

# A Study of Big Data Analytics in Internal Auditing

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**Abstract.** As the world is progressing towards an era of automation and artificial intelligence (AI), the use of data is becoming more valuable than ever before. Many professions and organizations have already incorporated automation and AI into their work to increase their productivity and efficacy. Auditing firms are not an exception in this regard as these firms are also using many data analytics processes to plan and perform audit. This paper provides a systematic review of big data analytics application in auditing with primary focus on internal auditing. The paper contemplates the advantages of incorporating big data analytics in internal auditing. The paper further discusses the state-of-the-art and contemporary trends of big data analytics in internal auditing while also summarizing the findings of notable researches in the area. Finally, the paper outlines various challenges in incorporating big data analytics in internal auditing and provides insights into future trends.

**Keywords:** Accounting, auditing, internal auditing, external auditing, big data, data analytics

## 1 Introduction

As businesses are becoming progressively complex, the decision-making for stakeholders is becoming increasingly arduous. This complexity makes the role of auditors, both internal and external, very crucial to the organizations as stakeholders are curious about how efficient, effective and innovative organizations are operating internally and what is the financial as well as non-financial outcome of the organization operations. Furthermore, there exists an expectation gap between financial statement users and auditors. Auditors constantly strive to reduce this gap by informing people about the reasonable assurance of fairness in financial statement presentation, which is provided by external auditors, versus absolute assurance of fairness in financial statement presentation which people assume. Auditors also try to reduce this expectation gap by conducting more quality and in-depth audit which sometimes can be very costly, time consuming, and not always fully possible due to the nature of some intangible assets such as Goodwill.

An in-depth and thorough audit means large samples of data and rigorous data analytics (DA) procedures to test both internal controls and different accounts. In external auditing, even with a very large sample size from a variety of accounts, such as accounts payable, accounts receivables, cash, etc., it is still not possible for an auditor to claim that a financial statement is 100% correct as he/she has not tested all the transactions in all the accounts. Similarly, in internal auditing, it is not possible for an auditor to claim that an operation of an organization is absolutely effective, efficient and in compliance with laws and regulations.

In recent years, big data analytics (BDA) has revolutionized many industries including auditing. Although, BDA is fairly new and hence infrastructure of many organizations is not ready for it yet, some avant-garde organizations have either already implemented it or preparing themselves to implement it in the near future. The unique features and characteristics of BDA allows almost all industries that use data to take advantage of it and enhance their operation and decision-making to become more profitable and customer-friendly. Like many other firms, audit firms also heavily rely on data and DA to perform their job, and thus BDA can play a significant role in the performance of these firms. BDA is used both in internal auditing and external auditing, however, their purpose of usage is different from each other. Although we will mention the differences in BDA for internal auditing and external auditing shortly, the focus of this paper is on internal auditing.

This paper provides a review of BDA application in auditing, primarily internal auditing. This paper provides a rich source of information for both academia and industry to learn at what stage big data in audit stands, and help prepare the organizations for implementing big data infrastructure. This paper also contributes to the available literature by filling the gap between the academic and industrial practices in the area of BDA in auditing. The main contributions of this work are:

- Providing an overview of DA in auditing.
- Elaborating the advantages of incorporating BDA in internal auditing.
- Discussing the state-of-the-art and trends of BDA in internal auditing.
- Contemplating the challenges involved in incorporating BDA in internal auditing.

The rest of this paper is organized as follows. Section 2 discusses BDA and its usage in business industry. An overview of data analytics in auditing is provided in Section 3. Section 4 elaborates the benefits of incorporating BDA in internal auditing. The state-of-the-art and trends of BDA in internal auditing are discussed in Section 5. Section 6 deliberates the challenges involved in assimilating BDA in internal auditing. Finally, Section 7 concludes this study.

## 2 Big Data Analytics and Its Usage in Business

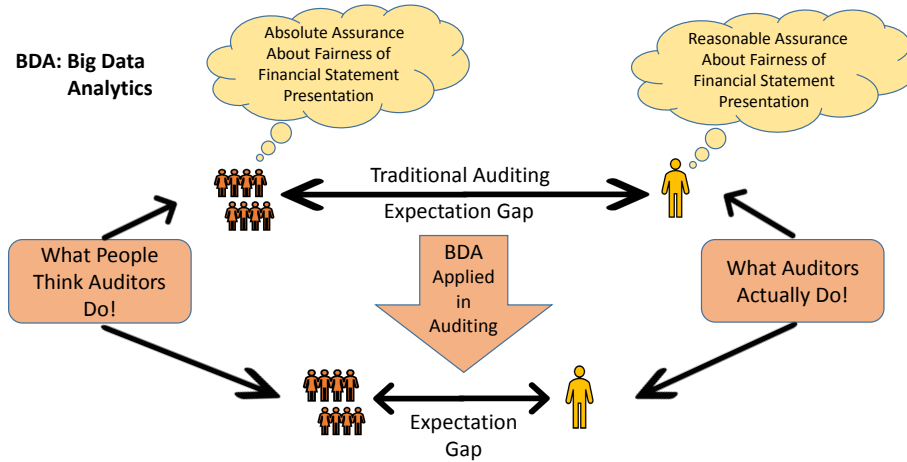
Big data is a set of data that can be characterized by six V's: Velocity, Volume, Value, Variety, Veracity, and Variability. As the name suggests, the size of big data must be "big", which is measured as Volume. Velocity refers to the rapidly increasing speed at which new data is being generated and the corresponding requirement for this data to be assimilated and analyzed in near real-time [14]. Value measures the worth of the big data, that is, the insights that are generated based on big data must lead to quantifiable improvements. Variety refers to the huge diversity of data types. The trustworthiness of the data attributes to Veracity. Variability hint that the way the data is captured varies from time to time and place to place. Furthermore, variability suggests that the interpretation of data may change depending on the context.

Cao et al. [7] have defined DA as "the process of inspecting, cleaning, transforming, and modeling Big Data to discover and communicate useful information and patterns, suggesting conclusions, and support decision making". DA has as many uses as the number of businesses that works with and handles data. Different firms and organizations use DA for a variety of purposes, such as predicting and describing new market trends, predicting consumer needs and demands, and anticipating the market's influence on the behaviour and pattern of customers. For example, many companies use data mining and DA in order to analyze the customers' comments and feedback for improving their services and products or to predict which competitors the customers would switch to in case they were not happy with the current services and products that they have received from certain companies. Voice pattern recognition is another tool that many companies can take advantage for enhancing their performance and improving customer satisfaction by identifying dissatisfied customers and their reasons of dissatisfaction [1]. Not only companies but also government and police forces can get benefit from BDA by identifying repeated criminal and fraudulent behaviours and regions not only locally but internationally.

As pointed out by Gershkoff [13], BDA is a fast-growing market. Companies, organizations and firms which are not incorporating BDA in their daily operation are likely to lose a lot of great opportunities and are prone to stay far behind than those that incorporate BDA in their operations.

## 3 Data Analytics in Auditing

Like many other professions, auditors, both internal and external, heavily use DA in their operations to obtain results and conclude their opinion about the firm they are auditing. According to Byrnes et al. [6], auditors use DA in their daily operation to analyze, identify and extract the information from the available data of their clients that can be useful in planning, fieldwork, and issuing final opinion about the firm they are auditing. Many scholars have given their opinion about importance and usage of DA in auditing. For example, Brown-Liburd, et al. [5] mentioned that DA is able to recognize and identify the existing patterns and



**Fig. 1.** Big data analytics in auditing can help reduce expectation gap.

correlation among data that can be very useful for auditors. According to Byrnes et al. [6], DA in auditing is not only a science but an art that exposes the patterns and anomalies and pulls out beneficial information of data which is related to the subject when an auditor performs analysis, modeling, and visualization in all phases of planning and performing the audit. Furthermore, DA helps auditors to process a lot of data at a very fast pace.

Auditors take advantage of innovative and competitive insights provided by DA to enhance efficiency and effectiveness of their audit performance [11]. Besides scholars and researchers, many organizations such as the International Auditing and Assurance Standards Board (IAASB), also have given opinion about BDA in auditing. The IAASB recognizes BDA as a science and art that discovers and analyzes existing patterns, deviations, and inconsistencies among data set, and pulls out the useful information related to the audit that is being done [1].

Many auditing firms either large or small constantly engage in utilizing BDA in their daily operations to reduce the amount of risk involved in both internal and external auditing as well as to offer value to their clients [1]. For instance, BDA can help reduce the expectation gap between financial statement users and auditors as depicted in Figure 1. While larger auditing firms have more resources such as capital to create customized DA platforms, smaller firms may choose to utilize the available platforms and packages for assistance in planning and performing their audit. We note that there is no single DA tool in auditing, and firms consistently develop and customize a variety of DA tools depending on their needs and available resources to help identify patterns, trends and correlations, and extract information from data via different visual and descriptive methods.

## 4 Advantages of Incorporating BDA in Internal Auditing

According to Cao et al. [7], although many professions, such as consulting and marketing, have already adopted BDA in their daily operations, the use of BDA in accounting is still nascent. Nevertheless, BDA can profoundly benefit both internal and external auditing. For instance, BDA can enhance the efficiency and effectiveness of financial statement audits [7]. Moreover, auditors can take advantage of BDA to analyze and test more transactions [11].

According to the results of a research [16] that has used an extensive database to distribute and compile surveys, there are ten areas in both external and internal auditing that can benefit the most by incorporating BDA. These areas are [16]: (i) accounts payable and accounts receivable, (ii) duplicate detection, (iii) sampling, (iv) data imports/extractions and analysis of large data sets, (v) continuous auditing and monitoring, (vi) fraud detection and forensic auditing, (vii) P-Cards analysis, (viii) payroll and time sheets, (ix) joins and comparisons, and (x) inventory audits.

According to [8], incorporating BDA can immensely benefit three phases of internal auditing, which are planning, audit execution (fieldwork), and reporting. Figure 2 depicts the benefits of incorporating BDA in the three phases of internal auditing. In *planning phase*, risk profiling, test data stimulation, and statistical sampling are the areas that give the most benefit to auditors by applying BDA. In *audit execution phase* continuous controls monitoring, fraud indicators, predictive risk identification and control simulation are the areas that are most improved by utilizing BDA. In *reporting phase*, risk quantification, real-time exception management, and root cause investigation are the areas that auditors can reap the most advantages by employing BDA. In the following, we discuss some of the vital areas in internal auditing that benefit the most from BDA.

### 4.1 Risk Assessment

One of the main things that internal auditors do, is to perform a thorough risk assessment for their organization. With the help of BDA, internal auditors can put together and analyze any data either from inside or outside of the organization in order to gain a deeper and more comprehensive insight related to their organization. The BDA can help internal auditors to better assess any existing and/or potential risks within or outside the organization, and help reach more distinct and precise findings. An accurate and detailed risk assessment and financial analysis help organizations to improve their daily and long-term business processes and internal controls. These findings also help the decision-makers and planners within the organizations to operate more strategically and be more efficient, effective and profitable. Incorporating BDA into internal audit process also helps transaction risks to be assessed in real-time. Real-time access to the information for internal auditors means they can gain a better insight about the organization and the efficiency and effectiveness of the business processes even before the actual fieldwork starts. This also helps continuous auditing for a better risk management. Furthermore, since internal auditors test and evaluate

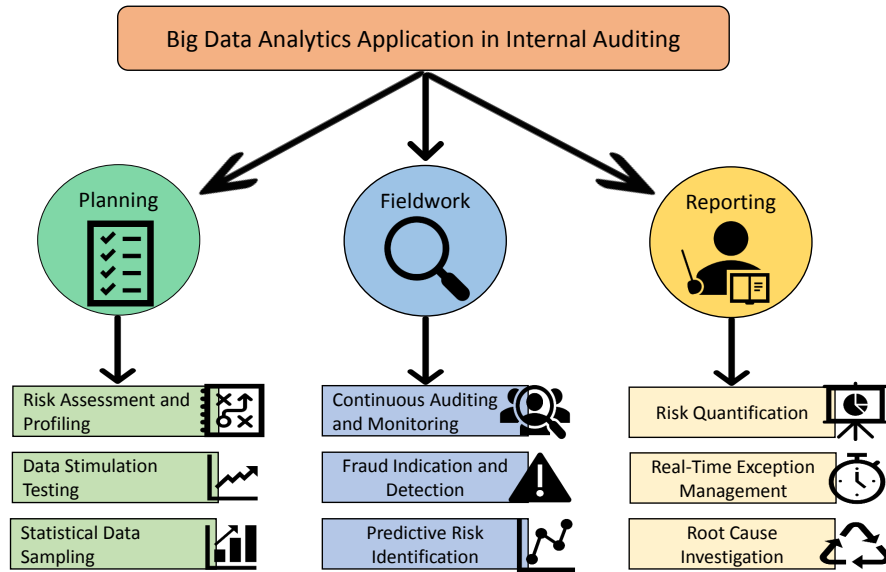


Fig. 2. Benefits of incorporating big data analytics in internal auditing.

non-financial data besides financial data to better assess the risks within the organization, it is much easier to do so through BDA tools [11].

#### 4.2 Audit Quality

Among other advantages of incorporating BDA in internal and external auditing is enhancement of the audit quality. Having professional skepticism is a significant requirement for both internal and external auditors that determines the quality of audit. While in traditional way of auditing, auditors bring their personal experience and judgement to their audit work, in the new and automated process of BDA, many documentations can be provided by artificial intelligence (AI) and machine learning (ML), which help enable the auditors to detect any potential fraud in reviewing financial statements, business processes, and internal controls [22]. This automated process of BDA allows the auditors to maintain their professional skepticism. Since big data works with automation processes, AI and ML, larger volumes of higher velocity data can be processed efficiently, and so auditors can gain valuable information and insights in a shorter period of time. Having BDA incorporated within the organizations, auditors can test all of the transactions thus improving the expectation gap between auditors and financial statement users [6].

### 4.3 Compliance Assurance

Internal auditors job demands constant scanning and review of the organization's performance and documentation to ensure the organization's financial documents are being prepared and done in compliance with standards [15]. Making any mistakes in this regard, as human errors are common, can put the business out of compliance or waste too much time of the auditors. Through the help of BDA and automation of manual, frustrating and time-consuming tasks, internal auditors are able to set up as many controls as they want in the auditing system, and monitor those controls to determine whether the organization is adhering to the standards and guidelines or not. According to EY [12], continuous investing in DA is essential as it helps auditors to provide more assurance and relevant audit.

### 4.4 Fraud Detection

One of the significant factors in performing quality audit is to have an effective communication related to the key issues and findings that BDA enables auditors to achieve through dynamic dashboards [20]. In this regard, BDA tools give this power to the auditors to convert all the raw data to a pre-structured form and presentation format so that anybody from auditors to clients be able to understand the presented information. BDA tools can also be adjusted based on a specific client's risk so that auditors plan and perform more efficiently and conclude their findings faster. BDA assists auditors to help detect any fraudulent action by interrogating all data and by testing all internal controls such as separation of duties [1].

### 4.5 Planning Assistance

With the help of BDA, auditors are able to not only use descriptive features of the tools to better understand the process, conducting a thorough risk assessment and obtain detailed findings, but also, they can use predictive and prescriptive features to better assist decision makers for setting future goals and objectives [3].

### 4.6 Cost of Operations

Incorporating and implementing BDA in internal audit process and hiring auditors with DA skills require an initial investment which may be seen as a costly and negative factor at first, however, in a long-term, incorporating BDA and hiring auditors with BDA proficiencies reduce the overall cost of audit, and further improve the efficiency and effectiveness of the business operations through more accurate recommendations and corrective action plans enabled by BDA [4].

## 5 State-of-the-Art and Trends of BDA in Internal Auditing

BDA is dynamic and continuously changing for better, so for an organization or firm to be always on the leading edge regarding their internal auditing processes and technologies, they must stay updated with innovations in BDA. This section discusses state-of-the-art and trends of BDA in internal auditing.

There are several researches that have been done by Protiviti [18], which show interesting results. Protiviti is a global consulting firm headquartered in Menlo Park, California that provides consulting solutions in internal audit, risk and compliance, technology, business processes, DA, and finance. In 2015, Protiviti's conducted an internal audit capabilities and needs survey [19], which contained 23 questions and distributed to a select group of the largest financial institutions in U.S. including 13 of 25 top banks and 2 of 5 top insurers. According to the findings from this survey, 69% of participants said that their internal audit functions have their own *data warehouse* for accessing data and 54% of participants reported that there are special requirements for the desktops assigned to internal auditors DA professionals. Also 54% of participants said that specific and defined protocols are used for the extraction of data leveraged during the audit process to validate the data's quality and completeness. Furthermore, 54% of participants indicated that internal audit functions also use *business intelligence* and related *dashboarding tools* to support their processes such as Business Objects, Oracle, QlikView, SAS JMP, SQL (Structured Query Language) and other internal tools. Moreover, 69% of participants indicated that members of their department, including professionals outside of the Internal auditor's analytics team, possess analytics skills that they deploy on audits. There are three tools that are most commonly being used by internal auditor analytics groups in their work, viz., Microsoft Excel, SQL and ACL (Audit Command Language). Internal auditor groups have been using these tools for a long time for performing and planning internal audit in a traditional and manual method, however, the trend of learning and using tools like Tableau and Spotfire shows a transition towards data visualization and other features of BDA to analyzing and assessing risk continuously.

The results of another Protiviti research regarding the usage of BDA by internal audit departments as a part of their audit planning and performance in different continents are as follows: Asia-Pacific 76%, Europe 76% and North America 63%. The organizations that uses BDA in their audit works have also rated the quality of available data to be analyzed as excellent or very good are as follows: Asia-Pacific 59%, Europe 58% and North America 28% [8].

The results of yet another research [17] indicate that only 42 percent of chief audit executives (CAEs) responding to the Institute of Internal Auditors (IIA) 2017 North American Pulse of Internal Audit are frequently or always using DA in their audit planning and performance. The same research was conducted in 2018 as well and the results of that research also indicate the similar trend with only 62 percent of CAEs who reported the partial or fully usage of DA. Those internal auditors who incorporate BDA into their audit work should know that



there are many risks involve in these processes. In order to reduce these risks, internal auditors should be aware of the risks and take appropriate measures into consideration while working with BDA, such as the use of clean and normalize data, dealing with outliers, accurately reading patterns and deleting noise, visualizing the data clearly, understanding correlation versus causation, and recognizing when data should not be used [17].

According to Deloitte, auditors need to update their knowledge and gain new *skill sets* in order to keep up with new demands, changes and technologies. These required skill sets can divide into two categories [10]: (i) technical and analytical, and (ii) business and communication. Technical and analytical skill set includes the following. *Testing and validation*, which means “defining, developing, and implementing quality assurance practices and procedures for technical solutions and validating hypotheses”. *SQL querying*, which means “querying and manipulating data to facilitate the solving of more complex problems”. *Data modeling*, which refers to “structuring data to enable the analysis of information, both internal and external to the business”. *Data analytics*, which means “valuing data using analytical and logical reasoning for the discovery of insight, e.g., predictive modeling”. Finally *reporting software*, which pertains to “understanding of the underlying theory and application of key reporting software”. Business and Communication skill set includes the following. *Technology alignment*, which means “understanding how technology can be leveraged to solve business problems”. *Macro-perspective*, which refers to “understanding of the company’s business strategy, current business issues and priorities and current industry trends”. *Business knowledge*, which means “understanding of business measurement of key performance indicators and business frameworks”. *Business commentary*, which relates to “articulation of insight to explain current and forecasted trends, their impact and opportunities for the business”. Finally *soft skills*, which pertains to “communication and interpersonal skills that are necessary to articulate insight gained from analysis”.

The growing market of BDA is transitioning towards more user-friendly software to enable even those auditors who are not very skilled in BDA to use the tools [2]. With developing skill sets and training, internal auditors and their teams will be able to have a mutual and common understanding of BDA behaviors and tasks. One significant factor that requires special attention is setting and following policies related to collection, storage, and disposal of audit documentation and working papers. Internal auditors should make sure to consider all the policies regarding what data to be stored and requested, how to access data, who can access data, where the data will be stored, what data can or cannot be distributed, to whom data can or cannot be distributed and what the data retention period is. Failure to follow these policies can have unfavorable outcomes for the firms and organizations and they can be sued by their clients.

## 6 Challenges of Incorporating BDA in Internal Auditing

There exist various challenges in incorporating BDA in internal auditing. This section discusses some of the salient challenges in integrating BDA in internal auditing.

### 6.1 Data-Access

Location identification of sought-after data is one of the most arduous endeavor in complex enterprise environments as operations are geographically distributed and each business unit within an organization operate autonomously and utilize a different system, which makes data sourcing laborious [19]. Furthermore, since auditors often do not have full access, it is difficult for auditors to acquire the data in a way that can be readily utilized.

### 6.2 Data Compatibility

Data acquired from different business units or client systems may be in different formats, which may render certain analytics techniques unusable. Even if the data acquired from different sources is compatible, data needs to be normalized to common terms to provide a fair comparison basis. Determining the terms for data normalization presents another challenge because of the variety and variability characteristics of big data. Consequently, data preparation and pre-processing before actual DA could be applied takes substantial time.

### 6.3 Data Relevance

Since new data is generated expeditiously, the mined information also becomes irrelevant quickly [9]. Hence, it is imperative to utilize the data in a timely manner. BDA with the help of tools can help to provide timely insights into the data.

### 6.4 Data Integrity and Veracity

It is difficult to guarantee the completeness and integrity of the extracted client data. Internal audit analytics specialists often need to perform data extraction, which may have limitations when either the firm does not have the right tools or understanding of the client data. This particularly can be the case when multiple data systems are utilized by the client. Furthermore, it is conceivable if clients only make certain data accessible or manipulate the data accessible for extraction [1]. Consequently, data veracity and ambiguity is another challenge that requires consideration. Auditors may not be confident to make meticulous decisions and are more likely to ignore additional information once a primitive solution is obtained when the acquired information is vague [5].

### 6.5 Data Management

Data management issues pertain to data storage and accessibility for the duration of the required retention period for audit evidence. The acquired data must be stored for several years in a form amenable to retesting. Thus, the firms may need to invest in hardware to store this huge volume of data or outsource data storage. Outsourcing of data storage increases the risk of data loss or privacy violations [1].

### 6.6 Data Confidentiality and Privacy

Confidentiality and privacy policies of different business units pose another challenge as it requires internal audit analytics professionals to sought approvals before accessing certain systems and data [19]. Copying and storing of detailed client data may violate data confidentiality and privacy laws as the data could be abused by the firms. Furthermore, the stored data is susceptible to security attacks which may cause grave legal and reputational repercussions. Internal audit analytics team may also need to obtain information technology (IT) certifications for their data warehouses before they can store the retrieved data, which requires addressing questions, such as (i) how the data will be utilized? (ii) what access control procedures will be employed for that data? (iii) what steps will be taken to keep the data secure? and (iv) how the chain-of-custody stipulations are met in data capturing, usage, and storage?

### 6.7 Regulations

Currently, there exist no regulations or guidelines that cover all the uses of DA in audit [2]. Hence, firms with more resources can have a competitive advantage in developing DA tools as compared to smaller firms thus reducing the competition in audit industry [1]. Consequently, the firms that do not invest in DA might lag behind their competitors in providing better services [2].

### 6.8 Training

Audit staff may not be qualified to comprehend the true nature of data to make appropriate inferences [11]. Hence, audit staff needs to be trained for DA which can be expensive. Scarcity of DA specialists and their unfamiliarity with audit as pointed out by [2] exacerbates the challenge of training audit staff.

### 6.9 Tools

The datasets are often too complex to be inspected by standard tools [21]. Hence, there is a need to develop new BDA tools for audit. Furthermore, as new ML and analytics methods are continuously being developed, it is imperative to incorporate the latest methods in BDA tools.

## 7 Conclusion

Big data has changed the landscape, performance, productivity, and profitability of many industries, organizations and firms. Auditing firms are not an exception in this regard as they are utilizing many data analytics processes to plan and perform audit. Big data analytics (BDA) has a plethora of unique features that offer many advantages to auditors, such as enabling them to gain a deeper insight into their auditing work, and help them develop a thorough understanding of various aspects of audit including risk assessment and compliance assurance. BDA helps auditors to reduce the expectation gap between auditors and people by performing more accurate audit through eliminating sampling and testing all transactions instead. Nevertheless, there are some challenges and issues involved in implementing and using BDA by audit firms, such as data-access, data compatibility, data relevance, data integrity and veracity, data management, data confidentiality and privacy, regulations, training, and tools.

It is envisioned that as artificial intelligence techniques become more sophisticated, solutions will be developed to address the standing challenges. Although, it will take some time and investment on human resources and capital to fully integrate BDA in internal audit and solve the existing challenges, the benefits of incorporating BDA in audit firms warrant the effort and investment.

## References

1. ACCA: Data Analytics and the Auditor. <https://www.accaglobal.com/in/en/student/exam-support-resources/professional-exams-study-resources/p7/technical-articles/data-analytics.html> (2020), last Accessed on January 15, 2020
2. Alles, M.G.: Drivers of the Use and Facilitators and Obstacles of the Evolution of Big Data by the Audit Profession. *AAA Accounting Horizons* 29(2), 439–449 (June 2015)
3. Appelbaum, D., Kogan, A., Vasarhelyi, M.: Big Data and Analytics in the Modern Audit Engagement: Research Needs. *AUDITING: A Journal of Practice & Theory* 36(4) (February 2017)
4. Bierwirth, M.: Improving the Internal Audit Function through Enhanced Data Analytics. <https://www.surgentcpe.com/blog/improving-internal-audit-function-through-enhanced-data-analytics> (September 2019), last Accessed on January 15, 2020
5. Brown-Liburd, H., Issa, H., Lombardi, D.: Behavioral Implications of Big Data’s Impact on Audit Judgment and Decision Making and Future Research Directions. *AAA Accounting Horizons* 29(2), 451–468 (June 2015)
6. Byrnes, P., Criste, T., Stewart, T., Vasarhelyi, M.: Reimagining Auditing in a Wired World. <http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.646.9343&rep=rep1&type=pdf> (August 2014), last Accessed on January 15, 2020
7. Cao, M., Chychyla, R., Stewart, T.: Big Data Analytics in Financial Statement Audits. *AAA Accounting Horizons* 29(2), 423–429 (2015)
8. Consultancy.uk: Data Analytics to Become a Game Changer for Internal Audit. <https://www.consultancy.uk/news/16863/data-analytics-to-become-a-game-changer-for-internal-audit>, last Accessed on January 15, 2020

9. Coyne, E.M., Coyne, J.G., Walker, K.B.: Big Data Information Governance by Accountants. *International Journal of Accounting & Information Management* 26(3) (March 2018)
10. Deloitte: Internal Audit Analytics: The journey to 2020: Insights-Driven Auditing. <https://www2.deloitte.com/content/dam/Deloitte/us/Documents/risk/us-risk-internal-audit-analytics-pov.pdf> (2016), last Accessed on January 15, 2020
11. Earley, C.E.: Data Analytics in Auditing: Opportunities and Challenges. *Elsevier Business Horizons* 58(5), 493–500 (September–October 2015)
12. EY: How Big Data and Analytics are Transforming the Audit. [https://www.ey.com/en\\_gl/assurance/how-big-data-and-analytics-are-transforming-the-audit#item1](https://www.ey.com/en_gl/assurance/how-big-data-and-analytics-are-transforming-the-audit#item1) (April 2015), last Accessed on January 15, 2020
13. Gershkoff, A.: How To Stem The Global Shortage Of Data Scientists. <https://techcrunch.com/2015/12/31/how-to-stem-the-global-shortage-of-data-scientists/> (December 2015), last Accessed on January 15, 2020
14. Jain, A.: The 5 V's of Big Data. <https://www.ibm.com/blogs/watson-health/the-5-vs-of-big-data/> (September 2016), last Accessed on January 15, 2020
15. Lynch, K.: The Role of Big Data in Auditing and Analytics. <https://www.analyticsinsight.net/the-role-of-big-data-in-auditing-and-analytics/> (September 2019), last Accessed on January 15, 2020
16. Palombo, S.: Top 10 Areas where Data Analysis Adds the Most Value. <https://www.audimation.com/top-10-areas-where-data-analysis-adds-the-most-value/>, last Accessed on January 15, 2020
17. Pelletier, J.: 6 Essentials to Jump-Start Data Analytics in Internal Audit. <https://iaonline.theiia.org/blogs/Jim-Pelletier/2018/Pages/6-Essentials-to-Jump-start-Data-Analytics-in-Internal-Audit.aspx>, last Accessed on January 15, 2020
18. Protiviti: A Global Consulting Firm. <https://www.protiviti.com>, last Accessed on January 15, 2020
19. Protiviti: Changing Trends in Internal Audit and Advanced Analytics. [https://www.protiviti.com/sites/default/files/united\\_states/internal-audit-data-analytics-whitepaper-protiviti.pdf](https://www.protiviti.com/sites/default/files/united_states/internal-audit-data-analytics-whitepaper-protiviti.pdf) (2015), last Accessed on January 15, 2020
20. PwC: Transforming Internal Audit Through Data Analytics. <https://www.pwc.com/us/en/services/risk-assurance/advanced-risk-compliance-analytics/internal-audit-analytics.html>, last Accessed on January 15, 2020
21. Thabet, N., Soomro, T.: Big Data Challenges. *Journal of Computer Engineering & Information Technology* 4 (September 2015)
22. Walsh, K.: Big Data in Auditing and Analytics. <https://reciprocitylabs.com/big-data-in-auditing-and-analytics/> (March 2019), last Accessed on January 15, 2020