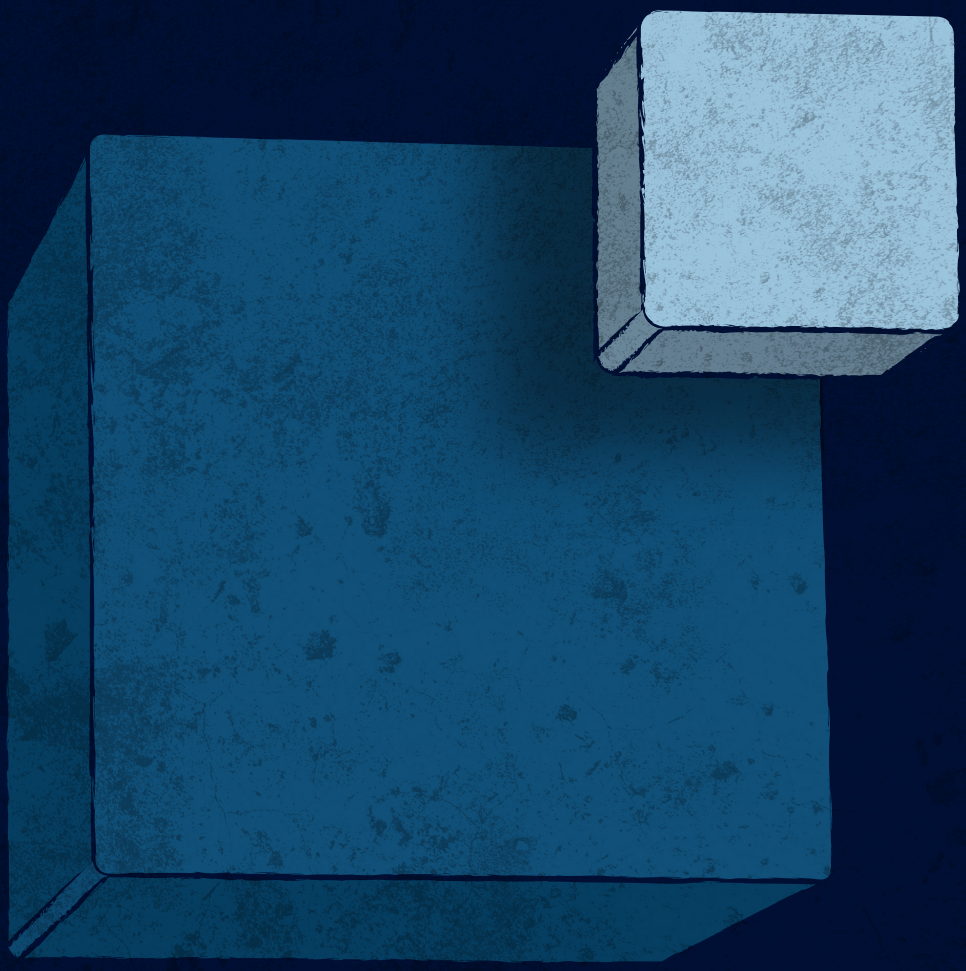
AN EVALUATION OF TECHNOLOGIES TO IMPROVE AUDITING

Eric Mantelaers



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On the Shoulders of Giants

"We are like dwarfs on the shoulders of giants, so that we can see more than they, and things at a greater distance, not by virtue of any sharpness of sight on our part, or any physical distinction, but because we are carried high and raised up by their giant size."
-Bernard of Chartres, French philosopher of the 12th century

Although Peter Graham attributes the phrase 'on the shoulders of giants' to a letter from Isaac Newton to Robert Hooke in 1676, the essence of the phrase has been around for a lot longer.

Bernard of Chartres (a French philosopher of the 12th century) and Didacus Stella (a theologian in the 16th century) are both quoted as using the phrase.

Perhaps the most poignant example, however, dates from a 1651 document, where George Herbert (a Welsh poet, author and priest) states that 'a dwarf on a giant's shoulders sees farther of the two'.

The whole idea of the concept is that modern developments, whether in science or brass playing, owe their existence to the pioneering work of our predecessors, whose devoted work put us where we are today.

In Graham's piece, the giants on whose shoulders the 'dwarfs' stand include the brass section of the Chicago Symphony Orchestra (to which Adolph Herseth and Arnold Jacobs belonged), Miles Davis and Tommy Dorsey of the jazz movement, and the various world-renowned soloists of the Sousa Band.

Finale from On the Shoulders of Giants by Peter Graham. World premiere by The Cory Band, conductor Robert Childs.

Preface

When I started working at an accountancy firm in 1988, I immediately started my accountancy training. In 1996, I graduated as a Registered Accountant (RA). Over the following years, I graduated as an Accountant-Administration Consultant (AA), as a Certified Information Systems Auditor (CISA), and as a Chief Information Security Officer (CISO). When I graduated as a Registered Accountant, the then director of the accounting course at Maastricht University, prof. dr. Roger Dassen RA, invited me to join the teaching staff. I accepted, and – with great pleasure – still teach here to this day.

Although the first years of my working life were mainly focused on learning the audit profession, I became particularly interested in the professional techniques used in auditing early on. My interest in these professional techniques, coupled with the passion with which I fulfill my role as a lecturer in accountancy, led to me starting my PhD research in 2011. Initially I was supervised by prof. dr. Ad Kil at Nyenrode Business University, and, when he retired, I switched to prof. dr. Gerard Mertens of the Open University.

In 2015, I became a researcher in the Future-proof Financial Research group of Zuyd University of Applied Sciences. I already knew this university of applied sciences quite well, as I had studied there myself. Moreover, after graduating as a registered accountant, I taught for a number of years at the evening HEAO. Since it was established, the Academy of Financial Management has resided in three locations in Sittard: 1) Limbrichterveld, 2) Havikstraat and 3) De Ligne. I am proud to have studied and / or worked at all of these locations. From the moment I returned to the Academy of Financial Management in 2015, and I got to know Martijn Zoet better and better, my PhD process got a huge boost.

My experience has taught me that - in the world of brass music - it is very important to work closely together. A soloist can only give an excellent performance when the others provide adequate support and follow and accompany in a flexible way. You may have heard of the well-known piece of work by Peter Graham, “On the Shoulders of Giants”. I see scientific research in much the same way; we always build on the work of others.

Although one person gets most of the credit, many people in fact contribute to a dissertation. My thanks go to everybody who made this PhD study possible. In particular, I would like to thank several people personally. First of all, I would like to thank my co-promotor Martijn Zoet for his insights and encouragement during this process and for answering dozens of questions. I appreciate the fact that he was always

patient. Our cooperation nowadays is not only centered on the supervision of my PhD. George Watson once said: "If you can find someone to say you are wrong and why you are wrong; you have found a friend.". In Martijn, I have found a friend.

Next, I would like to thank my first promotor Gerard Mertens and my second promotor Johan Versendaal for providing me with the opportunity to conduct this research and helping me to realize my scientific ambitions.

RSM Netherlands accountants, the firm I joined as an audit partner in 2010, supported and encouraged my intrinsic desire to pursue a PhD program. In a very natural way, I was able to combine my role as an audit partner and head of the Professional Practices Department at RSM with both of my positions at Maastricht University and Zuyd University of Applied Sciences. I am very grateful to my colleagues at RSM. Since I cannot personally name the 550 colleagues here, I must limit myself to a number of my direct colleagues: Leo van Wersch, Peter Janssen, Wilfred Castricum, my colleagues from the Department of Professional Practices, Martine Nuis, Pim van Batenburg, the management assistants Mandy Goffin and Patricia Irik, and all my colleagues from the RSM location in Heerlen. Furthermore, I am sincerely indebted to all my customers and relations at RSM.

Martijn Zoet in particular has introduced me to the ins and outs of the research world. In addition to the factual research, he also introduced me to the world of scientific conferences. I have been to conferences with him several times - also with Koen Smit, who, among others, has always lent me a listening ear.

My thanks go to everybody at Zuyd University of Applied Sciences. This includes colleagues from the research group Future-proof Financial, as well as colleagues from the Academy of Financial Management. In addition to all my other colleagues, I would like to express my appreciation to the following individuals personally: Dries Lodewijks, Diana Wetzels, the members of our research group (especially Rob Jacobs who is also on a PhD journey), Barry van der Ven, Twan Schevers, Maik Beuken, Kees van Berkel and Karin Dassen.

My thanks also go to my colleagues at the Department of Accounting and Information Management (AIM) of Maastricht, especially Roger Meuwissen, all of my fellow teachers and all colleagues of the secretariat, Elize Teeuwen, Sacha Bruinen, and Sabine Galama, and of course all of the students I worked with.

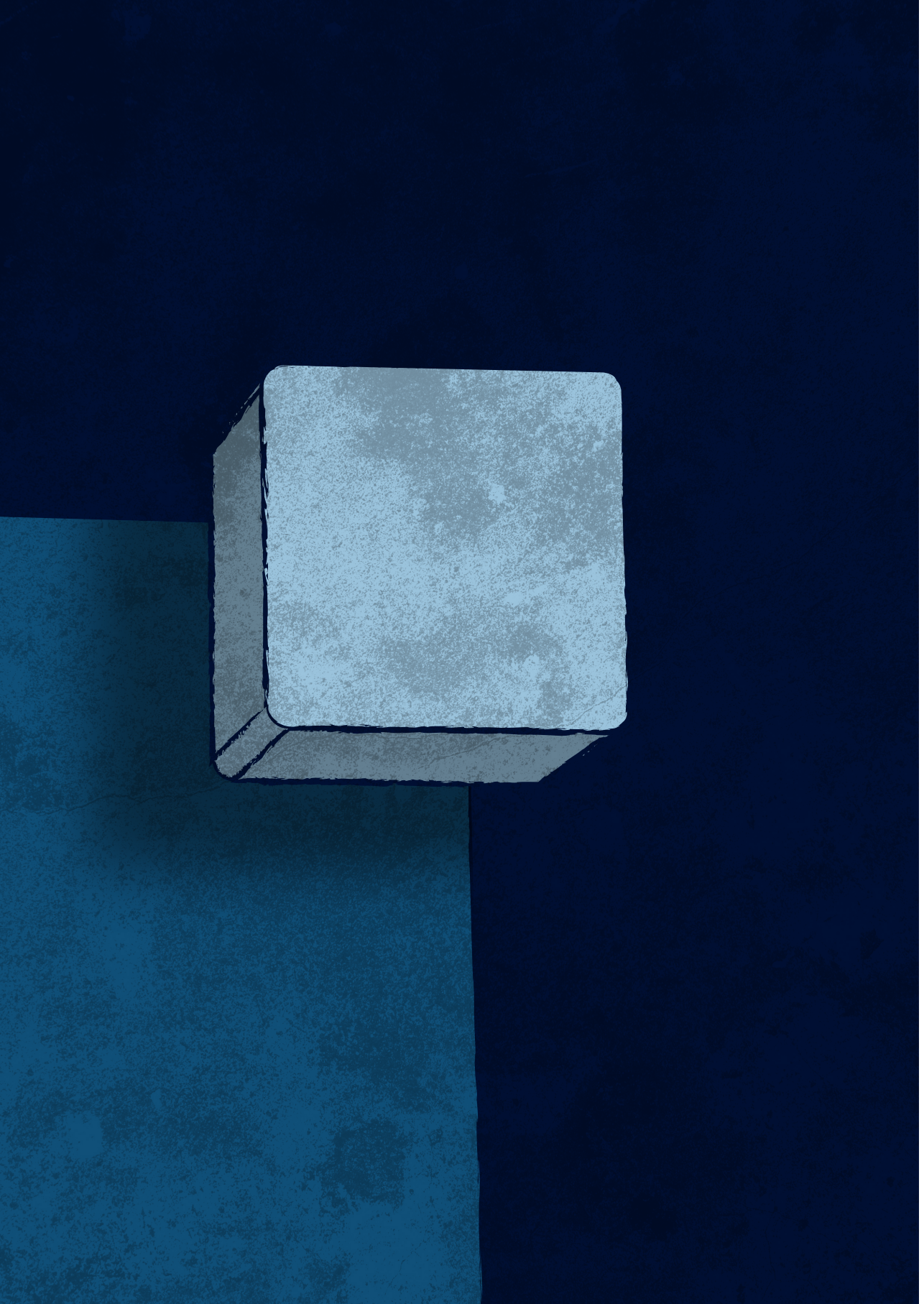
I would also like to recognize my fellow EDP classmates from the very beginning, particularly Tanja de Jonge, Marian Dragt, Wilbert Snoei, Scott Allen Mongeau, Peter Verbaas, and Ali Fenwick.

Furthermore, I would like to express my gratitude towards the reading committee, prof. dr. Buijink, prof. dr. Meuwissen RA, Prof. dr. Mulder, and prof. dr. Vasarheyli, for their dedication during the final stages of my PhD. I would also like to express my gratitude to the anonymous reviewers who were involved in reviewing the individual papers that are incorporated in this dissertation. In that respect, I would also like to thank the various co-authors of these articles. Also indispensable in the realization of this dissertation were the respondents of surveys and the organizations that provided data. Thank you for your cooperation and invested time in contributing to my research. You gave me the opportunity of validating my findings in practice and provided me with valuable new insights. Thanks to all, thank you very much. This dissertation could not have been finished without the support of my family and friends. I would like to thank you for putting up with my weird schedules, and for your interest in my research. Also thank you for the many distractions when I needed them most. My dissertation was finalized during the last two quarters of 2020. Since this coincided with the outbreak of the Coronavirus, I will not forget the year 2020 for several reasons.

I give a very special thanks to my friends Hub Steins, Paul van Birgelen, and Hub Westhovens. I am very proud of and grateful to my two Para-nymphs, my godchild Auke Steins and our son Benoît Mantelaers.

Finally, I would like to thank my beloved parents, Jeanne and Jef, my wife Désirée, and our son Benoît who have all supported and encouraged me throughout the years. Thank you for providing me with everything I needed to make my studies possible.

Contents



Chapter 1

Introduction

This dissertation is motivated by an intrinsic desire to gain a better understanding of the impact of technology on auditing. In this chapter, we first explain the origins of auditing and the need to focus on this (see Section 1.1). We then focus on the impact of technology on auditing (see Section 1.2). In Section 1.3, we discuss how to categorize technologies that influence the auditing process. In Section 1.4, we present our overall research questions. Finally, we provide an overview of the dissertation (see Section 1.5).

I. Auditing

Auditing is the process of providing assurance about the reliability of the information contained in financial statements prepared in accordance with generally accepted accounting principles (Knechel, 2001). The origins of auditing can be traced back to the ancient empires of Egypt, Greece, and Rome, in which auditing arose as a tool to ensure that public officials carried out their responsibilities to serve the empire as opposed to enriching themselves and abusing their authority (Flesher, Previts, & Samson, 2005). Historical texts that reference auditing often start with a discussion of the 1929 stock market crash, or with the British Companies Acts of the nineteenth century. In the Netherlands, the practice of auditing can be traced to the Pincoffs affair in the late 1870s. In the aftermath of this financial scandal, the first Dutch accountancy (accounting) firm, "Confidentia", was established in 1883. Unfortunately, the Pincoffs affair was not the only - and was certainly not the last - financial scandal to hit the corporate world. Many other examples of financial mismanagement involving a lack of audit quality can be found, including Enron (2001), Worldcom (2002), American International (2005), Lehman Brothers (2008), Bernie Madoff (2008), Carillion (2018), Gupta (2018), and Steinhoff (2019). However, an unambiguous and consistent definition of audit quality is still lacking in the literature.

In the past, several studies have shown that the deployment of technology (to automate parts of the audit process) has had a positive effect on audit quality (Vasarhelyi, 1983; Manson et al., 1998; Dowling & Leech, 2007), this relationship will be further explored in Section 1.2.

II. The impact of technology on auditing

A great deal of emphasis has been placed on maximizing the dual aspects of audit quality: independence and expertise (DeAngelo, 1981). Since independence and expertise are often treated as orthogonal constructs (Knechel, 2016), there is a general

belief that they can both be simultaneously maximized if the profession can simply get the right processes in place based on an evolving set of "optimal" standards, regulations, policies, and procedures (Knechel, Thomas, & Driskill, 2019). The search for consistent results and consistent audit quality in general has resulted in a renewed interest in the use of technology by audit firms and standard setters (IAASB, 2017). From an auditing perspective, multiple tasks can be partly or fully automated. Examples of such tasks include reconciliations, internal control testing, and test of details. As a consequence of automating these kinds of tasks, more resources can be allocated to aspects of auditing that require human involvement (Moffitt, Rozario, & Vasarhelyi, 2018). This renewed interest in technology has been coined "Audit 4.0". Dai & Vasarheyli (2016) illustrate the impact of "Audit 4.0" on the auditing profession from four perspectives: standards, principles, technology, and auditors. As smart organizations collect and integrate accounting and other audit-relevant information throughout the entire value chain, auditors can utilize those data and functions to facilitate monitoring and controls of accounting data flows within an organization, sharing accounting information among related parties, performing predictive and preventive audits, and eventually achieving close-to-real-time assurance, enlarging audit scope, and improving quality (Dai & Vasarhelyi, 2016).

III. Categorizing technologies used in the audit process

Dai and Li (2016) and Dai (2017) have proposed a framework to plot and evaluate technologies that can be used to improve audit quality. This model comprises the following dimensions: 1) assertion, 2) business cycle, 3) audit stage 4) risk level, 5) data, 6) data analytics technique, and 7) user. Our study adopts this framework but proposes two changes. The first change concerns the name of the dimension: "data analytic technique". Although a practical emphasis is currently placed on data analytics, the field of technology is much broader. Therefore, in our study, in place of data analytic technique, we refer to the dimension **technologies**. The second change concerns the user-related dimensions. Dai (2017) identified three different users of audit technology, namely: 1) external auditors, 2) internal auditors, and 3) fraud specialists. Since it is possible to identify even more stakeholders, we have expanded the interpretation of this dimension. In accordance to Luburić et al. (2015), Luburić (2017), and Dominova et al. (2019) we use: first, second, third, and fourth line of defense. In summary, then, our Technology Framework for Auditing consists of the following seven dimensions: 1) assertion, 2) business cycle, 3) risk level, 4) audit stage, 5) data, 6) technology, 7) users.

The first dimension relates to **assertion.** An assertion can be defined as "the concern of auditors of particular system faults" (Bumgarner & Vasarhelyi, 2018). The second dimension is the **business cycle**. Auditors currently investigate financial statements in cycles (Arens, Randal, & Beasley, 2012). In order to facilitate the auditing process, particular technologies should be linked to the cycles they are most useful (or relevant) to. The third dimension refers to **risk level**. At the beginning of an audit, auditors should assess client risks in order to determine the nature and extent of any further audit tests (Arens, Randal, & Beasley, 2012). During the audit, risk assessment remains critical because it provides a basis on which to decide the type (and number) of technologies to be used in the remainder of the audit. High-risk business processes would need audit technology with more sophisticated functions and require much more analytical tests than less risky processes. Due to the focus of our research, we have not investigated the impact of technology on risk levels or the business cycle.

The fourth dimension refers to **audit stage**. Each audit stage is comprised of different tasks and therefore has unique demands in terms of the appropriate technology that should be used. For example, at the planning stage, auditors may use technology to identify high-risk business processes. However, in order to perform substantive tests, auditors require technology that can test particular assertions. In order to help auditors, understand - and get the most out of – a new technology, developers should indicate which audit stage the technology has been designed for.

The fifth dimension focuses on the **data** perspective. The use of data-analytics within auditing has proven challenging for auditors (Brown-Liburd & Vasarhelyi, 2015; Dai & Li, 2016). ERP systems gather and generate financial data as well as non-financial information regarding business operations. In addition, data that are not recorded by ERP systems - such as customer telephone recordings, customers' comments from online forums, and surveillance videos - are now collected to facilitate governance and predictions (Vasarhelyi, Kogan, & Tuttle, 2015).

The sixth dimension refers to **technology** used in the audit process. Researchers are exploring the use of different techniques in auditing, e.g., the utilization of data mining or machine learning models used in fraud or anomaly detection.

The seventh dimension refers to **users.** In this dimension, the role of different users who can influence the selection of technology is considered. In our Technology Framework for Auditing, according to Luburić et al. (2015), Luburić (2017), and Dominova et al. (2019), we use: first, second, third, and fourth line of defense.

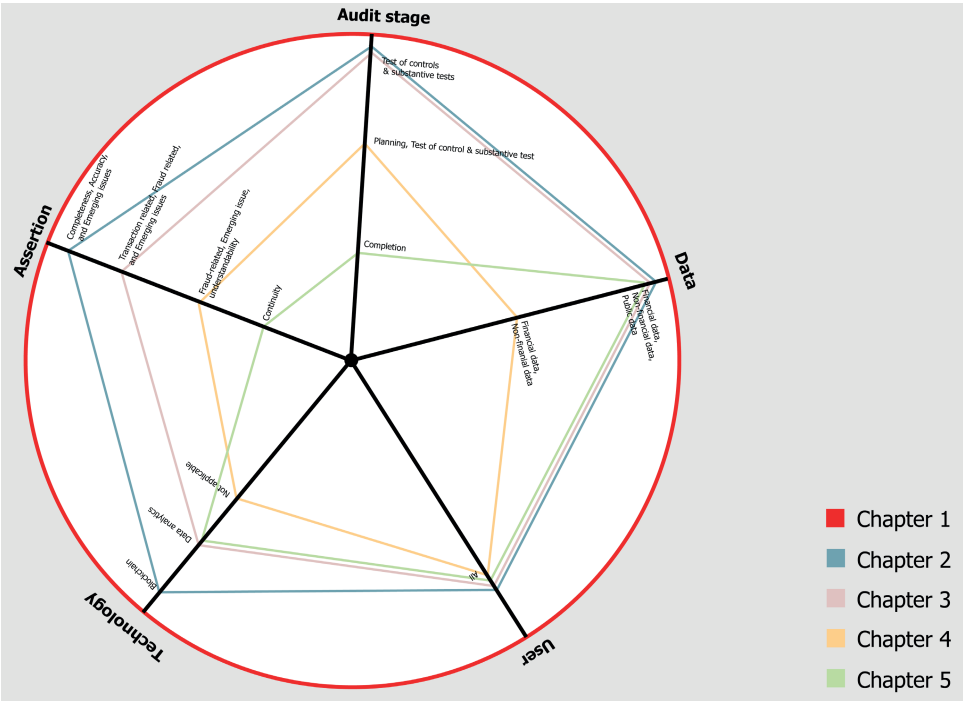


Figure 1. Technology Framework for Auditing

Table 1. Data collection

Chapter	Title	Literature review	Grounded theory	Case study	Survey	Mathematical Formalization
2	Blockchain	V		V		
3	Continuous Auditing	V	V		V	
4	Transparency	V				V
5	Financial Credit Risk Assessment	V		V		

IV. Research questions

The objective of this dissertation is to provide practitioners with a better understanding of the impact of technology on auditing. This leads to our main research question (MRQ): what are promising perspectives from technology for improving auditing? In order to answer the main research question, the relationship between technology and auditing is investigated (chapters 2 to 5).

To answer this main research question, we carried out four studies. These studies are outlined in Table 1. Building on the work of Dai and Li (2016) and Dai (2017), we propose a Technology Framework for Auditing, consisting of the following five dimensions: 1) assertion, 2) audit stage, 3) data, 4) user, 5) technology. These five dimensions are presented in Table 1, and in Figure 1 as well. Our four studies have been plotted on this framework, starting with the red circle that represents the concept of auditing. The blue pentagon is a representation of our blockchain study in which we investigated how the auditor's audit approach has changed in the blockchain era (Chapter 2). In Chapter 3, we explored ways of improving continuous auditing. This study is represented by a pink pentagon. The yellow pentagon is the representation of our transparency study, in which our aim was to identify how current design principles for business rules management add value in terms of transparency (Chapter 4). Lastly, the green pentagon visualizes our study with reference to the measurement of continuity, in which we investigated how best to categorize financial credit risk features.

In this thesis, the studies used a mix of different research methods. The research methods applied, per study as depicted in Figure 1 are elaborated in Table 1.

V. Dissertation outline

This section provides an overview of the dissertation, featuring three parts, each with corresponding chapters.

Part 1: Introduction

Chapter One introduces the research topic and outlines the scientific and practical contributions of this study. The overall research question is presented. To answer this, our studies are presented within our Technology Framework for Auditing.

Part 2: Technology

Chapter 2: The Impact of Blockchain on the Auditor's Audit Approach

In our first study, we focused on Blockchain. In this study, our aim was to find an answer to the following research sub-question: In what ways has the auditor's audit approach changed, in the blockchain era? To accomplish this goal, we conducted a study using offline experiments. In these experiments, we replaced current relationship tests with an inter-organizational ledger. From a research perspective, our study provides a starting point for further research regarding challenges that could potentially affect the work of the auditor, i.e. the development of best practices, concepts and methods in an inter-organization ledger area. From a practical perspective, our study provides a possible solution with regards to carrying out more stringent checks on the accuracy and completeness of the financial statement items.

This work was originally published as: Mantelaers, E., Zoet, M., & Smit, K., (2019). The Impact of Blockchain on the Auditor's Audit Approach. Proceedings of the 4th International Conference on Software and e-Business (ICSEB), Tokyo (Mantelaers, Zoet, & Smit, 2019).

Chapter 3: Continuous Auditing: A Practical Maturity Model

The existing body of knowledge on the application of information technologies in auditing is characterized by a predominant focus on a singular tool for a singular problem. Relatively few studies focus on a more holistic approach. Therefore, the objective of our second study was to find an answer to the following sub-question: How can the different stages and the improvement of Continuous Auditing (CA) be measured? We answered this question by developing a CA maturity model, presented in Chapter 3.

This work was originally published as: Mantelaers & Zoet (2018). Continuous Auditing: A Practical Maturity Model. Proceedings of the 12th Mediterranean Conference on Information Systems (MCIS), Corfu, Greece (Mantelaers & Zoet, 2018).

Chapter 4: An Evaluation of the Added Value of Business Rules Management Principles to Transparency

Business decisions and business logic are important organizational assets. As transparency is becoming increasingly important for organizations, business decisions and underlying business logic (i.e., their business rules) must be implemented, in information systems, in such a way that transparency is guaranteed as much as possible. Based on previous research, in our third study, our aim was to identify how current

design principles for business rules management add value in terms of transparency. In order to do this, we used criteria from a recently published transparency framework and used these to evaluate current business rules management principles.

This work was originally published as: Smit, K., Zoet, M., & Mantelaers, E. (2020a). An Evaluation of the Added Value of Business Rules Management Principles to Transparency. In ICSEB 2019. Smit, K., Zoet, M., & Mantelaers, E. (2020b). An Evaluation of the Added Value of Business Rules Management Principles to Transparency. Journal of Advanced Management Science.

Chapter 5: The Financial Credit Risk Assessment Model: Three Perspectives
In our fourth study, our aim was to find an answer to the following sub-question: What is the best way to categorize financial credit risk features so that an integrative relationship is established between the information type applied and the information sources used? To accomplish this goal, we conducted a literature study to identify features that have been designed and applied in previous research. We then coded the features based on an a priori coding scheme.

This work was originally published as: The Financial Credit Risk Assessment Model: Three Perspectives. Mantelaers & Zoet (2018a). International Journal on Advances and Measurements, vol 11 no 3 &. 4, year 2018 (Mantelaers & Zoet, 2018a).

A New Explorative Model to Assess the Financial Credit Risk Assessment. Mantelaers & Zoet (2018b). Proceedings of the Tenth International Conference on Information, Process, an Knowledge Management (eKNOW 2018), (Mantelaers & Zoet 2018b).

Part 3: Conclusion and Outlook (Chapter 6)

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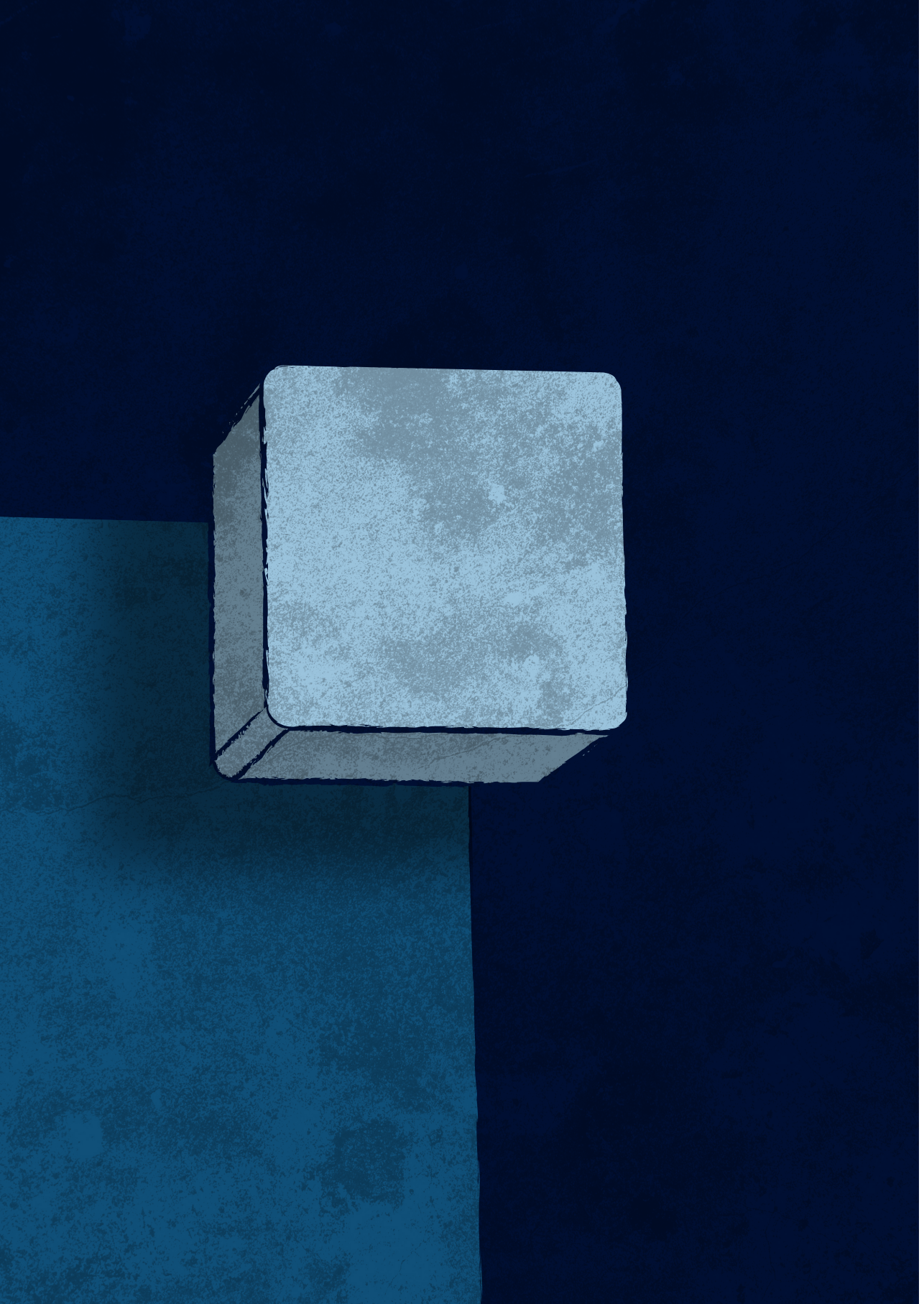


Chapter 2

The Impact of Blockchain on the Auditor's Audit Approach

I. Introduction

An audit approach is the combination of methods and techniques that auditors use in their audit assignments (Arens, Randal, & Beasley, 2012). In general, three different audit approaches can be recognized: *Before 1980* 1) substantive-based audit approach, because the audit environment was human created and used to be non-complex. *From 1980* 2) risk and system-based audit approach. *From 2014 and beyond,* auditors use 3) data-enabled auditing (Ajao, Olamide, & Ayodejitemitope, 2016). Technological breakthroughs bring new powerful insights and new evidence gathering possibilities. The amount of experience with electronic data retrieval by using data analytics and computer-aided audit tools (CAATs) is increasing, resulting in full population auditing. Each of the previously mentioned audit approaches is based on double-entry bookkeeping. However, double-entry bookkeeping has some inherent weaknesses concerning the completeness and accuracy of the financial statements. A technological breakthrough which has the potential to solve these limitations is blockchain. Blockchain has been introduced in 2008 by Nakamoto (2008): *"A purely peer-to-peer version of electronic cash would allow online payments to be sent directly from one party to another without going through a financial institution."*. Because the audit environment changes significantly as a result of new technological developments, it is necessary to get insight in the desired audit approach in the blockchain era. Therefore, the following research question has been developed: *In what way does the auditor's audit approach change, in the blockchain era?*

II. Literature review

The primitive mechanism of transaction and business activity recording is single-entry bookkeeping. Firms using the single-entry approach are effectively limited to reporting on a cash basis. To improve the accuracy of the bookkeeping system, traditional financial accounting is based on a double-entry system, according to Pacioli, who published in 1494 his book Everything About Arithmetic, Geometry, and Proportion in which he included a chapter on double-entry bookkeeping. He explained that it is to give information about assets and liabilities. This system enables confirmation that the transaction has been entered correctly (Sangster, 2016). Firms using the double-entry approach report financial results with an accrual reporting system. Today, double-entry bookkeeping is still being taught, following the principles set down by Pacioli, and all manual and computerized accounting systems owe much of their processing logic to the principles and processes he described. The single-entry approach contrasts with

a double-entry system, in which every financial event brings at least *two* equal and offsetting entries. One is a debit (D) and the other a credit (CR). The double-entry system can reduce the risk of human documentation error, such as accidental deletion of transactions, but it does not provide comprehensive assurance for companies' financial statements.

Although auditors serve as third-party examiners who perform a series of tests on organizations' accounting records and provide their opinions on the accuracy and completeness of the financial statements, improvements on the existing reporting and assurance system are still needed (Dai & Vasarhelyi, 2017). The triple-entry system is proposed to be utilized as an independent and secure paradigm in order to improve the reliability of companies' financial statements. Building on the double-entry accounting method as discussed in the previous paragraph, an audit approach based on the blockchain paradigm is proposed (Chedrawi & Howayeck, 2018) (Mahbod & Hinton, 2019).

Depending on the level of detail, the traditional audit approach described by different researchers show many similarities, with only the number of sub-phases varying (Abdolmohammadi, 1999) (Sweet, 2016). A three-phase variant is, for example: 1) Planning, 2) Fieldwork & Documentation, and 3) Reporting & Follow-up. Another separation of tasks can be as follows: 1) Engagement Acceptance, 2) Planning, 3) Risk Assessment, 4) Response to Assessed Risks, 5) Evaluation, and 6) Opinion. Arens et al. (2012) describe a four-phases audit approach: 1) Plan and design an audit approach, 2) Perform tests of controls and substantive tests of transactions, 3) Perform analytical procedures and tests of details of balances, and 4) Complete the audit and issue an audit report. Although the number of phases used in practical audit approaches and in literature differs, the content is comparable. This is not remarkable, because all audit approaches have to be based on international rules (Arens et al., 2012), being the International Standards on Auditing (ISAs). Within the traditional auditing process, the financial statements must be checked in such a way that the justification gives a true and fair view. Depending on the possible interests and tendencies of the audited company, a number of audit objectives have been appointed within the accountancy, namely: Completeness (C), Accuracy (A), Valuation (V), Existence (E), Cut-off (C), Obligation & Rights, (O), and Disclosures (D) (acronym CAVECOD) (A. Arens et al., 2012). Traditional audits exist out of a yearly review of the internal organization (interim audit) and a year-end audit, in which the accounts have been checked (Defond et al., 2013).

Double-entry accounting focuses on an audit in which the movements of cash and goods are audited by means of an interim audit as well as a year-end audit. The

primary purpose of an interim audit is to make an assessment of the organization as a whole, whereas the primary purpose of a year-end audit is to assess the respective organization's financial statement items. This results in an auditor's report, in which the auditor provides an (audit) opinion where he claims that he can (or cannot) provide reasonable assurance that the organization's financial statements are free (or not free) from material misstatements that are either caused by error or fraud (Steckel, Manry, & Tritschler, 2014).

In the context of the audit, the auditor uses relationship tests as shown in Figure 1 (Arens et al., 2012). Performing all necessary audit procedures provides reasonable assurance that the relationships hold (or do not hold) as a whole. These procedures form a basis for making a statement regarding the reliability of the financial statements, the audit opinion. Hence, an auditor should obtain reasonable assurance that financial statements are presented both accurate and complete. Consequently, the auditor should objectively obtain and evaluate evidence regarding all balance sheet items (i.e. inventory, cash, accounts payable, and accounts receivable), as well as all items from the income statement (i.e. cost of goods sold and sales) in order to provide reasonable assurance that all items are both accurate and complete. Figure 1 shows that if all procedures are carried out, all items are tested for accuracy and completeness.

Accuracy is usually not the biggest challenge, because the population is defined. All (journal) entries contain a price and quantity (P and Q component). The price and quantity elements need both to be audited for accuracy. On the contrary, completeness is a big challenge (Arens et al., 2012). Auditors need to obtain and evaluate evidence whether the population is complete. Testing for accuracy implies that auditors need to take a sample that is inside the population. On the other hand, testing for completeness implies that auditors need to take a sample that is outside of this population. Without going into too much detail, auditors would like to emphasize that this is only possible if they can rely on the 'segregation of duties'-principle within the organization - that is people in different positions or at different departments have a conflict of interest. This is because the auditor can't assess the financial statements of the suppliers and customer of the organization. If this would be the case the auditor could rely on the 'segregation of duties' between organizations. To realize the 'segregation of duties' of duties in such a manner changes have to be made to the current practice of financial registration in the following manner: when a transaction between two organizations is conducted, both organizations have to sign off on the actual transaction. This will be illustrated with an example. Company Supplier and Company Buyer, wholesaler and retailer respectively make a transaction concerning the procurement of mobile telephones. Company Supplier sells mobile phones of different brands and in various

price ranges. Company Buyer is a retailer and a direct client of Company Supplier. At a certain point in time, Company Buyer orders a batch of mobile phones for an amount of € 10,000. While Company Supplier sells and delivers the mobile phones, company Buyer has to pay and subsequently receives the mobile phones from Company Supplier. Both Company Supplier and Company Buyer have to sign an inter-organization ledger that the telephones are received (from Supplier to Buyer) and the payments (from Buyer to Supplier) have been conducted.

A possible solution to implement this is inter-organization ledger is blockchain technology. A blockchain provides a certain level of security, by coping with the malicious behaviors of some of the participants. As a blockchain maintains records of the ownership of digital assets, malicious users are incentivized to try to tamper with these records, to change ownership. It is thus crucial to have good ways to prevent such outcomes. There have been multiple initiatives created internationally to work towards blockchain and distributed ledger technologies (DLT) standardization (Tschakert, Kokina, Kozlowski, & Vasarhelyi, 2016) (Zhang, Dai, & Vasarhelyi, 2018). Consensus is a fundamental problem of distributed computing. While this problem has been known to be unsolvable since 1985, existing protocols were designed these past three decades to solve consensus under various assumptions (Wang et al., 2019) (Cachin & Vukoli´cvukoli´c, 2017). Today, with the recent advent of blockchains, various consensus implementations were proposed to make replicas reach an agreement on the order of transactions updating what is often referred to as a distributed ledger. However, some contributions have been devoted to exploring its theoretical ramifications (Dai & Vasarhelyi, 2017) (Zhang et al., 2018). As a result, existing proposals are sometimes misunderstood, and it is often unclear whether the problems arising during their executions are due to implementation bugs or more fundamental design issues. Gramoli (2017) discusses the mainstream blockchain consensus algorithms and how the classic Byzantine consensus can be revisited for the blockchain context. While the blockchain technology is reshaping ownership tracking through distributed ledgers, it remains difficult for blockchain users to understand the guarantees this technology has to offer.

III. Research method

The goal of this study is to evaluate the impact of an inter-organization blockchain ledger on financial auditing. An appropriate research method to evaluate the usefulness, applicability and impact of a product, algorithm, method, framework or categorization, is an experiment based on 1) synthetic or 2) real-life datasets (Gerring & McDermott,

2007). First, this is because experiments based on synthetic data allow the researchers to control 1) the model, 2) the input(s), 3) the experiment setup and 4) the actual simulation.

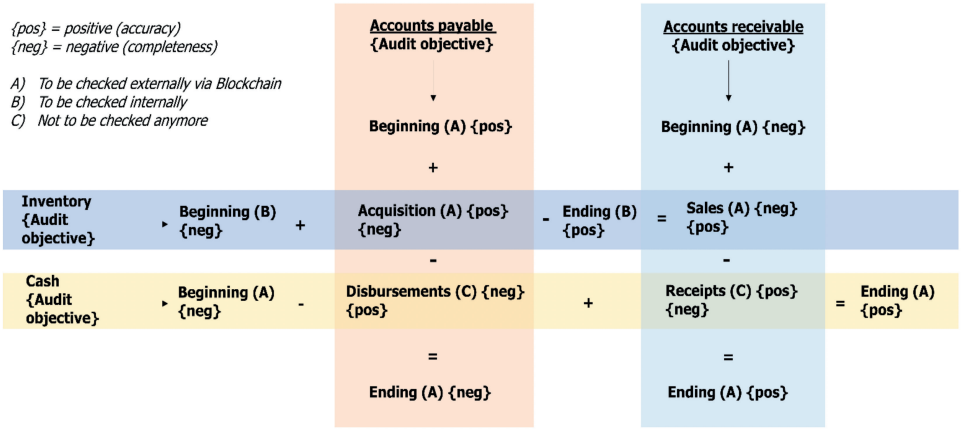


Figure 1. Representation of comprehensive relationship model.

Reproducibility and traceability are fundamental requirements for both synthetic and real-life-based experiments (Freddi & Salmon, 2019) (Dalle, 2012). To meet both requirements, researchers have to report on different aspects per type of experiment. With respect to the experiment model, researchers have to report the aim of the experiment, the purpose of the model and the model outputs (Gerring & McDermott, 2007). The data sources, the input parameters, the pre-processing of the dataset and underlying assumptions have to be reported with respect to the inputs (Wang, Zhang, Bai, & Mao, 2018). For the experimentation setup the following elements have to be reported: 1) the base model overview, 2) model logic, 3) the scenario logic, and 4) the components applied (Taylor et al., 2018) (Monks et al., 2017) (Rahmandad & Sterman, 2012). The reporting on the components mainly consist of the instruments (e.g. software or programming language), the system specification and the sampling. Lastly, the following elements of the experiment execution have to be reported: 1) the initialization, 2) the run length, and 3) the estimation approaches (Cucculelli, Peruzzi, & Zazzaro, n.d.). Each of the previously described aspects will be specified for this specific study in the next paragraphs. One synthetic dataset has been created for this study, with the purpose to assess the impact of an inter-organization ledger blockchain on the audit approach. The author of the synthetic dataset holds several titles in auditing, being Registered Accountant (RA), Accountant-Administration Consultant (AA), Certified

Information Systems Auditor (CISA), and Certified Chief Information Security Officer (C|CISO). Additionally, the dataset was checked by another researcher who holds a Ph.D. in Decision Management & Business Rules Management, and who has conducted ten years of research in this topic. The logic of the experimentation model is presented in Figure 1. For each process or object (Inventory, Cash, Accounts payable, and Accounts receivable) in the model, the traditional manner of registration will be replaced by an inter-organization ledger supported by the blockchain. After which the effect on the integrity of the entire model as well as the audit approach, including the audit objectives, are evaluated. The actual testing has been done as follows. For each process or object, the traditional registration has been translated to an inter-organization ledger after which the audit procedure has been conducted on the new situation. The actual tables have been saved in Microsoft Excel. The remainder of this experiment is performed on paper. The experiment had a run length of eight months, is predefined and tested on paper. In addition, because of a predefined business rule set, estimation is not relevant. Due to space limitations the complete logic of testing cannot be added to the paper. A snapshot of the complete logic has been added instead.

To give a proper assessment of the financial statements comprehensive relationship tests have to be performed by the auditor. These comprehensive relationship tests exist out of eight relationship tests. Four relational tests with regards to accuracy and four relationship tests with regards to completeness. These are depicted by the colors yellow, orange, dark blue and light blue. Each relationship test compares process results, for example the results of the acquisitions processes and the sales process with the inventory start balance and the inventory end balance, see Figure 1. The reasons that they have to be checked, is because currently the auditor has to take a leap of faith that the internal reporting is correct. By adding an inter-organization ledger for specific relationship tests, this leap of faith is reduced. This because both parties that are involved with the transaction have opposite interests. For example, the organization that orders the products, receives the products and pays for them. Thus, the first organization wants to receive as many products as possible for the lowest price. While the other organization wants to receive as much money as possible for the goods. In the new situation both organizations have to confirm the transaction and therefore are forced to report accurately. Therefore, with this experiment we assessed the situation that occurs when adding an inter-organization ledger for each relationship test. During the experiment we assessed this new situation for each individual relationship test.

The inventory relationship can be stated as: *"Beginning Inventory + Acquisition Inventory - Ending Inventory = Sales"*. Both sales and ending inventory are audited for accuracy (see Figure 1). In this case the auditor counts the ending inventory, the auditor is able

to obtain reasonable assurance regarding the accuracy of the inventory quantity [Q component]. The accuracy of inventory prices [P component] is verified through invoice and purchase orders. The auditor has to provide reasonable assurance that the inventory sold has been recognized in the correct period (cut-off testing). Furthermore, the auditor determines whether the prices used in revenue correspond with prices set by the management. In addition to accuracy also the completeness is audited. The completeness of inventory is commonly determined by an inventory count based on the 'floor-to-list' principle. Likewise, margin assessments can provide remarkable results. These remarkable results can provide a possible indication of an incomplete presentation of inventories. Acquisition completeness can only be determined by means of segregation of duties between employees who order, receive, and pay for the inventories. Whether an auditor can rely on an organization's segregation of duties, depends on his assessment of the organization.

After the inter-organization ledger implementation, based on blockchain, the following situation arises. By means of literally counting ending inventory (see Figure 1: B), the auditor is able to obtain reasonable assurance regarding the accuracy of the inventory quantity [Q component]. The accuracy of inventory prices [P component] is verified through invoice and purchase orders. This is similar to double-entry accounting. The accuracy and - at the same time - completeness of sales is guaranteed by providing reasonable assurance that the blockchain is reliable. Figure 1 shows that beginning inventory and acquisition are being audited for completeness. The completeness of inventory is commonly determined by an inventory count based on the 'floor-to-list' principle. Likewise, margin assessments can provide remarkable results. These remarkable results can provide a possible indication of an incomplete presentation of inventories. This is similar to double-entry accounting. The completeness of purchases (and at the same time the accuracy) is guaranteed by providing reasonable assurance that the blockchain is reliable.

IV. Analysis and results

This section presents the analysis and results of the experiments conducted. This section will describe the realization of the audit objectives, supported by an inter-organization ledger. Since in the previous section the relationship test for Inventory already has been elaborated to explain the research method, it will not be repeated in this section.

Relationship tests for Accounts Payables (accuracy)

This relation states: *"Beginning Accounts Payables + Acquisition (Inventory) - Disbursements = Ending Accounts Payables"*. According to Figure 1, both the beginning balance of accounts payable and additional (inventory) acquisitions are being audited for accuracy. The accuracy and - at the same time - completeness of accounts payable beginning balance and additional acquisitions is guaranteed by providing reasonable assurance that the blockchain is reliable (see Figure 1: A).

Relationship tests for Accounts Receivables (accuracy)

This relation states that: *"Beginning Accounts Receivable + Sales - Receipts = Ending Accounts Receivables"*. According to Figure 1, accounts receivables' beginning balance as well as sales are being audited for completeness. Whenever the blockchain application becomes usable, the receipts (see Figure 1: C) no longer need to be audited because the auditor can achieve his audit objectives by using the blockchain. The accuracy (and at the same time completeness) of the ending balance of accounts receivables is guaranteed by providing reasonable assurance that the blockchain is reliable (see Figure 1: A).

Relationship tests Cash (accuracy)

This relation states that: *"Beginning Cash - Payments + Accounts Receivables' receipts = Ending Cash"*. According to Figure 1, the disbursements as well as the ending balance of cash are being audited for accuracy. Whenever the blockchain application becomes usable, the disbursements (see Figure 1: C) no longer need to be audited because the auditor can achieve his audit objectives by using the blockchain. The accuracy (and at the same time completeness) of the ending balance of cash is guaranteed by providing reasonable assurance that the blockchain is reliable (see Figure 1: A).

Relationship tests for Accounts Payables (completeness)

This relation states: *"Beginning Accounts Payables + Acquisition (Inventory) - Disbursements = Ending Accounts Payables"*. Figure 1 concludes that both payments as well as ending inventory is being audited for completeness. Whenever the blockchain application becomes usable, the disbursements (see Figure 1: C) no longer need to be audited because the auditor can achieve his audit objectives by using the blockchain. The accuracy (and at the same time completeness) of the ending balance of accounts payables is guaranteed by providing reasonable assurance that the blockchain is reliable (see Figure 1: A).

Relationship tests for Accounts Receivables (completeness)

This relation states that: *"Beginning Accounts Receivable + Sales - Accounts Receivables' receipts = Ending Accounts Receivables".* According to Figure 1, Accounts Receivables' beginning balance as well as sales are being audited for completeness. The completeness (and at the same time the accuracy) of the beginning balance of accounts receivables as well as the sales is guaranteed by providing reasonable assurance that the blockchain is reliable (see figure 1: A).

Relationship tests for Cash (completeness)

This relation states that: *"Beginning cash - Disbursements + Accounts Receivables' receipts = Ending cash".* Figure 1 states that both the beginning balance as well as the cash receipts should be tested for completeness. The completeness (and at the same time the accuracy) of the cash' opening balance is guaranteed by providing reasonable assurance that the blockchain is reliable (see Figure 1: A). Whenever the blockchain application becomes usable, the receipts no longer need to be audited due to the fact that the auditor can achieve his audit objectives by using the blockchain (see Figure 1: C).

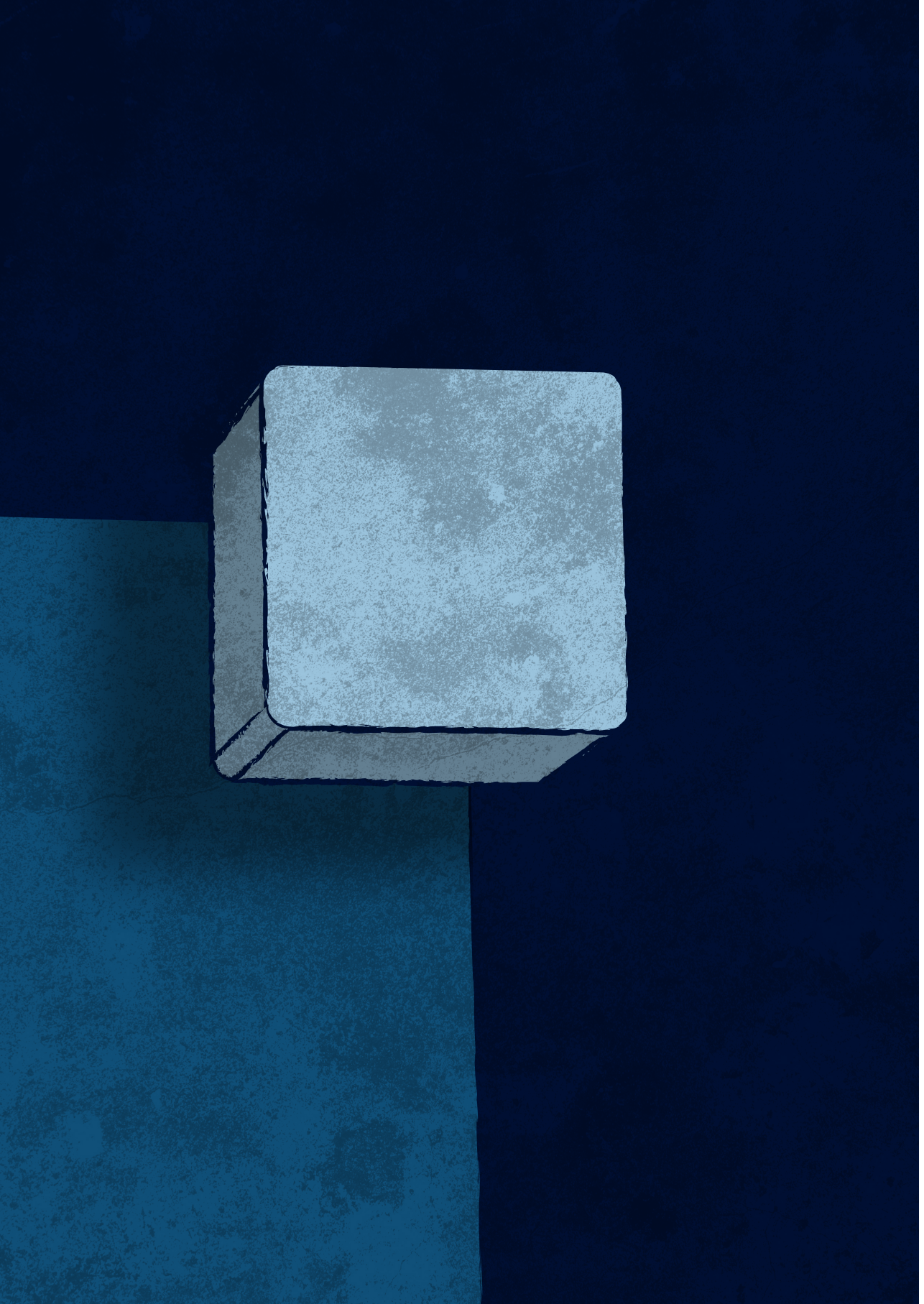
Overall can be concluded that once the reliability of the blockchain has been established, it can be assumed that the items marked with an A in Figure 1 are accurate and complete. That is, an auditor no longer needs to audit sales, opening and closing balances of accounts payables, purchases, opening and closing balances of accounts receivables, and opening and closing balances of cash for completeness and accuracy.

V. Conclusion and future research

In this chapter, we aimed to find an answer to the following research question: *In what way does the auditor's audit approach change, in the blockchain era?* To accomplish this goal, we conducted a study with offline experiments. In these experiments we replaced current relationship tests by means of an inter-organization ledger. From a research perspective, our study provides a fundament for further research regarding challenges that possibly affect the work of the auditor, i.e. the development of best practices, concepts and methods in an inter-organization ledger area. From a practical perspective, our study provides a possible solution with regards to a more stringent checks on the accuracy and completeness of the financial statements' items. Altogether, we can state that triple-entry blockchain accounting provides an opportunity for a more efficient and effective audit. The accuracy and completeness of financial statement items that

are marked with an A (Figure 1) is guaranteed by providing reasonable assurance that the blockchain technology is reliable. The items marked with a B must be audited in the same way under both double-entry accounting and triple-entry blockchain accounting.

It is important to note that the results of this study are not 1-to-1 generalizable for lessons learned as well as the implementation of practices regarding blockchain-based triple-entry accounting in other cases. Also, the results of this study do not aim to be a complete understanding of auditing in a blockchain environment. Our approach allowed the research team to learn and formulate what can be learned from a comparison of auditing the double-entry accounting system and the blockchain-based triple-entry accounting system, which resulted in three limitations. First, each organization has to agree to the fact that an inter-organization ledger is created between their organization and customers and suppliers. Second, the blockchain and smart contract applied must be technologic sound. Since blockchain is still a human creation, solutions can be fallible and corruptible. This has to be checked before implementing. Lastly, fraud can still occur when each of the organizations in the supply chain collaborate with each other. Of course, as is true with all research, our results are subject to interpretation and are limited to the data available. In our study, we draw our conclusions based upon an experiment. However, future research should be conducted to the real-life possibilities of this technique. Taking into account the limitations of our study and its results, we argue that studies with the goal to implement the described techniques. Another direction for future research is the consequences for the auditing education and for other desired capabilities. Lastly, the research could be extended towards a maturity model with reference to the possibilities of auditing in a blockchain environment.



Chapter 3

Continuous Auditing: A Practical Maturity Model

I. Introduction

Auditing practices have changed from full population auditing to sampling and risk-based approaches. In recent years discussion existed to change back to full population auditing. This is caused by two reasons. First, the evaluation of information technologies allows for full population auditing, and secondly, the corporate scandals that have occurred, ask for it. However, not only the information technology with respect to auditing has advanced, the same applies to the information technology used by their clients. Researchers find that the adoption of technology by the organizations increases at a faster pace than the adoption by the auditing firms. One reason for this is that auditing firms and accountants apply older information technology in their audits and lack knowledge about newer technologies. The lack and knowledge about data and systems as well as the application of older questions raises questions about a holistic approach.

A holistic approach to auditing is continuous auditing. Continuous auditing (CA) is defined as (CICA/AICPA, 1999): *"a methodology for issuing audit reports simultaneously with, or a short period of time after, the occurrence of the relevant events."* (Byrnes et al., 2012). This can only be realized by auditing directly on source data or on derived data. Therefore, an important competence to realize CA is the IT capability. However, it's not the only capability because people and processes also need to be in place. Although previous research on CA has been conducted. Only a few studies have been conducted on the performance of CA. Performance (classification in a certain maturity level) is often measured by the utilization of maturity models. Maturity models enable organizations to assess their current situation and provide handholds for improving their situation. An example of a maturity model is the Capability Maturity Model (CMM) proposed by Paulk et al. (1998). The CMM was originally developed to support organizations in improving their software process, but the success of the model made that different versions of the model appeared to suit other disciplines as well. Several maturity models are known in the IT domain. In order to make organizations more suitable for the introduction of CA, we started working with a number of experts on the basis of existing maturity models. Based on literature research in the area of CA, and on the basis of existing maturity models, we have organized knowledge sessions together with experts from the pension sector. This research project aims toward the development of a holistic and practical CA maturity model, which facilitates the assessment of CA capabilities. To construct the model mentioned above, the following research question is formulated: *"How can the different stages and the improvement of continuous Auditing be measured?"*

The remainder of this chapter proceeds as follows. The next section, section two, summarizes the topics that are related to this research. First the general state of auditing is explained, after which the state of information technology for auditing is described. After this the relation between the two is explained. Section three describes the research approach applied for the development of the CA maturity model. In section four, the data collection and analysis are described. The actual maturity model is described in section five. Finally, this chapter concludes with section six where the conclusions, limitation and further research are described.

II. Literature review

One of the main objectives of auditing is to provide an independent examination of an organizations financial, and non-financial, statement to determine if they present a fair view of the organization's status. This demands the need for correct and timely financial information. The manner in which this information is collected and analyzed has changed over the last decades (IAASB, 2013). During the first period (pre-1980) there were relative small data populations and auditors analyzed the full population, without sampling. During the 80's up to till 1995 the size of the datasets increased, and the concept of sampling was introduced. Additionally, new Computer-Assisted Audit Techniques (CAATs) were developed and existing CAATs were further developed. In auditing literature this time period is called a substantive based approach which is followed by the risk-based approach from 1995 to 2002. In this time period the data became more complex and audits became largely systems based and less focus was put on detailed testing. Auditors put more focus on manual, automated and information technology (IT) dependent controls and IT general controls (ITGCs) as well. Additionally, the second part of the risk-based period (2002-2014) is characterized as a more balanced top down risk-based audit approach, in which there was a development of substantive testing for all major balances and transactions. The current period, from 2014 till the present day, is called data enabled auditing in which the focus again is on testing the full population based on new and existing data techniques.

The application of data techniques is not new in auditing. In their research Thomas Lin et al. (1979) proposed among others 1) the utilization of pattern recognition techniques in the identification of abnormal trends in audit data and 2) the utilization of factor analysis for the analytical review process. Since then multiple different techniques are proposed to support the auditor to provide an independent examination of an organizations financial, and non-financial, statements to determine if their present a fair view of the organization's status. Examples of such technologies are: CAATs (Sayana,

2003), Data Analytics (Cao, Chychyla & Stewart, 2015) (Earley, 2015), expert systems (O'Leary & O'Keefe, 1997), decision aid (Dowling & Leech, 2007), Generalized Audit Software (GAS) (Kim, Kotb & Eldaly, 2016), on-line auditing systems (Van der Aalst et al., 2011), predictive business analytics (Good & Guidance, 2011), and prescriptive analytics and real-time audit mechanism based on compression techniques (Li, Yen & Chuang, 2016).

CAATs is an umbrella term for individual tools that support the auditing process. Examples of CAATs systems are 1) tests of details of transactions and balances, 2) analytical review procedures, and compliance tests of IT (information technology) general controls (Tuttle & Vandervelde, 2007). An additional umbrella term is Online Auditing Tool (OLAT) (Van der Aalst et al., 2011). An OLAT is a collection of continuous monitoring tools connected to the organization's information system but is not a part of it. In addition auditors also tried the implementation of expert systems (ES) in accounting, auditing and tax (Michaelsen & Messier Jr., 1987). An expert system is a set of techniques and methods for building systems that support, augment or automate decision making. However, research has not systematically examined issues that lead to improvement in problem solving or the impact of ES on supervision. Each of the previous described technologies are a separate part of a Continuous Control Monitoring System. In addition, previous research primarily has focused on expected benefits derived from the technology and "conventional wisdom", rather than the impact on organizational roles (O'Leary & O'Keefe, 1997). Technological changes and audit firm mergers over the last decade raise the question as to whether the decision aids reported in prior research are representative of the types of decision support currently employed in audit firms (Dowling & Leech, 2007). This is strengthened by research of Cao et al. (2015) who state that (advanced) analytics have been wide spread, however it is hardly applied by auditors. A research conducted under Egyptian external auditors also reinforces these results (Kim, Kotb & Eldaly, 2016). These results show that the basic features in Generalized Audit Software (GAS), for example database queries, ratio analysis, and audit sampling, have a higher use than the advanced features: digital analysis, regression/ANOVA, and data mining classification. In addition, also the perceived usefulness and perceived ease is higher for the basic features than the advanced features. The analysis also supports that the use of GAS by Egyptian external auditors is more affected by co-worker, supervisor, but not by job relevance (Kim, Kotb & Eldaly, 2016). Based on this fact and the fact that only simple functions are used, raises questions about the digital skills of the auditor.

New complex financial instruments as well as the advances in information technology have renewed the attention in an concept from the 80's: continuous auditing (Vasarhelyi, 1983). Continuous Auditing (CA) is a methodology that enables independent auditors

to provide assurance on a subject matter, using a series of auditors' reports, issued simultaneously with or a short period of time after, the occurrence of events underlying the subject matter. Vasarhelyi (1983) already published the groundworks for CA in the early 80's. From this point on, two streams started to exist. Those who view CA purely from a technical perspective and those who view CA from a holistic perspective. Examples of existing CA models can be found in Flowerday et al. (2006). Li et al. (2016) present a comparison of five different Continuous Audit Mechanisms. We agree with authors that CA should be viewed from a holistic and practical perspective. Hardy and Laslett (2015) state that still limited guidance about the practicalities of CA are researched. Based on the fact that we agree that CA should be viewed from a holistic perspective and should be practical, we set out to define a holistic approach from a practical perspective. An instrument to view a topic from a holistic perspective is a maturity model (Rosemann & Bruin, 2005).

Maturity models are a well-known instrument to support the improvement of functional domains in IS (Information Systems), like software development or testing. While maturity models may share a common structure, they have to be developed anew for each functional domain (Van Steenbergen et al., 2010). According to Derriks (2012) the majority of the maturity models use a five stage maturity approach (Paulk, 1998), (Koehler, Woodtly & Hofstetter, 2015), (Derriks, 2012), (Rohloff, 2009), (Rosemann & Brocke von, 2010), (Harmon, 2004), (Fisher, 2004), and only a few use a three (Rummler-Brache-Group, 2004), four (Hammer M., 2007) or six stages approach (Melenovsky & Sinur, 2006). A well-known 4 stages audit maturity model is the one of Vasarhelyi et al. (2012).

III. Research method

The goal of this study is to create a practical maturity model for continuous auditing. The maturity of the continuous auditing research field, with regard to frameworks, is nascent. An appropriate focus of research in nascent research fields is on identifying new constructs and establishing relationships between identified constructs (Edmondson & Mcmanus, 2007). Therefore, through grounded theory-based data collection and analysis we constructed a model.

For research methods related to exploring a broad range of possible solutions to a complex issue - and combine them into one view when a lack of empirical evidence exists – group-based research techniques are adequate (Delbecq & Van de Ven, 1971) (Okoli & Pawlowski, 2004)(Ono, Wedemeyer, 1994). Examples of group-based techniques

are focus groups, Delphi studies, brainstorming and the nominal group technique. The main characteristic that differentiates these types of group-based research techniques from each other is the use of face-to-face versus non-face-to-face approaches. Both approaches have advantages and disadvantages; for example, in face-to-face meetings, provision of immediate feedback is possible. However, face-to-face meetings have restrictions with regard to the number of participants and the possible existence of group or peer pressure. To eliminate the disadvantages, we combined a face-to-face technique, namely: "focus groups", together with the opportunity to provide feedback after each session.

IV. Data collection and analysis

The data for this study is collected over a period of nine months, between July 6th, 2017 and March 22th, 2018, through two series of a six-round coding and a five-round focus group, see Figure 1. This approach is applied for the maturity levels, the factors and the description of both. Between each individual round of coding and focus group, the researchers consolidated the results. Both methods of data collection are further discussed in the remainder of this section.

Before a focus group is conducted, a number of topics need to be addressed: 1) the goal of the focus group, 2) the selection of participants, 3) the number of participants, 4) the selection of the facilitator, 5) the information recording facilities, and 6) the protocol of the focus group (Morgan, 1996). For this study, the goal of the focus group meetings was to identify element of the CA framework and refine the framework. The selection of participants should be based on the group of individuals, organizations, information technology, or community that best represents the phenomenon studied (Strauss & Corbin, 1990). In this study, four types of organizations and individuals have been invited, namely pension funds, mortgagers, consultants to pension funds and auditors. The organizations that agreed to co-operate with the focus group meetings were the: 1) APG, 2) PGGM, 3) AZL, 4) Obvion, 5) PNA-Group and 6) Sprenkels and Verschuren.

Research Team	Experts: Focus Group (FG)
Round 1: **Coding**	
	Round 1: **Elicitation, Refinement and Validation**
Round 2: **Consolidation & Coding**	
	Round 2: **Elicitation, Refinement and Validation**
Round 3: **Consolidation & Coding**	
	Round 3: **Elicitation, Refinement and Validation**
Round 4: **Consolidation & Coding**	
	Round 4: **Elicitation, Refinement and Validation**
Round 5: **Consolidation & Coding**	
	Round 5: **Finalization**
Round 6: **Consolidation & Coding**	

Figure 1. Data Collection and Analysis.

Based on the written description of the goal and consultation of employees of each organization, participants were selected to take part in the 5 focus group rounds. In total, twelve participants took part in the focus groups regarding the elicitation capability. The following roles were included: 5 pension fund domain experts, two internal auditors, two IT-Auditors, one external accountant and two consultants. Each of the participants had at least five years of experience with auditing or auditing & information systems. Delbecq and Van de Ven (1971) and Glaser (1978) state that the facilitator should be an expert on the topic, and familiar with group meeting processes. The selected facilitator who is a Ph.D. in information systems and works for the finance and economics department, conducted eight years of research on related topics and facilitated many (similar) focus group meetings in the past. In addition to the facilitator, six additional researchers were present during the focus group meetings. Two researchers participated as 'back-up' facilitator who monitored whether each participant provided equal input, and if necessary, involved specific participants by asking for more in-depth elaboration on the subject. The remaining four researchers acted as secretaries. On average, the time spent on a focus group was three hours.

Every focus group meeting followed the same protocol, each starting with an introduction and explanation of the purpose and procedures of the meeting. After the introduction, ideas were generated, shared, discussed and refined by the participants. Prior to the first round, participants were informed about the purpose of the focus group meeting. Furthermore, the participants were invited to submit secondary data

regarding known continuous monitoring and continuous auditing frameworks and implementations. When participants had submitted their secondary data, they had the opportunity to elaborate upon their input during the focus group meetings.

After each focus group, the researchers analyzed and consolidated the results. The results of the analysis and consolidation were sent to the participants of the focus group one week in advance for the next focus group meeting. During these weeks, the participants assessed the consolidated results in relationship to three questions: 1) *"Is the framework described correctly?"*, 2) *"Do we need to address additional elements in the framework?"*, and 3) *"Do we need to remove elements from the framework?"* This process of conducting focus group meetings, consolidation by the researchers and assessment by the participants of the focus group was repeated four more times (round 2, round 3, round 4 and round 5). After the fourth focus group meeting (round 4), saturation within the group occurred. This resulted into a consolidated continuous auditing maturity model.

Data analysis was conducted in five cycles of coding, following Strauss and Corbin's process (2008) of 1) open coding, 2) axial coding, and 3) selective coding. Before the first focus group and after each focus group, open coding was conducted, involving the analysis of existing frameworks, documentation provided by participants and significant participant quotes, by the individual researchers. The existing frameworks are: KPMG (2013), Vikas Dutta (2012), Vasarhelyi et al. (2012), Kuhn & Sutton (2010), Ames et al., (2015), Deloitte (2011), and PWC (2011). In this process, the researchers tried to identify what Boyatzis (1998) refers to as 'codable observations'. Here, the researchers coded the data by identifying A) maturity model stage names and B) maturity model content were discussed. To illustrate this process one example is provided here. In the first round of the codable observations was as follows: *"financial ratio's"* in the framework of Vasarhelyi (Chan & Vasarhelyi, 2011). This was a part of the capability *"analytical methods"*. During the second round the capability and content had been transferred one-on-one into the model. During the third round the content *"financial ratio's"* is still transferred one-on-one however the domain *"analytical methods"* has been removed and *"financial ratio's"* is put under the organization dimension. During the second focus group an elaborated debate around the term *"financial ratio's"* emerged. Fueled by the idea of integrated thinking, respondents argued that *"financial ratio's"* limited the actual measurements too much. Also, a second discussion emerged about the fact if ratios are data or are an organization decision. Where the respondents until now shared *"financial ratio's"* under *"analytical methods"* they decided to put it in under *"organization"*. Therefore, during the fourth round the content *"financial ratio's"* is transformed into *"ratio's"* and put under

the data domain. In the last focus group, no additional discussions have taken place regarding *"ratio's"*. Therefore, during the last (fifth) round no additional changes were made.

V. Results

In this section the results of the research are presented. To ground our presentation, we refer to figure 2 which presents a snapshot of the final maturity model. Due to space constraints, only a snapshot of the model is provided, and the levels and capabilities are described high-level. First, the maturity levels are presented, after which the capabilities are discussed.

Maturity Level 1: Initial approach

At this level, some processes have been defined, but these are inconsistently implemented in practice. The initial approach is therefore ad hoc, unstructured, informal, chaotic and is mainly carried out on a reactive basis to understand and solve bottlenecks in processes. The controls are limited, with little research being carried out into the consistency and correctness of economic transactions (transaction level). A formal audit team is lacking and a solid infrastructure for the internal audit activities has not yet been established. The reliability of the initial approach is based on the personal skills and the degree of objectivity of the employees working in different departments.

Maturity level 2: Ad hoc approach

The input of process discipline ensures that basic audits and processes are carried out on a regular basis. The purpose and responsibility of the audit activities have been laid down, but these may still be organization-dependent and a plan of approach for quality assurance, improvement and real time monitoring is lacking. For the ad hoc approach, the information that is obtained, the resources that are used and the people carrying out the control tasks, an organization policy is drawn up. Qualitative and quantitative measures are applied, these may be trends that are derived from financial statements in combination with benchmark results from the relevant sector. This information is used to confirm and validate the results from the traditional initial approach. In order to achieve an honest ad hoc approach, standards are defined for the assessment of audits, processes are identified, a start is made with the formation of an audit department (software / system quality assurance group), and a start is made with the recruitment of people with the right competencies and relevant skills to be able to carry out the work. The reliability of the ad hoc approach remains dependent on personal skills and the objectivity of people. In comparison with level one, the ad hoc approach is more

disciplined and meets the basic needs of the organization because processes have been standardized. The ad hoc approach is also focused on the systems used and the course of the defined processes.

	Stage 2 - Ad hoc Approach
Systems	Localized, No-Normalized, Extract-Transform-Load Software
	Localized, No-Normalized, Scripting / Analysis Software
	Localized, No-Normalized, Reporting Software
Data	Ah-hoc data-analysis
	Localized approach for data analytics (methodology)
	Localized procedures for data analytics (performed ad-hoc)
	Ad-hoc access to data-sources
	Access to derived data
	Data quality is not enforced
	Only analyses on ratios
	Reactive, centralized data-governance
Organization	Localized key ratio's
	No specific monitoring on transaction level
	No detective alarm and follow-up process
	Organisational: high human dependency
	IT-Organisational: low IT dependency
	No Extract-Transform-Load Expert
	No Script Builder
	No championing
	(Internal) Accountant
	Independent IT-Auditor
	No PDCA Cycle
	Data-ownership function defined
People	No specific competence requirements ETL-Expert
	No specific competence requirements script-builder
	No specific competence requirements champion
	Well developed competence (internal) Accountant
	Limited developed skill IT-Auditor

Figure 2. Snapshot of Maturity level 2: Ad hoc approach.

Maturity level 3: Defined approach

The defined approach is formal, fully standardized, consistent and the policies and procedures are defined, documented and integrated into the infrastructure of the organization. The emphasis is now on process maturity and the continuous risk assessment is focused on changes in the organization, weaknesses in controls and business performance. The quantitative and qualitative measures for risk assessment

are geared to the business risks with the highest priority. The business risks and audit areas are re-prioritized based on the company risk profile and the risk appetite and coverage are further optimized by using data analysis. The types of data analysis that can be applied; descriptive, diagnostic and / or a mild form of predictive. The tools that are used to analyze data are used to identify risks that lie outside the set risk appetite parameters. These analyzes are performed at more frequent and fixed time intervals and are focused on processes so that the execution is monitored and assessed. A start is given to real-time checks and analyzes, and the defined approach is carried out by the recruited and / or trained people with the required skills.

Maturity level 4: Managed approach

The managed approach is fully integrated as part of the management and risk management of the organization, with the focus on proactive risk identification. Analyses contain both internal and external data and the resulting results are compared with benchmark data from the relevant sector. The quantitative and qualitative measures are balanced and fully integrated in the audit work to achieve strategic objectives and continuously improve performance. Business processes use business intelligence and continuous monitoring for the assessment of business risks, financial and operational results and to re-prioritize and rank audit trigger events and risks to control intervals (daily, weekly, monthly, quarterly). The reliability, risk appetite and coverage are even more optimized by applying predictive analysis tools that are widely applied by the organization. The data analyses are generated from the business units to speed up, postpone or reject the audits. By linking these analysis techniques to the KPIs (Key Performance Indicators), KRIs (Key Risk Indicators) and historical results, there is a dynamic managed approach. Processes are coordinated in such a way that sufficient certainty can be offered at operational level to achieve the objectives of the organization. Prescriptive analysis is introduced at this level.

Maturity level 5: Optimized approach

The ultimate maturity level (optimized approach) is characterized by a more extensive and consistent use of continuous advanced analysis tools consisting of predictive and prescriptive techniques. Strategic objectives and business process risks are monitored through the application of business intelligence, and the changing external environment of the organization is monitored by the implemented optimized approach. Both internal and external information is used to optimize the assessment of policy, risk management and control activities. KPIs and KRIs are continuously aligned with the strategic objectives, and the strategic risks consist of both internal and external factors.

Following on the 5 maturity levels, we describe our 4 capability areas:

Capability 1: Systems

To optimize the completeness and availability of data, it is important to realize a homogeneous system environment. Which means that the information systems used are connected to each other so that data flows between the information systems and access to these data. A standardized information system combined with an honest data entry ensures reliable data output. Relevant Key Performance Indicators (KPIs) are derived from these systems. In the realization of a homogeneous information system, the most important risk areas and the most important risk indicators are monitored. In case of deviations that are detected by the system, an alarm message is given to take immediate action. In order to arrive at a continuous optimized approach from an initial approach, the following question must be posed; does the software support the extraction of data from external sources and is this data transformed into operational needs? It is also important to assess whether the software is applied by one specific person, a limited number of people or a group in the organization and whether the software is supported or not supported by centralized software management.

Capability 2: Data

How is data analyzed, what are the possibilities to analyze this data and what is the quality of data? These concepts are central to the 'data' area. The process of data analysis is based on the following steps: data is extracted from the systems, then transformed into information and finally analyzed in order to finally come to a decision about a certain process in the organization. In order to produce a correct analysis of the data, it is important that these data meet a number of quality requirements. These requirements include integrity, completeness, validity, readability, topicality, originality and consistency. Data integrity means that data in the information systems must be reliable and accurate throughout the life cycle. Data integrity begins with the user entering data. Data must be recorded at the time of observation. The original source data must be accessible at all times and kept in its original form. In order to arrive at a continuous optimized approach from a traditional initial approach, the following questions need to be asked; do the information systems contain the same data formats, to what extent is the data quality consistently guaranteed and is the data available at all times (real time)?

Capability 3: Organization

What is the company's strategy and objective regarding continuous auditing / monitoring, and what is the vision of the management? In order to link a continuous

optimized approach to the strategy, objectives and vision, it is customary to use a risk-based finance plan in which the finance strategy is aligned with the strategic objectives and goals of the organization.

Capability 4: People

The executors must first of all understand the objectives and requirements of continuous auditing / monitoring. Just as well, good insight must be gained into the most important business processes, the information systems used and the associated infrastructure (the controls and the data contained therein). In addition, they must have skills to analyze the available data and to identify the most important control elements and risk areas of the organization. The role of the current controller will change as continuous auditing / monitoring is implemented more broadly in the organization. Related departments need to work together, and new functions / tasks will be created, including an Extract-Transform-Load Expert and a Script builder. To come from a traditional initial approach to a continuous optimized approach, the following questions need to be asked; are the employees involved aware of their new tasks, responsibilities and the role that is being performed? Should consideration be given to attracting new personnel who have knowledge about a particular area or is further training necessary for current staff?

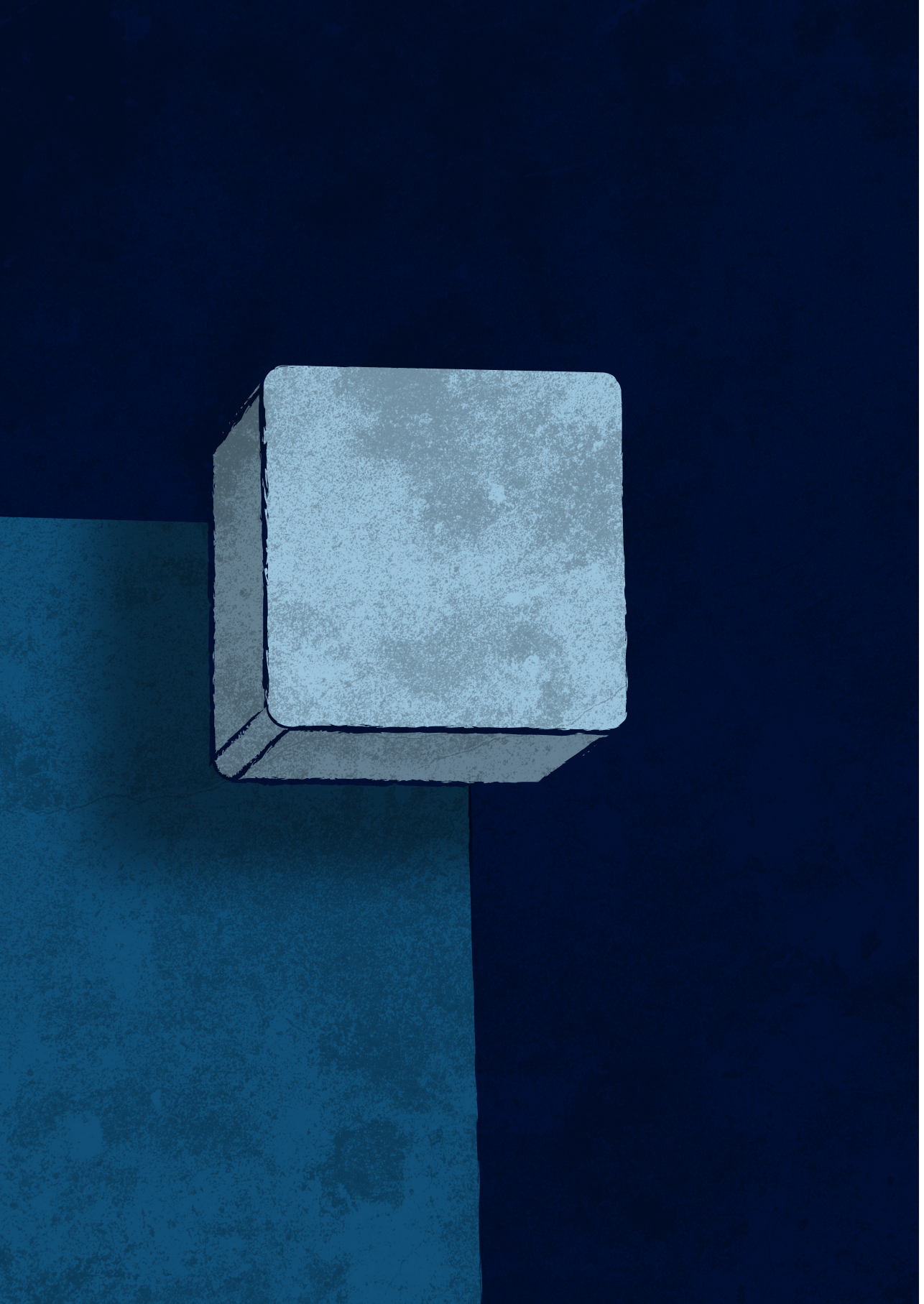
VI. Conclusion and future research

The existing body of knowledge on the application of information technologies in auditing is characterized by a predominant focus on a singular tool for a singular problem. While a small amount of contributions focusses on a more holistic approach. Therefore, the objective of this study is to find an answer to the following research question: *"How can the different stages and the improvement of Continuous Auditing be measured?".* We have answered this question with a CA maturity model, presented in this research. The first version of the maturity model is based on literature, after which it has been redefined in 5 validation iterations. Based on the results of the 2 interview rounds, the maturity model has been further redefined, which led to a model that consists out of five maturity levels and four factors. The maturity levels are: 1) initial approach, 2) ad hoc approach, 3) defined approach, 4) managed approach, and 5) optimized approach. The four capabilities are: A) systems, B) data, C) organization, and D) people. This study makes a number of contributions. From a theoretical perspective, it fills a gap in the literature concerning a more holistic approach on continuous auditing. Additionally, it answers the call for more practical oriented research on CA. This chapter aims, from a practical viewpoint, to provide a structure to the knowledge on this topic. From a practical perspective, the results of this study could guide organizations by providing

a blueprint for CA, leading to more effective planning and implementation of auditing capabilities. With our research we extend the existing studies. We present a 5 stages maturity model, existing of 4 capabilities and 28 factors. With our model it is possible to evaluate the current state of an organizations' CA.

Some limitations of our study must be acknowledged. The first limitation stems from the sample of organizations that participated in the data collection. Although the respondents came from a mix of organizations, namely pension funds, mortgagers, consultants to pension funds and auditors, the sample size is limited. One could argue that the results of this study are only limited generalizable. This is strengthened by the second limitation. The second limitation is the approach, which consisted of all qualitative data collection and analysis techniques. One characteristic of qualitative approaches is the limited generalizability of the findings towards similar and dissimilar contexts, thus our CA maturity model. However, research studies concerning nascent maturity research directions often utilize qualitative approaches that focus on (Edmondson & Mcmanus, 2007): "*identifying new constructs and establishing relationships between identified constructs.*" Applying quantitative research approaches would improve the generalizability of the framework and its concepts, nevertheless.

In this study, CA is explored in the context of Pension funds. Future research should therefore focus on CA outside the pension funds. Second, challenges and situational factors regarding CA still need to be identified and validated thoroughly. Furthermore, it is to be expected that situational factors also (significantly) influence human resources, implementation challenges and principles. Research into these relationships are also an important avenue for future research. Last, the maturity model presented would benefit from further validation and possible additions in future research in which quantitative approaches are utilized that allow for better generalizability.



Chapter 4

An Evaluation of the Added Value of Business Rules Management Principles to Transparency

I. Introduction

An organization's performance depends upon its ability to manage its business decisions and business logic (Blenko, Mankins, & Rogers, 2010; Rogers & Blenko, 2006). Currently decisions and underlying business logic are embedded in different information systems. For example: customer relation management systems, enterprise resource management systems and financial systems. These systems only provide a low level of transparency on how the decision is specified and actually executed (Horita, de Albuquerque, Marchezini, & Mendiondo, 2017; Mohemad, Hamdan, Othman, & Noor, 2010). Therefore, organizations are extracting decision from this type of systems and implementing them in separated information systems like decision support systems and business rules management systems. Thereby increasing the level of transparency.

In addition to the trend that decisions are managed as a separate entity an additional trend influences the management of decisions: the call for transparency within regulatory frameworks. For example, the new General Data Protection Regulation (GDPR) in the European Union demands transparency with regards to operational decisions that are integrated into the information systems (European Commission, 2017). Yet, in current literature, the frameworks to measure transparency in decision-making are predominantly focusing on a tactical and strategic level (Grimmelikhuijsen & Welch, 2012). For example, Drew & Nyerges (2004) in their study propose a framework for transparency existing out of seven elements: integration into broader decision context, clarity, accessibility, openness, accountability, truth and accuracy, logic and rationale. How to formulate design principles or quantitatively measure based on these elements is not presented. Another example is the transparency cube proposed by (Brandsma & Schillemans, 2012), which has three elements: consequence, information and discussion, with the following related measures: from few to many, little too much and intensive to non-intensive. These are again not very specific and do not allows the formulation of design principles or measurements. In the work of (Zoet & Smit, 2019) a framework with according measurements is proposed to measure the transparency of decisions and underlying business logic, thereby providing the possibility for organizations to score the level of decision transparency they uphold. Although this provides a means to measure the actual or desired transparency, the framework does not provide principles on how to design more transparent decisions and business logic.

This chapter extends on this by researching the effect of business rules management principle on transparency. With these premises, the following research question is addressed: *"Which business rules management design principles affect the transparency*

of the design and execution of a decision and business rules management solution?" Answering this question will help organizations to evaluate the actual transparency of their decisions and underlying business logic.

This chapter is organized as follows. First, we define transparency, which is the fundament of our research, after which the objects of transparency are presented and the measurements for transparency per area explained. Section three describes the research method and case selection. This is followed by the data collection and analysis in section four. Then, the results of the experiment are presented in section five. This is followed by section six, which discusses the experiment validity and limitations. We conclude and summarize our research in section seven.

II. Background and related work

To be able to determine if design principles have effect on the transparency of decisions and business logic, the exact elements for which transparency is required need to be determined. To do so, the Decision Transparency Framework (Zoet & Smit, 2019) is utilized. To ground the remainder of this chapter and present the elements the design principles affect, the DTF is summarized below. The DFT distinguishes three levels of transparency: 1) the decision level, 2) the decision service level and 3) the source-question-data level. Which are shortly explained hereafter.

Decision-level transparency

From an information/engineering perspective, business logic is an (Hay, Healy, & Hall, 2000; Von Halle & Goldberg, 2009): *"expression that evaluates conditions, by means of a calculation or classification, leading to a conclusion."* Decomposing this definition results in three different elements, namely: 1) conditions, 2) expression and, 3) conclusion. The condition can be further decomposed into two elements: the condition fact-type and the condition-fact values (Von Halle & Goldberg, 2009). For example, the condition fact-type is "weather temperature" while the condition-fact value is "16 degrees Celsius". The same applies to the conclusion, which also exists out of a conclusion fact-type and conclusion-fact values.

Decision service-level transparency

The previous object of transparency is a single decision; however, decisions are often part of a decision service (also known as business rule architecture). A decision service consists of two or more decisions and a derivation structure. The derivation structure depicts the relationship between the individual decisions. Therefore, the decision

service is the sum of all underlying decisions. Thereby the transparency of the decision service is the sum of the transparency of underlying decisions plus the transparency of the derivation structure.

Source-question-data-level transparency

As mentioned earlier in this section the second form of transparency is the transparency between objects. In the DTF framework, this implies the transparency between the decision service & underlying decision(s) and the three other artefacts: 1) the source, 2) decision questions and 3) data.

The source indicates where the knowledge is elicitated from to design and specify the decision and underlying business logic (Debevoise, Taylor, Sinur, & Geneva, 2014). In research, different types of sources from which knowledge can be derived exist, for example, human experts, documentation and/or data. Data indicates the data that is required to evaluate the condition-facts in a decision. In some cases, this data needs to be retrieved from third parties, for example, citizens or other organizations. To realize this, input forms with questions are built or API's can be connected. The connection, either being a question on a form or API is defined as a decision question. To reach optimal transparency, each decision, and therefore the entire decision service, needs to be able to be traced to the specific source(s), data and decision question(s).

The level of transparency of the service, decision service, decision, decision question, data and source documentation depend on the lifecycle phase in which the object is in. In total 10 phases can be distinguished: the elicitation, design, specification, verification, validation, deployment, pre-execution, pre+ execution, post execution or monitoring.

III. Decision and business rules management design principles

Now more and more DM/BRM solutions are introduced, organizations are searching for guidance to design such solutions. In multiple disciplines, such as industrial engineering, chemical engineering, civil engineering, electrical engineering, and system engineering an important mechanism to guide the design of products and/or information systems are principles (Greefhorst & Proper, 2011). A principle is a simple, direct statement of an organization's belief about how they want to use a specific system (The Open Group, 2011). In our context, principles are therefore statements of an organization's basic beliefs about how the organization wants to apply BRM and design BRM solutions.

In literature, many different types of principles are recognized: business process management principles, enterprise architecture principles, information technology principles, software design principles, data principles, software architecture principles, application principles, organization principles, and business principles. Each of these sets of principles are design principles to guide the design of a specific part of the organization and reduce the degree of freedom to create a specific solution. Therefore, these principles cannot be dealt with separately but must be considered as a network (Stelzer, 2009). Since BRM is becoming more and more important we propose it should be part of this network. However, research which focuses on principles for BRM is scarce. This chapter, therefore, extends the understanding of principles with regard to BRM solutions.

The body of knowledge on design principles for decision management and business rules management is thin. To the knowledge of the authors, contributions other than (Zoet & Smit, 2016) and (Smit, Zoet, & Slot, 2016) exist that focus on the formulation of design principles. Therefore, this chapter considers the twenty-two design principles presented in (Zoet & Smit, 2016). Due to space constraints, this chapter does not go into detail regarding these design principles. However, to ground the analysis in this chapter, a summary of the principles is provided:

1. **Automated decisions where possible, supported decisions if necessary**. Automation of decisions impact transparency. When they are well-defined, they increase transparency, when they are not explainable, e.g. because of the application of machine learning, they may decrease transparency.
2. **IT does not formulate business rules**. By ensuring that business rules are always defined by someone from the business domain, the risk of implicit decisions hidden in software code is decreased, which has a positive impact on transparency.
3. **No big bang but iteration approaches for business rules projects**. An iterative approach provides for more flexibility in incorporating changes in business rules during development and implementation.
4. **Authorization for decision-making**. This principle ensures that only authorized personnel can make decisions. This positively impacts transparency.
5. **Ownership of a decision is defined**. This principle assigns responsibility at the level of decisions. Clarity about who is responsible for what decision improves transparency.
6. **Traceable decisions**. This principle prescribes that the design of the BRM solution should make it possible to trace how decisions were taken. This directly links to transparency, as more detailed traceability enables more transparency.

7. **Data is recorded according to two-time dimensions**. This principle distinguishes between the validity dimension, when a business rule is valid, and the transaction dimension, the timing of registration. This is relevant in terms of transparency of past decision making.
8. **All business rules must refer to a source**. The source is the justification of the business rule. By making the source explicit, transparency is enhanced.
9. **P.E.N.S criteria are determined for each business rule set**. By determining criteria for precision, expressiveness, naturalness and simplicity for each business rule set, it becomes possible to fulfill differences in requirements that are borne from variations in situations. This allows for multi-dynamic architecture.
10. **Reuse before buying and creating software**. This principle is meant to prevent the same business rules being implemented in disparate software systems, thus ensuring that changes need only be executed in one system instead of many. This enhances flexibility.
11. **Best-of-suite approach**. A best-of-suite approach leads to better integrated functions. However, when integration is not transparent it may lead to less flexibility, as it is more difficult to replace specific functions.
12. **Gaming only permitted between 09:00 AM and 17:00 PM**. This rule limits the possibilities of experimenting with business rules. Experimentation may reduce transparency because it may be used to manipulate the outcomes of business rule application.
13. **Sharing knowledge concerning the execution of laws, regulations, and policies with employees and clients**. Sharing knowledge is related to participating in an ecosystem of collaborating parties.
14. **Adhere to context structures**. By organizing business rules and facts into sets of knowledge with maximum internal cohesion and minimal external coherence, it becomes easier to realize changes in the knowledge, thus improving flexibility.
15. **Create once and use multiple times**. By recording implementation-independent business rules only once and using this as the only source for the entire enterprise makes it much easier to share the knowledge contained in the business rules with other parties, thus contributing to the openness of the enterprise.
16. **Communication with the same standards wherever possible, communication with different standards where desirable**. This principle focusses on having a shared language among BRM stakeholders. To all persons concerned the definition of terms should be clear in the context in which they are used. This has a positive impact on flexibility.

17. **Flexible decisions**. This principles states that employees should be able to override decisions during execution. Though this allows for greater flexibility, it may negatively impact transparency when manual interventions are not faithfully recorded.
18. **Utilize government-wide standards**. Government-wide standards describe how business rules should be handled and processes performed. Applying such standards increases openness, as it allows for easier use of each other's (implemented) knowledge.
19. **Separation of the know and flow**. Business rules (know) have a higher frequency of change than business processes (flow). By separating the two, they can each be changed at their own pace, thus increasing flexibility.
20. **Develop business rules from a management perspective rather than an implementation perspective**. Developing business rules from a management perspective better takes into account the post-deployment maintenance of the rules, enhancing flexibility.
21. **Transparency concerning decision-making for clients and users**. This principle evidently aims at ensuring transparency of decision-making.
22. **Include compliancy in designing products and/or services**. By taking into account compliancy from the start when designing products and services it will be easier to justify the rightfulness of decisions, thereby impacting transparency.

IV. Research method

The goal of this research is to identify whether the current BRM design principles affect transparency. In addition to the goal of the research, also, the maturity of the research field is a factor in determining the appropriate research method and technique. The maturity of the BRM research field, with regard to non-technological research, is nascent (Kovacic, 2004; Nelson, Peterson, Rariden, & Sen, 2010). The focus of research in nascent research fields should lie on identifying new constructs and establishing relationships between identified constructs (Edmondson & Mcmanus, 2007). Summarized, to accomplish our research goal, a research approach is needed in which a broad range of BRM design principles are explored and combined into one view (the transparency viewpoint). To do so, we combine the knowledge of transparency measurement in a BRM context with existing BRM design principles to identify relationships. This combination, in the form of secondary data, is then qualitatively analyzed according to predefined and grounded transparency criteria, which is elaborated in the next section.

V. Data collection and analysis

The data collection consisted of secondary data, which is a form of third-degree data collection. According to (Runeson & Höst, 2009), when data such as requirements and/or principles are studied, third-degree data collection is a proper fit. The data collected are the principles described in the section two; background and related literature.

The data collection for this study occurred over a period of two months, between February 2019 and March 2019. The data collection is conducted by six researchers representing different levels of expertise on decision management and principles. Two researchers representing the expert group (researcher 1 and 2), two researchers representing the intermediate group (researcher 2 and 3) and two researchers representing the novice group (researcher 5 and 6). Separating the coders increases the inter-reliability in the coding [21] and internal validity of the research [22]. Researcher 1 is a professor with ten years of practical and research experience in the field of DM; Researcher 2 is a lecturer and postdoc researcher with seven years of practical and research experience in the field of DM; Researcher 3 is a PhD-candidate with five years of practical and research experience in the field of DM; Researcher 4 is a Master student with four years of practical and research experience in the field of DM; Researcher 5 and 6 are Bachelor students with two years of research experience in the field of DM. Based on the objects in DTF the following criteria have been formulated:

- **Criterion 1:** The principle adds to the level of transparency of the service, decision service, decision, decision question, data and source documentation.

The second criterion relates to actual transparency of the phases the different objects are in the process or the object in a specific process phase, therefore the following criteria is formulated:

- **Criterion 2**: The principle adds to the level of transparency of the elicitation, design, specification, verification, validation, deployment, pre-execution, pre+ execution, post execution or monitoring.

In addition to individual objects and the processes related to them, also the individuals in the organizations can have an influence on the transparency, therefore the last criteria is:

- **Criterion 3:** That the principle realizes demystification of the person/role responsible for the decision.

VI. Results

In this section, the results of the analysis of the relationship between BRM design principles and transparency are presented. The principles have been categorized to either 1) effect to transparency or 2) no effect to transparency. Table 1 contains the description the overall results of the mapping to the two categories. In the remainder of this section the overall results are presented.

Table 1. Mapping of added value of the BRM principles to transparency

	Effect	No effect		Effect	No effect
Principle 01		X	Principle 12	X*	
Principle 02	X		Principle 13	X	
Principle 03		X	Principle 14		X
Principle 04	X		Principle 15		X
Principle 05	X		Principle 16	X	
Principle 06	X		Principle 17	X*	
Principle 07	X		Principle 18		X
Principle 08	X		Principle 19	X	
Principle 09	X		Principle 20		X
Principle 10		X	Principle 21	X	
Principle 11		X	Principle 22	X	

The principles that have a positive effect on the transparency are principles: 2, 4, 5, 6, 7, 8, 13, 19, 21 and 22. With respect to principle two and eight, the decisions and underlying business logic have higher P.E.N.S. value, which is tied to a higher readability for business users (Kuhn, 2014). Principle four realizes that for each decision the employee that executed the decision is registered as such. In addition, principle five indicates who is responsible within the organization for the proper execution of the decision. For principle six, when decisions are traceable to the source, the organization can properly explain why and based on what the decision has been made. Principe eight is a further specification of principle six and, therefore, has a direct positive effect on transparency. Regarding principle seven, saving the execution date as well as the validation date of the decision realizes a higher transparency because stakeholders are able to time-travel (Zoet & Smit, 2016). Principle thirteen is straightforward since knowledge about the design of the decision-making is shared with stakeholders. With regards to principle 16, which focusses on having a shared language amongst stakeholders that execute or are

affected by the decision, transparency is positively impacted because all stakeholders should be able to use the same language. To all stakeholders concerned, the definition of terms should be clear in the context in which they are used, if for a specific stakeholder this is not clear, the communication can be altered to increase transparency. Principle nineteen has a positive impact on transparency since the decision logic is not embedded in business process diagrams/descriptions which allows for easier reading and transferability amongst stakeholders. Lastly, principle twenty-one states that the execution has to be transparent. Since more regulations, like GDPR state requirements for transparency, this principle automatically has a positive effect.

In total, two principles have an effect, but the effect can also be a negative effect. The first principle is principle twelve, which limits the possibilities of experimenting with business rules. This is to prevent experimentation with the business rules such that the most optimal outcomes can be realized. In this respect, the principle actually reduces transparency and therefore should be categorized as "no effect on transparency". The reason it is classified as "effect on transparency" is because the direct effect of the principle on transparency. However, to produce a positive effect, the principle should be: *"24-hour gaming permitted."* Furthermore, principle seventeen states that employees should be able to override decisions during execution. This allows for greater flexibility when executing decisions, however, it may negatively impact transparency when manual interventions are not faithfully recorded, or employees alter decisions based on personal preferences.

VII. Discussion & future research

Like every research study, several limitations may affect our results. The first limitation is the sampling and sample size. This limitation comprises the sampling of the BRM design principles, which are solely drawn from Dutch governmental institutions. However, the current body of knowledge is very thin on such design principles. We argue that the context of government institutions forms a solid fundament for this research and future research since they deal with the implementation of large amounts of business decision and rules derived from laws and regulations. Still, further generalization towards non-governmental organizations is recommended in future research, by validating whether the current set of BRM design principles are relevant in other contexts. Additionally, the generalization of the identification of effects can be increased by involving practitioners as well as other stakeholders that deal with the design and implementation of BRM solutions that have the goal to increase transparency. Lastly, while we argue that the research approach chosen for this research type is appropriate, research focusing on

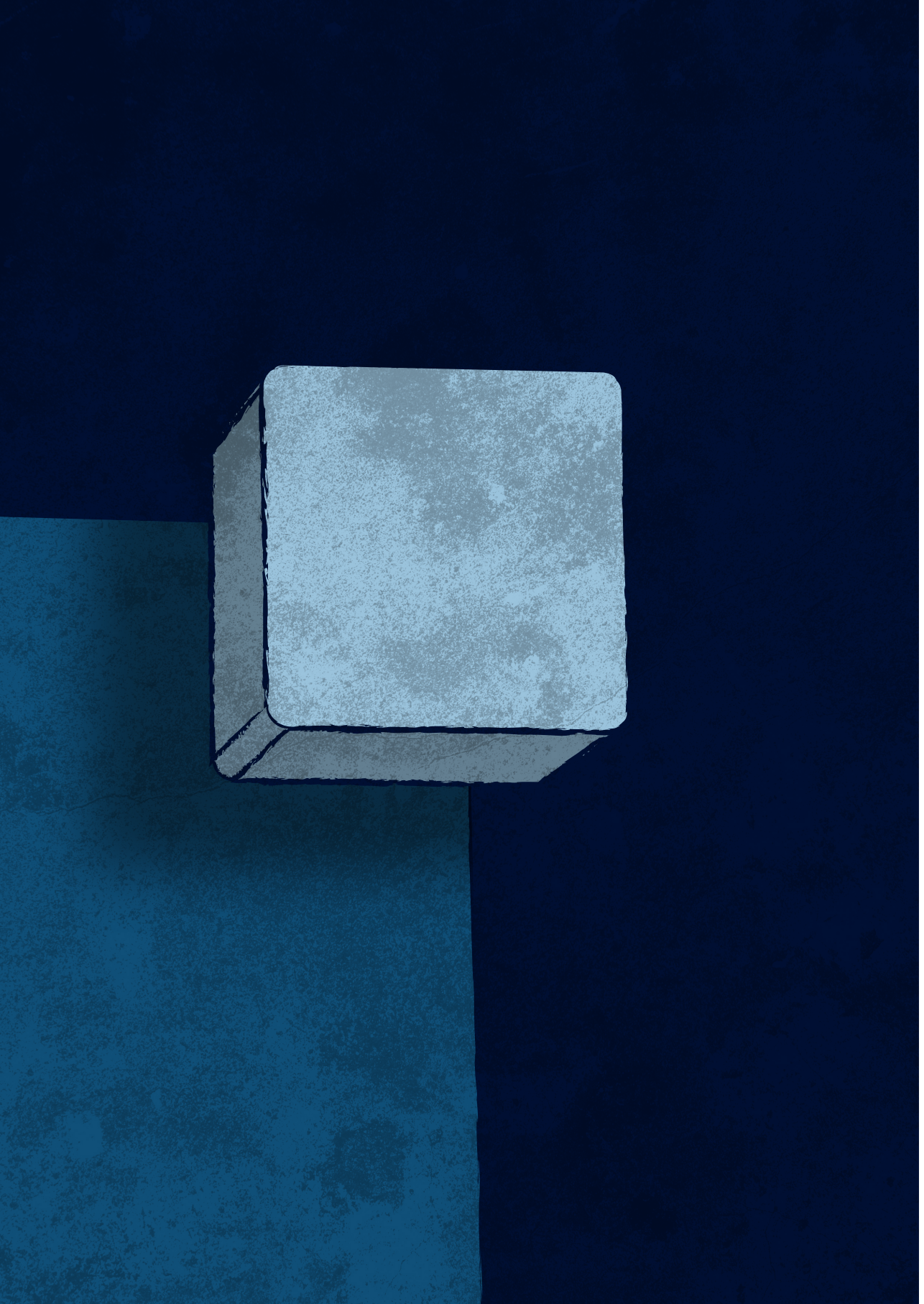
further generalization must apply different research methods, such as quantitative research methods, which also allow us to incorporate larger sample sizes to validate our findings.

VIII. Conclusions

The goal of this study is to identify whether the current BRM design principles affect transparency. To do so the following research question was posed: "*Which BRM design principles affect the transparency of the design and execution of a decision and business rules management solution?*" In order to answer this question, previously identified BRM design principles were selected and scored regarding their effect on transparency, based on five selection criteria. In total, eight principles have no effect on the transparency while the remaining twelve principles have an effect on transparency.

From a **theoretical perspective**, this study provides the knowledge base with knowledge on how principles, in this case BRM design principles, could be evaluated regarding transparency as well as interesting directions for future research to strengthen how BRM solutions could improve transparency.

From a **practical perspective**, this study provides organizations with a set of twelve BRM design principles that are proven to affect transparency at organizations. These twelve BRM design principles should be taken into account by organizations that want to realize better transparency. Furthermore, the results provide (enterprise) architects a framework that can structure thinking about the solution that needs to be designed and implemented.



Chapter 5

The Financial Credit Risk Assessment Model: Three Perspectives

I. Introduction

Within the field of the Financial Credit Risk Assessment (FCRA) there are two main areas of interest. The first main interest, credit rating (or scoring), is used to solve the problem to label companies as bad/good credit or bankrupt/healthy. Credit rating is used not only internally for screening borrowers, pricing loans and managing credit risk thereafter, but also externally for calibrating regulatory capital requirements (Cornee & Szafarz, 2014). The second main interest, bankruptcy (failure) prediction (or business failure prediction or going concern assessment) is intended to predict the probability that the company may belong to a high-risk group or may become bankrupt during the following year(s). Both of them are strongly related and solved in a similar way, namely as a binary classification task. In this chapter, both categories of problems are collectively called FCRA, which is a business decision-making problem that is relevant for creditors, auditors, senior management, bankers and other stakeholders.

FCRA is a domain which has been studied for many decades. According to Balcaen and Ooghe (2006), there are four main areas with reference to FCRA: (1) Classical paradigm (arbitrary definition of failure, non-stationarity and data instability, sampling selectivity), (2) Neglect of the time dimension of failure (use of one single observation, fixed score output/concept of resemblance/descriptive nature, failure not seen as a process), (3) Application focus (variable selection, selection of modelling method), (4) Other problems (use of a linear classification rule, use of annual account information, neglect of multidimensional nature of failure). The literature on FCRA and business failure dates back to the 1930's (Aruldoss et al., 2015). Watson and Everett (1996) described five categories to define failure: 1) ceasing to exist (discontinuance for any reason), 2) closing or a change in ownership, 3) filing for bankruptcy, 4) closing to limit losses and 5) failing to reach financial goals. When the FCRA is negative, it is called business failure, which is a general term and, according to a widespread definition, it is the situation that a firm cannot pay lenders, preferred stock shareholders, suppliers, etc., or a bill is overdrawn, or the firm is bankrupt according to the law (Ahn, Cho, & Kim, 2000). There is extensive literature in which this topic has been researched from the perspective of auditors or bankers. On the other hand, rare literature can be found about related literature from an information and decision perspective. The features (variables) which are relevant in the field of FCRA will be analyzed in this chapter. In this chapter the focus will be on the auditor's, bankers and crediting rating firms, hence forward the term financial industry will be used to describe all three. A combination will be made between the financial industry and an information and decision perspective.

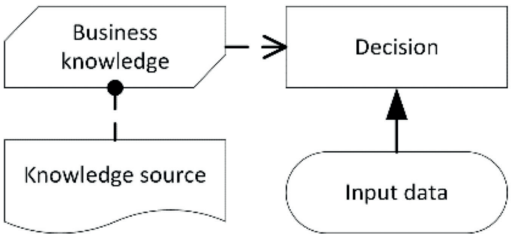


Figure 1. DRD-level Elements.

To do so, the DRD model will be used. The reason DMN (Decision Model and Notation) is used, is because it is currently the standard to model decisions. In September 2015, the Object Management Group (OMG) (Derriks, 2012) released a new standard for modelling decisions and underlying business logic, DMN The DMN standard is based on two levels; the Decision Requirements Diagram (DRD) level and the Decision Logic Level (DLL). The DRD level consists of four concepts that are used to capture essential information with regards to decisions: 1) the decision, 2) business knowledge, which represents the collection of business logic required to execute the decision, 3) input data, and 4) a knowledge source, which enforces how the decision should be taken by influencing the underlying business logic. The contents of the DLL are represented by the business knowledge container in the DRD level.

The remainder of this chapter is organized as follows. Section II contains a description of relevant literature regarding features, feature selection, and techniques with reference to FCRA, from a combined perspective of both the financial industry and information and decision analysts, followed by the research method in Section III. In Section IV, our data collection and analysis will be reported. Subsequently, in Section V, a presentation of the results derived from the applied data analysis techniques will be given. The conclusion (Section VI) closes this chapter.

II. Literature review

Feature selection is a critical step in FCRA, which refers to the process that reduces the feature space and selects an optimum subset of relevant features. Three possible methods can be distinguished: 1) human, 2) statistical and 3) hybrid. In the human approach, an auditor decides which features are important and how they relate to each other. The model in 'the head' of the auditor is rebuild into the system. For the statistical approach several alternative methodologies are applied for the feature selection.

Tsai (2009) compares five well-known feature selection methods used in bankruptcy prediction, which are: 1) *t*-test, 2) correlation matrix, 3) stepwise regression, 4) principle component analysis (PCA) and 5) factor analysis. The hybrid approach applies both the human and statistical manner.

Statistical techniques
1. Linear discriminant analysis (LDA)
2. Multivariate discriminate analysis (MDA)
3. Quadratic discriminant analysis (QDA)
4. Logistic regression (LR)
5. Factor analysis (FA)
Intelligent techniques
1. Neural networks (NN)
2. Decision trees (DT)
3. Rough sets
4. Case-based reasoning (CBR)
5. Support vector machines (SVM)
6. Data envelopments analysis
7. Soft computing (hybrid intelligent systems)
8. Operational research techniques
9. Other intelligent techniques

Figure 2. Statistical and Intelligent Techniques.

To apply the selected features from the features selection to take the FCRA-decision, different methods are applied. Broadly, these methods are dived into two broad categories: statistical and intelligent techniques (Ravi Kumar & Ravi, 2007) (Chen, Ribeiro, & Chen, 2016). They exist out of multiple sub-categories, see Figure 2. For a detailed description of the techniques we refer to Ravi Kumar and Ravi (2007).

Based on literature studied, we developed a model that exists out of three axes that determine the type of features applied. To ground our theory, we first present the end model: the FCRA Model.

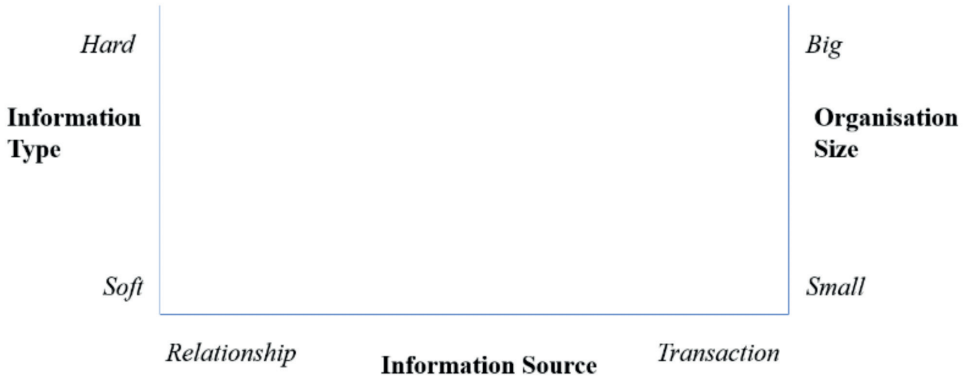


Figure 3. Financial Credit Risk Assessment Model.

The first axe describes the type of data that organizations retrieve to make a judgement about the financial credit risk. In the papers of Berger, the same distinction is made in an information type perspective: hard versus soft (or quantitative versus qualitative) data. Different related names are used in this field:

The second axe describes the manner in which this information is retrieved. For example, two manners in which information can be collected are: 1) through face to face contact between a loan officer and the organization's owner and 2) through a form on a website or any other digital manner. The third axe describes the organization size, varying from small to big. The loan decision model of small banks is known to differ from the loan decision model of large banks (Kim & Elias, 2008). According to Berger (2011) small organizations (organization size), make use of soft information (information type), based on the relationship with their clients (information source). Bollen et al. (2008) recognize four categories of business failures: 1) Tadpole (company failed because it was a basically unhealthy company, 2) Drowned frog (the company is over-ambitious or may show signs of extreme growth, 3) Boiled frog (companies in this category may be failing as a result of external conditions (e.g., disasters), bad economic conditions or fundamental changes in the business environment to which the company has failed to respond adequately, 4) Bullfrog (the companies in this category have drawn a relatively large portion of public attention, because they are often related to fraudulent activities of managers or employees).

A. Information Type

Hard

According to Petersen (2004) hard information is almost always recorded as numbers and is comparable. The durability of information is potentially greater when it is hard. The collection method of hard information is mostly not personal. Hard information is mostly standardized and easy to document and transfer to others (Kano, Uchida, Udell, & Watanabe, 2011). Nemoto et al. (2013) also recognize the verifiability which normally is higher in case of hard information. Decision processes which depend upon hard information are easier to automate. Knowing what information, you are looking for, and why it is valuable, is essential if information collection and possibly decision making, based on the information is to be delegated. Most features are based on data from the financial statements. Financial statements are, in most organizations, created once or twice a year. Therefore, the data needed to calculate the features is available once or twice a year. This causes an information opacity problem, thereby reducing the effectiveness of the features. Other organizations that also assess the financial credit risk of an organization are banks, credit assessors, etc. Both previously also had to trust numbers that are published once a year. Since this time period is too long for both parties, they searched for solutions to address this problem. According to Berger and Udell (n.d.) hard information may include, as examples, financial ratios calculated from audited financial statements; credit scores assembled from data on the payment histories of the small and medium sized entities (SME) end its owner provided by credit bureaus; or information about accounts receivable from transparent, low-risk obligors that may pledged as collateral by the SME or sold to the financial institution.

Soft

Soft information is mostly relationship-based and not easily quantified (Carter, Mcnulty, & Verbrugge, 2004). The replacement of soft with hard information inevitably results in a loss of information. The early studies for FCRA were univariate (a specific statistical method applied) studies which had important implications for future model development. These laid the groundwork for multivariate studies. Ravi Kumar and Ravi (2007) identify statistical and intelligent techniques to solve the bankruptcy prediction problem. For each type of technique, they describe the way they work. Chen, Ribeiro and Chen (2016) summarize the traditional statistical models and state-of-the-art intelligent methods. Auditors can utilize data mining techniques to analyze external (soft) data (e.g., census data, social media, news articles) in their assessments of client business risk, fraud risk, internal controls, going concern (Brown-Liburd & Vasarhelyi, 2015). Lu et al. (2016) explain the possibilities of data mining (text mining) based on soft information on websites and in financial reports to predict bankruptcy.

Altman et al. (2010) describe the value of qualitative (soft) information in SME risk management. They find that qualitative data relating to such variables as legal action by creditors to recover unpaid debts, company filing histories, comprehensive audit report/opinion data and firm specific characteristics, make a significant contribution to increasing the default prediction power of risk models, built specifically for SMEs. Lenders must invest in the production of 'soft information' to supplement the financial data used in these models (Mccann & Mcindoe-Calder, 2015). Dainelli et al. (Dainelli, Giunta, & Cipollini, 2013) give a summarization of determinants of SME credit worthiness under Basel rules. As their model does not include qualitative information, future research could aim to set out the qualitative determinants in the rating judgment. Petersen (2004) concludes that technology is changing the way we communicate. One of these changes is a greater reliance on hard relative to soft information. Despite this, very little research has been published on the concept of activities used by lenders to gather soft information (Suter & Anderson University (Anderson, 2007). Suter (2007) studied the collection of soft information by small community banks. He built a conceptual framework existing of four factors to reduce the asymmetric information: 1) Knowledge of business, 2) Knowledge of industry, 3) Knowledge of local market, and 4) Value of the social contract. Angilella and Mazzù (2015) structured the non-financial criteria hierarchically on the basis of the risk areas, specific to an innovative firm: development, technological, market, and production. The risk areas considered are: Technological risk, Market risk, Production risk, Innovation indicators, Financial criteria.

Performance

To measure performance, there are several metrics (Chen et al., 2016). One of the most important measures is accuracy. In terms of performance, an accuracy rate between 81 and 90% reflects a realistic average performance based on the results of the analyzed studies (Kirkos, 2012). The top five bankruptcy models with an accuracy level of more than 80 per cent are (Aruldoss, Travis, & Venkatesan, 2015): 1) Altman (1968), 2) Edmister (1972), 3) Deakin (1972), 4) Springate (Altman, 1968), and 5) Fulmer (Edmister, 1972). All of these only use hard features. Chen et al. (Chen, Huang, Tsai, & Tzeng, 2013) find that the use of soft information significantly improves the power of default prediction models.

The same conclusion is realized by Ju and Sohn (2014) who proposed to update the credit scoring model based on new features like management, technology, marketability, and business and profitability. Kosmidis and Stavropoulos (2014) even got one step further in their conclusion, as they state that factors such as economic cycle phase, cash flow information and the detection of fraudulent financial reporting can evidently enhance the predictive power of existing models. Altman, Sabato and

Wilson (2010) reach the same conclusion as they state: *"that qualitative data relating to such variables as legal action by creditors to recover unpaid debts, company filing histories, comprehensive audit report/opinion data and firm specific characters make a significant contribution to increasing the default prediction power of risk models built specifically for SMEs."*. This leads us to the first conclusion that the financial industry should not only rely on hard features, which have a time delay, but also on soft information to assess the financial credit risk; see bottom left side in Figure 3. Relationship lending is based on soft information and is best suited for entities that are more opaque; and transactions-based lending is best suited for SMEs that are more transparent (Udell, 2008).

To realize proper research in this area, the researchers have to go beyond the already cumulative features and look at the base data. E.g., no longer apply the cumulative feature: current assets but instead build features on the base information such as debtors' information.

B. Information Source

In addition to the type of information available, the data source and its fluidity are also factors. In financial literature, this phenomenon is called "the hardening of soft information" (Chen et al., 2016). The concept "the hardening of soft information" states that because personal contact with financial institutions has decreased, therefore they rely more and more on hard quantitative information. Since more banks, credit organizations, and accountants rely on non-personal contacts, this statement is gaining importance.

Thereby underlying the fact that the traditional features are the most useful features to analyze the financial credit risk. The main reason they state to support their claim is the adoption rate of technology.

However, a counter claim can be made that through the adoption of technology, soft information can be more easily collected. For example, through firehose access to social media websites. However, this will depend on the type of soft or hard information one wants to retrieve because not all soft information can be retrieved through social websites, some still might need to be retrieved face to face. Therefore, the bottom part of our model, see Figure 3, indicates the lending technologies, being the manner in which the information is retrieved. A lending technology is *"a set of screening and underwriting policies and procedures, a loan contract structure, and monitoring strategies and mechanisms"* (Berger et al., n.d.). Examples of lending technologies they apply are:

leasing, commercial real estate lending, residential real estate lending, motor vehicle lending, and equipment lending, asset-based lending, financial statement lending, small business credit scoring, relationship lending and judgment lending.

C. Organisation Size

In FCRA literature, from a banking perspective, a distinction is made between the manner in which small and big banks assess the risk. Small banks apply more of a relationship perspective to assess the risk, while big banks apply the analysis of transactions to determine the risk. Although this specific distinction cannot be found in accountancy and lending (firms) literature, the hypothesis is that the same basic rules apply. Therefore, the right axe of the FCRA Model contains the size of the firms, assessing the risk; see Figure 3.

Loans to small businesses have traditionally been based on intimate relationships between borrower firms and lenders, because many of these firms are much more informationally opaque than large firms. Thus, lenders primarily rely on soft information, gathering through long-lasting transaction relationships. For banks it is difficult to obtain detailed information from small firms since the financial reports of small firms are mainly for tax purposes (Bhattacharya & Thakor, 1993).

III. Research method

The goal of this research is to identify and classify features that have been applied to assess Financial Credit Risk. In addition to the goal of the research, also, the maturity of the research field is a factor in determining the appropriate research method and technique. Based on the number of publications and identified features, the maturity of the FCRA research field can be classified as mature. Mature research fields should A) focus on further external validity and generalizability of the phenomena studied, or B) focus on a different perspective on the constructs and relationships between identified constructs (Edmondson & Mcmanus, 2007). Current studies have focused on two elements: 1) selecting the best features to predict bankruptcy, while other studies have focused on 2) comparing the efficiency and effectiveness of the different features identified. However, current analysis focuses on two viewpoints: 1) a high abstraction level and 2) a high latency perspective.

Summarized, to accomplish our research goal, a research approach is needed in which the current features are explored, compared and mapped to the FCRA Model.

To accomplish this goal, a research approach is needed that can 1) identify features for FCRA, 2) identify similarities and dissimilarities between features, and 3) map the features to the FCRA Model. The first two goals are realized by applying a structured literature research and the use of a comparison table. The last goal is realized by coding the features identified, based on a priori coding scheme.

IV. Data collection and analysis

As stated in the previous section, the goal of this research is to 1) identify features for FCRA, 2) identify similarities and dissimilarities between features for FCRA, and 3) map the features to the FCRA Model.

The selection of the papers has been conducted via the link-tracing methodology (Spreen, 1992), more specifically via snowball sampling. The snowballing was applied to take advantage of the social networks of identified respondents to provide a researcher with an ever-expanding set of potential contacts (Thompson, 1997). Snowballing is an effective and efficient form of contact tracing for use in diversity of research methods and designs, and apparently well suited for a number of research purposes (Hjelm, Nyberg, Isacsson, & Apelqvist, 1999) (Patrick, Pruchno, & Rose, 1998). For both the hard features and soft features two different snowball samplings have been conducted. For the hard features this resulted in 238 papers that were included in the coding. With respect to the soft features this resulted in 20 papers to be selected for coding. For a study to be selected for coding, the study must explicitly address hard and/or soft features for FCRA (see Table II for details). The unit of analysis for coding is a single feature, implying that one study can contribute multiple units of analysis. For example, Alam et al. (2000) contributed five features: 1) "*Net loan losses / Total assets less Total loans*", 2) "*Net loan losses / Total loans*", 3) "*Net loan losses plus Provision for loan losses / Net income*", 4) "*Loans past due 90 days plus Nonaccrual loans / Total assets*" and, 5) "*Net income / Total assets*". This resulted in the identification of 700 hard features and 135 soft features. Each of the hard and soft features have been added to a comparison table, see Table I (Cornee & Szafarz, 2014)(Grunert, Norden, & Weber, 2005)(Altman, Sabato, & Wilson, 2010)(Trönnberg & Hemlin, 2014).

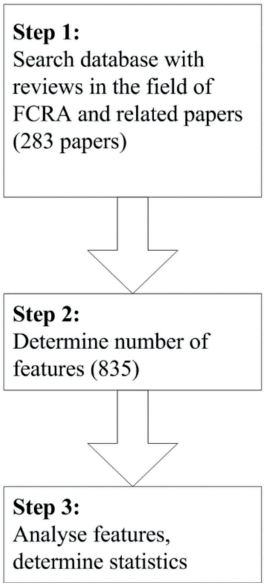


Figure 4. Feature Selection.

Data analysis was conducted in one cycle of coding with the use of a priori coding scheme. The reason an a priori coding scheme was applied, is because the concepts that needed to be coded were known upfront, based on the previously defined FCRA Model.

To code the selected items, the following questions are asked: 1) *is the feature a hard or soft feature?* and 2) *is the feature a relational or transactional feature?* For example, the feature *"net income/total assets"* is a hard feature from a transactional perspective. A hard feature because the ratio can be calculated and transactional, because the figures can be derived from a system. An example of a hard / relational feature is *"the number of times the annual financial statements are deposited too late".* A hard feature because the number can be calculated and relationship because it's a proxy of a soft feature, for example of management quality.

"The quality of management" is a soft feature from a relational perspective. A soft feature because it cannot be calculated directly and the (qualitative) information has to gathered via personal contacts.

Table I. Snapshot comparison table.

	Grunert (2005)	Altman (2010)	Cornee (2014)	Tronnberg (2014)
Management Quality	1		1	1
Country Court Decisions		1		
Audit Accounts		1		
Late Filling Days		1		
Sector				
Industry Risk				

V. Results

In this section, the results of the data collection are presented. As described in the previous section, first features from existing studies have been collected, added to a comparison table and coded. Therefore, three separate results can be identified: 1) descriptive statistics for hard features, 2) descriptive statistics for soft features and, 3) the mapping of the hard and soft features to the FCRA Model.

A. Results from an information type perspective

As stated in this section, most features are based on data from the financial statements. Financial statements are, in most organizations, created once or twice a year. Therefore, the data needed to calculate the features, is available once or twice a year. This causes an information opacity problem thereby reducing the effectiveness of the features. Other organizations that also assess the financial credit risk of an organization are banks, credit assessors, etc. Both previously also had to trust numbers that are published once a year. Since this time period is too long for both parties, they searched for solutions to address this problem.

Camacho-Miñano et al. (2015) show that sector, size, number of shareholdings, ROA, and liquidity can explain the bankruptcy process outcome and also predict the process for still-healthy firms. Three of five features exist of qualitative information.

Descriptive statistics for hard features

The extraction of the features resulted in the registration of 700 features from 238 papers. From this sample, the top ten features were identified and selected; see Table II.

Table II. Top ten features.

Feature 01: Net income/total assets	85 (papers)
Feature 02: current ratio	74
Feature 03: EBIT/total assets (*)	65
Feature 04: retained earnings/total assets (*)	62
Feature 05: working capital/total assets (*)	60
Feature 06: sales/total assets (*)	46
Feature 07: quick ratio	41
Feature 08: current assets/total assets	39
Feature 09: total debt/total assets	39
Feature 10: cash/total assets	32

Analysis of the hard features show that each of the top ten applied features are features that are applied in the financial statements of the organization. In addition, each feature lies a connection between the three main components of the financial statements namely: the cash flow statement, profit and loss statement, and the balance sheet. They do so by comparing the liquidity (features 02, 05, 07, 08, 09 and 10), the solvency (features 03 and 04) and the profitability (features 01, 03 and 06). Where the liquidity is primarily related to cash flow; the solvency is related to the balance sheet; the profitability is primarily related to the profit and loss statement. Of course, there is a main interrelationship between all these three main components of the financial statements.

Additionally, results show that our findings are in line with statements made in previous research, namely that the Altman model for bankruptcy prediction (Altman, 1968) is the most applied one. This is indicated by the fact that 4 features in the top 10 (indicated by an asterisk) are part of the Altman-Z score. And the fifth feature by Altman (Market Value of Equity/Total Liabilities) ranks thirteenth.

Descriptive statistics for soft features

The extraction of the features resulted in the registration of 135 features from 20 papers. Likewise, to the hard features a top ten can be derived. However, in contrast to the hard

features this top ten would exist out of features that are only mentioned four, three, or two times. One feature is listed four times, namely *"management quality"*. Four features are listed three times, namely: *"county court judgements"*, *"decision to check audited accounts"*, *"decision to issue cash flow statements"* and, *"late filing days"*. Followed by twelve features mentioned only twice. The remaining 118 features all are mentioned once. Therefore, creating a top ten didn't seem useful. In addition, the soft features have been additional coded to create a categorization (see Figure 5). The categorization has three main differentiations: 1) internal, 2) external and 3) social contract. 'Internal' is defined as qualitative (soft) information about the client; for example, about the client's management and its innovative power. 'External' can be seen as the environment that affects and interacts with the client. There are three main sub-categories: business (e.g., the number of visits with customer vendors & suppliers or visits with customers about business status), industry (e.g., the number of reviews of trade journals from customer's industries or the number of memberships in trade associations relating to customer's industries) and economy (e.g., the number of attendances at local chamber events or number of memberships in civic and community organizations). The last differentiation is 'social contract', which is defined as qualitative (soft) information about the lending relationship. 'Social contract' is further divided in two categories: quality of the credit relationship and value of the social contract.

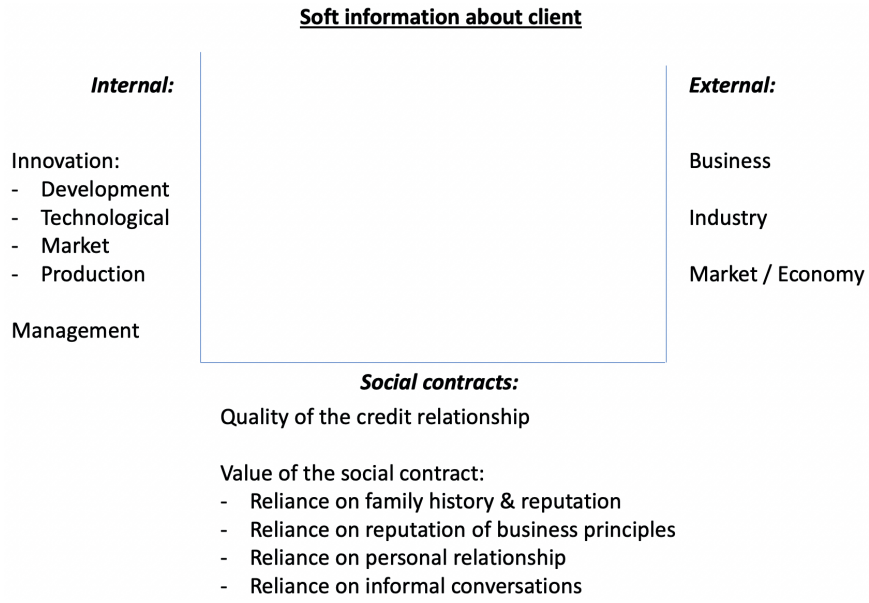


Figure 5. Categorization Soft Features.

Descriptive statistics for techniques

Based on the 128 papers (Ravi Kumar & Ravi, 2007) the frequency of the techniques applied to take the FCRA-decision have collected. In total 84 techniques have been identified. Seven techniques occur more than five times. Out of these seven techniques four occur more than 10 times, see Table III. The remaining 77 techniques occur up to 4, 3, 2 or 1 times.

Table III. Top 7 techniques.

Technique	#
BPNN (Back propagation trained Neural Network)	28
DA (Discriminant Analysis)	18
LOGIT	18
LDA (Linear Discriminant Analysis)	10
Rough Set	08
GA (Genetic Algorithm)	05
Probit	05

Descriptive Statistics for performance

Overall can be stated that research on feature identification does not clearly report on the (overall) performance of the features identified. Off the researched paper, only 16 report extensively on the performance of the applied techniques. We argue that further research should report on the performance of the identified and tested features. To measure the performance Chen (2016) identified 17 measurements which can be applied, for example: 1) accuracy, 2) root mean squared error, 3) true positive, and 4) true negative. For the detailed description of these 17 measurement we refer to Chen et al. (2016).

B. Results from a DMN perspective

Analyzing the top ten features from a DMN perspective shows four results. The first result: decision versus data input show that each feature is treated like a decision. The feature is derived from one or more conditions. For example, the first feature is derived out of two conditions: net income and total assets to which a mathematical formula is applied, in this specific case, net income divided by total assets. Each feature in the 10 retrieves the applied conditions from one data source, namely, the financial statements (the cashflow statement, the profit and loss account and/or the balance sheet).

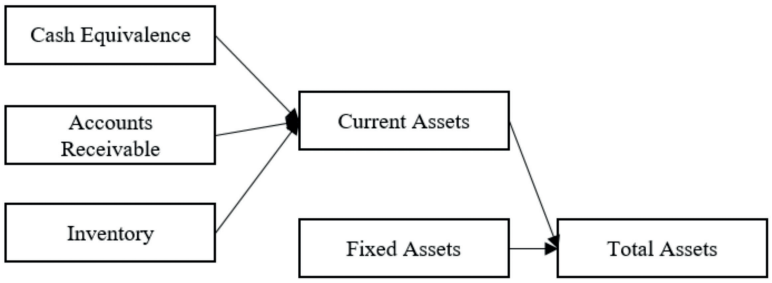


Figure 6. DRD-level Elements (Hard Features).

From the perspective of the financial statements, the conditions applied, e.g., net income, actually are data input since all are listed there. However, when analyzing one step deeper, each data input on the balance sheet or the profit and loss account is actually a decision. For example, total assets, is calculated as current assets plus fixed assets; see Figure 6. When analyzing all of the quantitative features selected, all features are derived from the cashflow statement, the profit and loss account and/or the balance sheet. A potential explanation of this phenomenon can be that the financial industry only looks at formal documents and formal statements. However, this raises the question if these combined features contain specific sub-decisions or specific input data elements that make them suitable for analysis. According to the researchers, this would be a subject to further investigate.

In addition, the features only apply information from the current financial statements. Formally, the cashflow statement, the profit and loss account and the balance sheet have to be created once a year. Most companies create this information more times a year, voluntarily or obligatory. Also, not comparing information from early years, thereby indicating that the patterns have no additional information value. By analyzing the deeper layers underneath the features described previously, the hypothesis is that a better and quicker FCRA can be performed.

C. Results from an information source perspective

The third perspective from which factors can be classified is the information source perspective. The concept *"the hardening of information"* states that because personal contact with the bank has decreased the banks rely more and more on hard quantitative information. However, if the model on which they base these conclusions is further dissected, two axes can be distinguished: A) the type of data and B) the manner in which the data is retrieved. The first axe describes the type of data that organizations retrieve to make a judgement about the financial credit risk. In the papers of Berger,

the same distinction is made in an information type perspective: hard versus soft data. The second axe described the manner in which this information is retrieved. For example, two manners in which information can be collected are: 1) through face to face contact between a loan officers and the organization's owner and 2) through a form on a website or any other digital manner. Since more banks, credit organizations, and accountants rely on the second, the statement of "the hardening of information" is that only quantitative data is used. Thereby underlying the fact that the traditional features are the most useful features to analyze going concern assessment. The main reason they state to support their claim is the adoption rate of technology.

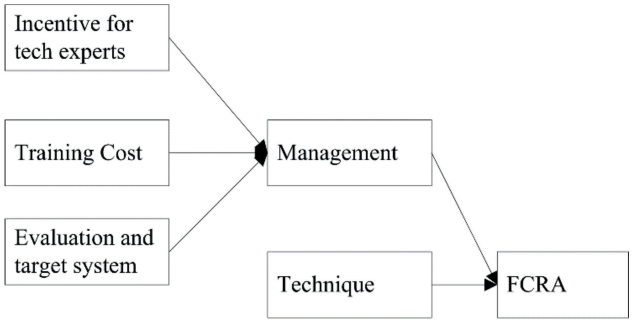


Figure 7. DRD-level Elements (Soft Features).

However, a counter claim can be made that through the adoption of technology soft information can be more easily collected. For example, through firehose access to social media websites. However, this will depend on the type of soft or hard information one wants to retrieve because not all soft information can be retrieved through social websites, some still might need to be retrieved face to face. Therefore, the bottom part of our model, see Figure 3, indicates the manner in which the information is retrieved.

D. Results from an organization perspective

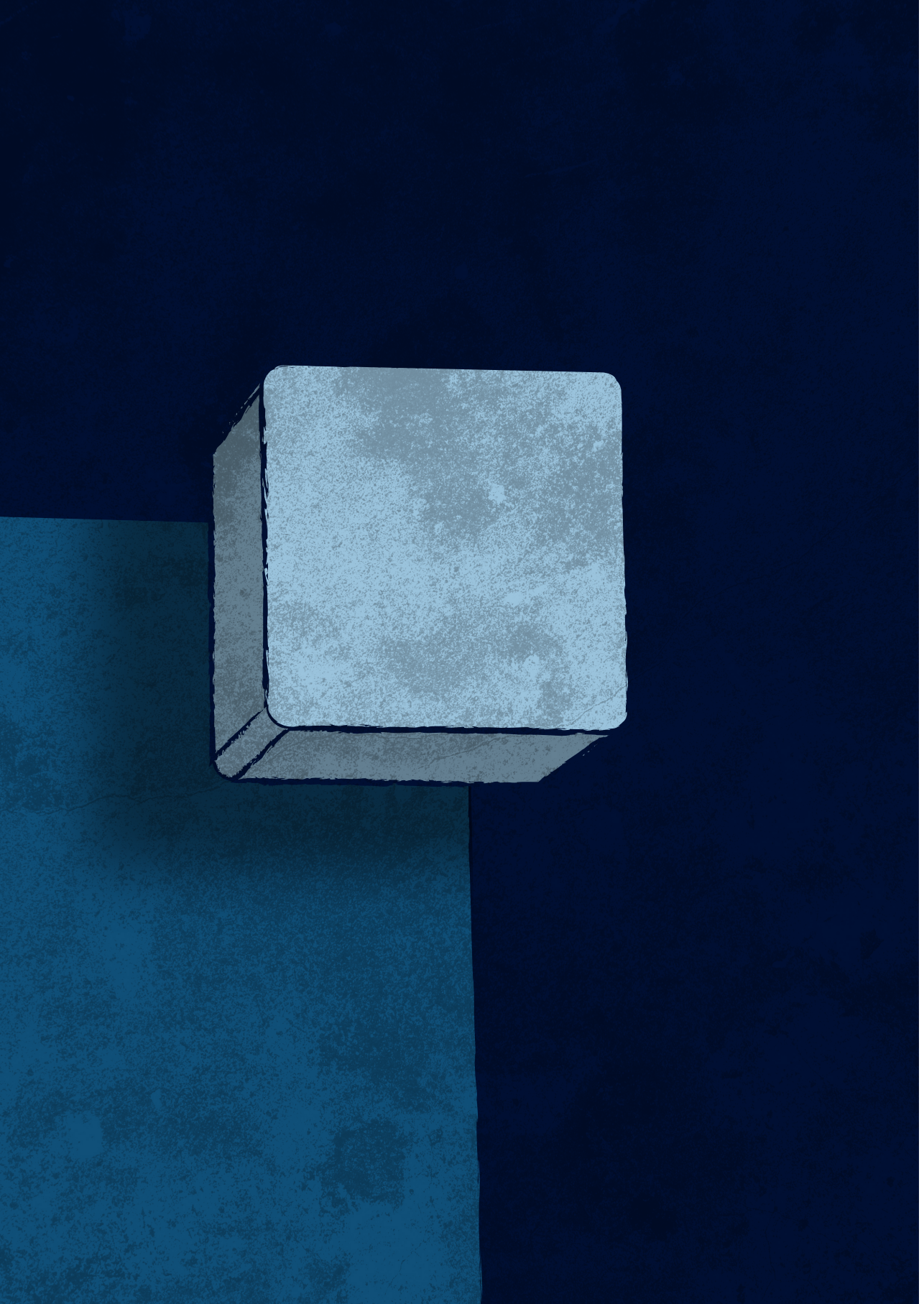
In FCRA literature, from a banking perspective, a distinction is made between the manner in which small and big banks assess the risk. Small banks apply more of a relationship perspective to assess the risk while big banks apply the analysis of transactions to determine the risk. Although this specific distinction cannot be found in accountancy and lending (firms) literature, the hypothesis is that the same basic rules apply. Therefore, the right axe of the FCRA Model contains the size of the firms assessing the risk; see Figure 3.

VI. Conclusion and future work

In this chapter, we aimed at finding an answer to the following research question: *"how to categorize financial credit risk features such that an integrative relationship is established with the information type applied and information sources used?"* To accomplish this goal, we conducted a literature study to identify features that have been designed and applied in previous research followed by coding the features based on an a priori coding scheme. The literature resulted in a total of 258 selected papers. From the selected papers, a total of 835 features were selected. Based on the a priori coding scheme, the features were mapped according to the following dimensions: A) the type of features applied, B) the information source applied and, C) the type of organization that applies the features. The results show that most features focus on hard information from a transactional source from official information with a high latency. In addition, the results show that most features still relate to the traditional Altman-Z score.

All the results have been mapped on the FCRA Model, which is based on Wand and Weber (1990), see Figure 3. The insights derived from this study provides a better understanding of the level on which the features are applied and where they score in the FCRA Model. This will enable further exploration and identification of features that have a low latency but still have a proper predictive power. From a practical perspective, our study provides an overview of features that can currently be applied, and which further exploration should be considered.

While we provide an integrative overview of features for FCRA, our study is not without limitations. The first limitation concerns the sampling and sample size. The sample group of features is drawn from the identified paper without considering the effectiveness of the features selected. The main reason for this choice is the fact that not all papers report on the effectiveness of the features applied. While we believe that for the purpose of this study this causes no problems, further refinement of the features selected is recommended. Additionally, our results should be further validated in practice.



Chapter 6

Conclusions and Outlook

Introduction

As described in the Introduction, the main research question (MRQ) of this dissertation is:

MRQ: What are promising perspectives from technology for improving auditing?

In this chapter, an overview of the results is provided. The conclusions and contributions are presented per research sub-question. We made practical and theoretical contributions to the field by: 1) taking a blockchain-based approach to audit the completeness assertion, 2) developing a practical maturity model for continuous auditing, 3) assessing a set of business rules management principles to evaluate transparency, and 4) refining the financial credit risk assessment model. Together, these deliverables contribute to finding an answer to the main research question presented in this dissertation. The summary is followed by the conclusions and implications, limitations, and suggestions for future research.

I. Stepwise summary

Our aim was to build on several findings showing that the deployment of technology (to automate parts of the audit process) has a positive effect on audit quality (Dowling & Leech, 2007; Manson et al., 1998; Vasarhelyi, 1983).

In order to answer our Main Research Question, it was subdivided into four sub-questions:

SQ-1: In what way has the auditor's audit approach changed, in the blockchain era?

In Chapter 2, our aim was to find an answer to the following sub-question: *In what way has the auditor's audit approach changed, in the blockchain era?* To accomplish this goal, we conducted a study using offline experiments. In these experiments, we replaced current relationship tests with an interorganization ledger. From a research perspective, our study provides a starting point for further research regarding challenges that could potentially affect the work of the auditor, i.e. the development of best practices, concepts and methods in an inter-organization ledger area. From a practical perspective, our study provides a possible solution with regards to carrying out more stringent checks on the accuracy and completeness of the financial statement items.

In summary, we can conclude that triple-entry blockchain accounting provides an opportunity for a more efficient and effective audit. Once the reliability of the blockchain has been established, it can be assumed that the items marked with an A in Figure 1 are accurate and complete. That is, an auditor no longer needs to audit sales, opening and closing balances of accounts payables, purchases, opening and closing balances of accounts receivables, and opening and closing balances of cash for completeness and accuracy. Taking into account the limitations of our study and its results, we argue that more studies are needed to investigate how these techniques can be effectively implemented. Further research is needed to provide insight into the capabilities of various technologies, and the impact of introducing these new technologies on auditing training programs. This research could be extended by incorporating a maturity model with reference to the possibilities of auditing in a blockchain environment.

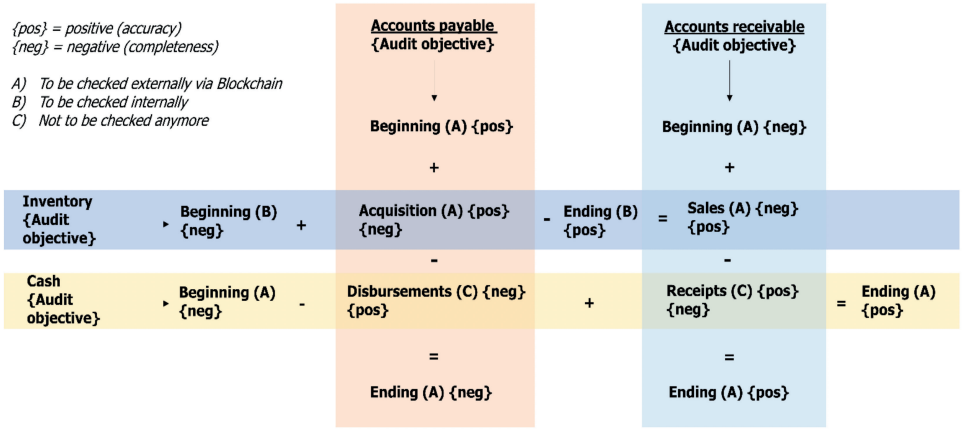


Figure 1. Representation of comprehensive relationship model.

SQ-2: How can the different stages and the improvement of Continuous Auditing be measured?

The objective of this study, as described in Chapter 3, was to find an answer to the following sub-question: *How can the different stages and the improvement of Continuous Auditing be measured?* We answered this question by developing a CA maturity model. Based on the results of the two interview rounds, this maturity model was further refined, resulting in a model that consists of five maturity levels and four capabilities.

The maturity levels are: 1) initial approach, 2) ad hoc approach, 3) defined approach, 4) managed approach, and 5) optimized approach. The four capabilities are: A) systems, B) data, C) organization, and D) people.

	Stage 2 - Ad hoc Approach
Systems	Localized, No-Normalized, Extract-Transform-Load Software
	Localized, No-Normalized, Scripting / Analysis Software
	Localized, No-Normalized, Reporting Software
Data	Ah-hoc data-analysis
	Localized approach for data analytics (methodology)
	Localized procedures for data analytics (performed ad-hoc)
	Ad-hoc access to data-sources
	Access to derived data
	Data quality is not enforced
	Only analyses on ratios
	Reactive, centralized data-governance
Organization	Localized key ratio's
	No specific monitoring on transaction level
	No detective alarm and follow-up process
	Organisational: high human dependency
	IT-Organisational: low IT dependency
	No Extract-Transform-Load Expert
	No Script Builder
	No championing
	(Internal) Accountant
	Independent IT-Auditor
	No PDCA Cycle
	Data-ownership function defined
People	No specific competence requirements ETL-Expert
	No specific competence requirements script-builder
	No specific competence requirements champion
	Well developed competence (internal) Accountant
	Limited developed skill IT-Auditor

Figure 2. Snapshot of Maturity level 2: Ad hoc approach.

To ground our presentation, we refer to Figure 2 which presents a snapshot of the final maturity model. In our study, the maturity levels are presented, after which the capabilities are discussed. For the ad hoc approach, the information that is obtained, the resources that are used and the people carrying out the control tasks, an organization policy is drawn up. Qualitative and quantitative measures are applied, these may be trends that are derived from financial statements in combination with benchmark results

from the relevant sector. The reliability of the ad hoc approach remains dependent on personal skills and the objectivity of people. In comparison with level one, the ad hoc approach is more disciplined and meets the basic needs of the organization because processes have been standardized. The ad hoc approach is also focused on the systems used and the course of the defined processes.

Some limitations of our study must be acknowledged. The first limitation is related to the sample of organizations that participated in the data collection. Although the respondents worked in a range of professions (pension providers, mortgage lenders, consultants, etc.), the sample size was limited. One could argue that the results of this study are not fully generalizable. The second limitation also concerns generalizability, and is related to our approach, which consisted entirely of qualitative data collection and analysis techniques. One characteristic of qualitative approaches is the limited generalizability of the findings towards similar and dissimilar contexts.

SQ-3: Which BRM design principles affect the transparency of the design and execution of a decision and business rules management solution?

Transparency might be viewed as both an effect of auditing and a prerequisite for auditing. To explore this issue, the following sub-question was posed in Chapter 4: *Which BRM design principles affect the transparency of the design and execution of a decision and business rules management solution?* In order to answer this question, previously identified BRM design principles were selected and scored with regard to their effect on transparency, based on five selection criteria. Our results show that eight principles have no effect on transparency, while the remaining twelve principles do have an effect on transparency. From a theoretical perspective, this study contributes to the knowledge base by investigating how principles – in this case BRM design principles – could be evaluated in terms of transparency (See Table 1). It also provides interesting directions for future research that could further explore how BRM solutions could improve transparency of decisions and business logic. From a practical perspective, this study provides organizations with a set of twelve BRM design principles that have been proven to affect transparency within organizations. Organizations that want to achieve more transparency should take these twelve BRM design principles into account. Furthermore, these results provide (enterprise) architects with a framework that can be used to structure thinking about the solution that needs to be designed and implemented.

It is worth noting that the study presented in Chapter 4 is not without limitations. An important limitation concerns the sampling of the BRM design principles, which were solely drawn from Dutch governmental institutions.

Table 1. BRM design principles.

1	Automated decisions where possible, supported decisions if necessary
2	IT does not formulate business rules
3	No big bang but iteration approaches for business rules projects
4	Authorization for decision-making
5	Ownership of a decision is defined
6	Traceable decisions
7	Data is recorded according to two-time dimensions
8	All business rules must refer to a source
9	P.E.N.S criteria are determined for each business rule set
10	Reuse before buying and creating software
11	Best-of-suite approach
12	Gaming only permitted between 09:00 AM and 17:00 PM
13	Sharing knowledge concerning the execution of laws, regulations, and policies with employees and clients
14	Adhere to context structures
15	Create once and use multiple times
16	Communication with the same standards wherever possible, communication with different standards where desirable
17	Flexible decisions
18	Utilize government-wide standards
19	Separation of the know and flow
20	Develop business rules from a management perspective rather than an implementation perspective
21	Transparency concerning decision-making for clients and users
22	Include compliancy in designing products and/or services

SQ-4: How to categorize financial credit risk features such that an integrative relationship is established with the information type applied and information sources used?

In Chapter 5, our aim was to answer the following sub-question: *How to categorize financial credit risk features such that an integrative relationship is established with the information type applied and information sources used?* Based on an priori coding scheme, the features were mapped according to the following dimensions: A) the type of features applied, B) the information source applied and, C) the type of organization that applies the features. The results show that most features focus on hard information from a transactional source from official information with a high latency. The insights

derived from this study provide a better understanding of the level on which the features are applied and how they are scored according to the FCRA model. This will enable further exploration and identification of features that have a low latency but still have a proper predictive power. From a practical perspective, our study provides an overview of features that can currently be applied, and which deserve further exploration.

An integrative overview of features for FCRA has been provided in Chapter 5. However, our study is not without limitations. The sample group of features was drawn from the identified papers, during the literature review, without considering the effectiveness of the features selected. The main reason for this choice was the fact that not all papers report on the effectiveness of the features applied. While we believe that - for the purpose of this study - this is not an issue, further refinement of the features selected would be recommended in any future research. Additionally, our results should be further validated in practice.

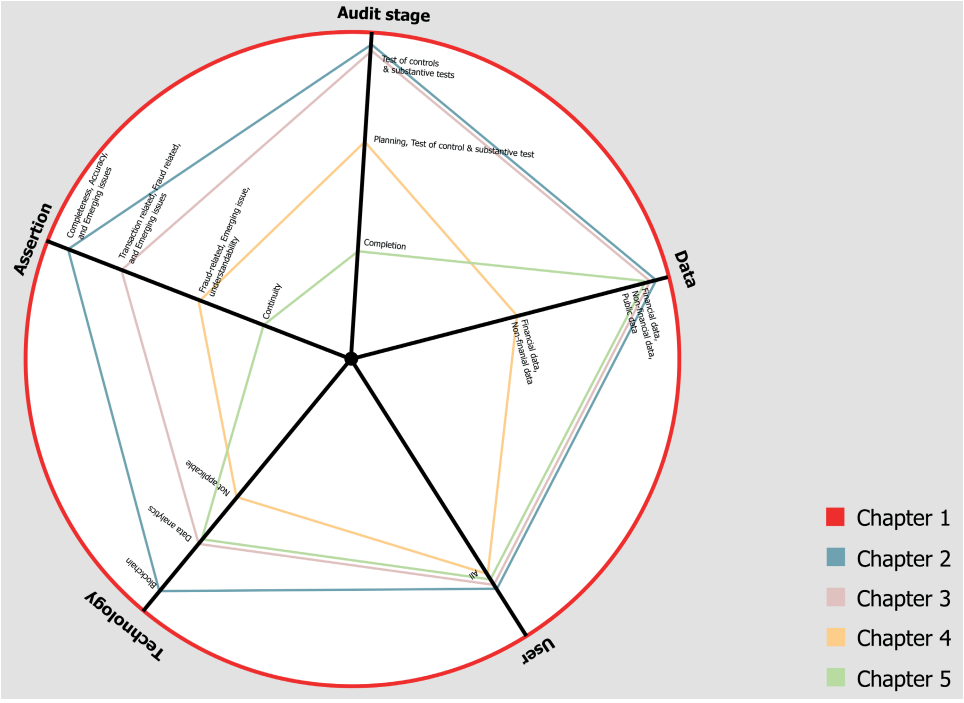


Figure 3: Technology Framework for Auditing

II. Technology framework for auditing

As described in Chapter 1, the deployment of technology (to automate parts of the audit process) is positively related to audit quality (Dowling & Leech, 2007; Manson et al., 1998; Vasarhelyi, 1983). In our research, we studied the impact of technology from several different perspectives: 1) the impact of blockchain on the auditor's audit approach (Chapter 2), 2) continuous auditing (Chapter 3), the connection between transparency and auditing (Chapter 4), and the financial credit risk assessment model (Chapter 5). Building on the work of Dai and Li (2016) and Dai (2017), we propose a Technology Framework for Auditing. Our final model consists of the following five dimensions: 1) assertion, 2) audit stage, 3) data, 4) user, 5) technology. Our five studies have been plotted on this framework, starting with the red circle that represents the concept of auditing. The blue pentagon is a representation of our blockchain study in which we investigated how the auditor's audit approach has changed in the blockchain era (Chapter 2). In Chapter 3, we explored ways of improving continuous auditing. This study is represented by a pink pentagon. The yellow pentagon is the representation of our transparency study, in which our aim was to identify how current design principles for business rules management add value in terms of transparency (Chapter 4). Lastly (Chapter 5), the green pentagon visualizes our study with reference to the measurement of continuity, in which we investigated how best to categorize financial credit risk features.

III. Discussion and future research

As in the saying "standing on the shoulders of giants", the technology that impacts auditing - evolves step by step. In our opinion, in order to achieve a high level of maturity, many 'giants' still need to 'climb' onto other people's 'scientific' shoulders. In this dissertation, we identify multiple opportunities for future research, related to technology and auditing.

In Chapter 2, using an experimental approach, data was collected to compare the double-entry method with the blockchain-based triple-entry method. The results show that the main difference concerns determining the completeness of the financial statement items. However, further research should be conducted exploring the real-life opportunities for using this technique.

In Chapter 3, CA is explored in the context of pension funds. Future research should therefore focus on CA in different contexts. Second, challenges and situational factors

regarding CA still need to be identified and thoroughly validated. Furthermore, it is to be expected that situational factors also (significantly) influence human resources, implementation challenges and principles. Research into these relationships also provides an important direction for future research. Finally, the maturity model presented would benefit from further validation, and any future approaches would benefit from incorporating qualitative methods that may increase generalizability. While we believe that - for the purpose of this study – our selection was adequate, further refinement of the features selection would be recommended for any future studies.

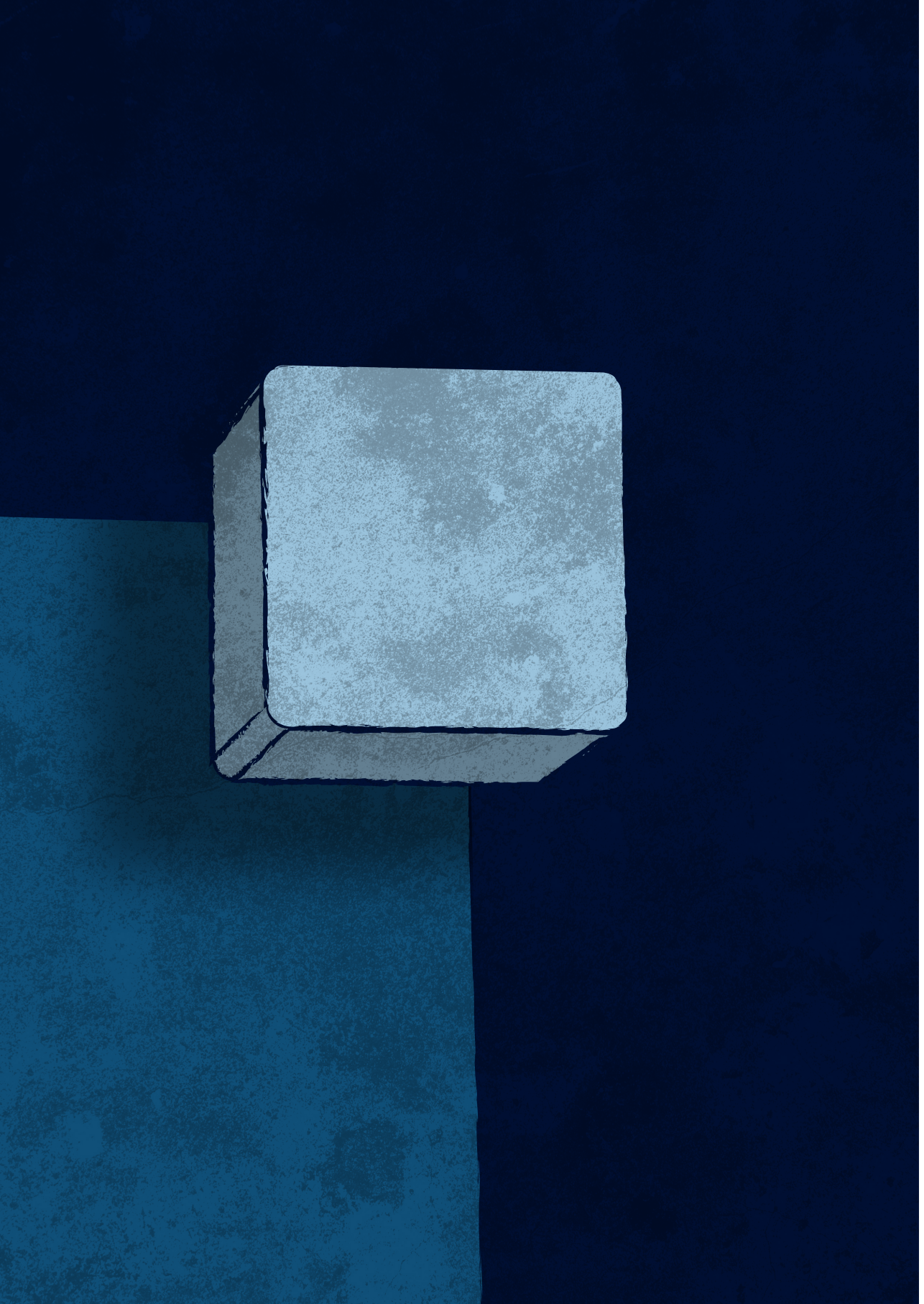
In Chapter 4 (the Added Value of Business Rules Management Principles to Transparency), one potential limitation concerns the sampling of the BRM design principles, which were drawn solely from Dutch governmental institutions. However, the current body of knowledge about such design principles is thin on the ground. We argue that our focus on government institutions – dealing with the implementation of many business decisions and rules derived from laws and regulations - provides a solid foundation from which to carry out future research. Nevertheless, in order for further generalizations to be made, future research should also focus on non-governmental organizations, to explore whether the current set of BRM design principles are also relevant in these other contexts. Additionally, generalization could be increased by involving practitioners as well as other stakeholders that deal with the design and implementation of BRM solutions with the goal of increasing transparency. Lastly, while we argue that the research approach chosen for this type of research is appropriate, research focusing on further generalization should apply different research methods, including quantitative research methods, which will allow for the incorporation of larger sample sizes in order to validate our findings.

In addition to our suggestion for further research directly related to our studies, we also identify a need for future research from a broader perspective. The existing approach to auditing corporate financial statements contains two inherent flaws that have raised concerns in both academia and practice. The nature of the traditional attestation framework hinders timely and relevant assurance reporting. This was already noted by Vasarhelyi & Halper (1991) in the early 90s. The final step to continuous assurance has been left largely unexplained. In particular, no clear and ambiguous definitions of continuous monitoring, continuous auditing and continuous assurance currently exist. As a result, the relationship between the three previous mentioned concepts is also unclear, as is the governance and the technical implementation of them (Kocken & Hulstijn 2017). In addition to continuous monitoring, auditing and assurance on financial statement accounting, also assurance engagements on additional objects is more and more frequently required (Decaux, 2015; Elliott, 2002; Knechel et al., 2006).

Hasan et al. (2005) identified assurance about environmental performance as the most common type of non-financial service. They also found that internal controls were the most common types of systems to be assured (Decaux, 2015). It is also worth noting that there is an increasing need for companies to receive assurance about their sustainability reporting (O'Dwyer, Owen, & Unerman, 2011). Due to increased interest, integrated reporting and integrated thinking is an up and coming field of research (Dumay et al., 2019; de Villiers, Venter, & Hsiao, 2017).

From a broader perspective, organizational dynamics and practices have become increasingly organized around risk (Knechel, 2001; Soh and Martinov-Bennie (2015) found that assurance on risk management is perceived to be of greatest importance. In line with the armchair auditor suggested by Dai & Li (2016), in future research we intend to develop a continuous assurance ecosystem, whereby attention will be paid to: 1) the frequency of the assurance tasks, 2) the reliability level, 3) the level of assurance, 4) the assurance objective, 5) the standards framework, and 6) who is performing the assurance tasks. Particular attention will be paid to the use of exogenous data in combination with internal data to achieve a certain level of assurance. Assurance services are not exclusively provided by internal and/or external auditors (Decaux, 2015). In terms of further research, we strongly encourage further development of a model for continuous (real-time) assurance that incorporates combined assurance (L. Decaux & Sarens, 2015) and the armchair auditor. (Dai & Li, 2016).

Techonology is never a goal, but a means. From our perspective, technology is one of the means to improve audit quality. To further explore this relationship, we have performed a study of which the results are submitted to the Auditing Research Journal (arjnl). We aimed to find an answer to the following research question: "Which factors influence audit quality?". To accomplish this goal, we conducted a survey study to investigate the factors that can be applied to measure audit quality. To measure audit quality, a conceptual model and three hypotheses have been created. In total we conducted three rounds of survey refinement after which the survey was send to 108 participants of which 77 responded (response rate 71%). Results show that "the input of resources into the audit process", "procedures of the audit processes" and "the quality of the output of audit process" have a significant impact in measuring audit quality.



Appendices

- References
- Publication List
- Summary
- Nederlandse Samenvatting
- Curriculum Vitae

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Summary

In the Netherlands, the practice of auditing can be traced to the Pincoffs affair in the late 1870s. In the aftermath of this financial scandal, the first Dutch accountancy (accounting) firm, "Confidentia", was established in 1883. Unfortunately, the Pincoffs affair was not the only – and was certainly not the last – financial scandal to hit the corporate world. Many other examples of financial mismanagement involving a lack of audit quality can be found, including those at Enron (2001), Worldcom (2002), American International (2005), Lehman Brothers (2008), Bernie Madoff (2008), Carillion (2018), Gupta (2018), and Steinhoff (2019). In order to prevent this sort of mismanagement occurring, audit quality must be improved. In the past, several studies have shown that the deployment of technology (to automate parts of the audit process) has had a positive effect on audit quality (Dowling & Leech, 2007; Manson et al., 1998; Vasarhelyi, 1983). From an auditing perspective, multiple tasks can be partly or fully automated. Examples of such tasks include reconciliations, internal control testing, and tests of details. As a result of automating these kinds of tasks, more resources can be allocated to aspects of auditing that require human involvement (Moffitt, Rozario, & Vasarhelyi, 2018). In order to understand the bigger picture, we developed our Technology Framework for Auditing, based on Dai and Li (2016) and Dai (2017). Our framework consists of the following seven dimensions: 1) assertion, 2) business cycle, 3) risk level, 4) audit stage, 5) data, 6) technology, 7) users.

The objective of this dissertation is to provide practitioners with a better understanding of the impact of technology on auditing. This leads to our main research question (MRQ) presented in **Chapter 1**: *What are promising perspectives from technology for improving auditing?* To answer these research questions, we carried out four studies concerning: blockchain (Chapter 2), continuous auditing (Chapter 3), transparency (Chapter 4), and financial credit risk assessment (Chapter 5).

In **Chapter 2**, our aim was to find an answer to the following sub-question: *In what way has the auditor's audit approach changed, in the blockchain era?* To accomplish this goal, we conducted a study using offline experiments. From a research perspective, our study provides a starting point for further research regarding challenges that could potentially affect the work of the auditor, i.e. the development of best practices, concepts and methods in an inter-organization ledger area. From a practical perspective, our study provides a possible solution with regards to carrying out more stringent checks on the accuracy and completeness of the financial statement items.

The objective of the study described in **Chapter 3** was to find an answer to the following sub-research question: *How can the different stages and the improvement of Continuous Auditing (CA) be measured?* We answered this question by developing a CA maturity model. Based on the results of the two interview rounds, this maturity model was then further redefined, resulting in a model that consists of five maturity levels and four capabilities. The maturity levels are: 1) initial approach, 2) ad hoc approach, 3) defined approach, 4) managed approach, and 5) optimized approach. The four capabilities are: A) systems, B) data, C) organization, and D) people.

In **Chapter 4,** our aim was to answer the following sub-question: *Which BRM design principles affect the transparency of the design and execution of a decision and business rules management solution?* From a theoretical perspective, this study contributes to the knowledge base by investigating how principles – in this case BRM design principles – could be evaluated in terms of transparency. It also provides interesting directions for future research that could further explore how BRM solutions could improve transparency. From a practical perspective, this study provides organizations with a set of twelve BRM design principles that have been proven to affect transparency within organizations.

In **Chapter 5**, our aim was to find an answer to the following sub-question: *How to categorize financial credit risk features such that an integrative relationship is established with the information type applied and information sources used?* To accomplish this goal, we conducted a literature study to identify features that have been designed and applied in previous research. We then coded the features based on an a priori coding scheme. The results show that most features focus on hard information from a transactional source from official information with a high latency.

This dissertation contributes to the scientific body of knowledge by developing our Technology Framework for Auditing. This framework provides insight into the impact of audit technology on audit quality. Based on the outcomes of the various studies included in this dissertation, in **Chapter 6** we present our overall conclusion. In summary, we conclude that technology does contribute in certain ways to auditing. However, the implementation of audit technology often appears to be quite a complex process for auditors. In terms of further research, we strongly encourage further development of a model for continuous (real-time) assurance that incorporates combined assurance and the armchair auditor.

Nederlandse Samenvatting

De Pincoffs-affaire markeerde rond 1870 in Nederland de start van de accountancy. Deze affaire resulteerde in het eerste Nederlandse accountantskantoor "Confidentia" dat werd opgericht in 1883. Helaas was de Pincoffs-affaire niet de enige en zeker niet de laatste affaire in het bedrijfsleven. Enron (2001), Worldcom (2002), American International (2005), Lehman Brothers (2008), Bernie Madoff (2008), Carillion (2018), Gupta (2018), Steinhoff (2019) duiden op een gebrek aan kwaliteit binnen de door accountants uitgevoerde controles. In het verleden hebben verschillende onderzoeken aangetoond dat de inzet van technologie (om delen van het auditproces te automatiseren) een positief effect heeft op controlekwaliteit (Vasarhelyi, 1983; Manson et al., 1998; Dowling & Leech, 2007). Vanuit het perspectief van de accountant kunnen meerdere taken gedeeltelijk of volledig worden geautomatiseerd. Voorbeelden van dergelijke taken zijn: onderlinge afstemmingen, het testen van interne beheersingsmaatregelen en detailcontroles. Als gevolg hiervan kunnen controletaken die normaliter veel menselijke betrokkenheid vereisen steeds meer worden ondersteund door automatisering (Moffitt, Rozario, & Vasarhelyi, 2018). Om een samenhangend geheel te presenteren, hebben wij, gebaseerd op Dai en Li (2016) en Dai (2017), ons Technology Framework for Auditing ontwikkeld. Ons framework bestaat uit de volgende zeven dimensies: 1) bewering, 2) bedrijfsfunctie, 3) risiconiveau, 4) auditfase, 5) data, 6) technologie, 7) gebruikers.

Het doel dat we in dit proefschrift willen bereiken is om accountants een beter begrip te geven van de impact van technologie op auditing. Dit leidt tot onze belangrijkste onderzoeksvraag (MRQ) die wordt gepresenteerd in **hoofdstuk 1**: Wat zijn - van uit het oogpunt van technologie - veel belovende perspectieven ter verbetering van auditing? Om deze onderzoeksvragen te beantwoorden, hebben we 4 onderzoeken uitgevoerd met betrekking tot: blockchain (hoofdstuk 2), continuous auditing (hoofdstuk 3), transparantie (hoofdstuk 4) en continuïteitsbeoordeling (hoofdstuk 5).

In **hoofdstuk 2** wilden we een antwoord vinden op de volgende onderzoeksvraag: op welke manier verandert de controleaanpak van de auditor in het blockchain-tijdperk? Om dit doel te bereiken, hebben we een onderzoek uitgevoerd met offline experimenten. Vanuit onderzoeksperspectief vormt onze studie een basis voor verder onderzoek naar uitdagingen die mogelijk van invloed zijn op het werk van de auditor, d.w.z. de ontwikkeling van beste praktijken, concepten en methoden in een wereld van gedecentraliseerde grootboeken van verschillende organisaties. Vanuit praktisch oogpunt biedt ons onderzoek een mogelijke oplossing met betrekking tot een striktere controle op de juistheid en volledigheid van de jaarrekeningposten.

Het doel van de studie beschreven in **hoofdstuk 3** is het vinden van een antwoord op de volgende onderzoeksvraag: Hoe kunnen de verschillende stadia en de verbetering van Continuous Auditing (CA) gemeten worden? We hebben deze vraag beantwoord met een CA-volwassenheidsmodel. Op basis van de resultaten van de 2 interviewronden is het volwassenheidsmodel verder geherdefinieerd, wat heeft geleid tot een model dat bestaat uit vijf volwassenheidsniveaus en vier factoren. De volwassenheidsniveaus zijn: 1) initiële benadering, 2) ad-hoc aanpak, 3) gedefinieerde aanpak, 4) beheerde aanpak en 5) geoptimaliseerde aanpak. De vier mogelijkheden zijn: A) systemen, B) gegevens, C) organisatie en D) mensen.

In **hoofdstuk 4** wilden we de volgende vraag beantwoorden: Welke BRM-ontwerpprincipes zijn van invloed op de transparantie van het ontwerp en de uitvoering van een oplossing voor besluitvorming en bedrijfsregelbeheer? Vanuit een theoretisch perspectief biedt deze studie de kennisbasis kennis over hoe principes, in dit geval BRM-ontwerpprincipes, zouden kunnen worden geëvalueerd met betrekking tot transparantie, evenals interessante aanwijzingen voor toekomstig onderzoek om te versterken hoe BRM-oplossingen de transparantie zouden kunnen verbeteren. Praktisch gezien biedt dit onderzoek organisaties een set van twaalf BRM-ontwerpprincipes waarvan is bewezen dat ze de transparantie bij organisaties beïnvloeden.

In **hoofdstuk 5** hebben we getracht een antwoord te vinden op de volgende onderzoeksvraag: Hoe zijn financiële kredietrisicokenmerken te categoriseren, zodanig dat er een integratieve relatie ontstaat met het toegepaste informatietype en de gebruikte informatiebronnen? Om dit doel te bereiken, hebben we een literatuurstudie uitgevoerd om kenmerken te identificeren die zijn ontworpen en toegepast in eerder onderzoek, gevolgd door het coderen van de kenmerken op basis van een a priori coderingsschema. De resultaten laten zien dat de meeste functies zich richten op expliciete informatie die gebaseerd is op transacties, waarvan het kenmerk is dat deze informatie achterloopt op de huidige (feitelijke) situatie. Dit proefschrift heeft bijgedragen aan de wetenschappelijke kennis, door het presenteren van ons Technology Framework for Auditing. Een raamwerk dat bijdraagt aan het inzicht in de impact van audittechnologie op auditing. Op basis van de resultaten van de verschillende onderzoeken die in dit proefschrift zijn opgenomen, presenteren we in **hoofdstuk 6** onze conclusie, discussie en beperkingen. Ook presenteren we ideeën voor verder onderzoek.

Curriculum Vitae

Eric Mantelaers was born on April 10th, 1966 in Nuth (Beekdaelen), the Netherlands. From 1988 he has been active in the world of accountancy and finance. In 1996, he earned his RA-title (Registered Accountant). He later earned the titles of Accountant Administration Consultant (AA), Certified Information Systems Auditor (CISA), and Chief Information Security Officer (CISO).

Since 1996, he has been a lecturer at Maastricht University (MURA: Maastricht University Registered Auditor). In 2015, he joined Zuyd University of Applied Sciences where he currently holds the position of researcher as a member of research group Future-proof Financial. As well as Eric's strong connection with these two universities, he is also an audit partner and head of the Professional Practices Department (PPD) with RSM Netherlands Accountants N.V.


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