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The future of audit: Examining the opportunities and challenges stemming from the use of Big Data Analytics and Blockchain technology in audit practice

By

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Abstract

Title:	The future of audit: Examining the opportunities and challenges stemming from the use of Big Data Analytics and Blockchain technology in audit practice
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Key Words:	Audit, Big Data Analytics, Blockchain, Distributed Ledger, Innovation
Thesis Purpose:	The purpose of this thesis is to contribute to the extant knowledge and further research regarding the effects of Big Data Analytics (BDA) and blockchain (BC) technology on the future of the audit profession and to provide a framework grounded in existing theoretical research which would explore ways in which BDA and BC technology could be integrated into the audit procedures of the future.
Methodology:	A qualitative approach has been chosen and mainly inductive reasoning has been used to answer the research questions. First, a systematic literature review has been performed. Second, a case study has been conducted using semi-structured interviews at KPMG Luxembourg and PwC Malmö.
Theoretical Perspective:	The theoretical perspective is an aggregation of the most relevant findings from the Systematic Literature Review (SLR) and the Case Study (CS), which represents the underlying theoretical foundation for this thesis. Moreover, a theoretical framework is built upon those results.
Empirical Foundation:	The empirical data for this thesis has been collected through semi-structured interviews with one employee at PwC in Malmö and five employees at KPMG Luxembourg. Furthermore, internal and external reports have been collected to derive conclusions.
Conclusions:	The body of research relating to BDA and BC technology has been growing at an increasing rate in the last three years. Increased standardisation of audit procedures and use of BDA could enable and foster the implementation of BC technology, which will change the audit profession. Semi- or full automation of time consuming but simple audit tasks will lead to more effectiveness and efficiency; and ultimately to cost-savings. The CS showed that contextual factors have an impact on interviewees' perception regarding the challenges and the future of their profession. However, they acknowledge that BDA and BC technology will play a big role in the future of audit. Furthermore, this thesis provides a theoretical framework which could enable audit firms to integrate BDA and the BC technology into future audit procedures.

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Nikola Kostić Xiao Tang

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List of Abbreviations

ADS	Audit data standards
ASEC	Assurance services executive committee
AICPA	American institute of certified public accountants
BC	Blockchain
BD	Big Data
BDA	Big Data Analytics
CA	Continuous auditing
CAAT	Computer assisted techniques
CAO	Chief audit officer
CEO	Chief executive officer
CFO	Chief financial officer
CS	Case Study
DA	Data Analytics
ERP	Enterprise Resource Planning
GAAP	Generally accepted accounting principles
GPS	Global Positioning System
GSL	Global Synchronisation Log
IFRS	International financial reporting standards
ISA	International standards of auditing
IT	Information technology
PCS	Private Contract Store
PSCD	Private store of confidential data
PSF	Professional service firm
RFID	Radio-frequency identification
SLCN	Shared log of commitments and notifications
SLR	Systematic Literature Review
SME	Small and medium-sized enterprise

1 Introduction

1.1 Background

The unprecedented rate of technological advancement is influencing organisations from various industries in profound ways, presenting numerous opportunities for improvement and innovation. However, these changes pose just as many threats to established companies and in some cases, whole professions. *"The only thing that is constant is change",* a quote from the Greek philosopher Heraclitus, has never seemed more accurate.

The audit profession is poised for rapid changes in light of these conditions. Organisations are producing and analysing more data than ever before. Smart usage of the latest technology, coupled with their extant knowledge and experience, would allow the audit professionals to take a much deeper dive into financial facets of an organisation and provide insights that would result in better decision-making, higher quality audits and ultimately create value for their clients (KPMG, 2017). At the core of these changes has been the ever-increasing amount of data that the auditors need to handle. In addition to the sheer volume, these data come in various, unstructured forms including text, images, sounds and video that require huge storage capacity (Cao, Chychyla and Stewart, 2015). Current legal regulations, professional standards and existing best-practices in the audit profession seem increasingly out of touch in this information-intensive, fast-moving environment, making it more and more difficult for the audit firms to fully serve the needs of their clients, and potentially threatening their long-term existence in the current form.

This kind of environment, in which everything can be recorded, measured and captured digitally and turned into data has been dubbed "datafication" (Mayer-Schönberger and Cukier, 2013). The product of "datafication" has been the emergence of "Big Data" (BD). The term "Big Data" has been used to describe large population of datasets whose size is beyond the ability of typical database software tools to capture, store, manage and analyse (McKinsey, 2011). Furthermore, BD is characterised by certain qualities, known as the four Vs, namely: massive volume or size of the database; high velocity of data added on a continuous basis; large variety of data; and the uncertain veracity of data (IBM, 2012) (See Appendix I for an illustration). Big Data analytics (BDA) offers numerous opportunities for improvement, not least of which is the shift away from "data sampling" which has long been a staple of the audit process. Instead of using data from small, clean datasets and focusing on causation, the auditor relying on BDA would use "all" the data in big, relatively messy datasets and focus more on correlation rather than causation. This would present a significant paradigm shift compared to the traditional audit process (Cao, Chychyla and Stewart, 2015).

These technological innovations are changing the very fabric of audit firms. Primary assets of audit firms—as of any professional service firm (PSF)—are a highly educated workforce whose outputs are intangible services encoded with complex knowledge (Greenwood et al., 2005). The most important skills clients look for in an auditor today are in the areas of technology, communication and critical thinking, followed by investigative financial skills. The most notable change since 2014 was observed in the increased demand for the ability of auditors to work across silos in order to provide a more complete picture of the organisation, a stark contrast compared to the current modus operandi in audit firms (KPMG, 2017) (See Figure 3.2). Audit firms have long struggled to recruit and, more importantly, retain the brightest graduates and experienced professionals, often losing out to tech companies which are able to offer them better financial incentives and more challenging and diverse work assignments. The aforementioned technological changes and the new skill-related requirements they entail could be a boon for audit firms, but only if they take proactive measures to redesign their hiring practises and incentive and development systems to make them suitable for the upcoming age.

Looking further, a technology which has the potential to change and disrupt industries from information technology (IT), finance, audit and many others is the blockchain (BC). BC represents a type of distributed ledger database that maintains a continuously growing list of transaction records ordered into blocks with various protections against tampering and revision (KPMG, 2016 (a)). It is the—often overlooked—underlying technology of bitcoin, a peer-to-peer cryptocurrency first introduced in a paper by an author—or a group of authors—called Satoshi Nakamoto in early 2009. The potential uses of BC are so diverse and their effects so far-reaching that some authors have called it "foundational technology", a technology with the potential to create new foundations for our economic and social systems (Iansiti and Lakhani, 2017), and "internet 2.0" (Tapscott and Tapscott, 2016). Some even go as far as to predict that the BC technology will, in time, do away with all of the financial intermediaries, if applied fully and in its purest decentralised form (Gupta, 2017). This threat has been recognised by many leading financial institutions such as JP Morgan, Deutsche Bank, BNY Mellon, UBS and Banco Santander as well as all of the "Big 4" accounting firms which are investing in BC-related projects and closely collaborating with start-ups in an attempt to stay ahead of the curve and use this emerging technology to their advantage rather than fall victim to it. For a more detailed description of the BC technology see Appendices C, D and E.

1.2 Problem description

Technological innovations, from the ones already established in various industries such as BDA, to the more novel BC technology are attracting ample interest among academics, practitioners and professional regulatory bodies. However, the debate and research has yet to yield a consensus on any of the relevant aspects of these technologies, including their level of importance for the audit industry, practical application, potential technical and financial drawbacks of implementation and the regulatory and legal framework. Most of the arguments are still on an abstract level and lean heavily on the experiences of successful applications in other related industries, especially in the case of BDA (Cao, Chychyla and Stewart, 2015; Zhang, Yang and Appelbaum, 2015).

Furthermore, since these technologies have not been fully implemented in any of the large audit firms yet, quantitative empirical studies in this subject area are virtually non-existent. On the other hand, there are a number of practitioner-led efforts which include qualitative, interview-based, reports focusing on the overall future of the audit profession (ACCA, 2016; KPMG, 2017), BC technology (Deloitte, 2016 (a); Deloitte, 2016 (b)) and the impact of BDA on the audit practices (KPMG, 2016 (a)). Professional regulatory bodies are, to a large extent, still lagging behind new technological developments. They have, however, recently recognised the importance of BDA for auditing, especially in terms of its effects on audit quality, risk assessment and maintaining the adequate level of professional scepticism in the changing informational environment (IAASB, 2016; IAASB, 2017(b)).

These trends are even more pronounced in the case of BC technology, where the theoretical and practical knowledge concerning its impact on the audit industry is severely limited at the moment, owing in part to the fact that the BC technology itself is still inchoate.

Taking all of this into consideration, it can be said that there is a need for further research efforts, especially regarding the establishment of a theoretical framework which could in the future be used as a reference point in the subsequent studies in this—still emerging—field. The lack of such a framework—in addition to the issues described above—has presented numerous obstacles in our research, as there is hardly any codified knowledge to lean on. It has, however, at the same time provided us with a unique opportunity to actively participate in the pioneering efforts in this field, efforts that we hope will result in relevant practical contributions, however small they may be.

1.3 Purpose and research questions

The purpose of this thesis is to contribute to the extant knowledge and further research regarding the effects of BDA and BC technology on the future of the audit profession and to provide a framework grounded in existing theoretical research which would explore ways in which BDA and BC technology could be integrated into the audit procedures of the future.

In order to achieve this, the following research questions will be explored:

1) What is the current state of academic literature and corporate research concerning the effects of Big Data analytics and the blockchain technology on the future of the audit profession?
2) Which framework could the audit firms use to integrate Big Data analytics and the blockchain technology into future audit procedures?

To answer the first question, we will provide an overview of the most relevant and recent research regarding BDA and BC technology in relation to the audit industry, from the perspective of academics, practitioners and regulators. This will be done by means of a systematic literature review (SLR) in which we will outline the development, definition and characteristics, as well as the opportunities, threats and future developments related to the concepts which are in the focus of this thesis. Thereby we aim to impart sufficient background information for the subsequent analysis, and to identify knowledge gaps in our sources. The SLR is based on the framework developed by Siddaway (nd).

Secondly, based on the work by Dai and Vasarhelyi (2016), we will develop a framework aimed at exploring different ways in which audit firms could improve their future procedures through the use of BDA and BC technology. Practical implications, trade-offs involved as well as possible drawbacks of our proposed framework will be considered based on the results of the SLR and a series of semi-structured interviews with audit professionals from KPMG Luxembourg and PwC Malmö, employed in areas related to financial audit, data analytics and risk assurance. The aim of our empirical approach, which involves an element of diversity in terms of audit firms involved, skillsets and everyday work assignments of the interviewed professionals, geographical location of the audit firms and the associated legal and regulatory environments they operate in was to—within a limited temporal scope of the Master thesis assignment—come as close as possible to gaining a holistic view of the audit profession and, from that perspective, suggest possible solutions for its future.

1.4 Outline of the Thesis

This chapter presents the outline of the thesis, with the aim to demonstrate the process of answering the research questions. Chapter 2 describes the research design and methodology which have been chosen for the purpose of the study. Moreover, the qualitative research method, the SLR and the case study (CS) approach are described thoroughly from the perspective of theory and the practical implications of the phenomena discussed in this thesis. Furthermore, trustworthiness, authenticity criteria and limitations of the SLR and the CS are discussed. Chapter 3 presents the results of the SLR with the aim to provide a snapshot of the current literature regarding BDA and BC technology, thereby answering the first research question. In chapter 4 the empirical results of the CS are presented and linked to the relevant literature. The framework constructed upon the results of the SLR and the CS is described and discussed in chapter 5. Finally, the findings of the SLR, the CS and the framework-related discussion are summarised in chapter 6. Moreover, practical and theoretical contributions of the thesis are outlined. At the end of the thesis, its limitations and questions for further research it opens are discussed.

2 Research design – Methodology

This chapter contains the description of the methodology and research design which was used as a framework to enable the collection and analysis of data—with the aim of answering the research questions presented in chapter 1.3—in a more structured way. Firstly, the argumentation behind the choice of a qualitative research approach and the theory behind it is elaborated. Secondly, the SLR method—developed by Siddaway (nd)—is presented and the process it proposes is described. Furthermore, the limitations of, and validity issues related to the SLR method are discussed. Thirdly, the argumentation for a case study approach is presented and the process behind it (e.g. data collection) is described. Additionally, the alternative reliability and validity criteria for qualitative research, namely trustworthiness and authenticity are put into the context of this study. Finally, the limitations of a case study approach are presented and discussed (Bryman & Bell, 2015).

2.1 Qualitative Approach

The research strategy follows a qualitative approach by using the SLR and the CS method, which are textual and non-quantitative in their nature (Bryman & Bell, 2015; Siddaway, nd).

A qualitative approach takes place in a natural and unstructured setting, enabling the contextual interpretation of empirical data and social behaviour of subjects. This is especially relevant for research conducted in the PSF environment, where individuals' behaviour dependents on the context in which they are operating. Additionally, this approach is suitable for answering the research questions since it allows the researcher to focus on understanding the underlying issue in addition to being close to the subject and seeing the problems from the subject's viewpoint. Furthermore, it provides a flexible structure which serves to describe and analyse thoroughly the problematisation, with a strong emphasis on the usage of words rather than the quantification of data. Qualitative research does not depend solely on the interpretation and results derived by the researcher, its validity and relevance are further fortified by results of previous academic studies conducted using different methods of data collection and analysis. However, the qualitative research method suffers from certain limitations and problems. Firstly, the interpretation and analysis of contextual data is subjective and depends on the values, priorities and viewpoints of the researcher. Secondly, qualitative research methods are difficult or, in some cases, impossible to replicate because the process is usually unstructured, not well documented, nor standardised and depends largely on the talent for qualitative research exhibited by the individual researcher in question. Thirdly, the scope of qualitative investigations is restricted (e.g. unstructured interviews with a small number of individuals) which means that they cannot produce generalisable findings. Therefore, the objective of a qualitative investigation should not be to find generalisations but rather to verify that the findings correlate with established theoretical concepts. Finally, the lack of transparency with regards to how the researcher arrives at the conclusion of the study—and the process behind it—has been a point of critique towards qualitative research methods raised by many scholars. In this study however, the procedure behind the process of data collection and findings are documented and described thoroughly to mitigate the lack of transparency (Bryman & Bell, 2015).

The methods used to underpin the reasoning behind any research can be classified as inductive or deductive. Inductive reasoning aims to connect observations or findings of the analysis to existing theory in order to strengthen the conclusions. In contrast, deductive reasoning is the process of constructing a hypothesis based on relevant theory and challenging its robustness by collecting data or conducting observations and analysing the findings. Despite these differences between the two methods, most research approaches use both inductive and deductive reasoning in an iterative way, by looping around data and theory (Bryman & Bell, 2015).

This paper is no exception and will follow an iterative reasoning method. Firstly, a deductive method is used to construct a framework based on relevant theory from academic, regulatory and Big 4 research papers and reports, which have been collected, synthesised and analysed through a SLR. The framework is then refined and confirmed according to findings of the empirical CS. Furthermore, the insights and data acquired by means of the SLR represent the knowledge base of our study. This knowledge base has been one of the main contributing factors in the process of formulating the interview guide used in this study. The interview guide aimed to capture the relevant specificities of the audit industry and raise the level of discussion to an advanced and context-specific level, which would not have been possible without the insights provided by the SLR. Finally, the nature of the technologies which are in the focus of this study—namely BDA and BC—in and of itself requires the researcher to review and improve the approach taken and processes applied, and consider different viewpoints and theories in an iterative way after a set of data is collected and analysed.

2.2 Systematic Literature Review

A systematic literature review (SLR) is an appropriate method to answer the first research question since it provides an objective, systematic, transparent and replicable framework, used in this case to produce a snapshot of the current state and overall picture of the literature in the field of BDA and BC technology in the context of audit. Technologies in question are evolving at an unprecedented speed which means that even the most recent SLR performed by other researchers would not fully reflect the state of technological developments at the time a new study is being conducted. Therefore, it is important to perform an independent SLR at the beginning of each research effort and try to incorporate the most recent developments in the context of a given study. A SLR can mitigate pertinent issues reliably and increase the replicability of the research method by increasing the transparency of the process involved. This is achieved by documenting the steps taken and discussing decisions made during the SLR. The main purpose and benefit of a SLR is to provide insights into the state of relevant theories, methods and concepts. Moreover, it helps in identifying relations, contradictions, gaps and inconsistencies in the research field. Finally, it provides a basis to evaluate, extend and develop existing theoretical frameworks and strengthen the argumentation for practical and theoretical implications (Siddaway, nd; Bem, 1995; Baumeister & Leary, 1997; Cooper, 2003;).

The SLR approach must follow a systematic search process, and the criteria used to distinguish between useful and rejected papers or reports must be explicitly defined and applied consistently. This is done in order to mitigate bias and increase transparency and replicability allowing other researchers to update the SLR under the same conditions.

This paper will follow the SLR guideline proposed by Siddaway (nd). The key stages of the process described by Siddaway (nd) are: (I) Scoping, (II) Planning, (III) Identification (searching), (IV) Screening, (V) Eligibility. The following table 2.1 describes the process of conducting the SLR by following the five key stages proposed by Siddaway (nd). The results of this process will be presented in chapter 3. The row titled "In this paper" is an addition to the original framework, its role being to present the distinct specificities of our study.

Stage	**Steps**	**In this Paper**
(I) Scoping	1) Formulate one or more research questions 2) Thoroughly clarify whether the planned systematic review has already been done	1) Research Question 1) Chapter 1.3 2) BDA and BC-related SLRs do exist; however, due to rapid advancements of these technologies and the increased focus on them by researchers, a new SLR should be done to account for the fast-growing amount of relevant literature
(II) Planning	3) Break your research question(s) down into individual concepts to create search terms 4) Formulate preliminary inclusion and exclusion criteria – and then review these in the initial stages of the literature searching and sifting process 5) Create clear record keeping systems and keep meticulous records for working systematically	3) Search terms: • Big Data Analytics • Blockchain • Audit • Future A combinations of these search terms has been used as well 4) Application of the following inclusion and exclusion criteria consistently throughout the SRL: • Inclusion o Focus on BDA and BC • Exclusion o Duplicates o Other meanings in other fields o Without full text availability o Not in English 5) The record keeping table will be presented in Chapter 3

(III) Identification (Searching)	6) Use your search terms to search at least two different (relevant) electronic databases 7) Carefully inspect the search results 8) Conduct additional searches to ensure you have located all potentially relevant published and unpublished work	6) Use exhaustively the search terms in different permutations in the following search engines: • Google Scholar • LUBSearch • HBR.com • AAA.com 7) Evaluate the search results to ensure that the search terms, inclusion and exclusion criteria are resulting in high quality, relevant and recent literature. Modify the criteria if needed 8) Due to the limited temporal scope of this research assignment, no additional effort to find potentially unpublished work has been made
(IV) Screening	9) Export references to a citation manager to collate the search results 10) Read the Title and/or Abstract of identified work	9) Reference list is kept up-to-date in an excel file 10) Read the Title and Abstract to gain a first insight into the paper and evaluate if it is relevant according to the inclusion or exclusion criteria
(V) Eligibility	11) Sift the full-text version of potentially eligible articles and extract relevant information to be included	11) Literature identified as potentially eligible is read in its entirety and relevant information is extracted. All the relevant articles and reports are collected in an excel sheet containing details about the author, title and a brief comment containing the most relevant insights

Table 2.1: Adapted from the SLR guideline by Siddaway (nd)

2.2.1 Limitations and Validity

Despite the best effort to conduct a comprehensive literature screening and subsequent review with the aim of increasing the replicability, reliability and transparency through a complete description of all procedures and the analytical reasoning behind findings and conclusions, several limitations of the approach can be identified (Yin, 2009).

Firstly, time constraints limit the SLR in performing a more extensive literature search, which would include using more than the most influential databases and give more time to search for unpublished working papers. However, through the search and collection of different literature sources like books, articles, white papers, reports and case studies, a comprehensive and multi-angled SLR has been produced, thereby strengthening the validity of this method. The SLR is considered comprehensive only in the context of the given time constraints (Bryman & Bell, 2015).

Secondly, in fast-evolving subjects like BDA and BC technology, new works are being published frequently. Therefore, it is impossible to produce a complete literature review; the aim of the first research question therefore cannot be to provide a complete and latest review in an absolute sense of those words but more of a snapshot of the current state of the research that has been published, to the best of our knowledge. Moreover, the additional use of the snowball principle to find more relevant literature, by looking up the reference lists for eligible works which fulfil the established criteria, can mitigate the limitation of an incomplete SRL.

Finally, the search terms and inclusion/exclusion criteria are not taking geographical differences and publication dates into account. The consequence is that the SLR conducted in this paper cannot show disparities between regions and evolution over time. However, it could be argued that due to the inter-connectedness of researchers and the global nature of research efforts into BDA and BC technology, geographical factors do not play a significant role (Siddaway, nd; Bryman & Bell, 2015)

2.3 Case Study Approach

The second research question is answered with the use of the case study (CS) approach. Namely, by collecting data from two of the Big 4 audit firms; we are able to provide a credible foundation on which conclusions about the current state of BDA and BC technology in audit firms can be made. This approach allows the researcher to collect and analyse processes, decisions, and development within the organisations in the proper context and take individual factors e.g. experience and specialisation into consideration. Furthermore, through inductive reasoning, the data collected during semi-structured interviews is linked to relevant theories gathered during the SLR. Moreover, the CS approach is suitable to answer "How" and "Why" questions; allowing relevant information to be collected where they originated (Yin, 2009; Bryman & Bell, 2015).

The CS conducted in this thesis includes two case companies; which would traditionally classify the approach taken as a comparative or multiple case study approach. However, the similarities in their structure and challenges that all the Big 4 audit firms face in providing audit and advisory services amount to an argument to treat those cases as a single case study. The benefits would be that the opinions and strategies of a considerable amount of the public audit industry can be analysed, which strengthened further the findings. Furthermore, an in-depth and contextual analysis of the public audit industry is highly relevant for constructing a framework which can be used to guide a successful implementation of new technologies like the BC (Yin, 2009; Bryman & Bell, 2015).

Semi-structured interviews are most appropriate to collect data for a CS; making it possible to follow a flexible list of general topics, ask contextual and background specific follow-up questions and adapt to unforeseen developments during an interview. However, the interviewer should avoid confirming questions, being biased and anchoring the interviewee with comments conveying personal views of the interviewer. Furthermore, multiple internal and external sources of documents and physical artefacts should be collected to improve the understanding of the case company and increase the depth of the interview questions (Yin, 2009; Bryman & Bell, 2015).

2.3.1 Selection of case companies

According to Yin (2009) a single case study is the most suitable approach for an in-depth and contextual analysis. Furthermore, an appropriate case company should be chosen according to the data and evidence needed to answer the second research question of this paper. The case company should be engaged on the frontier of research, development and implementation of new accounting technologies. Moreover, the company should be able to handle the challenges related to emerging technologies in order to stay competitive. The core business of the company should be in the public audit sector and the company should hold a large market share. In this case, the Big 4 firms (KPMG, PwC, Deloitte and EY) fulfil the requirements of representing the majority of the public audit market, in addition to having enough resources to finance research in the field of BDA and BC technology in the audit context. Furthermore, these firms act as role models for the whole industry and advise their clients in implementing new technological standards. The final decisive factor in the choice of case companies is the possibility of gaining access to employees of different seniority levels within those companies for the purpose of conducting interviews. KPMG has been chosen as the main case study company, due to personal connections between the authors and some of the employees, which facilitated the arrangement of interviews. Contact has also been established with PwC thanks to the help of our supervisor Rolf G. Larsson. The reasoning behind the decision to contact two of the Big 4 audit firms instead of just one was to strengthen our empirical results with data from a company relatively similar to the main case company, but at the same time gain additional insights since—due to numerous contextual factors described in chapter 1.3—no two companies can ever be the same. The interviewees have been selected to represent a wide range of positions from assistants to manager level to strengthen further the credibility of our CS.

2.3.2 Primary Data

The appropriate primary data source to be used to answer the second research question is information collected through interviews with employees of different functions and seniorities at the case companies. Interviews can give a more in-depth and contextual insight into the daily work of the interview subject. In this paper, a semi-structured interview will be used, enabling the researchers to ask detailed questions while keeping a degree of flexibility in order to adapt to the interviewees' experiences and knowledge and react to events when unforeseen details and information emerge during the conversation. Additionally, this method provides more flexibility and control over the process and selectivity among the subjects, compared to sending out large numbers of surveys. Clarifications and additional information can be gained through follow-up questions; moreover, potential misunderstandings of interview questions can be solved immediately during the interview. Finally, the downsides of higher flexibility, particularly reduced comparability between different interviews can be mitigated by working with a semi-structure constructed upon an interview guide suggested by Bryman & Bell (2015); which allows the interview to follow a flexible structure but still grants a sufficient level of comparability among all interviews (Bryman & Bell, 2015).

The planning process of the semi-structured interviews follows the development structure suggested by Bryman & Bell (2015), with the goal to construct an appropriate interview guide. The structure (Figure 2.1) starts with identifying the general research area and formulating specific research questions. The second step is to determine interview topics and put them into categories. Thirdly, appropriate interview questions are formulated according to the established categories and reviewed. After every round of interviews, newly gained insights and issues raised are used to further improve the existing questions.

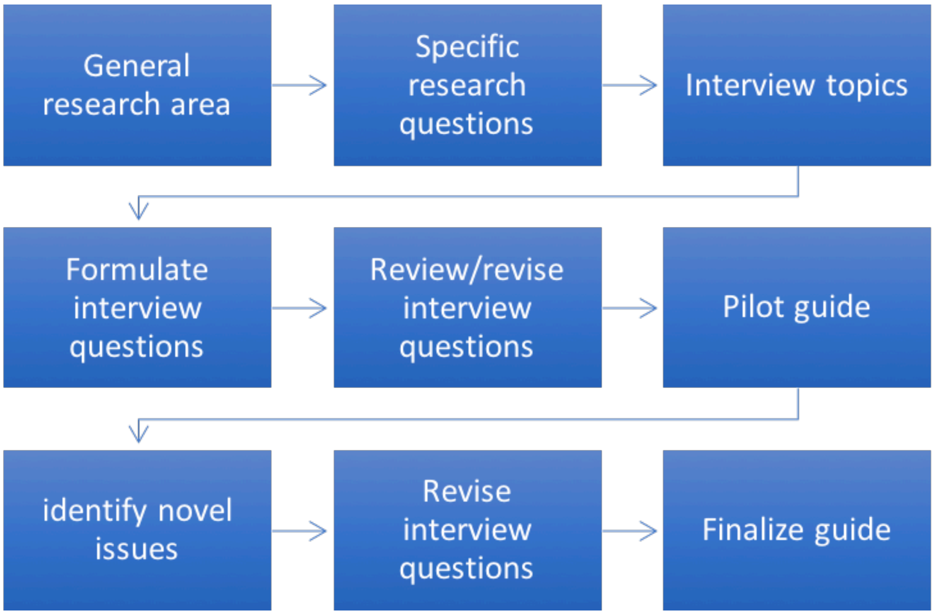


Figure 2.1: Formulating questions for an interview guide (Bryman & Bell, 2003, p.350)

The interview guide in this paper (Appendix A), is divided into eight categories (Table 2.2) and has been selected with the objective to cover a broad range of general IT-related questions regarding the outlook, risks, knowledge, experience and exposure to BDA and BC technology. Furthermore, general questions regarding the regulatory environment, corporate culture and structure and recruitment and employee development topics are formulated. The final category aims to examine how emerging technologies like BDA and BC can create more value for the client and increase public trust.

1. General Questions on the personal professional view concerning the future of audit
2. IT Competence
3. Big Data
4. Blockchain
5. Risk Management
6. Corporate Environment and Strategy
7. The role of Regulators and Legislators
8. Creating Value and Trust

Table 2.2: Interview Guide Categories

The interviewees have been contacted via email including a short introduction and purpose of the research topic. Additionally, the interview guide and a summary paper regarding the BC technology has been attached to the email (Appendix C). A short description of the BC technology for all our interviewees was included due to the difficulties experienced during earlier discussions with peers and professors which showed that not many people are familiar with this subject. The contacts have been gained through personal connections and through referrals by professors and interviewees.

The first interview was conducted in person, at the PwC office in Malmö; on the other hand, interviewees from KPMG Luxembourg have been interviewed via Skype due to the geographical distance. The participants were allowed to choose the settings of the interviews with which they felt most comfortable and familiar. The setup of the interviews was the following: Two interviewers were posing questions to the interviewee, notes were taken for later use or to raise direct follow up questions e.g. ask for clarification. Furthermore, each interview was recorded with two smart phones to mitigate the risk of potential technical issues. At the beginning of each interview, permission to record the conversation and to publish the acquired information in this study was asked of the interviewee. All of the interviews were conducted in English. The first category of questions included more general questions, which were crucial for getting a first impression of the interviewees' professional background and knowledge about the focal subjects of the interviews; subsequent questions were adjusted according but not limited to, the information and impression received during the first questions. Regardless of their background and knowledge, all of the interviewees were asked the same questions, following the semi-structured interview guide, in order to retain the comparability among the interviews.

The following Table 2.3 is a summary of all the interviews conducted, with details about e.g. interviewee's position, division in the company and length of the interviews in minutes.

Interviewee	Date	Position	Division	Company	Length (min)
1	26.04.17	Manager	Risk Advisory	PwC	60
2	01.05.17	Assistant	Banking Audit	KPMG	62
3	02.05.17	Assistant	Fund Audit	KPMG	93
4	04.05.17	Assistant	Corporate Audit	KPMG	130
5	05.05.17	Analyst	Data Analytics	KPMG	101
1 (follow up)	12.05.17	Manager	Risk Advisory	PwC	55
6	16.05.17	Assistant Manager	Corporate Audit	KPMG	40

Table 2.3: Detailed interview schedules

The interviewees have been chosen with the aim to collect opinions and views from different angles. The variety of different skillsets regarding IT competences, expertise and experience levels is needed to cover all the employees and divisions affected by new emerging technologies. The participants included financial audit assistants from three different division (fund, banking and corporate audit) with under 2 years of experience, an assistant manager with ACCA accreditation, a manager with over 7 years of experience in risk assurance and an in-house expert in data analytics. Consequently, the interviewees had different views on the effects and consequences of the changes occurring in the audit profession in the context of technological advancements. Furthermore, they provided us with valuable insights regarding benefits, risks and expectations from different seniority and expertise levels. The results are discussed in more detail in chapter 4.

The interviews have been recorded and transcribed to increase the reliability of the collected data. Listening to the recordings after the interviews has proven to be a good way to catch and recall certain information and statements that might have been missed during the interview itself. This approach has enabled us to conduct an in-depth analysis of the interviews. Furthermore, it has allowed us to avoid asking the interviewees to repeat his/her answers which would have been time-consuming and could have disrupted the flow of conversation. The process of improving the quality of follow-up questions and the results of the case study as a whole depended in large part on the quality of the transcripts. Furthermore, storing the recordings and transcripts into easy to access medias (e.g. Cloud server) can increase the transparency of the results and conclusions (Bryman & Bell, 2015).

2.3.3 Secondary Data

Complementary to the gathered primary data through semi-structured interviews, the inquiry of secondary data in the form of internal reports and guidelines can facilitate the understanding of organisational structures and processes. Moreover, publicly available Big 4 research, surveys and conference reports in the field of BDA and BC were examined thoroughly to gain a more holistic overview about the state of research towards a more extensive use of BDA and implementation of BC technology in the audit industry. The collection of secondary data from different sources and subsequent analysis based on that information strengthens the credibility of the results and improves the quality of interview questions by providing more in-depth knowledge and understanding of the case companies and their environment (Yin, 2009; Bryman & Bell, 2015).

2.3.4 Trustworthiness and Authenticity

Standard criteria for establishing and evaluating the quality of a research paper are reliability and validity. According to Yin (2009) a valid approach to ensure the credibility of a qualitative research paper is to conduct a logical test based on the reliability and validity criteria; namely, construct validity, internal validity, external validity and reliability. However, the relevance of these criteria has been a topic of controversial discussion among qualitative researchers, whom questioned their relevance; e.g. : *"[...] the issue of measurement validity almost by definition seems to carry connotations of measurement"* (Bryman & Bell, 2003, p.286), thus it is more valuable to assess quantitative research. It should be mentioned that qualitative researchers using the reliability and validity criteria without any or little adaptation are positioning themselves as realists; advocating that: *"[...] social reality can be captured by their qualitative researchers through their concepts and theories"* (Bryman & Bell, 2003, p.292). However, many researchers like Lincoln and Guba are arguing that: *"Concepts and theories are representations and there may, therefore, be other equally credible representations of the same phenomena"* (Bryman & Bell, 2003, p.292). The strategy of this paper will follow the guideline by Lincoln and Guba (1994); using: *"[...] thick descriptions, respondent validation and triangulations"* (Bryman & Bell, 2003, p.293) to fulfil the alternative criteria for qualitative research, namely trustworthiness and authenticity (Lincoln & Guba, 1985; Guba & Lincoln, 1994; Bryman & Bell, 2015).

This study's explorative nature is based on detailed descriptions of the findings, procedures and problems, depending on contextual factors and subjective interpretations; rather than on large data-sets of observations or measurements. Therefore, alternative criteria for the evaluation of qualitative research as mentioned above are used. The two primary criteria are trustworthiness and authenticity; of which trustworthiness entails four further criteria: credibility, transferability, dependability and confirmability. Those four criteria are the parallel counterparts of internal validity, external validity, reliability and objectivity. The alternative criteria are giving the thesis more weight on the contextual differences of social phenomena and emphasise that several truths about the social world are possible (Lincoln & Guba, 1985; Guba & Lincoln, 1994; Bryman & Bell, 2015).

The first of the trustworthiness criteria is the credibility of the research findings and conclusions; notably with the possible existence of multiple social realities. Therefore, a high degree of credibility is required, to increase the acceptability of the results for others. Credibility is increased by ensuring a consistent use of the: *"[...]canons of good practice and submitting research findings to the members of the social world who were studied for confirmation that the investigator has correctly understood that social world"* (Bryman & Bell, 2003, p.288). In this study, a triangulation approach is used to confirm the findings; this is achieved by conducting interviews with subjects of several seniority levels within the audit and other relevant (e.g. risk advisory, data analytics) departments and through the use of internal and external reports issued by the Big 4 audit firms regarding BDA and BC technology. Moreover, the findings are presented in a follow-up interview for respondent validation (Bryman & Bell, 2015).

Transferability of the conclusions to other environments is attained in the qualitative research by producing a "*thick description of the result*" (Bryman & Bell, 2003, p.289). The objective is to create a database which enables others to refer to it while making their own: *"[...] judgements about the possible transferability of findings to other milieux"* (Bryman & Bell, 2003, p.289). The explorative and qualitative approach of this thesis will produce a detailed and text based description of all the results in order to fulfil the thick description criterion, and consequently increase transferability (Geertz, 1973).

In parallel to reliability in quantitative research, dependability is used to establish the: *"[...] merit of research in terms of the criterion of trustworthiness, researchers should adopt an auditing approach"* (Bryman & Bell, 2003, p.289). As described by Guba and Lincoln (1994), complete records of all research processes should be kept and stored in an accessible way. Finally, peers should act as auditors in order to evaluate the consistent use of best practice and asses: *"[...] the degree to which theoretical inferences can be justified"* (Bryman & Bell, 2003, p.289). However, this approach is time consuming due to the large amount of data being collected during a quantitative research project. The dependability in this study is increased by providing a thorough documentation of planning procedures and the actions taken. Additionally, draft versions were sent to our supervisor for review and feedback. The dependability was strengthened further thanks to feedback we have received from a peer group in a mid-term seminar.

The procedure of confirmability entails the awareness that contextual interpretations of data cannot be fully objective and the expectation that researchers act in "good faith" (Bryman & Bell, 2003, p.289) by not allowing personal bias of "values or theoretical inclinations" (Bryman & Bell, 2003, p.289) to influence the research process and findings. Therefore, throughout the whole research procedure, the richness of reasoning can be achieved by going constantly back and forth from data to theory and maintaining constant awareness of personal biases, all of which can also increase confirmability (Bryman & Bell, 2015).

Finally, the authenticity criterion compromises five key components (Table 2.4), addressing primarily the impact of the research on the case companies and the interviewees.

Authenticity Criterion	**Description**
Fairness	Does the research fairly represent different viewpoints among members of the social setting?
Ontological authenticity	Does the research help members to arrive at a better understanding of their social milieu?
Educative authenticity	Does the research help members to appreciate better the perspectives of other members of their social setting?
Catalytic authenticity	Has the research acted as an impetus to members to engage in action to change their circumstances?
Tactical authenticity	Has the research empowered members to take the steps necessary for engaging in action?

Table 2.4: Authenticity Criterion and Description by Guba & Lincoln (1994)

The fairness criterion has been addressed by conducting interviews on multiple levels of seniority (Assistant, Senior, Assistant Manager, Manager). In the aspect of ontological authenticity, the interviewees received a summary of the state of the BC research in the audit sector and were allowed to ask for additional information and explanations. In this process, the participants gained a more detailed understanding of or at least got a good basic introduction to the subject. Educative authenticity has not been addressed since the interviews were conducted to understand the professional judgement and perception of the interviewees on the topic of emerging technologies in the audit profession. In the interview process, critical questions were integrated to give the interviewees the opportunity to think about changes in the corporate environment and culture to foster more technological innovations. Those questions could act as catalysts and empower the subject to question the current practices with regard to training and internal support for innovation. Thereby, the catalytic and tactical authenticity could be addressed during the interview; however, this effect is based purely on our assumptions and has not be measured in the scope of this thesis (Lincoln & Guba, 1985; Guba & Lincoln, 1994; Bryman & Bell, 2015).

2.3.5 Limitation of the Case Study

A case study approach provides an in-depth contextual analysis and insights into the area of interest. However, the benefit of being narrow in scope and somewhat unique in the choice of case companies is at the same time the biggest downfall of a case study because generalisations of results become less reliable or nearly impossible. Furthermore, the lack of independence regarding the context and the often criticised non-transparency of the case study execution and planning process, reduces the potential for replication (Yin, 2009; Bryman & Bell, 2015).

Another limiting factor of a single case study is, according to Yin (2009), that multiple case studies are superior in presenting compelling evidence and generating robust results. However, a single case study is an appropriate method to answer the second research question by providing an in-depth and contextual insight into a specific industry and leaving enough flexibility to be able to perform an explorative research. The second research question does not aim to construct a generalised framework, rather it aims to give advices and suggestions on how a successful implementation and use of BDA and BC in the case company could be facilitated according to the findings of the single case study (Yin, 2009; Bryman & Bell, 2015).

Furthermore, using interviews to gain information and insights comes with limitations. The interviewer can influence the direction of the inquiry by asking leading questions, thus making the interpretation of the collected data and the conclusions being drawn from it potentially biased. Lastly, the analysis would benefit from extending the circle of interviewees to audit clients, regulators, IT experts etc; which would lead to an increase in reliability and validity of the results (Yin, 2009; Bryman & Bell, 2015).

3 Results of the Systematic Literature Review

This chapter has the objective to present a snapshot of the current BDA and BC research in the field of public audit with the help of a systematic literature review (SLR). This will be done through the search and identification of relevant literature from different sources, as was described in Chapter 2.2. Moreover, this is an appropriate method to answer the first research question. Firstly, the numeric results of the electronic database search are presented and an overview with details of the most relevant literature regarding the current state of the BDA and BC research is elaborated. Second, the rapid development of BDA and BC in the past years and different definitions of BDA and BC according in the literature are described. Finally, the opportunities, risks, future developments and critique of those emerging technologies presented in the relevant literature are compiled and discussed.

3.1 Current State and Overview of the Research Field

The research in several electronic databases showed that the current state of the BDA and BC technology-related research regarding their implementation into audit procedures is still in its infancy. The SLR showed that scholars are still struggling to reach a consensus in the construction of a theoretical framework which would enable a successful implementation and use of those technologies; whereas the reports of Big 4 companies focus more on promoting the disrupting potential of e.g. the BC technology for the audit and other industries without any proof of concept. A common ground for both practitioners and academic researchers is that they are aware of those technologies and are responding to new developments by investing more resources towards researching them. A strong indicator of this trend that has been identified in the process of conducting the SLR is the recent spike in the number of publications in this area during a very short period of time, namely the last two years to date. However, both the industry and scholars are still far from a proof of concept in the direct use of e.g. the BC in the public audit. Therefore, white papers and proof of concept reports from other businesses e.g. the funds industry with advanced use of the BDA and BC technology have also been collected as a part of the literature analysed through the SLR. The assumption is that big and technologically advanced audit firms' clients such as firms from the fund industry are first adopters of advanced BDA tools and the BC technology, and will consequently be the drivers for higher adoption of these technologies in audit firms as well (Alles, 2015).

The following tables show the number of hits on different digital databases using combinations of the following search terms: Big Data Analytics, Blockchain, Audit and Future. Moreover, the number of papers and reports which have passed the screening test by fulfilling our inclusion criteria and the number of papers which have passed the eligibility test are presented.

Search Term Combination	Hits	Passed Screening Test	Passed eligibility test
Big Data Analytics	15.000	2	2
Audit Big Data Analytics	19.900	5	2
Blockchain	13.000	10	5
Audit Blockchain	1.360	6	2
Audit Blockchain Future	1.050	7	1
Future Audit	1.510.000	9	2

Table 3.1: Google Scholar Search

Search Term Combination	Hits	Passed Screening Test	Passed eligibility test
Big Data Analytics	13.151	2	0
Audit Big Data Analytics	86	2	0
Blockchain	2.550	10	5
Audit Blockchain	20	3	1
Audit Blockchain Future	3	1	0
Future Audit	12.818	7	5

Table 3.2: LUBSearch

Search Term Combination	Hits	Passed Screening Test	Passed eligibility test
Big Data Analytics	474	6	0
Audit Big Data Analytics	29	3	0
Blockchain	41	6	3
Audit Blockchain	7	2	0
Audit Blockchain Future	4	1	0
Future Audit	3.591	6	0

Table 3.3: Harvard Business School Search

Search Term Combination	Hits	Passed Screening Test	Passed eligibility test
Big Data Analytics	723	3	0
Audit Big Data Analytics	1.281	10	6
Blockchain	4	0	0
Audit Blockchain	869	0	0
Audit Blockchain Future	1.053	0	0
Future Audit	1.053	4	2

Table 3.4: American Accounting Association Search

The number of results decreased, as expected, with the addition of terms such as Audit or Future. Most of the literature found was excluded after performing as inspection of the titles for inclusion criteria on the first page of the most relevant article list. The decision to not go further than the first page follows the assumption that the relevance of the search parameters is decreasing with each hit. However, the SLR search in electronic databases has yielded many papers and reports that passed the screening test, which included reading their title and abstract. Finally, the literature passing the first test was subsequently assessed by an eligibility test involving sifting through the full text for relevant information.

In Appendix B an overview of the papers and reports which passed the screening and eligibility test is presented. Comments including the purpose and outcomes of the paper/report are added next to the references.

The examination of Figure 3.1, containing the publication year distribution of eligible literature shows that most publications came after 2015. This strengthens the observation that the research in the field of BDA and BC technology is a recent phenomenon, increasing in importance. This is however not surprising, a seminal moment in this field was the inception of the idea of triple entry accounting in the paper published by Grigg (2005) where the author has advocated for the use of financial cryptography to complement traditional double entry bookkeeping. The next big development was the publication of a white paper by Nakamoto (2009) where the world's first cryptocurrency bitcoin and its underlying BC technology were introduced. Furthermore, authors like Chan & Vasarhelyi (2011) are representative of a group of researchers advocating for and engaging in more innovation in the field of audit.

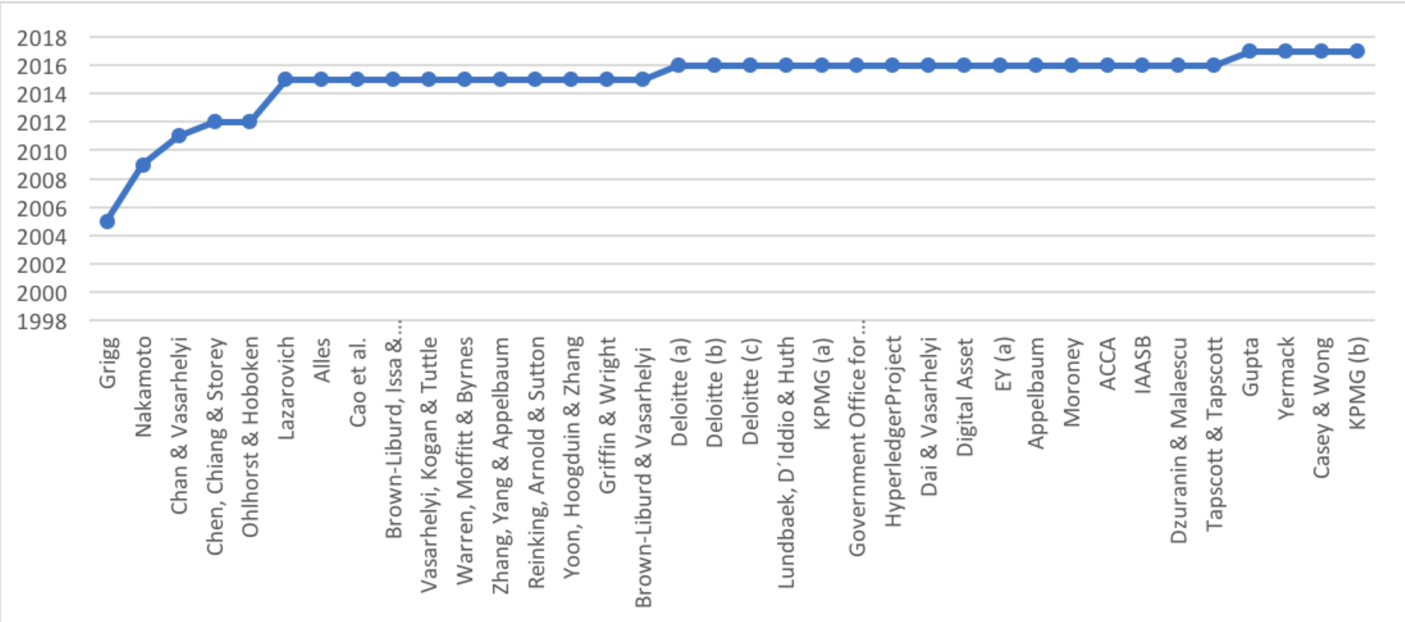


Figure 3.1: Publication year of the eligible literature

The current state of academic and practitioner-led research can be derived from the first overview of the literature, which has passed the SLR eligibility test. The following analysis will make use of the following matrix (Table 3.5), illustrating the distribution of eligible literature between different search terms.

	Search Results
BDA	**2**
Audit BDA	**8**
BC	**13**
Audit BC	**3**
Audit BC Future	**1**
Future Audit	**9**

Table 3.5: Matrix containing the number of eligible literature found during the SLR

First, the research in BDA and specifically regarding the public audit industry is much more advanced than is the case for BC technology; and is supported by a higher amount of eligible literature and more mature publications (see Table 3.5). The literature provides practical implications on how BDA can improve the efficiency and effectiveness of financial statement audits (Cao, Chychyla and Stewart 2015; Warren, Moffitt & Byrnes, 2015). Moreover, descriptions of limitations and risks regarding behavioural implications of BDA in audit (Brown-Liburd, Issa & Lombardi, 2015) and reliability of BD (Appelbaum, 2016) can be found. Furthermore, authors like Vasarhelyi, Kogan & Tuttle (2015) are strongly advocating the need for new accounting and auditing standards, to cope with the risks associated with the rise of BDA in companies and audit firms.

Second, the most relevant literature for this paper concerning the BC technology is directly related to the conceptualisation, opportunities and risks a general BC adoption into sectors e.g. finance, insurance, public sector etc. entails (Deloitte, 2016 (a), Deloitte, 2016 (b); Deloitte, 2016 (c); KPMG, 2016 (a); Government Office for Science, 2016). As table 3.5 suggests, thirteen articles have been found for the BC search term and only four in combination with audit, the literature relating the use of BC technology to audit procedures is scare and most of the time the discussion about the applicability of BC technology in audit was merely a brief addition to the description of different applications it could have. The majority of BC-related papers found are highlighting the benefits of the BC technology (e.g. immutability of data, perfect and trust-less audit trails etc.) in fostering innovation and proclaiming a new era of accounting principles (EY, 2016 (a); Lazarovich, 2015). Those findings are in line with past SLR in the field of BC technology; e.g. Yli-Huumo et al. (2016) which after an extensive SLR in the current state of research of BC technology concluded that: *"Over 80% of the papers is on Bitcoin system and less than 20% deals with other Blockchain applications".*

Moreover, Yli-Huumo et al. (2016) outlined that most of the publications focus on how to expose and improve on disadvantages of BC and highlighted that many proposals were neither tested nor challenged in terms of their effectiveness and scalability.

Finally, the literature provides a range of papers and reports related to the future of audit (Table 3.5). For this research paper, a diverse range of subjects from different angles have been selected to give a representative overview of the research regarding the future of the audit profession. However, with a focus not exclusively but mostly on technological innovations like BDA and BC technology. Analysis of the relevant literature shows that the necessity of innovation in the audit profession is supported widely in the academic research and closely monitored by the regulators (Chan & Vasarhelyi, 2011; ACCA, 2016; IAASB, 2016). Regulatory bodies are aware that a new generation of auditors is needed to cope with the increasing amount and complexity of data, and have raised issues in regard to information overload (ACCA, 2016). Furthermore, the challenges of recruiting and retaining the right professionals are discussed and the increased demand from clients to create more value for them is illustrated (ACCA, 2016; KPMG, 2017). Authors like Moroney (2016) are analysing the efficiency of new regulations concerning mandatory partner rotations and stricter audit inspections in increasing audit quality. Furthermore, regulatory bodies like the IAASB (International Auditing and Assurance Standards Board) are exploring and monitoring the increased role of DA (Data Analytics) in the audit profession, by discussing the benefits and limitations related to it. However, the IAASB is currently hesitant of prematurely commence standard setting activities and enact standards which are too rigid to accommodate rapid technological changes out of fear that it might restrict innovation (IAASB, 2016).

In chapter 3.3., the opportunities, risks and future developments of BDA and BC technology according to the SLR will be discussed and described more extensively.

3.2 Development and Definition

This sub-chapter will firstly focus on the development of BDA and BC technology in the field of public audit, as portrayed in the literature. Moreover, different definitions of BDA and BC found during the SLR are assembled and discussed.

3.2.1 Development of BDA and BC in the field of audit

The development of BDA has its origins in the digitisation of accounting records and management procedures from physical files into enterprise resource planning (ERP) systems (Davenport, 1998). Additionally, advancements in computing, telecommunication, data storage and network technologies have served to enable processing, transfer and storage of those enormous data packages (Vasarhelyi, Kogan & Tuttle, 2015). Moreover, the emergence of social media like Facebook, Twitter etc., is raising the public awareness of BD which is omnipresent in people's daily lives (Vasarhelyi, Kogan & Tuttle, 2015). Companies around the world are recognising the importance of BDA, and are increasingly using BDA tools to process and collect vast amounts of data to be able analyse their competitive environment ((Vasarhelyi, Kogan & Tuttle, 2015; Griffin & Wright, 2015). The implications for businesses are that BDA is influencing companies' decision-making process regarding business strategy and management control systems, with the expectance of increased business performance and profitability due to the use of BDA (Griffin & Wright, 2015; Warren, Kogan & Tuttle, 2015).

Alles (2015) is arguing that as BDA becomes an important daily business tool for the audit firms' clients, the audit firms themselves will eventually need to adopt BDA and other modern technologies in their work to increase audit quality (Brown-Liburd & Vasarhelyi, 2015). Cao, Chychyla and Stewart (2015) content that BDA brings advancements to so many fields that even the moderately innovative audit profession will and have to adapt to it. The use of BDA in audit can increase efficiency and effectiveness of audit assignments. BDA can enable automated data collection, thereby decreasing the dependency on data provided by clients which strengthens the reliability and relevance of audit data. Furthermore, BDA allows for the analysis of whole populations of data. This means that auditors can extend the data sources and formats to other forms of audit evidence which were not available in traditional audits (e.g. GPS locations, audio and video files). The conclusion is that the use of BDA is not only increasing the quality of audit evidence, it is also more cost-efficient and transparent than traditional audit approaches which cannot cope with technological advancements and the increasing amount and complexity of data (Brown-Liburd, Issa & Lombardi, 2015; Brown-

Liburd & Vasarhelyi, 2015; Cao, Chychyla and Stewart, 2015; Vasarhelyi, Kogan & Tuttle, 2015; Warren, Moffitt & Byrnes, 2015; Yoon, Hoogduin & Zhang, 2015).

In the development of BDA for the audit sector, the literature has identified several threats to be considered regarding computational, hardware, software, expertise, educational and training-related issues. Most of the researchers are arguing that audit professionals and regulators should be aware of the impact BDA and other technologies have on audit (Brown-Liburd & Vasarhelyi, 2015; Cao, Chychyla and Stewart, 2015; Griffin & Wright, 2015; Vasarhelyi, Kogan & Tuttle, 2015).

After the introduction of the concept of BC—originally the underlying technology of bitcoin which was outlined for the first time in a paper by Nakamoto (2009)—further development of, and interest in BC technology has been accelerated by the financial crisis in 2008 and the damaged public trust in large corporations and audit firms. BC technology has been successfully implemented and tested in the fields of supply chain management, funds, insurance and other financial products (Casey & Wong, 2017; Deloitte (b), 2016; EY(a), 2016; Fundchain, 2017). Moreover, the implications and feasibility of BC in the public sector has been in the focus of recent publications conducted by governmental institutions (Deloitte (b), 2016; Government Office for Science, 2016). First steps have been taken by academia, regulators and businesses to explore the opportunities and threats BC technology can bring to accounting and audit. Several reports published by the Big 4 accounting firms are describing the basics behind the BC, the possible application of BC in the audit profession and possible risks; however, without any practical frameworks for implementation, or proof of efficiency or scalability.

Finally, developments in the field of BDA have fostered technological innovation and awareness of their benefits and threats in nearly every field of the financial sector and beyond. Consequently, the audit profession should adapt and keep up with the developments to stay competitive and relevant. BC technology is still in a very early stage and has been only implemented in some areas but as for BDA, eventually when the majority of audit clients adopt BC technology, the audit profession has to follow and make use of the advancements (Alles, 2015). However, auditors should be trained to be mindful of the risks and regulators, and must set the rules to protect data security and be aware of the impact advanced technologies bring (Brown-Liburd & Vasarhelyi, 2015).

A more detailed analysis of the potential threats and opportunities of BDA and BC are presented in Chapter 3.3. Moreover, future developments regarding BDA and BC according to the literature are elaborated.

3.2.2 Definition of BDA and BC

BDA in the literature (Table 3.6) is mostly described as an analytical tool using algorithms based on statistical models to inspect and transform BD collected and extracted from: *"[...] operational, financial and other forms of electronic data internal or external to the organisation"* (KPMG, 2016 (a)). The purpose is to discover patterns of behaviour, irregularities and trends in structured or unstructured BD and turn those information into value to support business decisions. Furthermore, BDA can help in predictive trend analysis of e.g. competitive environment (Griffin & Wright, 2015). However, it needs advanced computation technology and great: *"[...] data storage, management, analysis and visualisation technologies"* (Brown-Liburd, Issa & Lombardi, 2015; Cao, Chychyla and Stewart, 2015; Chen, Chiang & Storey, 2012; KPMG, 2016 (a); Ohlhorst & Hoboken, 2012).

Author(s) (Year)	Definition of BDA
KPMG (2016 (b))	BDA is an analytical process by which insights are extracted from operational, financial and other forms of electronic data internal or external to the organisation. These insights can be historical, real-time or predictive and can also be risk or performance focused and frequently provide the "how?" and "why?" answers to the initial "what?" questions found in the information initially extracted from data
Cao, Chychyla and Stewart (2015)	BDA is the process of inspecting, cleaning, transforming and modeling BD to discover and communicate useful information and patterns, suggest conclusions and support decision making
Brown-Liburd, Issa & Lombardi (2015)	Data analytics tools used to analyse BD give auditors the ability to incorporate and use both structured and unstructured data to identify potential transactional anomalies, patterns of behavior and trends
Chen, Chiang & Storey (2012)	More recently BD and BDA have been used to describe the data sets and analytical techniques in applications that are so large and complex that they require advanced and unique data storage, management, analysis, and visualisation technologies

Ohlhorst & Hoboken (2012)	This is a process in which data are analysed from different perspectives and then turned into summary data that are deemed useful, [...] focus is on modeling and knowledge discovery for predictive, rather than purely descriptive, purposes - an ideal process for uncovering new patterns from large data sets. Statistical applications of BDA look at data using algorithms based on statistical principles. They ideally deliver sample observations that can be used to study populated data sets for the purpose of estimating, testing, and predictive analysis
IAASB (2016)	Data analytics, when used to obtain audit evidence in a financial statement audit, is the science and art of discovering and analysing patterns, deviations and inconsistencies, and extracting other useful information in the data underlying or related to the subject matter of an audit through analysis, modelling and visualisation for the purpose of planning or performing the audit

Table 3.6: Definitions of BDA

The Blockchain Technology is commonly described in the academic and professional research (Table 3.7) in its original decentralised form as a potential disruptive technology for many industries and institutions. Mostly defined as a global peer-to-peer distributed ledger database, which allows trust-less transactions between strangers. According to some authors, this decentralised BC technology can remove the need of intermediaries or centralised institutions with a database: *"[...] collectively maintained by all of the system's participants, where the principle of majority must agree on a proposed transaction"* (PwC, 2017). This principle of approving transactions in the BC needs the: *"[...] consensus among partners of the network"* (KPMG (a), 2016).

The BC technology has been described as a database which is resistant to forging with a high degree of security, transparency and low costs (Byström, 2016; Tapscott & Tapscott, 2016).

Author(s) (Year)	Definition of BC
Byström (2016)	The Blockchain is basically a ledger that can never be altered and whose records can never be destroyed
Tapscott & Tapscott (2016)	At its most basic, Blockchain is a vast, global distributed ledger or database running on millions of devices and open to anyone, where not just information but anything of value [...] can be moved and stored securely and privately
Deloitte (2016 (a))	Blockchain is a trustless, distributed ledger that is openly available and has negligible costs of use
Scott (2016)	Blockchain represents, for business leaders, the first digital medium for value, and promises to transform basically every institution. We have moved from an internet of information to an internet of value
KPMG (2016 (a))	Blockchain is a type of distributed ledger database that maintains a continuously growing list of transaction records ordered into blocks with various protections against tampering and revision. [...] At the heart of a Blockchain is a consensus among participants
Hyperledger (2016)	Blockchain is a peer-to-peer distributed ledger technology that first gained traction in the financial industry because of its capacity to issue, trade, manage, and service assets efficiently and securely
PwC (2017)	Blockchain is the underlying technology created in 2008 for powering bitcoin creation and transfers, [...] is collectively maintained by all of the system's participants, rather than by one central authority. [...] The principle is that a majority of participants must agree on a proposed transaction. Validating and adding a transaction through consensus is the only trigger to update the ledger

Table 3.7: Definitions of BC

3.3 Opportunities, Risks, Future Developments and Critique

3.3.1 Opportunities

Widespread usage of BDA and BC technology promises numerous opportunities and advantages for audit firms and their clients. These opportunities can be classified according to their nature, namely those affecting the effectiveness, efficiency and quality of audit; and risk assessment and risk management.

Effectiveness, efficiency and quality of audit

Quantity and diversity of data that auditors have to deal with have increased markedly over the years. The industry has looked to new IT technologies for solutions, and as a result BDA tools and techniques with tremendous potential to improve the efficiency and effectiveness of an audit engagement have emerged (Brown-Liburd, Issa and Lombardi, 2015). In its current form, the audit can be a protracted, expensive and inefficient process. Auditors often spend their time on menial assignments which add little value to the audit process. Technology solutions including algorithms and other BDA tools can reduce the amount of time spent on manual analysis, allowing the auditors to invest more of their time in aspects of the analysis which demand more professional judgement. Furthermore, auditors' judgements and the ability to be appropriately sceptical are themselves improved by the use of BDA, which thus provide an opportunity for the audit firms to maximise the effectiveness of the human element of the audit process (IAASB, 2016). The use of BDA within the audit process should be leveraged to enlarge the scope of an audit and provide a greater degree of assurance regarding effectiveness of controls and the accuracy of transactions, while at the same time significantly reducing audit costs, resources and time (KPMG, 2016 (b); Dai and Vasarhelyi, 2016).

BC technology takes the efficiency and reliability of audit a step further by ensuring a consistent interpretation and application of business logic, and by providing a real-time, auditable log of ordered evidences of events which are immutable and instantly accessible (Digital asset, 2016). In a BC system—once recorded on the BC and confirmed by sufficient subsequent blocks—a transaction becomes a permanent part of the ledger and is accepted as valid by all participants of the BC network, thus making the job of providing reasonable assurance much easier and faster which improves the efficiency of the audit (KPMG, 2016 (a)). Moreover, increased standardisation that BC technology brings would allow auditors to verify large portions of the most important data behind the financial statements automatically. This would bring the cost and time necessary to conduct an audit down significantly while maintaining data security, as data would only be available to trusted third parties (Deloitte, 2016 (a); PwC, 2017).

Further arguments for the greater cost efficiency of the audit due to the use of BDA and BC include the fact that the technology necessary to utilise them in audits is currently available and appears to be affordable—and with many of their clients using advanced ERP systems—auditors can take advantage of BDA capabilities already in place, without being forced to develop these capabilities themselves (Brown-Liburd, Issa and Lombardi, 2015; Alles, 2015). This benefit is enhanced through partnerships between audit firms, financial institutions, IT firms, BD solutions companies and BC initiatives. These collaborations have yielded efforts such as the Hyperledger project, Data Aliance Collaborative, Fundchain and others, which aim to create analytical methods and open-source BC frameworks that will cut costs while improving outcomes for all sides involved (Brown-Liburd, Issa and Lombardi, 2015; PwC, 2017; Hyperledger, 2016; Digital asset, 2016).

The quality of audit can be enhanced by BDA and BC technology in various ways. BDA allow the auditors to look at whole data populations, thereby avoiding much of the risks associated with relying on small sample sizes (Cao, Chychyla and Stewart, 2015; IAASB, 2016). Current analytical methods sometimes generate more false positives than can feasibly be manually investigated by the audit team, resulting in information overload (Cao, Chychyla and Stewart, 2015). The number of false positives can be dramatically reduced with the use of modern BDA techniques through more accurate identification of true anomalies and exceptions, along with better systems of prioritisation (Issa and Kogan, 2013). Using large datasets presents challenges such as ensuring that audit judgements and decisions are based on quality information that is relevant and trustworthy (Brown-Liburd, Issa and Lombardi, 2015). This challenge can be overcome with the use of BC technology since: *"Data on BC is akin to being carved in marble"*, this data is indelible, it would provide a single source of truth, thereby minimising the risk of error and avoiding data redundancy (PwC, 2017). Furthermore, using the BC makes it possible to prove integrity of data quickly and easily (Deloitte, 2016 (a)).

Even though audit firms increasingly rely on BDA and other forms of technology—and are automating more and more of their processes—the audit is still to a large degree influenced by auditors' professional competence and other personal traits. The use of BDA in an audit of financial statements will not replace the need for the auditor to exercise appropriate professional judgement and professional scepticism. This implies that the auditors need to possess a thorough understanding of the entity being audited and its environment. The ability of the auditor to analyse data underlying the financial information represented in financial statements using BDA, may enable the auditor to acquire a deeper understanding of what has actually occurred in the financial reporting system, which should have a positive effect on the audit quality and overall value creation (IAASB, 2016).

Risk assessment and risk management

Risk assessment is an integral part of an audit process, and in the age of BD it is becoming even more important. Nearly two-thirds (60%) of respondents in a recent study believe audits should help in assessing risks and risk management practices (KPMG, 2017). As was pointed out by Dzuranin and Mălăescu (2016), to evaluate the value of compliance, it is necessary to look beyond meeting minimum compliance standards, the process needs to begin with solid risk assessment and management, and technology such as BDA can help assess and alleviate those risks. Through the usage of BDA, auditors gain the ability to analyse large datasets more effectively and efficiently to inform the auditors' risk assessment. This further enables them to determine and assess the areas of audit risk earlier in the audit process (IAASB, 2016). Risk management is made even more effective through the usage of BC technology in areas related to compliance, especially across different jurisdictions (Deloitte, 2016 (c))

Audit activities that are likely to benefit from BDA have been outlined by Cao, Chychyla and Stewart (2015), they include: identifying and assessing risks associated with accepting or continuing an audit engagement; identifying and assessing the risks of material misstatement due to fraud; identifying and assessing the risks of material misstatement through understanding the entity and its environment; performing substantive analytical procedures in response to the auditor's assessment of the risks of material misstatement and performing analytical procedures near the end of the audit to assist the auditor in forming an overall conclusion. Furthermore, auditors' risk assessment and response are enhanced through the use of BDA, as they offer the auditors opportunities to obtain a more effective and robust understanding of the entity and its environment (IAASB, 2016). These broader and deeper auditor insights provide the entity being audited with more valuable information to inform its own risk assessment and business operations, as compared to the current—mostly manual—audit (IAASB, 2016).

3.3.2 Risks

As with any emerging technology, the opportunities presented by BDA and BC come with just as many potential risks that, if not properly understood and acted upon, can inhibit their development and make them ill-suited for audit firms and their clients. Risks and threats relating to BDA and CA outlined in the academic and corporate literature can be grouped into several categories, namely: Data related risks; security, privacy and compliance related risks; and behavioural and skill related risks.

Data related risks

In the age of BD, auditors and their clients are processing data which are becoming increasingly large not only in terms of volume, but also in terms of velocity, variety and veracity (IBM, 2012). Various sources of data, and their sometimes unstructured nature present additional challenges for auditors, thus making data related risks perhaps the most salient group of risks that they have to face in the new, data-driven, business environment. A risk that affects the audit on the most basic level is the risk that a torrential flow of BD from multiple sources serves no potential benefit, if the connection between them cannot be reliably established (Zhang, Yang and Appelbaum, 2015). Additionally, auditors need to have a clear understanding of the data they are analysing, particularly the relevance of the data to the audit (IAASB, 2016). This is especially important since—with the use of BDA—when "all" the data are processed through the data analytics systems and there is a failure to identify fraud or error, there is a risk that the auditor will be second-guessed (Cao, Chychyla and Stewart, 2015). Zhang, Yang and Appelbaum (2015) further outline possible data gaps stemming from the use of BDA. Namely, data consistency; data integrity; data identification; data aggregation and data confidentiality. These data gaps can lead to numerous audit challenges which include performing an audit on data with different formats; on conflicting data; on incomplete data; on asynchronous data; on illegally tampered data and on encrypted data (Zhang, Yang and Appelbaum, 2015).

Other more technical and conceptual data related risks include the concerns related to auditors having insufficient infrastructure to store and process the data due to their size and volume as well as the risk that the entity being audited is unwilling to provide all the data being requested, as the data requirements in the age of BD far exceed what the entity may be used to seeing (IAASB, 2016).

Even though BDA allow the auditors to observe and analyse more data than ever before—the benefits of which have been outlined in the previous section—this process is not without its downsides. Analysis of huge datasets occasionally yields a high number of outliers, which creates uncertainty regarding the extent of auditors' work effort on outliers to determine whether they are in fact exceptions (IAASB, 2016). This risk has a potential to negate much of the efficiency gains stemming from the use of BDA which were discussed in the previous section. Another pressing problem relating to efficiency and effectiveness of audit is being able to identify appropriate criteria in the analytics program, as well as the adoption of appropriate data analytics tools in the first place (Dzuranin and Mălăescu, 2016; Brown-Liburd, Issa and Lombardi, 2015). This problem is especially salient since audit firms often struggle to attract employees with a high level of IT skills and to adequately train current employees whose IT skill level is not sufficient to effectively analyse BD (KPMG, 2017; Dzuranin and Mălăescu, 2016; Brown-Liburd, Issa and Lombardi, 2015). In such an environment, the increased complexity can lead to an increase in costs for the audit firms, as the volume of data pushes the cost of technology upward and in the process puts pressure on firms to hire more expensive data scientists and invest in more advanced software (Golia, 2013; Inbar, 2013; Mansfield, 2013).

Despite its promise of immutable, reliable distributed databases, BC technology faces certain data related risks. The biggest data related issue concerns the speed and the cost of transactions in a distributed, as compared to a central ledger. This is due to the fact that the consistency guaranteed by the distributed ledger will always incur an overhead, which is the result of the need to compare each record with every other record to ensure they are unique, which consequently increases the time necessary to reach a consensus and validate the transaction (Deloitte, 2016 (c)).

Security, privacy and compliance related risks

Audit profession deals with issues related to security and privacy of customer data as well as compliance with relevant professional standards and legal requirements on a daily basis. With the emergence of data-driven, pervasive technologies we have discussed in this thesis, these issues become even more salient for the audit firms. This has been recognised in the academic and corporate literature. In the era of BD, data from one source can easily be associated with data from other sources. This means that once some sensitive data are leaked, they can propagate with high velocity, connecting with a large amount of related data, potentially endangering the security and privacy of many business entities, as was pointed out by Zhang, Yang and Appelbaum (2015). Thus, for an audit firm, preserving the security and privacy of data it receives from clients is of the utmost importance to preserve brand image and secure competitive advantage through the use of BDA (Zhang, Yang and Appelbaum, 2015). Privacy of data is an even bigger concern when BDA requires clients' non-public information beyond that usually made available to auditors (Cao, Chychyla and Stewart, 2015). As firms upload their data to the cloud—or a BC—the customers' accounting information as well as other sensitive data could be exposed to an untrusted environment, making cybersecurity an issue of particular concern (Dai and Vasarhelyi, 2016). Furthermore, due to audit firms' relative lack of expertise in developing and maintaining complex IT systems required for advanced technologies such as BDA and BC—and due to cost-related reasons—audit firms are likely to rely on third-party providers of BDA and BC solutions. This raises security and privacy concerns (Cao, Chychyla and Stewart, 2015). This has been recognised by Zhang, Yang and Appelbaum (2015) who point out that the principal challenge of technical development is protecting data privacy while guaranteeing utility for the audit.

In the BC community, issues of data security are on the very top of the agenda. In a system where much— or all—of the data is shared through a distributed ledger, assuring data privacy and security is paramount to the very functioning of the system. One of the most successful solutions for this issue has been strong data encryption and the issuance of a public, and private keys which accompany each confirmed transaction. Loss of private keys has been recognised as a key risk for BC networks, as this compromises the privacy of valuable data and the security of the entity, or entities, in question. Another major security risk is the risk of "double spending" which materialises when the data in the BC has been compromised and can potentially lead to further breaches of security (KPMG, 2016(a)).

The regulators have been very tentative when it comes to regulating the use of BDA and BC technology. And even though existing audit standards—primarily international standards on auditing (ISA)—do not seem to constrain auditors in their use of BDA for financial reporting purposes, the lack of reference to data analytics beyond mention of traditional computer assisted audit techniques (CAATs) in the ISAs can be perceived as a hindrance to their broader adoption in audit practice (Alles, 2015; IAASB, 2016). Consequently, there is a risk associated with the use of new innovative technologies, like the ones that have been discussed throughout this thesis, for which a strong framework within the standards does not exist. Auditors face the risk of being second-guessed by the audit oversight authorities if they use techniques which have not been clearly outlined in the auditing standards to substantiate the judgements made and procedures performed in the audit process (IAASB, 2016). There is also a risk that views of audit oversight authorities might evolve in an inconsistent manner if ISAs are enacted in a way that does not allow them to accommodate rapid technological developments, in which case they would be in a continual state of change and revision (IAASB, 2016). Other compliance challenges that the auditors face concern data security and privacy, but also jurisdictional laws and regulations which in some cases do not allow data to leave the jurisdiction where the entity being audited is located. This risk is especially salient for big audit firms auditing multinational companies (IAASB, 2016). Moreover, 66% percent of respondents in a recent study, mainly chief executive officers (CEO), chief financial officers (CFO) and chief audit officers (CAO) of big companies, expressed belief that the biggest challenge to enhancing the impact of audit is the regulatory environment (KPMG, 2017).

In the area of BC technology, and in relation to audit, regulatory efforts have so far been almost non-existent, save for a preliminary collaboration between Digital Asset Holdings—a BC-related start-up—and the Australian securities exchange (Digital Asset, 2016).

Behavioural and skill related risks

As was discussed throughout this section, emerging technologies pose numerous risks and challenges for audit firms. The same can be said of the audit professionals themselves, who are being put under increasing pressure to adjust to their new environment. BDA and BC technology are being promoted by the CEOs and CFOs of big companies, both explicitly and implicitly. A study by KPMG (2017) has found that nearly 80% of interviewed respondents believe that auditors should use bigger samples, with 78% believing that auditors should use more sophisticated technologies for data gathering.

Brown-Liburd, Issa and Lombardi (2015) pointed out several behavioural limitations relating to individual auditors and their processing of information in a BD environment, namely information overload, information relevance, pattern recognition and ambiguity. Ample accounting research suggests that large volumes of accounting information potentially lead to suboptimal auditing judgements, especially in a BDA environment where some of the information is unstructured (Brown-Liburd, Issa and Lombardi, 2015). Another negative effect of exposure to voluminous data is the inability of auditors to disregard irrelevant information. Higher levels of irrelevant information have been shown to reduce decision makers' ability to identify relevant information, this phenomenon is known as the "dilution effect" (Hodge and Reid, 1971; Well, 1971). The dilution effect is particularly problematic in this context since auditors must choose which items are most relevant for their audit judgements from a wide array of available information (Blay, 2005). Since the audit still is—and will continue to be for the foreseeable future—dependent on individual audit professionals, a major consideration in how BDA will be utilised in audit is dependent on the auditors' tolerance for ambiguity in the collected data (Brown-Liburd, Issa and Lombardi, 2015). It is likely that ambiguity-intolerant auditors will be uncomfortable with the sometimes unstructured nature of BD they are meant to analyse, leading to possible avoidance of ambiguous information which can ultimately result in suboptimal judgements (Brown-Liburd, Issa and Lombardi, 2015).

Other threats stemming from the use of advanced technologies are overreliance on data collecting and data analysis software solutions, overconfidence in the results of the performed data analysis and consequently, development of confirmation bias which negatively affects auditors' professional judgement and professional scepticism (IAASB, 2016). Being able to test 100% of a data population does not imply that the auditor is able to provide more than a reasonable assurance opinion (IAASB, 2016). Auditors often lack the necessary IT savvy and fundamental knowledge to fully understand the uses—and more importantly limitations—of technological solutions such as BDA and especially BC technology. This can lead them to believe the results produced by these tools to be infallible, thereby making them unable to exercise their professional scepticism and judgement in a proper manner (IAASB, 2016).

3.3.3 Future Developments

In this chapter, we have provided a review of some of the opportunities and risks related to the use of new technologies—namely BDA and BC—in the context of the audit practice. As the topic in question is still novel even in the technical, IT, world and practically unknown to many rank-and-file audit professionals, direct connections between these concepts—as described in the academic and corporate literature—was limited in the case of BDA and tangential in the case of BC technology. Nevertheless, an extensive investigation of the extant literature has yielded sufficient evidence for this review. A significant part of the reviewed literature—as well as the following chapters of this thesis—concerns future developments in this area and the ways in which the audit profession can adjust to the coming changes in a forward-looking, proactive fashion.

Higher degree of adoption of BDA and BC technology will undoubtedly change the auditing profession. Some of the current audit procedures will be automated, their scope enlarged, time required to conduct an audit will shorten, all of which should eventually improve the overall assurance quality (Dai and Vasarhelyi, 2016). BDA represents a new technology paradigm in the audit profession which will change the way in which transactions are supported. It will improve measurement processes through new, and more abundant, forms of evidence to support decision-making (Warren, Moffitt and Byrnes, 2015). Using what the authors call "Mirror World technologies"—which are comparable to the BC technology—Dai and Vasarhelyi (2016) argue that either individual business processes or the entire value chain can be digitally represented to facilitate control and analysis, a type of system which is already in development through projects such as the Hyperledger project, Fundchain, Digital Asset

Platform and many other (Hyperledger, 2016; Digital Asset, 2016; PwC, 2017). In this kind of system, auditors could use the information in the "Mirror World" as a substitute for physical inventory examination, as well as to link non-financial processes to the accounting records providing sequential integrity assurance (Dai and Vasarhelyi, 2016). Moreover, as the "Mirror World" records the details of business activities happening in the physical world, it can serve as an independent information resource to verify the accuracy of accounting records in the clients' ERP system which is comparable in principle to the system of permissioned BC technology which includes the Private Contract Store (PCS)—analogous to a private ERP system—and the Global Synch Log (GSL) which provides integrity and transparency guarantees for the shared replicated ledger in the BC system (Dai and Vasarhelyi, 2016; Digital Asset, 2016).

Auditors may also potentially see BDA as a way to reduce audit costs and enhance profitability in the case of external auditors, or cost effectiveness in the case of internal auditors (KPMG, 2016(b)). However, the effective use of BDA and BC in the audit requires audit professionals with skillsets different from those that a traditional auditor possesses. Thus, a re-skilling of a relatively large proportion of today's auditors will be necessary to fully realise the potential of these technologies (IAASB, 2016). In a study by KPMG (2017), the respondents have emphasised the need for auditors to be current with new technologies and to look ahead as they evolve. The top three skills clients look for in an auditor are in the areas of technology, communication and critical thinking (See figure 3.2) (KPMG, 2017). Additionally, as audit firms and their clients invest more into development of new technologies, they should be careful to design and build new processes with the oft insufficient technological aptitude of the auditors in mind, as they will be the ones who will ultimately run them on a daily basis (Dai and Vasarhelyi, 2016).

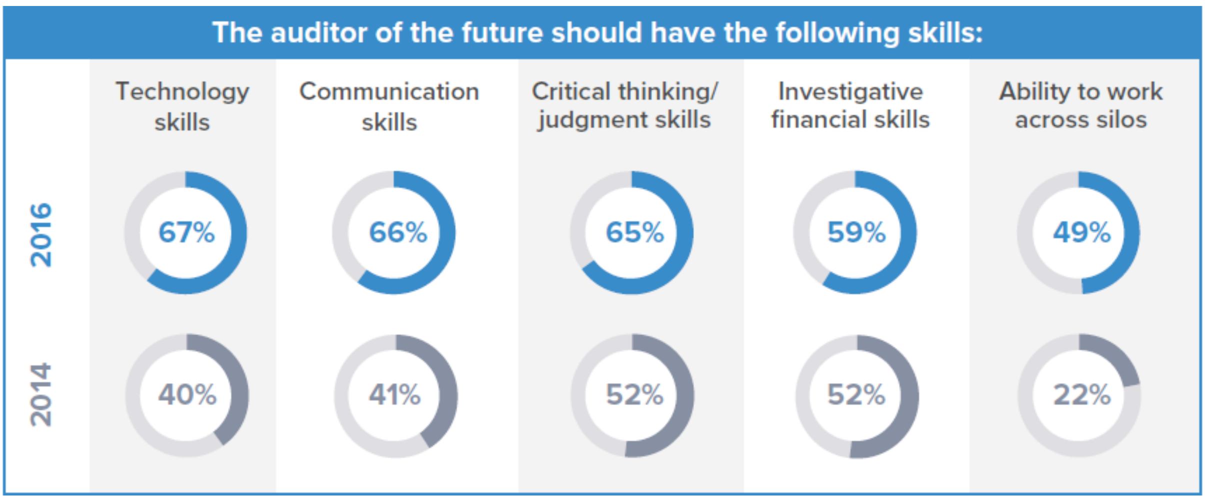


Figure 3.2: Auditors' skills for the future; KPMG (2017, p.11)

As was discussed previously in this chapter, the legal and regulatory frameworks regarding the use of technologies which are in the focus of this thesis in audit practice have been very slow to change, which has possibly caused innovation to move at a slower-than-expected pace. Regulatory bodies such as IAASB, see technological changes as an evolution, rather than a revolution. They highlight the pace of this evolution as a key component, stressing that the ISAs need to better address the increasing complexity, while also taking into account the rapidly changing technological developments in both the audit and business environments. Having this in mind, the IAASB must be careful not to prematurely commence standard-setting activities related to BDA—and especially BC technology—as doing so may inhibit innovation (IAASB, 2016). Moreover Krahel and Titera (2015) argue that, in the new technological paradigm, auditing standards must address situations where data are abundant, not only where data are sparse. The concept of materiality taken as a whole needs to be re-evaluated. With increased automation in audit—and increased reliance on BDA and BC tools—auditing of processes is becoming an ever more salient area of interest. Auditing standards must thus do more to address the concept of process auditing. When data are available on a continuous basis, and in large volume and various kinds, the processes generating those data must be continuously assured (Krahel and Titera, 2015). Despite the inherent, and in any case justified, tentativeness of the audit regulatory bodies regarding emerging technologies, there are arguments for them to take a more proactive stance going forward. Namely, as Alles (2015) notes, the openness of audit standards to sources outside the traditional general ledger data could be a major facilitator for the use of BDA. Furthermore, according to Warren, Moffitt and Byrnes (2015), widespread use of BDA and—it can be argued BC technology—can help address the disparity between U.S. generally accepted accounting principles (GAAP) and international financial reporting standards (IFRS) fair value accounting and help create a global set of accounting standards, long an unrealised ideal of the regulatory, professional and business community.

The benefits that the use of BDA and BC technology in audit promises are immense, however all the relevant stakeholders including the legislators, regulators, professional bodies in the audit profession, businesses and IT developers need to work together if the technology is to deliver those benefits. If the new technologies are applied in a stand-alone, ad hoc fashion without linkage to, or integration with an audit work plan, related audit objectives and other pertinent issues that have been outlined in this chapter, they will likely prove to be unsustainable (KPMG, 2016 (b)).

3.3.4 Critique

Earlier in this chapter we have discussed numerous risks stemming from the use of BDA and BC technology in audit which have been identified by academics, corporate researches and regulators. However, for the analysis of the said phenomena to be comprehensive we will now focus on the critique of these concepts.

This task has been far more challenging than was expected. Due to the novelty of BC technology and the fact that it has not been applied yet on a large scale—other than in cryptocurrencies such as bitcoin and etherium which are out of scope of this thesis—the literature containing critique of BC technology in the context of audit is virtually non-existent. The connection we have been able to identify is merely tangential and indirect, focusing more on one type of BC networks, rather than the technological concept as a whole (For more details on BC technology, including illustrations of different types of BC networks see Appendices C, D, E and F). Based on recent research by Bank of America Merrill Lynch, several authors have concluded that distributed ledger solutions—running on decentralised BC networks which rely on a "proof-of-work" concept to verify transactions through a consensus among mutually distrusting participants—suffer from an innate disadvantage compared to centralised networks in terms of performance and speed. "Proof-of- work" is a piece of data which is difficult (costly, time-consuming) to produce but easy for other members of the network to verify. Producing a "proof-of- work" can be a random process with low probability so that a lot of trial and error is required on average before a valid "proof-of-work" is generated, its main use is in bitcoin (Capco, nd). Consistency guarantee these networks provide will always incur communication overhead for every new peer added to the consensus process of the network (Deloitte, 2016). Namely, with the current technology in use in the bitcoin system, it takes more than 10 minutes for a transaction to appear on the ledger. Bitcoin BC's current transaction volume represents merely a 1/10,000th of VISA's, a bad sign for a technology which will only incrementally improve in the foreseeable future. The report by Deloitte (2016) highlights the issue of costs of the "proof-of-work" based networks in terms of energy consumption. Namely, the average cost per transaction at current volumes is equivalent to 157% of a US household's daily energy consumption or roughly $8.25 (Deloitte, 2016). As was mentioned earlier, the critique found in the Deloitte (2016) report is limited to a single type of BC technology, of the kind which uses "proof-of-work" concept in its consensus mechanism. The report further states that many BC technology advocates may want to distance themselves from a definition of the technology based on the "proof-of-work" concept and cryptocurrency. The market is responding to the challenges outlined in this section with a host of new distributed ledger platforms and frameworks which do not use "proof-of-work" nor cryptocurencies. The most notable effort of this kind to date has been the Hyperledger project (For illustrations of different kinds of BC networks see Appendices E and F).

BDA is not a new concept, it has been around for years. Moreover, it is not a standalone technology. It is intertwined with multiple other technological concepts which are well established in audit firms' as well as their clients' IT systems. It is our view that the use of BDA in everyday practice going forward is not a matter of choice, but of necessity for nearly all the market participants, including audit firms. The spread of BDA in the audit context is comparable to the spread of ERP systems a generation ago. As Alles (2015) points out, competitive forces made ERPs a necessity for businesses and once ERPs became ubiquitous they created the need for auditing to be done in a computerised environment. Consequently, the available literature does not take a stance of outright critique of the use of BDA in the audit context. Rather, the research focuses on risks associated with various levels of adoption of BDA and the effects of its integration with other technological and business concepts. Summary and analysis of the said research can be found in preceding sections.

4 Case Study Results

This chapter will present the results of the empirical findings. In chapter 4.1, a short introduction of the case companies, and more generally the Big 4 firms will be presented. In the subsequent chapters the empirical findings will be analysed and linked to the theory and literature in a mostly inductive way. The results of the CS will contribute to the construction of the framework outlined in Chapter 5, by providing practical implications and awareness of challenges gained through an in-depth analysis of the CS.

4.1 KPMG and other Big 4 Firms

The main CS company is KPMG Luxembourg, which is a part of a global affiliated network of independent KPMG entities. KPMG, PwC, Deloitte and EY are the so called "Big 4", offering professional services such as audit, legal services, tax and assurance advisory. In the financial audit market, they are the dominating providers, because most of the time they are the only firms that have the capacity to perform a statutory audit for medium to large size companies. Furthermore, their reputation is well-known in the financial sector and consequently their approval of the financial statements can be an advantage for their clients in terms of better credit-worthiness, which translates to lower interest rates and better solvency as pointed out by interviewee 3.

However, their success in securing the most important global companies as clients and the successful development of long-term relationships with those clients is putting them under permanent public scrutiny and increasingly strict regulatory requirements. In the U.S. Big 4 companies are auditing 497 companies in the S&P 500 index (Figure 4.2) and have been the public auditors of over 50 percent of the S&P companies for more than 20 years; some even more than 100 years (Figure 4.1). In the EU, they are holding more than 60 percent of the audit market share (Figure 4.3).

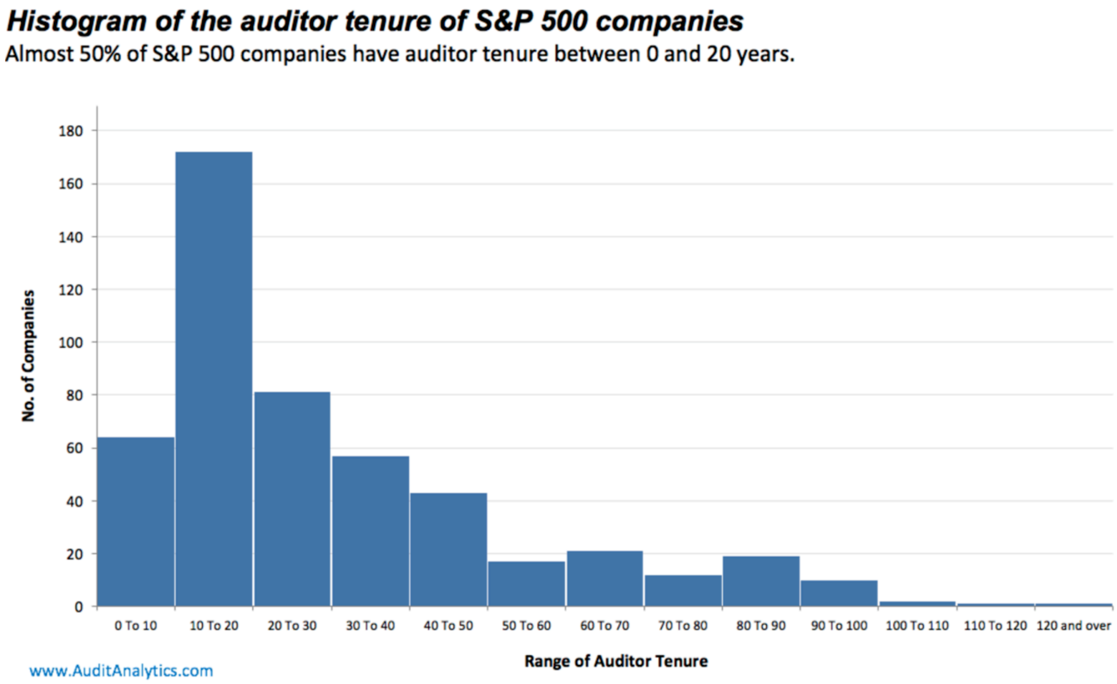


Figure 4.1: Auditor tenure of S&P companies, 2017 (Source: Pakaluk, 2017)

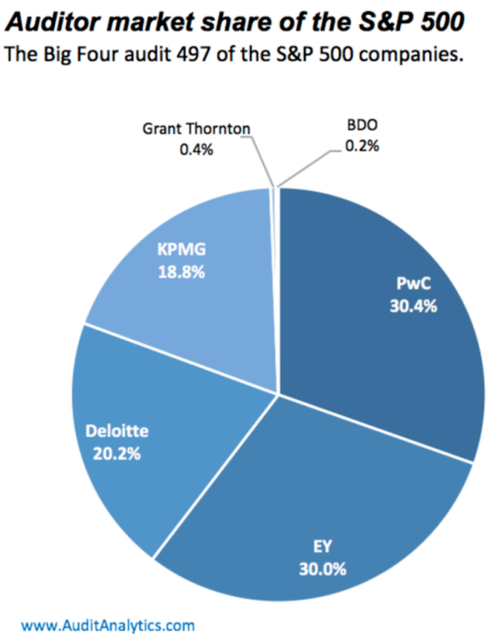


Figure 4.2: Big Four Market Share of the S&P 500, 2017 (Source: Pakaluk, 2017)

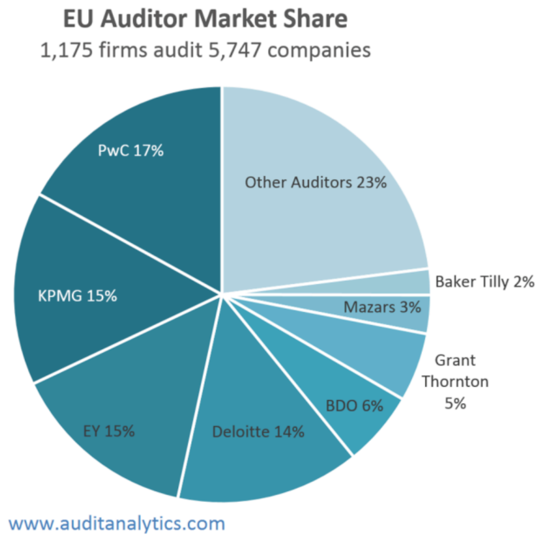


Figure 4.3: EU Auditor Market Share,2017 (Source: Ferullo et al., 2016)

The memories of the financial crisis in 2008 and the Enron scandal are still fresh in the minds of the public, governments and businesses around the world. The Big fours' audit departments should at the same time regain public trust and stay competitive in an environment of tightened regulations and advancing technologies. The technological development can, if adopted properly, represent the main driver for reclaiming the trust of the public and increasing the efficiency and competiveness. In a KPMG survey among CEOs and CFOs (KPMG, 2017), the need for more BDA and value creation for the client was highlighted. The implementation of new technologies like the BC in audit is described as potentially disruptive by many reports issued by the Big 4 (KPMG, 2016 (a); Deloitte, 2016 (a)). However, an efficient and effective use of advanced technologies is challenging for audit companies, businesses and regulators alike. It requires skilled and educated employees, advanced IT infrastructure, supportive regulations and common standards. All of these needs will need to be fulfilled in order for audit firms to benefit from the use of new technologies and reduce or prevent related risks at the same time.

4.2 Perception on the Future of the Audit Profession

This chapter describes interviewees' perception of how and in what direction the audit profession will develop in the next five years. The timeframe was chosen with the aim of exploring the current and future developments in the audit profession in a forward-looking manner, while at the same time avoiding the dilution of conclusions and the ambiguity inherent in predictions pertaining to a longer timeframe of e.g. ten years. The premise of our approach is that the audit profession is characterised by its inability to keep up with their customers in adopting new technologies, which is to a large degree caused by a highly-regulated environment with a slow pace of change (Dai & Vasarhelyi, 2016). Therefore, progression in technologies like AI (Artificial Intelligence), BDA and BC is potentially threatening for the current business model in audit firms. Moreover, the success of audit firms is today largely dependent on the workforce needed to conduct mostly manual and time consuming audit assignments. With the new technologies promising to do away with much of that workforce through automation, the profession's importance to the financial system is in danger. The following analysis of the empirical results regarding the future and quality of audit will provide an insight into the perception of professionals working at KPMG and PwC related to the developments mentioned above. Furthermore, the opportunities and challenges concerning new regulatory constraints are discussed.

4.2.1 Professional Outlook and Audit Quality

The consensus among the interviewees is that the future of the audit profession will be characterised by DA and other technologies supported by AI, which will promote automation of the audit process. Therefore, the auditors need more training in DA and to increase their collaboration with the in-house IT teams. Furthermore, the participants pointed out that further standardisation of audit procedures is required to achieve full automation of repetitive tasks. The first phase of this process was described by interviewees 1 and 3 who indicated that simple but repetitive and time consuming tasks will be automated in the near future. As a result, they concluded that a paradigm shift in the recruitment and function for assistant level jobs could occur; auditors will be required to have more IT skills and will—thanks to the aforementioned automation of repetitive tasks—have more time to perform more precise analysis. Interviewee 5 explained that the automation of simple but time consuming tasks could enable auditors to focus on testing exceptions and strengthening relationships with the clients; creating more value for the clients and the firm in the process. The perception of our interviewees regarding advanced use of DA and increased automation is in line with the literature, where authors like Brown-Liburd and Vasarhelyi (2015) point out that the traditional way of collecting and handling audit evidence is not sufficient anymore. New tools such as BDA and the overall data environment are enabling automated data collection. Dai and Vasarhelyi (2016) go even further by proclaiming a new revolution in the audit sector (Table 4.1); namely, that the profession is about to enter a new phase the authors call "Audit 4.0" where: *"[...] semi- and progressive automation of audit"* will become the norm with the help of real time tracking of intangible and tangible transactions using e.g. sensors, GPS (Global Positioning System) and RFID (radio-frequency identification). Furthermore, they identify the degree of standardisation of procedures as an important factor on the way to full automation, which has been highlighted as a first step towards technology assisted audit systems by most of the interviewees.

TABLE 1 The Generations of the Audit			
Audit 1.0	**Audit 2.0**	**Audit 3.0**	**Audit 4.0**
Manual audit Tools: pencils, calculators	IT audit Tools: Excel, CAAT software	Inclusion of Big Data in audit analytics Tools: analytical apps	Semi- and progressive automation of audit Tools: sensors, CPS, IoT/IoS, RFID, GPS

Table 4.1: Generations of the Audit presented by Dai & Vasarhelyi (2016)

Regarding the headcount, most of the interviewees do not see any changes happening; however, interviewee 5 posits that due to automation, regulations will become more strict and extended to cover the inherent risks of technology, resulting in more work for auditors e.g. IT reliability tests. Hence, the audit companies will continue to hire a high number of people due to the increased regulatory pressure. The proliferation of regulations caused by increasing amounts of data being processed and advancements in DA are discussed by Dzuranin and Malaescu (2016). Furthermore, the IAASB as a regulatory body argue that the use of more BDA and other emerging technologies will enable auditors to spend more time on substantive tests rather than time consuming and repetitive manual work. Moreover, the IAASB argue that professional judgement is still important for a decent audit procedure, which confirms the perception of interviewees that auditors will not be replaced soon by automation but will rather be supported by the technology. However, interviewee 5 argues that professional judgement can be misleading, because the role of auditors in: *"[...] applying rules leaves no room for judgements"*.

The audit quality can be improved in the future through automation, according to all the interviewees, by e.g. reducing human error (Interviewee 2), increasing the amount of time available to spend on value-adding problems (Interviewee 3) and reducing manual work (Interviewee 4). Interviewee 3 described two criteria on which audit quality depends, namely human resources and the degree of standardisation. The recruitment and retention of motivated and knowledgeable employees and standardisation of audit procedures are key for high quality audit assignments and the survival of the profession according to a report published by ACCA (2016). Chan & Vasarhelyi (2011) describe the: *"[...] need of innovation in the traditional audit process to support real time assurance",* by using automated and continuous auditing which will enhance the efficiency and effectiveness of the audit. Interviewee 5 has a rather pessimistic view on the potential to increase audit quality by providing more training and development opportunities to employees, claiming that the only reliable way to improve audit quality in the long run is through standardisation and automation of procedures.

4.2.2 Opportunities and Challenges of new Regulations

Since 2016, mandatory firm rotations for public interest entities (PIE) have been implemented by the EU. All PIE companies are listed organisations, including all credit institutions, insurers and all entities designated as PIEs by any of the member states of the EU. The baseline of the new regulation is a ten-year mandatory statutory audit firm rotation, extendable up to twenty-four years. The objective is to increase public trust in the work of audit companies which are often claimed to have ties to the upper management of their audit clients that are too close. As mentioned in Chapter 4.1. long-term relationships between companies and their auditors are threatening the independence and integrity of the whole profession (KPMG, 2014).

The interviewees agree that a mandatory rotation will be mostly beneficial for the clients and will increase the audit quality. However, the literature has identified inconsistencies in the relationship between partner rotations and audit quality (Moroney, 2016). The benefits as interviewees 1 and 4 point out are that a: *"[...] new set of eyes"* and a slightly different audit approach can reveal e.g. control inefficiencies. However, interviewee 1 notes that the new regulations will come with higher audit costs for the clients since new assigned auditors must first get familiarised with their organisational procedures, which is time consuming for clients' finance and accounting departments to facilitate. Regarding the competition between the Big 4 and smaller audit firms, the participants of the CS emphasised that companies which have been audited by Big 4 firms in the past will, when they are required to rotate their statutory auditors, hire one of the other Big 4 firms instead of looking to some of the smaller ones. Furthermore, interviewee 5 notes that an additional aim of the regulation is to increase the competitiveness among audit companies and consequently decrease the dominant market share currently enjoyed by the Big 4 firms. However, according to interviewee 5, the most likely outcome of the enactment of new regulations will actually be the opposite, as the new rules will make it harder for small audit companies to compete because their client acquisition and retention depend even more on personal relationships and trust—which usually take years to develop—than is the case for Big 4 firms. The interviewed auditors see the net effect of the new regulation as being neutral since the Big 4 firms will generally have as many chances to gain new clients as they will lose due to mandatory rotation of statutory auditors.

4.3 IT Competence

IT competence has become one of the most important skills required for future audit professionals, due to the increased use of DA by the clients of audit firms (Alles, 2015) and the digitisation of the whole industry. As described in the previous chapters, the Big 4 firms, academic researchers and regulatory bodies are aware of the importance of BDA and other emerging technologies like the BC (KPMG, 2017(b); Alles, 2015; Chan & Vasarhelyi, 2011, ACCA, 2016; IAASB, 2016).

This chapter aims to examine the current state of the interviewees' and other auditors' IT knowledge, discuss the relationship between IT qualification and audit quality and explore future developments regarding IT skill requirements for auditors.

4.3.1 IT Knowledge and Audit Quality

The current IT skill and knowledge level of the interviewees depended mostly on personal interests, internships and education prior to the audit employment. It ranged from pretty low to advanced regarding programming skills. It should be mentioned that except for the IT experts (Interviewees 1 and 5), the remaining interviewees are mostly using Excel as their primary software in their daily work, where we can further distinguish between interviewees and divide them into groups of basic users (e.g. filter function, basic formulas and pivot tables) and power users (e.g. programming macro functions). Interviewees 2 and 4 are specifying that their IT experience and skill have been mostly developed through performing daily work assignments and not so much through in-house IT training and seminars. This rather mixed level of IT levels could reflect that the case companies are not specifically looking for high IT knowledge in their assistant recruitment strategy. However, interviewee 3 notes that KPMG is actively recruiting more: *"[...] highly skilled IT people in order to strengthen the IT support team; with the objective to produce more data analytics software to support the audit teams"*.

Audit quality could be improved indirectly through an increase in auditors' understanding and knowledge of IT, according to interviewees 4 and 5. They argue that auditors should be proactive and develop more efficient ways to analyse data themselves, e.g. programming their own macros in Excel. Interviewee 2 noted that nowadays, the communication with the clients' accounting department requires at least a basic level of IT knowledge since most of the raw data received from clients must be adjusted and converted into usable data. These tasks would be very difficult to complete without a certain level of IT knowledge and experience. Alles (2015) emphasises the importance of auditors adapting to the technology used by their clients. Cao, Chychyla and Stewart (2015) pointed out that the increased use of BDA can lead to an improvement in the efficiency and effectiveness of financial statement audits. Furthermore, Yoon, Hoogduin & Zhang (2015) argue that technological advancements are complementary tools for auditors, assisting them to collect relevant and reliable audit evidence in a more timely and cost-efficient fashion.

4.3.2 Auditors' IT skills moving forward

The interviewees in agreement over the fact that IT skills are an essential asset of future auditors. This is in line with a KPMG (2017) survey which shows that most of the top management of audit clients are expecting their auditors to use more DA tools and more value adding methods going forward. However, interviewee 3 argues that there are limits to the extent to which auditors should develop their IT skills, arguing that their main job is still the financial audit which requires them to retain a high level of hard accounting skills, professional judgement and scepticism. Furthermore, advanced software and DA tasks should be performed by a separate *"highly specialised IT"* department (Interviewee 3) in close cooperation with the audit teams. In practice, the IT team develops e.g. new macros for the fund department by having the audit teams: *"[...] explaining to them the financial logic behind the raw data received from the client and what they are looking for"* (Interviewee 3). DA experts would prefer to have a closer cooperation with the audit department in the future, as right now the IT team is: *"[...] struggling with getting feedback and ideas from the auditors"*, arguing that: *"[...] if they knew a bit more about IT they may have more useful suggestions that would help"* the IT team develop more useful tools (Interviewee 5).

4.4 Big Data and Big Data Analytics

Advances in terms of computational speed and storage capacity, and the fact that they have become affordable even for the smaller market participants have enabled a dramatic increase in the level of use of BDA even in traditionally conservative industries like auditing. Griffin and Wright (2015) noted that companies are collecting client data to support strategic decisions and are adapting their management controls system to them. The audit field cannot neglect the importance of BDA, particularly since it has become an essential business tool for many of their most important clients (Alles, 2015).

The development and current state of BDA use in audit has been described and analysed thoroughly in chapter 3.2. Furthermore, the benefits, risks and future developments described in the academic and professional literature have been presented in chapter 3.3. Therefore, the following chapter will focus on the perception of practitioners regarding expected benefits and risks of the use of BDA in audit assignments. Moreover, contradictions with or similarities to the literature will be pointed out. They will not be elaborated in great detail to avoid redundancy since an extensive description and analysis of BDA can be found in chapter 3.

4.4.1 Big Data Analytics in Current and Future Audit Assignments

The level of exposure to BD and the use of BDA in the daily work environment of our interviewees are influenced by contextual factors such as different audit clients (e.g. banking, funds, corporate) and different levels of expertise in IT.

Interviewee 2, who works in the banking audit sector, notes that they mostly test small samples prepared by the IT team. Consequently, in their department they never deal with BD or use BDA tools for advanced analytics; basic Excel knowledge and manual checks are sufficient for their day-to-day work, at least on the assistant level. The discussion regarding the audit approach, risk level and appropriate sample size is a part of the communication between senior level auditors and the IT team. Regarding the corporate audit, interviewee 4 notes that due to the small or medium size of the companies being audited by that particular audit team, BD does not play a role in their daily work. However, if the client depends on IT controls and has large amounts of financial data, the audit team will engage the IT specialists to prepare a report assessing the reliability of the IT system and the financial data provided by the client, namely: *"The IT team is able to collect the entire general ledger and test it automatically and report the results back to us"* (Interviewee 4). Interviewee 3 claims that, in the fund sector where standardisation of data is high due tight regulation, the audit team can work with BDA. In this case, in-house IT experts and managers can program appropriate macros in Excel or provide other DA tools, enabling the audit team to test all the raw data received from the client since they deal with: *"[...] very similar standardised data packages with the same formats"*. However, interviewee 3 argues this process could be different and more complicated for other industries, which has been confirmed by interviewees 2 and 4.

In the future, BDA will play a more important role in all the audit sectors and will eventually lead to increased automation through advancements in technology and standardisation. The risk advisory manager at PwC asserts that they: *"[...] need to standardise the audit to be able to automate it"* and points out that they are running: *"[...] multiple projects simultaneously to keep the quality and standardisation of the audit as well as putting tools around it to enable automation"*. Furthermore, interviewees 1 and 5 note that PwC and KPMG are already actively outsourcing time consuming and manual tasks, e.g. general ledger reconciliations, to third party companies based in low-wage countries. They further speculate that this could also be done in the case of BDA. The benefit would be that standardised and automated procedures would be performed outside the audit firm, enabling auditors to focus on substantive and detailed testing of exceptions which would benefit the quality of audit (Interviewees 1 and 5). Griffin and Wright (2015) identified BD as the biggest challenge for the accounting and audit profession. According to Yoon, Hoogduin and Zhang (2015) audit quality can be improved with increased use of BDA; freeing auditors from time consuming manual tests and allowing them to focus more on substantive tasks.

4.4.2 Audit Evidence and Sample Size

Interviewee 1 asserts that using big sample sizes or testing the whole population of data would not be in line with the audit risk approach of PwC's risk assurance department, further stating that the sample sizes that are currently being used are appropriate and have proven to be more cost efficient for the clients and the firm itself. Conversely, interviewee 4 argues that, in the corporate audit, sampling is used as a *"last resort"*, if no substantive tests can be performed; claiming that small sample sizes do not give very high insurance against risks. When the risk is low they rather prefer to do expectation tests. For most clients, tests of details, vouching and third party confirmations provide better audit evidence then sampling (Interviewee 4). The fund audit is already performing full population test according to interviewee 3, as was mentioned in chapter 4.4.1.

In general, all interviewees agree that bigger sample sizes being used would lower the risk of fraud and increase audit quality; and in an ideal world, they would prefer to test the whole population every time. However, they all point out cost-efficiency issues regarding the higher workload that testing the whole population with current technology entails. Those cost-efficiency issues could be solved with BDA and automation, which according to interviewee 5 requires: *"[...] a more clever and efficient way to use big data and more sophisticated mathematical algorithms programmed by staff with high level of statistical and IT skills".* An argument for sampling is given by interviewee 1, who states that testing the process and controls of the client is also important: "*You are not focusing solely on the sample size since you are building confidence from different sources, for mature clients having small sample sizes may be the more efficient way to test and gather evidence and for more immature clients it might be best to collect all data and rebuild the system to test the processes"* (Interviewee 1).

The answers provided by the interviewees regarding the use of larger sample sizes to increase audit quality is in line with the results of the KPMG (2017) survey, in which it was outlined that CEOs and CFOs expect that new auditors should use more DA, : *"[...] test bigger samples and provide a more forward-looking view of the world and insights that can add value (e.g. identifying risks)".*

4.4.3 Downsides of BDA and Full Population testing in Audit

BDA is a powerful tool that can assist auditors in their daily work but there are several drawbacks of this technology beyond the ones mentioned in chapter 3.3. Interviewee 5 claims that auditors usually do not have a solid base when it comes to statistics and confidence intervals, resulting in people relying entirely on software to tell them how big a sample should be, without necessarily understanding the underlying principles of the software or the processes involved. The risk of overconfidence in the supporting BDA software could influence the judgement of auditors and decrease the quality and credibility of the audit evidence (Interviewee 5). The behavioural and skill-related risks involved are pointed out by Brown-Liburd, Issa and Lombardi (2015), and were the subject of detailed discussion in Chapter 3.3.2.

Interviewee 4 posits that the audit of the entire database, if done properly, is cost and time-efficient. However, there is a potential for conflict with the client if the client does not see the benefits of investing time of their finance and accounting departments in retrieving evidence for information that constitutes a minuscule part of the entire database being audited (Interviewee 4). Interviewee 5 argues that the regulators do not want to pressure smaller audit firms to perform full database audits, as that could drive those organisations out of business because it is, in most cases, too costly for them to invest in the required technology. The issue of high investment costs is also pointed out by interviewee 4, who states that: *"The biggest drawback of emerging technologies which will enable full population audits are investment costs and that companies may have to be forced through regulation and/or market forces to implement it, even if the technology proves to be very effective"*.

Storing vast amounts of data in order to take full advantage of the power of BDA tools in the context of an audit can come with major IT risks. Interviewee 5 argues that: *"Gathering all the data from all the clients at one place"* can potentially lead to a major breach of sensitive information, if unauthorised persons attack and break into the system. However, when the risk is mitigated through implementation of correct regulations and security tools, BDA can be used to: *"[...] analyse the entire database in order to avoid missing the bigger picture"* (Interviewee 5). Furthermore, Interviewee 5 notes that: "*It is not very expensive to store and analyse the data, what is expensive is if you get bogged down in details and spend too much time on irrelevant stuff. You need to setup the rules and then you can start working on it"*. Data, security, privacy and compliance related risks mentioned by interviewee 5 are in line with views held by researchers, e.g. Zhang, Yang and Appelbaum (2015) who note that data leaks are potentially threatening whole business sectors if breaches occur. For more details see chapter 3.3.2.

It is worth noting that interviewee 5 was able to provides us with the best insights and the most valid information regarding the risks and opportunities stemming from the use of BDA and BC technology in audit. This is due to the interviewee's high level of IT-related audit knowledge, and other IT skills which have been honed through daily activities in the data analytics department of KPMG Luxembourg. This, along with other relevant contextual factors which affect the knowledge on the topics focal to this study—and consequently the answers the interviewees were able to give us—is discussed in more detail in chapter 4.5.1.

4.5 Blockchain Technology

The audit industry is based on rules and regulations, its core structure as well as individual professionals it employs are inherently wary of overstepping regulatory boundaries all of which has made the industry perpetually slow to react to changes and innovations that are happening in its business and technological environments. This is somewhat understandable since the audit firms possess neither the legal mandate, nor the technical expertise necessary to push the technological frontier themselves. Nevertheless, with the emergence of a potentially transformative technology such as BC, the auditors should seize the opportunity to familiarise themselves with its practical implications, the associated benefits and risks, and leverage this knowledge along with their considerable business acumen to proactively guide their clients through its implementation. This stance is in line with the views of interviewee 1 who states: *"I see the lack of a proactive stance by the firm on the issue of BC and other new technologies as potentially threatening to our business model going forward"*. Full adoption of the BC technology on a large scale promises many benefits, some of which have been discussed throughout this thesis. Our empirical research has yielded mixed results in terms of the awareness of these technological changes and the perception of their importance for the audit industry. We will discuss these findings in greater detail in the following sections.

4.5.1 Blockchain in Audit

As was mentioned in chapter 2.2. there is significant variety among our interviewees in terms of their practical daily assignments, skillsets and the views they hold about the importance and possible effects of the technologies discussed in this thesis. We can broadly divide our interviewees into three groups. The first one includes interviewees 2, 3 and 4 who are assistants in a financial audit division of KPMG (banking, funds and corporate), and interviewee 6 who is an assistant manager. Daily tasks and skillsets of these interviewees are not conducive to a high level of technological savvy and forward-looking attitude in terms of the possible implications of BC technology in the audit industry. They were, however, very receptive to the information about BC technology that was provided to them and have generally expressed cautious optimism about the positive effects that it could have in the audit context. The second group includes interviewee 5 who is an analyst in the data analytics division of KPMG, and whose level of IT knowledge far exceeds the one held by interviewees in the first group. This, along with the fact that daily assignments of interviewee 5 include data extraction, transformation and systematisation in the form of working papers that are delivered to financial auditors, makes interviewee 5 much more familiar with the latest IT technology trends including BC technology. The third group consists of interviewee 1 who is a manager at PwC's risk advisory division. The level of familiarity with BC technology of interviewee 1 is comparable to the one of the interviewees from the first group, however due to the nature of the assignments interviewee 1 conducts—which necessitates regular use of BDA tools—it was easier for interviewee 1 to grasp the concepts behind BC technology and offer practical ideas about its use in audit and risk assurance in the future. Moreover, interviewee 1 has recognised the practical value of the framework we have constructed for the purpose this thesis and has requested permission to use its findings in educational seminars for auditors at PwC's Malmö office.

In this context, our empirical research has focused on three main topics, namely the suitability of the BC technology for the audit profession, the effects BC technology would have on the quality and cost efficiency of audit and BC technology's effect on audit firms' effort to automate their processes.

Suitability of Blockchain technology for audit

All of our interviewees see BC technology as suitable for the audit profession. Interviewees 2 and 3 see BC technology greatly improving time and cost efficiency of the audit due to the greater ease of obtaining data which would be stored on a distributed ledger in a BC network of the client. As interviewee 3 points out: *"Right now, a lot of auditors' time is being spent on obtaining documents, this could be made faster, or even instantaneous with the use of BC technology",* a point buttressed by interviewee 5 who argues for further efficiency gains due to the reliability of data stored on a distributed ledger*: "[...] we would not have to do any reconciliation, we would look at the BC and see that there is a consensus on the data we are looking at, you would have a general ledger that has been approved by everybody in the network"*. This is in line with the arguments raised in several practitioner-led collaborative efforts which predict greater cost efficiency and immutability of records stemming from the use of BC technology (PwC, 2017; Digital asset, 2016).

As was discussed previously in this thesis, BC technology suffers from several risks due to technology's relative novelty and the fact that it has not yet been fully tested in a real-world setting, and in the audit context. These threats have been recognised by several of our interviewees. Interviewee 4 notes that BC technology's application could be limited to certain activities and transactions and to certain—usually bigger and more technically savvy—clients, at least in the short run. Interviewee 2 has expressed pessimism about the wider adoption of BC technology unless that was required by law. Alles (2015) takes a logically comparable stance claiming that a major facilitator for the use of BDA, and—it could be argued—BC technology, is the openness of audit standards to sources of audit evidence outside the traditional general ledger data. Alles (2015) further emphasises the role of clients as drivers of the use of technologies including BDA and BC, arguing that the audit firms will have no choice but to embrace technological changes—not because they necessarily value the benefits of these technologies, but because their clients do. Interviewee 1 has expressed agreement with this line of reasoning, adding that the audit firms should be more proactive in this context in order to gain first-mover advantages relative to their competitors before these changes become a necessity. Additionally, interviewee 1 sees a short-term negative effect that BC technology could have due to the fact that it depersonalises data collection, thus in some cases making auditors unable to get a holistic picture of clients' businesses. On the other hand, interviewee 1 claims that this threat should be mitigated as auditors' skill level and understanding of BC technology increases, eventually becoming an asset: *"I think that the advice we give to our clients would be more precise [with the use of BC technology]"*.

Blockchain's impact on quality and cost efficiency of audit

In line with arguments outlined in chapter 3.3.1., our empirical data suggests that BC technology should increase the quality of audits. Interviewee 3 notes how BC technology could increase audit quality by arguing for the importance of data security. Namely, auditors currently use data from big companies, data which are in many cases selected and processed manually by individuals working at those companies. This process entails high risk of fraud. When describing possible benefits of implementing BC technology, interviewee 3 states that: *"If data was encrypted and easier to track, it would make the whole process much safer and to a large extent remove the possibility of fraud"*. Interviewee 4 compares BC technology to third party assurance and points out that using this technology would improve the quality of audit and the level of assurance in the work being done by auditors. The view is shared by interviewee 1 who claims that the quality of audit could greatly increase due to the fact that—in a BC run world—third party assurance could be obtained from a trusted source verified by numerous, mutually distrusting, participants of the BC network.

In chapter 3.3.2. we have discussed several skill and technology related risks associated with BC technology. Interviewee 5 uses analogous reasoning to argue that the increase in the quality of audit stemming from the use of BC technology would materialise only in the long-run. Interviewee 5 explains that: *"[...] we would need people who understand BC very well, there would be many mistakes at first since the technology is too complex for most people. [...] In the short run, there may be some internal resistance to change as well"*. Positive long-term effects in terms of cost efficiency have been recognised by interviewee 2. Interviewees 3, 4 and 5 further note positive effects for clients, materialising through lower audit fees due to the fact that audit would be a less time consuming, more efficient process with the use of BDA and BC technology. This would still be beneficial for the audit firms overall, according to interviewee 5: *"The audit firms would probably be heavily involved in deploying, implementing and monitoring of BC technology and related processes through their advisory departments"*.

Blockchain technology and automation in audit

Our empirical research has yielded mixed results pertaining to the effects that BC technology would have on automation in audit. The interviewees have differing perspectives on the extent and the nature of automation that would result from greater use of BC technology. It is our view that this inconsistency is due to insufficient knowledge about the technology itself displayed by some of the interviewees, as well as other contextual factors such as the type of industry they are auditing, different regulatory and legal environments their clients operate in and the different size and technological capability of their clients.

Interviewee 4 argues that full automation is not possible since auditors face specific problems and different processes in different companies, this is especially the case for medium and smaller size companies. Interviewee 4 however sees higher levels of automation in big institutions like funds and banks in the long-term future. Interviewee 5 somewhat agrees, although from a different perspective. Namely: *"[...] even with more automation that BC could enable, you will need many people to set up the processes and ensure that they are validated, both IT people and auditors would work together on that"*. As was mentioned earlier in this section, this inconsistency is likely due to differing levels of technology-related knowledge and the difference in the areas the interviewees work in. Despite these differences, interviewees 4 and 5 agree that only the bigger, better organised clients would be willing and able adopt BC technology in the short-term. This is consistent with our view, and can also be inferred from the available literature on the subject, although it is not directly stated as such. On the other hand, interviewee 2 is of the opinion that BC represents a step towards full automation, claiming that this would be a natural continuation of automation efforts which are already in full swing at all Big 4 audit firms. This view is further supported by interviewee 1: *"I would say that this [BC] technology will be an enabler of automation in the audit industry"*.

Conversely, interviewee 2 also highlights the dangers inherent in over-reliance on technology, stating that there is a risk that the auditors of the future will rely on data generated by the system without questioning them or necessarily understanding the underlying logic of the algorithms used to extract and process those data.

4.5.2 Auditors' role in a world of BC Technology

In the previous chapters, we have discussed various ways in which BC technology could potentially change the business world. A very important aspect of the analysis of the future of the audit profession is establishing its role in the BC and BDA-driven business environment. There is a consensus among our interviewees that ubiquity of BC technology will usher in a significant change in the role of the audit profession as a whole.

The nature of the tasks being performed by auditors—aided by gradual automation of repetitive tasks—will change towards a more supervisory role, with a: "*[...] higher focus on auditing the processes, reliability of the system as a whole instead of validating transactions manually like they [auditors] do now*" (Interviewee 5). This view is shared by interviewee 4 who notes that, in a BC-driven environment, the auditors should perform IT system audits, checking for breaches, and monitor the whole system. Moreover, interviewee 1 points out that auditors have a role to play in change management, to guide their clients through the implementation of BC technology in addition to assuring the control environment. Additional audit evidence over the process could be gained through the auditing of BC vendors. Interviewee 1 further explains that the audit work will concern: "*[...] understanding the technical aspects of the technology and the audit process, the outcome of the analysis of the BC will be more on the financial audit side than the risk assurance side*". Interviewee 2 envisions that the changes in technology and automation will allow auditors to focus more on the underlying issues in an audit process. Prevailing opinion among practitioners—based on our limited research—seems to be that the overall headcount in audit firms will not decrease, and might actually increase in this scenario, as was noted by interviewee 5. The ratio of IT specialists to financial auditors may decrease significantly though.

In spite of these changes, the core role of the audit will not change even in a BC environment, according to interviewee 3: *"Audit firms would still retain their role as guarantors of viability of the financial statements, even in a permissioned BC system"*.

These findings corroborate recent research which indicates that the clients of audit firms are no longer satisfied with just a "rear-view mirror" view of their business operations, but are instead looking for a view "through the windshield" which includes an expanded audit scope, better communication skills and the ability to bridge from the past to the future (KPMG, 2017). These findings are summarised in Figure 4.4.

Table 4.4: Clients are seeking more forward-looking auditors; KPMG (2017, p7)

4.6 Risk Management

Throughout this thesis, we have argued for the urgency among audit firms to increase awareness and be proactive in the area of new technologies; focusing on the most salient, BDA and BC technology. We have also preached caution, and outlined potential risks and threats stemming from the use of these technologies in audit (For more details see chapter 3.3.2.). Our research in this area can be broken down into two categories, configured with the aim of addressing the relevant aspects of these risks and different perspectives and contextual factors associated with them. The categories are: Risk identification and mitigation; auditors' and clients' awareness of and ability to handle risks.

Risk identification and mitigation

Our empirical findings are for the most part consistent when it comes to risks that the use of BDA and BC technology entails. The interviewees are in agreement that much of these risks are IT related, in terms of potentially debilitating: *"[...] hacking attacks, breaches of confidential information, a crash of the entire infrastructure, bugs and viruses"*, as pointed out by interviewee 4 who further sees a problem that a single crash or a data breach could threaten the entire network if companies would be fully interconnected through the BC system. In the same vein, interviewee 5 asserts that with higher levels of automation, potential mistakes would have a much higher impact than before. The overall level of risk would be much lower in the world of higher automation, however it can be argued that this opens up the possibility for the emergence of what Nassim Taleb calls "black swans", highly improbable events, that are impossible to predict prior to the fact but seem obvious in hindsight, and have a devastatingly extreme impact if and when they end up occurring (Taleb, 2007). Past accounting scandals such as Enron and WorldCom serve as warnings for what the failure to take those kinds of risks into consideration can account to. These data-related threats are especially salient in an inter-connected business world, and as the software running the global BC networks becomes more sophisticated. The Hyperledger project, an open-source collaborative BC effort which includes tech and software giants such as SAP, IBM, Intel, Huawei, Samsung and Nokia; financial institutions like J.P. Morgan, Wells Fargo, Deutsche Börse, BBVA and many others; is in its current, nascent stage, running on hundreds of thousands of lines of computer code, which will most likely escalate into millions for larger BC platforms as the technology progresses. The increasing complexity of the Hyperledger BC programming language is illustrated in figure 4.5, where the green section represents the number of blank lines, the grey section the number of comment lines and the blue section the number of lines of software code. Furthermore, Steve McConnell, a programming guru, claims that people writing source code—the instructions that are compiled, inside a machine, into executable programs—make between 10 and 50 errors in every 1,000 lines. Careful checking at big software companies, he says, can push that down to 0.5 per 1,000 or so. But even this error rate implies thousands of bugs in a modern program, any one of which could offer the possibility of exploitation. *"The attackers only have to find one weakness",* McConnell says (The Economist, 2017).

Auditors' role in auditing of processes, and monitoring the reliability of the system pointed out by interviewee 5, and discussed in the previous section, is very relevant in this context as well since: *"You need to be able to trust the results of the programs and of the technology, be sure that the data is correct. [...] even if some mistakes happen, you cannot blame it on the technology, the individual auditors and the firm are ultimately liable for it"* (Interviewee 2). To minimise risks in an IT dominated audit environment, it is essential to make sure that the processes which are used to generate and process data are appropriate, since data received from clients will not be trustworthy—even those generated through the use of the latest technology—if the system generating them is not secure and consistent (Interviewee 3). Interviewee 3 further emphasises questions of the access to and the security of data—especially in the context of BDA and BC technology—which is in line with our discussion on data related risks inherent in the use of BDA and BC technology in chapter 3.3.2. Interviewee 1 sees understanding the setup and figuring out how to properly test these automated processes—especially in the context of risks relating to IT competence of current auditors discussed in chapters 3.3.2. and 4.5—as big challenges going forward. Moreover, interviewee 2 predicts that the process of making the technology advanced and reliable enough for widespread use in the audit industry will impose substantial capital requirements on auditors' clients, which could present a large issue for smaller and medium-sized firms, a perspective consistent with arguments raised by interviewee 4 in the discussion about the suitability of BC technology in audit from chapter 4.5.1.

On the other hand, interviewees claim that these risks need not be wholly negative, as there are benefits to be had in the same context. Namely, interviewee 5 argues that some of the risks mentioned above will be easier to mitigate as BDA and BC technology become more ubiquitous and advanced since: *"[...] today it is hard to mitigate these risks because there are many systems running in parallel, if everyone would use a system like BC—built on a common platform—it would be much easier".* This is due to the fact that in a BC system transactions are agreed upon by all relevant participants, since data on it is immutable: *"[...] akin to being carved in stone"* (PwC, 2017); and since there is an investigable trail of transactions embedded in the distributed ledger. According to interviewee 5, this means that it would be possible to identify dishonest participants quickly and easily, thus removing the risk of fraud to a high degree. Moreover, interviewee 4 lists techniques the use of which would be enabled by BDA and BC technology and which could prove effective at mitigating those risks, namely: Real time control; continuous monitoring, maintenance and checks; and regular updates to the system.

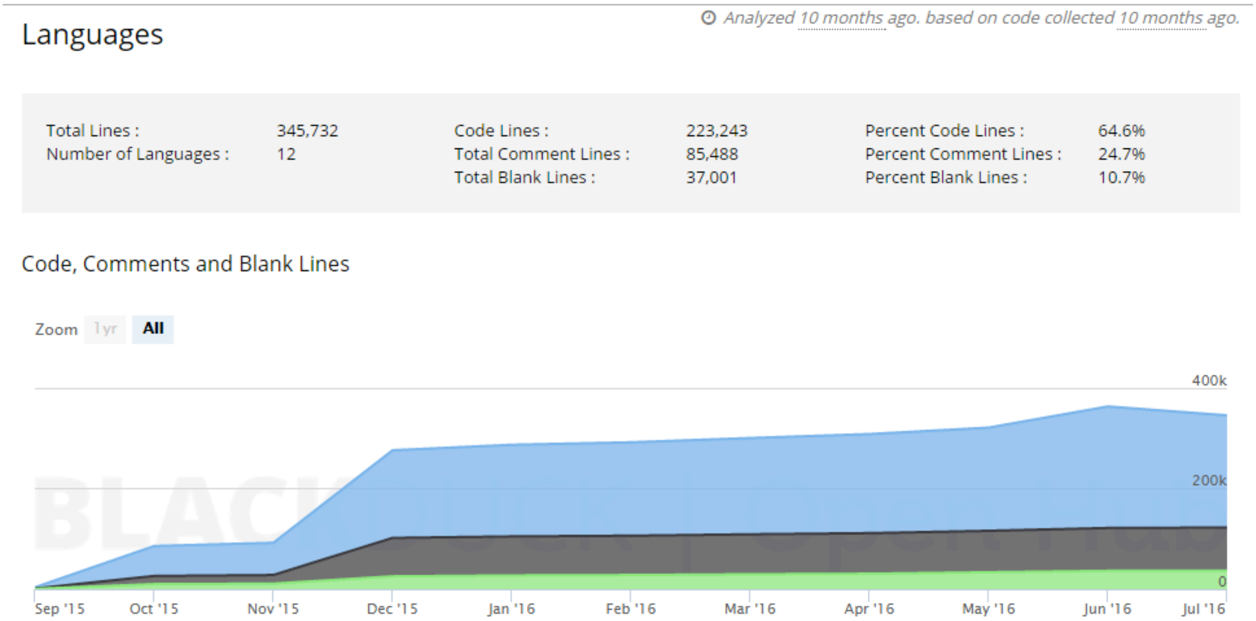


Figure 4.5: BC platforms are becoming more and more complex; Source: (https://www.openhub.net/p/hyperledger/analyses/latest/languages_summary)

Awareness of and the ability to handle risks

In chapter 3.3.2., we have discussed various skill-related risks stemming from the use of BDA and BC technology. Consequently, it is safe to assume that the issues outlined in chapter 3.3.2. represent significant causes for the inadequate level awareness of the implications and associated risks pertaining to the usage of advanced IT technologies in audit exhibited by today's audit professionals. Our empirical findings suggest a consensus among practitioners on this topic, with interviewee 4 noting that financial auditors are: *"[...] not really aware of any IT-related risks".* This can be attributed to technological ineptitude of audit professionals as well as to the segregation of duties between audit teams, where financial auditors accept the reports disseminated to them by the IT team as they are, often without understanding the underlying logic or the algorithms that were used to extract and transform the data. This view is corroborated by interviewees 4 and 5.

Another issue raised by our interviewees is the level of preparedness of clients' IT systems to handle advanced technologies. Interviewees 1,4 and 5 speak of two markedly different groups of clients. On the one hand, they identify sophisticated clients—usually funds or big banks—whose IT systems are, according to interviewee 5: *"[...] very well organised, with clean IT* *systems and clear processes. These clients provide us [auditors] with documents which are always of the same layout, which have been extracted from the system using a standardised procedure",* interviewee 1 further adds that these clients already use BDA to a large degree, and are ready to implement BC technology. On the other hand, interviewee 1 recognises that small and mid-sized clients—especially in the manufacturing sector—have not caught up with the digitisation, adding that implementing BC technology would represent a huge step for them. Interviewee 5 explains that: *"[...] there are clients who are not ready at all [for the technological changes]. [...] they manipulate the data they send manually, so it is quite random, you have different teams [...] applying different processes, extracting different formats of files".* As a corollary, it is safe to assume that these clients do not know how to properly setup their IT processes and are consequently likely to struggle as the technology further develops. It is likely that these companies will drag their feet and attempt to slow down the adoption of technologies such as BC on a wider scale. Interviewee 5 claims that this is made possible by a complex set of relationships between companies and different socio-economic and political factors which inhibit free-market forces—especially in the heavily bureaucratic EU area—thereby allowing these inefficient companies to stay in business.

As was mentioned in the previous chapter, Alles (2015) posits that the most likely driver of the use of advanced technologies by auditors is their use by audit firms' clients. Our view matches that of Alles (2015), moreover we argue that the potential collaboration between audit firms and technologically advanced clients could yield additional benefits for auditors. Namely, by gathering valuable insights from successful clients, audit firms would become better equipped to foster process standardisation and the implementation of advanced technologies in their own procedures. This would also enable them to offer better advice to their less technologically developed clients. Audit firms would thereby be managing future risks, since most of the benefits emanating from the enactment of BC technology and increased use of BDA would be negated in a scenario in which full standardisation of processes and higher levels of automation within audit firms is made impossible by a large gap in the level of sophistication of their clients' information systems.

4.7 Corporate Environment, recruitment and development strategies

The corporate environment and culture play a great role in enabling the audit staff to engage in improving the efficiency of current audit procedures and promoting the sharing of knowledge and experience with colleagues throughout the whole organisation. Notably in professional service firms (PSF) like the Big 4, employees are the most valuable and critical component in creating value for the company. Therefore, creating an environment which promotes knowledge creation and sharing among employees is crucial for the organisation (Løwendahl et al., 2001). Moreover, an innovative corporate environment can encourage the use of BDA and promote the support for new emerging technologies like the BC. Furthermore, recruitment and retention strategies of audit firms should focus more on IT skills of applicants, considering the increasing complexity of data and overall importance of technology (KPMG, 2017). This chapter will give an insight from the perspective of audit professionals regarding the role of the current organisational environment and employee recruitment and development strategies in supporting innovation and coping with the rise of emerging technologies.

4.7.1 Enabling Technological Innovation

At PwC where interviewee 1 is employed, the corporate culture promotes the entrepreneurial spirit of employees which fosters innovation regarding the: *"Automation of less demanding tasks"*. However, there are only informal incentives (e.g. appreciation of colleagues, feeling of competence) in place. Ryan and Deci (2000) assert that an increased feeling of competence, autonomy and relatedness caused in this case by a strong individual effort in engaging in innovative projects can foster intrinsic motivation, without any formal payment (e.g. monetary rewards). Innovation on a larger scale is at PwC coordinated regionally and globally through innovation hubs in the UK, India and the U.S., promoting knowledge sharing in a: *"[...] more informal way through the global intranet and global initiatives for e.g. data analytics"* (Interviewee 1). This sharing of knowledge and experience through a global informal tool can increase organisational knowledge creation, promote informal discussion within the audit and research teams and ultimately foster innovation (Nonaka, 1994).

At KPMG, interviewee 5 argues for a similar development strategy, proposing that KPMG set up: *"[...] departments, divisions, teams besides their regular organisation to focus on long term projects"* claiming that this is needed to promote new innovative approaches and tools for the audit profession. This assertion stems from the challenge that Big 4 companies face, namely overcoming high employee turnover, which comes with the negative effect that makes it: *"[...] hard to make people very committed to the firm and innovation if they leave after a few years. Corporate culture may need to change and firms would have to change the way they handle their employees, and the way they rely on the employees. The firms should focus more on long term employment, reward proactive behaviour and willingness to innovate and try new things"* (Interviewee 5).

Interviewees 2 and 3, who work in the banking and fund audit departments of KPMG, note that the IT teams they cooperate with are quite innovative in developing new procedures supported by tools which could potentially facilitate and speed up daily tasks. However, their main critique is that people are sometimes not aware that there are such tools, training in the proper use of those tools is inadequate and when the tools are introduced the users are confronted with the: *"[...] end-product without auditors being involved in the development and concept phase"* (Interviewee 3). Interviewee 2 sees the development of in-house tools and training as very important for auditors to help them to improve their IT skills without necessarily becoming experts, noting that the auditors should: *"[...] just get to an adequate level to be able to perform these daily tasks"*. Furthermore, Interviewee 4 emphasises that their IT teams have several tasks besides assisting the audit department, arguing that it would be more beneficial to have IT teams specialised in audit tasks so they could: *"[...] take-over or assist on very complicated engagements and train auditors to do it right, because currently they[auditors] are learning the techniques by themselves"*.

A positive example of an innovation enabling and knowledge sharing environment has been established in the corporate audit department at KPMG. Namely, the corporate audit department has introduced regular trainings on data analytics. An initiative by the Working Differently team introduced the: *"Morning refreshers enabling audit staff to share knowledge and train their colleges in an informal meeting within a small group of peers with the same level of experience and seniority"* (Interviewee 3). Furthermore, the management is encouraging the audit team to be more innovative in finding: *"[...] new ways of problem solving and promoting efficient thinking"* (Interviewee 3). Interviewee 3 further notes that they are actively supported and asked to: *"[...] update working papers and to contribute ideas in brainstorming sessions"*. The Working differently team is an initiative put in place by partners and managers in an attempt to promote different ways of working in the context of audit. However, this has as of today only been put in place in the corporate audit department.

4.7.2 Recruitment and Retention Strategies

At KPMG and PwC, a similarity regarding recruitment and retention strategies is a tendency to continuously hire large numbers of assistant auditors to compensate for the high employee turnover rates inherent in the business model of giving employees the possibility to become a partner in exchange for long working hours, poor work-life balance and payment (Interviewee 3). In the case of PwC, the majority of assistants are hired during promotional events and seminars which are held at Universities (Interviewee 1). The requirements are: *"[...] great business skills and it is important to understand both the technology and the context of the business"* (Interviewee 1). KPMG is recruiting future auditors mainly from business schools. However, according to interviewee 4, those recruits often do not have adequate: *"[...] accounting or IT skills"*. They are hired because there is a lack of seniors, which is in turn caused by the use of recruitment and retention strategies described previously in this section.

Interviewee 4 notes that this year's recruits' quality regarding IT e.g. Excel has dramatically decreased compared to previous years.

Interviewee 3 posits that the turnover among assistants is very high due to the fact that the tasks they generally perform are repetitive and not sufficiently cognitively challenging, wasting the skills and knowledge the assistants gain during their university studies. Interviewee 3 suggests that audit firms should be more transparent in informing graduates of what they should expect to experience while working in the audit industry, noting that: *"[...] if they knew what the job involves, the turnover would be much lower"*.

In pursuit of increasing the level of innovation in the audit field, Big 4 firms should take steps to improve their corporate environment and culture and their strategy regarding recruitment and retention of employees. In order to attract highly skilled IT people the: *"[...] working atmosphere and environment would need to change and financial incentives might help too but they are not crucial"* (Interviewee 2). Interviewee 5 notes that: *"KPMG struggles a lot to recruit IT people because they are more expensive than the audit people and it is difficult to convince the partners that they are necessary".* According to interviewee 5, who is an IT analyst, there is a risk that stems from a failure to invest sufficiently in IT employees. Despite the internal resistance to change an outdated model which has been utilised for years, changes: *"[...] will probably happen but it is a slow process"* (Interviewee 5).

A more practical suggestion made by interviewee 3 is to involve more auditors in the development process of new technologies for the audit, identifying the suitable individuals by screening the current staff for audit professionals with interests in and knowledge of IT, and contacting them directly. Interviewee 3 further argues that: *"[...] training everyone more in IT would be a waste of time and very costly; and KPMG still needs a huge number of traditional auditors"*. Consequently, interviewee 3 argues that this approach would get people: *"[...] more engaged and interested in their job and they would feel more motivated and valued"*. This is supported by Adams et al., (2006), who claim that a firm's success depends on its ability to identify, acquire and utilise knowledge. In contrast to that, interviewee 1 claims that for PwC it is: *"[...] sometimes better to hire external experts who know how to implement the more technical stuff in audit, then to offer costly trainings in-house"*.

Professional organisations like the ACCA (2016) perceive the recruitment and retention of qualified auditors as crucial for the survival of the audit profession in an environment shaped by technological innovations. Especially regarding the recruitment of IT-experts, as the competition for talent is tightening due to the increasing importance of technology for virtually every industry. IT experts are not only much costlier than financial auditors, they also need an environment that enables innovative knowledge creation and sharing, which stands in contrast to the highly regulated and formalised working environment in audit firms. Furthermore, going forward, clients are looking for great: *"[...] technological, communicational and critical thinking in their auditors, followed by closely by financial analytical skills"* (KPMG, 2017).

4.8 Role of Regulators and Legislators

Audit has always, understandably, been a heavily regulated profession. It is partly for that reason that the audit firms have generally erred on the side of caution regarding technological innovations, as was discussed in chapter 4.5. Professional regulatory bodies share this view, even more so since they are the ones who are to a large extent dictating the pace of innovation in the profession. At the present moment, the regulators are cognisant of the need to study the new technological trends in order to accommodate them in regulations so as to allow the profession to innovate and prosper. However, the regulators remain prudent in this context, arguing that without more information, wholesale change to the ISAs in the short-term may have unintended consequences in the form of inhibiting innovation due to the fast-paced nature of developments with BDA, BC and other technologies in the audit of financial statements. Prematurely commencing standard-setting activities, they claim, may very quickly render those standards obsolete and make them subject to continual reappraisal as the technological progress routinely outpaces regulatory efforts (IAASB, 2016). Therefore, they are calling for more academic studies examining the role that BDA and other technologies such as BC can play in enhancing audit quality, efforts this thesis aims at contributing to. With this in mind, we argue that there exists a need for a more collaborative relationship between the academia, practitioners and regulators in this area going forward.

Our empirical findings seem to support this stance, although interviewees fail to reach a consensus with some pointing out potential conflicts of interest in this scenario. Namely, interviewee 2 is of the opinion that—although auditors should be consulted by regulators—this should be done in a more informal manner, ultimately resulting in auditors having to comply with whatever regulations are formulated. Moreover, interviewee 2 sees advantages of a more cooperative relationship between regulators and audit firms, with an added caveat that audit firms and regulators often have competing interests—with auditors aiming for maximum efficiency in the audit process, and regulators for total reliability. Interviewee 3 shares this stance, citing that—in the case of BC technology—audit firms would at the same time be the examiners and clients of the BC system, emphasising the potential conflict of interests if the audit firms play a big role in formulating regulations. Interviewees 4 and 5 see regulators as having a bigger role in the world of BC networks, with interviewee 5 claiming that: *"If everyone was running BCs it may be cheaper for the regulators to themselves do some of the work the auditors do today, since the records would be agreed upon by everyone in the network and since regulators would have total and quick access to databases".* In the same vein, interviewee 4 adds that the regulators should put controls in place to monitor and assess the system, making sure that the companies are compliant with the rules. Interviewee 3 further notes the importance of the role that the regulators have to play in a world of permissioned BC networks regarding the permissions being given to market actors to participate in the network and access certain data.

On the other hand, interviewee 1 argues for a big role that the auditors should play in formulating new regulations, pointing out that: *"[...] we are seeing new threats and risks first hand and are in a good position to assess how new rules and regulations would affect the controls and processes put in place to handle those risks, so I think we have a big role to play".* Additionally, interviewee 1 highlights the fact that there is a way to work around much of the existing regulations by putting more efficient controls in place, which is in line with the arguments of Alles (2015) and the regulators themselves (IAASB, 2016) who point out that ISAs do not explicitly prohibit the use of advanced BDA techniques in audit, although they do not encourage it either. It is our view that these differences in perspective among our interviewees are caused by several contextual factors which have been discussed in chapter 4.5.1. Namely, working in a risk advisory department as opposed to a financial audit department entails different work assignments and different sets of regulations that have to be followed. These differences are further amplified through the positions being held by our interviewees, with interviewees 2,3 and 4 being assistants and interviewee 5 being a manager who may have a broader overall view. Finally, different educational backgrounds and variations in skillsets and prior professional experience may also play a role in influencing interviewees' views.

4.9 Creating Value and Trust

The interviewees agree that an increasing use of BDA and BC technology will in the long-term increase audit quality. The discovery of patterns through BDA can give insights to: *"[...] create a better tomorrow"* (Interviewee 1), in which value is created for the clients and shareholders by performing more precise, extensive and timely audit operations. The time saved by using BDA and BC technology can be put to better use to enable a deep and advanced testing of issues (Interviewee 2).

CEOs and CFOs are asking for more value adding services to be performed by their auditors enabled by: *"[...] capturing and exploring data interdependencies"* with advanced DA tools. Furthermore, they want the audit to provide them with insights and a forward-trending view on risks and data (KPMG, 2017). Dzuranin and Malaescu (2016) claim that auditors can help: *"[...] organisations meet compliance requirements and ensure that information systems add value to the organisation"*. Interviewee 3 agrees that through the implementation of BC technology the auditors would have more time to perform value adding services; however, further arguing that this should be done by the advisory department of KPMG. Moreover, interviewee 4 contends that: *"The first role of the auditor is not to create value for the client, it is about testing if the client follows the rules"*. An independence breach would be the consequence if the same auditors are performing the audit and: *"[...] selling advisory services to their clients"* (Interviewee 4).

Interviewees 3, 4 and 5 see a more indirect way to create value for the clients besides a higher audit quality. Namely, the clients could buy more value-adding advisory services from the audit firms using the funds saved due to lower audit fees which would be a consequence of the use of BDA and BC technology in standard audit.

Public trust can be increased through the implementation of immutable and timestamped distributed ledgers brought forth by the BC technology. These functions could potentially serve to prevent financial scandals e.g. Enron from happening again by increasing the transparency of the broader financial system and by providing more assurance of the work performed by the auditors (Interviewees 2 and 4).

5 Framework for Implementation

The following chapter aims to answer the second research question by presenting a theoretical framework which could be used by the audit firms to integrate BDA and BC technology into their future audit procedures. Firstly, the baseline framework by Dai and Vasarhelyi (2016) and the thought process behind the conceptualisation of the new theoretical framework are outlined. Secondly, the theoretical framework is described and constructed by incorporating BDA and BC into the framework of Dai and Vasarhelyi (2016). The most relevant results from the SLR and the CS are integrated into the framework to strengthen its theoretical and practical validity. Finally, challenges regarding data security and risk management are discussed.

5.1 Theoretical and Conceptual Background

The thought process behind the construction of the theoretical framework started off during the process of conducting the SLR, with the overall idea behind the framework developing as we were getting more knowledgeable about the focal topics of the thesis. This first phase was crucial for the identification of relevant practical implications and theoretical contributions in the subjects of BDA and BC technology. The results of the SLR have shown that there are several BDA concepts which are already in use in the audit firms; however, the BC technology has not yet been implemented, therefore BC-related papers referring directly to audit were few and far between to say the least. Through the SLR, the framework by Dai and Vasarhelyi (2016) has been identified as most relevant and suitable to be adapted for a future audit approach in which BDA and BC technology play a major role. The results of the SLR and the analysis of the empirical data have served to complement the original framework and were used to modify it to better fit the purpose of this study. The ultimate objective of this process being to integrate the aforementioned technologies into the audit context and support the proposed solutions with sound theory and practical insights. The result of this adaptation process will be presented in chapter 5.2. Furthermore, the first version of the new theoretical framework including BDA and BC technology was presented to Interviewee 1—a manager from PwC Malmö—in a follow-up interview. Interviewee 1 analysed the framework, suggested some minor modifications which could be made to it, commented that the framework is relevant overall and that the proposed solutions seem feasible from a standpoint of possible future implementation. Moreover, interviewee 1 requested permission to use the results of this paper for educational purposes among auditors at PwC Malmö.

Used in this way, the framework could help to raise awareness and the level of knowledge among audit professional relating to BDA and BC technology which have been identified in this study as relevant for the future of the industry. As a corollary, the catalytic and tactical authenticity of the thesis—discussed on chapter 2.3.4—have also been addressed. Finally, this constructive feedback we received from a senior practitioner has served to further strengthen the validity and credibility of our theoretical framework.

The subsequent part of this chapter will introduce and illustrate the framework of Dai and Vasarhelyi (2016) and describe the reasons why it was chosen to serve as a baseline for the adopted theoretical framework encompassing BDA and BC technology.

The original framework by Dai and Vasarhelyi (2016) aimed to: *"[...] imagineer the effects and usage of the technologies that encompass Industry 4.0 upon the audit process"*. The main implications of industry 4.0. are related to the implementation and smart usage of advanced technologies in the supply and value chain of manufacturers; namely, data collection, transmission and analysis. Furthermore, industry 4.0 is built upon the following six major principles: Interoperability, Virtualisation, Decentralisation, Real-Time Capability, Service Orientation, and Modularity (Hermann, Pentek and Otto, 2015). The data collected includes all movement and modifications of tangible and non-tangible assets generated: *"[...] in manufacturing and business processes that reflect machine health, product quality, surrounding environment, energy expense, labour cost, inventory location";* using e.g. GPS trackers and other sensors. The information collected is exchanged continuously between: *"[...] objects across entire companies, and even outside entities such as suppliers and customers"*. Moreover, DA is used to analyse and to monitor: *"[...] product quality, identify machine faults, save costs, and facilitate decision making"*. Furthermore, Dai and Vasarhelyi (2016) claim that industry 4.0 will have a significant effect on the audit profession by providing automated, near real-time, monitoring and collection of data; increasing the scope of audit and decreasing its timing; probably ultimately leading to improved audit quality. Audit 4.0 as illustrated by Dai and Vasarhelyi (2016) has an impact on the audit from the following four perspectives: standards, principles, technology, and auditors.

The use of continuous and near real-time data collection and monitoring of each object can be used to create a so called *“Mirror World”* of the physical world. This concept could give an outsider the impression of something revolutionary. However, this *"Mirror World"* could be understood as representing nothing else than the interconnection of databases and related networks into a common and standardised frame; facilitated and enabled through the use of advanced DA, tracking and sensor technologies. The result of this framework are interlinked organisations as presented in Figure 5.1, where transactions between different firms are collected, processed and exchanged. Moreover, audit firms can be granted access to the data flow, enabling them to audit and monitor continuously every transaction without third parties.

FIGURE 2
Basic Structure and Functions of Audit 4.0

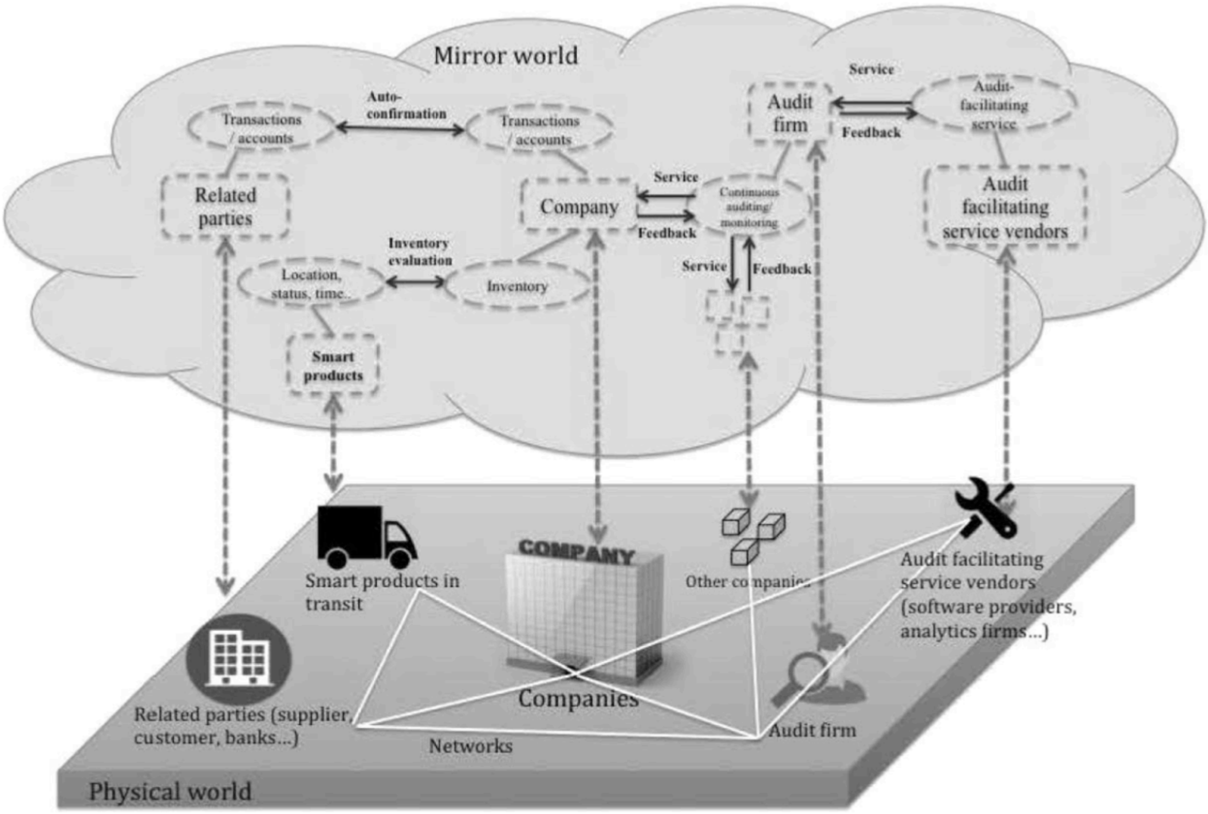


Figure 5.1: Interlinked Organisations; Source: Dai and Vasarhelyi (2016)

A model representing ways in which the aforementioned technologies, principles and standards can be used to make intra-business procedures and processes more effective and efficient is presented in Figure 5.2 (Dai and Vasarhelyi, 2016). Furthermore, in this model, the supervision of tasks by audit firms and other relevant institutions is facilitated.

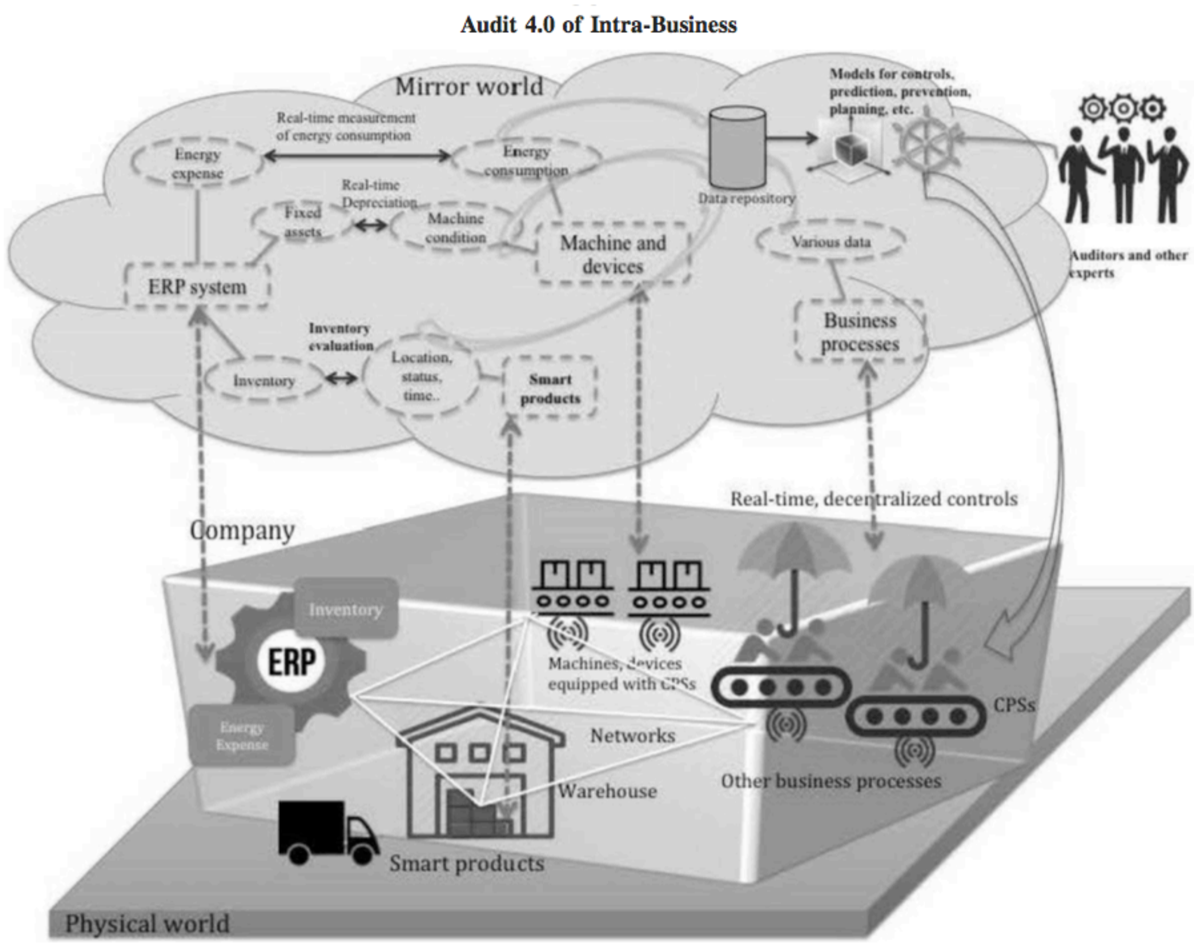


Figure 5.2: Intra-Business Model; Source: Dai and Vasarhelyi (2016)

Finally, Dai and Vasarhelyi (2016) are pointing out several challenges, regarding data security, standardisation of information and data, and the: *"[...] natural and accelerated evolution of the audit profession"*.

This framework of the *"Mirror World"* and the concept of Audit 4.0 have been identified during the SLR as the most fitting model to be used as a basis on which the adapted version of the theoretical framework enabling the use of BDA and BC technology in audit can be constructed. The benefits of this framework are that it incorporates the use of advanced technologies like BDA, real-time monitoring, the interconnection within a single business entity and the ability of organisations to become interlinked. This framework advocates solutions which contain very similar aspects to those of the BC technology, in which a single business is connected to the distributed ledger which links the said business with other participants in its own or other industries. Furthermore, BC technology enables timestamped and immutable records of every transaction, facilitating the work of auditors through increased reliability of audit evidence. However, BC technology depends—as do the solutions outlined in the original framework by Dai and Vasarhelyi—on further standardisations of work processes. Moreover, security concerns regarding data safety are the same for BDA, BC technology and for the concept of the *"Mirror World"*. All these similarities provide a valid framework on which the results of the SLR and CS regarding BDA and BC can be integrated, with the aim to create a new adapted theoretical framework, which is described in the following chapter 5.2.

Finally, different technologies and concepts underlying the BC technology will be elaborated in chapters 5.2.2, 5.2.3. and 5.2.4. The BC system used in the outlined theoretical framework is a permissioned distributed ledger, the technical and conceptual foundation of which has been adapted based on the platform developed by Digital Asset Holdings (Digital Asset, 2016). The collection and interconnection of huge amounts of data call for the adoption of advanced BDA tools that can help the auditors to utilise the available information in the best possible way. Furthermore, Smart Contract technology, as presented in Appendix H and chapters 5.2.2 and 5.2.3., is an important element of this system since it embodies much of the benefits stemming from the use of BC technology in the context of audit.

5.2 Framework for implementation of the BC and BDA in audit

5.2.1 Evolution of Auditing

Traditional manual audits have existed for centuries, fulfilling many needs. Despite the fact that the IT audit emerged in the 1970s, and that almost all businesses today are computer-based, only about 15 percent of auditors are IT enabled (Protiviti 2015), a result in line with our empirical findings. This delay of IT adoption—discussed in detail in earlier chapters—can partly be attributed to the inherent conservatism of the audit profession itself, as well as the occasional innovation-inhibiting effects of professional regulation, but also to the general lack of quality tools that would allow traditional auditors—those with limited general IT and data analytics knowledge—to automate the functions that they currently perform manually (Brown-Liburd, Issa, and Lombardi, 2015). The key characteristics of different audit generations, as described by Dai and Vasarhelyi (2016), are presented in Table 4.1.

It is arguable that this new version of audit will emerge much faster than the previous generations, as it may be impossible to assure modern data-intensive, integrated systems with the tools of the past. Anachronistic regulation, where for example a population of millions of transactions is examined with a sample of 70 transactions, may contribute to delays that reduce the efficiency of the audit process and the relevance of external assurance. Higher adoption of BDA and BC technology will significantly change the audit profession by automating current procedures, enlarging their scope, shortening timing, and eventually improve the overall assurance quality.

This section illustrates the impacts of these new technologies on the audit profession from four perspectives: Standards, principles, technology and auditors (Dai and Vasarhelyi, 2016). Furthermore, illustrations of different relevant aspects of the proposed framework are presented in Figures 5.3, 5.4, 5.5, 5.6 and 5.7.

5.2.2 Standards

In preceding chapters, we have discussed challenges that the audit firms are facing regarding the regulatory environment which is at present hardly conducive to greater use of technology in audit, in the case of BDA, and even less so in the case of BC technology. In chapter 4.8., we argued for a more collaborative relationship between academics, regulators and practitioners in this sense—a view generally supported by our interviewees—admittedly with a slight dose of restraint in some cases and with several caveats which were described in detail in the said chapter. The world of BC brings with it an important feature known as smart contracts–programmable contracts that automatically execute when pre-defined conditions are met (Capgemini, 2016). They allow agreements to be written in code and be executed automatically by the network. Some proponents of the technology argue for an approach in which the smart contract code is immutable, meaning that every outcome of the code necessarily represents the intentions of the involved parties. This approach thereby negates the possibility of disputing the outcome through existing legal systems. In a system we are proposing, the code would be subservient to legal systems in all jurisdictions, market rules and professional audit regulation, thus delivering the benefit of automated workflows while ensuring the legal and regulatory certainty of the contracts (For an illustration of the Smart Contract technology see Appendix H).

It is our view that the current standard setting procedures will prove to be inadequate in a world of self-executing contracts and increased automation of business and audit processes which were discussed earlier in this thesis. Formalisation of audit standards was discussed by Krahel (2012), who argues that most standards should be programmed into software as their implementation in modern systems tends to be done by computers, a practice which will be even more common as BDA algorithms become more automated and BC technology takes hold. The ambiguity in current auditing standards—noted by the regulators themselves: *"The ISAs do not prohibit, nor stimulate, the use of data analytics"* (IAASB, 2016)—should be replaced by a formalised representation which would allow for near real-time assurance. If ubiquitous usage of BC technology by clients of the audit firms becomes a reality, assurance will be largely dominated by formal inter-network protocols and the objective functions of the interlinked permissioned BCs. Standards should be programmed into the BC mainframe and supporting algorithms to enable real-time measurement, reconciliation, processing and transmission of financial information.

In the previous chapters we have discussed benefits in terms of cost and time efficiency stemming from the use of BDA and BC technology in audit. This view is corroborated by both the theoretical and the empirical research we have conducted. These gains, enjoyed by audit firms as well as their clients, would be mutually supportive. Namely, accountants at the clients' premises would be able to formulate more accurate financial statements thanks to the possibility of proper allocation of many items which were in the past incorrectly allocated as overhead due to inadequate measurement systems. Consequently, the job of auditors would become much more time and cost efficient. In line with the arguments brought forth by our interviewees in chapter 4.5.1, increased reliability of financial statements enabled through the use of BDA and BC technology could greatly reduce, or even eliminate, auditors' effort in terms of conducting vis-à-vis physical observation and collection of documentation, additionally providing precise—and agreed upon by relevant parties—performance and risk information in near real-time.

5.2.3 Principles

Industry 4.0 consists of six main technological principles, namely: Interoperability, virtualisation, decentralisation, real-time capability, service orientation and modularity (Hermann, Pentek and Otto, 2015). As they will increasingly drive the businesses of their clients, the audit firms should also adopt these principles in order to increase data availability, enable continuous data validation and monitoring and increase the rate of automation of audit procedures (Dai and Vasarhelyi, 2016).

Interoperability

BDA and BC technology advocates—especially through inter-industry collaborative efforts such as the Hyperledger project—aim at achieving total interoperability between different BC networks, which would lead to reconciliation of transactions and assurance becoming cost-efficient and near frictionless. Through communication and interoperation, business models could become more intelligent and informative, achieving a higher level of optimisation in the process.

As the level of interoperability among market participants increases, it impacts the currently prevailing business model. Owing to the very nature of the audit business, and the connections with other business entities it entails, the increased interoperability in the wider market could have further impact on the audit profession as well. In future audit, interoperation among suppliers, customers, banks, BC vendors, regulators and other business entities could enable near real-time examination of transaction-level occurrences and completeness assertions (Dai and Vasarhelyi, 2016) (For an illustration of the functioning of a permissioned BC system on a single-transaction level, see Appendix J). Communication across different business entities would be enabled through secure BC networks. If a transaction involving two business entities operating in different BC networks takes place, the fact that they are built on a common mainframe would enable the two BC networks to share the related accounting information quickly and securely with the use of end-to-end encryption, allowing only the concerned parties to access the data with the use of private cryptographic keys. This data exchange can even be automated with the use of smart contracts. The parties would receive the information, match it with the corresponding data in their private database, and issue warnings if they cannot be matched. The warnings would be issued through a network-wide, shared log of commitments and notifications that guarantees the integrity and auditability of data transfers. One of the primary functions of a shared log in a permissioned BC network is to serve as an assured notification mechanism, notifying any entity affected by the exchange of or a change in data. Such level of interoperation could automate the examination of transactions and pinpoint anomalies which could be further investigated by auditors.

As was discussed at length in chapters related to regulation in the audit industry, the regulators are typically wary of approving the use of radical new technologies as the technologies implemented by financial institutions must undergo extensive review since they—once deployed—can remain in use for many years. Extensibility is one of the most important aspects of these technologies, given that they need to stand the test of time, must not be functionally limited in the services they can offer, different businesses and markets they can support and must be able to handle a large future expansion in terms of the number of users and the volume of transactions without suffering performance degradation. Therefore, it is our view that a platform introduced to replace existing legacy software must allow for the consolidation of technologies, and foster market forces by enabling formation of new business models, if it is to be financially viable and widely adopted. Furthermore, formalisation of standards and standardisation of procedures should be encouraged, as that would drive interoperability across different BC platforms and hence drive adoption of BC technology overall.

Virtualisation

BC technology has the potential to enable companies to integrate all of their data in a standardised and safe way, thus making the information about their business sharable and integrated, easily searchable, explorable, analysable and auditable. A BC would thereby represent a virtual copy of the every-day business reality of the firm, including all business objects and their inter-relations and activities. In such a scenario, each piece of data belonging to the firm is uniquely identifiable; information about it being continuously updated, verified through the consensus protocol in the BC network and transmitted to related parties. Management of audit firms' clients could thus detect problems and bottlenecks in real time through virtual process monitoring, making the job of auditors easier in the process. Furthermore, our empirical findings suggest that, in the future, audit firms will increasingly focus on auditing processes and validating the entire system, a view supported by the literature, with Krahel and Titera (2015) positing that when data are available on a continuous basis, and in large volume and various kinds, the processes generating those data must be continuously assured. Additionally, information stored on the BC could dramatically reduce auditors' fieldwork and serve as an independent third party to facilitate accounting information evaluation, a perspective shared by our interviewees, as was described in chapter 4.5.1. As all relevant "things" in a business process will be virtualised and have representations on the BC, auditors could perform most of the onsite examination remotely and continuously. BCs could also be used to link nonfinancial processes to the accounting records providing sequential integrity assurance (Dai and Vasarhelyi, 2016) (See Figure 5.3).

Decentralisation

The business environment is becoming increasingly complex and dynamic, which in many cases necessitates higher levels of decentralisation than was the case in the past. Some examples of this decentralisation are the use of off-site cloud computing storage and outsourcing of certain parts of the business process to other divisions of the same company or third parties. As their clients become more decentralised, the trend will likely extend to the auditing profession as well. With the use of BC technology, all of the relevant business and accounting data of the clients could be stored in a secure, immutable and easily accessible shared network running on advanced algorithms and self-executing smart contracts. Such systems could, in time, become able to adjust thresholds on their own based on the changing environment and inputs from auditors, and submit failures and complex decisions to auditors for further investigation (Dai and Vasarhelyi, 2016). These systems would be substantive enhancements towards the continuous audit (CA) process envisaged by Vasarhelyi and Halper (1991) which aims to: "*Provide assurance simultaneously with, or a short period of time after, the occurrence of events underlying the subject matter"* (CICA/AICPA, 1999).

Real-Time Capability

Vasarhelyi and Halper (1991) argued for "audit by exception" where metrics would measure systems, standards would serve as benchmarks and analytics would encompass the guiding issuing alarms to trigger actual audits. Audit enhanced by the use of BDA and BC technology could potentially broaden these concepts to have diagnostics activated and run through self-correcting data algorithms (Kogan et al. 2014). Furthermore, Issa and Kogan (2013) highlighted the potential of modern BDA techniques to significantly reduce the number of false positives in an audit process through more accurate identifications of true exceptions and better systems of prioritisation, as was discussed previously in chapter 3.3.1. A successful real-life example of a CA system is an efficient model that enables real-time controls monitoring, developed and implemented by Siemens Corporation (Alles et al., 2006). It analyses control settings and provides real-time identification of high-risk transactions that exceed expected limits and established parameters. Through a system of inter-connected BC networks, this model could be applied much more broadly. Increased efficiency of businesses and improvements in their internal accounting practices would, in turn, bring benefits to the audit profession as well in a way that was discussed in chapter 5.2.2. Further example of such systems represents a model built by Kim and Vasarhelyi (2012). The purpose of the model is to continuously detect fraudulent transactions in the wire transfer payment process. By examining each transaction with predefined fraud indicators and estimating overall fraud risk automatically, the model can identify potential fraud immediately and alert auditors who could then perform further investigation (Dai and Vasarhelyi, 2016).

Service orientation

The audit profession could adopt the service-oriented architecture to facilitate cooperation between auditors and providers of related services. BDA is a useful and powerful technology that has been acknowledged by the audit profession but, as we have discussed at length in previous chapters, its use in audit is at an almost rudimentary level, especially in financial audit. Analysis in chapters 3.3.2. and 4 confirms that academics, regulators and practitioners—including the ones we have interviewed for the purpose of this study—are in agreement over some of the reasons behind this low level of adoption of BDA techniques in audit, citing inherent complexity of those techniques—which in most cases requires understanding that is beyond auditors' current level of IT knowledge—as the main reason. To circumvent this obstacle, audit firms have resorted to forming data analytics teams—such as KPMG's ETL (extract, transform, load) team described by our interviewees—which cooperate with auditors and currently perform most of the data analytics assignments. In the future, when BC and other data-intensive technologies reach higher levels of adoption among audit firms' clients, and as data analytics algorithms become more complex, the auditors could outsource the workload to professional data analytics companies or analytics software providers.

Through the use of IT experts' services, auditors could free themselves from data analytics work and focus on essential decisions regarding assurance. In a similar vein, audit software service could become BC enabled. Instead of selling audit software to individual audit firms or companies, the providers could embed their software in a secure BC network and charge based on usage. This service-oriented model reduces both the upfront cost of audit software and later maintenance expenses, making the technology more financially viable in the long-term. An important caveat is that a failure to secure close cooperation between auditors and software service providers may result in auditors using the provided data without understanding the underlying logic of the algorithms applied, which would consequently lead to suboptimal decision-making, an issue raised by our interviewees and discussed in chapter 4.5.1.

Modularity

Modularity is one of the key features of BC networks. Since different vendors may supply the BC systems to firms from different industries, operating in different jurisdictions, those different networks may need to deploy slightly different frameworks and consensus algorithms to fit their usage scenarios. Consequently, the BC mainframe needs to run on algorithms which are modular, possible to apply in different versions depending on specific customer needs.

Looking further, Vasarhelyi et al. (2011) imagined how modularity could enable auditors to perform the audit efficiently, in a flexible manner. They suggested using audit apps in a modular fashion, assembling them together to perform complete analytics procedures. Audit apps represent a set of formalised analytical routines that can be performed by computerised tools (Vasarhelyi et al., 2011). In this scenario, each audit app performs a single analytics-based audit test. Auditors are able to choose and deploy apps appropriate in a certain context based on the individual audit plan and auditing by exceptions which was discussed in the previous sections. A new set of apps would be chosen and used for different clients, based on clients' specific risks, capabilities, business environment and the competencies of auditors working on a particular case (Vasarhelyi et al., 2011). These modular characteristics of BC networks and audit apps could be harnessed in tandem and potentially lead to more efficient, better quality audits.

5.2.4 Technology

Technologies, such as BDA can be integrated through BC networks to support the next generation of auditing. The acquisition of accounting data is increasingly becoming automated (Alles and Issa 2013). Interoperable BC networks could hasten data acquisition to a near real-time level. Moreover, the scope of data being collected, processed and analysed could be expanded dramatically with the use of advanced BDA tools. With BC infrastructure already in place, sophisticated sorting algorithms could be used to capture accounting data throughout the business process with small extra cost. Using this strategy, auditors could obtain real-time accounting information that reflects current performance, such as quantity and quality of inventory, working hours of employees, energy consumption etc., and discover system faults in time (Dai and Vasarhelyi, 2016). A BC system that is, in our view, suitable to enable these developments is the permissioned BC system. In this scenario, its adoption by the audit firms' clients would precede and drive its use in the audit profession, a process which has been envisioned by both academics and interviewed practitioners alike and has been discussed in detail in earlier chapters.

A permissioned BC system is designed to maintain the same confidentiality guarantee as physically segregated ledgers but also to allow for the same data integrity assurances of typical, "proof-of-work" BC solutions. This is achieved by the participants involved physically segregating and storing locally confidential information, and sharing a globally replicated log of only "hashes" of the sensitive data and execution commitments. These "hashes" are one-way cryptographic functions which can be proven to accurately match a participant's data but do not contain any information about the confidential data itself nor the parties involved. A "hash" is a unique cryptographic key, akin to a digital fingerprint, given to each file or transaction in the BC. The distributed ledger in a permissioned BC system is accessible (for reading or for writing) only to known and pre-approved parties, hence the name "permissioned". The distributed ledger in this system is comprised of two subcomponents: the shared log of commitments and notifications (SLCN) and the private store of confidential data (PSCD) (See Appendix G, Figure 5.6).

Each participant in the network has its own PSCD, which contains a historical log of all contracts and other transactions pertaining to a participant that owns it. An important security feature of this system is that data from a PSCD must be paired with corresponding active evidences in the SLCN. SLCN serves to guarantee the integrity and auditability of the distributed data stores to participants of the network. SLCN establishes a common and complete set of valid transactions that, when combined with corresponding private data stored in the PSCD, comprises the distributed ledger (For illustrations see Figures 5.4 and 5.6). A permissioned BC system has a significant advantage over legacy systems in use today in terms of privacy of data. Namely, the current process of determining which parties are entitled to view which data is typically manual and error-prone. In contrast, permissioned BC systems automatically identify relevant stakeholders based on data in their PSCD and SLCN. Furthermore, network-wide rules—encoded in the BC mainframe—are shared with all network participants, but the actions taken by the participants are private.

In a permissioned BC system, unlike in BC's more decentralised versions, it is not required for every pertinent party to a transaction to approve each ledger update or acknowledge that they have been notified, unless their consent is explicitly required. This function serves to increase the robustness of the system since it ensures that if one participant fails to approve a ledger update due to unforeseen circumstances, e.g. a power or system outage, the business process will not be brought to a standstill. It also allows to avoid interdependency of one participant's service on another's availability. Furthermore, the streamlined consensus mechanism in a permissioned BC system enables the network to achieve higher levels of performance and speed of transaction processing by simply limiting what the network is actually trying to manage. This can additionally be a boon for scalability, an important issue since the viability of BC technology in audit, and in general, largely relies on its wide cross-industry adoption.

In a permissioned BC network there are two primary roles, that of operator and participant. An operator has network-wide responsibilities such as maintaining the SLCN, creating and distributing network rules and validating a superset of data in the network. A participant is an entity which has been granted permission to join the network by the operator, or operators, of the network. A participant is also granted permission to control and maintain its own data within the network. This includes reading and validating rights for all the transactions it is a part of, the right to validate updates to the distributed ledger and the right to locally store its private data and the shared information from the SLCN. Participants can see and validate their transactions evidenced on the SLCN by verifying both the transaction and their own signatures. The system allows parties to play multiple roles.

In addition to the two primary roles, there is a specialised type of participants whose role is to verify and provide assurance about events and notifications in the network. This role can be played by regulators, auditors and other similar bodies. This mechanism, in our view, makes permissioned BC systems especially suitable for the audit context, reinforcing numerous other arguments for their use that have been outlined in this study.

Many opponents of the permissioned BC system state that the gains from this, partly centralised, type of a BC network do not bring significant change compared to current, less capital and knowledge intensive solutions. They claim that the centralised structure of permissioned BC networks undermines the immutability of records and the overall reliability of the system, both major features of BC technology overall. However, in a system that we see as suitable for the financial system in general and the audit profession in particular, even though network participants cannot prevent fraud or error on the part of the operator outright, the validity and reliability of the network are preserved thanks to participants' ability to independently detect fraud or error through authorising and authenticating their own transactions and validating the distributed ledger. This further allows participants to rely on the distributed ledger for their own internal books and records, thus eliminating reconciliation requirements against other participants and indirectly making the subsequent audit process easier and more efficient, as was discussed in previous chapters.

Understandably, not all audit firms' clients would be willing—or able for various reasons—to invest in BC technology and sophisticated BDA capacities. This is especially the case for small and medium-sized enterprises (SME) in the manufacturing sector, as was identified both in our theoretical and empirical analysis. The power of permissioned BC networks lies in their adaptability and flexibility, which has already been illustrated through various examples. An additional feature to this end is the possibility of entities becoming indirect participants who would be able interact with the BC network through existing messaging protocols without having to read the SLCN, and would maintain their own private records. For the indirect participants to interface with the BC network they need to delegate the effectuation of their actions to a participant of the network. This can be done with the network operator, much like firms do today with clearing houses, or through a regular participant that offers network access as a service. Indirect participants can become regular network participants at a time of their choosing.

In summary, a permissioned BC system in tandem with the use of BDA tools, offers numerous benefits including continuous data integrity, increased transparency, standardisation of data in terms of type and format as well as generation, collection, reconciliation and analysis processes which could ultimately have positive effects for auditors. These effects would make the audits easier and more efficient, thereby freeing up auditors' time and enabling them to perform more activities that add value than is the case today (For an illustration see Figure 5.7).

5.2.5 Auditors

In a world of intense automation and process scrutiny, the required skillset of auditors is poised to change dramatically. In earlier chapters we have outlined the views of academics, practitioners and regulators who are in agreement of this issue. Our empirical findings suggest that the prevailing opinion among audit professionals is that of the necessity of improvement in auditors' technical skills going forward, emphasising on-the-job learning and internal training programs. Additionally, considering the importance of audit, accounting and finance-related skills—even in the largely automated audit profession of the future—we argue that the new advanced IT processes should be user-friendly and developed with insufficiently trained users in mind. For example, a "super-app" developed by Byrnes (2015) aims at supplementing auditors' usage of clustering techniques. In addition to performing clusterisation, this tool applies statistical knowledge to complement the statistical knowledge of the auditor, which is especially important since—according to our empirical data—auditors today generally struggle to grasp statistical concepts relating to large datasets, most notably confidence intervals. With the increased level of adoption of BDA and BC technology, the business world is moving toward a highly automated, highly flexible and highly interconnected environment, with real-time capabilities of fault detection, prediction and decision-making (Dai and Vasarhelyi, 2016). The audit profession should embrace these changes, adapt to them and leverage the emerging technology to enlarge the scope of auditing, shorten timing, improve accuracy of measurements and inspections and ultimately enhance the assurance level it can offer to its clients.

Blockchain technology

Achieving a high degree of inter-connectedness among companies in the business world through compatible BC networks would allow for data collection, processing, storage and transmission on a level necessary to create a virtual representation of the physical world, running on a global network of distributed ledgers. In this scenario, data about each object in the physical world would be stored on the BC, with information about its conditions, location, surrounding environment, history etc. updated on a continuous basis, according to the consensus mechanism among the participants of different BC networks. BC networks could be established through interoperable, technologically compatible clouds, which would ultimately serve as a trusted third party in the process of auditing transactions between participants. Using data from various sources, a BC network could enable automatic confirmation between related business entities, automation of inventory and cash balance evaluation, real-time energy measurement and management, real-time faults and irregularity detection, remote continuous auditing and monitoring, and remote audit-facilitating service (Dai and Vasarhelyi, 2016). Figure 5.3 visualises the basic structure and functions in this scenario.

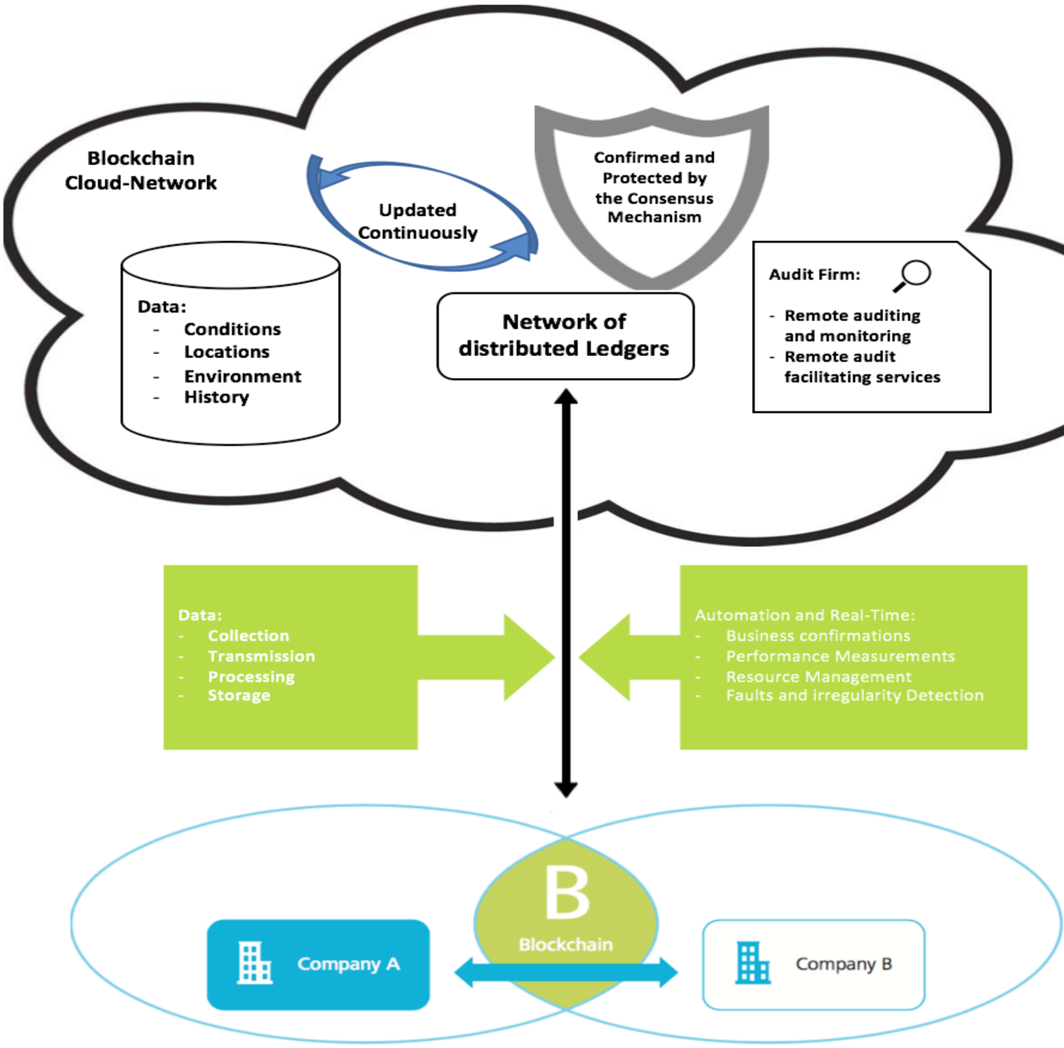


Figure 5.3: Basic Structure and Function of a Blockchain enabled Network

Interlinked Organisations

BC technology could allow the audit of the future to automate the confirmation process by facilitating connections between related business entities (Figure 5.4). Confirmations are a type of evidence held in high regard but they have historically been costly and/or difficult to obtain for auditors. Future audit has the tools at its disposal with the potential to minimise these costs by autonomously matching related accounts and transaction records from different parties through the BC system, these tools would issue alerts intended for concerned entities if the information cannot be matched (Figure 5.5). Furthermore, in a permissioned BC network, organisations would be able to autonomously store their confidential information while still retaining a shared log of commitments and notifications that guarantees the integrity and auditability of data transfers, which was discussed earlier in this chapter (For details see Appendix G, Figure 5.6). BC technology could enable a new model that would automatically collect confirmation evidence. Relating accounting information (receivables and corresponding payables, cash account and bank balance) from audit firms' clients could thus be easily located on the BC and matched. Such near-instantaneous confirmation could provide real-time, reliable, on-demand verification at both the transaction and account levels through the collaboration between clients themselves, clients and auditors and all the participants in the BC network with the operator of the network. This level of confirmation would serve to further verify the accuracy of accounting records of all the participants in the BC network.

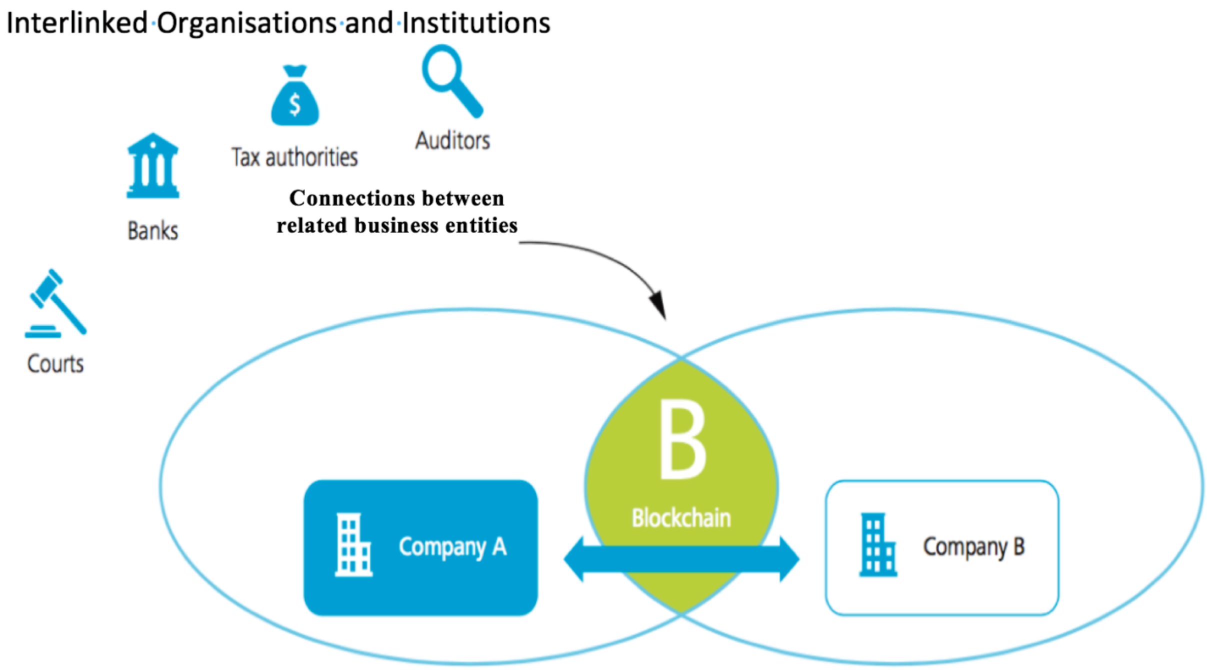


Figure 5.4: Organisation and Institutions interlinked via Blockchain Technology

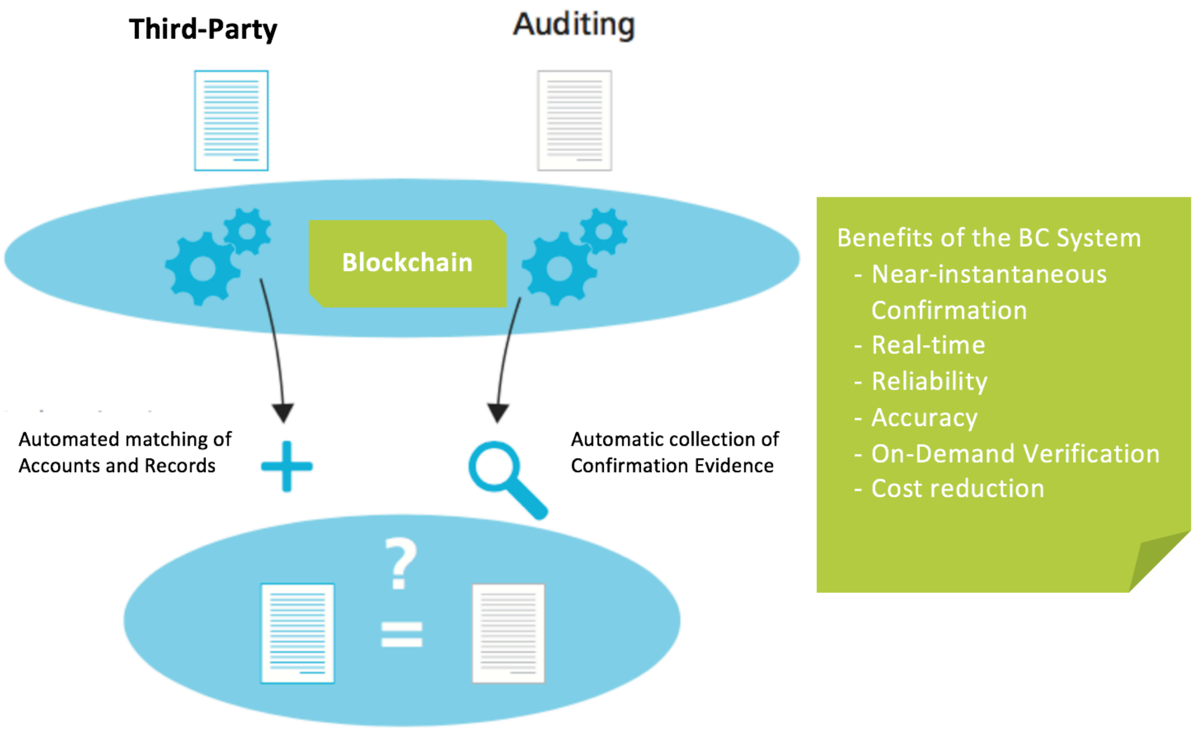


Figure 5.5: Automation of Third Party Confirmations

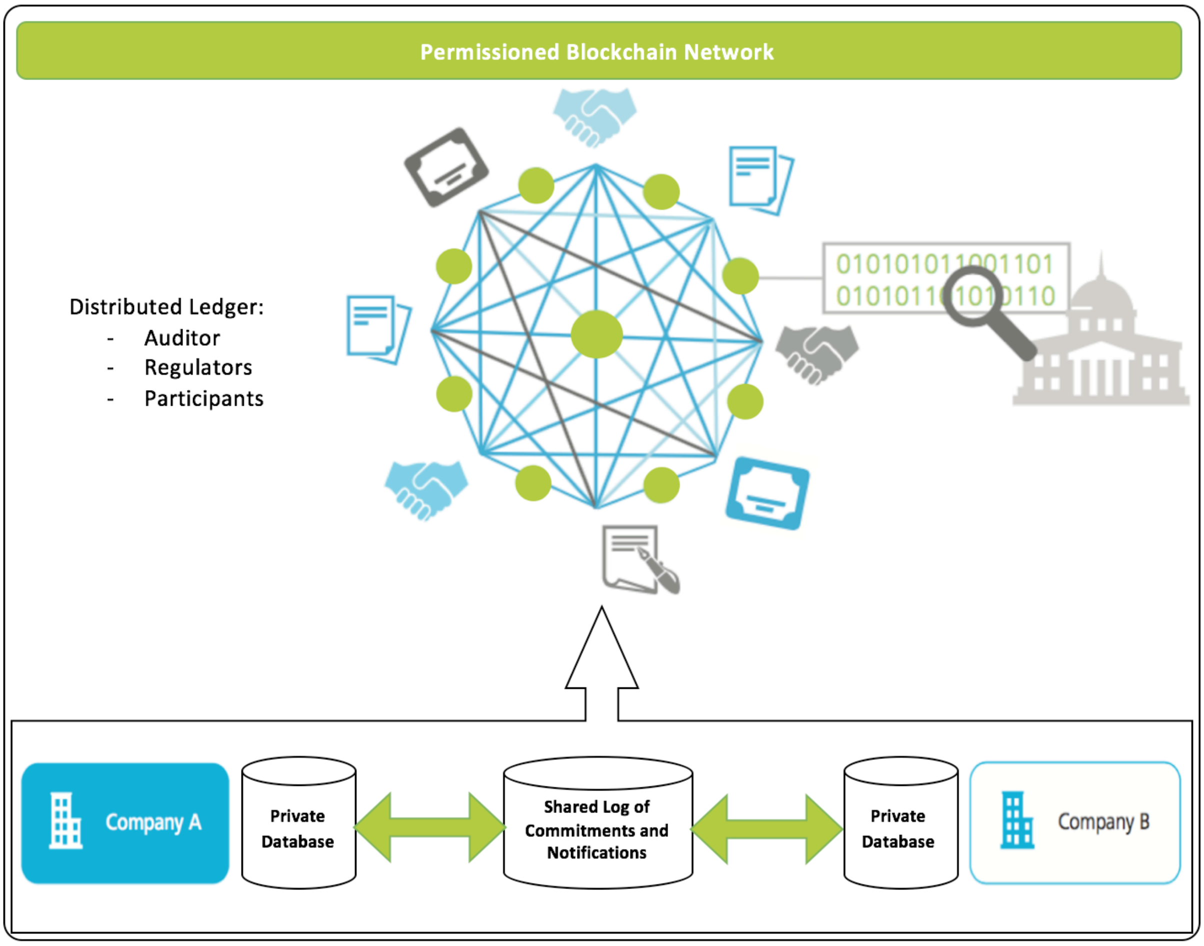


Figure 5.6: Permissioned Blockchain Network

Connecting the BC and the Real World

Figure 5.7 shows how an audit firm in the future could provide comprehensive assurance to a client by gathering and analysing accounting and other business-related data. The data would continually be added and confirmed on the BC, and those data would reflect the current status and performance of any participant in the network. Additionally, business processes could be monitored against predetermined rules to detect violations of key controls, and cross-verified via certain continuity equations (Kogan et al., 2014). With the use of BC technology, real-time data from the entire organisation could be integrated onto a secure data repository. Auditors and other experts could then create BDA models on top of the data repository in order to continuously detect anomalies, discover system faults, identify control inefficiencies and manage resources. Once an anomaly or fault occurs, the models could send an alert to auditors or management, who would promptly take action if needed (Dai and Vasarhelyi, 2016).

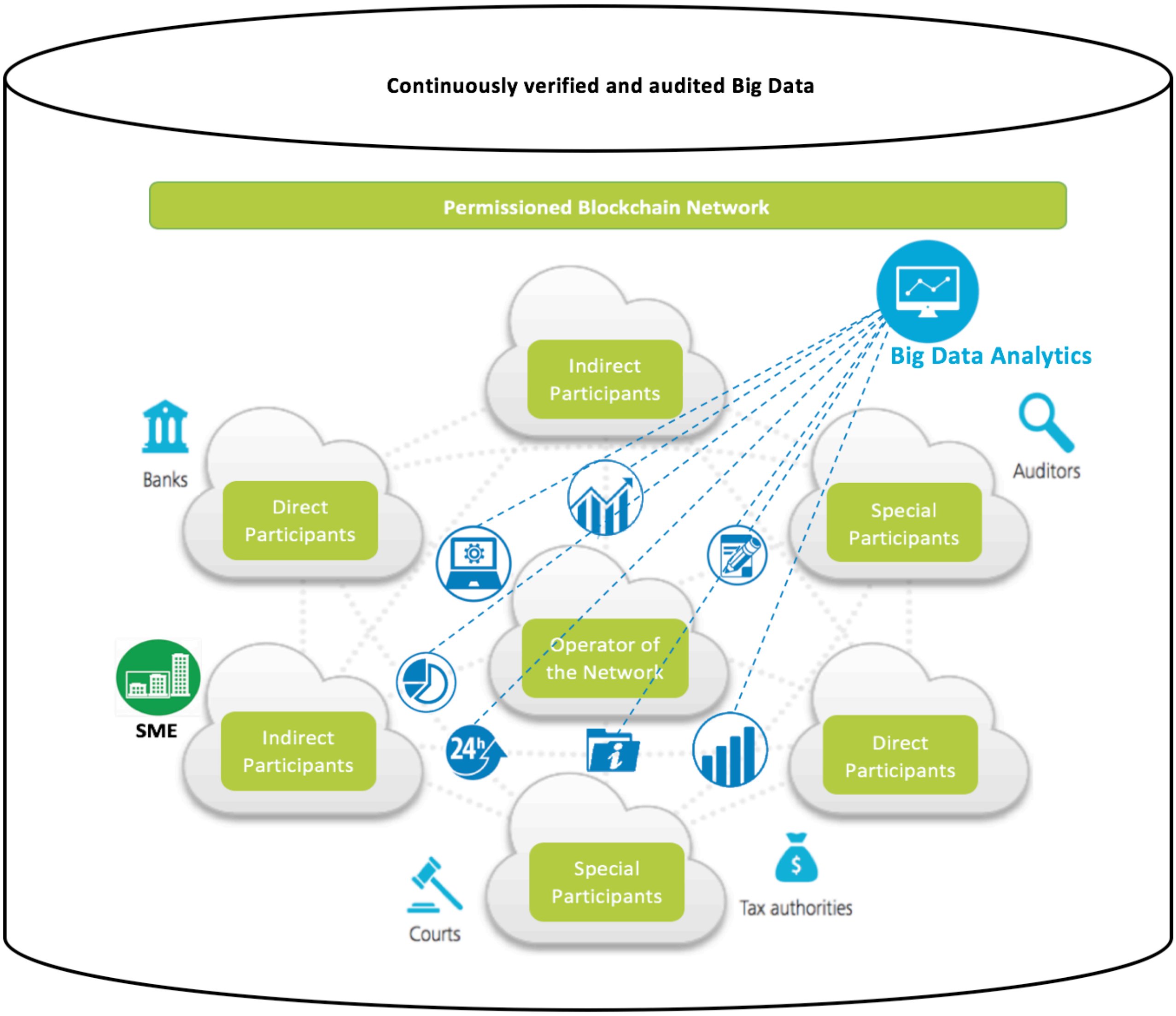


Figure 5.7: BDA and the BC working in harmony to enhance audit quality and efficiency

5.2.6 Challenges

Digital crime

Technology has been developed to facilitate and enhance a wide spectrum of human activities, but in parallel with these benefits, it also allows for a certain level of its dysfunctional use (Dai and Vasarhelyi, 2016).

Shared access to certain portions of datasets opens the door to unauthorised use, no matter how strong the encryption is. This is perhaps the most pressing issue relating to BC technology. These concerns have been confirmed in our empirical study conducted among audit practitioners. A highly integrated BC system with an online audit layer can be a boon for businesses but can also be breached and subsequently used e.g. as an overbearing system of spying by a totalitarian regime; to gain unfair market advantage or to misappropriate assets or valuable data by different criminal actors (Dai and Vasarhelyi, 2016). Of particular concern in this context is the issue of cybersecurity, as the power of technology can be used to potentially steal massive amounts of information, if the cryptographic protection is broken, without obvious traces. Despite considerable efforts in the BC community to raise the level of security, the question of cybersecurity is admittedly still very pressing and will probably continue to be so in the near future.

Security and Privacy Issues relating to Companies' Data

As was discussed in detail in the previous chapters of this thesis—and confirmed by both theoretical and empirical research we have conducted—certain aspects of the emerging technologies, higher levels of integration of data and inter-connectedness among market participants can pose a significant threat to the security and privacy of organisations' information. For example, as firms upload their data to the BC, their accounting information as well as clients' sensitive data could be exposed to an environment the safety of which is inadequate. Besides, the increasing frequency of communication between different business parties and the sharing of financial information enhance the probability of a data breach. To avoid potential damage and reputation loss due to security and privacy flaws, companies and audit firms should create strict policies to keep the data secure and private. Some effective approaches include encrypting sensitive information before disseminating it across the network, using secure channels to communicate with other entities, and hiring professionals to install secure products, detect and respond to attacks, and evaluate security and privacy risks over time (Dai and Vasarhelyi, 2016).

Standardisation of Information and Data

Developing uniform data standards is vital for the long-term success and sustainability of the technology-driven business model we have argued for in this thesis. This view is strongly supported by the theoretical and empirical research we have conducted. In a BD environment, information can originate from a variety of sources, traditional ones such as clients' own ERP systems and databases of associated outside parties but also from non-conventional public and non-public ones (e.g. news, social media, emails etc.). Data from these sources will in this new environment be analysed by different parties which, at present, have different models of data structure, formats and naming rules. To facilitate information exchange and analysis, regulators and standardisation agencies should formulate suitable standards that define the formats and naming rules of commonly used data (Dai and Vasarhelyi, 2016). This would further allow businesses and audit firms to achieve higher levels of cost and time efficiency and audit quality through standardisation and automation of data generating, collecting, confirming and analysis processes, as was discussed in earlier chapters.

A recent initiative in audit practice in this context are the four voluntary, audit data standards (ADS) issued by the American institute of certified public accountants' (AICPA) assurance services executive committee (ASEC) Emerging Assurance Technologies Task Force (AICPA, 2015) which define the information necessary for three audit cycles. Those ADSs provide an example of the efficient exchange of data from various companies (Dai and Vasarhelyi, 2016). With standardisation and further development of BC technology through cooperative efforts such as the Hyperledger project, the Fundchain project and others, interparty data transmission could become seamless, and various analytical tools could be directly employed upon the data in the BC without cumbersome data preparation processes which are in use today.

Natural and accelerated evolution of the audit profession

Conceptually, many questions arise in this context as it could be argued that a layer of automated assurance is not an audit but a set of controls. This issue will become even more salient with further developments of concepts such as predictive audits (Kuenkaikaew 2013), prescriptive audits, and CA (Vasarhelyi and Halper 1991). As we have discussed in earlier chapters, and was especially highlighted by practitioners in our empirical study, layers of technology and the utilisation of BDA will change the natural roles of the three lines of defence (management, internal audit, and external audit), possibly affecting hiring and internal organisation practices of the audit firms in the process. Internal audit has, in some instances, taken a more aggressive role in the adoption of data analytics technology

(Vasarhelyi et al., 2012). External audit has, on the other hand, on occasions relied on this more advanced work and, in certain cases under adverse economic incentives, adopted advanced BDA to decrease its risks (Dai and Vasarhelyi, 2016). Nevertheless, the traditional audit steps are still required by regulators which along with the regulatory ambiguity regarding the use of BDA in audit discussed earlier, makes the audit firms hesitant to fully embrace the technology. Management of audit firms' clients is increasingly utilising BDA in their processes and is starting to require their assurers to do the same, which could be a major driver for a higher level of adoption of BDA in audit in the future, as was argued by Alles (2015) and suggested by our empirical findings.

6 Conclusion

6.1 Summary of the SLR and CS Results

6.1.1 Systematic Literature Review

Numeric results of the electronic database search regarding the current state of BDA and BC research showed that there has been a rapid development recently, especially in the past three years. However, a strong link between BDA and BC research regarding their implementation into the public audit practice has yet to be established. Practitioners and scholars have recognised the importance of emerging technologies and have been increasing their resource allocation towards research of those topics during the past year. However, their conclusions and recommendations are still ambiguous with regard to which form of BC technology and consensus mechanism the firms should use in different contexts. There exist several distributed ledger concepts, technologies and consensus mechanisms, as illustrated in Appendices E and F. Moreover, the whole BC technology community is still in the conceptualisation phase, without any proof of concept in the context of audit. It is thus safe to assume that a full implementation of BC technology into the audit practice is still a few years away. This, however, does not make the topic less salient, as we have argued in this study.

BDA is described as a collection of analytical tools that use algorithms based on statistical models to discover patterns of behaviour, irregularities and trends in structured or unstructured BD. BC is defined as a distributed ledger, which enables transactions between strangers based on the mechanism of consensus among the peers in a network.

The benefits of a successful implementation of BDA and BC technology can potentially lead to increases in the effectiveness, efficiency and quality of audit assignments. The risks are divided into data related risks; security, privacy and compliance related risks; and behavioural and skill related risks. The right approach to risk assessment and risk management is needed to reduce and prevent those threats. Therefore, it is essential to formulate a sound code of conduct, regulations and best practice guidelines related to the use of BDA and BC technology.

In the long-term, higher standardisation of audit procedures, increased use of BDA and implementation of BC technology will change auditing considerably. Semi- or full automation of time consuming but simple audit tasks will lead to more effectiveness and efficiency; and ultimately to cost-saving. Nevertheless, the audit itself will probably not become less time-consuming overall. Time-efficiency promised by BDA and BC technology advocates will materialise in the form of elimination of manual assignments through automation, thereby freeing up auditors' time to perform more substantial tests and monitor and assess processes which will lead to the increase in the overall quality of audit. The critique outlined by the literature is mostly linked to scalability and technological limitations of BC solutions relying on "proof-of-work" consensus mechanisms (e.g. bitcoin) in terms of speed and the cost per processed transaction. Conversely, many projects like the Hyperledger and other initiatives lead and supported by global banks, audit firms and IT giants are trying to address those flaws from different angles.

6.1.2 Case Study

The case study approach resulted in valid and credible empirical data collected at KPMG Luxembourg and PwC Malmö, two of the Big 4 audit companies. Semi-structured interviews with interviewees of different seniority levels and from various departments have been conducted, with the aim of gaining insights from different angles regarding interviewees' perception of the future audit profession and the importance of IT in the current and future audit practice. Despite differences in their personal skill in IT, a consensus was reached among the interviewees regarding several IT-related topics. Namely, the interviewees agree that the importance of IT knowledge will increase and that automation of work processes will be a major driver of change in their profession in the future. However, they note that further steps regarding standardisation of audit procedures need to be taken before full automation can become a reality.

Moreover, the interviewees provided information about the current state of BD and BDA usage, shared their thoughts about the BC technology regarding its feasibility and the associated benefits and risks. In a standardised and highly regulated setting in which e.g. the fund audit department operates, raw data can be extracted and treated by IT specialists in their full population. Fund auditors can analyse large amounts of data in a time-efficient manner with the help of macros and other DA tools, whereas auditors from the corporate audit department still struggle to use many DA tools due to differences among, and special needs of their clients. In summary, the interviewees agree that—in a BD environment—sufficient audit evidence can only be acquired by testing full data populations. However, this is only cost-efficient when standardisation and automation can be realised in all the different audit fields.

The interviewees also commented on the feasibility, opportunities and risks regarding the BC technology, arguing that it will change the way the audit is performed. Time consuming manual reconciliation of accounting data and the collection of third party confirmations can be automated, which will result in a more efficient and effective audit. Better time efficiency will allow the auditors to focus on more specific and substantive tests. Overall, the interviewees conclude that the risks regarding data security can be prevented or reduced through proper risk management and training of employees, noting that the BC technology could lead to an increase in audit quality.

Furthermore, the interviews touched on other relevant aspects e.g. the corporate environment, recruitment and retention strategies, and the role of regulators. The results here showed that fund and banking audit departments are increasingly incorporating IT specialists to support their auditors and make better use of the standardised raw data received from the clients. Nevertheless, the auditors highlight what they perceive to be an insufficient level of cooperation and communication with the IT department and note that they are rarely encouraged to engage in innovative activities. In the corporate audit department, the lack of standardisation and the challenges stemming from audit engagements with different—sometimes unique—clients have contributed to the formation of a corporate culture which is different from the one in the fund and banking departments. In this case, the auditors are actively supported and encouraged by the management to actively engage in knowledge sharing activities (e.g. seminars) and to improve and update the existing audit workflows. In the context of recruitment and retention, the audit firms must recruit more IT experts to be able cope with the advancements in technology and to reduce the risk of falling behind their competitors. Our interviewees have further emphasised the need for audit firms to be more transparent in their recruiting practices, especially regarding new assistants (e.g. showing them the real work routine) in order to reduce high rates of turnover. This change could result in more commitment to the company and possibly more innovative participation by the auditors.

Finally, the opportunities for creating more value for audit firms' clients and regaining the trust of the public in the context of emerging technologies were discussed. The interviewed auditors disagree with the demand to create more value beyond the verification of the financial statements, arguing that insistence on this would stand in conflict with their professional independence. However, they agree that the increased use of BDA and BC technology would lead to audit assignments becoming more cost-efficient—and consequently cheaper for the clients through lower audit fees the firms would charge—and would enable them to provide a higher quality of insurance. These cost savings could be used by the clients to buy more advisory services from the firm. This could be an indirect way for audit firms to add value beyond the audit assignment.

The conclusion of the CS is that many contextual differences regarding the level of existing IT knowledge, the type of clients and culture of the departments the interviewed auditors work in had an impact on their perception of the future of their profession and the challenges which they are facing. Nevertheless, the interviewees are acknowledging that BDA and emerging technologies like the BC will increase in importance and that audit firms should play a major role in the research and adaptation of those innovations; arguing that this is the future of audit.

6.2 Theoretical and Practical contributions

6.2.1 Theoretical contributions

The overall theoretical contribution of this thesis is that it adds to the existing knowledge in the research area of auditing in general, and the context of BDA and BC technology in audit in particular. It closes the gap in the existing literature since there are, to our knowledge, no academic papers explicitly linking the concepts of BDA and BC technology taken together, to the audit practice. Current research, especially in the case of BC technology is mostly corporate in nature and focuses on technical aspects and broad applications of the technology, with audit receiving only scant mention. In this context, our study serves to synthesise the existing fragmented knowledge on the topic of BDA and BC technology in audit in an academic fashion thereby providing a foundation for further research.

The SLR provides an overview of the current state of research from the perspective of academics, practitioners and regulators. The available relevant information on the topic in question is combined, analysed and summarised in a logically consistent fashion. Furthermore, the empirical data we have collected through interviews with audit professionals is analysed in a way that relates the said data with the findings of the SLR, thereby complementing them and serving to support certain arguments outlined in the literature but at the same time raising multiple questions and pointing out risks related to proposed theoretical concepts and solutions. The contribution of this approach is that it helps future researchers in the sense that it elucidates questions that require further examination, such as the issues of increased standardisation and automation of processes in audit firms enabled by the use of BDA tools, feasibility of the effort to develop a comprehensive set of regulations that could be programmed into the BC mainframe to allow for real-time assurance and handling the inevitable changes which will beset the audit industry both from an internal and an external point of view as modern technologies become more and more important. Moreover, our study provides insights which reveal that the awareness among auditors relating to the discussed technologies—especially BC technology—is at a very low level, for which the academic community is partly to blame since the research in this area is still very much inchoate. This thesis has aimed to, at least in part, address this issue.

Furthermore, the framework outlined in chapter 5 builds on the ideas of Dai and Vasarhelyi (2016) and takes them a step further, arguing for the practical value of integrating BDA and BC technology in the audit industry of the future, thereby opening up possibilities for further development, or questioning, of the outlined ideas. The use of this iterative, "prototyping", approach could in the future enable the researchers to accumulate a sufficient body of knowledge to spur further innovation in the audit industry.

6.2.2 Practical contributions

In addition to their theoretical contributions, the findings of this study are relevant from a practical point of view as well. The empirical research has revealed a low level of knowledge among the interviewed audit professionals pertaining to technological concepts which were in the focus of this thesis. Although the thesis has been constructed and written in an academic manner, core concepts and ideas are closely related to the audit practice and were thus comprehensible for the practitioners.

Despite their relative lack of IT knowledge, the practitioners in our empirical study have shown a keen interest in the concepts of BDA and BC technology in the context of audit. Thereby, it is our view that the very least our thesis will achieve in a practical sense is to raise awareness to the importance of the concepts discussed in this study among the practitioners we were in contact with, as well as the ones who happen to read our work. The framework developed in chapter 5 looks into the future of the audit profession from the perspectives of principles, standards, technology and auditors. As such, it can serve as a roadmap for audit firms and aid them in their future in-house and collaborative research and educational efforts.

The framework has already proven its practical relevance, at least on a single case basis. Namely, one of the participants in our empirical study—a manager in the risk advisory department at PwC's Malmö office—has requested permission to use our framework as an educational tool for auditors at PwC, citing the framework's holistic approach to the research topic, a number of promising solutions backed by theoretical concepts and examples of possible practical applications of the discussed technological concepts as the reasons behind the framework's relevance and practical value. Looking forward, practitioners who use our framework will have an opportunity to critically examine it, identify gaps in our research, make modifications in order to adapt it to their particular context and build on our ideas to potentially create a fully functional framework which would outline the steps that need to be taken in order to make the vision behind our original work a reality.

6.3 Limitations and Further Research

6.3.1 Limitations

This thesis suffers from several limitations relating to both the theoretical and the empirical portions of the study. Firstly, we have endeavoured to relate the concepts of BDA and BC technology and analyse their combined effect on the future of audit, something that has not been done before in an academic setting, to the best of our knowledge. As a corollary, we could not rely on a tried and tested theoretical frame of reference to guide our research. Thereby, it is entirely possible that our study suffers from knowledge gaps and certain inconsistencies in the process of collecting and analysing the data used in the study. Secondly, despite our best efforts, a review of the literature can never be fully comprehensive, especially in this case since some of the papers we have used in the SLR were published long after we started working on the thesis and performed an initial screening of the relevant literature. Thirdly, the theoretical framework by Dai and Vasarhelyi (2016) which was used as the basis for the framework we have developed in chapter 5 is highly relevant, however parts of it concern certain technological principles which were out of scope of our thesis and were consequently excluded from the final version of our framework. By doing that, we risk misinterpreting certain conclusions and messages of the original framework by Dai and Vasarhelyi (2016) and filling the gaps caused by our slightly different focus with claims and principles which are not entirely consistent with the original ones.

The empirical portion of the study suffers from limitations that relate to the very design of the study, the choice of interviewees and the actual empirical data that was collected. Firstly, our aim in designing the empirical study was to gain a holistic view of the current situation in the audit profession as well as to explore practitioners' views about the future in relation to the technological developments which were in the focus of the thesis, as was discussed in chapters 2 and 1.3. Even though this was not emphasised by our interviewees, there may be important aspects that were missed, which could have potentially contributed to us gaining a better understanding of the topic in question. Secondly, some interviewees' knowledge of BC technology which was a core topic of the thesis was severely limited, which could lower the validity of our empirical findings in this regard. Thirdly, a significant level of variance is to be expected in terms of answers provided by interviewees for this sort of academic work. The data collected through the interview process can be biased since topics that were discussed are subject to interpretation by individual interviewees, which does not necessarily amount to an objective representation of the views held by the profession as a whole.

Additionally, the scope of our study can be criticised and highlighted as another limiting factor. Due to temporal limitations of the assignment itself, it was not possible to perform further theoretical and especially empirical investigations. Follow-up interviews with our interviewees, as well as interviews with additional audit professionals and some of their clients could have strengthened our conclusions or pointed our research in a slightly different direction. Finally, we have identified several relevant technological concepts which we were unable to follow-up on and include in the final version of the study due to time constraints of the assignment as well as the fact that grasping some of those concept on the level appropriate for an academic study requires IT knowledge that is beyond what we as authors with a background in accounting, auditing and finance currently possess.

6.3.2 Further Research

The focal topics of this study have hitherto received only limited attention from academics in the field of auditing. This fact was exemplified in the SLR. There, we were able to identify several gaps in the existing literature and multiple under-researched phenomena, as was discussed in previous chapters. All of these gaps represent opportunities for further research, with the issues of standardisation and automation of audit procedures, formulation of adequate regulations for the technology-driven audit of the future and the overall effects of BDA and BC technology on the business environment and the audit's role in such a world being the most salient.

The framework developed in chapter 5 offers multiple opportunities for further research. First of all, there is a need for its central ideas and proposals to be—in the first instance—re-evaluated and subjected to academic scrutiny in order to establish their validity and actual level of relevance. Secondly, researchers could test the proposals outlined in the framework through collaborative efforts with practitioners at one or multiple Big 4 accounting firms. As was mentioned in chapter 6.2., a manager from one of the Big 4 accounting firms, namely PwC, has already expressed interest in our framework and wishes to use it for educational purposes. Further research into the issues raised in this study could thus one day, with the help of practitioners' practical input, lead to formulation of a framework which would outline the required steps the audit firms need to take to be able to fully adopt emerging technologies and integrate them into their practice.

7 References

ACCA, 2016: *The Future of Audit*; Available at: http://www.accaglobal.com/content/dam/ACCA_Global/Technical/audit/ea-future-of-audit.pdf

Adams, R., Bessant, J., Phelps, R. 2006: *Innovation management measurement: A review, International Journal of Management Reviews.* Vol: 8. No: 1. pp. 21-47

Alles, Michael G., 2015: *Drivers of the Use and Facilitators and Obstacles of the Evolution of Big Data by the Audit Profession*; Accounting Horizons. Jun2015, Vol. 29 Issue 2, p439-449. 11p.

American Institute of Certified Public Accountants (AICPA), 2015: *Audit Data Standards Library;* Available at: http://www.aicpa.org/ interestareas/frc/assuranceadvisoryservices/pages/auditdatastandardworkinggroup.aspx

Appelbaum, Deniz, 2016: *Securing Big Data Provenance for Auditors: Big Data Provenance Black Box as Reliable Evidence.,* American Accounting Association, Journal of Emerging Technologies in Accounting, Vol. 13, No. 1, Spring 2016, pp. 17-36

Baumeister, R. F., & Leary, M. R., 1997: Writing narrative literature reviews. *Review of General Psychology*, *3*, 311-320.

Bem, D. J., 1995: Writing a review article for Psychological Bulletin. *Psychological Bulletin*, *118*, 172- 177.

Blay, A. D., 2005: *Independence threats, litigation risk, and the auditor's decision process*; Contemporary Accounting Research 22: 759–789.

Brown-Liburd, H.; H. Issa; D. Lombardi. 2015: *Behavioral implications of Big Data's impact on audit judgment and decision making and future research directions.* Accounting Horizons 29 (2).

Brown-Liburd, H.; Vasarhelyi, M. A., 2015: *Big Data and audit evidence.* Journal of Emerging Technologies in Accounting 12 (1): 1– 16.

Bryman A., & Bell E., 2003: Business Research methods, Oxford, Oxford University Press

Bryman A., & Bell E., 2015: Business Research methods, Oxford, Oxford University Press

Byström, Hans, 2016: *Blockchains, Real-Time Accounting and the Future of Credit Risk Modeling*; Working paper, 2016:4.

Byrnes, P. E., 2015: *Developing Automated Applications for Clustering and Outlier Detection: Data Mining Implications for Auditing Practice*; Doctoral dissertation, Rutgers, The State University of New Jersey, Newark.

Canadian Institute of Chartered Accountants/American Institute of Certified Public Accountants (CICA/AICPA) 1999: *Research Report: Continuous Auditing*; Toronto, Canada: CICA, AICPA.

Cao, M; Chychyla, R. ; Stewart, T., 2015: *Big Data Analytics in Financial Statement Audits*; Accounting Horizons. Jun2015, Vol. 29 Issue 2, p423-429

Capgemini, 2016: *Smart Contracts in Financial Services: Getting from Hype to Reality;* Available at: https://www.capgemini-consulting.com/resource-file-access/resource/pdf/smart-contracts.pdf

Casey, Michael J.; Wong, Pindar, 2017: *Global Supply Chains Are About to Get Better, Thanks to Blockchain*, International Business, Harvard Business Review (HBR), March 13 2017

Chan, David Y.; Vasarhelyi, Miklos A, 2011: *Innovation and practice of continuous auditing*; In Special Issue on Methodologies in AIS Research, International Journal of Accounting Information Systems. 2011 12(2):152-160 Language: English

Chen, H.; R. H. Chiang, and V. C. Storey, 2012: Business intelligence and analytics: From Big Data to big impact. MIS Quarterly 36 (4): 1165–1188.

Cooper, H. M., 2003: Editorial. *Psychological Bulletin*, *129*, 3-9.

Dai, Jun; Vasarhelyi, Miklos A., 2016: *Imagineering Audit 4.0*; Journal of Emerging Technologies in Accounting. Spring2016, Vol. 13 Issue 1, p1-15. 15p.

Deloitte, 2016 (a): *Blockchain Technology A game changer in accounting?*; Available at: https://www2.deloitte.com/content/dam/Deloitte/de/Documents/Innovation/Blockchain_A%20game-changer%20in%20accounting.pdf

Deloitte, 2016 (b): *Blockchain- Enigma. Paradox. Opportunity*; Available at: https://www2.deloitte.com/content/dam/Deloitte/uk/Documents/Innovation/deloitte-uk-Blockchain-full-report.pdf

Deloitte, 2016 (c): *Bitcoin, Blockchain & distributed ledgers: Caught between promise and reality*; Available at: https://www2.deloitte.com/content/dam/Deloitte/au/Images/infographics/au-deloitte-technology-bitcoin-Blockchain-distributed-ledgers-180416.pdf

Deloitte, 2016 (d): *Tech Trends 2016: Innovating in the digital Era: Blockchain: Democratised trust Distributed ledgers and the future of value:* Available at: https://www2.deloitte.com/content/dam/Deloitte/uk/Documents/technology/deloitte-uk-tech-trends-2016-blockchain.pdf

Digital Asset, 2016: *The Digital Asset Platform: Non-technical White Paper,* Digital Asset Asset Holdings, LLC, December 2016

Douglass C. North, 1991: Institutions; Journal of Economic Perspectives - Volume 5, Number 1 - Winter 1991 - Pages 97-112

Dzuranin, Ann C.; Mălăescu, Irina, 2016: *The Current State and Future Direction of IT Audit: Challenges and Opportunities*; Journal of Information Systems , Spring2016, Vol. 30 Issue 1, p7-20, 14p

EY (2016 (a)): *Blockchain Technology as a platform for digitalization – Implications for the insurance industry*, Available at: http://www.ey.com/Publication/vwLUAssets/EY-Blockchain-technology-as-a-platform-for-digitization/$FILE/EY-Blockchain-technology-as-a-platform-for-digitization.pdf

Ferrulo, J., Babb, A., Winder, N., Akman, S.: *Eu Auditor Market Share: 2016*. Available at: http://www.auditanalytics.com/blog/eu-auditor-market-share-2016/

Fundchain, 2017: *White Paper "Distributed Ledger Technology – The genesis of a new business model for the asset management industry "*; Available at: http://fundchain.lu/?ed=download&guid=wxmsji-lzetgn-zehxuy-libsdr-ifybmk--qzphen-bljoct-obgmya-vhoqxa-grwhsi

Geertz, C., 1973: *"Thick Description: Toward an Interpretive Theory of Culture",* in C. Geertz, The Interpretation of Cultures (New York: Basic Books)

Golia, N. 2013: *What Big Data means for infrastructure costs;* Insurance and Technology (May): 30–31.

Government Office for Science, 2016: *Distributed Ledger Technology: beyond block chain*, A report by the UK Government Chief Scientific Adviser, Available at: http://www.ameda.org.eg/files/gs-16-1-distributed-ledger-technology.pdf

Greenwood, Royston; Li, Stan X.; Prakash, Rajshree; Deephouse, David L., 2005: *Reputation, Diversification, and Organizational Explanations of Performance in Professional Service Firms*; Organization Science, 11/1/2005, Vol. 16, Issue 6, p. 661-673

Griffin, P. A.; Wright A. M., 2015: *Commentaries on Big Data's importance for accounting and auditing*. Accounting Horizons 29 (2).

Grigg, Ian, 2005: *Triple Entry Accounting*, Work in Progress, Systemics, Inc., Http://iang.org/papers/triple_entry.html

Groomer, S. Michael; Murthy, Uday S, 1989: *Continuous Auditing of Database Applications: An Embedded Audit Module Approach*; Journal of Information Systems. Spring89, Vol. 3 Issue 2, p53. 17p

Guba, E. G., & Lincoln, Y. S., 1994: Competing paradigms in qualitative research. In N. K. Denzin & Y. S. Lincoln (Eds.), The handbook of qualitative research (pp. 105–117). Thousand Oaks, CA: Sage.

Gupta, Vinay, 2017: *The Promise of Blockchain Is a World Without Middlemen*; Harvard Business Review Digital Articles. 3/6/2017, p2-5. 4p

Hermann, M., T. Pentek, and B. Otto. 2015: *Design Principles for Industrie 4.0 Scenarios: A Literature Review*; Available at: http://www.snom.mb.tu-dortmund.de/cms/de/forschung/Arbeitsberichte/Design-Principles-for-Industrie-4_0-Scenarios.pdf

Hodge, M. H., and L. S. Reid. 1971: *The influence of similarity between relevant and irrelevant information upon a complex identification task*; Perception and Psychophysics 10 (4): 193–196.

Hyperledger, 2016: *Hyperledger Whitepaper*; Available at: http://www.the-Blockchain.com/docs/pledger%20Whitepaper.pdf

Iansiti, Marco; Lakhani, Karim R., 2017: *The truth about Blockchain*; Harvard Business Review. Jan/Feb2017, Vol. 95 Issue 1, p118-127

IAASB, 2014: *Strategy for 2015-2019: Fulfilling our Public Interest Mandate in an Evolving World*; Available at: https://www.ifac.org/system/files/publications/files/IAASB-Strategy-2015-2019_0.pdf

IAASB, 2016: *Exploring the Growing Use of Technology in the Audit, with a Focus on Data Analytics*; IAASB Data Analytics Working Group. Available at: https://www.accountancyeurope.eu/wp-content/uploads/IAASBs-Discussion-Paper-on-the-use-of-Technology-with-a-focus-on-Data-Analytics.pdf

IAASB, 2017: *The IAASB's Work Plan for 2017–2018 and Continuing Relevance of Its Strategic Objectives*; Available at: http://www.ifac.org/system/files/publications/files/IAASB-Basis-for-Conclusions-IAASB-Work-Plan-2017-2018.pdf

IAASB, 2017 (a): *Work Plan for 2017–2018: Enhancing Audit Quality;* Available at: https://www.ifac.org/system/files/publications/files/IAASB-Work-Plan-for-2017-2018-Enhancing-Audit-Quality.pdf

IBM, 2012: *The Four V's of Big Data*, Available at: http://www.ibmbigdatahub.com/infographic/four-vsbig- data

Inbar, D., 2013: *Making the most out of your data: Big Data opportunities*; Siliconindia (February): 35.

Issa, H., and A. Kogan 2013: *A Predictive Ordered Logistic Regression Model for Quality Review of Control Risk Assessments*. Working paper, Rutgers Accounting Research Center.

KPMG, 2016 (a): *Consensus, immutable agreement for the Internet of value*; Available at: https://assets.kpmg.com/content/dam/kpmg/pdf/2016/06/kpmg-Blockchain-consensus-mechanism.pdf

KPMG, 2016 (b): *Leveraging data analytics and continuous auditing processes for improved audit planning, effectiveness, and efficiency*; Available at: https://assets.kpmg.com/content/dam/kpmg/pdf/2016/05/Leveraging-Data-Analytics.pdf

KPMG, 2017: *Audit 2025, the future is now*; Forbes insights (March). Available at: https://assets.kpmg.com/content/dam/kpmg/us/pdf/2017/03/us-audit-2025-final-report.pdf

Krahel, John Peter; Titera, William R., 2015: *Consequences of Big Data and Formalization on Accounting and Auditing Standards*; Accounting Horizons. Jun2015, Vol. 29 Issue 2, p409-422. 14p.

Kuenkaikaew, S, 2013: *Predictive Audit Analytics: Evolving to a New Era*; Ph.D. dissertation, Rutgers, The State University of New Jersey.

Lazarrovich, A., 2015*: Invisible Ink: Blockchain for Data Privacy*, Master of Science in Media Arts and Sciences Thesis, MIT

Lincoln, Y. S., & Guba, E. G., 1985: Naturalistic inquiry. Beverly Hills, CA: Sage.

Li, H., and M. A. Vasarhelyi, **2016:** *Automatic Confirmations*. Working paper, The University of Sydney CARlab.

Løwendahl, B. R., Revang , Ø., Fosstenløkken ,A. M., 2001: *Knowledge and value creation in professional service firms: a framework for analysis,* Human Relations; 54 (7): 911-931.

Lundbaek, Leif-Nissen; D'Iddio, Andrea Callia; Huth, Michael., 2016: *Optimizing Governed Blockchains for Financial Process Authentications;* Database: arXiv

Mansfield, D., 2013: *Keepin' it clean*; NZ Marketing Magazine (July): 72.

Mayer- Schönberger, V., and K. Cukier, 2013: *Big Data: A Revolution That Will Transform How We Live, Work, and Think*. Boston, MA: Eamon Dolan/Houghton Mifflin Harcourt

McKinsey, 2011: *Big Data, The Next Frontier for Innovation, Competition and Productivity*; McKinsey Global Institute (June). Available at: http://www.mckinsey.com/business-functions/digital-mckinsey/our-insights/big-data-the-next-frontier-for-innovation

Moroney, R., 2016: *Editorial: Regulating Audit Quality – Ramification and Research Opportunities*, Department of Accounting, Monash University, International Journal of Auditing, 20: 105-107 (2016)

Nakamoto, Satoshi, 2009: Bitcoin: A peer-to-peer Electronic Cash System

Nick Scott, 2016: *Blockchain: The Internet's Second Generation*; Available at: http://www.director.co.uk/Blockchain-internets-second-generation-19926-2/

Nonaka, I.,1994: *A dynamic theory of organizational knowledge creation*, Organization Science 5(1): 14–37.

Ohlhorst, Frank J.. Hoboken, 2012: *Big Data Analytics : Turning Big Data into Big Money*; Wiley, 2012. 1 online resource (176 pages). Language: English, Database: Library catalogue (Lovisa)

Pakaluk, J., 2017: *Auditor Market Share of the S&P 500*; Available at: http://www.auditanalytics.com/blog/auditor-market-share-of-the-sp-500/

PwC, 2016: *Making sense of bitcoin, cryptocurrency, and Blockchain*, February, 2016; Available at: https://www.pwc.com/us/en/financial-services/fintech/bitcoin-blockchain-cryptocurrency.html

PwC, 2017: *Distributed ledger technology - The genesis of a new business model for the asset management industry, May 2017*; Available at: https://www.pwc.lu/en/fintech/docs/pwc-fintech-distributed-ledger-technology.pdf

Reinking, Jeffery; Arnold, Vicky; Sutton, Steve G., 2015: *Antecedents and Consequences of Early Adoption of Emerging Technologies: The IT Revolution*; University of Central Floria, American Accounting Association, Journal of Emerging Technologies in Accounting, Vol. 12, 2015, pp. 51-70

Ryan, R., Deci, E., 2000: *Self-Determination Theory and the Facilitation of Intrinsic Motivation, Social Development, and Well-being*' American Psychological Association, Inc. Vol. 55. No. 1. pp. 68-78

Siddaway, A., n.d.:
https://www.stir.ac.uk/media/schools/management/documents/centregradresearch/How%20to%20do%20a%20systematic%20literature%20review%20and%20meta-analysis.pdf. ; 1st ed. Stirling, UK: Dr Andy Siddaway, pp.1-13. [Accessed 20 April 2017]

Taleb, Nassim Nicholas, 2007: *The Black Swan: The Impact of the Highly Improbable*; Allen Lane; 1st edition (3 May 2007);

Tapscott, Don; Tapscott, Alex, 2016: *The Impact of the Blockchain Goes Beyond Financial Services*; Harvard Business Review Digital Articles. 5/10/2016, p2-5. 4p

The Economist, 2017: *Why everything is hackable: Computer security is broken from top to bottom;* Published on Apr 8th 2017. Available at: http://www.economist.com/news/science-and-technology/21720268-consequences-pile-up-things-are-starting-improve-computer-security

Vasarhelyi, M. A., M. G. Alles, S. Kuenkaikaew, and J. Littley, 2012: *The acceptance and adoption of continuous auditing by internal auditors: A micro analysis;* International Journal of Accounting Information Systems 13 (3): 267–281.

Vasarhelyi, M. A.; Kogan, A.; Tuttle, B. M., 2015: *Big Data in accounting: An overview.* Accounting Horizons 29 (2).

Vasarhelyi, Miklos A.; Halper, **Fern B., 1991:** *The Continuous Audit of Online Systems;* Auditing: A Journal of Practice & Theory. Spring91, Vol. 10 Issue 1, p110-125

Vasarhelyi, M. A., J. D. Warren, Jr., R. Teeter, and B. Titera, 2011: *Embracing the Automated Audit*. Working paper, Rutgers, The State University of New Jersey.

Warren, Jr., J. Donald; Moffitt, Kevin C.; Byrnes, Paul, 2015: *How Big Data Will Change Accounting*; Accounting Horizons. Jun2015, Vol. 29 Issue 2, p397-407. 11p

Well, A. D. 1971: *The influence of irrelevant information on speeded classification tasks;* Perception and Psychophysics 10 (2): 79–84.

Zhang, Juan; Yang, Xiongsheng; Appelbaum, Deniz, 2015: *Toward Effective Big Data Analysis in Continuous Auditing;* Accounting Horizons. Jun2015, Vol. 29 Issue 2, p469-476. 8p

Yermack, D. 2015: *Corporate Governance and Blockchains.* Working Paper, NYU Stern School of Business.

Yin R. K., 2009: Case Study Research – Design and Methods, SAGE Publications

Yoon, K.; Hoogduin, L. A.; Zhang, L., 2015: *Big Data as complementary audit evidence*. Accounting Horizons 29 (2).

8 Appendix

8.1 Appendix A – Interview Guide

Interview Guide – The future of Audit Profession – Staying competitive in a world of Big-Data recommended by Bryman & Bell (2003)

Main Topic:

The Future of the audit profession

Research Area:

The use of Big Data analytics and Blockchain technology in the audit profession.

Research Questions:

1) What is the current state of academic literature and corporate research concerning the effects of Big Data analytics and the blockchain technology on the future of the audit profession?
2) Which framework could the audit firms use to integrate Big Data analytics and the blockchain technology into future audit procedures?

Case study based on a Semi-structured interview

Interview Guide Categories

1. General Questions on the personal professional view concerning the future of audit
2. IT Competence
3. Big Data
4. Blockchain
5. Risk Management
6. Corporate Environment and Strategy
7. The role of Regulators and Legislators
8. Creating Value and Trust

Interview Guide

1. General Questions on the personal professional view concerning the future of audit

    1. Where do you see the audit profession in 5 years?
    2. In your opinion, what could increase audit quality?
    3. In what way do you think the audit quality would be changed (increased/decreased) by the automation of the hitherto manually performed analytics assignments?
    4. What are the challenges and opportunities regarding the new Public Interest Entities (PIE) regulations?
2. IT Competence
    1. How would you describe your level of IT knowledge?
    2. How important are IT skills in your profession?
    3. In what way would the audit quality you are able to deliver be affected by the potential improvement of your IT skills?
    4. What are your thoughts about the importance of auditors' IT skills moving forward? (individually and regarding the profession as a whole)
3. Big Data
    1. Does Big Data play a role in your daily work?
    2. Do you think Big Data analytics are important for your work? If so, why and how?
    3. How comfortable are you with proving audit evidence based on a small sample size?
    4. Big Data analytics enables auditors to look at the whole database provided by the client. How would a much larger sample size, compared to what is currently being used, affect the reliability and quality of the performed audit?
    5. What are the possible downsides of auditing the entire database?

4. Blockchain
    1. Do you think Blockchain technology is suitable for the audit profession?
    2. Would Blockchain technology increase the quality of audit? How, why?
    3. Does Blockchain technology represent a step towards full automation of the audit process? Why do you think so?
    4. What would the role of auditors be in such a world?
    5. How would a business environment shaped by the latest technologies affect the importance of the role that the audit profession currently plays in the financial system?
5. Risk Management
    1. What are the risks in the use of Big Data/Big Data analytics, Blockchain technology?
    2. How can those risks be reduced or prevented?
    3. How capable are the IT systems currently in place at the clients' premises of handling these risks?
    4. To what extent are audit teams aware of, and trained to precisely identify and handle those risks?
    5. How does the ability to analyse very large populations of data using Big Data analytics affect the level of risk in the audit process?
    6. What are the risks that relying on automated procedures in the audit process entails?
6. Corporate Environment and Strategy
    1. In what way do the current corporate structure and culture in the audit firms support technological innovations?
    2. How should audit firms' professional (employee) development strategies be adapted in order to enable auditors to make best use of emerging technologies like Big Data analytics and Blockchain?
    3. How does your firm intend to design/change their recruitment and employee retention strategies to keep up with the aforementioned developments? How should it go about doing so in your opinion?

7. Role of Regulators and Legislators
    1. Where do you see the role of the regulators and legislators in this area of interest?
    2. How big of a role should audit firms play in formalising new professional regulations?
    3. The regulators are currently vary of prematurely commencing standard setting activities and enacting standards which are too rigid to accommodate rapid technological changes out of fear that it might restrict innovation. How can this be avoided, while remaining proactive and forward-looking?
8. Creating Value and Trust
    1. How would the usage of these technologies affect the value created for the clients?
    2. How would it affect public trust towards the audit firms?
    3. What impact would the technology have on your daily work?
    4. How would the enactment of big data analytics, Blockchain technology and continuous auditing affect the cost-efficiency of the audit process? What are the trade-offs involved?
9. Repeated question: Where do you see your profession in 5 years?

8.2 Appendix B: Summary and overview of the results of the SLR

Author(s) (Year)	Comment
ACCA (2016)	ACCA future of Audit report 2016. Auditors need to adapt, experiment in all sorts of areas and constantly innovate. In the world of technology and information overload, it is essential that auditors can navigate the information, provide judgement and focus on important issues. Recruiting and retaining the right people is what we need to survive as a profession.
Alles (2015)	Explores the growing significance of Big Data as a business tool. Focusing on how the audit professions usage of Big Data will evolve over time. The hypothesis tested is that auditors cannot operate too far from the practices of their clients. Hence, if Big Data becomes an essential business tool, it will become as important in auditing. However, American and international auditing standards, technological advances, and market forces are some of the facilitators and obstacles that will determine the use of Big Data by auditors and that will shape how that usage will evolve over time.
Appelbaum (2016)	Discussion of an issue regarding the reliability of audit evidence derived from Big Data, specifically the security of the originating source of the data (data provenance). The author points out that with increasing complexity and amount of data; third party evidence has become "messy" external data sources and as such evidence should be considered as less reliable for audit evidence. The paper discusses the role of the auditor in a world of "messy" data; advocating that external auditors should be aware of the lack of secure data provenance in the corporate community in its haste to utilize Big Data and suggesting a system for secure provenance collection (the Big Data Provenance Black Box).
Brown-Liburd & Vasarhelyi (2015)	Overview about the emerging big data environment, automatic data collection, the past and future of audit evidence and how to use moderns technology to increase audit quality.

Brown-Liburd, Issa & Lombardi (2015)	This paper addresses information processing weaknesses and limitations that can impede the effective use and analysis of Big Data in an audit environment. Especially, the behavioural implications Big Data has on audit judgment by addressing the issues of information overload, information relevance, pattern recognition, and ambiguity. We also discuss the challenges that auditors encounter when incorporating Big Data in audit analyses and the various analytical tools that are currently used by companies in the analysis of Big Data.
Cao, Chychyla and Stewart (2015)	This article hypothesizes that Big Data analytics can improve the efficiency and effectiveness of financial statement audits. The paper describes how Big Data analytics known from other domains might be applicable in auditing. Furthermore, it points out the differences of Big Data analytics, to traditional auditing, and its implications for practical implementation.
Casey & Wong (2017)	The possibility of the feasibility of Blockchain technology in a global supply chain is discussed. The benefits would be efficiency improvements and therefore vast savings for the companies. However, the lake of standards, regulations and laws are hindering at the moment a successful implementation.
Chan & Vasarhelyi (2011)	Describes the need of innovation in the traditional audit process to support real times assurance. A framework for continuous auditing is presented and methodological propositions concerning the future of assurance for practitioners and academic researchers are formulated. Continuous auditing enhances the efficiency and effectiveness of the audit process by providing real time assurance and monitoring.
Chen, Chiang & Storey (2012)	"Provide a framework that identifies the evolution, applications, and emerging research areas of BI&A. BI&A 1.0, BI&A 2.0, and BI&A 3.0 are defined and described in terms of their key characteristics and capabilities. Current research in BI&A is analyzed and challenges and opportunities associated with BI&A research and education are identified. Business intelligence and analytics (BI&A) has emerged as an important area of study for

	both practitioners and researchers, reflecting the magnitude and impact of data-related problems to be solved in contemporary business organizations. "
Dai & Vasarhelyi (2016)	Development of a framework which supports a new generation of an Audit 4.0., which includes Semi- and progressive automation of audit. The tools are sensors, Internet of Things (IoT), Internet of service (IoS), Cyber-Physical Systems (CPS), GPS and smart factors.
Deloitte (2016a)	Short introduction into the first steps of Blockchain technology based accounting practice. Showcase how the integrity of records can be verified through the use of Blockchain.
Deloitte (2016b)	Report of Deloitte UK about the key challenges for a successful implementation and operation of Blockchain technology in the financial sector. Furthermore, it discusses the gap between vision and reality. Moreover, it gives examples in how Blockchain could be applied in different sectors; namely, banking, insurance, public sector, media industry and energy trading.
Deloitte (2016c)	Deloitte UK technology trends report, describing how Blockchain technology can rewire markets, promoting trust, transparency, disintermediation, collaboration and security.
Digital Asset (2016)	This paper provides a high-level overview of the architecture of the Digital Asset Platform, a common foundation on which financial services applications can be built. It provides the business rationale for our design decisions and is intended for a non-technical audience. The Digital Asset Platform uses Distributed Ledger Technology to allow the mutualisation of financial market infrastructure across distinct market participants. It does this while maintaining confidentiality and scalability, both vital for large, regulated markets. The DA Platform eliminates discrepancies between disparate but duplicative siloed data records, reducing the current errors,

	latency, risk, cost and capital requirements involved in processing financial transactions. Participants in the Platform share a single source of truth which provides continuous data integrity, any desired or mandated degree of transparency and the opportunity for rapid innovation.
Dzuranin & Malaescu (2016)	Discussion on the role of internal and external IT auditors in helping organizations meet compliance requirements and ensuring that information systems add value to the organization. Furthermore, the future of IT audit in a world of advanced analytics and emerging technologies is discussed; because of the increasing volume of data available, coupled with changing technology and increasing regulatory requirements.
EY (2016a)	EY report about the Blockchain technology implications for the insurance industry. Innovations like the Blockchain are still in its infancy and developing in a very fast past, therefore timing and adoptions are unclear; careful examinations of the attributes and benefit are mandatory. In regards of transparency and risks, firms have engaged proactive in compliance and regulatory frameworks to fit the new model. Companies should design and build their organizations to cope with disruptive innovation.
Government Office for Science (2016)	UK Government report from the Office for Science acknowledging the importance of spending more resources to investigate the feasibility of Blockchain technology for the use in the public sector. Furthermore, it discusses the role of government to put the right regulations in place for security and privacy reasons. Moreover, several case studies are presented where the Blockchain technology has been implemented in the corporate as well in the public sector.

Griffin & Wright (2015)	Commentaries on Big Data's Importance for Accounting and Auditing. Identifying Big Data as the most pressing challenge for the audit and accounting profession. Exploring the threats and opportunities for acccounting and auditing. A collection of comments from academis and business professionals are "not only define and frame the important issues for accounting and auditing but, also, they identify many feasible, yet difficult, pathways forward, wherein Big Data and traditional accounting and auditing might meld to better serve firms, stakeholders, and the public."
Grigg (2005)	Development of the accounting as we know with the support and implementation of cryptocurrencies into 3 local entries with 3 roles for each into a something called triple entry accounting. This system is resistant to forging and can lower costs by delivering reliable accounting information; increasing governance for the future needs of corporate and public accounting.
Gupta (2017)	Proclaiming and discussing a world without middle men, allowing frictionless trading; lowering transactions costs and other sources of friction. Making an example on how a small transaction fees at the beginning of a long supply chain can become very costly for the global economy. The decentralization that Blockchain provides would change that, which could have huge possible impacts for economies in the developing world. Any transformation which helps small businesses compete with giants will have major global effects.
Hyperledger (2016)	Illustration of a new emerging Blockchain fabric called the Hyperledger and the basic requirements and high-level architecture which drives this development. The Hyperledger is a protocol for business-to-business and business-to-customer transactions; allowing compliance with regulations, while supporting the varied requirements that arise when competing businesses work together on the same network. The central elements of this specification are smart contracts (a.k.a. chain code), digital assets, record repositories, a decentralized

	consensus based network, and cryptographic security. To these Blockchain staples, industry requirements for performance, verified identities, private and confidential transactions, and a pluggable consensus model have been added.
IAASB (2016)	The International Auditing and Assurance Standards Boards is exploring the growing use of technology in the Audit, with a focus on Data Analytics. It discusses the benefits and the limitations of data analytics. For the regulator, professional judgement is still one of the most important skills, even with more use of data analytics. Furthermore, it acknowledges that a wide spread of data analytics and other emerging technologies in the audit will be mostly beneficial in helping auditors to spend more time on substantive testing than manual repetitive tasks. However, the regulators are hesitant in introducing new regulations, with the argument that they would be old again because the technology is advancing very fast. This hinders however the implementation of innovation, through the uncertainty an unregulated technology leaves in a highly regulated area.
KPMG (2016a)	Providing an overview and explanation of consensus mechanisms and distributed ledger technologies. Furthermore, it presented the key findings of a survey including over 20 creators and corporate users of Blockains and other consensus mechanisms; divided in the categories: Overall consensus methodology; Governance, risks, and control; Performance; Security; Cryptography/Strength of Algorithm; Tokenization; Privacy and Implementation approach. Finally, it includes a questionnaire helping an organization to assess whether Blockchain technology is right them.

KPMG (2017 (b))	Results and insight of a survey of CEOs, CFOs and other financial executives regarding their views on the future of audit in relation to quality, insights and overall value. The focus is on new technologies and how the "explosion" of data has changed the profession since the last report in 2014. The conclusions are that the auditing profession has continued to change with the accelerating pace of advancing technologies relating to data, advanced analytics, robotic process automation, cognitive and other emerging innovations. The expectation on new auditors by both employer and clients has increased regarding the effective use of these tools to e.g. test bigger samples and providing more forward-looking view of the world and insights that can add value (e.g. identifying risks).
Lazarovich (2015)	This paper constructed a platform that securely distributes encrypted user-sensitive data. Blockchain technology is used to keep a trust-less audit trail for data interactions and to manage access to user data. It aims to increase transparency, control, and security of their personal data. At the same time the service provider becomes much less vulnerable to single point-of failures and breaches, which in turn decreases their exposure to information-security liability, thereby saving them money and protecting their brand.
Lundbaek, D´Iddio & Huth (2016)	Analysis of governed Blockchains that are owned and controlled by organizations and that neither create cryptocurrencies nor provide any incentives to solvers of cryptographic puzzles. Those puzzle solvers are seen as resources under the control of the owners. The developed mathematical model is validated and proven by a case experiment and strengthened by statistical experiments This mining calculus model also supports change management. It could be used to determine how many new miners are needed for different specifications e.g. to react to new energy prices.

Moroney (2016)	Discussion about what exactly constitutes a quality audit and how it is best achieved. As audits are unobservable, audit quality is difficult to assess and so evaluating the relative success of different types of regulation can be problematic. The focus of discussion will be put on two regulations aimed at enhancing audit quality: partner rotation and audit inspections.
Nakamoto (2009)	The original paper of the introduction into the bit-coin (a crypto currency) with the underlying Blockchain technology. Discussing a purely peer-to-peer version of electronic cash without any intermediaries like a financial institution, supported through an encryption and distributed ledger technology.
Ohlhorst & Hoboken (2012)	Describes Big Data Analytics procedure as modeling and knowledge discovery for predictive, rather than purely descriptive, purposes - an ideal process for uncovering new patterns from large data sets. Statistical applications of BDA look at data using algorithms based on statistical principles. They ideally deliver sample observations that can be used to study populated data sets for the purpose of estimating, testing, and predictive analysis
Reinking, Arnold & Sutton (2015)	This study focuses on the productivity paradox and investigates the antecedents and consequences of early adoption of emerging technology. The results do not support the shortened cycle expected, as firms that adopt technology early do not exhibit productivity gains in either the short term or long term despite experiencing performance gains throughout. However, results do support the theorized nature of early adopters in that both organizational slack and available slack are strong antecedents to a firm's early adoption of technology, and that early adoption leads to increased performance in both the short and long term.

Tapscott & Tapscott (2016)	The authors describe five underlying principles of the Blockchain Technology; namely, Distributed Database, Peer-to-Peer Transmission, Transparency with Pseudonym, Irreversibility of Records and Computational Logic. Blockchain could be a use for numerous intermediate functions in the finance industry: e.g. identity and reputation, moving value (payments and remittance), storing value (savings), lending and borrowing (credit), trading value (marketplaces like stock exchanges), insurance and risk management, and audit and tax functions.
Vasarhelyi, Kogan & Tuttle (2015)	Collection of essays illustrating the ongoing evolution of corporate data into Big Data; focusing on the sources, uses, and challenges of Big Data in accounting (measurement) and auditing (assurance). The paper advocates the need for new accounting and auditing standards. Furthermore, it presents new opportunities for audit analytics enabled by Big Data and the impact of Big Data on audit judgment and behavioural research.
Warren, Moffitt & Byrnes (2015)	Description of how Big Data in form of video, audio and textual information can be important for the improvement of managerial accounting, financial accounting and financial reporting practices. Exploration on how Big Data will increase effectiveness, quality, relevance and transparency in those fields by providing information in a dynamic, real-time and global way.
Yermack (2017)	Analysis of the corporate governance implications of a Blockchain technology implementation into the financial record-keeping. This includes the potential implications for managers, institutional investors, small shareholders, auditors, and other parties involved in corporate governance. The benefits are lower cost, greater liquidity, more accurate record-keeping, and transparency of ownership offered by Blockchains.

Yoon, Hoogduin & Zhang (2015)	Explanation on why Big Data can be used as a complement to audit evidence; evaluating if the use of Big Data can provide cost-efficiency, reliability, and relevance for audit. "Critical challenges, including integration with traditional audit evidence, information transfer issues, and information privacy protection, are discussed and possible solutions are provided".
Zhang, Yang & Appelbaum (2015)	Examine the gaps between Big Data and the current capabilities of data analysis in continuous auditing (CA). It identifies four dimensions of Big Data and five subsequent gaps: namely, data consistency, integrity, aggregation, identification, and confidentiality. For each gap, the paper outlines challenges and possible solutions derived from traditional data systems, which can be further applied to CA systems in an era of Big Data.

8.3 Appendix C: The Blockchain Technology

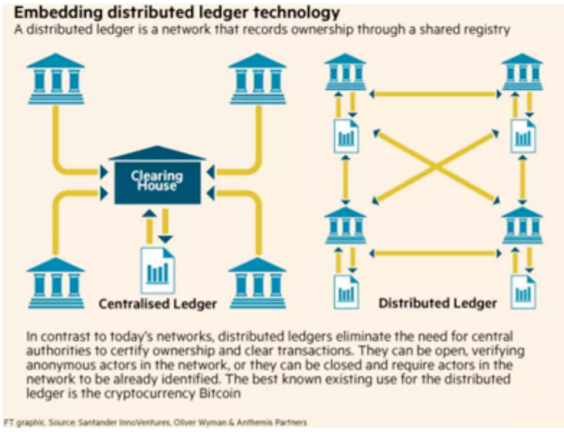
BC technology can be viewed as a new technological institution. Institutions represent humanly devised constraints that structure political, economic and social interactions. They include formal rules such as the constitution, laws and informal constraints like codes of conducts and traditions (North, 1991). In the past institutions have been used to lower uncertainty in the economy and facilitate trade between individuals, companies and states. BC has the potential to lower uncertainty by means of technology alone. The power of BC lies in the fact that the very thing that makes it work, that keeps it secure and verified is the mutual distrust among its users. With BC technology, the collective uncertainties of all the participants in the system can be harnessed and used to foster collaboration within the system in a faster, more open way, rather than having that uncertainty slow it down, requiring institutions such as banks, governments and corporations to mitigate the uncertainty. In a way, the BC technology becomes a technological institution similar in many ways to institutions we are used to seeing in our society, the difference being that the BC technology does this in a way that reduces uncertainties, turning them into manageable risks. For an illustration and overview of the BC technology see Appendix D.

The following introduction paper into the Blockchain technology has been send in to the interviewees, with the aim to broaden their understanding of the BC technology.

Blockchain Technology in Short

The blockchain is the underlying technology of cryptocurrencies like the Bitcoin, first introduced by a group of authors called Satoshi Nakamoto in early 2009.

A Blockchain is “a technology that allows people who don’t know each other to trust a shared record of events” (Bank of England). This shared record, or ledger, is distributed to all participants in a network who use their computers to validate transactions and thus remove the need for a third party to intermediate. Furthermore, the distributed ledger database maintains a continuously growing list of transaction records ordered into blocks with various protections against tampering and revision.



Current state of the technology in accounting

Technological advancements in accounting are restrained due to high regulatory requirements in respect to validity and integrity. The accounting system relies on mutual control mechanisms, checks and balances which are achieved through repetitive manual, labour intensive work. Systematic duplication of efforts, extensive documentation and periodical controls are costly and time consuming. Furthermore, in the process of gaining the trust of stakeholders, independent public auditors are appointed which become costly and time consuming by binding the company′s accountants for long periods of time.

How Blockchain technology can change the way of today´s accounting:

Instead of keeping separate records based on transaction receipts, companies can write their transactions directly into a trusted, distributed register, creating an interlocking system of enduring accounting records at a negligible cost of use. Since all entries are distributed and cryptographically sealed, falsifying or destroying them to conceal activity is practically impossible. It is like the transaction being verified by a notary – only in an electronic way. In short Blockchain technology is faster, cheaper, more reliable and transparent than traditional accounting systems.

Benefits for external auditors' work

Standardisation would allow auditors to verify a large portion of the most important data behind the financial statements automatically. The cost and time necessary to conduct an audit would decline considerably. Auditors could spend freed up time on areas that can add more value, e.g. on very complex transactions or on internal control mechanisms.

It is not necessary to start with a joint register for all accounting-entries. The Blockchain as a source of trust can also be extremely helpful in today’s accounting structures. It can be gradually integrated with typical accounting procedures: starting from securing the integrity of records, to completely traceable audit trails. At the end of the road, fully automated audits may be reality.

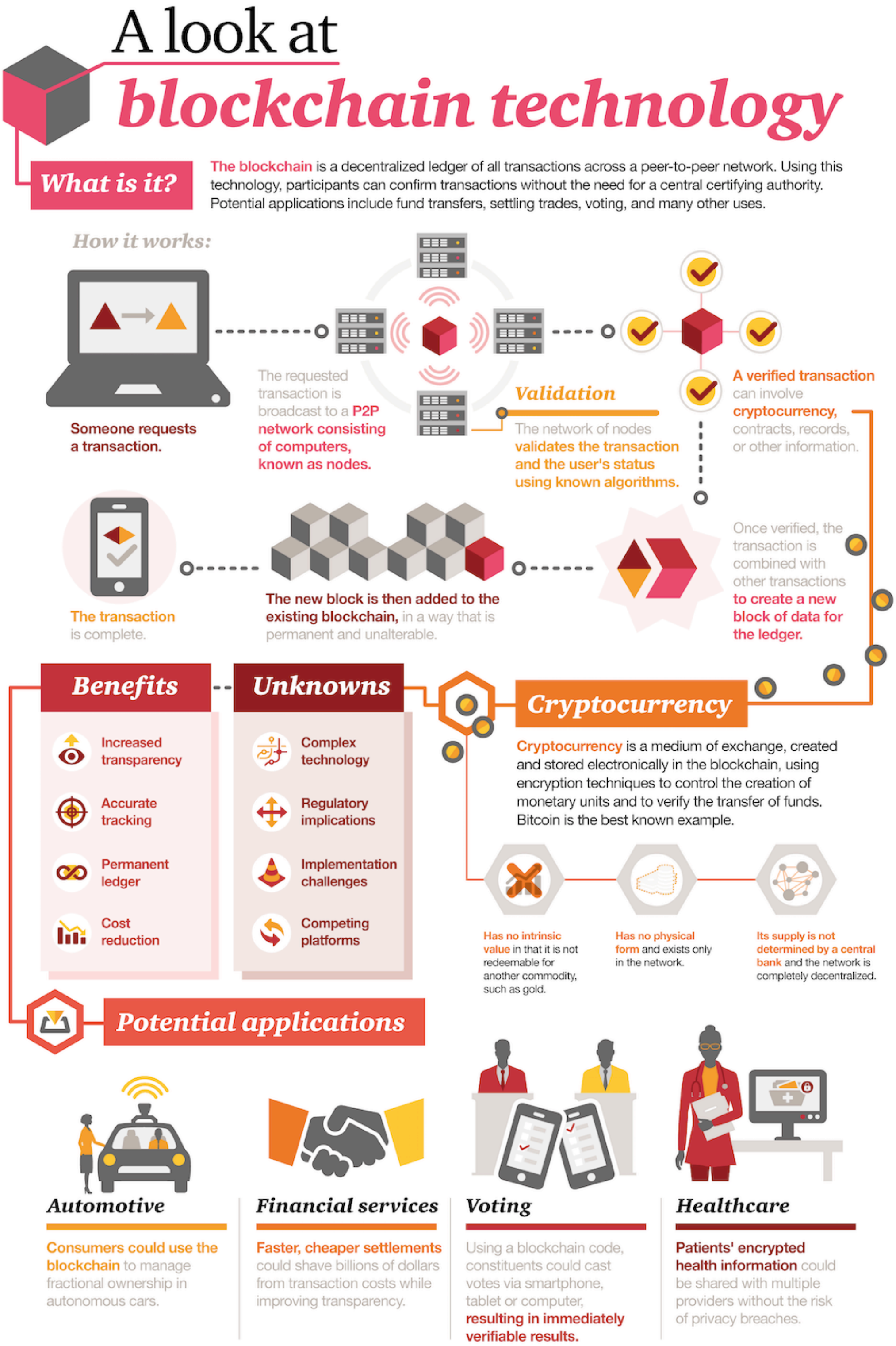
Using the blockchain makes it possible to prove integrity of electronic files easily. One approach is to generate a hash string of the file. That hash string represents the digital fingerprint of that file. Next, that fingerprint is immutably timestamped by writing it into the Blockchain via a transaction.

Permissioned vs fully decentralised blockchains

Permissioned blockchain networks allow the network to appoint a group of participants in the network who are given the express authority to provide the validation of blocks of transactions. Or, to participate in the consensus mechanism. The second primary difference between a properly conceived permissioned blockchain network and an unpermissioned blockchain network is whether the participants in the network have an ability to restrict who can create smart contracts (if the blockchain node is logic optimized) and/or transact on the blockchain network.

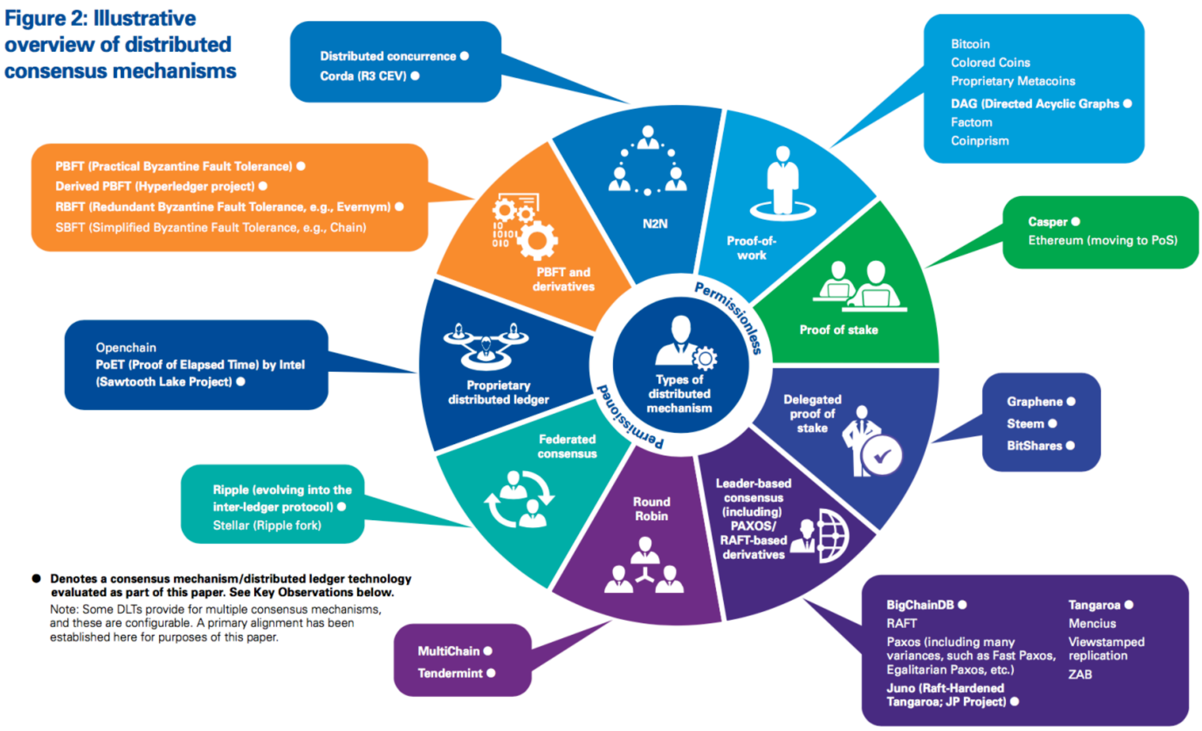
8.4 Appendix D: Example and Illustration of the Blockchain Technology

Source: **PwC, 2016**: *Making sense of bitcoin, crypto currency, and Blockchain*, February 2016; Available at: https://www.pwc.com/us/en/financial-services/fintech/bitcoin-blockchain-cryptocurrency.html



8.5 Appendix E: Consensus Mechanisms

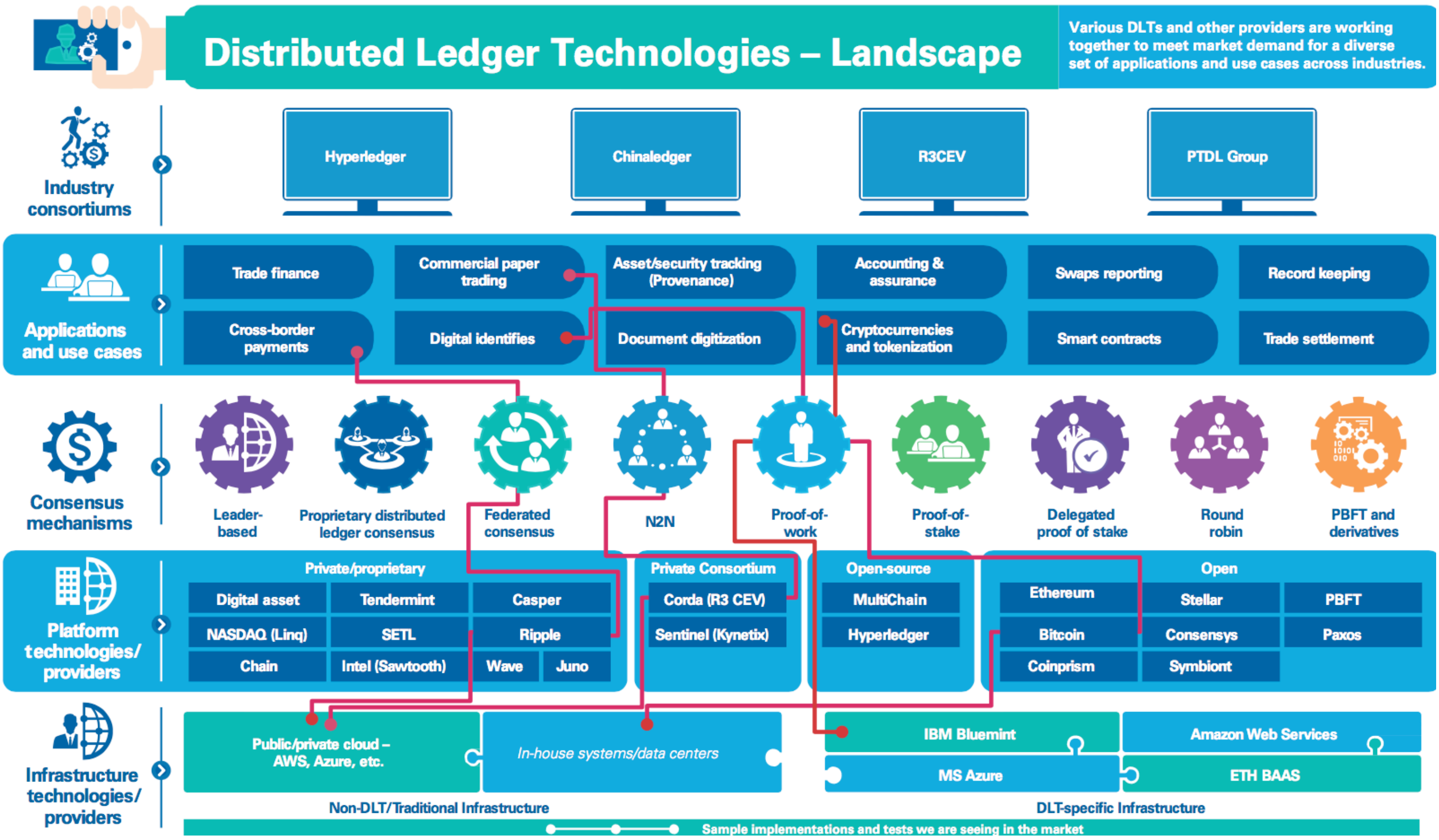
Source: KPMG, 2016 (a): *Consensus, immutable agreement for the Internet of value*; Available at: https://assets.kpmg.com/content/dam/kpmg/pdf/2016/06/kpmg-Blockchain-consensus-mechanism.pdf



8.6 Appendix F: Distributed Ledger Technologies – Overview

Source: KPMG, 2016 (a): *Consensus, immutable agreement for the Internet of value*; Available at: https://assets.kpmg.com/content/dam/kpmg/pdf/2016/06/kpmg-Blockchain-consensus-mechanism.pdf

Figure 4: Illustrative distributed ledger technologies



8.7 Appendix G: Multi-layered Permissioned Distributed Ledger

Source: **Digital Asset, 2016:** *The Digital Asset Platform: Non-technical White Paper,* Digital Asset Holdings, LLC, December 2016

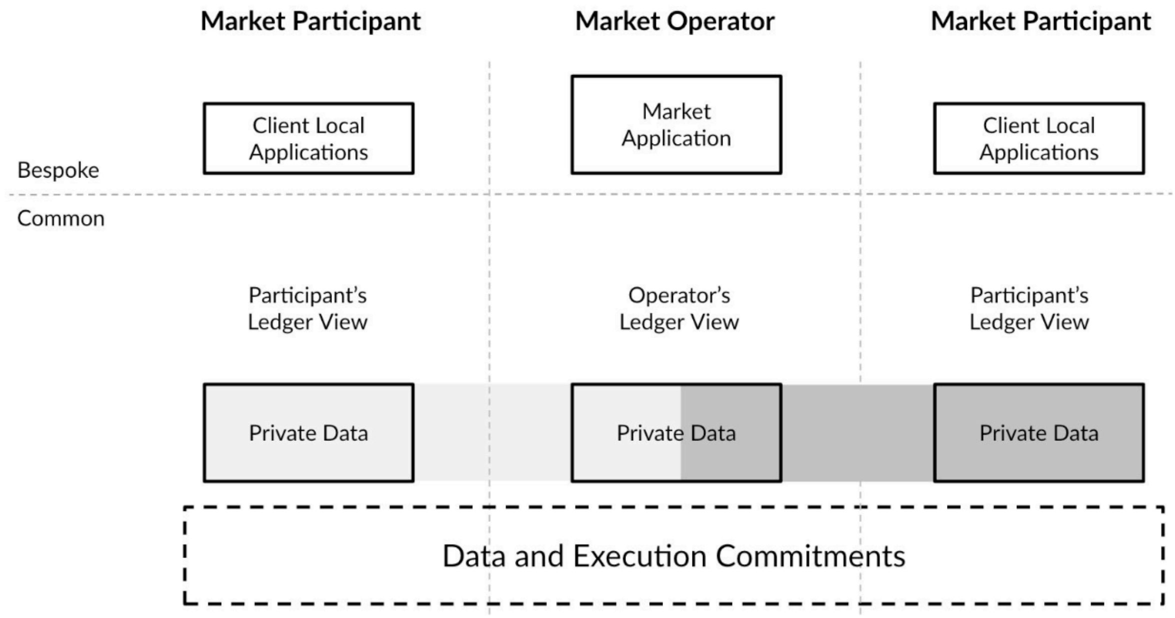
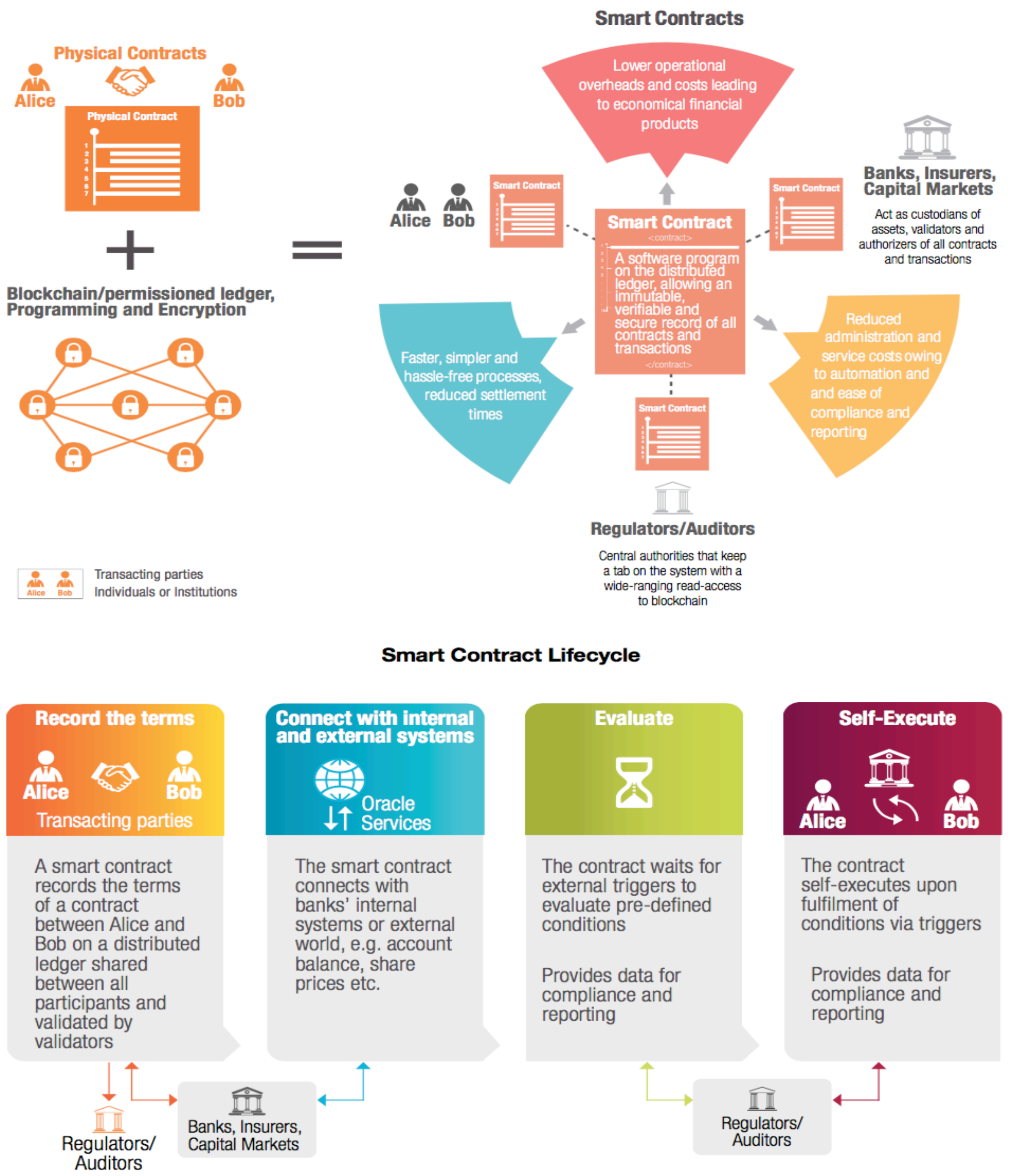


Figure 6. Synchronizing private data across a distributed network

8.8 Appendix H: Smart Contracts in a Permissioned Blockchain System

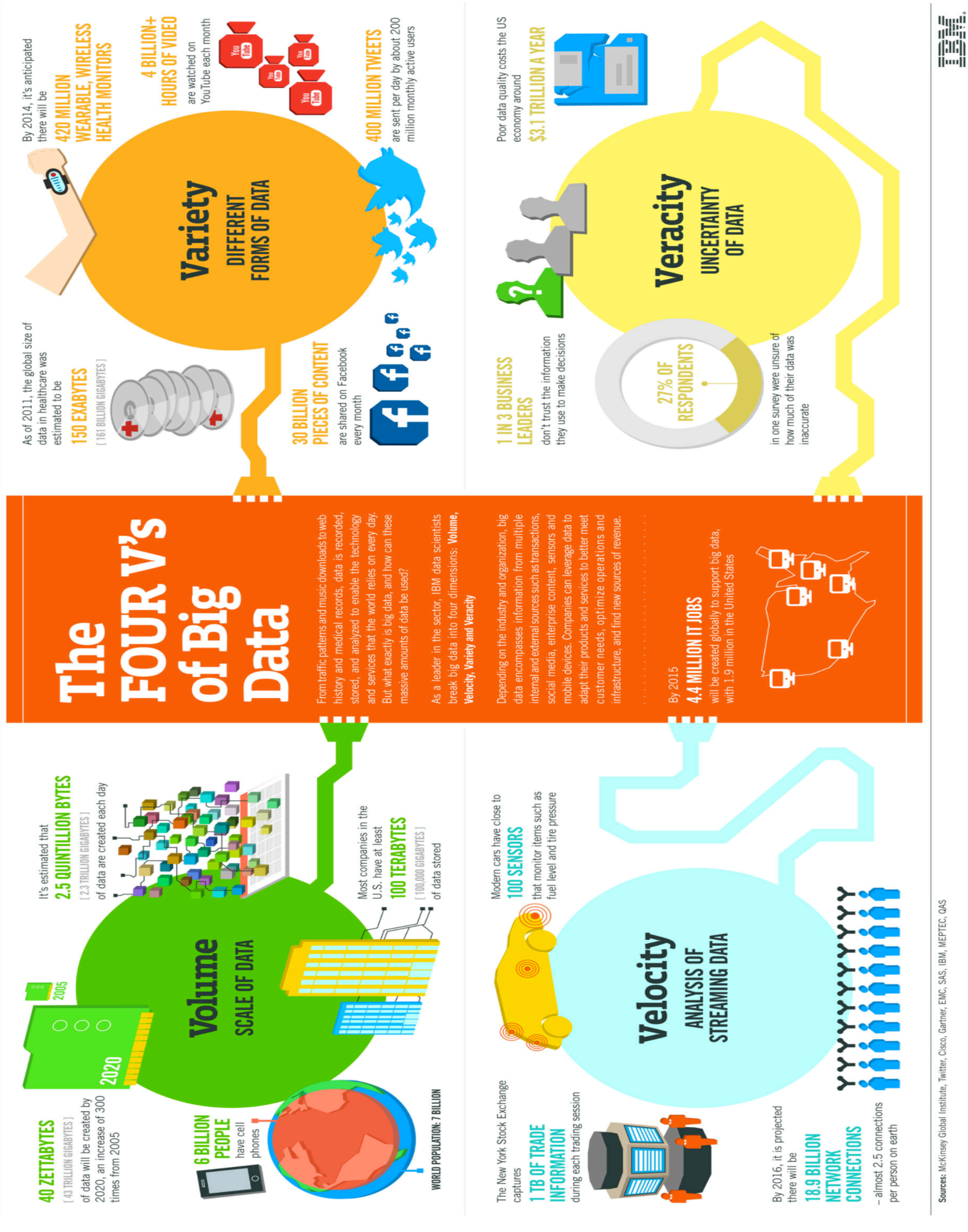
Source: **Capgemini, 2016:** *Smart Contracts in Financial Services: Getting from Hype to Reality;* Available at: https://www.capgemini-consulting.com/resource-file-access/resource/pdf/smart-contracts.pdf

Figure 2. How Smart Contracts Work in a Permissioned Blockchain System



Source: Capgemini Consulting Analysis

8.9 Appendix I: The four V´s of Big Data (Source: IBM, 2012)



8.10 Appendix J: Transaction Process with Blockchain Technology

Source: Adapted from Deloitte, 2016 (d)