical representation of the words in the corpus [35]. Accordingly, these vectors were combined to form a document-term matrix representing the entire corpus and providing the necessary matrix form for topic modeling analysis [33,36,37].

3.3. Fitting and Implementation of Topic Modeling

The topic modeling method is used to reduce large volumes of data to a small number of topics and to discover hidden topics [38]. Topic modeling is a text mining tool that has been used frequently recently [13,27,39,40]. Its purpose is to detect confidential topics covered in a collection of documents automatically. The document production process is reversed, and the document-topic and topic-word distributions are revealed with the help of observable documents and the words that make them up. There are many subject modeling algorithms in the literature. However, Latent Dirichlet Allocation (LDA), which forms the basis of topic modeling algorithms and is widely used, stands out among these algorithms [31]. Therefore, LDA is a more preferred topic modeling approach in research [13,36]. Sing an unsupervised machine learning method, LDA needs no predetermined label or training set [31]. The LDA algorithm can be applied to discover semantic patterns in an extensive collection of documents [31,41]. In this study, the LDA algorithm was adopted for topic modeling analysis.

We used the tmtoolkit package for text preprocessing and topic modeling to adapt and apply the LDA-based topic modeling procedure to the preprocessed BI corpus [34]. In order to fit the LDA model to the empirical corpus, firstly, the values of the prior parameters that allow the optimization of the model were determined [13]. Considering

the prior parameter values recommended for topic modeling of short texts in previous studies, the α parameter that determines the topic distribution in the documents was chosen as $\alpha = 0.1$, and the β parameter that determines the word distribution in the topics was $\beta = 0.01$ [13,36]. Next, the LDA model was adapted for the number of K topics ranging from 10 to 60 to determine the optimal number of topics (K) that best depicted the BI research landscape. A consistency measure (CV) was calculated for each trial run with each K value using the semantic consistency approach during this process [42]. Four field experts evaluated each K topic number, distribution, and semantic consistency of discovered topics. As a result of this evaluation, the topics that define the BI research field at the most optimal level were obtained with the model adapted to the number of topics K = 36. After examining the consistency of the topics, two field experts determined and assigned each topic's label, considering the topics' descriptive keywords. In addition, the percentage distribution per topic document, the percentages of descriptive words of each topic, and the percentages of the topics in the entire corpus were calculated [43]. At the end of this process, 20 representative keywords with the highest frequency were determined for each of the 36 topics. These 36 topics discovered as a result of this analysis were used in all subsequent analyses.

4. Findings

In order to answer the research questions stated in the introduction, the study's findings were evaluated under five main sections. In the first stage, the bibliometric features of BI research were analyzed. Secondly, research topics were determined by applying topic modeling analysis in the BI field. Third, the change in the topics of BI research over the past 20 years has been examined. Finally, a taxonomy map was created by considering the background of the emerging issues in the BI field.

4.1. Bibliometric Analysis (RQ1)

A descriptive analysis was applied to answer the first research question (RQ1). Thus, the number of articles, topic areas, publication sources, countries, and keywords in the BI research corpus were determined. Figure 1 shows the total number of articles (N) and their percentages (%) by year.

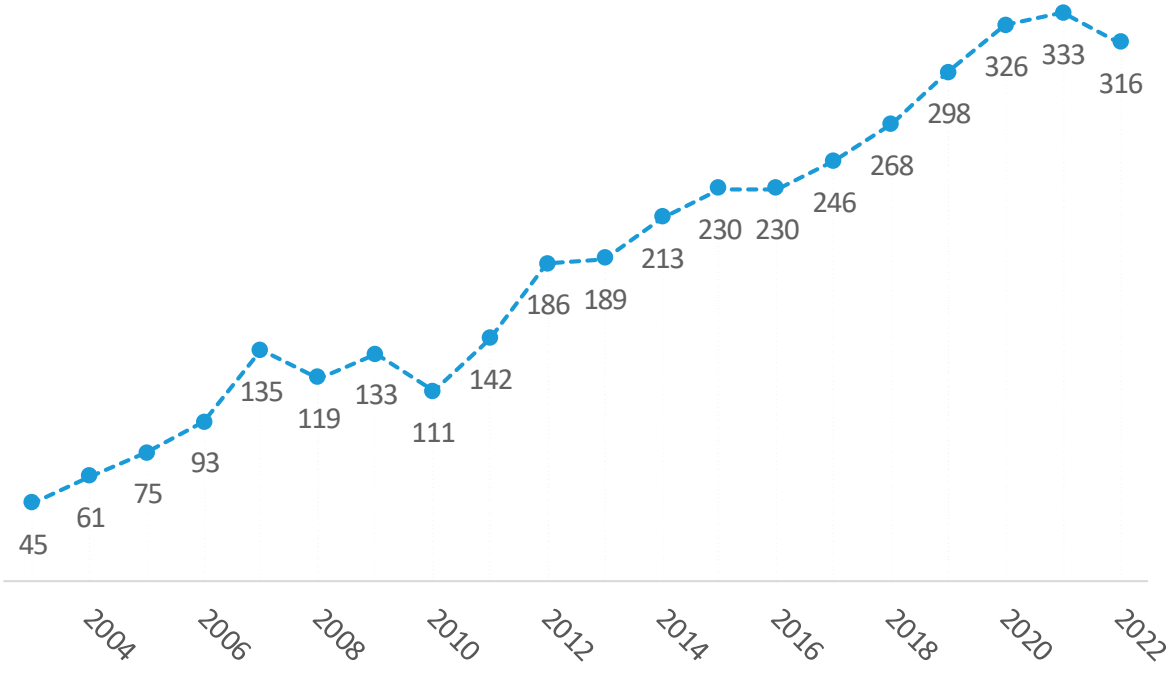


Figure 1. Number of articles by year.

As shown in Figure 1, the number of articles increased from approximately 1% in 2003 (45 articles) to approximately 8% in 2022 (316 articles). In other words, the number of articles has increased significantly over the past two decades. The number and percentage of BI articles by subject area are shown in Table 1.

Table 1. Subject areas of the BI articles.

Subject Area	N	%
Computer Science	1953	52.09
Business, Management, and Accounting	1152	30.73
Engineering	978	26.09
Decision Sciences	688	18.35
Social Sciences	639	17.04
Mathematics	348	9.28
Medicine	214	5.71
Economics, Econometrics, and Finance	200	5.33
Materials Science	131	3.49
Environmental Science	128	3.41
Energy	112	2.99
Arts and Humanities	111	2.96
Psychology	102	2.72
Chemical Engineering	60	1.60
Physics and Astronomy	58	1.55
Multidisciplinary	50	1.33
Biochemistry, Genetics, and Molecular Biology	49	1.31
Agricultural and Biological Sciences	47	1.25
Earth and Planetary Sciences	46	1.23
Chemistry	35	0.93
Health Professions	29	0.77
Pharmacology, Toxicology, and Pharmaceutics	27	0.72
Nursing	19	0.51
Neuroscience	9	0.24
Immunology and Microbiology	8	0.21
Veterinary	6	0.16
Dentistry	2	0.05

Table 1 reveals the interdisciplinary nature of BI research. The majority of contributions to BI research come from "Computer Science" (52.09%), "Business, Management, And Accounting" (30.73%), and "Engineering" (26.09%). The top 15 publication resources for BI research are displayed in Table 2.

Table 2. Publication sources.

Source Title	N	%
Journal of Intelligence Studies in Business	52	1.39
Expert Systems with Applications	51	1.36
Decision Support Systems	42	1.12
Sustainability Switzerland	41	1.09
International Journal of Information Management	36	0.96
International Journal of Business Intelligence and Data Mining	33	0.88
Journal of Theoretical and Applied Information Technology	33	0.88
IEEE Access	30	0.80
Information Systems Management	29	0.77
Journal of Computer Information Systems	28	0.75
Journal of Decision Systems	27	0.72
Studies in Computational Intelligence	25	0.67
DB2 Magazine	23	0.61
Journal of Advanced Research in Dynamical and Control Systems	22	0.59
Healthcare Financial Management Journal of The Healthcare Financial Management Association	21	0.56

According to Table 2, many sources have published BI research. This may be due to the multidisciplinary nature of BI. The top three journals that publish these studies the most are the *Journal of Intelligence Studies in Business* (1.39%), *Expert Systems with Applications* (1.36%), and *Decision Support Systems* (1.09%). Table 3 shows the top ten countries that contributed the most to BI research.

Table 3. Top contributing countries.

Country	N	%
United States	779	20.78
India	328	8.75
China	322	8.59
United Kingdom	222	5.92
Australia	168	4.48
Spain	141	3.76
Germany	140	3.73
Canada	130	3.47
Italy	120	3.20
Malaysia	119	3.17
Taiwan	114	3.04
Iran	90	2.40
France	82	2.19
South Korea	74	1.97
Portugal	72	1.92
Sweden	71	1.89
Saudi Arabia	69	1.84
Indonesia	66	1.76
Hong Kong	63	1.68
Poland	56	1.49

According to Table 3, the USA (20.78%), India (8.75%), and China (8.59%) contribute to BI research. Finally, Table 4 lists the most preferred keywords in BI research.

Table 4. The most used keywords.

Keyword	N	%
Business Intelligence	1343	35.82
Competitive Intelligence	564	15.04
Data Mining	432	11.52
Decision Making	406	10.83
Information Analysis	383	10.22
Big Data	304	8.11
Artificial Intelligence	283	7.55
Decision Support Systems	231	6.16
Data Warehouses	210	5.60
Information Management	192	5.12
Knowledge Management	146	3.89
Business Intelligence Systems	130	3.47
Data Warehouse	123	3.28
Information Systems	122	3.25
Information Technology	119	3.17
Machine Learning	117	3.12
Sales	117	3.12
Commerce	116	3.09
Competition	116	3.09
Data Analytics	114	3.04
Business Analytics	110	2.93
Intelligence	98	2.61
Semantics	89	2.37
Forecasting	86	2.29
Data Handling	85	2.27
Enterprise Resource Planning	85	2.27
Marketing	79	2.11
Data Visualization	78	2.08
Social Media	76	2.03
Social Networking	76	2.03

According to Table 4, the most used keywords are "Business Intelligence" (35.82%), "Competitive Intelligence" (15.04%), "Data Mining" (11.52%), "Decision Making" (10.83%), and "Information Analysis" (10.22%).

4.2. Topic Modeling Analysis (RQ2)

The LDA topic modeling algorithm was applied to the experimental corpus to explore emerging topics in BI research (RQ2). The 36 main topics identified by LDA are given in Table 5 in decreasing order according to their percentages. In addition, Appendix A, Table A1, gives descriptive keywords that make up the topics.

Table 5. The 36 topics discovered by LDA.

Topic Name	(%)
SDLC (System Development Life Cycle)	4.73
Big Data Analytics	4.62
Data Warehousing	4.24
Success Factors	3.88
MIS (Management Information Systems)	3.77
Competitive Intelligence	3.72
CRM (Customer Relationship Management)	3.55
AI Applications	3.34
BPM (Business Process Management)	3.31
HIS (Health Information Systems)	3.25
Knowledge Management	3.25
Organizational Capability	3.14
Data Mining	3.14
Prediction	3.14
Intelligent Systems	3.12
Industry 4.0	2.98
Sentiment Analysis	2.76
Social Media	2.65
TAM (Technology Acceptance Model)	2.57
Query Optimization	2.54
DSS (Decision Support Systems)	2.52
Supply Chain	2.49
Higher Education	2.43
Smart Grid	2.24
Algorithms	2.21
Emotional Intelligence	2.19
Visualization	2.16
Database	2.10
Semantic Web	2.08
Cost of Crime Index	2.00
Event Processing	1.89
HRM (Human Resource Management)	1.75
Government Services	1.69
Risk Analysis	1.69
Information Security	1.53
Graph Streams	1.31

As seen in Table 5, the five most studied topics are "SDLC", "Big Data Analytics", "Data Warehousing", "Success Factors", and "MIS", respectively. The five least studied topics are "HRM", "Government Services", "Risk Analysis", "Information Security", and "Graph Streams", respectively. In addition, Table 6 lists the topics according to the topic citation rates (TCR). Table 6 shows that the most cited topics are "Big Data Analytics", "TAM", "Intelligent Systems", "DSS", and "Success Factors", respectively. The least cited topics are "Risk Analysis", "Government Services", "Database", "Graph Streams", and "Cost of Crime Index", respectively.

Table 6. Citation rates of the topics.

Topic Name	TCR (%)
Big Data Analytics	12.87
TAM	4.74
Intelligent Systems	4.72
DSS	4.28
Success Factors	4.13
BPM	3.97
AI Applications	3.95
Event Processing	3.94
Data Warehousing	3.56
Sentiment Analysis	3.56
Organizational Capability	3.35
CRM	3.06
MIS	2.99
Competitive Intelligence	2.91
Social Media	2.81
SDLC	2.77
Supply Chain	2.59
Knowledge Management	2.46
Industry 4.0	2.46
HIS	2.36
Data Mining	2.28
Emotional Intelligence	2.21
Prediction	2.19
Semantic Web	1.80
Algorithms	1.73
Smart Grid	1.68
Query Optimization	1.56
HRM	1.42
Higher Education	1.36
Visualization	1.13
Information Security	1.02
Risk Analysis	1.01
Government Services	1.01
Database	0.80
Graph Streams	0.75
Cost of Crime Index	0.59

4.3. Temporal Topic Trends (RQ3)

In order to better understand the changes in the trends and evolutions of 36 topics over time, the trend values of each topic were calculated by taking into account the annual changes in the distribution of the topics. The percentages of topics by year, trend values, and trend directions are shown in Appendix A, Table A2, where topics are listed in descending order of overall trend. Appendix A, Table A2 has a colorized heatmap table format. Each line shows the annual percentage changes for a topic and provides many inferences about how that topic has evolved. Green indicates percentages above the average percentage of the topic in a row, and red indicates percentages below that. As the annual values approach the average value, their colors become whiter (See Appendix A, Table A2). Moreover, Figure 2 is a visualization of the top ten topics with the most increasing and decreasing acceleration.

As seen in Figure 2, the trends of "Organizational Capability", "AI Applications", "Data Mining", "Big Data Analytics", and "Visualization" are increasing. On the other hand, the topics of "Knowledge Management", "Semantic Web", "SDLC", "Intelligent Systems", and "Database" have a decreasing trend.

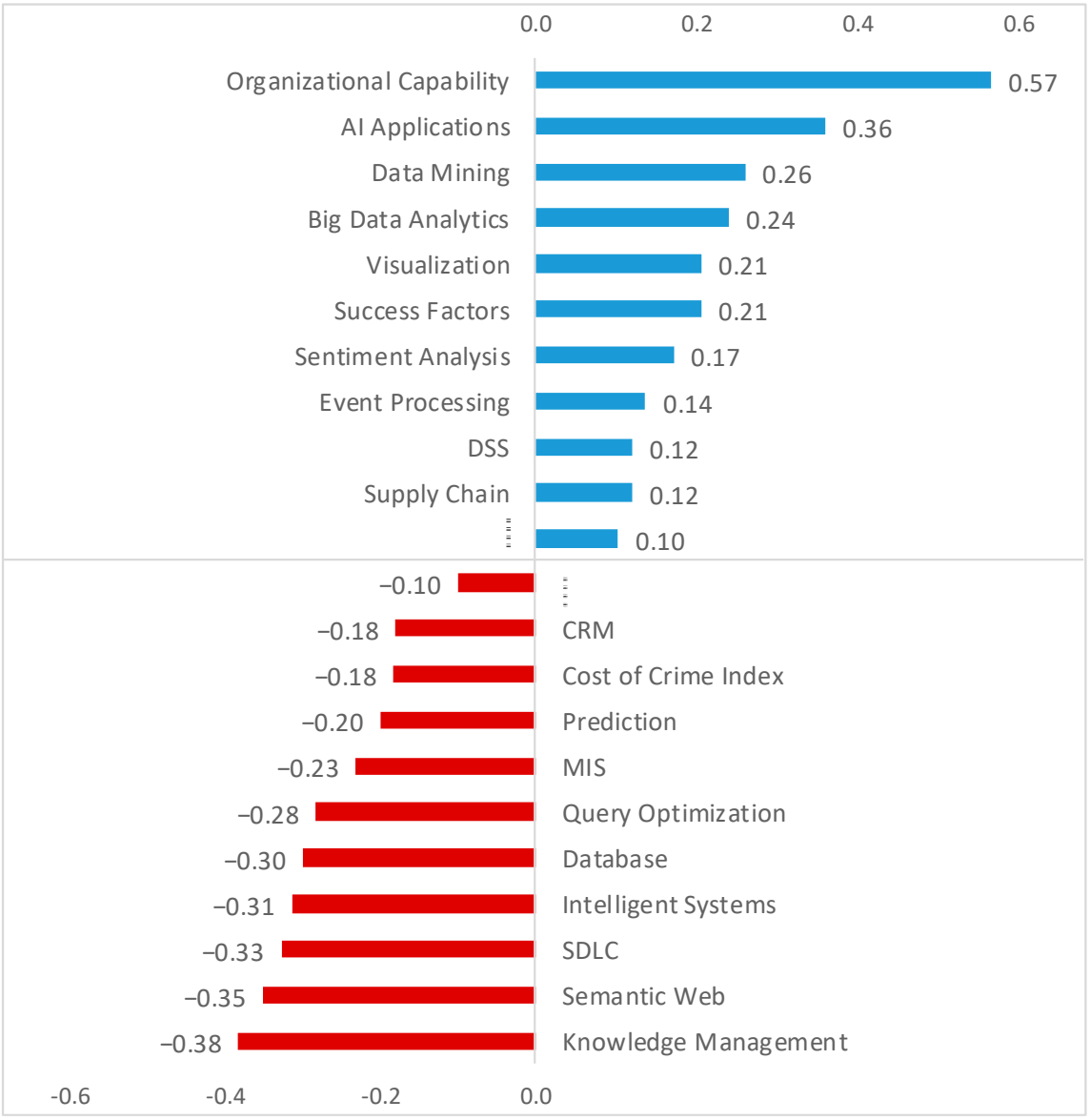


Figure 2. Temporal topic trends.

4.4. Taxonomy Developed for BI (RQ4)

Taking into account the context and scope of the 36 main topics identified in the analysis, a systematic taxonomic map was developed that classifies the research background and perspectives of BI [44]. This taxonomy presented in Figure 3 shows the BI field as two classes: business and information technologies (IT). The business class was also divided into two subclasses, domain and managerial. The IT class was divided into two subclasses, implementation, and data. The taxonomy in Figure 3 was created by distributing the 36 main topics obtained in the study to these subclasses based on expert opinions.

According to Figure 3, the research topics are mostly related to IT (19 topics: 53.39%). Data is the most studied subclass in IT subclasses (10 topics: 27.91%). The topics in the business field (17 topics: 46.61%) showed a higher distribution compared to the IT class. The most studied subclass in business subclasses is managerial (9 topics: 26.87%).

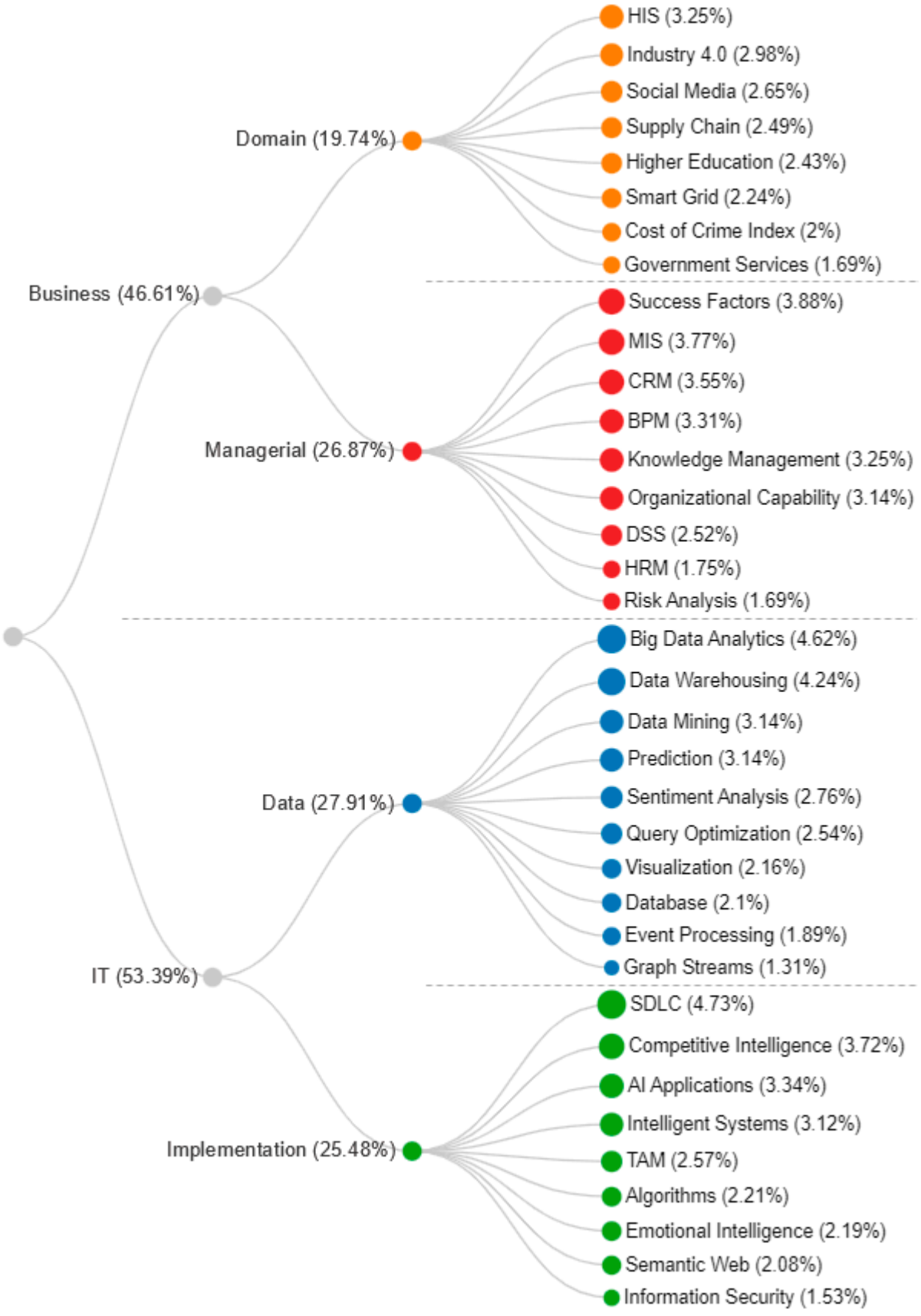


Figure 3. Systematic taxonomy of the BI topics.

5. Discussion

This study analyzed all significant research published in the BI field from 2003 to 2022 to understand better the bibliometric characteristics, main topics, trends, and future directions of the field. This study presented valuable findings to researchers and decision-makers in the BI field. The following headings summarize and discuss these findings.

5.1. Bibliometric Features of BI

Analysis of bibliometric data in BI publications can provide insights into the growing impact of publications on academia. Specifically, the number of research published on BI from 2003 to 2022 has increased daily. In addition, publications during this time period were published in 27 research areas. Among these research areas, the most striking was the field of "Computer Science", with a rate of approximately 53%. This area was followed by "Business, Management and Accounting", "Engineering" and "Decision Sciences", respectively. BI is a synergy between computer science and decision science. BI provides computer science-based decision-making for business management purposes [21]. In addition, artificial intelligence is created with neural networks and deep learning methods in computers today, and data is analyzed more "intelligently". Therefore, the prominence of "Computer Science", "Business, Management and Accounting", "Engineering", and "Decision Sciences" in BI research confirms our findings.

Among the BI publication resources, prominent journals are "The Journal of Intelligence Studies in Business", "Expert Systems with Applications", "Decision Support Systems", and "Sustainability". It is recommended that researchers who want to follow the field of BI and publish in the field should follow these journals. Moreover, according to country/region analysis, the three most productive countries were the USA, India, and China.

Finally, the most used keywords in BI research were analyzed. Accordingly, the keywords "Business Intelligence", "Competitive Intelligence", "Data Mining", and "Decision Making" are used more. In scientific research, words are often derived from "author keywords". Therefore, it is not enough to interpret the field by focusing only on these keywords. There are some disadvantages to using keywords for analysis. Donthu et al. [45] stated that keywords could be used in many contexts, and thus re-reading publications may become necessary to understand the relationships between keywords. They also stated that the keywords used could be very general, and it could be challenging to classify them in a thematic cluster. As a result, the increase in BI publications shows that it will find more place in different disciplines, and its use in different disciplines will continue to increase.

5.2. Prominent Topics of BI

The findings obtained from the topic analysis in this study provided inferences about important topics related to the field of BI, and the most studied and cited topics were especially emphasized. First, the most studied topics are "SDLC", "Big Data Analytics", "Data Warehousing", "Success Factors" and "MIS", respectively. The most cited topics were "Big Data Analytics", "TAM", "Intelligent Systems", "DSS", and "Success Factors", respectively. "SDLC" is in first place among the most studied topics and in 16th place among the most cited topics. This may mean that the relevant topics are not studied as much as before and have lost their popularity. As a classical concept, the System Life Cycle (SLC) concept uses the systems approach to analyze and develop relative applications. It provides a methodical approach and logical framework for a system's development, operation, and sustainability. As an alternative, System Development Life Cycle (SDLC) or Software Development Life Cycle (SDLC) is used on occasion [46]. "SDLC" was frequently preferred during the development of BI software. However, with the effect of cloud-based BI software, LEAN, and Agile-like methods have been preferred recently instead of classical "SDLC" [47–50].

The second most studied topic is "Big Data Analytics". This topic ranks first among the most cited topics. Therefore, it has been the most striking topic among the 36 main

topics in the BI field. Big data analytics is the process of applying advanced analytical techniques to large data sets. "Big Data Analytics" is a trending topic in the BI field by bringing together the concepts of big data and analytics [51]. Today, the data produced by sensors in mobile devices, web pages, personal blogs, social media applications, and fixed or mobile devices has reached an incredible size [52]. It is not easy to manage, store, process, analyze for scientific or commercial use and interpret the results of this data, which is thousands of exabytes in size and increasing exponentially every day. Therefore, "Big Data Analytics" is used in data-related transactions in many fields, such as customer relations [53], marketing [9], human resources [54], supply chain [55], tourism [56], and health [57].

The third most studied topic was "Data Warehousing". This topic was ranked 9th among the most cited topics. The vast majority of BI applications are included as a part of data warehouse projects. The term entered our lives with the data warehouse projects. Since BI is frequently used in data warehouse applications, the word BIDW, which consists of the initials of the concepts of data warehousing and BI, has been included in the literature [58]. We can see BI projects as a result of data warehouse applications in some cases and as a reason for data warehouse implementation in others [59].

The fourth most studied topic was "Success Factors". This topic draws attention in fifth place in the most cited studies. BI applications enable the prediction of risks by analyzing data and, as a result, increase the success of business management. Many information technology project ideas are rejected and remain as concepts or are blocked at the management level. The chances of success of implemented projects are very risky, or some are used below capacity. According to the Gartner 2019 report [60], senior management still prefers BI applications highly, and investments in this field are constantly increasing. Provisioning BI applications is much easier than implementing them. The main problem lies in the successful implementation of such systems. Therefore, it is unsurprising that research on "Success Factors" is so prominent. These studies generally examined the critical success factors required for implementing BI software in businesses [61].

The fifth most studied topic is "MIS". This topic ranks 13th among the most cited topics. MIS refers to a system that uses the information required by all levels of management in making operational, tactical, and strategic decisions [62]. In the past, BI applications were developed for strategic use only by senior management. However, this has changed recently, and BI applications have started to be utilized at both tactical and operational levels. Therefore, it is not surprising that the "MIS" field, which mainly supports the tactical level in organizations, is one of the most studied topics.

Some topics are outside the top five most studied topics, although they are among the top five most cited topics in the BI field. Therefore, "TAM", "Intelligent Systems", and "DSS", which are among the top five most cited topics, need to be discussed in more detail.

The second most cited topic is "TAM". Namely, "TAM" can provide important insights to researchers and practitioners in explaining and, more importantly, predicting the behavior of individuals in general and their behavior on using or not using technology in particular. Today, as data becomes more important, BI software for analyzing, sharing, and managing data is increasing [63]. Therefore, the factors affecting users' adoption of this BI software have become important. Many studies examining the adoption of BI software draw attention [64]. In addition, Chang et al. examined the factors that affect managers' intention to use BI software in decision-making [65]. Among the studies on the adoption of BI, the fields of higher education [66], health [67], and the electronics industry [68] draw attention.

The third most cited topic is "Intelligent Systems". More precisely, "Intelligent Systems" allow for solving complex problems with a standardized method approach and obtaining reliable and consistent results over time [69]. It also refers to the systems enabling decision-makers to make decisions using different software tools in information and decision processes [70]. The leading technologies to create intelligent systems are fuzzy systems, artificial neural networks, expert systems, and evolutionary computing.

Intelligent systems are typically used for diagnosis, optimization, classification, clustering, selection, prediction, and control [71].

The fourth most cited topic is "DSS". George defined DSS as a combination of computer and communication technology designed to coordinate the decision-making process across functional areas and hierarchical layers to align decisions with business objectives [72]. DSS has become more advanced with the emergence of data warehouse, OLAP, and BI concepts in the late 1980s. The term BI began to be used more instead of DSS in the 1990s [73]. BI is the latest version of DSS with data processing and analysis capabilities [74]. However, it is stated that DSS is an essential set of systems that increase BI [75]. In this context, there is an essential relationship between DSS and BI. BI refers to technologies and actions that enable a business to process valuable information to support management and decision-making. In order to do this as quickly as possible, BI systems are responsible for processing huge amounts of data and turning it into visuals, reports, graphics, and presentations that can be easily perceived by decision-makers. Thus, the BI system is a decision support system that increases the ability of users to make the right decision.

5.3. Emerging Trends in BI Research

In order to better understand how trends and developments in each topic have changed over time (RQ3), details of the identified topics from 2003 to 2022 were calculated and presented for each year. As shown in Figure 2, while some topics such as "Organizational Capability", "AI Applications", "Data Mining", "Big Data Analytics", and "Visualization" are increasing, the topics of "Knowledge Management", "Semantic Web", "SDLC", "Intelligent Systems" and "Database" have decreased.

Although "Organizational Capability", which has the highest positive acceleration value, is not among the most studied and cited topics, it has shown a significant increase in the positive direction. Today, since knowledge acquisition and evaluation is accepted as crucial organizational capability, the organizations of the information society are turning into structures that profit by turning knowledge into value. Organizational capabilities refer to organizations' ability to assemble, integrate and distribute resources, often in combination or co-existence [76]. Due to the increasing importance of "Big Data" in the modern business world, data, information, and information have become the most valuable resources for organizations. As the need for real-time data collection, analysis, and decision-making grows, BI capabilities that collect, integrate, and distribute data help thread an organization's future path.

Other topics with the highest positive acceleration value are "AI Applications", "Data Mining", "Big Data Analytics", and "Visualization", respectively. These issues are broadly interconnected, and their increasing momentum is unsurprising. It focuses on data analysis and report management through BI, data mining, and data warehouse procedures. BI is the use of various technologies and tools to collect and analyze business data [77]. As BI tools begin to be applied to daily operations, empowering them with Artificial Intelligence (AI) has become a top priority. Therefore, AI applications affected the way BI worked in the past. Because AI can analyze vast amounts of data and provide recommendations based on that data, it makes analytics and big data insights accessible and understandable to data scientists and the average user [77,78].

On the other hand, "Knowledge Management" (KM) is the topic that attracts the most attention among the topics with the lowest acceleration value. BI is a broad category of applications and technologies used to collect, access, and analyze large volumes of data for organizations to make effective business decisions. On the other hand, KM is a set of practices for creating, developing, and applying knowledge to improve organizational performance [79]. Similar to BI, knowledge management improves how an organization uses existing knowledge. However, KM differs from BI in many ways. In general, knowledge management deals with human subjective information rather than data or objective information [80]. Therefore, the negative momentum of the "knowledge management" topic is probably due to the recent significant increase in data, the increasing importance of the

concept of "Big Data", and the significant investments in data processing by organizations. In addition, it can be stated that organizations realize that the management of data, rather than the management of information, gives more vital results.

5.4. Insights into the Taxonomy of BI Research

BI is a system that transforms raw data into usable information and supports decision-making processes at operational, tactical, and strategic levels. These systems allow managers to measure and improve the current performance of businesses. BI systems divide the large data sets they use into parts, report, summarize, analyze in real-time, visualize with graphs, and make predictions for the future [81]. Venter & Tustin also stated that information technology is crucial in enabling BI technology to collect, store, analyze, and present business information in a simple and useful way. Therefore, we classified BI topics under two groups, business (46.61%) and IT (53.39%), in the taxonomy we presented in the study [82].

Later, the business category of BI topics was divided into two sub-categories as domain (19.74%) and managerial (26.87%). As the taxonomy in Figure 3 shows, eight topics were identified under the domain category. The most studied topics are "HIS", "Industry 4.0", and "Social Media", respectively. BI plays an increasingly critical role in various industries. Since knowledge is defined as the most valuable asset of a business, it is a fundamental resource for its development [3]. This technological tool can provide many benefits, such as architecture, efficient information, and customer data management when implemented in a business [83]. HIS stands out among the fields where BI is used. The healthcare industry has historically generated a significant amount of data due to record keeping, regulatory requirements, and demand for patient care [84]. "Success Factors", "MIS", and "CRM", are the most studied topics in the managerial category. The decision-making process covers all processes, from which tools to use in businesses to which questions need to be answered. Therefore, topics related to decision-making came to the fore under the managerial category.

The IT category, the other BI category, was divided into two sub-categories: Implementation (25.48%) and Data (27.91%). According to the taxonomy, nine topics were identified under the implementation category. "SDLC", "Competitive Intelligence", and "AI Applications" were among the most studied topics. Topics in this category are usually related to developing and implementing the BI tools. Data (27.91%), the other sub-category of BI, draws attention as the most studied sub-category. This category covers "Data Mining", "Big Data Analytics", "Visualization", "Sentiment Analysis", and "Event Processing", which have been trending topics recently.

6. Conclusions

This study aimed to examine the research interests and trends of articles in the BI field between 2003 and 2022. The results of the analysis have shown that 36 topics have business emerged in the BI field. The most studied topics are "SDLC", "Big Data Analytics", and "Data Warehousing". Moreover, "Big Data Analytics" has come to the fore by far among the most cited topics. The acceleration of "Knowledge Management", "Semantic Web", and "SDLC" topics in the BI field has slowed over the years. The topics with the highest momentum in recent years are "Organizational Capability", "AI Applications", "Data Mining", and "Big Data Analytics". We have also developed a taxonomy for emerging topics in the BI field. The taxonomy is divided into two subcategories, business, and IT. The Business category was divided into two subcategories: domain and managerial and consisted of 17 topics in total. The IT category was divided into two subcategories, implementation and data, and consisted of 19 topics. In the taxonomy, the IT category from the main categories and the data category from the subcategories came to the fore.

The most innovative aspect of this study is that it is the most comprehensive study of content analysis based on topic modeling in the BI field. The LDA algorithm, which is widely used in the literature, was used for topic modeling analysis. Different algorithms may be used in future research for comparative studies. It is anticipated that the findings

to be obtained from future studies in this perspective will make important contributions to the understanding of the evolution of BI or its subtopics in the near future. Thus, it will be possible to see how the findings of this study evolve over time and how the trend of increasing/decreasing the topics has changed. Finally, it is suggested that future studies conduct a similar analysis on more specific sub-headings in the BI field.

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Appendix A

Table A1. Discovered topics, keywords, and percentages.

Topic Name	LDA Keywords	%
SDLC	system design software solution project requirement development support application need tool process report develop evaluation user engineering implementation component analysis	4.73
Big Data Analytics	datum analytic big business analysis insight predictive technology organization data-driven decision opportunity tool understand ba industry technique advance analyze lead	4.62
Data Warehousing	datum warehouse analysis olap quality multidimensional source process analytical integration information dw cube warehousing decision spatial integrate support architecture dimension	4.24
Success Factors	factor implementation success organization critical project organisation organizational analysis strategy benefit adoption qualitative develop successful interview business technology important industry	3.88
MIS	system information management enterprise resource support erp strategic technology plan decision planning company integration integrate control decision-making application process corporate	3.77
Competitive Intelligence	company competitive business market technology advantage strategy information industry innovation decision opportunity intelligence development environment change growth economic strategic patent	3.72
CRM	customer marketing product sale business relationship market consumer service company retail online e-commerce crm strategy brand help store satisfaction price	3.55
AI Applications	intelligence business artificial technology digital application learn development trend analysis bibliometric machine discuss automation perspective world innovation human ecosystem increase	3.34
BPM	business process performance management indicator improve operational tool analysis measurement improvement measure metric organization time efficiency monitoring monitor operation objective	3.31
Knowledge Management	knowledge management organization business information need role process creation technology create organizational km change design development structure asset tool share	3.25
HIS	health healthcare care clinical patient medical hospital datum quality improve treatment information electronic cost disease informatics tool improvement increase medicine	3.25
Data Mining	datum mining analysis information technique mine application tool knowledge process large amount analyze decision extract apply help various generate technology	3.14

Table A1. *Cont.*

Topic Name	LDA Keywords	%
Organizational Capability	performance capability impact organizational relationship effect role datum examine positive organisational innovation orientation influence show structural manager questionnaire empirical dynamic	3.14
Prediction	learn prediction machine algorithm network learning predict neural classification deep accuracy datum dataset feature technique performance predictive classifier regression time	3.14
Intelligent Systems	intelligent cloud system mobile application network service business compute technology platform agent computing architecture internet environment device user solution sensor	3.12
Industry 4.0	business industry enterprise sme digital small production process product manufacturing intelligent manufacture sustainable technology sustainability industrial company development develop medium	2.98
Sentiment Analysis	sentiment text analysis online recommendation news feature language word image user opinion video aspect term product natural topic classification recommender	2.76
Social Media	social media network analysis content share opinion relation information user community twitter public platform online open number consumer topic digital	2.65
TAM	system user information quality adoption influence intention technology usage perceive satisfaction acceptance individual effect determinant factor perception significant impact find	2.57
Query Optimization	query performance time datum workload optimization system algorithm cost parallel reduce benchmark execution memory flow task resource application large mapreduce	2.54
DSS	decision support system fuzzy decision-making dss selection information criterion theory process analysis environment maker technique set evaluation group cognitive expert	2.52
Supply Chain	chain supply iot logistics management supplier demand rfid inventory network internet thing operation cost collaboration information technology industry collaborative port	2.49
Higher Education	student education university learn course business higher educational academic program institution design teach curriculum school development training teaching technology system	2.43
Smart Grid	energy smart power datum grid consumption city system facility electricity management vehicle location analysis cost building production transportation sensor transport	2.24
Algorithms	algorithm cluster rule association mining pattern datum classification set database clustering attribute utility churn genetic frequent mine item feature transaction	2.21
Emotional Intelligence	intelligence business emotional leadership tourism cultural destination skill competency leader job south emotion entrepreneurial african hotel africa international relationship gender	2.19

Table A1. *Cont.*

Topic Name	LDA Keywords	%
Visualization	dashboard visualization datum tool visual user map interactive design information analysis usability trajectory exploration report location interface display visualisation presentation	2.16
Database	database datum etl olap warehouse analytical report tool ibm query relational application technology processing solution process open sql xml platform	2.10
Semantic Web	web information semantic search document ontology page extraction engine language application text structure user site website unstructured extract task access	2.08
Cost of Crime Index	cost report crime index expect growth packaging law unit rate increase time unite receive global annual part device drift board	2.00
Event Processing	process event business log pattern workflow activity discovery detection mining discover complex detect execution audit system intelligence anomaly sequence real	1.89
HRM	human global resource practice environmental accounting crisis employee manager management modern potential opportunity workforce safety question change pandemic complex worker	1.75
Risk Analysis	risk financial bank stock credit market banking analysis investment return economic management card price surveillance exchange show commercial application reduce	1.69
Government Services	service public technology sector government architecture private policy provider governance solution cost soa infrastructure open quality collaboration resource local technological	1.69
Information Security	security privacy information blockchain attack threat contract signal cyber protect trust protection share risk weak protocol sensitive military detection secure	1.53
Graph Streams	graph stream object distribution dynamic time scenario global logic temporal node linkage form real-time real entity change define physical operator	1.31

Table A2. Annual percentages and trends of the topics.

Topic Name	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	Trend
Organizational Capability	0.00	1.67	0.00	1.11	0.00	0.00	0.00	0.00	0.73	0.55	0.00	0.96	3.56	3.60	3.78	3.86	3.42	5.05	4.60	10.75	0.57
AI Applications	0.00	0.00	1.35	4.44	2.24	2.56	0.76	2.73	3.65	3.31	1.08	0.48	0.44	1.35	2.52	5.02	3.08	5.05	7.36	6.84	0.36
Data Mining	2.22	0.00	1.35	1.11	0.75	1.71	1.53	1.82	2.19	2.76	2.70	2.40	1.33	1.35	2.52	2.32	4.11	5.05	5.83	7.17	0.26
Big Data Analytics	0.00	0.00	1.35	0.00	0.75	0.85	1.53	0.00	0.73	2.76	3.24	4.81	4.89	5.41	7.56	8.88	10.27	4.73	5.83	4.56	0.24

Table A2. *Cont.*

Topic Name	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	Trend
Visualization	0.00	5.00	2.70	2.22	2.24	0.85	3.05	0.00	0.73	2.21	1.62	2.88	1.33	4.05	0.84	1.16	2.05	2.52	2.15	3.91	0.21
Success Factors	0.00	0.00	0.00	1.11	0.00	0.85	2.29	3.64	2.92	3.31	2.70	1.92	5.33	5.41	2.94	6.95	3.77	5.68	7.36	3.91	0.21
Sentiment Analysis	0.00	0.00	4.05	1.11	1.49	0.85	0.76	4.55	1.46	6.63	1.08	3.37	2.22	2.25	3.78	3.86	3.42	1.89	3.07	3.26	0.17
Event Processing	0.00	1.67	0.00	0.00	2.24	2.56	1.53	1.82	2.92	3.87	1.08	0.96	2.22	2.25	2.52	1.16	2.40	1.89	0.92	2.61	0.14
DSS	0.00	0.00	2.70	0.00	0.75	2.56	1.53	0.91	2.92	4.42	3.24	4.33	2.67	4.50	3.36	2.70	2.05	1.89	1.84	2.28	0.12
Supply Chain	0.00	3.33	4.05	0.00	2.24	3.42	4.58	4.55	2.19	3.87	2.16	1.44	3.11	1.35	3.78	1.54	1.37	2.21	3.07	2.28	0.12
Government Services	0.00	1.67	1.35	1.11	0.75	0.85	0.76	0.91	2.92	1.10	1.62	0.96	2.22	3.15	2.10	1.54	1.71	2.52	1.23	1.95	0.10
TAM	0.00	1.67	1.35	1.11	0.00	0.85	1.53	0.00	2.19	2.21	5.41	5.29	4.00	1.35	4.20	2.70	2.05	1.26	4.60	1.95	0.10
BPM	0.00	8.33	8.11	7.78	5.97	7.69	7.63	2.73	2.92	1.10	2.16	3.85	2.67	3.60	2.10	4.25	1.03	2.52	2.76	1.63	0.09
Social Media	0.00	0.00	0.00	1.11	0.00	1.71	0.76	1.82	2.19	2.76	3.78	2.88	5.33	1.80	4.20	2.32	2.74	5.05	3.07	1.30	0.07
Industry 4.0	4.44	5.00	2.70	6.67	3.73	3.42	2.29	0.91	1.46	1.10	2.16	0.96	0.89	1.35	2.10	3.47	5.48	3.47	3.07	5.54	0.06
Risk Analysis	0.00	0.00	5.41	3.33	2.99	3.42	3.05	0.91	1.46	1.10	3.78	0.00	3.11	0.90	1.26	1.54	0.68	1.58	1.53	0.98	0.05
Information Security	2.22	1.67	4.05	0.00	4.48	1.71	1.53	0.91	2.92	1.10	1.62	1.44	1.33	0.45	0.00	1.54	1.03	1.89	0.61	2.93	0.04
HIS	2.22	0.00	2.70	2.22	3.73	5.13	3.05	9.09	3.65	2.21	4.32	5.29	1.78	3.15	2.52	4.25	3.08	2.21	2.45	2.93	0.04
Algorithms	2.22	1.67	0.00	4.44	1.49	0.00	3.82	2.73	2.92	2.76	3.24	0.96	2.22	1.80	3.36	1.93	3.42	0.95	1.53	2.61	0.02
Higher Education	2.22	0.00	0.00	1.11	0.00	0.85	1.53	2.73	1.46	1.66	1.62	2.40	4.44	3.15	3.78	3.09	2.74	2.84	2.76	2.61	0.02
HRM	2.22	0.00	2.70	0.00	2.24	1.71	0.76	0.91	2.19	2.21	1.08	2.88	0.89	1.35	1.26	0.77	1.71	2.84	2.76	1.95	−0.01
Emotional Intelligence	2.22	5.00	4.05	3.33	2.24	0.85	2.29	1.82	1.46	1.10	1.08	2.40	2.22	2.25	1.26	3.09	2.40	1.89	3.07	1.95	−0.01
Competitive Intelligence	2.22	6.67	2.70	5.56	2.24	4.27	7.63	5.45	8.76	3.87	1.08	2.88	5.78	3.60	5.04	2.32	2.74	2.52	3.68	1.95	−0.01
Smart Grid	2.22	6.67	4.05	2.22	3.73	0.85	0.76	1.82	1.46	3.31	2.16	0.96	3.11	3.15	2.52	1.93	1.37	1.58	3.07	1.63	−0.03
Data Warehousing	2.22	1.67	2.70	3.33	4.48	4.27	3.82	7.27	2.19	2.21	4.86	9.62	4.44	4.50	5.04	3.09	5.14	5.68	3.37	1.30	−0.05
Graph Streams	2.22	5.00	0.00	1.11	2.24	2.56	1.53	2.73	2.19	1.10	1.62	0.96	0.00	0.45	1.26	1.54	1.71	1.26	1.23	0.33	−0.10
CRM	6.67	1.67	5.41	1.11	5.97	1.71	2.29	3.64	2.92	6.08	2.16	2.40	3.11	4.50	3.78	1.93	4.45	5.05	3.07	3.26	−0.18
Cost of Crime Index	4.44	6.67	6.76	4.44	6.72	0.85	3.05	0.91	3.65	2.76	1.08	1.44	2.22	3.15	0.42	0.39	2.05	0.63	0.92	0.98	−0.18
Prediction	4.44	5.00	2.70	7.78	2.24	5.98	4.58	3.64	3.65	1.66	4.32	2.88	2.22	6.31	4.62	3.09	3.42	1.89	0.92	0.65	−0.20
MIS	6.67	5.00	8.11	8.89	8.96	4.27	3.05	10.00	7.30	6.63	2.70	4.81	2.67	2.70	2.94	3.86	1.37	1.26	1.53	2.28	−0.23
Query Optimization	6.67	1.67	0.00	0.00	0.75	4.27	3.05	3.64	0.73	2.76	4.32	3.37	3.56	2.70	4.20	4.63	1.37	1.58	1.53	1.30	−0.28
Database	6.67	6.67	1.35	2.22	4.48	7.69	4.58	2.73	4.38	3.31	4.86	1.44	0.89	1.35	0.42	1.16	0.68	0.95	0.61	0.98	−0.30
Intelligent Systems	8.89	3.33	4.05	3.33	5.97	2.56	0.76	4.55	4.38	3.31	3.24	2.40	2.67	2.70	1.26	2.32	3.42	3.79	3.07	2.93	−0.31
SDLC	11.11	1.67	1.35	6.67	6.72	2.56	6.11	3.64	5.84	3.87	8.11	6.25	5.33	5.86	4.20	3.47	3.42	4.73	2.76	4.89	−0.33
Semantic Web	6.67	6.67	4.05	4.44	2.99	3.42	3.05	2.73	2.92	2.76	2.16	2.88	3.11	1.80	1.68	0.77	1.37	1.26	0.92	0.00	−0.35
Knowledge Management	8.89	5.00	6.76	5.56	2.24	10.26	9.16	1.82	1.46	2.21	6.49	4.81	2.67	1.35	0.84	1.54	3.42	2.84	1.84	1.63	−0.38

In this heatmap table, the green colors specify percentages above the topic's average in a row, the red colors specify percentages below the topic's average, and their colors approach white as these annual values approach the average.

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