An overview of Business Intelligence research in healthcare organizations using a topic modeling approach

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Abstract— The intersection of Business intelligence (BI) and data analytics with healthcare has witnessed remarkable growth in recent decades. With the aim of identifying the most attentive themes, topics, and research priorities, this review endeavors to perform a literature analysis on research articles addressing business intelligence in healthcare. To conduct the study, a total of 751 articles, published between 2002 and 2023, were analyzed through topic modeling, a technique used in natural language processing (NLP) and machine learning. As a result, seven major themes were identified: Unique Device Identification, Big Data and Data Analytics, Operational Efficiency, Effective Decision-Making, Healthcare Delivery Optimization, Resource Optimization and Cost Reduction, and Nosocomial Infections are growing. The analysis revealed that there is a growing interest in leveraging business intelligence for infection control and operational improvements using health information technology and data analytics, while efforts to optimize resources/reduce costs appear to be on the decline. The research findings shed light on the increasing capabilities and use of business intelligence in healthcare, highlighting opportunities for future research.

Keywords—Business intelligence; Healthcare organizations; Topic Modeling; Text mining

I. INTRODUCTION

The Healthcare Industry is one of the greatest and widest-developing industries in the world and its improvement is taken into consideration as an economic and national necessity for each country. As healthcare services demand increases, many countries are experiencing a shortage of healthcare professionals, especially physicians [1]. In this regard, information systems(IS) are an essential and inseparable component in this sector to meet these challenges and also the problems related to quality and cost[2]. In fact, IS can help healthcare organizations organize their schedules and resources in a way that effectively maximizes the utilization of available doctors by providing accurate information at the right times and for the right person. However, the necessity of information systems in healthcare organizations is insufficient and unclear, as they also need to be integrated with business intelligence systems(BI), which are essential for comprehensive data analysis and effective decision-making[3].

BI, a specific application or component of information systems[4], gives a competitive advantage to organizations through the process of transforming data first into information and then into meaningful and actionable knowledge. Accordingly, BI can empower managers and supervisors in decision-making by providing new business insight. In healthcare, BI is considered a real boost to improve traditional decisions made by physicians (i.e., medical doctors)[5]. Actually, BI can improve reporting and analytical capabilities for physicians by integrating data collected from external and internal sources and providing data visualization, leading to better-informed decision-making. Considering the mentioned importance and applications, many healthcare organizations are turning their attention to Business Intelligence to improve the quality of healthcare services and the healthcare delivery system over the competitiveness in the global healthcare scenario[6].

With the increasing usage of BI and its importance in healthcare, exploring and uncovering the underlying themes of BI in this industry gives a theoretical and practical foundation for both researchers and practitioners who are initiating or at an advanced stage of their efforts. This article provides an automated text-mining literature analysis from 2002 to 2023, of BI applications in the healthcare industry, to identify its recurring patterns, latent themes, and unexplored areas. Here are the specific research questions that this study aims to address:

1. Which topics and themes dominate the literature on BI in healthcare?

2. What changes have occurred in these topics over time?

3. What are the priorities and emerging directions of BI healthcare research at present?

The structure that is come after in this article is as follows: Section 2 presents the literature analysis. Next, Section 3 presents the methods used for analyzing the literature. Then, the research results and main findings are discussed in Section 4. Finally, conclusions, summarized in Section 5, bring the paper to an end. The future research directions are also presented in the last section.

II. RELATED WORKS

For any academic project, a literature review is considered a must feature to develop knowledge and formulate theories

within a particular field of study. In the domain of BI, most of the literature is focused on the implementation and effects of BI in industrial organizations. However, increasing interest has been observed in recent years in leveraging BI to support clinical decision-making in healthcare, representing a turning point in BI evolution. There have been a number of systematic litreature reviews that have investigated the adoption and impact of BI in healthcare.

Salisu et al. [7] conducted one systematic literature review that specifically looked at the adoption of BI systems in small and medium-sized enterprises (SMEs) in healthcare. The study is done with the emergence of the deadly global pandemic of COVID-19 to explore the most possible determinants and theories that impact the adoption and recognition of BIS in organizations. For this purpose, a total of 63 studies from 2011 to 2020 were collected and analyzed, and a total of 22 determinants were identified. As a result, the determinants were grouped into four contexts, namely technology[8-10], organization[11-13], environment[13-15], and CEO characteristics[16, 17]. Additionally, Zheng et al. [18] reviewed the use of BI to increase patient-centeredness, , which is an extremely important aspect of providing healthcare to patients. For this aim, the researchers identified and analyzed 89 studies, published between 2000 and 2016 and focused on incorporating BI into patient-centered care (PC). The findings of the research confirmed the positive impact of implementing BI on PC and the need to improve the infrastructure of health information systems, so that BI analysis is supported. Subsequently, Loewen, & Roudsari [19] conducted a systematic literature review, examining in detail the effects of Business Intelligence BI on healthcare system decisions and organizational performance. Regarding their purpose, a total of 342 out of 2290 were selected from 10 reputable databases to review comprehensively. The findings of this review reinforce the need for BI, leading to increase confidence in decisions and improve organizational performance in healthcare. This review presents six overarching themes, identified through qualitative analysis. These explored six themes include information needs/ system indicators [15, 20, 21], information system quality[22], demonstrated/anticipated benefits[23], barriers to accessing/using information[24], decision-making impacts[25-27], and factors influencing the adoption of BI[7, 28]. Moreover, the researchers identify and report the implementation success factors for BI in healthcare, including addressing organizational weaknesses, i.e., lack of capacity for analytical intelligence resources[29], use of outside compliance or reporting requirements[30], promotion of a strong organization vision, focus on care coordination elements[31], ensuring technological integration between platforms and the firm technology platform[32], tackling data quality and semantic interoperability[33].

The existing literature reviews on BI in healthcare, while valuable and insightful, are predominantly based on manual categorization of studies. In contrast, the approach we use in our study achieves a significant step forward by automatically extracting topics from a substantial corpus of literature and analyzing them. This approach, namely topic modeling analysis, has become increasingly popular in recent years for defining a field's scope by comprehensively covering a larger

body of research. To the best of our knowledge, topic modeling within BI field has been the subject of only a few scholarly studies, predominantly in industries outside of healthcare, such as banking[34]. Accordingly, this study will analyze BI research in healthcare through topic modeling to fill this gap in the literature and provide a broader overview of research in this field.

III. METHODS AND MATERIALS

This research employed a well-structured framework to collect, preprocess and textual data analysis, depicted in Figure 1. This framework is divided into four modules: (1) data collection, (2) preprocessing, (3) Text Data modeling and parameter settings during modeling, and (4) exploring the topic distribution from multiple perspectives.
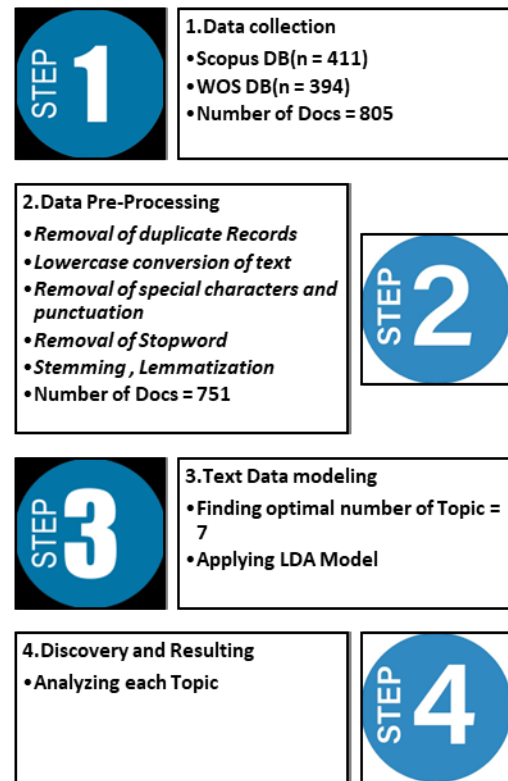

Figure 1: Research Framework

A. Journal Selection

Given the emphasis on exploring the most attention-getting themes of BI research in healthcare, reputable journals including Web of Science and Scopus were used for article selection. As a result, a total of 805 articles, published between 2002 and 2023 were excerpted. Out of the totals, Scopus was the source of 411 articles, and the remaining 394 were obtained from Web of Science.

B. Article Search

For article search, the online search engines of both Scopus and Web of Science were used. These search engines allow users to perform complicated queries, using special

fields and Boolean phrases namely "AND" or "OR". To ensure maximum coverage of relevant studies, search phrases such as business intelligence and healthcare were used in different combinations. The query consists of two OR connections for business intelligence and healthcare terms, connected by AND to provide that all articles should include at least one business intelligence term and one healthcare:

("Business intelligence" OR "Business analytics" OR "Data Analytics" OR "Data visualization") AND ("Healthcare" OR "Health services" OR "Healthcare Industry" OR " Clinical Care")

The collected dataset includes relevant information, including the title, abstract, and keywords of peer-reviewed research papers, conference proceedings, and relevant book chapters

C. Preprocessing

The preprocessing of data refers to a set of procedures that improve the quality of raw data [35]. A number of steps were involved in preprocessing to ensure that the text data was ready for subsequent analysis. These included:

- *Removal of duplicate Records*: To eliminate redundancy, the dataset was checked for duplicate records, leading to 54 duplicate records being excluded.

- *Lowercase conversion of text*: All textual data have been converted to lowercase forms to ensure consistency and prevent complications, caused by case sensitivity.

- *Removal of special characters and punctuation*: The characters such as punctuation marks, symbols, and other special characters, not carrying significant meaning for analysis, are removed from the text.

- *Removal of Stopword*: To reduce noise and focus on more relevant words, stopwords (e.g., "and," "the, and "is"), occurring frequently, rather than contributing to its overall meaning, were removed.

- *Stemming or Lemmatization*: To handle different word variations and further standardize the dataset, stemming or lemmatization was performed to reduce words to their root forms.

Utilizing the preprocessing steps to transform the raw text into a standardized, clean format paves the way to draw insightful conclusions based on data-driven analysis. After completing these steps, a dataset containing 751 records was obtained.

D. Text Data Modeling

The process of knowledge discovery in text documents, unstructured data, appears to be much more complex than that in structured[36]. The process of text data modeling involves creating a model that represents the structure and content of textual data to extract meaningful information. Topic modeling, a text analytics approach, is a technique used in natural language processing (NLP) and machine learning to find latent topics hidden within a collection of documents[37], providing categorization and exploration of large text databases. In this research, Latent Dirichlet Allocation

(LDA)[38] a widely adopted algorithm for topic modeling was employed. As a result of LDA, we were able to identify how topics are distributed within documents as mixtures of topics. The number of topics was determined through a coherence score that is an iterative process to identify the optimal number of topics. According to the coherence values provided in Figure 2, the number of topics that demonstrate the greatest coherence is 7.
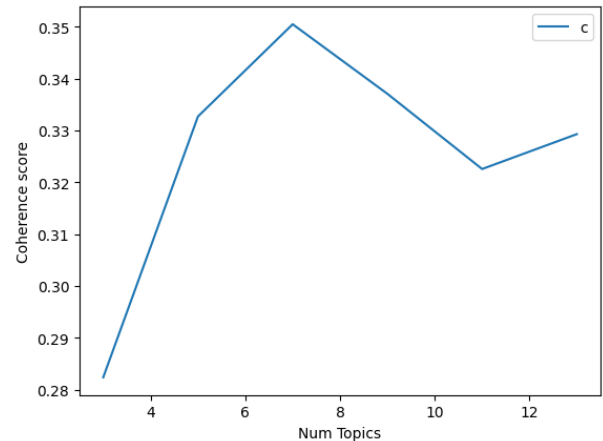

Figure 2: Coherence-Based Topic Selection

IV. RESULT

As a result of this research, the latent themes of BI research in healthcare are provided under 7 topics. The words in a topic are related and share a semantic correlation, so they are grouped together. Using a word cloud representation, Figure 3 in Appendix shows the most frequently words and terms in each cluster.

Topic 1 : Unique Device Identification

In this cluster, the most commonly surfaced words include medical device, adoption, UDI, benefit, and product. These words indicate that the studies in this cluster deals with the benefit of Unique Device Identifications (UDIs) implementation for hospital. Despite the lowest number of documents were assigned to this cluster, it is noteworthy because it is primarily focused on adoption of UDIs. More specifically, Durack [39] and Abdulsalam et al. [40] are the examples, reporting business intelligence systems can become more effective by using UDA data which contains specific information about medical devices. While effective, UDA has been challenged for its complexity in implementing[41].

Topic 2 : Big data and Data analytics

Frequently surfaced words in Cluster 2 are data, analytics, big, mining, and technology, highlighting the importance of business intelligence and big data analytics in healthcare. Observing the frequently used words, this cluster focuses mainly on the application and potential of big data analytics in the healthcare industry. As a result of various sources, this cluster reports that healthcare organizations accumulate massive amounts of data called big data. Big data analytics techniques, such as predictive modeling [42, 43], data mining[44-46], statistics[47, 48], and machine learning[49-

51], are employed in these studies to extract valuable insights from large healthcare data sets, highlighting significantly improvement in decision making. In the field of healthcare, specific applications, mentioned in these studies for Big Data Analytics include early disease detection, personalized medicine[46], clinical decision support[52], optimizing healthcare operations and costs, and improving the quality of care and patient outcome[46]. Additionally, the challenges related to the implementation of Big Data Analytics in health care, e.g., integrating data[53], security and privacy concerns[54], lack of experience or extraction of important insight from massive amounts of data have been recognized by studies that are part of this cluster.

Topic 3 : Operational Efficiency

This cluster is composed of information, systems, technology, analytics ,services, performance, process, and quality. The prominence of the words such as "information" , "systems", and "technology" highlight a focus on information systems. Words like "performance", "process", and " services "suggest a focus on the operations in healthcare organizations. Taken together, the word frequencies indicate that the studies' emphsise on improving healthcare services and operations using technology and analytics. The implementation of these technologies has the potential to improve operational efficiency[55], quality of care, patient outcomes, and overall satisfaction[56]. In summary, the majority of focus in this cluster is placed on using data, analytics and technology for streamlining processes, reducing costs, achieving better quality and enhancing management shows an effort to improve operating efficiency across the healthcare ecosystem.

Topic 4 : Effective Decision-Making

Business intelligence (BI) systems are integral to the healthcare industry, enabling digital transformation and facilitating effective decision-making. Cluster 4, characterized by frequent keywords like decision, effect, information, system, service, model, analysis, role, impact, social, and media, emphasizes BI's role in enhancing operational efficiency in healthcare. Articles highlight how BI systems provide valuable insights to support informed decision-making by healthcare organizations, leveraging big data, predictive analytics, and adaptive BI platforms to improve overall effectiveness and drive digital transformation. Addressing challenges, determinants, and critical success factors in BI adoption, these articles stress the significance of data-driven decisions, enabling healthcare organizations to transform their practices and improve patient outcomes significantly[7, 22, 57, 58].

Topic 5 : Healthcare Delivery Optimization

Cluster 5, consisting of keywords like Optimization, information, patient, solution, quality, decision, and system, aligns perfectly with the crucial role of Business Intelligence

(BI) in enhancing healthcare delivery efficiency and effectiveness. The increasing adoption of BI tools and technologies in healthcare settings allows organizations to harness the power of data for valuable insights, informed decision-making, and operational optimization. BI enables healthcare professionals to analyze vast amounts of data, spanning from patient records to financial information, in real-time, facilitating evidence-based decision-making and efficient resource allocation. The utilization of data visualization, dashboards, and reports empowers healthcare leaders to monitor key performance indicators, identify trends, and discover areas for improvement. By leveraging BI, healthcare organizations can streamline processes, reduce costs, elevate patient care quality, and ultimately achieve better health outcomes, solidifying its role as a critical component in improving healthcare services[54, 59-62].

Topic 6: Resource Optimization and Cost Reduction

Cluster 6 includes care, cost, patient, service, data, quality, team, measurement, and access. As the words often appear, the emphasis of this cluster is on the optimal use of resources and reducing costs. Effective resource management and cost reduction are critical goals for healthcare organizations. By leveraging data-driven approaches and business intelligence tools, healthcare providers can gain insights into their resource utilization patterns and identify areas for improvement. Analyzing data can help identify inefficiencies and areas of waste, allowing organizations to implement strategies that optimize resource allocation and reduce unnecessary costs. Additionally, data analysis can identify opportunities for process improvement and workflow optimization, leading to increased efficiency and reduced expenses. By making informed decisions based on data, healthcare organizations can allocate resources more effectively, ultimately improving patient care while achieving cost savings[63-65].

Topic 7 : Nosocomial infections

The most frequently surfaced words in Cluster 7 include infection, COVID, hospital, risk, clinical, data, study, outcome, and result. The common ground between the four articles is that they all focus on the prevention and treatment of healthcare-associated infections (HAIs). The general theme of the articles is the importance of using innovative technologies and strategies to prevent and treat HAIs. For instance, the first article utilizes a data-driven approach to identify patients at risk for HAIs, while the second article employs artificial intelligence to track the spread of COVID-19. The articles also emphasize the significance of collaboration between healthcare professionals and researchers to develop effective prevention and treatment strategies. For example, the third article describes a partnership between nuclear medicine experts and dementia researchers to create new diagnostic tools for dementia. Overall, these articles provide valuable insights into the challenges and opportunities in HAI prevention and treatment, suggesting that innovative

technologies and strategies can improve patient outcomes and alleviate the burden on healthcare systems[3, 66-69].

Topic distribution over time

In Figure 4, the identified seven dominant themes are depicted as they have changed over time. Having an understanding of the change in the prevalence of each topic can provide insight into the evolving research prioirities within the healthcare rsearch. By analyzing the trends , ranging from 2003 to 2023, the rising (e.g., nosocomial infections, and operational efficiency), the falling (e.g., resource optimization and cost reduction), and the fluctuating trends (e.g., healthcare delivery optimization) are recognized.
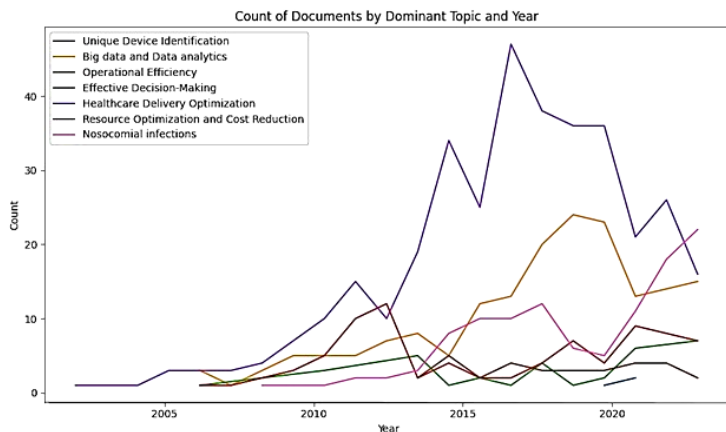

Figure 4: Time-based distribution of topics

V. CONCLUSION

In conclusion, this litreature analysis provides an overview on scientific researches of BI in healthcare, with the goals of identifying key topics and themes, analyzing changes over time, and determining current priorities and emerging directions of this field using text analysis technique. Accordingly, this research paper sheds light on the wide range of business intelligence applications in healthcare through topic modeling. The analysis of a total 751 articles, extracted from trustworthy sources such as Web of science and Scopus and preprocessed led to the identification of seven major themes: unique device identification, big data analytics, operational efficiency, decision-making, healthcare delivery optimization, resource and cost optimization, and nosocomial infections.

A rising interest is noted in utilizing BI for the prevention of nosocomial infections, coinciding with global efforts to combat infections like COVID-19. Additionally, operational efficiency is becoming increasingly important as health information technologies and data analytics are being used more widely to drive process improvements, facilitated by business intelligence platforms through evidence-based techniques. Meanwhile, efforts to optimize resource utilization and reduce costs have declined, indicating that there is a shift from solely financial goals to more holistic goals in pursuit of quality care. The result also indicates that some topics such as healthcare delivery optimization have shown a pattern of fluctuating scientific activity within the specified time frame, despite having received a substantial volume of research. Moreover, this analysis highlights relatively nascent themes, such as unique device identification, that illustrate new directions in healthcare with the maturation of business intelligence.

These major themes demonstrate the breadth of focuses and applications of business intelligence across healthcare settings, emphasizing the need for further research and investment in the intersection of advanced data analytics and healthcare. The study provides an in-depth understanding of the current landscape and serves as a call to action to guide future investments aimed at maximizing the impact of BI on care quality, efficiency, and patient outcomes.
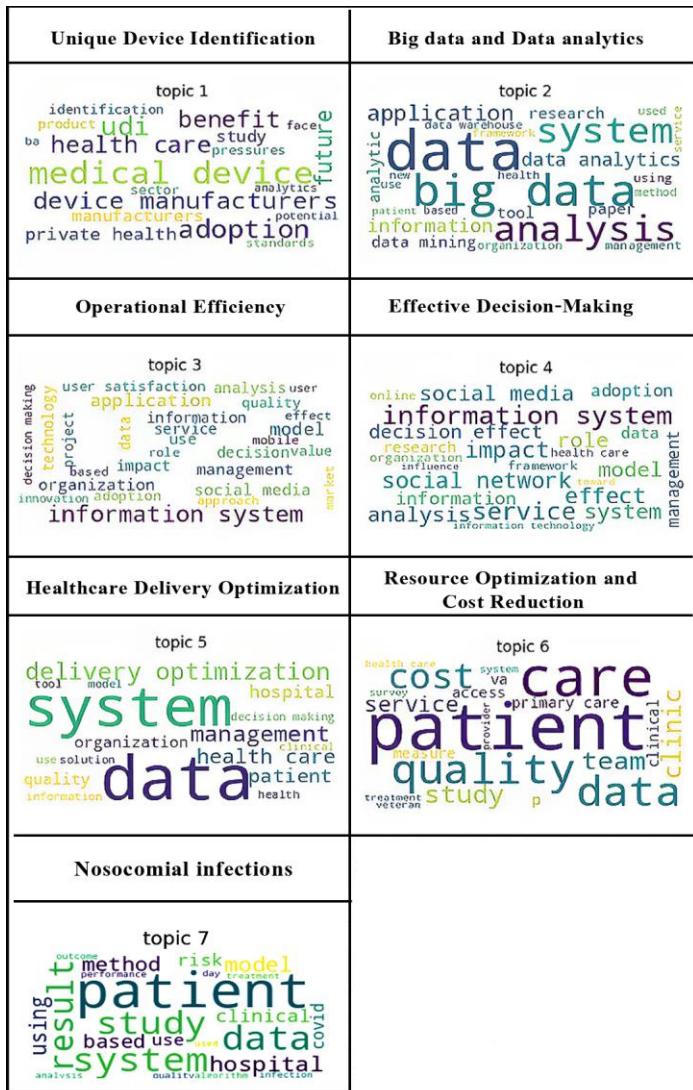
APPENDIX

Figure 3: Wordcloud for each Topic

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