Continuous Auditing in Big Data Computing Environments:

Towards an Integrated Audit Approach by Using CAATTs

Andreas Kiesow, Novica Zarvic, Oliver Thomas

Information Management and Information Systems
University of Osnabrück
Katharinenstr. 3
49069 Osnabrück, Germany
andreas.kiesow@uni-osnabrueck.de
novica.zarvic@uni-osnabrueck.de
oliver.thomas@uni-osnabrueck.de

Abstract: Through the risen operating of autonomous and automated Accounting Information System (AIS), enterprises are increasingly faced with the growing size of accounting-relevant data. Therefore, the audit's purpose, which is namely to examine the true and fair view of financial statements, is heavily increasing in complexity. To cover the requirements to AIS in Big Data Computing Environments, we strive for the development of a Continuous Auditing (CA) approach. Since, the implementation of CA is a recognized challenge among researchers and practitioners, and traditional audit tools and techniques neglect the potential of Big Data Analytics, we strive for the development of appropriate computer-assisted audit tools and techniques (CAATTs). Therefore, we analyzed established CAATTs considering the dimensions of the Big Data paradigm in this paper. To do so, we analyzed relevant literature and viewpoints of occupational organizations. This led us to a first proposal of a conceptual architecture for the integrated audit approach. We conclude this paper with a critical discussion and emphasize implications for further work.

1 Introduction

The paradigm of Big Data has tremendous impacts on both IT departments and audit. On the one hand, since financial statements are produced in automated Accounting Information Systems (AIS), the auditor is faced with risen complexity and risks due to an increasing processing of ever-growing data [GDW11], [VCK12]. With respect to this development, prevention and detection of fraud are gaining in importance [FSP13]. Furthermore, through the permanent processing of unstructured data, increased demands on data privacy and information security have to be addressed. On the other hand, chances occur in using data analytics techniques for the auditor's purposes, such as fraud detection or risk-assessment [ISACA14]. Hence, the audit needs the support of the IT department to evaluate the completeness and the accuracy of the financial statements (e.g. data sets, system access) according to national and international laws and standards (e.g. §317 HGB [BMJV14] or ISA 200 [IFAC13]). In general, the financial statements result from business events, such as purchases, payments, inventory changes, or shipments [SB13]. However, correct financial statements require the proper development and implementation of AIS as well as the integrity of programs, data files and computer operations. Therefore, all procedures, processes, and controls which refer to the Information Technology environment (IT General Controls) have to be evaluated by the auditor [SB13]. In brief, auditors need the support of the IT Management to use chances and address risks in Big Data Computing Environments (BDCE).

The development of an appropriate audit approach demands the consideration of the complexity and the prevalence of the Big Data paradigm from a holistic and theoretical perspective. Remarkable findings in the field were reached by MOFFITT and VASARHELYI, who stated that "*auditors can also take advantage of Big Data*" by implementing continuous monitoring and auditing tools and techniques. In addition, they stated that due to the digitalization, storage, retrieval and analytics of financial data could improve the complete audit process [MV13]. SUN stated that the development of innovative computer-assisted audit tools and techniques (CAATTs) contributes to the handling of increasing data complexity. Moreover, the quality of audit could benefit from the usage of intelligent data analysis implemented with CAATTs [Su12]. Hence, a reasonable support of the auditor, Continuous Auditing (CA) has to be realized with appropriate Information Systems (IS), which represents the scope of this paper.

To set a baseline for further investigations, we analyzed established types of CAATTs in terms to their support of the IT auditor to conduct a proper examination of financial statements in a BDCE. This analysis required a sound exploration of specific requirements of audit in BDCE and the CA approach. Therefore, our paper is structured as follows: At first, the analysis of the related literature and the theoretical background in the areas of audit and Big Data, CA, and CAATTs is presented. Then, the applied research methodology is described. In the following section, the types of CAATTs are analyzed considering the requirements of Big Data and CA. Additionally we present a first conceptual architecture of the envisioned audit approach. This leads into a summary, where a concept of an integrated Audit Module is introduced, and limitations are discussed. Finally, we conclude with the results for researchers and practitioners and propose an outlook to further work in this research area.

2 Related Work and Theoretical Background

2.1 Audit in a Big Data Computing Environment

As shown in the prior section, the prevalence of the Big Data paradigm has manifold impacts on the accounting-relevant processes. Therefore, internal audit departments as well as external audit companies have to face the upcoming consequences of these impacts. Particularly, the Information Systems Audit and Control Association (ISACA) provides possible considerations in different white papers. The results of these papers are shown in this section.

Obviously, the occurrence of data in a BDCE is manifold. According to DOUG LANEY, data are defined as Big Data, if it is characterized through the dimensions *Volume*, *Velocity* and *Variety* [La01]. In literature, *Veracity* has become apparent as a 4th dimension [IBM12]. Before selecting appropriate tools and techniques, these four dimensions are analyzed from the perspective of accounting and audit. Additionally, we consider the usage of *Big Data Analytics* in terms of audit.

Computer-assisted accounting processes are defined by automatic and frequent generation and processing of data, which result in a higher and ever-growing size of data [VCK12] [MV13]. The *Volume* and *Velocity* of accounting-relevant data disable the manual evaluation (e.g. sample selection) completely [RES01]. ISACA suggests the use of CAATTs since it "*serves as an important tool for the IS auditor to evaluate the control environment in an efficient and effective manner*" [ISACA08].

Furthermore, manifold interfaces and data formats lead to increasing complexity and complicate the ex post traceability of data source (*Variety*). The source of accounting-relevant data has to be identified and defined. Generally, accounting-relevant data are processed within the Enterprise Resource Planning Systems [Bl12]. This *structured accounting-relevant data* are usually generated as "*a result of common business events, such as purchases, payments, inventory changes or shipments for instance*" [SB13]. Additionally, structured accounting-relevant data are also generated by recording events related to security, availability modifications and approvals of IT systems. *Unstructured accounting-relevant data* includes text, such as documents for organizational regulation, e-mails, test results, as well as data from mobile devices, audio and video files, server logs, web data for instance.

This dimension *Veracity* refers to the uncertainty of data that incorporates their confidence and quality i.e. accuracy of data [Fa13]. Confidence and quality of data are strongly related to their privacy and security. Hence, to prevent data breaches and establish data security along the accounting-relevant processes, robust data-privacy solutions are needed. Especially, the proactive monitoring of sensitive data and the processing IT environment as well as the fast reaction to data or privacy breaches are prevalent requirements [ISACA13b].

Moreover, ISACA defines *Big Data Analytics* (BDA) as "*the application of emerging statistical, processing and analytics techniques to big data for the purpose of advancing the business*" [ISACA14]. Additionally, the ISACA states that BDA, i.e. the analysis of data to find patterns and correlations, can be used to enforce business risk management and security operations [ISACA13a]. The chance to use BDA for the purposes of audit is increasingly recognized by researchers and auditors. SETTY and BAKHSHI propose the concept of a Big Data Refinery, which enables the analysis of logs generated by ITGC or the fraud analysis of large volumes of transactional data [SB13]. MOFFIT and VASARHELYI list several examples of using data analysis for audit purposes [MV13]: First, using Big Data for the continuity equations to link processes, to model lagged information processes, and to perform automatic error correction according to KOGAN et al. 2011. Then, the cluster analysis for anomaly detection in accounting data according to THIPRUNGSRI and VASARHELYI (2011) and, finally, applying process mining on the audit process according to JANS et al. (2010). POULOVASSILIS sees the prevalence of large volumes of graph-structured data in the areas finance chains, fraud detection, risk analysis [Po13]. ABBASI et al. developed a design science approach to detect fraud in financial statements, which is based on a meta-learning Business Intelligence and Analytics (BI&A) framework [Ab12].

2.2 Reviewing Continuous Auditing

The paradigm of CA is well established in literature (e.g. [RES01], [Va12]). A substantial study in the field of CA was published by SUN in 2012. SUN stated, since CA is completely implemented as an automated, (i.e. computer-assisted) process, it contributes to efficiency whilst the audit of large volume of transaction data [Su12]. However, a CA approach is not limited to *handle* Big Data. Furthermore, CA can be used to *produce* Big Data which can be analyzed to improve audit efficiency and efficacy [MV13].

In 2012, the Americas Institute of Certified Public Accountants (AICPA) published a survey about the current state of CA from the perspective of external auditors [By12a]. A sustainable result of this survey is that CA approaches are rarely implemented in practice. AICPA carved out the following reasons for this deadlocked situation: First, practitioners stated that due to high complexity of the implementation of CA is recognized as a challenge and related to high cost. Furthermore, for external auditors, audit relationships are characterized as instable, which complicates the estimation of payback periods. Additionally, many businesses are described as protective of their data, which disables the ongoing access to systems, which is necessary for the implementation of CA. At last, external auditors see limitations in the current state of audit standards, which do not cover the requirements to CA or other future audit approaches. However, the survey carved out that practitioners are aware of the benefits of CA, which are namely reduced costs, time, and increased quality, if a CA solution is in place. Finally, the AICPA concludes that the full potential of the CA approach can be envisioned if the implementation of this approach can be effectively demonstrated, documented, and disseminated. In Germany, the current state of CA is mainly discussed among practitioners. In 2014, EULERICH and KALINICHENKO published an article about CA from a research perspective [EK14]. In 2011, HÖLZER and ARENDT stated, that the implementation of CA is the „*optimum of the auditors activities*“ [HA11]. However, according to AICPA, for the time being, we do not know any CA solutions in place.

2.3 Prevalence of CAATTs

Since accounting transactions are processed automatically by computer-assisted Information Systems, the need for tools and techniques, which support the audit of these transactions, has arisen [IFAC13b]. The definitions and application areas of computer-assisted audit tools and techniques (CAATTs) have changed through the decades, depending on the state of technology. Regarding the aim of this paper, we define CAATTs according to HALL, who expresses CAATTs as the "*tools and techniques used to examine directly the internal logic of an application as well as the tools and techniques used to draw indirectly inferences upon an application's logic by examining the data processed by the application*" [Ha10]. In literature five different types of CAATTs can be distinguished, which are namely Test Data, Integrated Test Facility (ITF), Parallel Simulation, Embedded Audit Modules/ System Control and Audit Review Files (EAM/SCARF) and Generalized Audit Software (GAS) [BD03]. Additionally, the technique of tagging and tracing (snapshots) can be added to these types [RJG09]. These six types, their individual descriptions, and examples are shown in Table 1.

Types of CAATTs	**Description**
Test Data	Fictitious, auditor-prepared data, which will be processed by the audited systems. The evaluation bases on a comparison between the results of the test data and the auditor's expectations. The processing within the audited systems is a "black box".
Integrated Test Facility	Processing of Test Data in separated areas or modules within the audited system. The results of the internal system controls are visible for the auditor.
Parallel Simulation	Auditor-developed application, which is completely separated from the client's systems. The results of processing real data are compared with the results of the client's systems.
Embedded Audit Module, System Control and Audit Review Files (EAM/ SCARF)	Auditor-developed module which is implemented within a client's system. EAM evaluates real data by predefined criteria while it is processed. Results of EAM evaluations can be written into a SCARF, which is send to the auditors for further examination
Generalized Audit Software	Auditor-developed and self-contained applications, which evaluate extracted real data and analyze them, regarding predefined criteria.
Snapshot Method (tagging and tracing)	Selection and marking of accounting transactions and monitoring their processing within the AIS. After every step, a snapshot is created and analyzed.

Table 1: Typology of CAATTs [BD03] and [RJG09]

3 Research Methodology

The goal of our work is the development of an IT artifact, namely a computer-assisted audit solution for BDCE. The matter of this paper is the selection and analysis of appropriate CAATTs, which support the prevalence of CA of accounting-relevant processes. Generally, CAATTs are used to examine accounting-relevant information to support the audit to reach valid and sufficient evidences for the true and fair presentation of financial statements. According to MARCH and SMITH, the development of appropriate CAATTs and their usage to realize a CA approach support human (i.e. auditors, IT Management and, finally, stakeholders) purposes [MS95]. Furthermore, we strive for an audit approach in a BDCE which is an unsolved problem so far. Additionally, with the implementation of computer-assisted audit tools and techniques, internal and external auditors should be empowered to gain assurance in effective and more efficient ways [He04]. For these reasons, we apply a Design Science approach, which is characterized by both building and evaluating IT artifacts.

ÖSTERLE et al. [Ös11] state that "*design-oriented IS research follows an iterative process*" and consists usually of four distinct phases. These phases are *analysis*, *design*, *evaluation* and *diffusion*. The work presented in this paper can mainly be situated in the first two phases, namely analysis and design (see Figure 1). Next to the identification of the practical problem, we represent an iteration considering the analysis of requirements from practitioner's perspective. To do so, we supplement our results from academic literature as well as the viewpoint of occupational organizations, such as ISACA and AICPA. This sets the baseline for the needs of audit in a BDCE. Our investigation of CAATTs is presented and discussed in terms of the needs that come up in the context of BDCE. Building on these results, we construct a first proposal of a conceivable IT architecture for an integrated audit approach. The evaluation of this instantiation according to HEVNER et al. [He04] will be performed in future work.

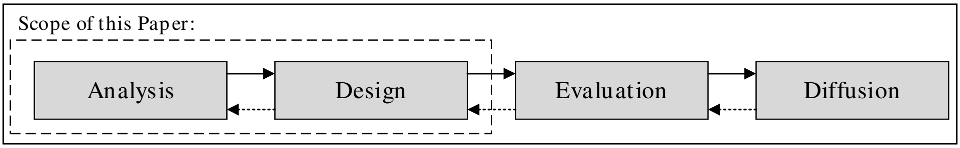

Figure 1: Design-oriented IS research according to Österle [Ös11]

4 A General Concept of an Integrated Audit Tool

4.1 Investigating Existing Audit Tools and Techniques

As mentioned above, CA has to be based upon computer-assisted tools and techniques. Therefore, the question arises which CAATTs contribute to an appropriate implementation of CA in a BDCE. With respect to this goal, the types of CAATTs have to be assessed considering the specifications of a Big Data. It has to be analyzed to what extent the types of CAATTs are able to support the audit of accounting-relevant processes within a BDCE. The results of the assessment are discussed in the following sub-sections.

As mentioned above, *Test Data* are data, which is created by the auditor and processed within the client's system. Considering the dimension *Volume*, Test Data can be used to test the load capacity of programs, i.e. to what extent is the program able to process large data sets. The dimension *Veracity* could be addressed through the examination of the completeness and accuracy of programs. Privacy aspects could be addressed by simulating personal data and examine their processing considering data leaks. *Velocity* is not covered by using Test Data, since the continuous input of data in the AIS cannot be tested by a single Test Data set. Testing *Variety* is generally possible, but not efficient, since the creation of Test Data with manifold data formats is complex and need a sound exploration of the interfaces in use. Combining Test Data with BDA is at most useful to test the basic functions. Since the Test Data are created by the auditor, analyzing it with BDA does not result in additional value. In short, Test Data can support a CA approach through punctual analysis of large, various or personal related data sets. However, the creation of Test Data is related to both high costs and effort.

The *ITF* approach is strongly related to Test Data. Therefore, the same conclusions, which are mentioned for Test Data are also valid for ITF. However, since ITF demands the implementation of separated entities within the audited systems, and the simultaneous processing with live input, the realization of ITF covering Volume, Velocity, Variety and Veracity are from increasing complexity. A Continuous Approach realized by ITF requires the implementation thorough all accounting-relevant systems, which is unrealizable in practice. Furthermore, the results have to be gathered and analyzed, which is not proposed by ITF. Therefore, we conclude that ITF are inapplicable to implement CA in a BDCE.

The *PS* demands the complete rebuild of the audited AIS, considering all data processing steps and the integrated controls. Although this approach is certainly effective, it is quite inefficient and unrealizable in practice. Furthermore, it does not contribute to BDA, since Parallel Simulation replicates the results, which excludes further investigations. Therefore, we believe that Parallel Simulation is inapplicable to implement CA in a BDCE.

EAM are implemented as separated add-ons within accounting-relevant systems. Therefore, EAM enable the permanent evaluation of the data flow. The audit of large data sets (*Volume*) and the dimension of *Velocity* are covered by the continuous evaluation of data either before or after its generation or processing. To cover the *Variety* of accounting-relevant data, the implementation of relevant interfaces is required. *Veracity*, which is related to the completeness and accuracy of data, can also be addressed by the continuous evaluation, if the necessary checks are implemented within the EAM. The consideration of privacy is difficult, since the violation of privacy can be normally checked a-posteriori. The implementation of BDA functions within EAM is basically possible, but not efficient, since the analysis of Big Data sets (e.g. Data Mining) requires high processing capacity, which is normally not integrated in EAM. In short, a CA approach using EAM addresses *Volume* and *Velocity* of the BDCE. Furthermore, it can contribute to *Variety*, *Veracity* and BDA.

Generally, *GAS* is used to analyze extracted data sets *after* their processing in the system (e.g. annual Journal Entry Testing). Furthermore, the development of GAS-tools requires extensive test activities. Therefore, we state that GAS is inapplicable for the permanent audit of high volume of data, fast processing of data and various data formats. However, GAS offers several functions for fraud detection [La04] and, if it is combined with Data Mining techniques, it can be used for punctual analysis of large data sets. Therefore, we believe that GAS-Tools can contribute to audit *Veracity* and BDA.

The *tagging* of accounting transactions and the *tracing* throughout their processing within the BDCE is basically possible. However, it has to be considered that an adequate large sample of transactions must be tagged, to address the dimension *Volume*. Furthermore, defining of an adequate sample is difficult, since data are generated quickly and in various formats (*Velocity*, *Variety*). The possibility to test *Veracity* is given, if completeness and accuracy of the tagged transactions are traceably documented after every step. The Snapshot Method does not contribute to BDA, since it does not enable further investigations of the source and structure of the transaction. Overall, we believe that the Snapshot Method is not applicable to realize an Audit Approach in a BDCE. However, it could be used to support the sought solution. The results of these considerations, i.e. the applicability of CAATTs to cover the requirements of a BDCE, are shown in the upcoming Table 2.

Types of CAATTs	**Dimensions of Big Data**					**Overall Applicability**
	Volume	**Velocity**	**Variety**	**Veracity**	**BDA**	
Test Data	⊙	○	⊙	⊙	○	⊙
ITF	○	○	○	⊙	○	○
PS	○	○	○	○	○	○
EAM, SCARF	●	●	⊙	⊙	⊙	⊙
GAS	○	○	○	⊙	●	⊙
Snapshot Method	○	○	○	⊙	○	○
Legend: ○= low, ⊙= medium, ●= high						

Table 2: Applicability of CAATTs for the Dimensions of Big Data

As shown in Table 2, Embedded Audit Modules in relation with SCARF are most appropriate to cover the dimensions of Big Data. Test Data, GAS and Snapshots propose different supporting functions. Therefore, we propose a combination of different tools and techniques. The questions arises, *how* these techniques can be combined to an audit approach in a BDCE.

4.2 Conceptual IT Architecture for the Integrated Audit Approach

Through our investigations, we believe that a CA approach is the best way to address the complexity and requirements of a BDCE. This approach has to be realized with the computer-based techniques of EAM, which enable the audit of controls, Test Data to audit the processing within the system, and GAS to use BDA. To combine the results of these functions to a tangible and traceable solution, we revert to the pilot system, which was proposed by ALLES et al. in 2006 [Al06], and VASARHELYI, who achieved remarkable results by designing a CA approach for online systems in 1991 [VH91]. Basically, our approach consists of an audit database, which includes three major data tables, an Audit Cockpit as user front-end, and a computational core for analytics (Figure 2). In the data table "*Data Inventory*" all accounting-relevant data are included (Data Table 1). Furthermore, the origin of data (internal or external), sensitivity, and relevance data should be labeled. Additionally, for every audited interface data producer and data consumer have to be defined. The second data table "*Controls*" includes all controls along the accounting-relevant processes, added with specific information (e.g. related risks, detective or preventive, frequency). The EAM enable the direct and permanent monitoring of the controls, and generate automated alerts in the case of control violation. The results of these monitoring activities will automatically be transferred in the third data table "*Results*". In the Audit Cockpit, the link between "*Data Inventory*", "*Controls*", and "*Results*" is visualized. Therewith, the auditor is able to understand, which data are controlled with which result. Overall, the audit data base and the computational core should be protected according to security and privacy standards. Finally, the CA infrastructure (i.e. EAM, Audit Cockpit, data base, hardware) has to be covered by disaster recovery arrangements. Additional functions should propose the visualization of the data flows and a list of current control violations.

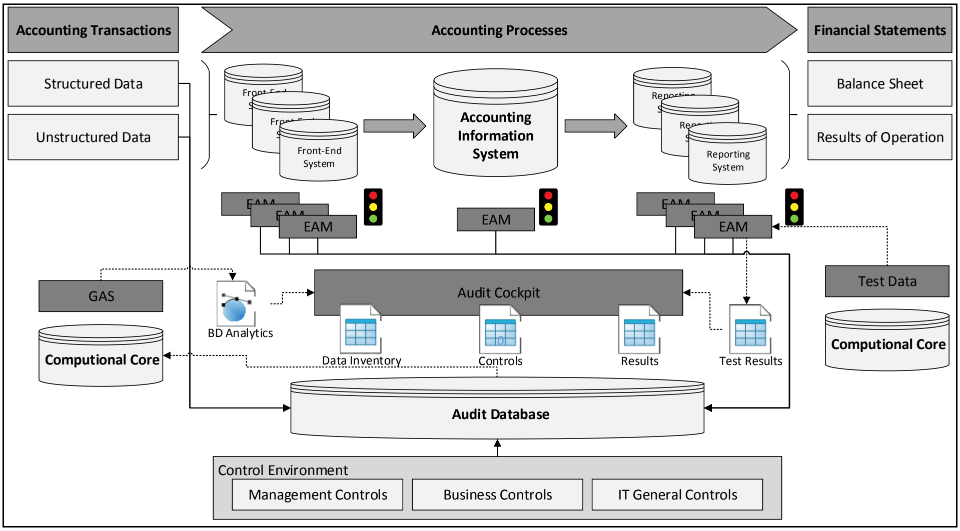

Figure 2: Integrated Audit Approach

5 Summary and Discussion

The discussion of our approach is based on an assessment according to the typology of audit methods, which is presented by MARTEN et al. [MQR07]. The results are subsequently summarized: The implementation of the approach can be risk-oriented in terms of the definition of high-risk areas, which are characterized by material impact on the financial statements. However, in the final stage, this approach covers all accounting-relevant areas, independent of the inherent risk. Furthermore, if the accounting-relevant areas are identified, the approach enables a direct examination of the subjects. The approach is designed system-oriented as well as goal-oriented, which means that internal controls can be examined as well as results from procedures. Incontestable, the approach enables the examination on transaction level, which empowers the auditor to investigate further audit activities in a fast and precise manner. If implemented, the approach covers the population of all transactions, which leads into rigorous conclusions of the audited subject and reduces the probability of audit errors. Furthermore, if implemented, the approach set the baseline for progressive audits from the accounting transaction to the financial statement and, vice versa, for retrograde audits. Additionally, the approach empowers the auditor to conduct formal, and material audit checks, which means to assure *whether* and *to what extent* a transaction is accurate. However, we are aware that the implementation of this approach is a big challenge. The technical realization of this approach requires the implementation of manifold interfaces throughout the organization. Hence, this refers to the reorganization of the processes, which is related to tremendous costs and effort [Su12]. Controls and data flows have to be carved out and analyzed. Thus, the implementation is definitely a long-term solution and has to be considered through the strategic planning of the management. Furthermore, the approach is not able to cover manual controls, such as management approval by signature. The approach requires the implementation of automated controls within the systems and interfaces, possibly supported by a workflow management system. Finally, due to reduced system performance, code modifications, and the creation of excessive data, AICPA stated in 2012 that an approach using EAM "*exists as primarily an academic topic*" [By12b]. In summary, the usage of new technology in audit is a voluminous task for both IT management and audit. However, we believe that our findings imply new considerations in the field of computer-assisted audit which will benefit to researchers and practitioners. Since the proposed Audit Cockpit approach enables the permanent monitoring of the control environment, we set a further baseline for the alignment of IT and audit.

6 Conclusion

The design of appropriate audit solutions for BDCE is of increasing importance. On the one hand, opportunities could be exploited due to the usage of Big Data Analysis on transaction level, which could benefit to increased performance and quality of audit. On the other hand, the complexity in analyzing and auditing accounting-relevant data are recognized as a challenge by experts and researchers. Furthermore, the compliance with privacy and security guidelines in BDCE has to be audited. According to the relevant literature and occupational requirements, we suggest a CA approach, which has to be basically realized by computer-assisted audit tools and techniques (CAATTs). To do so, we analyzed existing CAATTs regarding the requirements of the Big Data paradigm (4 V's). Finally, we proposed the combination of different techniques, which are managed and monitored within an Audit Cockpit. Limitations were carved out in the technical reorganization of the accounting-relevant processes and the demand of automated controls along the processes. In future work, we strive for the cooperation with an organization, to analyze accounting-relevant processes and to develop a prototype of an Audit Cockpit. In this context, the requirements to Internal Control Systems as well as the application of common IT Frameworks such as COSO and COBIT have to be analyzed. Furthermore, we strive for a sound exploration of implied risks for auditors in BDCE.

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