


Auditing in the New Age of Industry 4.0: The Need for More Research

Chijioko E. Nwachukwu, Horizons University, Paris, France

 <https://orcid.org/0000-0002-7982-2810>

Timothy Onechojon Usman, University of Benin, Nigeria

Sadiq Oshoke Akhor, College of Education, Igueben, Nigeria

Agboola Omoniyi Oladipupo, Joseph Ayo Babalola University, Nigeria

ABSTRACT

As the world moves towards a knowledge-based economy, technology is rapidly becoming a necessity. As a result, Industry 4.0 is gradually changing the face of many aspects of human endeavour. From manufacturing to construction and business, data analytics, blockchain, and artificial intelligence, among other things, look promising and may bring a paradigm shift within the accounting profession. This may be significantly drawn towards auditing. While technological changes seem rapid, taking giant strides towards revamping the accounting industry via modern kinds of audit evidence and testing, it is important to tread cautiously in the adoption of technology for auditing. This is because even though technological improvements are useful to achieve speed and accuracy in the audit work, they pose challenges of causing loss of jobs, difficulty in tracing errors, and other potential problems. This paper, therefore, looks at some recent technological development in audit work, and why this aspect of the accounting profession may require further research.

KEYWORDS

Artificial Intelligence, Audit Work, Auditing, Big Data, Block Chain Technology, Fraud Modelling, Industry 4.0, Performance Expectancy, Social Influence

1. INTRODUCTION

Industry 4.0 in audit started-off as electronic processing of data and grew based on the increased use of technology in accounting. General Electric was first to utilize computers in accounting in 1954, with very few accountants being able to use computers at the time (Senft et al., 2012). As development entered the profession, smaller computers were designed, and given the lesser prices of these new computer versions, a lot of companies were able to purchase it and train workers on electronic data processing. In 1968, the first accounting software generalized audit software (GAS) came into existence. Once developed, the apex accounting certification body in the U.S had eight accounting companies develop an audit framework. This was the book titled “*Auditing & EDP*” which details the use of computers in auditing was developed (Senft et al., 2012).

The buzzword, *Industry 4.0*, was introduced about a decade ago by the Deutsche government to represent the fourth industrial revolution (Alcácer and Cruz-Machado, 2019; Grieco et al., 2017; Lu, 2017; Motyl et al., 2017; Peruzzini et al., 2017). It refers to an era of improved efficiency brought forth by automation of the many aspects of manufacturing (Lu, 2017; Peruzzini et al., 2017), one

DOI: 10.4018/IJBSA.20210101.oa2

This article, published as an Open Access article on December 18, 2020 in the gold Open Access journal, International Journal of Business Strategy and Automation (converted to gold Open Access January 1, 2021), is distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/4.0/>) which permits unrestricted use, distribution, and production in any medium, provided the author of the original work and original publication source are properly credited.

in which the virtual and the real worlds are linked (Baena et al., 2017). Technology researchers and scholars alike have mostly viewed industry 4.0 as the meeting point between cyber and physical system units. This is due to its nature of merging diverse heterogeneous data and ideas into its processes in an optimized manner, using updated algorithms (Motyl et al., 2017; Peruzzini et al., 2017).

As the world moves towards a knowledge-based economy, technology is rapidly becoming a necessity and has found its way into human professional endeavours. The accounting profession is beginning to appreciate technology-oriented progress largely as a result of the speed and quality it offers (Tekbas, 2018). In a report published by Global Financial Integrity, Heydt (2020) emphasized the importance of auditing, stating that it is one aspect of accounting where speed and quality cannot be over-emphasized. As defined by Aghaei Chadegani (2011), auditing is the gathering of information that helps to validate the financial and non-financial standing of an organization (Aghaei Chadegani, 2011). Hence, it requires dependable, detailed and error-free processes, which feeds organizations with the right information needed to make appropriate decisions about their future. Such processes and results can only be offered with cutting-edge technology, such as those offered by artificial intelligence, blockchain, and big data analytics among other things. The present paper contributes to the literature by reviewing and discussing the role of technology in the field of auditing. Specifically, both academicians and auditors will be informed of the importance of computer-assisted technology such as artificial intelligence, blockchain technologies and big data-data mining approach in ensuring effective audit of firms.

Given the potentials of the fourth industrial revolution for accounting and auditing, there are challenges which also pose threats to continuous usage of its systems (Kruskopf et al., 2019). Figure 1 is a schematic representation of the current study.

In figure 2, the potential relationship that could exist between industry 4.0 and some audit functions, if fully harnessed is also described. It shows the interconnectivity between aspects of Industry 4.0 and how they resolve common auditing challenges. Every aspect of Industry 4.0 as shown in the diagram below is able to independently resolve one or more challenges faced in a typical audit work (Alcácer and Cruz-Machado, 2019). It is important to note that beyond the aspects of auditing described on figure, there are several other areas where technology play crucial roles in the auditing process (Gepp et al, 2018).

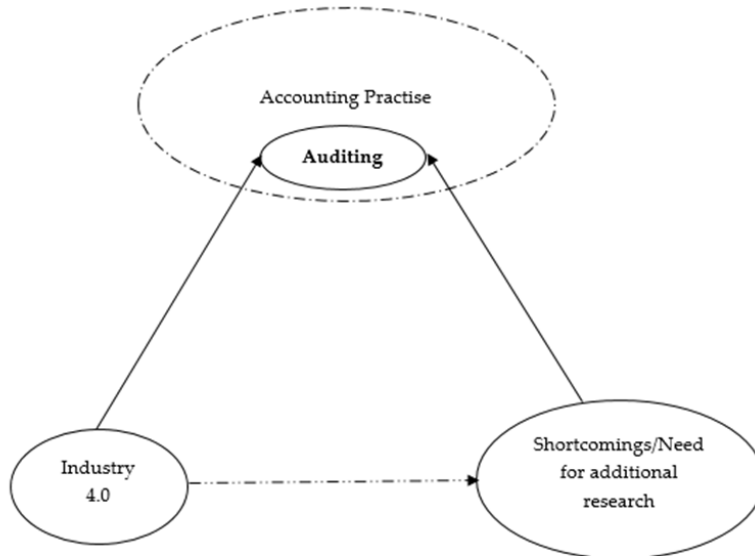
2. RELEVANT LITERATURE

2.1 Big Data and Internet of Things In Audit Work

Big data is a rapidly emerging tool useful for the manipulation of large data sets (Buyya et al., 2013). It adopts many techniques (e.g., decision tree) for data management and analysis (Oussous et al., 2018). Since data processing is at the heart of the accounting profession, aspects of the field such as projections, forecasting, modelling and detection rely on data for optimal delivery. Some researchers argue that big data techniques have found extensive usage in auditing, with three critical aspects; *distress* and *fraud modelling*, as well as in the *prediction of the stock market* (Gepp et al., 2018) being the central focus. Others believe that auditing as a process is yet to fully appreciate big data use, a situation that has triggered serious outcry amongst several accounting researchers (Acito and Khatri, 2014; Brown-Liburud et al., 2015). While the reluctance of some auditors to fully adopt methods that may be difficult to comprehend by clients has been tagged a reason for under-appreciation of big-data in auditing, this idea was been disproved by Gepp et al. (2018), who noted that only detailed research could lead to a better appreciation and use of big data techniques in typical audit work.

The use of data mining for understanding organizations' going concerns is becoming popular nowadays (Koyuncugil and Ozgulbas, 2012; Sun and Li, 2008). Sun and Li (2008) designed a data mining tool for the failure prediction of over 100 firms using; entropy-based discretization technique, attributes of financial ratios and one class respectively. The decision-tree big data technique was

Figure 1. Schematic representation of the current study



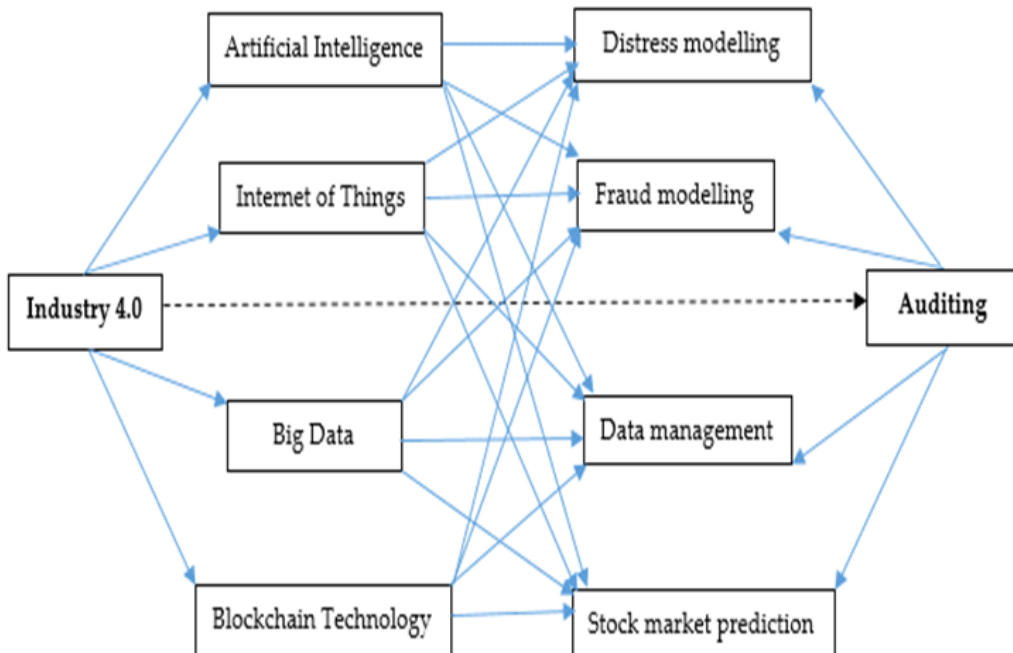
the foundation for this model design. Data mining was also adopted to fore-warn small firms on a distress-course (Koyuncugil and Ozgulbas, 2012). This was tested on thousands of small companies to develop financial risk pointers and ways of mitigating them.

In the determining evolving fraud situation in some organizations, Zhou and Kapoor (2011) noted that even though big data techniques may be close to perfect, it is indeed useful to merge such ideas with residual knowledge by audit professionals. This is particularly because such frauds seem to evolve with computer-assisted technology and may sometimes go undetected. The implication of this is that a combination of big data-data mining approach and the conventional professional pathways may be more accurate (Lin and McClean, 2001). Although there is an ongoing argument as to what the term “*reasonable assurance*” in financial fraud truly signify, big data models are useful in detecting fraudulent financials to a reasonable assurance level (Hogan et al., 2008). By carrying out a systematic review, Ngai et al. (2011) maintained that data mining techniques (discriminant analysis, logistic model, and hidden Markov models among others) have mostly been used to detect fraud in insurance, in credit card deals, as well as corporate systems.

Another aspect of auditing where big data remains invaluable is in data, gathering, availability and usefulness. According to the International Auditing and Assurance Standards Board (IAASB), clients who give out audit jobs nowadays expect touches of big data analytics in its execution. Given the existing use of randomly sampled data in audit work, big data analytics offers real-time data, tied to existing case-histories which makes them comparable to new/ongoing events, as well as in the prediction of future ones (IAASB, 2016). While the ordinary auditor focuses on aggregation, sampling and presentation, big data empower auditors to be able to have a grasp of the procedures that lead to data generation, and the population make-up, which are crucial for audit data quality and value (Krahel and Titera, 2015). Furthermore, Brown-Liburd et al. (2015) opined the judgment of an auditor may be affected when there are too many data chunks. This results in an overload of information, for which only knowledge of big data can ultimately resolve.

A study carried out by Yoon et al. (2015) showed that big data utilities give room for additional information otherwise referred to as audit evidence in audit work. However, this may require critical evaluation based on the guidelines of; evidence sufficiency, evidence reliability, and relevance of the

Figure 2. Key aspects of Industry 4.0 in relation to audit functions (Author's idea)



evidence respectively. In process mining, a system that examines how events are recorded within a business (Jans et al., 2014), big data can give more accurate results, especially when the data series are derived from real-time situations (Werner and Gehrke, 2015). Besides, texts and audio-visuals processed by big data are very important to accounting systems, especially audit work (Crawley and Wahlen, 2014; Warren et al., 2015). An example is seen in transaction verification in audit functions which require the auditor to check all receipts and invoices. Traditionally, the auditor will only focus on generated transaction receipts. However, the advent of big data helps for better verification using GPS location and photos (Moffitt and Vasarhelyi, 2013).

As reported by Smith (2015) big data is value-added in auditing, not only for improved data and information but due to the improved relevance of an auditor who understands its rudiments. Such an auditor is mostly seen as a business partner, rather than a mere service provider. Gepp et al (2018) explained that with big data technique, reasonable information can be derived from data sets, no matter how small they are. For instance, in understanding the association that exists between audit tenure and its reporting, Read and Yezegel (2015) pointed that analysing the data without the ideas of a big data technique would imply squaring data to cater for nonlinear associations. This may bring about challenges leading to a quadratic relationship. However, by using the decision tree, a big data method, the data can be visualized from the onset, so that the constraints are catered for before data analysis.

In carrying the response of auditors to estimation risk, Lennox and Kausar (2017) stressed that adjusting for possible non-linearity by taking the square of terms led to data skewness. However, the use of big data decision tree meant that the analysis could be done without having to worry about skewness. As reported by Xu and Zhang (2009) who attempted to predict the bankruptcy of listed Japanese firms using a 13year data span, the need for variable elimination from the bankruptcy model was inevitable. However, the use of “Lasso regularized regression”, could have easily handled independent variables. Furthermore, this big data technique can as well be used to eliminate the

variables, or even drastically reduce the values of coefficients to approach zero. As such, elimination may not be necessary.

While big data analytics in auditing continue to look promising, some researchers have so far identified areas of potential challenges. These include; representation of auditing problems in the big data domain, selections of the most suitable technique for fraud of distress detection/prediction, selection of required characteristics, as well as performance analysis (West and Bhattacharya, 2016).

2.2 How Does Artificial Intelligence (AI) and Blockchain Technology Influence Auditing?

While there is so much discussion on how much research is currently ongoing on artificial intelligence in accounting, there abound several unsubstantiated claims on findings which can be merely replicated, especially concerning artificial intelligence in audit work (Issa et al., 2016). Nevertheless, a lot has also been done since AI was first mentioned in auditing. Chen and Du (2009) opined that adopting data mining within an artificial neural network frame of reference is better suited for modelling financial distress than using data mining only. This was carried out using a data sample of 68 listed companies of the Taiwanese stock exchange. It was concluded that artificial intelligence may be more useful than mere statistical approaches in the prediction of the financial failure of a company.

Asides the analysis of financial prediction and performance of corporations, the use of machine learning is also able to accurately study financial distress in individuals. As revealed by Khandani et al. (2010), the credit risk of an individual (customer) may be verified, given his/her credit card transaction history, as well as data obtained from the credit bureau. This result may determine whether an individual should be granted additional credit in future.

Apart from the programs described in table 1, Deloitte's has also adopted another tool called "Argus". As described by Kepes (2016), Argus is based on machine learning and can read contracts and leases. Argus algorithms also equip the tool to be able to identify outliers. With Argus, the interpretation of the main attributes of documents is easy to address. As such, auditors can ignore contracts without serious risk, leading to audit speed. PricewaterhouseCoopers also has "Halo" (Kokina and Davenport, 2017), which carries out critical analyses on entries of a journal to identify errors/ peculiar issues. Halo ca also provide auditors with annual testing of entries of a company's journal, and then concentrate on outliers with very high/potential risk. Again, quality and speed can be improved when this is done.

As a disrupting tool of industry 4.0, blockchain *proof-of-work* and *proof-of-stake* have started gaining attention in auditing. An example is in the use by Factom, a U.S.-based blockchain company of the so-called "Factom Harmony", a blockchain tool able to convert huge document and data files into blockchain-based ones (Abreu et al., 2018). This means that loads of data, documents and information in audit work can be kept safely, and without the challenges of having to worry about lost data.

There is also a "dLoc", which authenticates data and documents on the platform (Abreu et al, 2018). One popular area of research of blockchain in accounting is in audit assurance. As reported by Liu et al. (2019), blockchain offers an avenue for the verification of digitals assets claim of some organizations, this facilitates the audit comparison of blockchain-based information and those of the physical world. Table 1 describes the ongoing usage of some intelligent tools.

2.3 Underlying Theory For Adoption of Industry 4.0 In Audit

For effective adoption of industry 4.0 technological tools, such adoption must be based on an established protocol, model or theory. As proposed by Venkatesh et al. (2003), the UTAUT model could be useful for the adoption of Industry 4.0 tools in audit work (Alheety and Marei, 2018). UTAUT is an acronym for "unified theory of acceptance and use of technology". The theory is comprised of four unique aspects that help determine the extent to which potential users (auditors) will accept and use industry 4.0 tools, these are; effort expectancy (EE), facilitating conditions (FC), performance expectancy (PE), and social influence (SI) (Venkatesh et al., 2003). As reported by Alheety and

Table 1. Industry 4.0 application in accounting and auditing (Adapted from Kruskopf et al, 2019)

Organization	Programme	Technology	Case Description	Reference
Pricewaterhouse Coopers (PwC)	Digital Accelerator	Big data analytics, blockchain and artificial intelligence (with special emphasis on machine learning)	The program was an in-house training for employees of the organization. It comprises of learning the rudiments of some new technology and using the knowledge to solve new problems. It took the shape of classroom lecture attendance and sharing of projects which are real projects from customers. Participants needed to use ideas learnt on the program to solve the challenges posed by the client's work.	Liffreing(2018)
Ernst & Young Global Limited, Pricewaterhouse Coopers (PwC) and Deloitte	Natural Language Processing (NLP)	Artificial intelligence	EY utilizes NLP in the form of a business by adopting very little efforts to achieve rapid returns on investment. The company also ensures the technique is adopted when there are new lease standards by revenue service. PwC makes use of AI sprints in the creation of models to solve client's problems within the shortest possible time. The AI sprints are subjected to verification and approval after which they are refined for use by clients. For Deloitte, NLP is adopted to look through several thousand of client's cases for comparison of past audit work for the adoption of the solution method. This saves the company a lot of time on their job	Thomas (2018)
Pricewaterhouse Coopers (PwC)	ABBYY FlexiCapture	Artificial intelligence	PwC adopted ABBYY Flexi Capture to speed up the processing of documents which were manually done by staffs in the past. The technology adopts artificial intelligence to search and streamline documents. By uploading document details unto the ABBYY server, an auditor can get all required information without going through the stress of paperwork.	Kruskopf et al, (2019)
Deloitte	Blockchain laboratory	Blockchain and machine learning	This U.S-based laboratory created by Deloitte if for research into Blockchain for audit work. It comprises of a real-time fraud detection unit.	Deloitte (2019)

Marei (2018) experience and voluntary nature of use are some of the variables that moderate UTAUT. Given that technology, user-friendliness has been pointed as a major factor that determines whether technology will be accepted for use or not (Venkatesh et al., 2012), tools such as big data, artificial intelligence, and blockchain technologies must be simplified so that it is easy to use. Having all been found to possess the ability to speed up the entire audit work, industry 4.0 tools will create such ease to the audit work within the framework of UTUAT.

2.4 Impact of The Use of Industry 4.0 Tools on Stakeholders

Having described the positives of Industry 4.0, this section takes a look at some potential challenges of the use of Industry 4.0-linked technologies to auditing, especially with considerations to stakeholders who are affected. According to Najjar et al. (2019), the advent of technology-driven solutions may affect the job security of some auditors, especially those who are not readily equipped with skills relevant to manage these systems. As reported by Kokina and Davenport (2017), individuals who should start as early career professionals do not get the chance to do so when Industry 4.0 is fully functional within the job market. For instance, given the speed with which the audit work can be done, a single auditor can complete several audit tasks within a very short time. As such, it would not be necessary to hire new ones. The implication here is that hands-on experience will eventually be lacking in many new auditors.

Another major challenge posed by technologies associated with Industry 4.0 in audit work is the need to evolve as soon as there is another new technology in place. This means that workers would generally need to possess the abilities to retain older skills while learning new and updated ones almost immediately (Dickinson, 2018). While this may be some worth advantageous for competitiveness, the cost implication for learning most new skills may be high, and this has so far been a serious issue for financial officers (Ernst and Young, 2016). When these skills are not learnt, some audit firms may be outpaced by technology, thus affecting organizational agility (Kruskopf et al., 2019). Furthermore, it is important to note that not all societies are ready to fully embrace the changes that come with Industry 4.0 (Marr, 2016), especially due to the fact some are yet to fully evolve from certain economic woes.

As reported by Kruskopf et al (2019), smaller auditing firms may not have the wherewithal to manage the implementation of new technologies unlike the Big 4 firms, this may be linked to the complex procedures involved (Caramela, 2018), as well as possible skill deficit. The advent of new technologies also poses new security challenges for firms (Marr, 2016), especially in the case of blockchain for which concerns have been raised amongst researcher concerning the level of risk it poses for security and privacy of data (Fuller and Markelevich, 2020). For instance, Tysiac (2018) stressed that even though a secured blockchain transaction may be good evidence for a financial statement, it may not give an insight into the evidence for audit concerning the transaction. This means that if a bitcoin transfer is recorded on the blockchain platform, it is beyond the auditor to ascertain whether the product has been delivered based on the information provided on the platform.

Beyond the aforementioned challenges and impact on auditors, firms and customers, a more important problem is that some aspects of Industry 4.0 offer similar services. For instance, certain artificial intelligence techniques can be used in the lure of those of big data (Chen and Du, 2009). This poses a problem of choice concerning the best-suited method for an audit task. While firms expect innovation on the part of auditors, auditors are careful to rush into the use of new technologies they are not aware of. No investor will want to invest in a firm that is not tech-driven, especially in its financial reporting.

3. METHODOLOGY

This study is a systematic literature review. We employed an exploratory study technique using existing literature. The authors used both qualitative and quantitative studies in our review. Our literature review identifies relevant articles within the computing, artificial intelligence and auditing literature. Specifically, we reviewed fifty seven (57) studies conducted between 2001 and 2020.

4. DISCUSSIONS

Our review shows the usage of big data techniques in distress and fraud modelling and the prediction of the stock market. We observe that big data is not fully employed in auditing. Audit firms are using data mining to predict the failure of firms and to understand organizations' going concerns. The literature review suggests that adopting data mining within an artificial neural network is more effective for modelling financial distress (Chen and Du, 2009). Besides, machine learning can predict accurately financial distress in individuals. It was observed that audit firm use machine learning to read contracts and leases and analyse journal entries to identify errors/ peculiar issues. Consequently, saving time, cost and reducing errors. The review highlights the use of blockchain to convert huge document and data files into blockchain-based ones (Abreu et al., 2018), which ensures that audit work/ file are safely stored. Blockchain foster audit assurance by offering an avenue for the verification of digitals assets claim and comparing it with those of the physical world. (Liu et al., 2019). The analysis reveals that auditing in industry 4.0 presents some challenges. First, technology-driven solutions may affect the job security of some auditors, especially those who refuse to develop the skills needed to manage these systems. Second, the need for audit work to evolve as soon as another new technology emerges. This call for constant learning of new skills and competences with huge cost implications. Smaller auditing firms may not have the financial resources and capabilities to implement these new technologies (Kruskopf et al., 2019). Again, these new technologies pose new security and data privacy challenges for firms, especially blockchain technologies (Fuller and Markelevich, 2020).

5. CONCLUSIONS AND RECOMMENDATIONS

Industry 4.0 will surely assist in the improvement of speed and quality of auditing and auditors around the globe. Furthermore, fraud and distress related matters will be processed more easily, with the use of Industry 4.0 enabled technologies. Nevertheless, more research needs to go into how human-machine interactions would be facilitated so that the number of persons whose jobs would be lost due to technology can be reduced. It is also important for individuals saddled with the responsibilities of handling corporate technologies to advise firms on the type of technology to be adopted so that they don't become "jack of all trade". This will help them focus better on how the technologies may be useful in full-scale auditing. Judging from the foregone discussion and the complexity of a full-scale adaptation of Industry 4.0, it is safe to say that there is more or less skill deficit in the world of technology-driven audit work. This is especially prevalent amongst recent graduates (Pan and Seow, 2016). To address this challenge, Universities need to upgrade existing management programmes and courses, so that they tend more toward the latest technological drives. Furthermore, attention must be given to technologies that have found extensive usage in audit work. In addition, organizations may take up community training on aspects of Industry 4.0. This could be in the form of corporate social responsibilities (Kruskopf et al, 2019). The same must be replicated amongst employees to build technology-oriented societies. Although such CSR responsibilities and investment on employees may be expensive to achieve, it has been predicted that companies that do not key into this trend may either go bankrupt or lose their capacity to compete (Kruskopf et al., 2019). In a report published by Forbes, Marr (2018) argued that Industry 4.0 may take over many complex audit procedures, so that audit professional will only be left to play advisory roles in the future. In contrast, Kruskopf et al. (2019) believe that the era of Industry 4.0 will mainly be based on human-machine cooperation. This is because designed programs and software must be controlled by humans. On the challenges posed by the selection of most appropriate methods for use in specific auditing work, it may be useful for organizations to hire persons with multiple skillsets, who can effectively manage more than one aspect of Industry 4.0 as discussed within the breadth of the current study.

5.1 Limitation of Study

The present study is exploratory and focused on the review of the extant literature on the subject, which somewhat limits its applicability. Future research should empirically test the impact of this new technology on audit quality in various contexts, especially in developing economies. Nonetheless, the paper adds to the ongoing debate on emerging technologies and auditing research.

REFERENCES

- Abreu, P. W., Aparicio, M., & Costa, C. J. (2018). Blockchain technology in the auditing environment. *13th Iberian Conference on Information Systems and Technologies*, 1–6. doi:10.23919/CISTI.2018.8399460
- Acito, F., & Khatri, V. (2014). Business analytics: Why now and what next? *Business Horizons*, *57*(5), 565–570. doi:10.1016/j.bushor.2014.06.001
- Aghaei Chadegani, A. (2011). *Review of Studies on Audit Quality (SSRN Scholarly Paper No. ID 2227359)*. Social Science Research Network. doi:10.2139/ssrn.2227359
- Alcácer, V., & Cruz-Machado, V. (2019). Scanning the Industry 4.0: A Literature Review on Technologies for Manufacturing Systems. *Engineering Science and Technology, an International Journal*, *22*, 899–919. 10.1016/j.jestch.2019.01.006
- Alheety, S., & Marei, A. (2018). The impact of information technology on the development of audit process: Review of accepted theories of IT by the auditors. *Journal of Business and Management*, *4*, 106–117.
- Baena, F., Guarin, A., Mora, J., Sauza, J., & Retat, S. (2017). Learning Factory: The Path to Industry 4.0. *Procedia Manufacturing*, *7th Conference on Learning Factories, CLF 2017*, *9*, 73–80. doi:10.1016/j.promfg.2017.04.022
- Brown-Liburd, H., Issa, H., & Lombardi, D. (2015). Behavioral Implications of Big Data's Impact on Audit Judgment and Decision Making and Future Research Directions. *Accounting Horizons*, *29*(2), 451–468. doi:10.2308/acch-51023
- Buyya, R., Vecchiola, C., & Thamarai Selvi, S. (2013). Data-Intensive Computing: MapReduce Programming. In *Mastering Cloud Computing*. Morgan Kaufmann. doi:10.1016/B978-0-12-411454-8.00008-5
- Caramela, S. (2018). AT&T's Anne Chow on Why Small Businesses Shy Away from Early Tech Adoption. *Business News Daily*. <https://www.businessnewsdaily.com/10742-anne-chow-att-tech-adoption.html>
- Chen, W.-S., & Du, Y.-K. (2009). Using neural networks and data mining techniques for the financial distress prediction model. *Expert Systems with Applications*, *36*(2), 4075–4086. doi:10.1016/j.eswa.2008.03.020
- Crawley, M., & Wahlen, J. (2014). Analytics in empirical/archival financial accounting research. *Business Horizons*, *57*(5), 583–593. doi:10.1016/j.bushor.2014.05.002
- Dickinson, K. (2018). *Top 6 fears about future technology - Big Think*. <https://bigthink.com/technology-innovation/fear-future-technology>
- Ernst and Young. (2016). The evolving role of the CFO in the digital age Agile finance for financial services. *Ernst & Young Global Limited*. [https://www.ey.com/Publication/vwLUAssets/EY-the-evolving-role-of-the-CFO-in-the-digitalage/\\$FILE/EY-the-evolving-role-of-the-CFO-in-the-digital-age.pdf](https://www.ey.com/Publication/vwLUAssets/EY-the-evolving-role-of-the-CFO-in-the-digitalage/$FILE/EY-the-evolving-role-of-the-CFO-in-the-digital-age.pdf)
- Fuller, S. H., & Markelevich, A. (2020). Should accountants care about blockchain? *Journal of Corporate Accounting & Finance*, *31*(2), 34–46. doi:10.1002/jcaf.22424
- Gepp, A., Linnenluecke, M. K., O'Neill, T. J., & Smith, T. (2018). Big data techniques in auditing research and practice: Current trends and future opportunities. *Journal of Accounting Literature*, *40*, 102–115. doi:10.1016/j.acclit.2017.05.003
- Grieco, A., Caricato, P., Gianfreda, D., Pesce, M., Rigon, V., Tregnaghi, L., & Voglino, A. (2017). An Industry 4.0 Case Study in Fashion Manufacturing. *Procedia Manufacturing*, *27th International Conference on Flexible Automation and Intelligent Manufacturing, FAIM2017*, *11*, 871–877. doi:10.1016/j.promfg.2017.07.190
- Heydt, M. (2020). *Unaccountable: The Role of Accountancy Firms in International Financial Scandals*. Global Financial Integrity. <https://gfintegrity.org/unaccountable-the-role-of-accountancy-firms-in-international-financial-scandals/>
- Hogan, C. E., Rezaee, Z., Riley, R. A. Jr, & Velury, U. K. (2008). Financial Statement Fraud: Insights from the Academic Literature. *Auditing*, *27*(2), 231–252. doi:10.2308/aud.2008.27.2.231
- International Auditing and Assurance Standards Board. (2016). *Exploring the Growing Use of Technology in the Audit, with a Focus on Data Analytics*. IFAC. <https://www.ifac.org/iaasb/publications/exploring-growing-use-technology-audit-focus-data-analytics>

- Issa, H., Sun, T., & Vasarhelyi, M. A. (2016). Research Ideas for Artificial Intelligence in Auditing: The Formalization of Audit and Workforce Supplementation. *Journal of Emerging Technologies in Accounting*, 13(2), 1–20. doi:10.2308/jeta-10511
- Jans, M., Alles, M. G., & Vasarhelyi, M. A. (2014). A Field Study on the Use of Process Mining of Event Logs as an Analytical Procedure in Auditing. *The Accounting Review*, 89(5), 1751–1773. doi:10.2308/accr-50807
- Kepes, B. (2016). Big Four accounting firms delve into artificial intelligence. *Computerworld*. <https://www.computerworld.com/article/3042536/big-four-accounting-firms-delve-into-artificial-intelligence.html>
- Khandani, A. E., Kim, A. J., & Lo, A. W. (2010). Consumer credit-risk models via machine-learning algorithms. *Journal of Banking & Finance*, 34(11), 2767–2787. doi:10.1016/j.jbankfin.2010.06.001
- Kokina, J., & Davenport, T. H. (2017). The Emergence of Artificial Intelligence: How Automation is Changing Auditing. *Journal of Emerging Technologies in Accounting*, 14(1), 115–122. doi:10.2308/jeta-51730
- Koyuncugil, A. S., & Ozgulbas, N. (2012). Early warning system for financially distressed hospitals via data mining application. *Journal of Medical Systems*, 36(4), 2271–2287. doi:10.1007/s10916-011-9694-1 PMID:21626293
- Krahel, J. P., & Titera, W. R. (2015). Consequences of Big Data and Formalization on Accounting and Auditing Standards. *Accounting Horizons*, 29(2), 409–422. doi:10.2308/acch-51065
- Kruskopf, S., Lobbas, C., Meinander, H., & Söderling, K. (2019). Digital Accounting: Opportunities, Threats and the Human Factor. *ACRN Oxford*, 8, 1–15.
- Lennox, C. S., & Kausar, A. (2017). Estimation risk and auditor conservatism. *Review of Accounting Studies*, 22(1), 185–216. doi:10.1007/s11142-016-9382-y
- Liffreing, I. (2018). *PwC launches 2-year digital skills course to train 1,000 employees on everything from drones to blockchain*. Digiday. <https://digiday.com/marketing/pwc-launches-two-year-digital-skills-course-train-1000-employees-everything-drones-blockchain/>
- Lin, F. Y., & McClean, S. (2001). A data mining approach to the prediction of corporate failure. In A. Macintosh, M. Moulton, & F. Coenen (Eds.), *Applications and Innovations in Intelligent Systems VIII* (pp. 93–106). Springer. doi:10.1007/978-1-4471-0275-5_7
- Liu, M., Wu, K., & Xu, J. J. (2019). How Will Blockchain Technology Impact Auditing and Accounting: Permissionless versus Permissioned Blockchain. *Current Issues in Auditing*, 13(2), A19–A29. doi:10.2308/ciia-52540
- Lu, Y. (2017). Industry 4.0: A survey on technologies, applications and open research issues. *Journal of Industrial Information Integration*, 6, 1–10. doi:10.1016/j.jii.2017.04.005
- Marr, B. (2016). Why Everyone Must Get Ready For The 4th Industrial Revolution. *Forbes*. <https://www.forbes.com/sites/bernardmarr/2016/04/05/why-everyone-must-get-ready-for-4th-industrial-revolution/>
- Marr, B. (2018). The Digital Transformation Of Accounting And Finance - Artificial Intelligence, Robots And Chatbots. *Forbes*. <https://www.forbes.com/sites/bernardmarr/2018/06/01/the-digital-transformation-of-accounting-and-finance-artificial-intelligence-robots-and-chatbots/>
- Moffitt, K. C., & Vasarhelyi, M. A. (2013). AIS in an Age of Big Data. *Journal of Information Systems*, 27(2), 1–19. doi:10.2308/isis-10372
- Motyl, B., Baronio, G., Uberti, S., Speranza, D., & Filippi, S. (2017). How will Change the Future Engineers' Skills in the Industry 4.0 Framework? A Questionnaire Survey. *Procedia Manufacturing*, 27th International Conference on Flexible Automation and Intelligent Manufacturing, FAIM2017, 11, 1501–1509. doi:10.1016/j.promfg.2017.07.282
- Najjar, F. B. (2019). *Startup Uses AI to Automate Accounting System*. The Balance Small Business. <https://www.thebalancesmb.com/is-artificial-intelligence-the-future-of-accounting-4083182>
- Ngai, E.W.T., Hu, Y., Wong, Y.H., Chen, Y and Sun, X., (2011). The application of data mining techniques in financial fraud detection: A classification framework and an academic review of literature. *Decision Support Systems*, On *Quantitative Methods for Detection of Financial Fraud*, 50, 559–569. 10.1016/j.dss.2010.08.006

- Oussous, A., Benjelloun, F.-Z., Ait Lahcen, A., & Belfkih, S. (2018). Big Data technologies: A survey. *Journal of King Saud University - Computer and Information Sciences*, 30, 431–448. 10.1016/j.jksuci.2017.06.001
- Pan, G., & Seow, P. (2016). Preparing accounting graduates for digital revolution: a critical review of information technology competencies and skills development. *Journal of Education for Business*, 91(3), 166-175.
- Peruzzini, M., Grandi, F., & Pellicciari, M. (2017). Benchmarking of Tools for User Experience Analysis in Industry 4.0. *Procedia Manufacturing, 27th International Conference on Flexible Automation and Intelligent Manufacturing, FAIM2017*, 11, 806–813. doi:10.1016/j.promfg.2017.07.182
- Read, W. J., & Yezegel, A. (2015). Auditor Tenure and Going Concern Opinions for Bankrupt Clients: Additional Evidence. *Auditing*, 35(1), 163–179. doi:10.2308/ajpt-51217
- Senft, S., Gallegos, F., & Davis, A. (2012). *Information Technology Control and Audit* (4th ed.). Auerbach Publications.
- Shukarova–Savovska, K., & Sirois, B. A. (2017). *Audit Data Analytics: Opportunities and Tips*. Academic Press.
- Sivarajah, U., Kamal, M. M., Irani, Z., & Weerakkody, V. (2017). Critical analysis of Big Data challenges and analytical methods. *Journal of Business Research*, 70, 263–286. doi:10.1016/j.jbusres.2016.08.001
- Smith, S. S. (2015). Strategy, Analytics, and the Role of Accountancy. *Strategic Management Review*, 9, 87–93.
- Sun, J., & Li, H. (2008). Data mining method for listed companies' financial distress prediction. *Knowledge-Based Systems*, 21(1), 1–5. doi:10.1016/j.knosys.2006.11.003
- Tekbas, I. (2018a). *The Profession of the Digital Age: Accounting Engineering*. IFAC. <https://www.ifac.org/knowledge-gateway/preparing-future-ready-professionals/discussion/profession-digital-age-accounting>
- Tysiac, K. (2018b). How blockchain might affect audit and assurance. *Journal of Accountancy*. <https://www.journalofaccountancy.com/news/2018/mar/how-blockchain-might-affect-audit-assurance-201818554.html>
- Venkatesh, V., Morris, M. G., Davis, G. B., & Davis, F. D. (2003). User Acceptance of Information Technology: Toward a Unified View. *Management Information Systems Quarterly*, 27(3), 425–478. doi:10.2307/30036540
- Venkatesh, V., Thong, J. Y. L., & Xu, X. (2012). Consumer Acceptance and Use of Information Technology: Extending the Unified Theory of Acceptance and Use of Technology. *Management Information Systems Quarterly*, 36(1), 157–178. doi:10.2307/41410412
- Warren, J. D. Jr, Moffitt, K. C., & Byrnes, P. (2015). How Big Data Will Change Accounting. *Accounting Horizons*, 29(2), 397–407. doi:10.2308/acch-51069
- Werner, M., & Gehrke, N. (2015). Multilevel Process Mining for Financial Audits. *IEEE Transactions on Services Computing*, 8(6), 820–832. doi:10.1109/TSC.2015.2457907
- West, J., & Bhattacharya, M. (2016). Some Experimental Issues in Financial Fraud Mining. *Procedia Computer Science, International Conference on Computational Science 2016, ICCS 2016*, 80, 1734–1744. doi:10.1016/j.procs.2016.05.515
- Xu, M., & Zhang, C. (2009). Bankruptcy prediction: The case of Japanese listed companies. *Review of Accounting Studies*, 14(4), 534–558. doi:10.1007/s11142-008-9080-5
- Yoon, K., Hoogduin, L., & Zhang, L. (2015). Big Data as Complementary Audit Evidence. *Accounting Horizons*, 29(2), 431–438. doi:10.2308/acch-51076
- Zhou, W., & Kapoor, G. (2011). Detecting evolutionary financial statement fraud. *Decision Support Systems, On Quantitative Methods for Detection of Financial Fraud*, 50, 570–575. 10.1016/j.dss.2010.08.007