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Business Intelligence & Analytics in Accounting studies: A 20-year Bibliometric Visualisation

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ABSTRACT

The purpose of this paper is to provide an overview of the business intelligence and analytics (BI&A) research trends in accounting studies. The review includes an assessment of the thematic evolution of BI&A over 20 years' duration. Published articles that combine BI&A, Accounting, and Audit keywords were searched from the Web of Science (WoS) database. Biblioshiny from the Bibliometrix R Package was utilised to analyse 320 articles published between 2002 and 2022. The review indicates that articles with BI&A themes have grown gradually within those two decades. Nevertheless, there is a sharp increase in the number of articles published in 2021, with a linear trend line predicting growth at the end of 2023. Publications for these articles were mostly from the USA, covering almost half of the publications for the past twenty years. Notably, the BI&A article that received the highest citations is an article written in 2020 with a focus on managerial accounting. WoS database was used to investigate BI&A from multiple angles in accounting studies. This paper adds to the knowledge as this is one of the first attempts to decipher the research streams that, through time, have prepared the way for the junction of Big Data Analytics and management domains.

Keywords: Bibliometric analysis; business intelligence and analytics; business analytics; data analytics; accounting

INTRODUCTION

Recent development in the accounting field has seen tremendous innovation, especially with the support of advanced business intelligence and analytics (BI&A). BI&A implements core operational factors such as pricing and process improvement as well as fraud detection and differential analysis and production placement, blending external data with internal data in order to get the most out of business intelligence (Eggert & Alberts 2020). The technology enables the analysis of diverse data types, hence, uncovering new strategic business opportunities.

A timely, informed decision is crucial for firms to sustain themselves in today's impulsive business environment. Should managers be able to reap the full benefit of BI&A technology, the deployment of algorithms to evaluate large datasets would elevate managers' ability to draw out insights from the accounting data that may not have been previously obvious to them. The BI&A technologies have been connected with the emergence of Industry Revolution 4.0 (IR4.0), along with the Internet of Things (IoT), Mobile and Augmented reality, additive manufacturing and 3D printing, cloud computing, and cybersecurity (Santos et al. 2017). BI&A has been routinely regarded as one of the most important agenda topics by senior executives (Paradza & Daramola 2021). Nevertheless, Bentley (2017) claims that more than 35 percent of the top 5,000 global companies regularly fail to make insightful decisions about significant changes in their business and markets due to a lack of information, processes, and tools.

Despite the advancement in BI&A, there is a noticeable gap in understanding its direct impact on accounting practices. In fact, many researchers have focused on enhancing and augmenting BI&A procedures and algorithms, yet how these techniques and algorithms impact accounting practices has not been systematically studied (Appelbaum et al. 2017; Peters et al. 2016; Rikhardsson & Yigitbasioglu 2018; Schneider et al. 2015). While it is acknowledged that BI&A activity is important to enterprises in order to obtain a long-term sustainable competitive advantage, it would be meaningless without further elaboration on the subject from an accommodating perspective (Chen et al. 2012; Chen & Lin 2021; Schneider et al. 2015). With the development in practice, it is highly timely that scholars improve their understanding of how BI&A techniques are assimilated within business processes, and this goal may be better guided if the facets of the research on the technicality behind BI&A are connected. Several organisations are currently employing BI&A-related solutions to optimise their business processes, while academic research related to accounting fields has thrived (Youssef & Mahama 2021). Despite this increasing interest, the study of BI&A in accounting is evolving without a solid theoretical foundation.

In an attempt to pave the way for the intersection between data analytics and accounting fields, this study will examine the literature connecting BI&A and accounting domains using bibliometric analysis. Bibliometrics refer to the quantitative analysis of academic publications using statistical and mathematical methods. Bibliometric methods are frequently used to provide evidence of research impact, trace developments within a field, and identify relationships between research areas and authors. Common techniques include publication count analysis, citation analysis, co-citation analysis, co-authorship network analysis, and keyword frequency analysis (Ellegaard & Wallin 2015). While business intelligence and analytics (BI&A) techniques have become integral in accounting practices, few studies have comprehensively reviewed this emerging literature. Existing reviews have focused on specific applications like auditing (Appelbaum et al. 2017), financial reporting (Yoon et al. 2015), and tax planning (Alles 2015). However, the intersection of BI&A and accounting has not been

examined holistically. Furthermore, prior literature reviews have relied on qualitative synthesis, failing to provide a quantitative, bibliometric perspective.

This study fills the gap by conducting a systematic bibliometric analysis of BI&A research trends across the broader accounting discipline over the past two decades. Bibliometric reviews quantitatively analyse academic publications to uncover patterns and themes in a research domain (Ellegaard & Wallin 2015). By visually mapping networks and statistics, this technique reveals insights that complement traditional qualitative reviews. Specifically, this study is seeks to answer the following questions:

RQ_1: How has research output at the intersection of BI&A and accounting evolved over the past 20 years in terms of volume of publications and active journals?
RQ_2: Which countries, institutions, and authors are leading this research domain?
RQ_3: What are the major research themes and collaboration networks in BI&A accounting research?
RQ_4: How can findings inform future research directions and knowledge gaps in this domain?

The attempt to respond to the above research questions in this study, thus, shall provide a holistic overview of the development of BI&A in accounting literature. Findings will benefit both researchers seeking to advance this field and practitioners aiming to harness BI&A innovations. The quantitative bibliometric approach also offers unique insights to complement prior reviews.

This research lays the groundwork for uncovering new areas of study by recognising the researchers who have published on themes that are now trending. Published studies have been reviewed to provide research clusters, such as those based on citation analyses. Using these clusters as a starting point, published models were categorized and examined and its evolution was visualized. As a result of these findings, new information about current research priorities and potential future avenues in research is revealed.

The remainder of this paper is organised as follows. Section 2 reviews relevant literature to discover established and emerging themes. Next, the literature search strategy of the bibliometric analysis was described under the methodology section. Section 4 reports the results of the bibliometric analysis, which are the descriptive analysis and network analysis. Section 5 discusses the insights from the analysis and provides the underlying research streams identified using R Studio. Section 6 concludes the findings, identifies the limitations, and suggests areas for future studies.

LITERATURE REVIEW

The highly globalised current business landscape is heavily influence by the advancement in technology and innovation. For reasons of sustainability and survival, businesses will need not only to have access to accurate, actionable and timely data, but also to be able to practice using insight from such data to make timely decisions. Hence, the BI&A practiced in firms with the capacity to analyse large amount and various data, will allow businesses to uncover new strategic opportunities.

Despite being regarded as one of the most important agenda topics by senior executives (Paradza & Daramola 2021), the literature is lacking in consensus over a specific definition of analytics and how it varies from similar topics. The most frequently cited definition comes from (Davenport et al. 2007) where data analytics is seen as "*the extensive use of data, statistical and quantitative analysis, explanatory and predictive models, and-fact based management to drive decisions and actions. The analytics may input human decisions or may drive fully automated decisions. Analytics are a sub-set of business intelligence.*". The perspective that analytics is a subset of business intelligence (BI) is supported by some studies (see for example, Bartlett 2013) that argue that Business Intelligence equals Business Analytics plus Information Technology. In sum, many studies regard business intelligence and data analytics to be a composite and refer to it with the name "BI&A" (Chen et al. 2012; Chen et al. 2012; Lim et al. 2013). The implication that can be drawn from their work is that the first part of the acronym relates to the technologies that process and alter data, and that the second part refers to its analysis. From a more cynical point of view, the distinction between the two is fundamentally irrelevant, and the debate of "analytics" is essentially an attempt to revitalise interest in the already established discipline of business intelligence (BI) (Mortenson et al. 2015).

This paper regard BI&A as a composite in which both work simultaneously and complementarily process structured, semi-structured and unstructured data to meet business needs. Accordingly, BI&A is an "umbrella term" because it encapsulates a broad range of tools and methodologies that enable organisations to collect data from internal and external sources, prepare it for analysis, develop and run queries against the data, and create reports, dashboards, and visualisations for end users. Accordingly, this study adopts the definition by Chen et al. (2012), viewing BI&A as emerging fields in analytics such as mobile and sensor-based content analytics and, more generally, big data (Chen et al. 2012).

It is contended that the influence of the industry revolution 4.0 (IR 4.0) on businesses has resulted in an increasing interest in BI&A (Santos et al. 2017). The key technological advancements that have been applied to manufacturing processes in the areas of automation, control, and information technologies are part of what is known as the IR4.0 era (Hermann et al. 2015). The fundamental concept of IR4.0 is based on the idea that businesses are able to build intelligent grids all

along the value chain by connecting their machines, technologies, and assets together. These smart grids can then control the production processes on their own. Within the scope of IR4.0, businesses will have the ability and autonomy to schedule maintenance, foresee breakdowns, and adapt themselves to new demands and unplanned changes in the manufacturing processes (Jazdi 2014). BI&A are essential components of IR4.0 because they are used to manage the data that is produced by a variety of sources, including machine controls, sensors, manufacturing systems, daily customer activities, etc. It deals with a massive amount of data that is entering at a rapid pace and in a variety of formats. The analysis of large amounts of data in order to discover valuable insights, patterns, or models is the essential component of an IR4.0 corporation's capacity for sustained innovation (Lee et al. 2014). Several prior studies compared IR4.0 with IR3.0, and it was argued that IR3.0 depends on a smaller amount of data, and allows more human intervention (Lau et al. 2019; Torn & Vaneker 2019). The comparison is summarised in the following table:

TABLE 1. Comparison between IR3.0 and IR4.0

Features	IR3.0	IR4.0
Concept	Operational decision and automation	Self-flexible, self-adaptable, and self-learning, smart intelligence and decentralised analytics
Production	Mass production	Mass customisation and personalisation
Production planning	Demand forecasting	On-demand production
Quality control	Statistical process control	Self-aware and self-predict
Base for revenue model	Selling products	Servitisation (integrating services into manufacturing)
Alignment	Interconnection of production process	Interconnection of the whole value chain

The main characteristic of IR4.0 is in the use of hyper-technological solutions and super-intelligent machines. The main distinction between IR3.0 and IR4.0 is as if IR3.0 gave us computers, while the IR4.0 gives us interactive computational forms. As summarised in Table 1, the concept of automation under IR3.0 transform into smart intelligence and decentralised analytics.

BI&A has been operated by accounting professionals to lead the data-driven decision analysis processes (Appelbaum et al. 2017; Rikhardsson & Yigitbasioglu 2018). It has been found that BI&A improves performance measurement and harnesses management control by integrating diagnostic and interactive dimensions; this augments knowledge competency and enhances the pursuit of competitive advantage (Peters et al. 2020). The financial performance drivers can be pinpointed by utilising structured and unstructured data through BI&A solutions. The roles of BI&A not only stop with management accounting practices such as budgeting, forecasting, deferential analysis, performance, and measurement but also include risk management, forensic accounting, audit, and financial analysis. For example, bias and anomalies in financial accounting can be efficiently predicted, financial performance can be evaluated and forecasted, and fraud can be detected using BI&A (Schneider et al. 2015).

Several studies found that data analytics assist in identifying overpayment of taxes for multinational corporations, are used in auditing to detect fraud to ensure regulatory compliance or determine the effectiveness of controls, and discover anomalous transactions or irregular transaction volumes that indicate money laundering (Smith et al. 2019; Schneider et al. 2015; Siegel 2013). Extant literature indicate focuses on different aspects of BI&A in accounting, for example, the role of BI&A to boost management control, performance measurement, and costing strategies (Elbashir et al. 2008, 2021; Peters et al. 2016; Uyar & Kuzey 2016; Youssef & Moustafa 2014), the new skillset that is required from managerial accountants who deals with big data and analytics modelling (Schneider et al. 2015; Spraakman et al. 2020), the role of BI&A in fraud detection, audit, and risk management strategies (Appelbaum et al. 2021; Haq et al. 2020; Holt & Lang 2021; Tang & Karim 2018), insurance claim prediction problems (Manski et al. 2021), role of BI&A in SMEs and business in organisations (Llave 2017; Paradza & Daramola 2021).

Each study has shed light on various aspects of the area; however, subsequent analysis of this literature using rigorous bibliometric approaches has the potential to shed light on aspects that have not been fully comprehended or evaluated up until this point. The emergent research literature has been combed through, and these reviews have uncovered a variety of timely con cerns. Although bibliometric analysis of BI&A has been found in the literature, those contributions were conducted in different contexts than accounting research, for instance, decision-making effectiveness in the public sector, big data analytics in business, mainly in retail operations, and BI&A in manufacturing decision-making, (Vaio et al. 2022; Nobanee et al. 2021; Sahoo 2021; Aboelmaged & Mouakket 2020) the determinants of big data analytics. The last bibliometric study found is Liang & Liu (2018) which focuses on the two core disciplines of Computer Science and management information systems. Accordingly, the current paper reviews academic literature associated with "Business intelligence and analytics" and "accounting" to explore the development and research trends.

RESEARCH METHODOLOGY

TOOLS AND ANALYSIS

Biblioshiny, under the Bibliometrix R package, was used for the analysis. Biblioshiny application provides additional data statistics including author, affiliation and keyword statistics. It has the potential to introduce a systematic, translucent and reproducible review process (Derviş 2019). Generally, Biblioshiny enabled automated downloading of publication metadata, references, and citations from Scopus and Web of Science (Perianes-Rodriguez et al. 2016), allowing construction of comprehensive datasets. It also provided access to analytical and visualisation functions for co-authorship network analysis, research trend mapping, performance measurement with indices like the h-index, and temporal visualisation of citation trajectories (Aria & Cuccurullo 2017).

Network analysis was also performed through the citation analysis, by revealing that the top 10 papers based on the number of global citations, most cited authors, and the collaborative effort among countries and topical content-based classification of the existing literature of BI&A in accounting research. The search strategy and the criteria used to determine inclusions and exclusions of the reviewed literature are presented in Figure 1.

DEFINING KEYWORDS

A search was conducted in the WoS database using a combination of keywords related to Business Intelligence and Analytics (BI&A) and accounting, specifically "Business Intelligence and Analytics" or "business analytics" or "data analytics" or "Business Intelligence" AND "accounting" AND "audit". The search was limited to the "topic" option, which includes article titles, abstracts, and keywords. The WoS database was selected for this search due to its vast collection of over 85.9 million entries from various publications, including journals, books, and conference proceedings (Clarivate 2023). Besides, multidisciplinary coverage spanning science, social science, arts, and humanities with over 33,000 indexed journals (Aria & Cuccurullo 2017). After filtering the results by language, document type, and research areas, a total of 1906 articles were obtained.

SEARCH STRATEGY AND SCREENING

Two authors reviewed the titles, abstracts, and keywords of the 1906 articles, identifying 320 articles as relevant to BI&A and accounting. Articles published in journals categorised under the "Business Finance" category were included, as this category encompasses research relevant to accounting and auditing contexts. For articles categorised under "management," "economics," and "business," they were screened and only included if the content focused specifically on applications of business intelligence and analytics in accounting or auditing contexts. Articles were excluded if they did not substantially discuss applications of business intelligence and analytics in accounting or auditing, such as articles broadly focused on business intelligence in general management, marketing, or other business areas. Additionally, articles were excluded if they focused purely on technical aspects of business intelligence tools without linking to accounting or auditing practices. Duplicates were removed, and missing dates for 12 publications were manually added by comparing with the output of WoS. Finally, the 320 selected articles were used, and their full records were obtained in the "bib" extension format, which includes the article's title, author name(s) and affiliation, journal name, number, volume, pages, date of publication, abstract, and cited references.

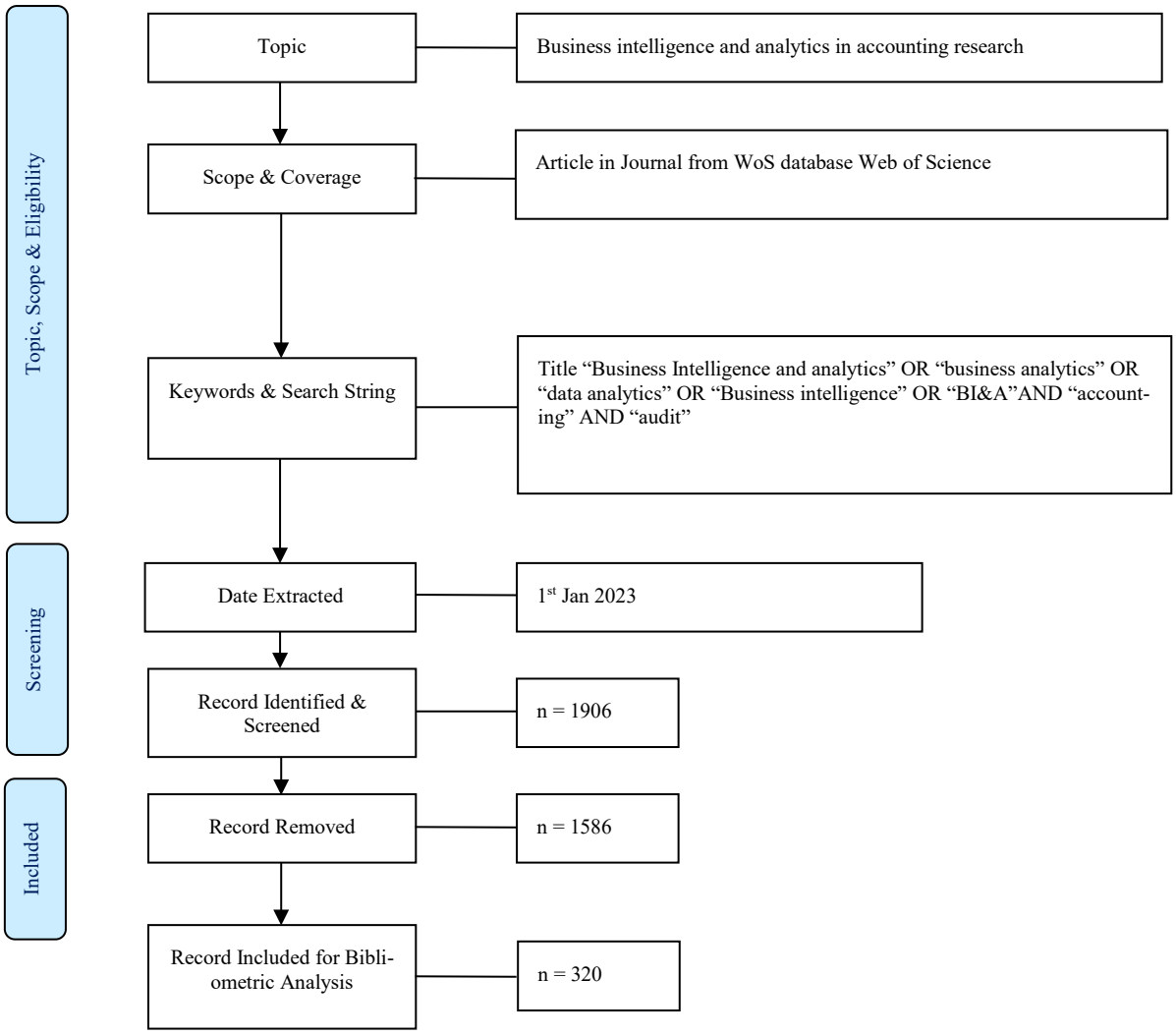


FIGURE 1. Flow of the search strategy

ANALYSIS AND RESULTS

The following sections reports the findings based on the bibliometric analysis.

DESCRIPTIVE ANALYSIS

BACKGROUND INFORMATION

The earliest paper discussing business intelligence and analytics in accounting appeared in the WOS database in 2002. As shown in Table 2, the dataset contains a total of 320 articles published between year 2002 to 2022. During the 20 years-time span, articles with BI&A themes have shown a growth rate of 24.34 percent. The dataset also revealed that 86 percent of the articles are not single authored, with around 3 authors per document. The following sections elaborate on the background information for the articles examined.

TABLE 2. Background information

Description	Results
Timespan	2002:2022
Sources (Journals, Books, etc)	126
Documents	320
Annual Growth Rate %	24.34
Document Average Age	3.79
Average citations per doc	10.55
References	1
DOCUMENT CONTENTS	
Keywords Plus (ID)	583
Author's Keywords (DE)	1074

AUTHORS	
Authors	673
Authors of single-authored docs	37
AUTHORS COLLABORATION	
Single-authored docs	44
Co-Authors per Doc	2.62
International co-authorships %	25
DOCUMENT TYPES	
Article	275
Article; book chapter	13
Article early access	29
Article proceedings paper	3

ANNUAL PUBLICATION TRENDS

A visual inspection of the annual publication trends (see Figure 2) indicates that the first published paper related to the research theme was in 2002. Until year 2014, less than 15 academic outputs of the research were published. Nevertheless, the number of publications in the field of BI&A in accounting research increased gradually, reaching its peak in 2022 with a total of 93 publications. This growing trend of published BI&A in accounting research probably indicates a growing interest by researchers. Figure 2 also shows the linear trend line that predicts the growth of the publication at the end of 2023.

The annual publication trend was further examined to provide insights into the possibilities of increasing interest in the area. Accordingly, Table 3 displays the number of articles published per year and their corresponding citations. The table also shows the total citation per article and the total citation per year.

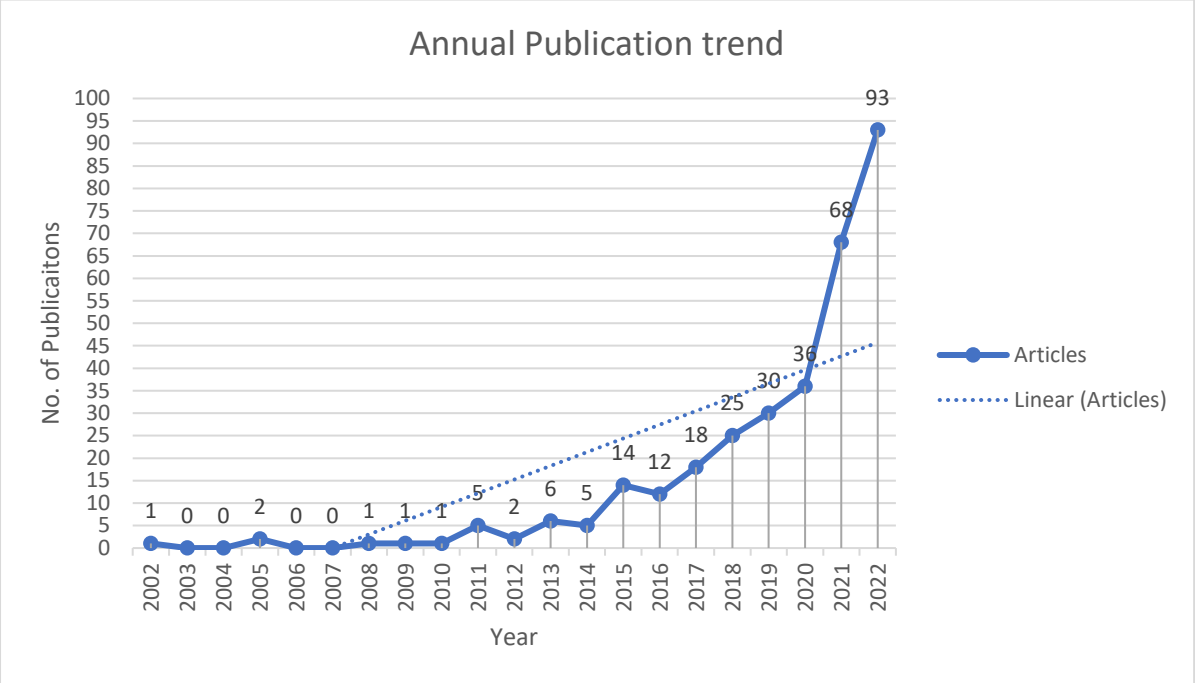


FIGURE 2. Annual publication trend

TABLE 3. Annual publication trend

Year	N	TC/D	TC/Y	Citable Years
2002	1	3.00	0.14	21
2003	0	0.00	0.00	0
2004	0	0.00	0.00	0
2005	2	33.50	1.86	18
2006	0	0.00	0.00	0
2007	0	0.00	0.00	0
2008	1	20.00	1.33	15
2009	1	8.00	0.57	14
2010	1	0.00	0.00	13
2011	5	34.00	2.83	12
2012	2	58.00	5.27	11
2013	6	15.67	1.57	10
2014	5	28.00	3.11	9
2015	14	31.43	3.93	8
2016	12	12.08	1.73	7

2017	18	24.11	4.02	6
2018	25	14.40	2.88	5
2019	30	10.20	2.55	4
2020	36	23.97	7.99	3
2021	68	2.01	1.01	2
2022	93	0.78	0.78	1
Total	320	-	-	-

Note: TP: Total publications, TC: Total Citations, TC/Y: Total Citation Per Year

The number of citations may indicate the importance and relevance of BI&A in accounting studies. It probably shows an emerging area that deserves further investigation. Compared to other established areas in accounting, the number of articles published on the intersection of the BI&A area and the accounting domain is considered low. It should be noted, however, that this small publication number could be due to the overlap in the applications of BI&A that are conducted in different management and business disciplines such as human resources, marketing, operations, logistics, and supply chain, where the articles published in those areas have been excluded from the analysis. Furthermore, BI&A has been covered from a technical orientation perspective; thus, due to specific search keywords for this study, those papers too have also been excluded.

MOST PRODUCTIVE AUTHORS

TABLE 4. Top authors contributed to the literature on BI&A in accounting

Row Labels	TP	TC	TC/Y
SUTTON SG	11	235	28.656
ARNOLD V	7	53	11.167
VASARHELYI MA	7	150	23.666
APPELBAUM D	4	215	31.953
KOGAN A	4	245	35.536
ELBASHIR MZ	4	180	16.237
GEPP A	4	96	17
KOREFF J	4	4	2
KOZLOWSKI S	4	21	3.262
O'LEARY DE	4	57	7.371

Note: TP: Total publications, TC: Total Citations, TC/Y: Total Citation Per Year

The most productive authors were gathered through the Biblioshiny application, where the frequency of occurrence of the authors' names in different domains of the bibliographic data was revealed. The author field was extracted from the data file, and the frequency of appearance of all authors was recorded.

Table 4 depicts the top ten contributing authors, their respective number of publications, total citations, and total citations per year. The data indicate Sutton S.G. as the most productive author, followed by Arnold V. Both authors affiliate with "The University of Central Florida" in the USA and have an accounting background. Browsing through their publications, their contributions in the field of accounting have most pertained to accounting information systems and emerging technologies in the auditing and accounting domains. Interestingly, authors Appelbaum D. and Kogan A., who ranked fourth and fifth with regard to the number of publications, have shown a high number of total citations. Browsing through Google Scholar H Index of Kogan is 39, while Appelbaum is 13. Compared to Sutton, the google scholar H Index is 44, while Arnold is 35. It was unclear as to what influenced an author's citation at this moment, but further examination of which journal the author published their article would probably reveal some insights.

MOST CITED ARTICLES

The top-cited article determines the popularity and acclaim of the article (Guo et al. 2021). The initial citation analysis in the R package revealed that the top 10 papers were based on the number of global citations. The article with the highest citation (total citation of 605) is Wu et al. (2020) and focuses on conducting linear programming under managerial accounting tools and techniques using data analytics. The authors provided a concise summary of the primary advantages of using data analytics in this management accounting practice, as data-driven business analytics can perform highly sophisticated computational challenges of stochastic linear programming. Table 5 provide the list of ten most cited articles with the paper titles and citation counts.

TABLE 5. Ten most cited articles

Author	Title	TC	TC/Y
Wu et al. (2020)	Application of stochastic linear programming in managerial accounting scenario analysis approach	605	201.67
Brown-Liburd et al. (2015)	Behavioural implications of big data's impact on audit judgment and decision making and future research directions	115	14.38
Elbashir et al. (2011)	The role of organizational absorptive capacity in strategic use of business intelligence to support integrated management control systems	113	9.42
Bhimani & Willcocks (2014)	Digitisation, 'big data' and the transformation of accounting information	111	12.33

Cao et al. (2015)	Big data analytics in financial statement audits	108	13.5
Appelbaum et al. (2017)	Big data and analytics in the modern audit engagement: research needs	105	17.5
(Abbasi et al. 2012)	Meta-fraud: a meta-learning framework for detecting financial fraud	102	9.27
Appelbaum et al. (2017)	Impact of business analytics and enterprise systems on managerial accounting	100	16.67
(Gepp et al. 2018)	Big data techniques in auditing research and practice: current trends and future opportunities	74	14.8
Richins et al. (2017)	Big data analytics: opportunity or threat for the accounting profession?	70	11.67

Note: TP: TC: Total Citations, TC/Y: Total Citation Per Year

MOST PRODUCTIVE COUNTRIES

TABLE 6. The country's scientific production and countries total citation of BI&A in accounting

Country	TP	CSP	%	SCP	MCP
USA	134	434	42%	122	12
Italy	18	46	6%	16	2
Australia	16	48	5%	12	4
United Kingdom	16	50	5%	9	7
China	13	55	4%	9	4
Canada	9	26	3%	6	3
Germany	9	22	3%	8	1
Norway	7	17	2%	1	6
India	6	15	2%	4	2
Jordan	6	15	2%	0	6

CSP: Country's scientific production, SCP: single country publications, MCP: multiple country publications

Table 6 presents the data on countries with high publications for articles of BI&A in the accounting area. These countries are led by the USA, followed by Australia and Italy, the UK, China, Canada, Germany, and Norway. The USA is the most productive country, where total publication encompasses almost half of the publications in the area for the 20 years' duration. The data indicates that this country, by far, has the most globally cited articles. Table 6 also displays the two key indices that can be used to analyse international collaboration. Single country publications (SCP) and multiple country publications (MCP) show intra-country and inter-country collaboration, respectively. Again, the US dominates the list in both MCP, or international collaboration, and SCP. The analysis from this study did not provide insights into why a particular country become a lead into this research area, yet general information on the USA indicates that money and resources available in US universities and research institution enables them to hire and retain best talent and provide them the proper resources needed for good research (Lu, 2022).

MOST FREQUENT JOURNALS

The initial statistics show that 126 journals have contributed to the publication of 320 articles. Notably, almost half, or 159, of the identified publications were published by only 15 journals. The Journal of Emerging Technologies in Accounting (*JETA*) has the highest number of publications, followed by Issues in Accounting Education and International Journal of Accounting Information Systems. The highest h-index is connected to *JETA* with a value of eight, followed by *International journal of accounting information systems* and *Accounting horizons* with an H-Index of 7.

MOST FREQUENT KEYWORDS

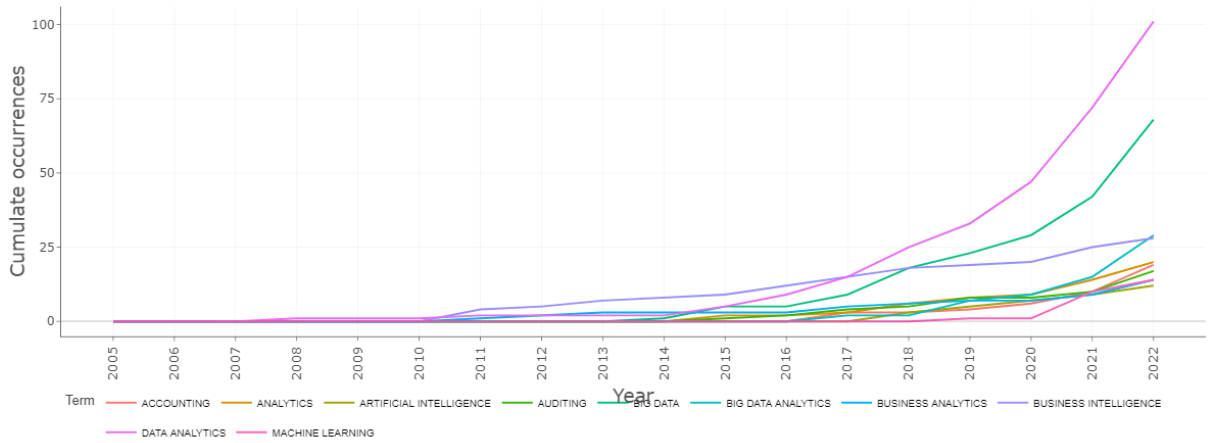


FIGURE 3. The keywords dynamics (Authors' keywords)

The most frequent keywords used in the authors' publications are illustrated in Figure 3. As seen from the figure, "data analytics" and "big data" are the top two keywords with a high frequency of occurrence, which is far larger than other used keywords in the authors' categorised keywords. Increasingly, the "data analytics" keyword is at the top of the

publication's titles and authors' keywords. The other keywords include business intelligence, big data, business analytics, accounting and auditing. Based on the frequency of the keywords used, it is evident that there is overlapping and interchangeability between using BI&A as "data analytics" and "business analytics" and connecting it to big data. Apparently, the main functional role of BI&A emerged when the data grew to a massively huge volume and rapidly changed.

Table 7 shows the search for keywords in both authors' keywords and the title of the articles published in the accounting area. Again, it appears that the word 'data analytics' was most commonly used in this area of research studies.

TABLE 7. Most frequent keywords in authors' keywords and titles.

Author Words	Occurrences	Title Words	Occurrences
data analytics	101	data analytics	98
big data	68	business intelligence	22
big data analytics	29	audit data	12
business intelligence	28	machine learning	12
analytics	20	business analytics	9
accounting	19	internal audit	7
auditing	17	management accounting	7
business analytics	14	risk management	7
machine learning	14	accounting information	6
artificial intelligence	12	artificial intelligence	6
data	12	audit quality	6
management accounting	11	accounting curriculum	5
blockchain	10	continuous auditing	5
business	10	data analytic	5
audit data analytics	9	emerging technologies	5
audit	8	management accountants	5
internal audit	8	management control	5
social media	8	performance measurement	5
audit quality	7	auditors' reliance	4
financial	7	external auditing	4
fraud	7	financial statement	4
fraud detection	7	accounting directions	3

The visualised cloud of keywords in the 320 publications in BI&A in accounting is depicted in Figure 6. Keyword clouds, also known as tag clouds or word clouds, are a popular tool used in bibliometric analysis for data analytics and business intelligence. These clouds provide a visual representation of the most commonly used keywords or phrases in a given literature dataset. In the accounting literature, keyword clouds can be created using different clusters to identify trends and patterns in research over time. In the accounting literature, the cluster of management accounting is presented in the green keyword clouds, the significant keywords are denoted by a huge spot. A keyword cloud for this cluster might include terms such as "performance management," and "management controls system." Another cluster shown is data analytics in accounting and auditing, which could include terms such as "accounting," "auditing," "data analytics," "big data," "machine learning," and "block chain.". Increasingly, this cluster includes different tools such as text mining, data visualisation such as the Tableau platform, and data analysis for social media. By examining keyword clouds for different clusters, the most prevalent themes in the literature are identified.

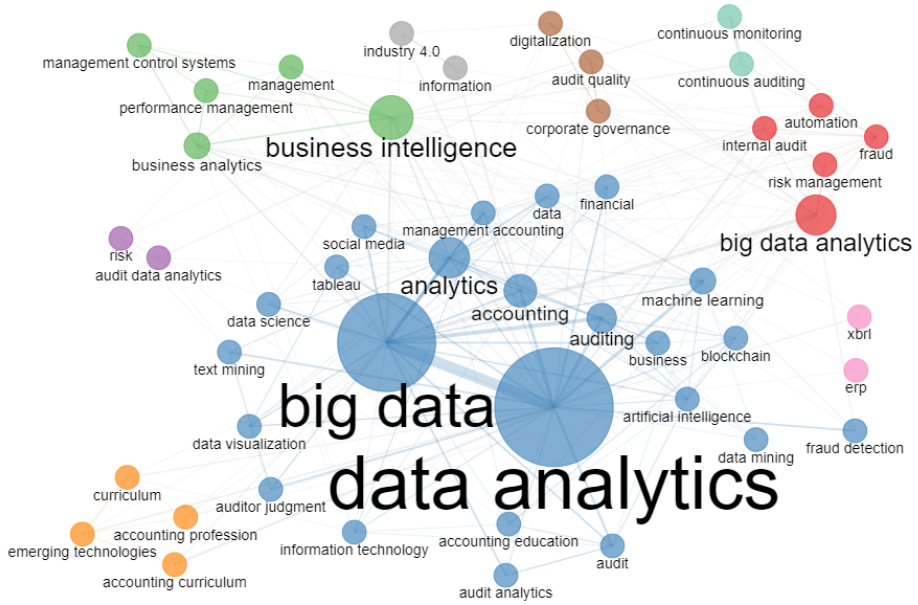


FIGURE 5. Keywords clouds

NETWORK ANALYSIS

Figure 6 presents an analysis of critical collaborations among countries. The figure effectively demonstrates that the advancement and cultivation of research in this field are primarily driven by the United States, Australia, Norway, and China. These pioneering nations exhibit robust collaborative efforts among themselves and with other countries as well.

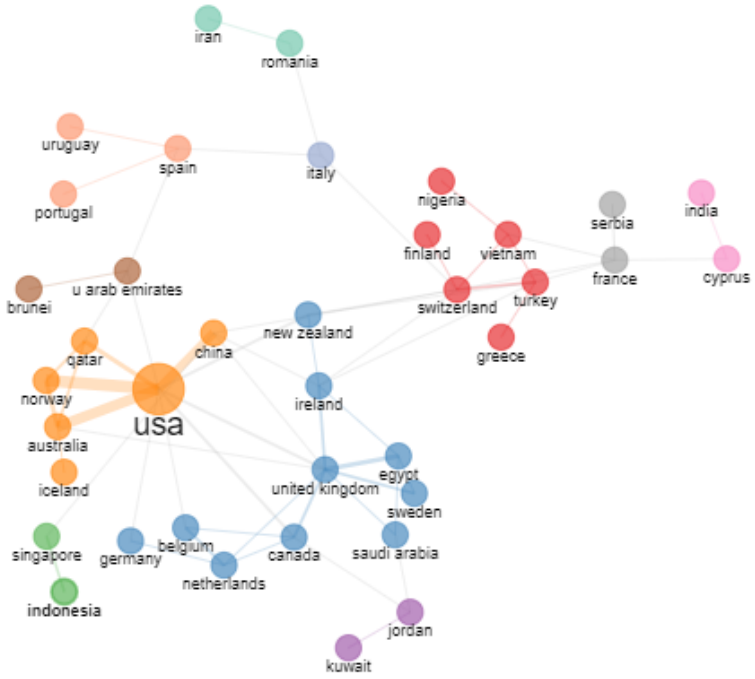
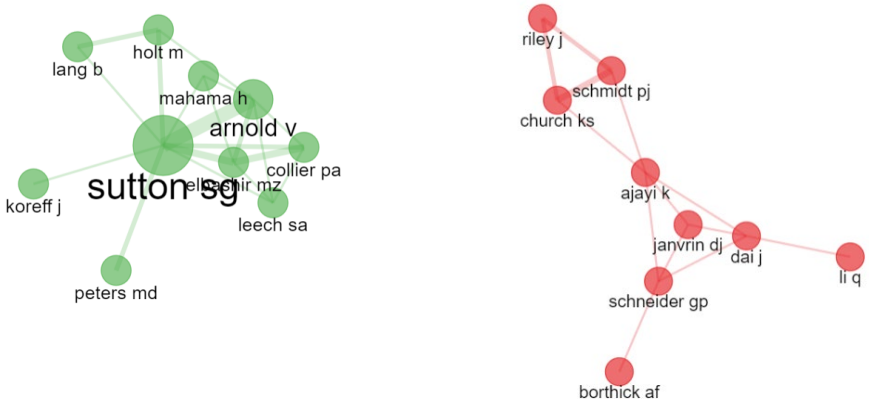


FIGURE 6. Countries Collaboration Network

The collaboration cloud figure shows some contributions from the Middle Eastern countries such as Qatar, Egypt, Saudi Arabia, the United Arab Emirates, and Jordan, while China is strongly representing Asia. According to author collaboration, Figure 7 shows the author collaboration network. As shown in the figure, there are three different groups of collaboration, where Sutton SG and Arnold V are showing a high level of collaboration in the green group, while Appelbaum D and Vasarhelyi MA show a high level of collaboration in the blue group (Arnold et al. 2004; Elbashir et al. 2013; Elbashir et al. 2021; Elbashir et al. 2021; Koreff et al. 2021).



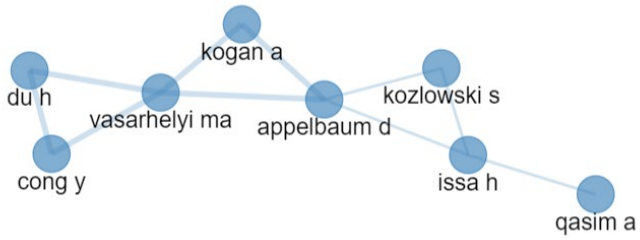


FIGURE 7. Authors collaboration network

THEMATIC EVOLUTION

This section shows the thematic evolution based on the authors' keywords for two intervals, namely from years 2002-2014 and from 2015 - 2022. Year 2014 was chosen as a cut-off point in order to show the difference in publication numbers, before and after the emergence of IR 4.0. Thematic evolution reveals information and assumptions about the topics or themes of interest before and after the cutting year. Key terms have been represented across four quadrants, according to their relative development degree or density, centrality, or frequency of use.

Figures 8 and 9 show the thematic evolution for the two intervals. Relevance degree is a metric that measures the frequency of a term within a given set of documents. This metric can be used to identify the most relevant topics in a particular set of articles. For example, by analysing the relevance degree of terms in a set of articles on financial reporting, researchers can identify the most commonly discussed topics within that field. Development degree, on the other hand, measures the growth or decline of a term over time. This metric can be used to identify the motor themes driving the evolution of the accounting literature. For example, by analysing the development degree of terms related to sustainability reporting, researchers can identify how this topic has grown in importance over time. By analysing the relevance and development degree of different terms, researchers can identify the motor themes driving the evolution of the accounting literature. For example, they might find that terms related to data analytics and business intelligence have a high relevance degree and a high development degree, indicating that this is a rapidly evolving field that is driving the thematic evolution of the accounting literature.

The upper right quadrant displays the motor themes. High centrality and density are used to classify them, as this is the most well-developed theme in the literature and the primary focus of BI&A studies in the field of accounting. The motor quadrant in the first interval shares limited themes of "business intelligence" and "data analytics" with the basic theme quadrant. On the contrary, the second interval demonstrates themes of "management control systems," "accounting curriculum," "accounting profession," "outlier detection," and "audit innovation." This explains why the well-developed theme has evolved to incorporate many practices from the accounting literature. It also shows how these sections have received the "business intelligence" and "business analytics" themes from lower density areas before 2015 to higher density areas of focus after 2015. Niche themes or high-density themes, which have a big impact but aren't widely used, are displayed in the upper left quadrant. The first interval shows only two topics, which are "corporate performance management" and "management control systems." While in the second interval, themes such as "value creation," "intellectual capital," and "audit data analytics" have risen, which might indicate that those new themes have replaced the formers in terms of researchers' interest.

The emerging or declining themes quadrant is filled in the second interval with themes of "digital transformation," "corporate governance," "ERP," "XBRL technology" in financial reporting, and financial technology. Those themes are either on the rise or on the decline and are found in the bottom left quadrant. Those themes did not seem to occur in the accounting research before 2015, which might indicate that those themes are emerging themes. For example, the theme of extensible Business Reporting Language (XBRL) has been used in many solutions to collect, store, process, and disseminate accounting information. This experience has emerged in accounting research, although this technology has been around since the early 2000s (Guo et al. 2021). On the contrary, digital transformation is an emerging theme in association with the main keywords in this research, most probably due to the pandemic impact on business. The lower right section displays the overarching and foundational ideas presented throughout the research area. Topics in the second interval range from "data analytics," "big data," "internal audit," "dynamic pricing," "tableau" visualisation, "management accounting," and "machine learning." These topics have been determined to be more central, although they receive less attention. These issues must be taken into consideration in future accounting studies, and studies can expand to cover the various subcategories of these issues, particularly within the IR 4.0 framework.

In sum, this section presents the results of bibliometric analysis on the thematic evolution of the accounting literature based on authors' keywords between years 2002-2014 and from 2015 - 2022. Using the relevance and development degree metrics, the motor themes driving the evolution of the literature was identified. Specifically, the upper right quadrant represents the most well-developed and central motor themes in the literature, while the upper left quadrant displays niche themes with a big impact but are not widely used. The emerging or declining themes are shown in the bottom left quadrant,

which contains themes that were not present in the accounting research before 2015, such as digital transformation, corporate governance, and financial technology. Finally, the lower right section highlights foundational ideas that should be considered in future accounting studies, particularly within the IR 4.0 framework.

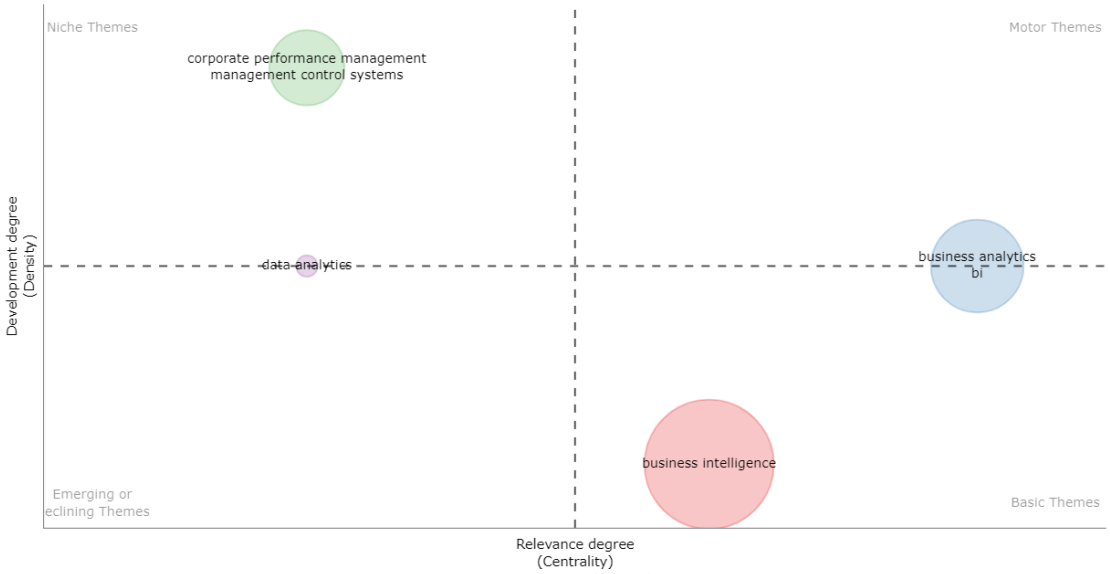


FIGURE 8. Thematic map (2002 – 2014)

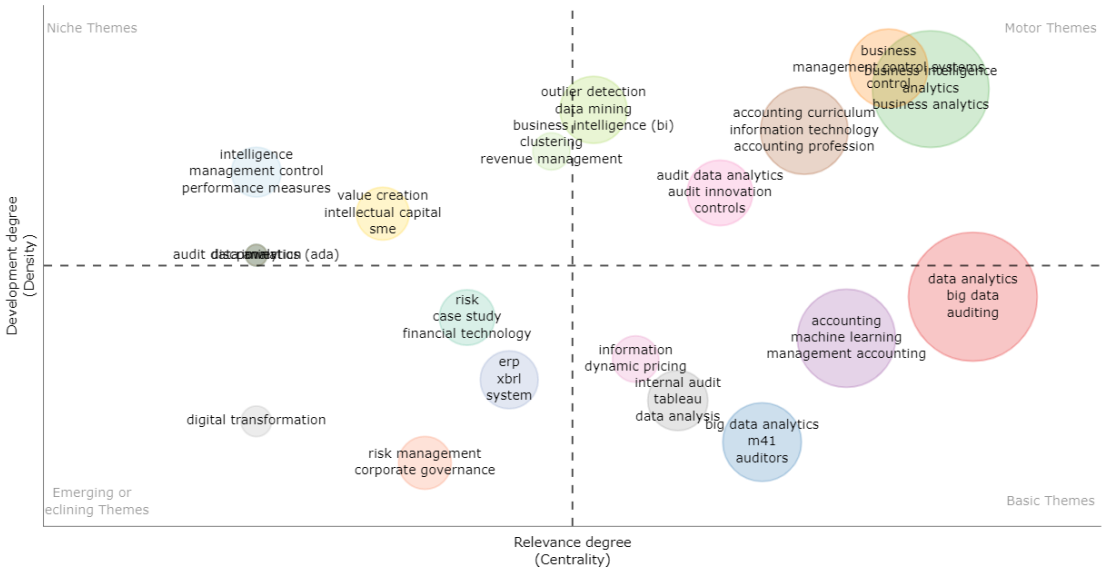


FIGURE 9. Thematic map (2015 – 2022)

DISCUSSION

The last two decades have witnessed the emergence of the discussion of BI&A in various accounting domains, including financial accounting, management accounting, and auditing. Despite the increasing importance of BI&A in accounting studies, as of the year 2020, it has been determined that future scholars will be more critical of the issue under discussion, particularly in terms of the research clusters that are appropriate to cover in order to fill the significant current gap. According to our findings, only a small number of academics are responsible for a disproportionately large share of the most prominent bodies of work (Sutton, Arnold and Kogan with google scholar h-index of 44, 35 and 39 respectively). However, as time goes on and the industry continues to develop, more authors have joined the sub-discipline of accounting, which has resulted in an expansion of the work in a number of different fields. It seems that many of the studies that have had the most impact have been published only in the past five years. This outcome should not come as a surprise, given that it occurred around this time when the level of scrutiny applied to the research began to increase. The recently published works, within the last two to three years, have not had the opportunity to gain as much traction as they could have because

citations have not yet accumulated. This is due to the fact that management and business research typically require a longer period of time to build up citations.

Accounting researchers may proceed with analysing the various BI&A activities from different stakeholder perspectives (accountants, investors, management, and government). The increasing interest in studying BI&A and its related technologies may have started due to the pandemic that started early in 2020. This possible reason can be linked to the jump in the number of publications in 2020. The successful integration of BI&A methodologies into managerial accounting practices provides many benefits for management accounting. Given that management accounting is a decision-supporting activity, there is a natural connection between BI&A and management accounting. However, contributions and efforts in this area reside in the low-density area of the thematic map, which signifies that further research is still required in this area.

The geographical distribution of the works demonstrated that the United States, which is home to numerous extremely influential publications, appeared to be in possession of the highest number of works, with Europe following close behind. Alongside the countries of the Middle East, there are indications that the effort is beginning to spread into Asia as well. Visualisation of the keywords indicated that data analytics has been widely engaged in the publications, showing that authors are using business intelligence, business analytics, and data analytics interchangeably (Chen et al. 2012; Lim et al. 2013). However, this would neglect the main technical difference between each technology as well as the skillset required to apply and employ the technology (IBM 2021).

The implemented research in the era of industry 4.0 has shown the emergence of themes that emphasize on technological innovations that integrate more automation, controlling and information technologies. For example, big data analytics which deal with massive volume, variety and velocity of data had increased with the increase of digital transformation or business and individuals. Machine learning, for example, robotics, can link computers with machine learning algorithms, allowing different systems to learn from data and improve in response time, accuracy, and flexibility. Increasingly, the visualization, represented in Tableau as an emerging-customizable technology, has been found in the current research. Comparing this with the research conducted in the IR3.0, we can find some contributions in the intelligence systems, and negligible contributions in the data analytics and business analytics. This implies that at this time those themes in the accounting domains were not thought-provoking. In addition, this indicates that appropriate BI&A and big data technologies were not adopted and integrated in the IR3.0 to meet the requirements for data gathering, storage, processing, and analysis. The emerging themes in the IR4.0 have been engendered from the dominant journals in the research scheme which are *JETA*, Issues in Accounting Education, International Journal of Accounting Information Systems, which have impact factors of (0.69, 0.30, and 1.26) respectively (Clarivate Analytics 2022). This may signify that those sources would lead future research of BI&A-related topics in different accounting domains, especially for the themes such as achieve automation in accounting, conduct time series analysis to exploit accounting information, continuous auditing, emerging accountants' skillsets, cognitive computing to conduct accounting tasks, visualisation using dashboards and storyboards, blockchain, and risk management of digital assets. It is probable that those themes are influenced by the influence and contribution of affiliations. For example, it has been found that the top three affiliations of Rutgers State University (US), University Central Florida (US), and NHH Norwegian School of Economy (Norway) are most frequent entities to exercise and practice the themes.

The findings of this study proves increasing interest around the globe in research on BI & A technology and accounting area. As such, these findings are beneficial not only to academicians and researchers, but also to professional accounting bodies such as the Chartered Institute of Management Accountants (CIMA), American Institute of Certified Public Accountants (AICPA), institute of management accountants (IMA), and institute of internal auditors (IIA). Professional bodies may benefit from such studies on BI & A role towards advancement of accounting functions such as enhanced capabilities in audit engagement, detecting financial fraud, accuracy in monitoring performance and risk. Accordingly, those institutions can renovate their knowledge and competency framework in which they assess their members and affiliates with the most contemporary topics for accounting and finance professionals.

CONCLUSION

The current research paper envisaged the current state of research that integrates BI&A technologies in accounting domain through a bibliometric analysis.

The research has articulated comprehensively necessary data about the publications analysed in this study, stressing essential information such as publication years, article type, sources, and document content. The analysis reveals that several sources namely, *JETA*, Issues in Accounting Education, International Journal of Accounting Information Systems appeared as dominant journals providing significant publications that merge the issues of BI&A technologies within the accounting domain. The analysis also provide key information on annual publication trends, the most productive authors, the most cited papers, the most productive countries, the most productive institutions or affiliations, the most productive source titles, the top keyword collaboration analysis, and the thematic map of the theme study in the BI&A in accompanying research. In sum, the analysis presents a visualisation of emergent research themes that emphasize on technological innovations with specific numbers and figures. Referring to Figure 8 and 9, it appears that the accounting domain that received consistent attention in the BI&A studies is the management accounting and control area, while BI&A within

auditing evolves rapidly during the IR4.0. Despite various reforms in the public sector, the keywords presented from the analysis indicate that this domain in accounting is currently not visible in the studies reviewed.

To the knowledge of the authors, this paper has presented among the first studies to concentrate on bibliometric research in accounting information systems fields. In reality, this paper has highlighted key areas where future research should concentrate. BI&A and other associated technical advances have a significant impact on all industry stakeholders. This bibliometric analysis enriches our knowledge of the crucial feature of BI&A research in the accounting field.

In interpreting the findings, certain limitations of this study should be acknowledged. One limitation is the keyword-based search approach for BI&A publications in accounting. Because the search is using a combination of keywords and the keywords plus strategy (which are terms that appear frequently in citation titles but are not necessary in the article's title or author keywords), it is not guaranteed that all of the published articles related to the subject area will be included. Nevertheless, it is believed that this study has covered an adequate quantity of previous work in the fields of accounting and BI&A. The online database that was used for this research is the second limitation that should be highlighted in this study. The WoS online database is extensively utilised throughout this research as the primary source for bibliometric analysis. In this particular instance, the search can be constrained due to the selection of this database. Future studies may combine different types of review databases to improve this study.

The Scopus database could probably complement the WoS database in future to enable a more comprehensive bibliometric analysis.

The geographic distribution of the literature showed that the US has the most significant number of publications and influence and expanding to the UAE. Notably, the impact of the BI&A on firms is worldwide. Studies should also be expanded to other emerging economies facing rapidly changing social, economic and political landscape.

Future research may also explicitly investigate the subject of BI&A and its different applications in areas under management accounting such as marginal analysis, risk management, pricing, cost management methodologies, value chain analysis, financial statements. Specifically, prospective academics might investigate the problem of data quality and different methodologies to improve data quality in the accounting context in greater depth in the future. It is possible for the inquiry to be carried out by a variety of organisations, including those in the private and public sectors as well as professional accounting bodies.

Notably, within the management and control area, measuring internal management such as budgeting and cost accounting still receives little consideration. Potential research lines can be associated with the utilisation of more focused management accounting techniques for the purpose of locating and evaluating, from among a variety of BI&A applications, the most appropriate technology to be implemented in businesses. This is consistent with what Rikhardsson and Yigitbasioglu (2018) have suggested that BI&A and digitalisation are quickly becoming important research area to investigate in the field.

On top of the contribution to future academic knowledge, the study contribution to practice should also be acknowledged. Managers of service or manufacturing operations may benefit from the knowledge found in studies on BI&A in accounting as it provides evidence on the escalating needs to specialist working in departments with integrated knowledge and focus in order to sustain in contemporary business setting. Accordingly, universities should offer appropriate interdisciplinary courses relevant to current needs in the market. Government or funding agencies should then focus on studies that bridge the gap in knowledge between IT and accounting in order to be relevant to industry needs. Thus, the 'core' articles that have been identified may serve as a suitable beginning point for those who are interested in conducting research in the subject area as well as for educational purposes.

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