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Review Article

Big Data Analytics and Auditing: A Review and Synthesis of Literature

Yaseen A. A. Hezam [1*], Lilian Anthonysamy [2], Susela Devi K. Suppiah [3]

[1] *Faculty of Information Science and Technology, Multimedia University, Selangor, Malaysia.*

[2] *Faculty of Management, Multimedia University Cyberjaya, Selangor, Malaysia.*

[3] *Department of Business School, Sunway University, Subang Jaya, Malaysia.*

Abstract

The use of data analytics in auditing is increasingly growing. The application of common data analytics to audit engagements appears to be lagging behind other areas of practice, even though data analytics is thought to represent the future of audit, and there are still few publications that have examined this influence. This article reviews data analytics in audits and its potential for future audit engagements to describe the evolution of this research trend and picture its future growth directions. Future audit research potential and difficulties are also discussed. Data analytics application in auditing has enormous potential for refining audit quality, decreasing errors, increasing process transparency, and enhancing stakeholders' confidence. We conducted a systematic literature review using the PRISMA approach. A total of 100 articles published in English from January 2011 to November 2021 were identified through a systematic search of reputed databases, including Web of Science and Scopus and many others. Our analysis reveals that data analytics is a promising domain for the auditing practice as it improves audit efficiency and promotes audit work digital transformation. While reviewing the most pertinent literature in the context of data analytics in auditing, this study offers insights on potential new directions and waning views on big data analytics in auditing.

Keywords:
Data Analytics;
Big Data;
Analytics in Auditing;
Future Audit Practice;
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1- Introduction

Technological advancement has propelled business leaders to develop and implement digital transformation strategies to ensure the sustainability of their businesses. Public accounting is no exception, as it is an industry with potential revenue growth in its main business of external auditing. Furthermore, [1] observed that although practitioners have utilized computer-assisted auditing tools (CAAT) for a long time, adopting new technologies still poses challenges and resistance. However, Justenhoven et al. [2], Chedrawi & Howayeck [3] believe that such a mindset has begun to change as emerging technologies, such as blockchain, robotic automation, cloud computing, and big data are gaining prominence in the audit of financial statements.

Financial reporting has evolved and has gained significance as a primary task of accounting with implications for business performance [4]. Big Data changes the nature and operationalization of these businesses, allowing them to trace financial activities more efficiently [5]. The concept of "big data" has dramatically impacted business management and compelled companies to reconsider their strategies and adopt intuitive and meaningful methods to exploit available information [6, 7]. Paul et al. [8] discuss the challenges of technology development and real-time information, which call for the utilization of more up-to-date approaches to auditing. Hence, using emerging resource databases and

* **CONTACT**: yaseen.abdullah@mmu.edu.my

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analytical methods can consistently provide auditors with high-quality assurance services, which may facilitate their profession.

The usage or adoption of big data is also based on the company's market orientation [9]. The companies operating in small domestic markets have small data. Thus, they adopt the traditional auditing methods, whereas the big companies or companies operating in big markets employ big data and business analytics approaches to ensure more effective auditing [10]. Big data and the approaches associated with data analysis are known as data analytics or predictive analytics. It has been accordingly reported that in addressing data analytics competencies, university programs have been developed rather swiftly [11]. In August 2014, at the American Accounting Association (AAA) annual meeting, a panel session co-sponsored by PricewaterhouseCoopers and the University of Illinois deliberated adapting the accounting curricula to incorporate more data analysis courses [12]. It was agreed that students must learn to become data scientists in order to be competent in both audit and tax.

Big data is expected to be comprehensively employed in future business [13, 14]. Hence, for businesses to remain competitive, they need to be abreast in their data analytics competencies, or dire consequences can be expected [15]. Auditing companies can use data analytics to reduce the risk of irrelevant or wrong conclusions and better understand their client's business environment [7]. In addition to big data, data analytics can also help improve audit quality [16]. In the 2014 KPMG survey of CFOs and CIOs, nearly all (99%) admitted the importance of data and analytics to their business strategy, and nearly all (96%) indicated that they were able to utilize big data within their organizations in a better manner. Biglari & Pourabedin [17] show that auditors rely on big data analysis tools to improve the depth and quality of audit services. Therefore, big data analytics helps promote accounting firms' legitimacy and social credibility. Accordingly, like other service organizations, public accounting firms are highly compelled to make superior and more comprehensive data analytics services available to their clients. Still, the burning question is: How do these firms achieve this in reality? Another question relates to whether (or not) auditing, the core business of public accounting, will benefit from an investment in data analytics capabilities or whether data analytics is eventually more helpful in the consulting services these firms offer

Accordingly, this paper seeks to achieve two objectives: First, describe the relevancy of data analytics to auditing firms and explain how it can transform how audits are executed. Second, explore the extant audit research to synthesize the opportunities and challenges associated with data analytics. Data analytics in the auditing field has been highlighted by scholars [18-20]. Nonetheless, many of these works were mainly for developing the frameworks for approaching the data analytics-associated literature, as in Alles and Gray [19]. There is a body of research questions [20-22] that could be valuable for future studies. The analysis of raw data to detect trends and answer questions is known as data analytics. Data analytics approaches and methods have been mechanized into physical methods and algorithms that operate over original data for human utilization. Data analytics can help a business to improve its operational efficiency. The data analytics approach has been investigated in many studies in different contexts supporting high-velocity data capture, storage, and analysis: the data analytics and business process innovation [٢٣], data analytics and decision-making [٢٤], data analytics and health care [25], data analytics and marketing [26, 27], data analytics and accounting [28, 29], and data analytics and the green supply chain [30]. However, there is a large body of research articles in the last five years that indicate its significance (We found 8050 articles on Google Scholar whose titles contained the data analytics keyword and were published from 2016 to 2021).

To achieve the objectives stated above, we conducted a systematic literature review of articles published in reputable journals for the last ten years (2011–2021). Moreover, various types of articles, such as empirical vs. conceptual, geographic publication, location, data collection methods, and the different themes presented in these published articles, are also explored using the PRISMA method. Nonetheless, partly owing to a lack of information from public accounting firms concerning the approaches they were employing concerning data analytics, empirical academic research on its application in auditing is still highly rudimentary. Accordingly, the general focus of data analytics areas for driving the research questions applicable to public accounting firms, users of financial statements, and regulators will be addressed in this paper

2- Background on Big Data and Data Analytics in Auditing

Big data technology has gained prominence in various sectors, including government, business, science, and research [31]. This technology is also popular in accounting and auditing, as companies commonly deal with an unprecedented level of semi-structured and unstructured colossal data, thus needing to promote innovation, effectiveness, and competitiveness. Meanwhile, recognizing opportunities in many areas has expedited the emergence of big data [32-35]. Big data has been described as high-volume, high-velocity, and high-variety information assets, which call for the utilization of cost-effective, innovative forms of information processing to enhance insights and improve decision-making [36].

Big data is colossal, encompassing unstructured data generated by people, transactions, and machines. It consists of four Vs: volume, velocity, variety, and veracity. Volume refers to the amount of the generated data, while velocity refers

to the speed of the data production and analysis [37]. In this regard, with the fast generation of new data, information can render useless faster. As for variety, it signifies the diverse generated data forms, while veracity relates to the reliability matters of the data [38]. Standard tools could not efficiently examine the complex datasets of big data [39].

Data analytics refers to examining, cleaning, transforming, and modeling big data to identify and communicate valuable information and patterns, proposing conclusions, and supporting decision-making. Accordingly, computerized tools will allow patterns and anomalies in large and unstructured datasets to be identified, allowing the discovery of concealed information. Many domains of business are already utilizing data analysis [40]. A study investigating the use of DA in the audit process of external affiliated audit firms in Jordan found that the Jordanian audit profession implemented big data analytics to manage large amounts of data and detect errors, risks, and fraud [41]. In addition, analyzing consumer trends and other patterns allows consultancy firms to determine the best course of action to decrease costs or increase revenues for a given company [42]. Big data, data analytics, and artificial intelligence have enabled accountants to create greater value for businesses by increasing revenue and optimizing operations [43]. Due to its relevancy to the auditing context, we employed the data analytics suggested by Byrnes et al. [44]. Data analytics in auditing encompasses the science and art of discovering and analyzing patterns, recognizing anomalies, and extracting other valuable information in the essential or applicable data to the audit theme through analysis, modeling, and visualization to allow the planning or execution of auditing. They further introduce two distinct approaches to data analytics: exploratory (inductive) and confirmatory (deductive). Exploratory data analytics is mostly used within the planning phase of the audit to understand the firm, recognize and evaluate risks and devise additional procedures. Confirmatory data analytics is employed in the final two phases.

Substantive procedures are adopted to ensure the accuracy of the items in the financial statements. Confirmatory data analytics is used to decide if there are material misstatements in the financial statement. Wang and Cuthbertson [22] address the prospective significance of big data and big data analytics (BDA) within innovative auditing. The general domains of big data and BDA within the setting of external auditing have been scrutinized in several studies [1, 45, 46]. As indicated by some (e.g., [20, 47, 48]), for the assurance of audit quality, the application of BDA is both fitting and useful. It has been mentioned in some studies (e.g., [7, 49, 50]) that BDA may increase the efficiency and effectiveness of financial statement audits, while reducing audit risks [14]. However, more competencies and technological competencies will be needed in BDA implementation [25, 51, 52].

Nonetheless, the application of BDA in auditing seems to lag behind other research streams [50, 53]. Furthermore, extant studies do not address the necessity of implementing BDA by companies. Notably, the analysis of an audit is based on two processes: the audit process between the audit firm and client and the audit process between the audit firm and regulatory bodies. Big data was not accessible until only recently with the availability of powerful analytical tools. Nonetheless, the utilization of big data information or the implementation of BDA by the institutional forces at the corporate level is still unclear.

2-1- Data Analytics in Auditing Firms and Research Direction

Data analytics can be used in various domains, including the investment domain for public accounting firms, particularly in advisory (consulting) practice, tax, and auditing. Accordingly, companies gather enormous amounts of data that can be concerned with customers, rivals, and the outside environment. In this regard, it is not uncommon for companies to not know how to handle the next step of analyzing and using the data in their business operation. KPMG [54] reports that most respondents (85%) indicated figuring out how to best analyze the gathered data as among their biggest challenges.

Public accounting firms show a different approach to data analytics in auditing compared to the advisory practice. Here, the focus is more on increasing the effectiveness and efficiency of audits rather than on innovation and competing on visually appealing analytics for impressing the clients. However, it has been observed that, as opposed to other domains (e.g., advisory and forensic investigation), data analytics adoption within the domain audit has been slower [55, 56]. Considering the concerns of liability and the auditing environment that is heavily regulated, firms should venture into data analytics with more caution, especially within the audit practice. Still, data analytics is considered the future of audit [57, 58]. Since the introduction of paperless audit tools and technologies, data analytics has become the most significant shift in how audits are performed [59]. Within the audit context, data analytics is both beneficial and challenging, as discussed below.

A large host of research, including general reviews and conceptual articles, addresses the concept of big data and data analytic tools, producing significant results. Accordingly, the three most popularly used essential dimensions of BD are known as the 3Vs: volume, variety, and velocity. It was first introduced in [60], which addressed 3D data management by controlling data volume, variety, and velocity. Big data in many business studies has been regarded as a new opportunity for improving companies' productivity, efficiency, and innovativeness [31, 61, 62]. For social research, big data is both encouraging and challenging, which is also true about accounting and auditing as they are intrinsically data intensive. For the environments of accounting, Warren et al. [62] indicate the increasingly significant implications of BD

in all contexts, even as new kinds of data become available, as will the integral technological paradoxes of BD and corporate reporting [63-65] and new performance indicators grounded upon BD [66].

Cao et al. [40] describe BDA as the process of inspecting, cleaning, changing, and modeling BD for discovering and communicating valuable information and patterns, recommending conclusions, and supporting decision-making. In BDA, "*smart*" algorithms are employed [67]. Wang & Cuthbertson [22] highlight BDA's significant potential in improving the auditing practice. Generally, a comprehensive review of past relevant work can be considered the research initiation. Also, recognizing the applicable research within a given domain is crucial. Hence, this study is initiated by a literature review on BD, BDA, and auditing. In this regard, the method used for the literature review is research synthesis, as it involves the utilization of the prevailing literature [68, 69]. Accordingly, the literature review delineates several primary directions and potential influences of BDA in the auditing context. As highlighted by some, the utilization of BDA is valuable in audit quality assurance [20, 40, 48] as it enhances the efficiency and effectiveness of financial statement audits and the utilization of BD as audit evidence. Another research stream focuses on the necessary additional competencies for assuring an effective process in BDA utilization [51]. Accordingly, the need to incorporate big data and BDA-related issues into the accounting curriculum has been highlighted [70-72] as these technologies transform the accounting professions [8, 73, 74].

We have focused on the role of changes in auditing standards. The available standards do not hinder or prevent the application of BDA [75]. However, the economics of external audits can hinder or even rule out the use of analytics. Meanwhile, [76] the use of audit evidence has been evidenced as the key methodological problem. BDA evidence is less reliable for audit evidence [77]. As such, it has been indicated that [21, 48, 78] changes within the methodological audit approach and the standards to focus on data, the processes that create these data and the analysis thereof, as well as the changes within the nature of accounting records and auditing domains, will add value and significance to the accounting profession. Furthermore, updated standards may facilitate addressing the auditing profession's clear unwillingness to use BDA [50]. The last research stream elaborates on the technological challenges that companies have to face when employing BDA, particularly regarding continuous auditing technology [53, 79, 80] and BD techniques [50, 75]. Accordingly, the audit analytics used in many audit stages have been classified [52]. It should be noted that external auditing relates to the characteristics of business clients. The innate technological paradoxes of BD utilization in corporate reporting are recognized in [64].

The literature review shows that the main streams of research are highlighting the outcomes and value of BDA utilization within the context of auditing, the aspect impacting the efficient BDA utilization, the interaction between BDA and the conventional data sources, and the effect of BDA on audit judgment and behavioral research. Also, in auditing, BDA usage can be impacted by external conditions and the environment. Still, it can be stated that past studies on this subject are fragmented, showing diverse but restricted aspects that motivate or oppose BDA utilization within the context of auditing.

2-2- Opportunities of Data Analytics on Audits

Many researchers have discussed the benefits of big data, particularly data analytics, emphasizing the adoption of data analytics in accounting/auditing practices [81, 82]. The disparities between diverse reporting and accounting standards could be removed with the help of big data and data analytics [62]. Moreover, adopting data analytics can "accelerate the movement toward a global accounting regime with fair value accounting as a key cornerstone". The application of data analytics to audits is beneficial in four major ways. First, it allows auditors to test more transactions, considering that data analytics increases sufficiency, that is, the correct amount of audit evidence. The risk-based model and sample transactions are used to determine the fair statement of account balances. The utilization of data analytics will enable auditors to automate the testing of transactions; theoretically, the entire population is testable. Accordingly, Jim Liddy, as the Vice Chair of Audit and Regional Head of Audit for the America's practice of KPMG LLP, believes that high-powered analytics are predicted to be used in the future, allowing auditors to examine all transactions by sorting, filtering, and analyzing colossal amounts of transactions in the identification of anomalies, consistent with other DA discussions in the literature [20, 56, 83, 84].

Anomalies encompass situations where the data contradict the auditor's expectations based on their familiarity with the client's business, as can be exemplified by sales to customers recognized as non-creditworthy or bankrupt by the client, which generally would lead to no sales records for such customers, thus facilitating the treatment of potential concerns and drilling down on those items with the potential highest risks. Consequently, auditors could quickly evaluate risks and identify trends via the audit process. The implementation of data analytics increases the audit quality because it makes more available insights into the processes of clients [57] by allowing auditors to establish a database comprising knowledge of each engagement transferrable every year. This can be exemplified by the information about the resolution of those anomalous transactions. It will inform auditors in the following year as expectations are established.

2-3- Challenges of Data Analytics on Audits

The potential of data analytics for audit quality improvement has been affirmed [47]. However, several challenges to the extensive implementation of data analytics on audits have been equally reported. The literature shows that these challenges relate to the training and expertise of auditors, data availability, relevance, integrity, and expectations of regulators and financial statement users [85]. Many researchers and practitioners have highlighted the challenges of data analytics in different domains, particularly in auditing [22, 40, 86]. The biggest challenge of using data analytics in auditing can relate to data destruction [87]. The auditor can lose the data while filtering it or any cyber-attack. Another challenge for an auditor is job loss because everything, including registering, controlling, and auditing data, will be automatic [16]. The auditing business appears to lag behind in the application of data analytics [88-89]. There are consistent reports on auditors' inability to keep abreast of the latest technological developments [88]. Auditors appear to lack the needed skills to implement data analytics, which has contributed to the lack of its use in the auditing domain [46]. These emerging technologies are claimed to pose a threat to accountants. Experts argue that those not coping with this change appreciate the new features technology has left behind [90].

Meanwhile, accountants understand the impact of debits and credits on the balance sheet or income statement and the costs of overstating or understating accounts [91]. Accountants also understand how risks associated with the financial statement can be reduced. The use of data analytics calls for a different skill set, and as indicated in Brown-Liburd et al. [20], data analytics recognizes patterns and correlations that should be analyzed. For this purpose, a different data use approach must be employed to reach the conclusions [92]. The auditor must acclimate to this novel financial and non-financial data analysis method to ensure a more efficient and effective audit [93].

There are challenges of the four Vs that signify big data. As mentioned in Aljarallah & AlShathry [39], the high data volumes will need storage and analytical programs with high rates of data processing in order to preserve efficiency. Another challenge is the variety of data, considering that it may be challenging to analyze different data types. Numbers from texts or graphs are different from one another. Still, both carry information that can impact the audit's conclusion [93, 94]. Data analytics extracts and processes massive amounts of data, in addition to generating much data at a speedy pace [38]. For the auditor, the large amount of data output could lead to information overload [20, 95]. The introduction of big data to audit procedures makes the task more complex. However, due to a finite amount of immediate memory, auditors, like other humans, information overload can occur when the amount of information input exceeds the auditors' limited cognitive capacity, which can make it difficult for auditors to process the information effectively without getting distracted and stressed that might degrade the information [96]. Additionally, having too much information may prevent auditors from recognizing important information or ignoring unimportant information. The "dilution effect" is another name for this occurrence. In interpreting data analytics data output, the auditor needs to evaluate the valuable data and ignore the immaterial ones, and failure in doing so will result in wrong decisions and inferior audit quality [38].

The availability and integrity of data are essential, and the auditor's independence is also crucial. Hence, the auditor needs to have free access to all data. That is, there is no external interference, such as from clients [97]. However, some claim that auditors do not always have complete access [98]. Also, auditors often find it challenging to capture the data meaningfully. Hence, an IT specialist needs to be available, as the IT specialist could assist in assuring the trustworthiness and accuracy of the analyzed data by sorting and processing it. In addition, the data rely on internal and external sources, which means that the auditor has to be certain of data completeness, unbiasedness, and originality, should the data be used for auditing purposes [99]. However, PCAOB auditing standards indicated that it is impossible if the auditor depends on externally produced data [56]. Another data-related challenge is data ambiguity, and as mentioned in Brown-Liburd et al. [20], auditors who feel uneasy about making full decisions because of ambiguous information are likely to disregard other information the moment the first solution is discovered. Considering the massive amount of information generated by data analytics, it would be helpful (for the auditor) to include all applicable information during the decision-making process.

Data extraction is generally regarded as the major challenge for accountants in data analytics usage [52,75]. The data extraction process can be carried out by the client or the auditor. In this regard, the data extraction by the auditor will increase the data integrity, considering that the data are produced directly by the accounting system, diminishing the possible data tampering. The reliability of data will also increase [35]. However, it is a time-consuming task for the auditor, and the task is costly as well. In addition, clients may differ in terms of the employed accounting system, implying the need for the auditor to have the right extraction tool for data extraction for a given client [66]. Data extraction is not an auditor's expertise area, meaning that a specialized team might be needed to correctly carry out the data extraction task from the client's system [93]. Before usage, the extracted data need to be entered into the auditor's analytics system to allow the execution of data analytics. During the process, the auditor will determine the specific data that will be entered into the data analytics system, and this process will usually involve a team of specialists. The entire data extraction process can take several weeks to complete. Considering that the auditor needs considerable time to get the correct data, the efficiency during the actual audit can be compromised [50].

The development of data analytics within the auditing domain will significantly depend on the acceptance of both the public and the legislators. The expectation gap is a crucial dimension that should be addressed by both the auditors and legislators [46]. The expectation gap highlights the public's expectation of the auditors' role and accountabilities, surpassing the auditors' performance as viewed by the public [99]. The public and legislators have now called for more effective audits and require auditors to propound more assurance [83]. In this regard, more advanced data analytics may decrease the gap, but auditors need to constantly explain the possibilities and impossibilities to prevent the widening of the gap [50].

Moreover, Alles [1] stated that regulations and standards are not designed for data analytics in audits. Furthermore, the current standards do not restrict the implementation of data analytics in audits. However, these standards do not delineate how data analytics can and should be utilized. An even more pressing issue is the non-existence of legislation specifically for data analytics usage [47]. Auditors' interest is to abide by the rules and satisfy all the legislation requirements instead of providing more guarantees with data analytics. For public accounting firms, the legislation issue has become a concern for further development and acceptance of data analytics in the auditing industry. The accountants involved in data analytics are all concerned with the legislation and the advancement of data analytics in the audit.

Moreover, partners are personally held accountable. Hence, it is more desirable to perform audits following the standards of the regulators rather than using data analytics to improve assurance. However, standards and laws may take time to amend. This may restrict the readiness to employ data analytics, which in turn may decrease the growth of DA within the auditing business [88].

Text Mining, Deep Learning, Predictive Analytics, Blockchain accounting/smart contracts, R Programming, Hadoop, and Structured Query Language (SQL) are emerging data analytics approaches that may facilitate the audit process [3]. Still, explicitly explained data analytical approaches need to be available to allow the proper training and education of future auditors, as such availability can affect the pre- and post-qualifications that professional bodies of accounting and auditing presently catered to [93, 94].

3- Methodology

3-1- The Review Protocol

The systematic literature review is a valuable strategy to identify, evaluate, and synthesize comprehensive, important research data on a particular topic to acquire a complete picture of the studies and their findings [100, 101]. Furthermore, this strategy reduces the risk of bias due to human errors [102, 103]. Generally, the systematic literature review flow is shown in Figure 1.

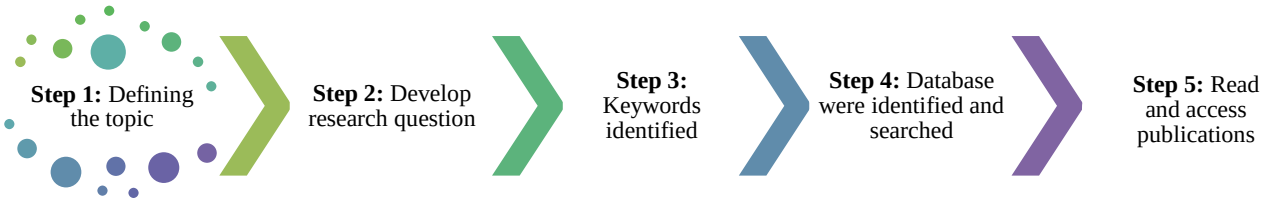

Figure 1. Systemic Literature Review Flow

However, the current paper reviews the literature concerning data analytics in the context of auditing using the PRISMA approach. PRISMA is a reporting guideline that was published in 2009 in order to overcome the problem of poor reporting in systematic literature reviews [104]. Researchers should present a clear, complete, and accurate narrative of why the review is conducted, what researchers achieved, and their findings to establish that a systematic review benefits user. PRISMA-2009 statement is modified and now available as PRISMA-2020. This PRISMA 2020 statement updates reporting guidelines for systematic reviews to reflect advancements in methodologies for identifying, selecting, evaluating, and synthesizing articles [105]. This systematic review will help understand the benefits, challenges, and use of big data analytics in auditing.

A comprehensive review was performed to collect relevant literature from various sources, with the following goals and objectives:

1. To take the overview of big data and DA within the domain of auditing.
2. To present the notion of DA in auditing firms' context in addition to its research directions.
3. To highlight the benefits of DA, especially within the field of auditing.
4. To highlight the challenges associated with the DA adoption in auditing

3-2- Formulation of Research Question

The research question was guided by PICo [106]. PICo is a tool that helps authors formulate research questions. PICo is based on three elements of population, interest, and context. Based on these three concepts, the authors included auditors (population), big data analytics (interest), and auditing and accounting firms (context) which was used to guide the development of the leading research question (Table 1).

Table 1. Systematic Literature Review Process using PRISMA protocol

Sr. #	Topic definition	Journal Articles on "Data Analytics and Auditing" published between 2011 and 2021.
1	Define the research questions	1. How can big data analytics transform the manner in which audits are executed? 2. What are the opportunities and challenges associated with data analytics in auditing?
2	Determine search criteria "keywords"	Data Analytics, Analytics in auditing, Auditing future practice, Auditing professions, Analytical auditors
3	Identify Databases and carryout search	Web of Science, Scopus, Science Direct, Springer Link and Emerald Insight
4	Selection of articles	Studies published in English language, in reputed journals, and in the context of data analytics and auditing.
5	Synthesize articles	Critically assessment of included studies
6	Publicize review findings	Findings are based on the summary of data or current evidence from the findings of numerous individual studies, which can facilitate evidence-based practice.

3-3- Search Strategies

The search strategy consisted of three parts: keyword identification, screening, and eligibility. The identification of keywords stemmed from the research question. The keywords identified for this review were data analytics, analytics in auditing, auditing future practice, auditing professions, and analytical auditors. This study searches studies related to big data analytics in auditing from Science Direct, Springer Link, Emerald Insight, Web of Science, and Scopus. The databases were selected based on access privileges, time, and the reference list in published papers related to big data analytics and auditing over the last ten years. Furthermore, the selected databases have published many peer-reviewed articles in the studied field. Table 1 indicates the search criteria. The inclusion criteria (IC) are as follows:

IC-1: Studies that deal with DA in auditing context;

IC-2: Studies published between 2011 and 2021;

IC-3: Studies published in English language;

IC-4: Studies published in the most cited and reputed journals.

Other papers that did not fall within these criteria were excluded. The summary of Systematic literature review process using PRISMA is shown in Table 1 and Figure 2.

3-4- Data Extraction and Analysis

The following four phases were used to conduct the searching and extraction of research data:

1- Identification of articles through searching electronic databases using keywords "data analytics," "auditing" or "analytics in auditing". Moreover, duplicated records were also removed.

2- Based on selection criteria, titles, keywords, and abstracts were scrutinized and exclusion of irrelevant articles was made.

3- Eligibility was established through full-text assessment of articles, and exclusion was made with solid reasons.

4- For detail study, cross-reference articles were scanned and final selection of articles was made that are included in the systematic review.

The duplicate studies were deleted. The titles of the research articles and their abstracts were scrutinized to see their relevance. Moreover, the reference lists from previously selected papers were scanned to locate any additional relevant research. Finally, the selected publications were examined.

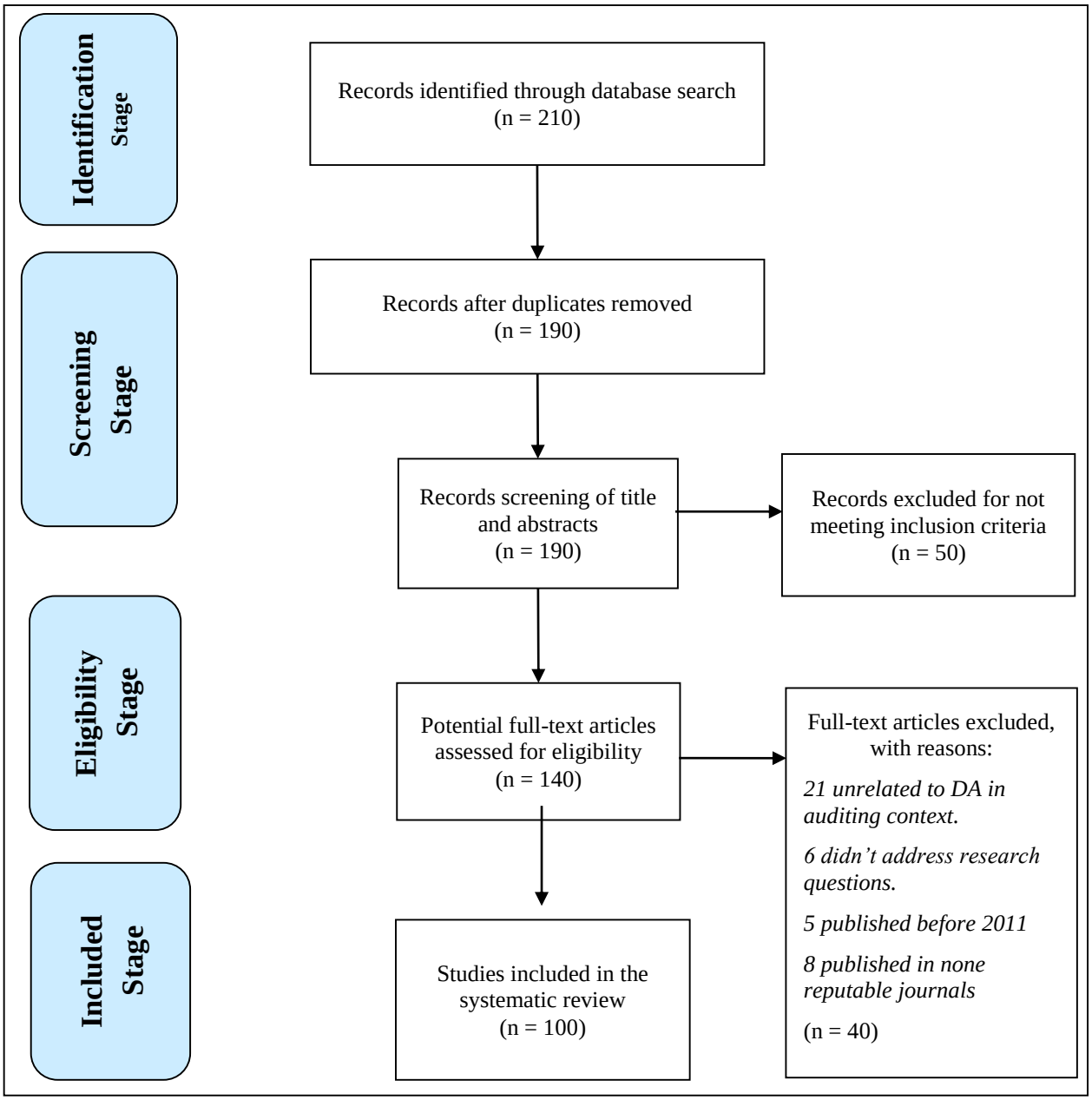

Figure 2. Flow diagram of papers included in review based on PRISMA

4- Descriptive Findings

4-1- Description of Included Papers

Overall, this research considered 100 peer-reviewed articles that met the criteria from high-quality databases. Based on publishers, the total number of relevant articles is given in Table 2.

Table 2. Articles reviewed by publishers

Publisher	Number of relevant articles
Elsevier	39
Taylor and Francis / Springer	18
Emerald	22
Wiley and Sage	7
Other	14

Figure 3 presents a time distribution analysis of big data analytics in auditing (from 2011–2021). All articles published from 2011 to 2021 were included in this systematic review. The review indicated that 3 articles were published in 2011, 2 in 2012, 4 in 2013, 18 in 2014, 35 in 2015, 13 in 2016, 22 in 2017, 19 in 2018, 11 in 2019, 5 in 2020, and 10 in 2021.

A rapid increase in published papers was seen in 2015 (35) and 2017 (22). We found 2021 as the year in which the most relevant studies were published. The studies mainly focused on the practical application of data analytics in auditing.

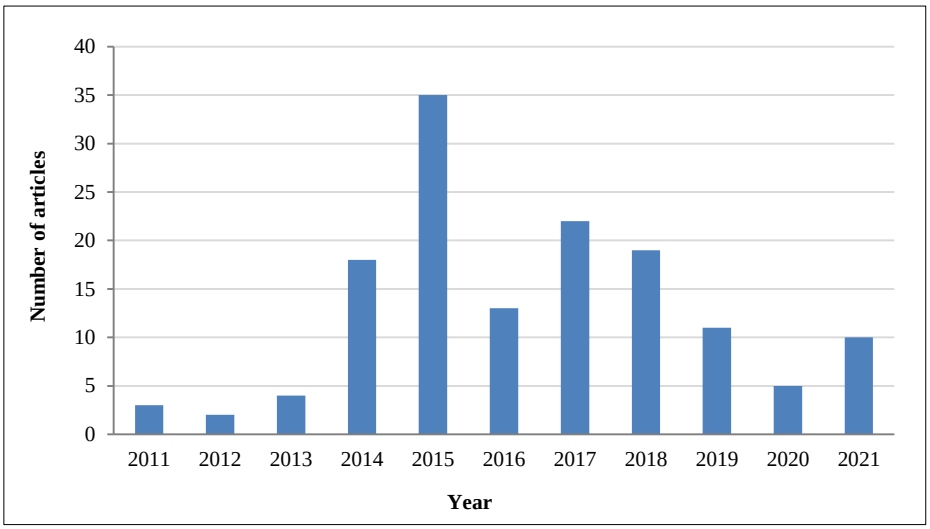

Figure 3. Time distribution of articles

4-2- Summary of Reviewed Paper

Our analysis reveals that data analytics is a promising domain for the auditing practice. However, the application of common data analytics on audit engagements appears to lag behind other practice areas. Considering that auditing has its distinct challenges in auditing, data analytics has not been readily embraced. Public accounting firms consistently invest in developing audit-related data analytics, which can transform organizational operations. This study has explained the concept of data analytics in auditing and highlighted the overview of big data and data analytics within auditing, the benefits of data analytics in auditing, and the challenges associated with adopting data analytics in auditing. Thus, this study has expanded the literature on big data, data analytics, and the use of data analytics in auditing. Organizations should be familiar with the benefits and challenges of adopting data analytics in auditing. Therefore, this literature review research has directed the attention of practitioners towards adopting data analytics in auditing. The methodological contributions of this study stem from a unique way to analyzing the data gathered. Instead of gathering data from respondents, this study is based on the data collected from renowned databases. Therefore, the study sample was the research articles published from 2011 to 2021. This research also has many practical implications by directing the attention of top management to implement data analytics in auditing. The results and literature-based pieces of evidence provided by this research are key for auditing policymakers.

5- Conclusion

The use of data analytics in auditing procedures is examined in this study, along with the opportunities and challenges it presents throughout ten years. This study adds to many ongoing concerns about various obstacles to the general implementation of data analytics in auditing identified in the literature. We dealt with the importance of data analytics in auditing firms and how it can change and raise audit quality. We found that big data analytics are conspicuously absent from the audit space. In regard to the second research question, eight problems have surfaced for audit quality improvement as organizations are developing the ways for data analytics utilization, including 1) challenges linked to training and competence of auditors, 2) The potential for data destruction incidents in auditing owing to cyberattacks or a lack of ability in data filtering, 3) Joblessness as a result of automation of data registration, data monitoring, auditing, etc., 4) Massive amounts of data must be extracted and processed, which requires large computer storage and analytical software, 5) the ability of the analytical software to be able to handle various forms of data, 6) the abundance of output could lead to information overload, which could result in incorrect interpretation and, ultimately, incorrect decisions, 7) Auditor access to all data is limited and data-related issues, such as data ambiguity, and lastly, 8) the expectation gap, which requires attention from legislators and auditors. This knowledge aids audit companies in formulating plans for effectively using big data analytics to provide favorable audit outcomes.

We faced several limitations: The investigation began by examining how frequently data analytics is used in auditing. External factors and settings can have an impact on big data analytics. Future studies could therefore look at the motivational driving forces behind applying big data analytics to auditing. Comparison studies may also help identify differences in auditor attitudes concerning the usage of big data analytics tools in audit firms. Second, the review does not outline the abilities and skillset required for auditors to employ data analytics in auditing. In this regard, auditors are expected to have the ability to use big data to increase audit effectiveness and efficiency. In all facets of the accounting profession, data analytics is a relatively new skill set that is expanding quickly. Big data dependability is also crucial.

Thus, knowing how to analyze big data extraction and storage solutions is vital. Hence, future research can examine the specific skillset needed by auditors. Additionally, how big data can facilitate the detection of accounting anomalies, material misstatements, and fraud may be explored in the future.

6- Declarations

6-1- Author Contributions

Conceptualization, Y.A.A.H.; methodology, Y.A.A.H.; writing—original draft preparation, Y.A.A.H., L.A., and S.D.K.S.; writing—review and editing, Y.A.A.H., L.A., and S.D.K.S. All authors have read and agreed to the published version of the manuscript.

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6-5- Informed Consent Statement

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6-6- Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancies have been completely observed by the authors.

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