Designs for Accounting Information Systems using Distributed Ledger Technology

Søgaard, Jonas Sveistrup

Document Version
Final published version

Publication date:
2021

License
Unspecified

Citation for published version (APA):
Søgaard, J. S. (2021). *Designs for Accounting Information Systems using Distributed Ledger Technology*. Copenhagen Business School [Phd]. PhD Series No. 33.2021

COPENHAGEN BUSINESS SCHOOL
SOLBJERG PLADS 3
DK-2000 FREDERIKSBERG
DANMARK

WWW.CBS.DK

ISSN 0906-6934

Print ISBN: **978-87-7568-043-6**
Online ISBN: **978-87-7568-044-3**

DESIGNS FOR ACCOUNTING INFORMATION SYSTEMS USING DISTRIBUTED LEDGER TECHNOLOGY

PhD Series 33.2021

Jonas Sveistrup Søgaard

DESIGNS FOR ACCOUNTING INFORMATION SYSTEMS USING DISTRIBUTED LEDGER TECHNOLOGY

CBS PhD School

PhD Series 33.2021

CBS COPENHAGEN BUSINESS SCHOOL
HANDELSHØJSKOLEN

Designs for Accounting Information Systems using Distributed Ledger Technology

Jonas Sveistrup Søgaard

Supervisors:

Associate Professor Morten Holm

Professor Thomas Riise Johansen

Doctoral School of Business and Management

Copenhagen Business School

Jonas Sveistrup Søgaard
Designs for Accounting Information Systems
using Distributed Ledger Technology

1st edition 2021
PhD Series 33.2021

ISSN 0906-6934

Print ISBN: 978-87-7568-043-6
Online ISBN: 978-87-7568-044-3

The CBS PhD School is an active and international research environment at Copenhagen Business School for PhD students working on theoretical and empirical research projects, including interdisciplinary ones, related to economics and the organisation and management of private businesses, as well as public and voluntary institutions, at business, industry and country level.

ACKNOWLEDGEMENT

This thesis was created from January 2019 to June 2021 as an industrial PhD thesis with affiliation with Deloitte and Copenhagen Business School, Department of Accounting. As a PhD student, I have been thankful for the support from Deloitte, the Innovation Fund Denmark, and the Danish Business Authority, both financially and in terms of insight into the problem area. Becoming a PhD student has given me a new intellectual understanding of how rigor supports relevance in business and beyond life as a doctoral student.

I am thankful for the guidance and valuable suggestions from my supervisors, Morten Holm and Thomas Riise Johansen. The thesis has benefited significantly from our discussions and your constant focus on overall research direction and essential details. Your guidance has pushed the research papers to a better and more mature level. When I was in doubt about the research direction, you successfully guided my research – not with force but with great questions. I want to thank you for your interest in my research.

I want to thank my company supervisors, Rasmus Winther Mølbjerg and Ulf Hilton, for paving the way for my research and shield it in a business environment that is not used to long-term research projects. I am thankful to Deloitte for taking a chance on me and especially: Tax (Thomas Svane Jensen), Audit & Assurance (Christian Lehman Nielsen and Henrik Christian Grønnegaard), Risk (Thomas Kühn), and Consulting (Rasmus Winther Mølbjerg and Ulf Hilton). Furthermore, I would like to thank the NextGen team that I have worked with daily as well as the international blockchain community in Deloitte.

In addition, I would like to thank the Department of Accounting employees for creating an inviting environment and providing comments at my presentations, especially for the comments and critique that I have received from my pre-defense opponents Deniz Appelbaum and Páll Ríkharðsson. I appreciate your time and effort.

I also want to thank the staff at Rutgers University for their willingness to invite me for a research stay in New Jersey, USA. Even though the Corona pandemic forced the stay to be shortened, I will forever be grateful for the time spent at 1 Washington Park in Newark, NJ. Thank you, Barbara Jensen, for making me feel welcome, and all of the other faculty members for helping me and my family settle in.

I want to extend my thanks to my co-authors, Michael Werner, William E. McCarthy, G. Ken Holman, Peter Eklund, Jason Spasovski, and Lasse Herskind. Without our discussions and your contributions, my PhD thesis would not provide this level of insight and move the field forward.

Finally, I would like to thank my friends and family for your support during my PhD time. Ida, you are the love of my life, and you support me in whatever I try to achieve. Adam, Yrsa, and Saxo, you make my days brighter, and you make me remember that the PhD thesis is also just a piece of paper. Thank you!

ENGLISH SUMMARY

This thesis seeks to provide designs for accounting information systems (AIS) using distributed ledger technology (DLT) through a design science research (DSR) approach that academics and practitioners can use and extend. Each of the four papers is summarized below.

Paper 1: Divide et Impera: Structuring Design Science Research Projects

Co-authored with Michael Werner

Design science research (DSR) is an important research approach that has gained increased attention in information systems research (ISR) over the past decades. DSR is commonly carried out in the form of research projects. These are complex and difficult to manage due to the duality of the epistemological and design objectives that characterize DSR. It leads to large research projects with diverse tasks and numerous stakeholders. This study deals with how DSR projects can be structured to facilitate decisions regarding the division of research work, the allocation of resources, and the overall management of such projects. It formally introduces a framework to separate the content of DSR projects into well-defined and individually manageable research segments. A case study illustrates how using the framework facilitates the management and coordination of parallel and mutual research work within a typical DSR project. Applying the presented framework to DSR projects described in scientific literature confirms the general applicability of the framework. This illustrates that the framework is also suitable to assess whether research projects are well-balanced in terms of research output.

Paper 2: A Blockchain-enabled Platform for VAT Settlement

Governments may unintentionally impose heavy administrative burdens on companies as they want to ensure the flow of tax revenue. Drawing on an engagement involving the Danish Business Authority and following a DSR approach, this paper develops a prototype of a platform for value-added tax (VAT) settlement that is enabled by DLT and design principles for designing DLT platforms. The proposed prototype and design principles demonstrate how AIS,

DLT, and public governance may be interrelated to enhance social welfare. Regarding its practical implications, this paper provides a use case for governments seeking to reduce administrative burdens on small and medium-sized enterprises (SMEs) while still ensuring the flow of tax revenue.

Paper 3: Crash vs. Byzantine Fault Tolerance at Scale: the Cost of Distributing Trust in a (Trans)National Invoicing System

Co-authored with Peter Eklund, Lasse Herskind, and Jason Spasovski

This paper examines the feasibility of a blockchain solution for national and transnational business-to-business and business-to-government (B2B/B2G) compliance frameworks, namely a trustless, decentralized, self-regulating distributed ledger. In particular, the paper examines whether blockchain platforms can be scaled to support national and transnational blockchain-based invoicing platforms that are presented in paper 2. The case study looks at the resources required to operate a B2B/B2G compliance framework in two different geographic scenarios. The first considers a national scale based on Denmark, the tenth-largest European country by GDP. The second scenario considers all 27 member states of the European Union (EU) (and the UK). The paper addresses the performance of blockchain solutions; two are Byzantine fault tolerant (BFT), and one is crash fault tolerant (CFT). Specifically, the paper measures the additional cost of the trust that results from a BFT blockchain solution at scale compared to a CFT blockchain solution.

Paper 4: Accounting Contracts in Collaboration Space

Co-authored with William E. McCarthy, Lasse Herskind, and G. Ken Holman

This paper proposes a design theory for accounting transaction systems that is based on the resource-event-agent (REA) accounting ontology and DLT. Following a design science research approach, we present a novel blockchain-based prototype that implements the REA ontology as a business process state machine. Our prototype utilizes the unique features of DLT to ensure data integrity and transparency among the economic agents in recorded and distributed repositories that reside outside of the enterprise systems of those parties. This provides evidence that the independent view of business transactions between companies and between companies and government agencies – in what we call collaboration space – is technologically feasible and opens avenues for exploring innovative ways of performing economic exchanges. As our business transaction choreography is orchestrated by accountability contracts for reciprocated delivery of economic resources, we title our treatment *accounting contracts in collaboration space*.

DANISH SUMMARY

Denne afhandling søger at give designmønstre til regnskabsinformationssystemer (AIS) ved hjælp af distribueret ledger-teknologi (DLT) gennem en design science research- (DSR) tilgang, som akademikere og praktikere kan bruge og udvide. Nedenfor er hver af de fire artikler opsummeret.

Artikel 1: Divide et Impera: Strukturering af design science research-projekter
Medforfatter: Michael Werner

Design science research (DSR) er en vigtig forskningsmetode, der har fået øget opmærksomhed indenfor informationssystemforskning igennem de seneste årtier. DSR udføres almindeligvis i form af forskningsprojekter. Disse er komplekse og vanskelige at håndtere på grund af dualiteten i de epistemologiske og designmæssige mål, der kendetegner DSR. Det fører til store forskningsprojekter med forskelligartede opgaver og adskillige interessenter. Denne artikel handler om, hvordan DSR-projekter kan struktureres for at lette beslutninger vedrørende opdelingen af forskningsarbejdet, tildelingen af ressourcer og den overordnede styring af sådanne projekter. Artiklen introducerer et rammeværk til opdeling af DSR-projekters indhold i veldefinerede og individuelt håndterbare forskningssegmenter. Et casestudie illustrerer, hvordan anvendelsen af rammeværket letter styringen og koordineringen af parallelt og fælles forskningsarbejde indenfor et typisk DSR-projekt. Anvendelsen af det præsenterede rammeværk på DSR-projekter, der er beskrevet i den videnskabelige litteratur, bekræfter rammeværket generelle anvendelighed. Dette illustrerer, at rammeværket også er egnet til at vurdere, om forskningsprojekter er velafbalancerede med hensyn til forskningsoutput.

Artikel 2: En Blockchainaktiveret platform til momsafregning

Staten kan utilsigtet pålægge virksomheder store administrative byrder, da de ønsker at sikre strømmen af skatteindtægter. Med udgangspunkt i et samarbejde, der involverer Erhvervsstyrelsen, og som følger en DSR-tilgang, udvikles der i denne artikel en prototype af en momsafviklingsplatform, der er muliggjort af distribueret hovedbogsteknologi (DLT) og designprincipper for design af DLT-platforme. Den foreslåede prototype og designprincipper viser, hvordan regnskabsinformationssystemer, DLT og offentlig styring kan være indbyrdes forbundne i forhold til at forbedre velfærden i samfundet. Med hensyn til prototypens praktiske betydning giver artiklen en usecase til regeringer, der søger at reducere små og mellemstore virksomheders administrative byrder, samtidig med at de sikrer strømmen af skatteindtægter.

Artikel 3: Nedbruds- vs. byzantinsk fejltolerance i stor skala: omkostningerne ved at distribuere tillid til et (trans)nationalt faktureringssystem

Medforfattere: Peter Eklund, Lasse Herskind og Jason Spasovski

I denne artikel undersøges muligheden for at indføre en blockchainløsning til nationale og transnationale compliancerammeværk indenfor virksomhedsnetværk (B2B) og netværk mellem virksomheder og staten (B2G), nemlig en tillidsfri, decentraliseret og selvregulerende distribueret hovedbog. Navnlig undersøges det i artiklen, om blockchainplatforme kan skaleres til at understøtte nationale og transnationale blockchainbaserede faktureringsplatforme, der er præsenteret i artikel 2. Casestudiet ser på de ressourcer, der er påkrævet til at drive et B2B-/B2G-compliancerammeværk i to forskellige geografiske scenarier. Det første scenarie er i national skala og vedrører Danmark, der er det tiende største europæiske land målt på BNP. Det andet scenarie vedrører alle 27 medlemslande i EU (og Storbritannien). Artiklen omhandler blockchainløsningers ydeevne; to løsninger er byzantinsk fejltolerante (BFT), og en er nedbrudsfejltolerant (CFT). Specifikt måler artiklen de ekstra omkostninger, der er forbundet med den tillid, der er følger af skaleret BFT sammenlignet med CFT.

Artikel 4: Regnskabskontrakter i samarbejdsområdet

Medforfattere: William E. McCarthy, Lasse Herskind og G. Ken Holman

I denne artikel foreslås en designteori vedrørende regnskabsmæssige transaktionssystemer, der er baseret på den regnskabsmæssige ontologi resource-event-agent (REA) og distribueret hovedbogsteknologi (DLT). I henhold til en DSR-metode præsenterer vi en ny blockchainbaseret prototype, der implementerer REA-ontologien som en forretningsprocestilstandsmaskine. Vores prototype udnytter de unikke funktioner i DLT til at sikre dataintegritet og gennemsigtighed blandt de økonomiske agenter i registrerede og distribuerede arkiver, der ligger udenfor disse parters virksomhedssystemer. Dette beviser, at det uafhængige syn på forretningstransaktioner mellem virksomheder og mellem virksomheder og offentlige organer – i det, vi kalder samarbejdsområdet – er teknologisk muligt og åbner muligheder for at udforske innovative måder at gennemføre økonomisk udveksling på. Da vores forretningstransaktionskoreografi er orkestreret af ansvarlighedskontrakter om gensidig levering af økonomiske ressourcer, betegner vi vores behandling som *regnskabskontrakter i samarbejdsområdet.*

TABLE OF CONTENTS

SYNOPSIS

1. MOTIVATION

Accounting focuses on recordkeeping within organizations to create transparency and an overview of the current state of the business. Internal transactions within the organization are easier to manage compared to transactions outside the organization since the need for trust is, all else being equal, greater when transacting with external parties. In its essence, the modern organization's structure being in individual entities with clear boundaries inherently designs for information asymmetry. To address the information asymmetry problem between transacting organizations, "managers, lawyers and judges, tax professionals, accountants, and auditors" (Davidson et al., 2018, p. 1) have become an integral part of the market, infusing trust when buyers and sellers transact. According to Davidson et al. (2018), these third parties accounted for 35 percent of the US economy in 2010, and that does not include rating websites and other social media rating mechanisms. In other words, the cost of trust using a third party takes up more than one third of the economy.

Besides the added transaction cost incurred by third parties, companies also operate in an environment where government compliance through tax and financial reporting forces administrative burdens on them. Several governments, including those in Brazil, Mexico, Hungary, Italy, and China, have prioritized retaining tax revenue at the expense of increasing administrative burdens (see, for example, EY, 2018; Hungarian Tax Authority, 2018). This means that the authorities force companies to obtain digital stamps of approval on their invoices to comply with legislation and enable them to settle value-added tax (VAT). However, requiring digitally signed invoices implies that governments add administrative burdens on companies. Furthermore, business-to-government (B2G) reporting has been criticized in many countries for being inefficient, complex, and often duplicative (Bozanic et al., 2012; Chen, 2012).

What if the information asymmetry problem could be addressed by a novel technology focusing on recording transactions with the transacting parties and being tamper-resistant? In 2008, Nakamoto introduced the Bitcoin blockchain and, as a result of this, created a new class of technology called DLT. Nakamoto's goal was to create a system that could replace banks as middlemen when exchanging digital currencies. The design of the Bitcoin blockchain solved the double-spending problem through a tamper-resistant audit log shared by the nodes in the blockchain network, ensuring that a Bitcoin could only be spent once by its owner. This piece of innovation increased the transparency in transactions on the Bitcoin blockchain and is one of the ingredients in solving the trust problem described in the first paragraph. In 2013, the development community maintaining the Ethereum blockchain implemented a so-called smart contract layer (Buterin, 2013), which allows for decentralized applications (dApps) on top of the blockchain layer. The smart contract layer enables users and developers to enforce mutual contracts automatically, for example, the automatic settlement of VAT when a buyer and a seller have agreed on a business transaction. In general terms, the smart contract layer acts as autonomous agents on top of the tamper-resistant data layer (blockchain). Combining a tamper-resistant data layer and a decentralized logic layer provides an opportunity for trustless environments between buyers and sellers, not needing the trust-infusing parties anymore.

In the field of accounting, practical implementations begin to emerge.[1] For example, the US-based company, Armanino, provides accounting services tailored to digital assets and cryptocurrencies using its custom-built *TrustExplorer* that "… enhances trust and transparency of digital asset service providers, asset-backed token issuers … by enabling users to reconcile on-chain data, such as token supply or address balances, to off-chain data, such as fiat reserves or user platform accounts in real-time!". The Big 4 all offer services ranging from assurance of smart contracts, tax advisory on cryptocurrencies, implementation projects across all sectors, and many more (Cointelegraph, 2020). In the academic literature, Schmitz and Leoni (2019) summarize their research agenda for blockchain technology in the field of accounting, stating that the current literature focuses on "… blockchain-enabled continuous audits, smart contract applications and the paradigmatic shift in accountants' and auditors' roles." (p. 331). Specifically, Dai and Vasarhelyi (2017, pp. 5-6) argue that "… blockchain's functions of protecting data integrity, instant sharing of necessary information, as well as programmable and

[1] There are already DLT systems deployed in many industries and use case areas outside of blockchain technology's origin within decentralized finance (De-Fi) centered around the bitcoin and Ethereum ecosystems, for example, interbank settlement (Zhao et al., 2018), central bank digital currencies (Sveriges Riksbank, 2021), the TradeLens platform focusing on optimizing the bill of lading on supply chain management (Jensen et al., 2019), settlement of roaming fees in telecommunications (Lazaar, 2019), preventing financial fraud in public sector services (Hyvärinen et al., 2017), tokenization of expensive sneakers (Infinite, 2021), and many more. The common denominator of the examples mentioned is to increase trust through a higher degree of transparency.

automatic controls of processes, could facilitate the development of a new accounting ecosystem."

There is a collection of studies (Coyne & McMickle, 2017; Dai & Vasarhelyi, 2017; Kokina et al., 2017; Rückeshäuser, 2017; Yermack, 2017) that agree that DLT-based solutions are going to change the accounting practice while the trends of increasing government compliance demands continue as highlighted earlier in this section. However, the extent of these changes and the timeline of when they occur are still unsure. To manage these uncertainties and be forward-looking, some accounting scholars call for more normative, practice-oriented, and conceptual modeling accounting research (Bennis & O'Toole, 2005; Corley & Gioia, 2011; McCarthy, 2012; Rajgopal, 2020; Waymire, 2012; Wood, 2016). Therefore, this thesis provides design guidelines, design prototypes, and a design theory for practitioners and academics, ensuring both rigor and relevance in designing AIS enabled by DLT.

2. POSITIONING AND CONTRIBUTION

This section starts with an overview of the thesis followed by a discussion of the publication trends and faculty sentiment in the field of accounting to position this thesis. After the discussion, a visual representation of the coherence of the thesis is presented, followed by a short description of the different DSR contribution types. Finally, each paper's positioning and contribution to academia as well as impact on practice are discussed in four separate sections.

2.1 Overview of the thesis

Figure 1 provides an overview of the thesis and shows the relationship between the four papers. As shown in the figure, paper 1 is isolated from the rest of the papers (the boxes within the dotted lines) due to the focus of paper 1 on DSR projects in general, whereas paper 2, paper 3, and paper 4 build on the same case study: a blockchain-based platform for VAT settlement. Paper 1 is methodology-driven, meaning that it focuses on how DSR projects are structured, and it uses paper 2 and paper 3 as input for the case study analysis.

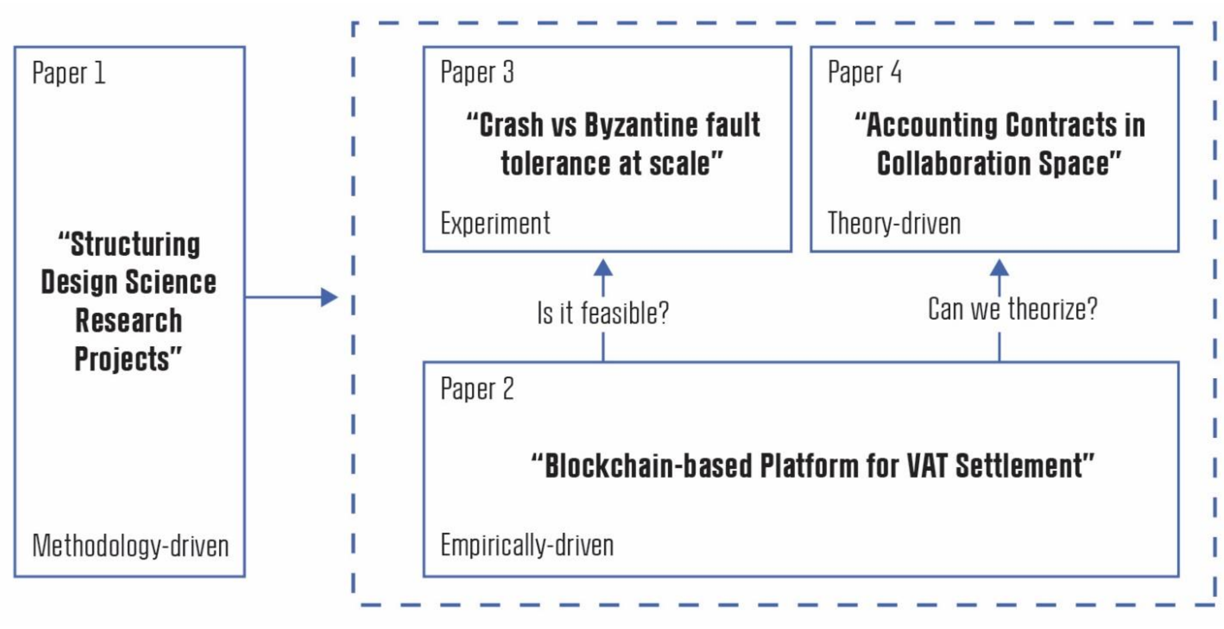

Figure 1. Overview of the relationship between the four papers

Paper 2 proposes a prototype and design principles formulated using Meth et al.'s (2015) methodology that identifies requirements through interviews with multiple stakeholders and evaluation data from the development and test cycles. Paper 3 asks if the prototype proposed in paper 1 is feasible on an EU scale by creating in-the-wild experiments with three different blockchain platforms and one non-blockchain platform. Paper 4 also originates from paper 2 but is theory-driven. It embeds DLT into the existing REA accounting ontology formulated by McCarthy (1982). It proposes a design theory and a more general prototype of the one in paper 2. The relationship described above justifies why all four papers are deemed relevant in the field of AIS. Paper 1 guides how to perform a DSR project, paper 2 lays the case study foundation, paper 3 runs a feasibility study, and lastly, paper 4 theorizes the findings in an academic sense.

2.2 Challenges in the field of accounting

This thesis proposes designs of solutions with novel technology that should be relevant for practice and founded on academic rigor in accounting. Balancing rigor and relevance is a longstanding issue in accounting research as the development of practical solutions is often perceived as *consulting work* with little or no academic merit (Rajgopal, 2020). A pivotal aim of this thesis is to demonstrate how DSR can help accounting researchers strike this balance and develop practical solutions rigorously. Rajgopal uses Stoke's quadrants (1997) on rigor and relevance as a framework for his discussion (see Figure 2). He states that: “The aspirational goal is for accounting academic research to fall in Pasteur’s quadrant, where scholars seek a fundamental understanding of phenomena with a desire to tackle problems relevant to practice.” (p. 9). He continues: “Unfortunately, a vast majority of accounting research falls in the ‘No-No’ quadrant or, at best, in Bohr’s quadrant with no near-term plan to move to Pasteur’s quadrant.” (p. 9).

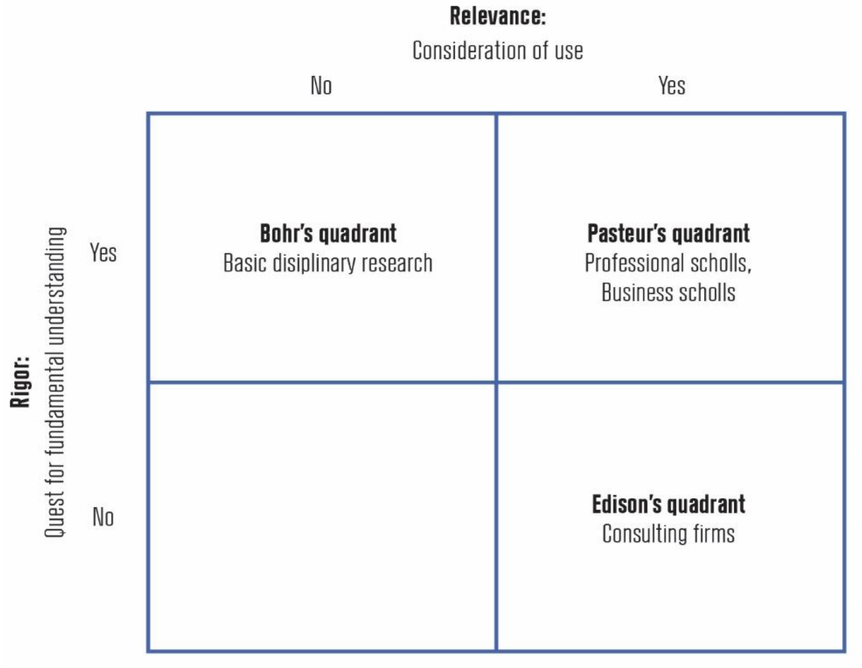

Figure 2. Stokes’s Quadrants. Source: adapted from Stokes (1997)

To further understand the dynamics of a possible movement from Bohr’s toward Pasteur’s quadrant in accounting, I will discuss rigor and relevance and explore the sentiment at the accounting faculty.

The discussion on rigor and relevance is far from new in the field of accounting (Basu, 2012; Chapman, 2012; Fogarty & Markarian, 2007; Gendron, 2008; Hermanson, 2017; Hopwood, 2007; Kaplan, 2011; McCarthy, 2012; Moser, 2012; Tuttle & Dillard, 2007; Waymire, 2012; Wood, 2016). Dyckman and Zeff (1984) describe that before 1970, The Accounting Review (TAR) and Journal of Accounting Research (JAR) regularly published papers that were accessible to practitioners. However, that notion changed in the mid-1970s where Rashad Abdel-Khalik (1976) found that the American Accounting Association’s (AAA) educators and practitioner members wanted TAR to publish more applied and methodologically diverse studies that related to the profession’s needs. As a result, in 1987, the AAA introduced a new journal, Accounting Horizons, that should focus on providing more practice-oriented studies. Unfortunately, 30 years after the creation of the journal, the content and methodology used are very close to TAR (Zeff & Dyckman, 2018).[2] More recently, the Pathways Commission in 2012 and AAA Research Relevance Task Force in 2018 called for more practice-oriented research and advocated for wider dissemination also focused on practitioners. Wood (2016) and Burton et al. (2021) find evidence that the accounting faculty supports the AAA's new directions.[3] Even though initiatives have been initiated to change the focus in the field of accounting, Burton et al. (2021), which is a continuation of the Wood (2016) survey, finds that "[accounting] academics generally perceive that the overall process has not improved or has become worse since 2016" (p. 1). The faculty also thinks that "reviewers focus too much on incremental contribution rigor and method and that reviewers and editors give too little consideration for research that contributes to practice." (p.1). From the above, it is clear that research focused on practice has been debated for a long time; the faculty wants to be more practice-oriented but feels that the rewards and outlets do not create the right structure.

One reason why the accounting field has strayed away from practice could be the dominating methodologies applied in Top 6 journals.[4] Summers and Wood (2017) categorize the published papers as analytical, archival, experimental, and other. Except for the journal of Accounting, Organizations and Society (AOS), the combined percentage of analytical and archival studies in Top 6 is above 75 percent with Review of Accounting Studies at 98 percent. These results also imply that experimental studies represent only up to 18 percent. When applying analytical and archival methodologies, the results typically explain a relationship in historical data. These insights can be of great value to both practice and academia if they reside in Pasteur's quadrant. The results from the quantitative analyses may quantify the problems that practitioners deal with or surface underlying dynamics in the practitioner's industry they did not know existed.

---

[2] See Zeff & Dyckman (2018) for an elaborate historical analysis of 30 years with Accounting Horizons.

[3] Burton et al. (2021) find that the perceptions are largely the same across editors, reviewers, the topic area, and university ranking of respondents.

[4] Defined as the *Top 3* (The Accounting Review [TAR], Journal of Accounting Research [JAR], and Journal of Accounting and Economics [JAE]) or *Top 6* (the Top 3 and Accounting, Organizations and Society [AOS], Contemporary Accounting Research [CAR], and Review of Accounting Studies [RAST]) (Summers & Wood, 2017).

However, suppose the practitioners look for forward-looking guidance or designs on how to tackle a future phenomenon. In that case, they may find it hard to translate the statistically significant results into a solution to their business problem. Rajgopal (2020) points to one reason why practitioners and academics sometimes find it hard to collaborate: "… [the] industry is happy with approximately correct answers necessitated by considerations, such as time to market." However, Rajgopal (2020) also argues that this may pose an opportunity since: "[the] industry's quest for approximate solutions presents an opportunity for academic research to discover the costs and benefits of relying on heuristics in the real world … Perhaps academic research can strike a balance between the microproblems of industry and the overly abstract problems that intrigue scholars." Furthermore, the need for speed may also introduce biases that the rigorous methodology used by academics avoids and, in some areas, increase the commercial outcome even though the time to market may be a bit slower.

The interest in bridging microproblems with overly abstract problems may not be enough without changing some methodological foundations. As Zeff & Dyckman (2018) points to, "normative argument no longer seems to be in vogue, and almost all of the publication outlets in the practitioner world either have disappeared or have turned their backs on such research." (pp. 126-127) and furthermore, Rajgopal (2020) explains how junior scholars respond when he suggests a new question focused on practice: "Ah, but that question is not publishable because referees would say the paper is normative or purely descriptive." (p. 2). Therefore, I ask what if practitioners would like normative conclusions that bring the vast knowledge base of the academic field of accounting into play for a broader audience focusing on developing solutions?

Besides the orientation of the problem and methodology applied, accounting is, of course, also influenced by an increasing degree of digitalization. The increased degree of digitalization increases the speed at which changes to business processes and business models occur. One way for accounting to manage these changes is to be inspired by Nobel laureate Herbert Simon's work. Simon was heavily influenced by engineering, medicine, and computer science when he introduced the sciences of the artificial to social sciences. In his 1968 book, Simon argues that designing and evaluating artifacts are essential for social sciences. He writes: "Schools of engineering, as well as schools of architecture, business, education, law, and medicine, are all centrally concerned with the process of design." and "The intellectual activity that produces material artifacts is no different fundamentally from the one that prescribes remedies for a sick patient or the one that devises a new sales plan for a company or a social welfare policy for the state." (Simon, 1996, p. 111). Simon's design paradigm provides an opportunity to propose and design artifacts that are solution-focused in a rigorous scientific manner.

Hevner et al. (2004) built on Simon's work and introduced DSR that offers an alternative way of encapsulating the forward-looking nature of designing new artifacts, typically enabled by technology, with the rigorous evaluation methodologies, in which quantitative methods are as common as qualitative ones. Historically, in accounting, the evaluation cycles have been long. Looking at some of the largest innovations within accounting, Rajgopal (2020) points to four areas after Ball and Brown (1968): 1) activity-based costing (Cooper & Kaplan, 1991) and the balanced scorecard (Kaplan & Norton, 1992); 2) Edwards-Bell-Ohlson's framework that formalized residual income valuation models (Ohlson, 1995); 3) Sloan (1996) and Beneish (1997) who identified accruals and other signals trading and Piotroski (2000) who built the foundation for exchange-traded funds (ETFs); and lastly, 4) continuous auditing by Vasarhelyi and Harper (1991) and REA accounting ontology by McCarthy (1982). These innovations have all been evaluated ever since. However, the shorter evaluation cycles in DSR provide an opportunity to propose, create, and evaluate artifacts rigorously (see, for example, Venable et al., 2016) within one study. This rapid iterative approach to build and evaluate artifacts makes DSR a good candidate for software solutions, in which the speed of digitalization increases the demand for change. Even though DSR was introduced to the field of information systems (IS), the DSR approach has been used in AIS for more than 25 years (see, for example, Dull et al., 2006; G. Geerts, 2004; G L Geerts & Wang, 2007; Guido L. Geerts & McCarthy, 2000, 2006; Grabski & Marsh, 1994; Murthy & Groomer, 2004) but has not been adopted by Top 6 journals, in which only one study by Christ et al. (2021) has been published.

Every methodology has its advantages and limitations; DSR is no different. The ongoing discussion related to IS shows that there are still areas of DSR that can be refined. Geerts (2011) wants best practices for: "when a problem is considered relevant, how to articulate the research contribution embedded in the artifact, how to select the most effective knowledge tools, what is considered a sufficient demonstration …" (p. 146). Since Geerts made his request for more best practices, the field has advanced. For example, Gregor and Hevner (2013) have provided guidelines for dissemination structure and contribution categorization, see Figure 3. Meth et al. (2015) have provided a framework for analyzing qualitative data to identify design requirements, design principles, and design features for IT artifacts using what they call requirements mining. Regarding the evaluation of artifacts, Venable et al. (2016) have created an evaluation framework that offers different evaluation strategies dependent on which type of artifact and context the researcher(s) wants to evaluate. Furthermore, Baskerville and Pries-Heje (2019) have contributed with a framework for better projecting the life cycle and impact of DSR artifacts and contributions. Lastly, vom Brocke et al. (2020) have presented "a model for conceptualizing design knowledge as a resilient relationship between problem and solution spaces" (p. 1). These examples show that DSR literature provides methodological guidance and answers to some of the questions Geerts (2011) raised about best practices.

However, even with these recent methodological advances, Peffers et al. (2018) point out that DSR scholars sometimes get confused due to ambiguous terminology and misunderstanding of expectations from reviewers. Therefore, Peffers et al. suggest that any DSR project should be categories into one of five potential genres of DSR; 1) IS design theory, 2) DSR methodology, 3) design-oriented IS research, 4) explanatory design theory, and 5) action design research. The author(s) of a DSR project should state which genre the project belonged to let the reviewers know which grounds the paper should be evaluated on. This could help both authors and reviewers since the rules of engagement would be clearer. Lastly, it is not only within accounting that the balance between rigor and relevance is being discussed. In the field of decision support systems (DSS), a field that shares traits with AIS, Arnott and Pervant (2014) state: "It is clear from the analysis that DSS is undergoing a transition from a field based on statistical hypothesis testing and conceptual studies to one where DSR is the most popular method." (p. 269). Could this also happen to AIS? The review of the challenges within accounting and DSR presented above let me conclude that DSR is a good fit for this thesis since it provides a methodological answer to the question I posed at the beginning of this section. DSR offers one alternative for moving accounting research, especially AIS, from Bohr's to Pasteur's quadrant.

2.3 Contribution types

Now that the arguments for applying DSR to ensure both rigor ***and*** relevance and the relationship between the four papers have been presented, it is vital to describe the different types of DSR contributions before the exact positioning of each of the papers is presented.

The contributions of the four papers are categorized following Gregor and Hevner (2013). They present three levels of DSR contribution ranging from level 1 representing situated implementation of artifacts to level 2 representing nascent design theories, such as constructs, methods, models, and design principles, and finally to level 3 representing design theories, see Figure 3.

	contribution types	example artifacts
More abstract, complete, and mature knowledge	Level 3. Well-developed design theory about embedded phenomena	Design theories (mid-range and grand theories)
	Level 2. Nascent design theory – knowledge as operational principles/architecture	Constructs, methods, models, design principles, technological rules
More specific, limited, and less mature knowledge	Level 1. Situated implementation of artifact	Instantiations (software products or implemented processes)

Figure 3. DSR contribution types. Adapted from Gregor and Hevner (2013)

Gregor and Hevner's categorization uses the artifacts as examples of how to distinguish between the three levels. According to Simon, an artifact is "an interface … between an inner and … an outer environment"; here the inner being "the substance and organization of the artifact itself" and the outer being "the surroundings in which it operates" (Simon, 1996). Further evolving the field of IS, March and Smith (1995) extended the literature with their categorization of artifacts into four:

1. "***Constructs*** or concepts form the vocabulary of a domain." (p. 256)
2. "A ***model*** is a set of propositions or statements expressing relationships among constructs." (p. 256)
3. "A ***method*** is a set of steps (an algorithm or guideline) used to perform a task." (p. 257)
4. "An ***instantiation*** is the realization of an artifact in its environment." (p. 258)

Simon's definition resonates across the four categorizations by March and Smith (1995) and is the core of the DSR framework presented by Hevner et al. (2004).

Before describing each of the positionings in writing, Figure 4 provides a visual representation of the positioning and the contributions. First, each paper is described by locating the residing knowledge bases and the building blocks used. Second, the building blocks are typically specific artifacts from the knowledge bases but can also be broader constructs. Third, each of the building blocks points toward the contribution(s) of each of the papers.

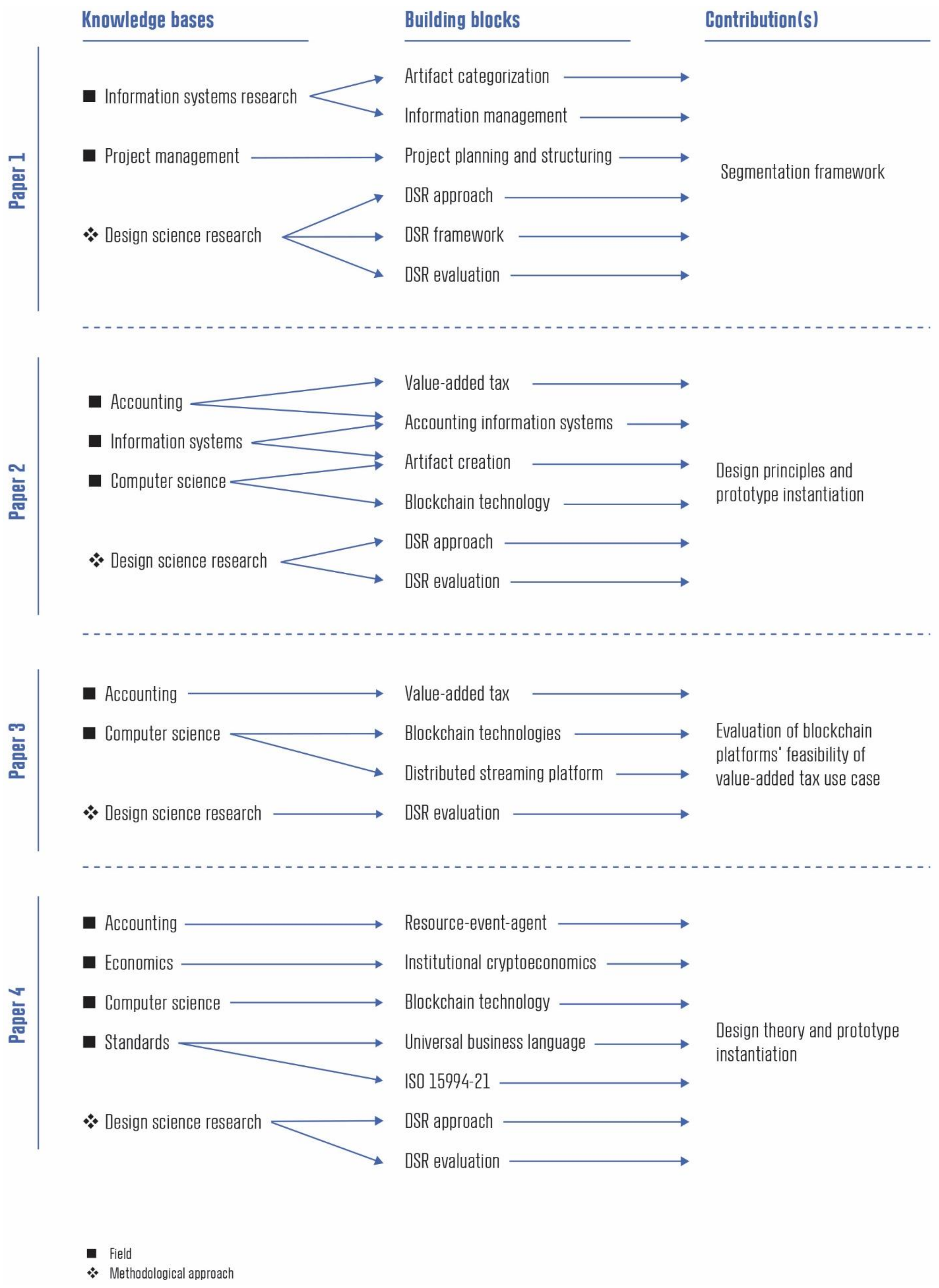

Figure 4. Positioning of papers in the literature

2.4 Paper 1

Paper 1 resides within the knowledge bases of information systems research (ISR), project management, and DSR while also applying DSR. The position of paper 1 within ISR builds on the increased attention to DSR in the ISR community as an important research approach (Vaishnavi & Kuechler, 2017). Several publications about the role and interaction of design science, natural science (March & Smith, 1995), and social science (Gregor & Baskerville, 2012) have clarified the differences, relationships, and interactions between different research approaches in the scientific domain. Scientists have made valuable contributions on how to conduct DSR activities in a structured and rigorous manner (Hevner et al., 2004; Hevner & Chatterjee, 2010; Österle et al., 2011; Peffers et al., 2007), consider ethical aspects (Myers & Venable, 2014), and position DSR results in the academic arena (Gregor & Hevner, 2013). Although sophisticated models do exist that guide researchers in performing DSR (Alturki et al., 2011; Gregor & Baskerville, 2012; Kuechler & Vaishnavi, 2008; Peffers et al., 2007), little attention has yet been paid to the question of how DSR projects can be set up, structured, and managed. The DSR methodology ensures project outcomes that contribute to rigor and moves the academic field forward while ensuring relevance for practitioners. Since DSR projects often engage with organizations, the project setup typically involves multiple stakeholders, which increases the complexity and risks. Managing all the risks associated with DSR projects is no trivial task (Pries-Heje et al., 2014; Venable et al., 2019). If these risks are not managed properly, the research project may not provide the impact as hoped for, and valuable time and resources have been wasted.

Paper 1 provides a framework for segmenting DSR projects that rely on a well-established model in the field of information management that considers these aspects presented by Krcmar (2015). This reference model describes the different levels of information management with the aim of structuring information and the management hereof. The project management knowledge base provides literature and methodologies for managing large and complex projects and how they can be broken into smaller, more manageable components. It is a key requirement to develop a suitable project management plan, to define, sequence, and monitor activities, as well as making good decisions for allocating resources adequately (Project Management Institute, 2017). This is common practice in software development where long-established systems development lifecycle models, such as the waterfall model, prototyping, iterative and incremental development (O'Regan, 2017), and newer methodologies, such as agile programming (Dybå & Dingsøyr, 2008), guide researchers and practitioners in their efforts alike. DSR is closely related to software development as the instantiation of an artifact as part of DSR often includes developing a software prototype. Whereas it is common to divide software development projects into smaller segments, such as sprints in agile methodologies (Pries & Quigley, 2010), and to manage these separately, such an approach does not seem to exist in DSR.

2.4.1 Contributions to academia

With the positioning of paper 1 explained, see Figure 4, the contribution of the paper is a DSR project segmentation framework that extends the DSR literature with a new model that helps structure the content of DSR projects by dividing the overall research tasks into manageable segments. The segmentation framework is a level 2 contribution and is relevant for academics and practitioners who participate in DSR projects.

2.4.2 Implications for practice

This paper helps practitioners with a clear framework for project management when engaging with DSR scholars. The visual representation of the entire project broken down into segments makes it possible for multiple project members to discuss the scope of a given task simultaneously. Furthermore, the visualization ensures that redundant work is minimized while safeguarding that no gaps between segments are unaddressed unconsciously. The entity-relationship diagram provided makes it easy to implement a working prototype of the framework and adjust it to the organization's needs in any database system.

2.5 Paper 2

Paper 2 resides within the knowledge bases of accounting, information systems (IS), and computer science and applies DSR as a methodological approach, see Figure 4. When surveying the literature, Fatz et al. (2019) have conducted a DSR project focusing on VAT systems using DLT. Furthermore, Wijaya et al. (2017), Alkhodre et al. (2019), and Fatz et al. (2019) do not present any general knowledge that is easily applied to other contexts, or that specifically categorizes their artifacts.[5] Prototypes and case studies are useful since they are rich in their

[5] See an extensive overview of all the literature surveyed in paper 2, appendix B.

description and provide context. However, for a more general-purpose, they have their limitations. Therefore, this study does not only provide a prototype; it also provides general design principles that both academics and practitioners can use and extend in the future.

Paper 2 also draws on fundamental studies of blockchain technology (Nakamoto, 2008) and smart contracts (Szabo, 1997). The combination of blockchain technology and smart contracts makes it possible to materialize distributed processes and shared truth without involving any third parties (Berkeley, 2015). Furthermore, paper 2 utilizes academic taxonomical studies (Glaser, 2017; Xu et al., 2019, 2017) of DLT to articulate the specificities of DLT design.

Paper 2 highlights the existing literature on DLT and VAT, and Ainsworth, Alwohaibi et al. (2017), Ainsworth, Cheetham et al. (2017), and Ainsworth and Shact (2016) describe how blockchain technology can address, at a conceptual level, the EU's tax gap described in the paper. From an accounting and DLT perspective, Brandon (2016) suggests that DLT replaces traditional IS, Wang and Kogan (2018) propose a tokenized design to preserve privacy on public blockchains, and Coyne and McMickle (2017) find that public blockchains are not fit for accounting purposes. However, any of the prior studies mentioned do not offer any design guidelines or prototypes indicating how to implement the conceptualizations presented.

2.5.1 Contributions to academia

Based on the above, paper 2 contributes with a prototype instantiation (level 1) and four general design principles (level 2), extending the knowledge base of DLT literature within AIS and VAT. I hope that other scholars want to extend the prototype and design principles by evaluating them in other projects. See Figure 4 for a visualization of the positioning.

2.5.2 Implications for practice

Paper 2's implication for practice is twofold. First, the prototype provided in the paper shows how to use blockchain as a service (BaaS) to create real-life instances of blockchain applications fast. It also highlights the errors we encountered during the development cycle. Together with the source code of the smart contracts and a small animated video that demonstrates the core principles of the prototype, these insights are shared on GitHub and provide a good starting point. Second, the design principles should help practitioners apply a technology that may be new to them and are intended to be a conversation starter with non-technical executives and other team members when creating the vision for their blockchain project.

2.6 Paper 3

Paper 3 is primarily positioned in the computer science knowledge base, specifically with the building blocks of blockchain technology and distributed streaming platforms, see Figure 4. The use of VAT is a building block of the accounting knowledge base and is inherited from paper 2. This paper provides insight into multiple DLT platforms and their performance. These insight could prove useful as DLT become an integral part of the AIS architecture in the future (Dai & Vasarhelyi, 2016). Furthermore, the paper offers a conceptual framework for performance testing other AIS, making it possible to compare and start a more informed discussion of fundamental issues, such as the cost of trust when designing a new AIS.

Paper 3 employs a DSR methodology by creating the testing artifacts for each of the four platforms and evaluating them based on the use case presented in paper 2. Performance studies for blockchains (Hao et al., 2018; Pongnumkul et al., 2017; Spasovski & Eklund, 2017; Z. Wang et al., 2018) usually follow common distributed system testing practices, keeping as many parameters as possible constant to obtain the best like-for-like comparison of variability in resource demand, throughput, and/or transaction latency. In these studies, it is easy to choose an experimental setup that will bias for (or against) a given blockchain framework, so while such studies are self-contained, it is impossible to conclude the performance between different blockchain systems. To address this, some researchers have tried to create sophisticated testing frameworks, Blockbench (Dinh et al., 2017) and Chainhammer (Krüger, 2019), but these are still considered work in progress (Sund et al., 2020).

The downside of most existing blockchain performance tests is that they are mostly artificial, in the sense that the topology of the network, its geographic distribution, message lengths, and transaction volume are not realistic in terms of how the system will be deployed. Paper 3 addresses this; it aims for an in-the-wild distributed system test. This is possible because, in the use case of paper 2, the national and transnational B2B/B2G invoicing system requirements exactly determine performance expectations. This means that the size and number of transactions arriving at the system will match the use case as closely as possible during empirical testing, while the number, geographic spread of nodes, and consensus validators will likewise closely match the use case using common hardware and network infrastructure.

2.6.1 Contributions to academia

Paper 3 contributes at level 1 through four different instantiations of performance platform evaluations. The results of these evaluations provide insights into academic studies of the performance measures of blockchain technology and its implications. In particular, these insights could be used in the field of accounting when designing new AIS. For example, the design principles from paper 2 and the contributions from this paper provide an informed foundation for designing new AIS with which it should be possible to handle large volumes of data, such as invoices and other business documents that are important to the processes of accounting. Accounting research normally does not consider scalability issues when proposing digitalized solutions. However, this study shows that focus on scalability in scientifically rigorous manner makes the contribution more practice-oriented preparing for the allegedly increased digitalization of accounting in general.

2.6.2 Implications for practice

Practitioners should use these results as a starting point for platform selection and architectural design since the results are obtained through real tests and not simulated ones. Practitioners who design AIS or other IS could use the results from paper 3 when considering the non-functional requirements of scalability. Since the scalability of a given system depends heavily on the architecture, the conceptual test framework created in paper 3 could be used as a common framework when experimenting with other designs. The paper also refers to resources that could be helpful when conducting performance evaluations of different blockchain-based platforms.

As a result of the contributions and implications presented, paper 3 extends the knowledge base within the performance evaluation domain by creating in-the-wild DLT tests through the use case presented in paper 2.

2.7 Paper 4

Paper 4 resides within the knowledge bases of accounting, economics, computer science, and standards while applying DSR to create the design theory and artifacts proposed, see Figure 4. Within the field of accounting, paper 4 builds on the resource-event-agent (REA) accounting ontology (McCarthy, 1982) and is positioned as a response to David et al.'s (2003) paper on IS that kept intercompany exchange transactions in an independent collaboration space, stored only once. It is important to note that paper 4 does not compare REA with double-entry bookkeeping (DEB) since the principles are fundamentally different and therefore offer an alternative to DEB (McCarthy et al., 2021; Pazaitis, 2020; White & Clinton, 2014). As Pazaitis describes, the REA ontology is a "generalized framework designed to cover accounting needs for enterprise environments, utilizing shared data amongst their functional constituents. The main motivation behind the development of REA was the limited capacity of double-entry bookkeeping to facilitate information flows in post-industrial business entities. These limitations are addressed by the REA framework through a semantic approach that aims to reflect real-world business activities rather than double-entry accounting objects." (pp. 5-6).

Focusing on the building blocks of economics, paper 4 uses and extends one of the central components of Berg et al.'s (2019) analysis: the microfoundations of ledgers. This analysis is founded on what they say is "institutional cryptoeconomics" (p. 1) and is the application of the transaction cost economics of Ronald Coase, James Buchanan, Oliver Williamson, and Elinor Nostrom to blockchains. Paper 4 proposes that Berg et al.'s (2019) essential concept of a *general ledger* (which is not the same as the accounting master file of the same name[6]) be replaced by components of the independent view of the REA accounting and economic ontology. In the computer science knowledge base, paper 4 uses the same building blocks as presented in paper 2.

Paper 4 is heavily influenced by two standards: 1) ISO/IEC 15944-21 (2020) and 2) Universal Business Language (UBL). First, the ISO standard provides a practical, non-technical description of core concepts, such as the distributed business transaction repository (DBTR), presented in the paper. Two of the authors of the paper have been part of the working groups formulating the standard. Second, UBL helps with document standards and well-accepted business communication procedures. The use of these two standards provides evidence that the DSR methodology applied in this study not only guides the evaluation of the artifacts; it makes the results relevant for practitioners since globally accepted standards are used and integrated

[6] Berg, Davidson, and Potts (like the authors of this paper) consider double entry ledgers ("A collection of accounting entries consisting of credits and debits") (https://en.wiktionary.org/wiki/ledger) to be too limited of a paradigm to constitute the semantic foundation of a blockchain ledger.

into the design theory. It is important to note that current technical challenges, such as raising the gas cost and general scalability, are considered out of scope. It does not mean that those challenges should not be considered when designing DLT systems. Already today, platforms, such as Hedera, Concordium, and Ethereum, move toward proof of stake, and many layer 2 solutions work heavily on meeting these challenges.

2.7.1 Contributions to academia

Paper 4 proposes a design theory that does not consider technical issues but rather builds on well-established theory within accounting, economics, computer science, and widely accepted standards resulting in a level 3 contribution to future DLT-based AIS. I encourage accounting scholars to evaluate the design theory and develop it for more accounting contracts in collaboration space. In short, this paper provides a foundation of where DLT finds a firm theoretical accounting ontology – and REA finds a practical technology for implementation.

2.7.2 Implications for practice

The practical implications from paper 4 fall into two categories. First, the code is available for anyone on GitHub, consisting of state machine descriptions in human- and machine-readable formats and smart contract code in Solidity. Furthermore, a narrated video demonstrates the principles behind accounting contracts in the collaboration space. Second, the standards used (ISO 15944-4 and ISO 15944-21)[7] in paper 4 offer assurance that adopting these principles is not just a design theory for academics to discuss but the implications are built on firm ground.

3. LIMITATIONS AND FUTURE RESEARCH

The limitations and future research opportunities are tightly coupled with the three levels of DSR contributions (Gregor & Hevner, 2013). I will use the three levels as the framework for this section.

At level 1, the core case of the thesis is situated in Denmark, where the public sector drives digitalization through regulatory requirements and open data, which has resulted in Denmark

[7] https://www.iso.org/obp/ui/#iso:std:iso-iec:15944:-4:ed-2:v1:en and https://www.iso.org/obp/ui/#iso:std:iso-iec:15944:-21:dis:ed-1:v1:en

being named the world's most digitalized country in 2018 (European Commission, 2018) and in 2020 being proclaimed to be the best country at e-government development (United Nations, 2020). This thesis rests on this context and tries to compensate by generalizing the contributions to the largest extend possible. However, it would be interesting to see other scholars embark on similar projects within another public administration to investigate similarities and differences in digital maturity, specifically DLT maturity and administrative burdens. It could also be less complex projects that focus on instantiations of DLT-based AIS. Furthermore, the results from paper 2 and paper 3 are limited to the selected DLT platforms. It would be of great interest to see another BaaS to further develop the prototype of paper 2 and extend the in-the-wild test concept of paper 3 used with other DLT platforms, different types of tests, and extended into other use case domains.

For level 2, scholars are encouraged to use and extend the four design principles in other contexts than those in paper 2. For example, which conclusions could be drawn from using the design principles when applied to different organizational sizes (small, medium-sized, and large), and do these design principles also apply to processes and IT systems outside of the accounting domain? Since the DSR segmentation framework presented in paper 1 is initiated from previous DSR projects, it would be interesting to see new DSR projects apply it and provide feedback on the framework. This would create a real evaluation and help DSR scholars and practitioners learn more about driving good DSR projects.

Finally, for level 3, scholars and practitioners are encouraged to use and extend the design theory for accounting contracts in collaboration space (paper 4). For example, imminent studies could examine other parts of the value chain than already done in the paper. Furthermore, future research opportunities may focus on the transition and barriers to adopting the design theory in its entirety and further developing the cryptoeconmics theory presented by Berg et al. (2019).

REFERENCES

Abdel-Khalik, A. R. (1976). An Analysis of the Attitudes of a Sample of the AAA Members toward the Accounting Review. *The Accounting Review*, *51*(3), 604–616. http://www.jstor.org/stable/245468

Ainsworth, R. T., Alwohaibi, M., & Cheetham, M. (2017). VATCoin: The GCC's

Cryptotaxcurrency. *SSRN Electronic Journal*, *17*. https://doi.org/10.2139/ssrn.2916321

Ainsworth, R. T., Cheetham, M., Tirand, C. V, Ainsworth, R. T., Cheetham, M., & Tirand, C. V. (2017). a Vatcoin Solution To Mtic Fraud : Past Efforts , Present Technology , and the Eu ' S 2017 Proposal. *Boston University School of Law Law & Economics Series Paper No. 18-08*, *18*.

Ainsworth, R. T., & Shact, A. (2016). Blockchain (Distributed Ledger Technology) Solves VAT Fraud. *Law & Economics Working Paper*, *16*(41). http://www.bu.edu/law/faculty-scholarship/working-paper-series/

Alkhodre, A., Ali, T., Jan, S., Alsaawy, Y., Khusro, S., & Yasar, M. (2019). A Blockchain-based value added tax (VAT) system: Saudi Arabia as a use-case. *International Journal of Advanced Computer Science and Applications*, *10*(5), 708–716. https://doi.org/10.14569/ijacsa.2019.0100588

Alturki, A., Gable, G. G., & Bandara, W. (2011). *A Design Science Research Roadmap BT - Service-Oriented Perspectives in Design Science Research* (H. Jain, A. P. Sinha, & P. Vitharana (eds.); pp. 107–123). Springer Berlin Heidelberg.

Arnott, D., & Pervan, G. (2014). A critical analysis of decision support systems research revisited: The rise of design science. *Journal of Information Technology*, *29*(4), 269–293. https://doi.org/10.1057/jit.2014.16

Ball, R., & Brown, P. (1968). An Empirical Evaluation of Accounting Income Numbers Author (s): Ray Ball and Philip Brown Published by : Wiley on behalf of Accounting Research Center , Booth School of Business , University of Chicago Stable URL : http://www.jstor.com/stable/2490232 A. *Journal of Accounting Research*, *6*(2), 159–178.

Baskerville, R. L., & Pries-Heje, J. (2019). Projectability in Design Science Research. *Journal of Infomation Technology Theory and Application*, *20*(1), 53–76.

Basu, S. (2012). How Can Accounting Researchers Become More Innovative? *Accounting Horizons*, *26*(4), 851–870. https://doi.org/10.2308/acch-10311

Beneish, M. D. (1997). Detecting GAAP violation: Implications for assessing earnings management among firms with extreme financial performance. *Journal of Accounting and*

Public Policy, *16*(3), 271–309. https://doi.org/10.1016/S0278-4254(97)00023-9

Bennis, W. G., & O'Toole, J. (2005). How business schools lost their way. *Harvard Business Review*, *83*(5).

Berg, C., Davidson, S., & Potts, J. (2019). *Understanding the Blockchain Economy - An Introduction to Institutional Cryotoeconomics*. Edward Elgar Publisning Limited.

Berkeley, J. (2015). The Trust machine - The technology behind bitcoin could transform how the economy works. *The Economist.*

Bozanic, Z., Dirsmith, M. W., & Huddart, S. (2012). The social constitution of regulation: The endogenization of insider trading laws. *Accounting, Organizations and Society*, *37*(7), 461–481. https://doi.org/10.1016/j.aos.2012.06.003

Brandon, D. (2016). The Blockchain - The Future of Business Information Systems? *International Journal of the Academic Business World*, *10*(2), 33–40. https://doi.org/10.1364/BOE.6.003898

Burton, F. G., Heninger, W. G., Summers, S. L., & Wood, D. A. (2021). Updated Perceptions of Accounting Academics on the Review and Publication Process. *SSRN*.

Buterin, V. (2013). A next-generation smart contract and decentralized application platform. *Etherum*, *11*(January), 7. https://doi.org/10.1016/j.jchromb.2013.02.015

Chapman, C. S. (2012). Framing the Issue of Research Quality in a Context of Research Diversity. *Accounting Horizons*, *26*(4), 821–831. https://doi.org/10.2308/acch-10314

Chen, Y. C. (2012). A comparative study of e-government XBRL implementations: The potential of improving information transparency and efficiency. *Government Information Quarterly*, *29*(4), 553–563. https://doi.org/10.1016/j.giq.2012.05.009

Christ, M. H., Emett, S. A., Summers, S. L., & Wood, D. A. (2021). Prepare for takeoff: improving asset measurement and audit quality with drone-enabled inventory audit procedures. *Review of Accounting Studies*. https://doi.org/10.1007/s11142-020-09574-5

Cointelegraph. (2020). *The Big Four Are Gearing Up to Become Crypto and Blockchain Auditors*. https://cointelegraph.com/news/the-big-four-are-gearing-up-to-become-crypto-and-blockchain-auditors

Cooper, R., & Kaplan, R. S. (1991). Profit priorities from activity-based costing. *Harvard Business Review*, *69*(3), 130–135.

Corley, K. G., & Gioia, D. A. (2011). Building Theory About Theory Building : What Constitutes a Theoretical Contribution? *Academy of Management Review*, *36*(January), 12–32. https://doi.org/10.5465/AMR.2011.55662499

Coyne, J. G., & McMickle, P. L. (2017). Can Blockchains Serve an Accounting Purpose? *Journal of Emerging Technologies in Accounting*, *14*(2), 101–111. https://doi.org/10.2308/jeta-51910

Dai, J., & Vasarhelyi, M. A. (2016). Imagineering Audit 4.0. *Journal of Emerging Technologies in Accounting*, *13*(1), 1–15. https://doi.org/10.2308/jeta-10494

Dai, J., & Vasarhelyi, M. A. (2017). Toward Blockchain-Based Accounting and Assurance. *Journal of Information Systems*, *31*(3), 5–21. https://doi.org/10.2308/isys-51804

David, J. S., McCarthy, W. E., & Sommer, B. S. (2003). Agility - The Key to Survival of the Fittest in the Software Market. *Communications of the ACM*, *46*(5), 65–69.

Davidson, S., Novak, M., & Potts, J. (2018). The Cost of Trust: A Pilot Study. *The Journal of the British Blockchain Association*, *1*(2), 1–7. https://doi.org/10.31585/jbba-1-2-(5)2018

Dechow, P., Ezzell, B., Harris, T., Healy, P., Kaplan, B., Kinney, B., Lambert, R., Libby, B., Munter, P., Sloan, R., Swieringa, B., Wood, D., & Yohn, T. (2018). *AAA research relevance task force : Recommendations*.

Dinh, T. T. A., Liu, R., Zhang, M., Chen, G., Ooi, B. C., & Wang, J. (2017). *Untangling Blockchain: A Data Processing View of Blockchain Systems*. https://arxiv.org/pdf/1708.05665.pdf

Dull, R. B., Tegarden, D. P., & Schleifer, L. L. F. (2006). ACTVE: A proposal for an automated continuous transaction verification environment. *Journal of Emerging Technologies in Accounting*, *3*(1), 81–96.

Dybå, T., & Dingsøyr, T. (2008). Empirical studies of agile software development: A systematic review. *Information and Software Technology*, *50*(9–10), 833–859. https://doi.org/10.1016/j.infsof.2008.01.006

Dyckman, T. R., & Zeff, S. A. (1984). Two Decades of the Journal of Accounting Research. *Journal of Accounting Research*, *22*(1), 225–297. http://www.jstor.org/stable/2490710

European Commission. (2018). *Digital Economy and Society Index 2018 Report*. https://ec.europa.eu/digital-single-market/en/news/digital-economy-and-society-index-2018-report

EY. (2018). Worldwide electronic invoicing survey. In *EY*.

Fatz, F., Hake, P., & Fettke, P. (2019). Towards Tax Compliance by Design: A Decentralized Validation of Tax Processes Using Blockchain Technology. *IEEE 21th Conference on Business Informatics (CBI)*, *01*, 559–568. https://doi.org/10.1109/CBI.2019.00071

Fogarty, T. J., & Markarian, G. (2007). An Empirical Assessment of the Rise and Fall of Accounting as an Academic Discipline. *Issues in Accounting Education*, *22*(2), 137–161. https://doi.org/10.2308/iace.2007.22.2.137

Geerts, G. (2004). An XML architecture for operational enterprise ontologies. *Journal of Emerging Technology Accounting*, *1*(1), 73–90.

Geerts, G L, & Wang, H. J. (2007). The timeless way of building REA enterprise systems. *Journal of Emerging Technologies In Accounting*, *4*(1), 161–182.

Geerts, Guido L. (2011). A design science research methodology and its application to accounting information systems research. *International Journal of Accounting Information Systems*, *12*, 142–151. https://doi.org/10.1016/j.accinf.2011.02.004

Geerts, Guido L., & McCarthy, W. E. (2000). Augmented Intensional Reasoning in Knowledge-Based Accounting Systems. *Journal of Information Systems*, *14*(2), 127–150. https://doi.org/10.2308/jis.2000.14.2.127

Geerts, Guido L., & McCarthy, W. E. (2006). Policy-Level Specifications in REA Enterprise Information Systems. *Journal of Information Systems*, *20*(2), 37–63. https://doi.org/10.2308/jis.2006.20.2.37

Gendron, Y. (2008). Constituting the Academic Performer: The Spectre of Superficiality and Stagnation in Academia. *European Accounting Review*, *17*(1), 97–127. https://doi.org/10.1080/09638180701705973

Glaser, F. (2017). Pervasive Decentralisation of Digital Infrastructures: A Framework for Blockchain enabled System and Use Case Analysis. *Hawaii International Conference on System Sciences*, 1543–1552. http://hl-128-171-57-22.library.manoa.hawaii.edu/bitstream/10125/41339/1/paper0190.pdf

Grabski, S. V, & Marsh, R. J. (1994). Integrating accounting and manufacturing information systems: An ABC and REA-based approach. *Journal of Information Systems*, *8*(2), 61–80.

Gregor, S., & Baskerville, R. L. (2012). The fusion of design science and social science research. *Information Systems Foundation Workshop*.

Gregor, S., & Hevner, A. R. (2013). Positioning and Presenting Design Science Research for Maximum Impact. *MIS Quarterly*, *37*(2), 337–355. https://doi.org/10.25300/MISQ/2013/37.2.01

Hao, Y., Li, Y., Dong, X., Fang, L., & Chen, P. (2018). Performance analysis of consensus algorithm in private blockchain. *2018 IEEE Intelligent Vehicles Symposium (IV)*, 280–285.

Hermanson, D. R. (2017). 25 Reflections on Accounting Research. *Issues in Accounting Education*, *33*(1), 3–15. https://doi.org/10.2308/iace-51883

Hevner, A. R., & Chatterjee, S. (2010). Design Research in Information Systems. In *Springer* (Vol. 22). Springer US. https://doi.org/10.1007/978-1-4419-5653-8

Hevner, A. R., March, S. T., Park, J., & Ram, S. (2004). Design Science in Information Systems Research. *MIS Quarterly*, *28*(1), 75–105. https://wise.vub.ac.be/sites/default/files/thesis_info/design_science.pdf

Hopwood, A. G. (2007). Whither Accounting Research? *The Accounting Review*, *82*(5), 1365–1374. https://doi.org/10.2308/accr.2007.82.5.1365

Hungarian Tax Authority. (2018). *Hungarian Tax Authority*. https://onlineszamla.nav.gov.hu/home

Hyvärinen, H., Risius, M., & Friis, G. (2017). A Blockchain-Based Approach Towards Overcoming Financial Fraud in Public Sector Services. *Business & Information Systems Engineering*, *59*(6), 441–456. https://doi.org/10.1007/s12599-017-0502-4

Infinite. (2021). *Infinite*. https://www.getinfinite.io/

Jensen, T., Hedman, J., & Henningsson, S. (2019). How TradeLens delivers business value with blockchain technology. *MIS Quarterly Executive*, *18*(4), 221–243. https://doi.org/10.17705/2msqe.00018

Kaplan, R. S. (2011). Accounting Scholarship that Advances Professional Knowledge and Practice. *The Accounting Review*, *86*(2), 367–383. https://doi.org/10.2308/accr.00000031

Kaplan, R. S., & Norton, D. P. (1992). The balanced scorecard--measures that drive performance. *Harvard Business Review*, *70*(1), 71–79.

Kokina, J., Mancha, R., & Pachamanova, D. (2017). Blockchain: Emergent Industry Adoption and Implications for Accounting. *Journal of Emerging Technologies in Accounting*, *14*(2), 1–15. https://doi.org/10.1002/isaf.1417

Krcmar, H. (2015). Informationsmanagement. In *Springer*. Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-662-45863-1

Krüger, A. (2019). *Chainhammer*. https://github.com/drandreaskrueger/chainhammer

Kuechler, W., & Vaishnavi, V. (2008). On theory development in design science research: Anatomy of a research project. *European Journal of Information Systems*, *17*(5), 489–504. https://doi.org/10.1057/ejis.2008.40

Lazaar, B. (2019). Telecommunication Use Cases for Blockchain Technology. In *Enterprise Ethereum Alliance* (Vol. 1, Issue April).

March, S. T., & Smith, G. F. (1995). Design and natural science research on information technology. Decision Support Systems. *Decision Support Systems*, *15*, 251–266.

McCarthy, W. E. (1982). The REA Accounting Model: A Generalized Framework for Accounting Systems in a Shared Data Environment. *The Accounting Review*, *57*(3), 554–578.

McCarthy, W. E. (2012). Accounting craftspeople versus accounting seers: Exploring the relevance and innovation gaps in academic accounting research. *Accounting Horizons*, *26*(4), 833–843. https://doi.org/10.2308/acch-10313

McCarthy, W. E., Geerts, G. L., & Gal, G. (2021). *The REA Accounting Model as an Accounting and Economic Ontology*. 1–144.

Meth, H., Mueller, B., & Maedche, A. (2015). Designing a Requirement Mining System. *Journal of the Association for Information Systems*, *16*(9), 799–837.

Moser, D. V. (2012). Is Accounting Research Stagnant? *Accounting Horizons*, *26*(4), 845–850. https://doi.org/10.2308/acch-10312

Murthy, U. S., & Groomer, S. M. (2004). A continuous auditing web services model for XML-based accounting systems. *International Journal of Accounting Information Systems*, *5*(2), 139–163. https://doi.org/10.1016/j.accinf.2004.01.007

Nakamoto, S. (2008). *Bitcoin: A Peer-to-Peer Electronic Cash System*. www.bitcoin.org

O'Regan, G. (2017). *Concise Guide to Software Engineering*. Springer International Publishing. https://doi.org/10.1007/978-3-319-57750-0

Ohlson, J. A. (1995). *and Dividends in Equity Valuation **. *11*(2), 661–687.

Österle, H., Becker, J., Frank, U., Hess, T., Karagiannis, D., Krcmar, H., Loos, P., Mertens, P., Oberweis, A., & Sinz, E. J. (2011). Memorandum on design-oriented information systems research. *European Journal of Information Systems*, *20*(1), 7–10. https://doi.org/10.1057/ejis.2010.55

Pazaitis, A. (2020). Breaking the Chains of open innovation: Post-blockchain and the case of sensorica. *Information (Switzerland)*, *11*(2), 1–18. https://doi.org/10.3390/info11020104

Peffers, K., Tuunanen, T., & Niehaves, B. (2018). Design science research genres: introduction to the special issue on exemplars and criteria for applicable design science research. In *European Journal of Information Systems* (Vol. 27, Issue 2, pp. 129–139). https://doi.org/10.1080/0960085X.2018.1458066

Peffers, K., Tuunanen, T., Rothenberger, M. A., & Chatterjee, S. (2007). A design science research methodology for information systems research. *Journal of Management Information Systems*, *24*(3), 45–77. https://doi.org/10.2753/MIS0742-1222240302

Piotroski, J. D. (2000). Value Investing: The Use of Historical Financial Statement Information to Separate Winners from Losers. *Journal of Accounting Research*, *38*, 1. https://doi.org/10.2307/2672906

Pongnumkul, S., Siripanpornchana, C., & Thajchayapong, S. (2017). Performance analysis of private blockchain platforms in varying workloads. *2017 26th International Conference on Computer Communication and Networks (ICCCN)*, 1–6.

Pries-Heje, J., Venable, J. R., & Baskerville, R. L. (2014). RMF4DSR: A risk management framework for design science research. *Scandinavian Journal of Information Systems*, *26*(1), 57–82.

Pries, K. H., & Quigley, J. M. (2010). *Scrum project management*. CRC press.

Project Management Institute. (2017). *A guide to the project management body of knowledge - PMBOK Guide* (Sixth). https://www.pmi.org/pmbok-guide-standards/foundational/pmbok

Rajgopal, S. (2020). Integrating Practice into Accounting Research. *Management Science, Special Issue of Management Science: 65th Anniversary*, 1–25. https://doi.org/10.1287/mnsc.2020.3590

Rückeshäuser, N. (2017). *Distributed Ledgers for the Prevention of Accounting Fraud Blockchains Between Expectations and Reality*. 1–200. https://d-nb.info/1137466235/34

Schmitz, J., & Leoni, G. (2019). Accounting and Auditing at the Time of Blockchain Technology: A Research Agenda. *Australian Accounting Review*, *29*(2), 331–342. https://doi.org/10.1111/auar.12286

Simon, H. A. (1996). The Sciences of the Artificial. In *Technology and Culture*. https://doi.org/10.2307/3102825

Sloan, R. G. (1996). Do stock prices fully reflect information in accruals and cash flows about future earnings? *Accounting Review*, *71*(3), 289–315. https://doi.org/10.2469/dig.v27.n1.5

Spasovski, J., & Eklund, P. (2017). Proof of stake blockchain: Performance and scalability for groupware communications. *9th International Conference on Management of Digital EcoSystems, MEDES 2017*, *2017-Janua*(November), 251–258. https://doi.org/10.1145/3167020.3167058

Stokes, D. E. (1997). *Pasteur's quadrant: Basic science and technological innovation*. Brookings Institution Press.

Summers, S. L., & Wood, D. A. (2017). An evaluation of the general versus specialist nature of top accounting journals. *Accounting Horizons*, *31*(2), 105–124. https://doi.org/10.2308/acch-51712

Sund, T., Lööf, C., Nadjm-Tehrani, S., & Asplund, M. (2020). Blockchain-based event processing in supply chains—A case study at IKEA. *Robotics and Computer-Integrated Manufacturing*, *65*(March), 101971. https://doi.org/10.1016/j.rcim.2020.101971

Sveriges Riksbank. (2021). *E-krona pilot Phase 1*. 1–21.

Szabo, N. (1997). Formalizing and Securing Relationships on Public Networks. *First Monday*, *2*(9). https://doi.org/10.5210/fm.v2i9.548

The Pathways Commission. (2012). *The Pathways Commission: Charting a National Strategy for the Next Generation of Accountants*.

Tuttle, B., & Dillard, J. (2007). Beyond Competition: Institutional Isomorphism in U.S. Accounting Research. *Accounting Horizons*, *21*(4), 387–409. https://doi.org/10.2308/acch.2007.21.4.387

United Nations. (2020). *E-Government Survey 2020 - DIGITAL GOVERNMENT IN THE DECADE OF ACTION FOR SUSTAINABLE DEVELOPMENT*.

Vaishnavi, V., & Kuechler, W. (2017). *Design Science Research in Information Systems*. http://www.desrist.org/design-research-in-information-systems/

Vasarhelyi, M. A., & Halper, F. B. (1991). The continuous audit of online systems. *Auditing: A Journal of Practice & Theory*, *10*(1), 110–125.

Venable, J. R., Pries-Heje, J., & Baskerville, R. (2016). FEDS: A Framework for Evaluation in Design Science Research. *European Journal of Information Systems*, *25*(1), 77–89.

https://doi.org/10.1057/ejis.2014.36

Venable, J. R., Vom Brocke, J., & Winter, R. (2019). Designing TRiDS: Treatments for Risks in Design Science. *Australasian Journal of Information Systems*, *23*, 1–36. https://doi.org/10.3127/ajis.v23i0.1847

Vom Brocke, J., Winter, R., Hevner, A. R., & Maedche, A. (2020). Accumulation and Evolution of Design Knowledge in Design Science Research – A Journey Through Time and Space. *Journal of Association for Information Systems*.

Wang, Y., & Kogan, A. (2018). Designing confidentiality-preserving Blockchain-based transaction processing systems. *International Journal of Accounting Information Systems*, *30*(June), 1–18. https://doi.org/10.1016/j.accinf.2018.06.001

Wang, Z., Dong, X., Li, Y., Fang, L., & Chen, P. (2018). Iot security model and performance evaluation: A blockchain approach. *2018 International Conference on Network Infrastructure and Digital Content (IC-NIDC)*, 260–264.

Waymire, G. B. (2012). Introduction for essays on the state of accounting scholarship. *Accounting Horizons*, *26*(4), 817–819. https://doi.org/10.2308/acch-50236

White, L. R., & Clinton, B. D. (2014). *Conceptual Framework for Managerial Costing*.

Wijaya, D. A., Liu, J. K., Suwarsono, D. A., & Zhang, P. (2017). A New Blockchain-Based Value-Added Tax System. *Provable Security*, 471–486. https://doi.org/10.1007/978-3-319-68637-0

Wood, D. A. (2016). Comparing the publication process in accounting, economics, finance, management, marketing, psychology, and the natural sciences. *Accounting Horizons*, *30*(3), 341–361. https://doi.org/10.2308/acch-51443

Xu, X., Weber, I., & Staples, M. (2019). *Architecture for Blockchain Applications* (1st ed.). Springer International Publishing.

Xu, X., Weber, I., Staples, M., Zhu, L., Bosch, J., Bass, L., Pautasso, C., & Rimba, P. (2017). A taxonomy of blockchain-based systems for architecture design. *Proceedings - 2017 IEEE International Conferense Software Architecture*, 243–252. https://ieeexplore.ieee.org/abstract/document/7930224/

Yermack, D. (2017). Corporate governance and blockchains. *Review of Finance, 21*(1), 7–31. https://doi.org/10.1093/rof/rfw074

Zeff, S. A., & Dyckman, T. R. (2018). A historical study of the first 30 years of accounting horizons. *Accounting Historians Journal*, *45*(1), 115–131. https://doi.org/10.2308/aahj-10582

Zhao, X., Zhang, H., Rutter, K., Thompson, C., & Wan, C. (2018). *Cross-Border Settlement Systems : Blockchain Models Involving Central Bank Money*.

PAPER 1

Divide et Impera: Structuring Design Science Research Projects

Michael Werner

University of Amsterdam | Faculty of Economics and Business

Section Accounting| m.werner@uva.nl

Jonas Sveistrup Søgaard

Copenhagen Business School | Department of Accounting | *jss.acc@cbs.dk*

ABSTRACT: Design Science Research (DSR) is an important research approach that has gained increased attention in Information Systems Research (ISR) over the past decades. DSR is commonly carried out in the form of research projects. These are complex and difficult to manage due to the duality of the epistemological and design objectives that characterize DSR. It leads to large research projects with diverse tasks and numerous stakeholders. This study deals with how DSR projects can be structured to facilitate decisions regarding the division of research work, the allocation of resources, and the overall management of such projects. It formally introduces a framework to separate DSR projects' content into well-defined and individually manageable research segments. A case study illustrates how its usage facilitates the management and the coordination of parallel and mutual research work within a typical DSR project. Applying the presented framework to DSR projects described in scientific literature confirms the model's general applicability. It illustrates that the framework is also suitable to assess whether research projects are well-balanced in terms of research output.

KEYWORDS: design science research; research projects; research methodology; case study; project management; philosophy of science

1. INTRODUCTION

This study investigates how DSR projects can be structured to facilitate decisions regarding the division of research work, resource allocation, and the overall management of such projects through a segmentation framework. DSR projects typically consist of multiple stakeholders with different backgrounds, professions, and aims for the project's outcome. Typically, these stakeholder groups are academics, companies, public organizations, government agencies or the public administration, and not-for-profit organizations (Werner, 2019). Further, this study aims to provide a segmentation framework for these identified stakeholders when collaborating in a DSR project, ensuring both *rigor* and *relevance*, as Hevner et al. (2004) introduced with the Information Systems Research Framework. Practitioners get insight into the project management of DSR and a higher degree of the process towards a solution to a *relevant* real-world problem. Simultaneously, academics follow a rigorous framework for managing the creation and evaluation of artifacts that can lead to streams of publications.

Over the last decades, DSR has gained increased attention in the ISR community as an important research approach (Vaishnavi & Kuechler, 2017). Several publications about the role and interaction of design science, natural science (March & Smith, 1995), and social science (Gregor & Baskerville, 2012) have led to more clarity about the differences, relationships, and interactions between different research approaches in the scientific domain. Scientists have made valuable contributions on how to conduct DSR activities in a structured and rigorous manner (A. Hevner & Chatterjee, 2010; Hevner et al., 2004; Österle et al., 2010; Peffers et al., 2007), consider ethical aspects (Myers & Venable, 2014), and position DSR results in the academic arena (Gregor & Hevner, 2013). Although sophisticated models do exist that guide researchers in performing DSR (Alturki et al., 2011; Gregor & Baskerville, 2012; Kuechler & Vaishnavi, 2008; Peffers et al., 2007), little attention has yet been paid to the question of how DSR projects can be set up, structured, and managed.

DSR projects are a complex phenomenon since they are affected by the duality of the epistemological objective and the design objective that characterize DSR (Riege et al., 2009). Besides contributing to the scientific knowledge base (the epistemological objective) – which distinguishes it from routine design (Hevner et al., 2004) – DSR researchers strive to create useful artifacts that can solve real-world problems and thus be applied in a specific practical environment (the design objective) (Baskerville et al., 2018; Hevner et al., 2004). Researchers involved in DSR projects must deal with this complexity by simultaneously constructing a problem space and a solution space (Baskerville et al., 2018). Creating artifacts that are valuable for practical purposes requires stakeholder groups' involvement and participation from the application domain (Österle et al., 2010).

The research work itself is carried out in different phases (Gregor & Baskerville, 2012; Peffers et al., 2007) that at least includes: analysis, design, evaluation, and diffusion (Österle et al., 2010). The completion of all phases is a resource- and time-consuming task. DSR projects can also be conceived as longitudinal streams of research (Baskerville et al., 2018) that take place over a relatively long period of time. A variety of different research methods are used throughout a DSR project's lifecycle to carry out analysis, design, and evaluation (Werner, 2019). The evaluation of designed artifacts is a crucial aspect of DSR (Riege et al., 2009; Venable et al., 2012). Typical evaluation methods – such as simulations, labs, or field experiments – require instantiated artifacts that can be used in natural or artificial evaluation environments (Venable et al., 2012). The instantiation of designed artifacts requires other skills compared to those required in the analysis or evaluation phases. Due to these characteristics, DSR projects usually span several years, and various junior and senior researchers with different skill sets and project members from the partner companies or organizations work together (Werner, 2019). DSR projects are usually funded by external stakeholders, such as industry partners or associations, government institutions, or supranational institutions, such as the European Union. The average project budget usually lies between USD 250,000 and 500,000, although it can also reach several million USD (Werner, 2019). Design science, natural science (March & Smith, 1995), and social science research (Gregor & Baskerville, 2012) rely on and reinforce each other. Successful DSR is therefore important for the progress of ISR in general. Considering the significance and prevalence of DSR, especially in continental Europe (Schauer, 2011), the appropriate management of DSR projects is especially important. If DSR projects are not managed appropriately, it is likely that scarce research resources are wasted, that projects get out of control, or that they do not deliver the intended output, as is the case for any project. This does not only impede the progress of ISR as a specific scientific discipline; it also results in a loss to society in general as DSR projects may fail to achieve their intended social impact (De Leoz & Petter, 2018).

Subdividing project deliverables and project work of a large and complex project into smaller, more manageable components is a key requirement to develop a suitable project management plan, to define, sequence, and monitor activities, as well as to make good decisions for allocating resources adequately (Project Management Institute, 2013). This is common practice in software development where long-established systems development lifecycle models, such as the waterfall model, prototyping, iterative and incremental development (O'Regan, 2017), and newer methodologies, such as agile programming (Dybå & Dingsøyr, 2008), guide researchers and practitioners in their efforts alike. DSR is closely related to software development as the instantiation of an artifact as part of DSR often includes developing a software prototype. Whereas it is common to divide software development projects into smaller segments, such as sprints in agile methodologies (Pries & Quigley, 2011), and to manage these separately, such an approach does not seem to exist in DSR.

The research described in this study addresses this gap by describing and evaluating a framework that makes it possible to improve the research process by giving guidance on how the research content and tasks can be structured with the purpose to facilitate parallel research work by simultaneously encouraging mutual research efforts and synergies. This differs from prior research focusing on the research process and the different research activities in that process (Alturki et al., 2011; Gregor & Baskerville, 2012; Kuechler & Vaishnavi, 2008; Peffers et al., 2007).

The framework employs a divide-and-conquer approach to separate a DSR project into small and manageable components. It contributes to the body of knowledge on research process management (Leist & Rosemann, 2011), research processes (Peffers et al., 2006), methodologies (Kuechler & Vaishnavi, 2008; Peffers et al., 2007) specific to DSR, and managing DSR projects (vom Brocke & Lippe, 2010). It is not meant to serve as an all-embracing project management framework on its own. Instead, the presented framework is meant to be a tool to facilitate decisions about the assignment of research tasks to involved researchers, especially during the set-up and the initial phase of a project, which is an essential part of successful project management (Deutsches Institut für Normung, 2009; Great Britain & Office of Government Commerce, 2009; International Organization for Standardization, 2012; Project Management Institute, 2013).

This study formalizes the segmentation framework used in other studies (Däuble et al., 2014; Werner et al., 2014) by using conceptual modeling. It provides an additional case study to illustrate how the framework can be used in real settings. This illustration is complemented by an evaluation to test the general applicability of the framework. A set of scientific publications that describe DSR studies has been reviewed for this purpose. The aim was to assess whether the framework can capture the main components of the projects described in the literature and whether its application would derive useful insights for improvement. The framework's applications in this general sense also provided several additional insights into DSR projects' nature, the artifacts they created, and the maturity of DSR in ISR.

This paper is structured as follows: Section 2 describes the research methodology. Section 3 provides information about the characteristics of the investigated phenomenon (DSR projects) in combination with a discussion of related literature. Section 4 provides a formal presentation of the segmentation framework. Section 5 describes a novel case study that deals with the application of the framework to a specific DSR project in the context of distributed ledger technology (DLT). Section 6 describes the evaluation of the framework. In section 7, we reflect on the insights derived from evaluation and the review of identified literature that describes DSR projects before the study closes with a conclusion and outlook to future research in section 8.

2. METHODOLOGY

The research presented in this study follows a DSR methodology allowing for a multi-method approach (Mingers, 2001) within Hevner et al.'s (2004) Information Systems Research Framework (ISRF). The ISRF consists of three main parts; the knowledge base, the application domain, and the IS research part that further comprises building and evaluating blocks. In this study, the knowledge base is the entire DSR literature and Krcmar's (2010) Model of Information Management. Further, the knowledge base also includes methodologies and tools applied; in our study, this also entails the Mingers (2001) multi-method approach, Yin (2008) case study methodology, Empley and Thalheim (2011)'s framework for conceptual modeling, and Venable's (2012) methods for evaluation of artifacts. The application domain resides within research projects involving academics and/or practitioners performing DSR projects. Within the IS research part, the 'build' block is performed by extending the project segmentation framework that was designed by amalgamating components from two existing and well-established models

(Werner et al., 2014). The ‘evaluate’ block is performed by evaluating a case study and ten DSR articles; see a detailed description in the next section.

Werner et al. (2014) presented the segmentation framework comprising the ISRF and the Model of Information Management (Krcmar, 2010). The ISRF describes the essential characteristics of DSR. Therefore, it describes fundamental aspects of DSR, which is useful to differentiate the output, research tasks, and research methodology relevant in DSR projects according to whether these relate primarily to the application domain or the scientific knowledge base. The Model of Information Management (Krcmar, 2010) describes the different levels of information management and focuses on the resource information, which is central to any research in ISR. The hierarchical model makes it possible to determine which management level an artifact refers to. Combining both models' elements makes it possible to capture essential features of DSR projects in ISR for characterizing and splitting them into individual work packages. The framework is formalized by relying on conceptual modeling (Embley & Thalheim, 2011). The different components and relationships among them are described using an entity-relationship diagram (ERD) (Jukic, 2014) following the unified modeling language (UML) specification (Object Management Group, 2017). The models and their role in designing the segmentation framework presented in this study are explained in detail in section 4.

The applicability of the framework was evaluated through a case study. Case study research – a common form of qualitative-empirical research (Thomas Wilde & Hess, 2006) in ISR (Chen & Hirschheim, 2004) – involves the close examination of people, topics, and issues (Hays, 2004). It is especially suited for investigating complex phenomena in their natural environments. DSR projects are complex undertakings. Many individuals with differing or sometimes even opposing motivations interact in such projects (Werner, 2019; Werner et al., 2014) have to carry out diverse research tasks within the different phases of DSR (Peffers et al., 2007). Case study research is a suitable research method in this context for investigating in detail how the segmentation framework can be applied to real-world projects. The included case study, described in section 5, extends the research from prior case studies related to the use of the framework (Däuble et al., 2014; Werner et al., 2014).

It is usually difficult to generalize results gained from case study research (Yin, 2008). While the embedded case study demonstrates how the framework can be practically applied in a particular setting, the general applicability of the framework was evaluated by reviewing published information about DSR studies in the scientific literature. This literature was reviewed to identify information about the underlying DSR projects, artifacts presented, and research questions answered. The following evaluation criteria were used to evaluate the general applicability of the framework:

(a) Is it possible to instantiate the framework for each identified study?
(b) Can different artifacts be identified that clearly relate to specific segments?

If both criteria are met, the evaluation confirms the adequacy of the dimensions of the model (a) and its usefulness in dividing research content (b). The literature was coded independently by both authors to discuss and commonly agree on the coding subsequently. Samples for the evaluation were drawn from publications in the journals Decision Support Systems (DSS) and Management Information Systems Quarterly (MISQ). This choice was made because seminal work on DSR (Hevner et al., 2004; March & Smith, 1995), which greatly impacted the acceptance of DSR in ISR (also at an international level (Schauer, 2011), was significantly influenced by these DSS and MISQ publications as citation scores and related literature reveal.[8]

The analysis of publications showed that a comparatively rich body of DSR-related literature exists in these journals.[9] The evaluation followed a similar approach used by (Baskerville & Pries-Heje, 2019) and started with an analysis of MISQ publications in a dedicated special issue on DSR from 2008 (Abbasi & Chen, 2008; Adomavicius et al., 2008; Lee et al., 2008; Parsons & Wand, 2008; Pries-Heje & Baskerville, 2008). More recent DSR publications from both journals (Carvalho, 2020; Horita et al., 2017; Reinecke & Bernstein, 2013; Sun Yat-sen University et al., 2019; Wimmer & Yoon, 2017) were added to the sample until a state of saturation was reached

[8] Several meta-studies related to DSR rely on the concepts developed in these papers (e.g. (Baskerville et al., 2018; Gregor, 2006; Gregor & Hevner, 2013; Kuechler & Vaishnavi, 2008; Peffers et al., 2007)).

[9] 54 DSR-related papers were found and of those 37 papers were identified that clearly used DSR to design artifacts.

where no further evidence was gathered by adding additional literature.[10] Ten papers were reviewed for the evaluation in total. The results of this analysis are described in detail in section 6. Appendix A provides an overview of the selected papers and summarized results.

The methodology described in this section describes and evaluates a framework designed to improve the research process by guiding the structuring and dividing of DSR projects into small and manageable components. Different studies have described the use of the framework in different projects (Däuble et al., 2014; Werner et al., 2014), but this study extends the knowledge base by providing:

a) A formalized definition of the framework using conceptual modeling (Embley & Thalheim, 2011)
b) A case study (Yin, 2008) as an ex-post evaluation to test the applicability of the framework in a natural setting (Venable et al., 2012)
c) An ex-post criterion-based evaluation (Venable et al., 2012) assesses its general applicability across different DSR projects.

3. DSR PROJECTS AND RELATED LITERATURE

Although DSR is well-established in ISR, few studies provide empirical data about DSR work and projects as such. Empirical data on DSR projects are scarce and difficult to collect because very little information on research project details is publicly available. Table 1 summarizes typical characteristics of DSR projects according to an empirical study on DSR project characteristics, which relied on information collected via semi-structured interviews with senior scholars experienced in DSR (Werner, 2019). It illustrates that DSR projects are a complex phenomenon. Various researchers and stakeholders work together and interact in typical medium-sized DSR projects over several years. Such projects typically have a budget of several thousand USD, with funding usually provided from different sources. Medium-sized projects are the norm; significantly larger and smaller projects are less common (Werner, 2019).

[10] Only those publications were considered, which showed a clear application of DSR (applied DSR studies), whereas theoretical studies about DSR (meta-DSR studies) were not considered for evaluation purposes.

All DSR projects have in common that they differ from projects following other research approaches because they focus on designing artifacts (March & Smith, 1995; Werner, 2019). Another important characteristic is the engagement of users or contact persons from an application domain for the evaluation of and the reflection on the research output, its relevance, and its utility (Werner, 2019). DSR projects often involve larger research resources than other types of research work (Werner, 2019). Due to its nature regarding the duality of the epistemological and design objectives, DSR requires researchers to interact with practice. As a result, DSR projects have in common that at least one project partner representing the application domain participates in such projects. A variety of different research methods are used by scholars carrying out DSR. These differ across the phases of a project. Consequently, researchers with different skill sets commonly work together during typical DSR projects.

Characteristics	Small	Medium	Large
Research group size	1-2	3-6	More than 6
Project partners	1	2-4	More than 4
Project duration	Less than 3 years	3-4 years	More than 4 years
Project budget	Less than USD 250,000	USD 250,000-500,000	More than USD 500,000
Project funding	Exclusively university internal	Public grants Industry partners University internal	Public grants Industry partners University internal
Publications[11]	1-3	3-6	More than 6

Table 1. DSR Project Categories (Werner, 2019, p. 5711f.)

In recent years, several scholars have highlighted the need for structured and commonly agreed research processes in the DSR community (Leist & Rosemann, 2011). Peffers et al. present a DSR methodology (DSRM) (Peffers et al., 2007, 2006), which embodies six phases: (1) Identify problem and motivate, (2) Define the objectives of a solution, (3) design and development, (4) demonstration, (5) evaluation, and (6) communication. Peffers et al.'s framework draws from a review of existing publications related to the information systems' research process and related research disciplines. Further, their research framework is composed of process elements that scholars from different disciplines have identified, including information systems (Cole et al.,

[11] The figures relate to the number of publications that describes the actual research output of the DSR project itself. Not considered are those publications that might be a result of the reflection on the actual project that can be considered as meta-research output.

2005; Hevner et al., 2004; Nunamaker et al., 1991; Takeda et al., 1990; Walls et al., 1992) and engineering (Archer, 1984; Eekels & Roozenburg, 1991). The authors argue that the maturity of DSR in general calls for a segmentation through DSR genres since the diversity of methodologies and mental models has increased to a point where reviewers and editors are unsure about which standards to apply to particular research submissions.

Österle et al. (2010) suggest four phases: (1) analysis, (2) design, (3) evaluation, and (4) diffusion. Gregor and Baskerville (2012) examine the research process to provide a framework for the combination of design science and social science research. The presented research process consists of the phases: (A) Construct and test artifacts, (B) Formulate prescriptive knowledge and theory, (C) Study artifact(s) in use, (D) Test knowledge of artifacts in use, and (E) Formulate descriptive knowledge. Kuechler and Vaishnavi (2008) describe a five-step process for reasoning in the design science research cycle, which embeds abductive and deductive phases. All authors explicitly emphasize the iterative relationship between the different research steps in each model. Alturki et al. (2011) present a more detailed model that consists of 14 research steps. These authors also present an extensive summary of relevant literature.

Closely related to DSR is Action Design Research (ADR). Coenen et al. (2018) have described how their project shifted from the application of the DSRM (Peffers et al., 2007) to ADR (Sein et al., 2011) during the project lifecycle as the development effort became increasingly steered by organizational requirements. The shift provides an example of how DSR projects change in nature, requiring researchers to be equipped with good methods and tools to respond to those changes. Mullarkey and Hevner (Mullarkey & Hevner, 2019) provide an elaborated action design research process model extending the ARD approach (Sein et al., 2011). They identify four distinct types of ADR cycles: diagnosis, design, implementation, and evolution of the growing artifact-based solution. Each ADR cycle moves through problem formulation, artifact creation, evaluation, reflection, and learning.

Moving even closer to practice, Nagle et al. (2017) present the Practitioners Design Science Research (PDSR) Canvas, a visual guide for practitioners undertaking DSR. The study suggests that the gap between practice and academia can be closed if the ISR community is willing to change and rethink its definition of engaged scholarship from one that solely focuses on the academic as the researcher to one that also includes the practitioner (Nagle et al., 2017, p. 161)

(p. 414). Further, staying within the practical focus, De Leoz and Petter (2018) argue that DSR studies tend to be (too) techno-centric, and they suggest that researchers should include a societal focus on DSR by following the authors' proposed guidelines based on the DSRM, ensuring that social impacts are considered appropriately.
The aforementioned studies provide guidance on how an individual researcher should undertake DSR. They describe what the necessary steps are to conduct DSR successfully. Although they provide valuable information for this purpose, they do not explicitly consider the fact that DSR projects are commonly complex endeavors consisting of multiple sub-tasks in which several people are involved. Such projects must be managed appropriately to allocate scarce resources efficiently and to achieve the project objectives.

Well-established international (International Organization for Standardization, 2012) and national guidelines (Deutsches Institut für Normung, 2009; Great Britain & Office of Government Commerce, 2009; Project Management Institute, 2013) provide guidance on project management. It seems that knowledge embodied in these guidelines has rarely been considered in the context of DSR yet, although research work carried out in DSR projects has many similarities with traditional project work. Vom Brocke and Lippe try to build a bridge between research processes and project management in the context of DSR in particular (vom Brocke & Lippe, 2010) and collaborative research projects in ISR in general (vom Brocke & Lippe, 2013, 2011). These authors conclude that DSR projects' outcome is uncertain to a certain degree, and necessary project procedures – the necessary research steps – are a prior unknown. The goals of such projects and the methods for achieving these are ill-defined. According to Turner's and Cochrane's classification model, these characteristics are typical of soft projects (Crawford & Pollack, 2004) of type 4 (Turner & Cochrane, 1993). Vom Brocke and Lippe (2010) use a deductive approach to identify common characteristics of DSR work and classical project work and significant differences, such as creativity in designing artifacts or uncertainty in terms of the research method or outcomes. They point out the need to tailor existing project management guidelines for DSR projects.

The research presented in this study complements the work mentioned above. It focuses on a broader view of DSR projects' phenomenon by considering that DSR commonly consists of diverse research tasks carried out by a group of researchers and project partners. Researchers responsible for DSR projects can use the presented framework to divide a DSR project into smaller segments. The researchers who work on a specific segment can then refer to the guidelines, for example, published by Peffers et al. (2007), to carry out the research work for the particular segment and to follow relevant management suggestions (vom Brocke & Lippe, 2013, 2011).

4. SEGMENTATION FRAMEWORK

Previous research has indicated that DSR projects are challenging endeavors. Such projects are typically complex in terms of the research scope, interaction of participating project members, the diversity of stakeholders, and the overall duration. This section describes a framework for structuring typical design science-oriented research projects. It relies on two different models that formed the basis for the development of the framework. These are the Information Systems Research Framework (Hevner et al., 2004) and the Model of Information Management (Krcmar, 2010).

4.1 Information Systems Research Framework

Hevner et al. (2004) present a research framework that describes fundamental aspects of DSR. It provides an illustration of how aspects of ISR relate to each other, as shown in Figure 1. It describes the relationships between the main research activities for design science (build and evaluate) and behavioral science (develop and justify) research, the environment, and the knowledge base. The environment or application domain defines the problem space. The phenomena of interest for design science-oriented research are derived from the environment. The knowledge base represents the already existing body of knowledge. DSR should be informed by already existing knowledge to execute the research activities. The objective of DSR is to provide useful artifacts to the application domain and to add generalized knowledge to the knowledge base. DSR is therefore characterized by the duality of the design and the epistemological objectives (Riege et al., 2009).

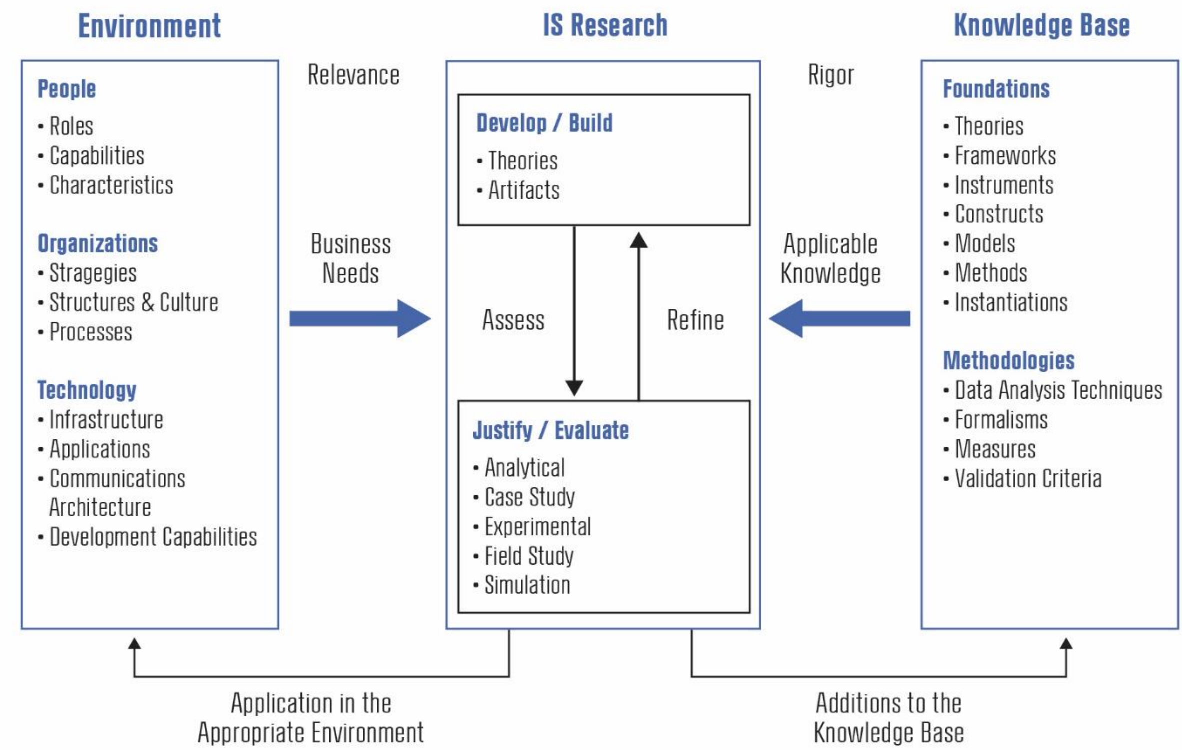

Figure 1. Information Systems Research Framework [1 p. 80]

This duality is illustrated by the feedback loops going from the research activities to the environment and the knowledge base. Feedback from the field indicates that this duality creates significant challenges for researchers during their daily research work (Werner, 2019). Research output in the form of a designed artifact that provides a benefit for the application domain commonly does not provide a theoretical contribution to the application domain per se. The epistemological objective can only be reached if a certain level of generalization is achieved, which creates knowledge that is not only useful for a specific case or organization but can be seen as an addition to the scientific knowledge base. The difficulty of reaching the ontological objective and communicating it appropriately is also evident from the literature that provides guidelines (Gregor & Hevner, 2013) and examples (Cascavilla et al., 2018) to DSR scholars about how to position and present their research and in which it is argued that these contributions can be of descriptive or prescriptive nature (Baskerville et al., 2018).

It can be summarized that the duality of the design and epistemological objectives in DSR is an essential characteristic that distinguishes it from other forms of research and which creates significant challenges for involved researchers. Evidence from case studies (Daeuble et al., 2015; Werner et al., 2014) and interviews with DSR scholars (Werner, 2019) indicate that achieving the epistemological objective and communicating corresponding results is particularly difficult. If this observation is considered, it can also be the starting point for structuring or analyzing a given DSR project by defining or analyzing which contributions to the application domain and knowledge base should be or are generated by a specific project. The duality can serve as a criterion to distinguish between the generated output and, in particular, to assess if both objectives are addressed appropriately with a DSR project and whether they are balanced in this regard. Figure 2 shows how the research contribution can serve as a first dimension to segment research output and tasks accordingly.

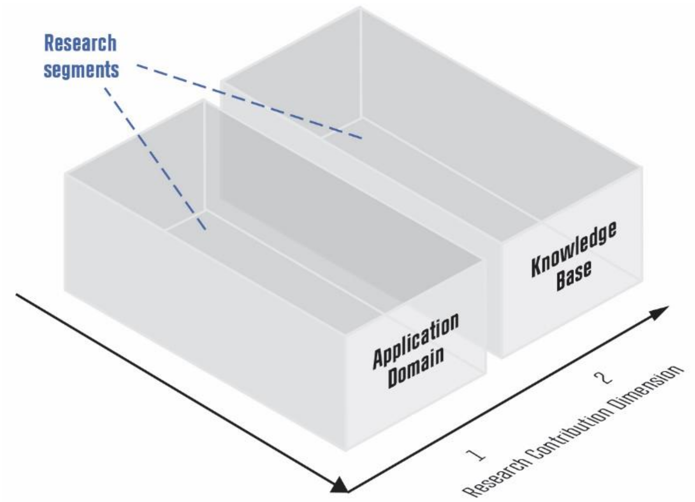

Figure 2. Research Contribution Dimension

4.2 Model of Information Management

Gregor (2006) points out that the distinguishing characteristic of ISR is the consideration of both worlds – technology and humans – and the investigation of phenomena that emerge from their interaction in socio-technical systems. The main subjects of interest in ISR are information technologies and the man/machine interaction in all its diversity (Shirley Gregor, 2006) "to understand and improve the ways people create value with information" (Giboney et al., 2019, p. 12). Österle et al. (2010) emphasize that design science-oriented ISR is related to both organizations and individuals. Information systems are considered socio-technical phenomena related to three object types: people, information and communication technology, and organizational concepts. A framework for structuring research work in ISR should therefore consider technological but also human interaction aspects.

A model well-established in information management that considers these aspects is presented by Krcmar (Krcmar, 2010).[12] This reference model describes the different levels of information management with the aim to structure information and the management hereof. It distinguishes between three different levels of management tasks, which are shown in Figure 3. These are accompanied by independent leadership tasks that are relevant for all levels. According to this model, information management is considered a task that has to deal with all three different levels. The object of consideration at the highest level is resource information. It deals with decisions regarding information supply, demand, and usage. The human aspect is primarily considered at the highest level regarding which information is needed within the organization and its purpose. This forms the requirements relevant for the lower levels defined based on the needs of human information recipients and users of the applications, processes, data, and technology managed at the lower levels.

The second level deals with the management of information systems. Information systems are considered systems that combine specific interrelated elements of organizational and technical nature that meet the users' information demands. The core activities at this level are the management of processes, applications, their lifecycles, and the data that these create. This level provides the information resources that are consumed at the usage level.
The lowest level concerns the tasks related to the management of the technical infrastructure that is necessary for the use of information and communication technology at the higher levels. This includes the management of data storage, communication technologies, and technological infrastructure, which is referred to as a technology bundle in this context. This level deals with providing the physical foundation to operate the applications at the higher levels.

The Model of Information Management addresses both elements that are subject to research in information system science: information systems and human interaction in socio-technical systems. The two lowest levels mainly concern the technical aspects of information management, whereas the human aspect is considered at the highest level. The model is primarily addressing

[12] The model refers to the models originally introduced by Wollnik (Wollnik, 1998) and Szyperski and Winand (Szyperski & Winand, 1989). The three levels of the information management model relate to the levels of information usage, information and communication systems, and infrastructure of the information processing and communication in Wollnik's reference model (Wollnik, 1998).

information management tasks in organizations and, therefore, clearly has a practical focus. The same is the case for DSR, which aims to provide solutions for practice in contrast to purely theoretical research. While the Model of Information Management makes it possible to differentiate management tasks in organizations, it can also be used for determining which level an artifact refers to in terms of its contribution to an application domain. It helps identify whether an artifact generated as an output of a DSR project primarily relates to the level of usage, system, or infrastructure.

The three levels – usage, system, and infrastructure – can be combined as an additional human-technical dimension to the research contribution dimension derived from the ISR framework shown in Figure 2. The result is shown in Figure 4.

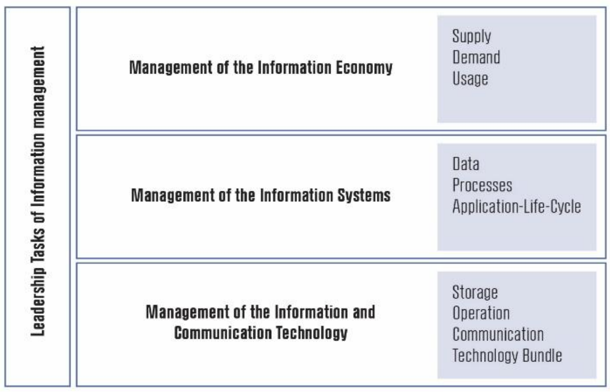

Figure 3. Model of Information Management (adapted from Krcmar 2010 p. 50)

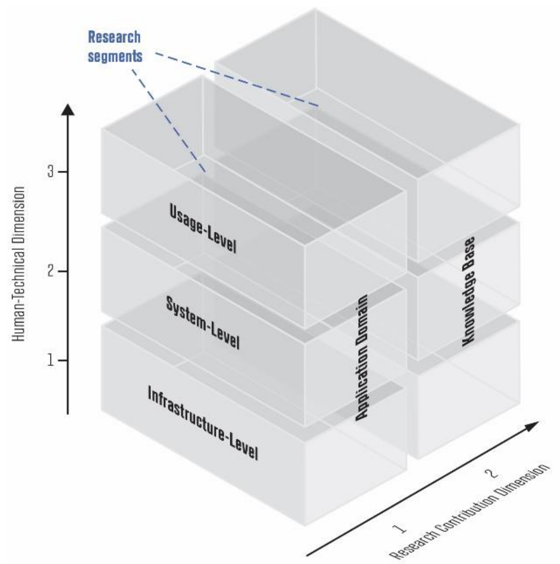

Figure 4. Integration of the Human-Technical Dimension

4.3 Research Question Dimension

Different individuals usually work together in DSR projects. They deal with specific research tasks and research questions (Daeuble et al., 2015; Werner et al., 2014). DSR projects' output commonly consists of different interrelated sub-artifacts that provide a solution to the research problem (Werner, 2019). The overall research question in a DSR project can usually be decomposed into several sub-questions, such as: What are the requirements for the artifacts to be designed, how should they be designed, put into place, and evaluated, or what is the impact of their implementation for an organization? Researchers must find answers to these sub-questions to find solutions to the overall research problem. The different sub-artifacts in DSR projects are usually the answer to a specific sub-question. The review of DSR publications as part of this study confirms this assumption. Dividing an overall complex research question into lower-level research questions can serve as a categorization criterion for a third dimension to segment a DSR project. The integration of a third dimension into the framework is useful to identify more fine-grained segments that have proven helpful in the field (Daeuble et al., 2015; Werner et al., 2014). The number of lower-level research questions per project may differ from project to project and is arbitrary to a certain degree. Figure 5 exemplarily shows the effect if the overall research question is divided into several lower-level research questions. For illustration purposes, the diagram in Figure 5 shows three different values for the research question dimension. The choice of the number of detailed lower-level research questions determines how granular research tasks can be assigned to the involved project members.

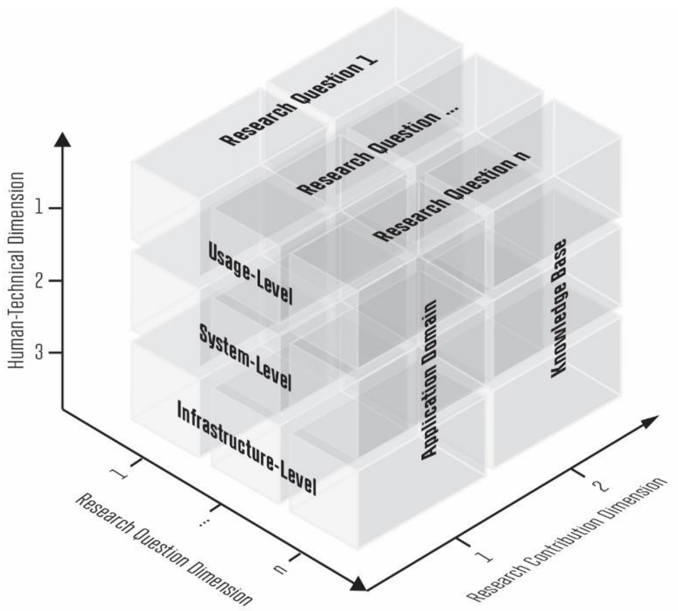

Figure 5. Integration of the Research Question Dimension

4.4 Formalization and Usage

The application of all three dimensions, as shown in Figure 5, divides a given research project into separate segments. Its location describes each segment in the framework (X = research contribution dimension (RCD), Y = human-technical dimension (HTD), Z = research question dimension (RQD)), considered separately, and be assigned to specific researchers. The division into research segments can be considered a divide-and-conquer approach. The overall research project is decomposed into manageable components that can be dealt with individually. This approach is similar to breaking down a product backlog into sprint backlogs in Scrum (Pries & Quigley, 2011).

How this can be used is illustrated in Figure 6, which highlights a single segment from an instantiated model of the framework. For each segment (or set of segments), it is possible to identify and describe different components essential for managing each segment from a research perspective. Each segment should be associated with a specific artifact that constitutes the output of this segment. The research methods for the analysis, design, evaluation, and diffusion type (Österle et al., 2010) can be described. A template for such a description is illustrated in Table 2. While each segment should be associated with one (or more) artifact(s), the same artifact can also relate to different segments.

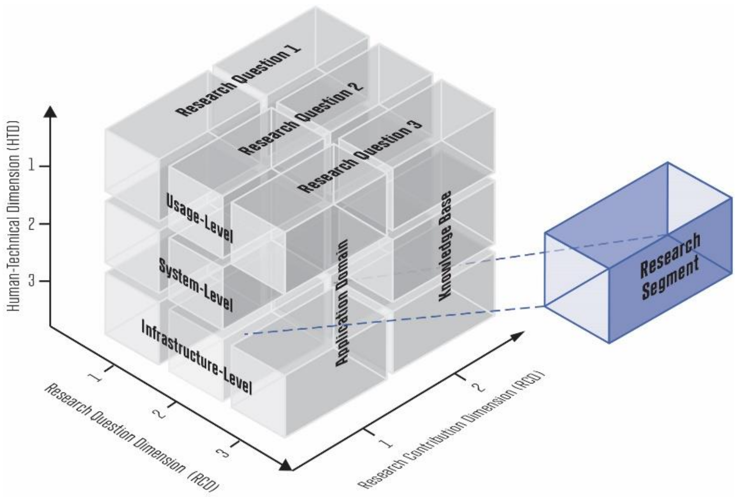

Figure 6. Research Segment

Segment
ID
Related artifact
Research methods
Analysis
Design
Evaluation
Diffusion
Type name

Table 2. Segment Description

Figure 7 shows an ERD that formally describes the relationship of the model components. The ERD shows the minimum number of entities, attributes, and relationships necessary to instantiate the model. Additional entities can be added if, for example, the involvement of a project partner is supposed to be critical for the management of the project. The proposed framework illustrates that each project has a unique project number and non-key attributes, such as project name, project description, project start, and project end-date. Each project is characterized by the three dimensions discussed before 1) research contribution, 2) human-technical, and 3) research questions contribution dimension. They constitute the framework axes X, Y, and Z. Each dimension can have different values and names (e.g. { (1, “natural disaster management in Brazil”); (2, “business process management”)} for dimension research contribution (RCD).[13] Only the human-technical dimension has a fixed number of values: {(1, “infrastructure level”); (2, “system level”); (3, “usage level”)}.[14] The number of values for the research contribution and research question dimensions are arbitrary and depend on each specific project. Each DSR project consists of a number of segments, and each segment refers to exactly three different dimension values: one value from each dimension. These form the segment coordinates, which also serve as the primary key for each segment. The segment shown in Figure 6, for example, has the coordinates (1; 2; 3).

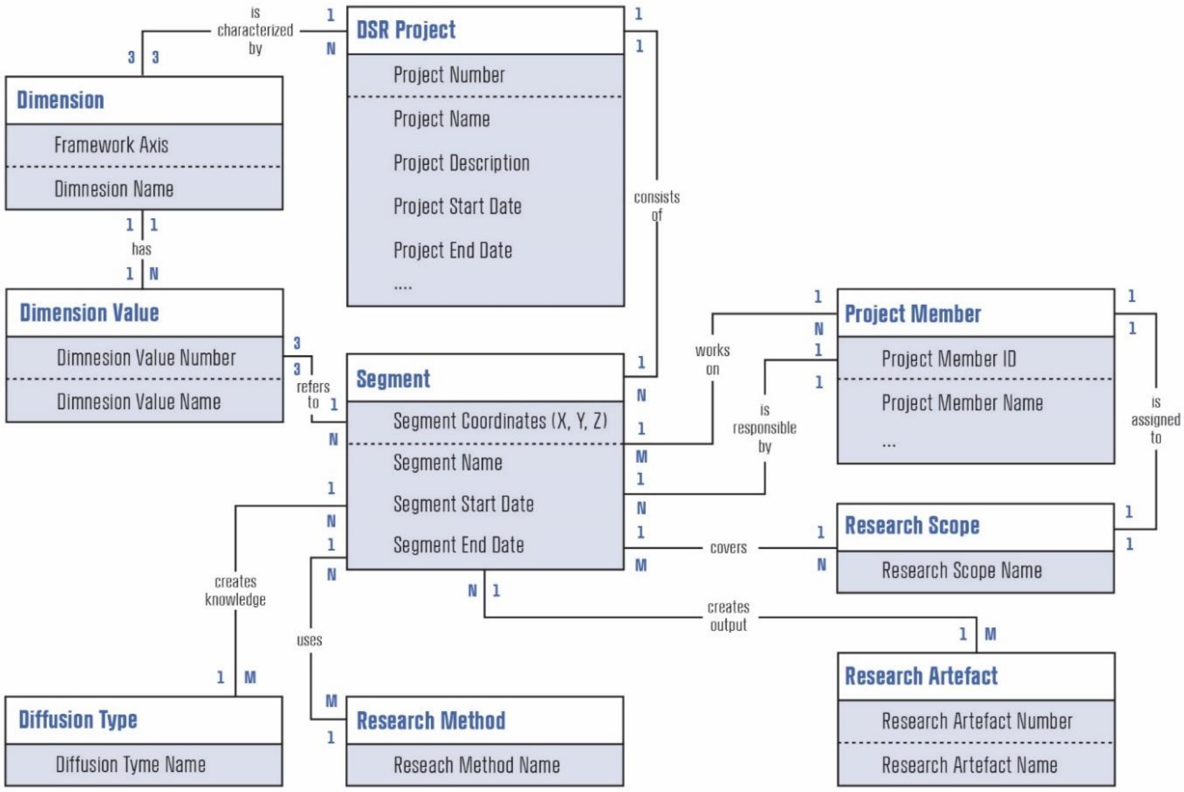

Figure 7. ERD for the Segmentation Framework

Each segment creates output. March and Smith (March & Smith, 1995) define four types of research artifacts that form the primary output of DSR: constructs, methods, models, and

[13] This example was derived from (Horita et al., 2017).

[14] This definition can also be amended if it is deemed to be appropriate to model more detailed differences on this dimension as shown in (Daeuble et al., 2015; Werner et al., 2014).

instantiations. Gregor (2006) argues that design theories are also an important outcome of design science-oriented research, while design principles (Baskerville et al., 2018; Gregor & Hevner, 2013) and technological rules (Gregor & Hevner, 2013) are also seen as typical examples of artifacts created by DSR. Each artifact that is supposed to be created in a DSR project should receive a name and distinctive number. It is not necessarily the case that a specific artifact just relates to a single segment; quite the opposite is usually the case. A software prototype, for example, usually stretches across the human-technical dimension. It requires the consideration of data storage and necessary infrastructure components, algorithms at the system level that define the operations of the software, and a user interface component that is necessary to meet the user requirements in terms of information consumption.

Different research methods are used to perform the research tasks, which are necessary to create the research output of each segment. A variety of research methods exist for analysis, design, and evaluation purposes (March & Smith, 1995; Österle et al., 2010; Palvia et al., 2003, 2004; T. Wilde & Hess, 2007). Usually, different research methods are necessary to analyze requirements and to design and evaluate (Venable et al., 2012) an artifact. Different research methods can be used to carry out the research work represented by an individual segment, while the same research method can be employed for different segments in a research project. Carrying out analysis of design requirements, for example, using interviews or observations from the field, can inform the design of a variety of artifacts within a DSR project.
Each segment creates knowledge that is either relevant for the application domain or the scientific knowledge base. The type of knowledge distribution or diffusion (Österle et al., 2010) can be determined by referring to the knowledge contribution level of design science-oriented research (Gregor & Hevner, 2013). Possible outlets for the diffusion of contributions to the knowledge base can be, for example, conference or workshop presentations and journal publications, while outlets for the diffusion of knowledge relevant for the application domain can be, for example, the participation at industry-specific fairs, distribution via professional organizations, or standard-setting activities.

Several researchers can work on the same segment, while each segment should have one member assigned to it who is responsible for it. Segments can be grouped into different research scopes. Each research scope covers one or several segments and is assigned to an individual project member. They may be overlapping. The usage of research scopes makes it possible to clearly delineate the research content and boundaries for each involved researcher. An example of a research scope is shown in Figure 8. It highlights five segments that constitute a research scope, which is assigned to an individual researcher. The example also shows that it is not necessarily the case that a research segment exists in a project for every possible combination of dimension values. The evaluation results discussed later in this study indicate that this was indeed the case for all analyzed projects. Case studies using the framework showed that specific segments were explicitly excluded from the project scope to focus on the most important artifacts that were most relevant to find an overall research solution (Daeuble et al., 2015; Werner et al., 2014). Another explanation may be that some projects were simply ill-defined.

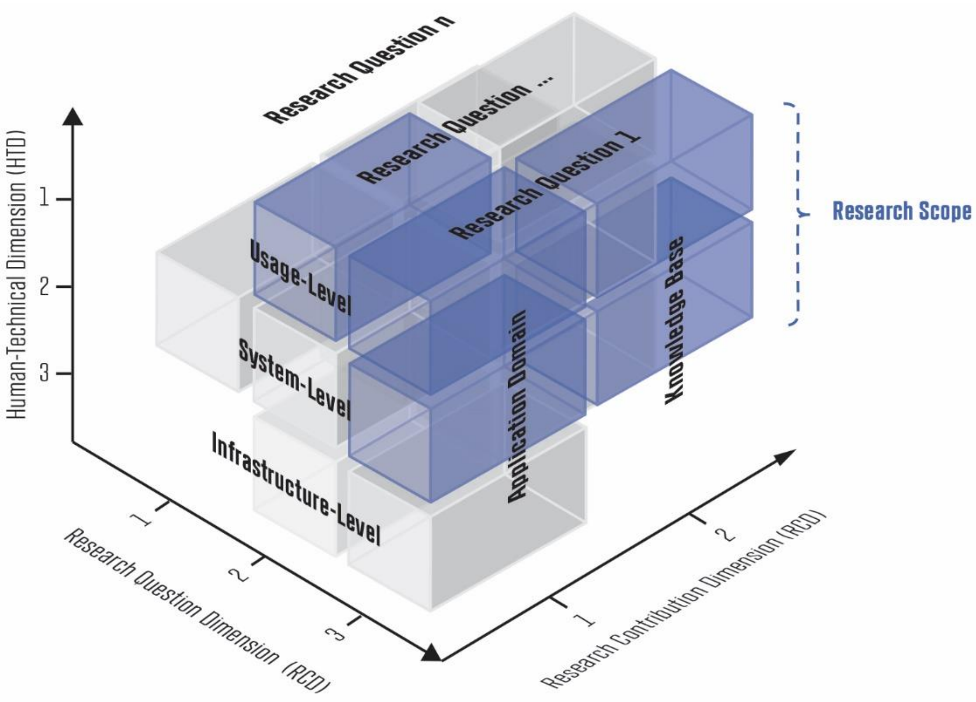

Figure 8. Example Research Scope

This section has introduced a segmentation framework for dividing a typical DSR project, which is inherently complex due to the common characteristics of DSR, into well-defined and manageable segments. It has provided a formal definition of the framework in combination with an illustration of how the framework can conceptually be used. The next section deals with describing the instantiation and usage of the framework in relation to a real-life DSR project, which falls into the category of typical medium-sized DSR projects. This description aims to illustrate how the framework can be used in a realistic context and highlight potential benefits and limitations of its usage in addition to already existing examples (Daeuble et al., 2015; Werner et al., 2014).

5. CASE STUDY EXAMPLE OF A BLOCKCHAIN DSR PROJECT

The case study refers to a research project that deals with the settlement of value-added tax (VAT) for small and medium-sized enterprises (SME) in Denmark (Innovationsfonden, 2020; Søgaard, 2021). Denmark is leading worldwide in terms of digitalizing businesses and society (European Commission, 2020a, 2020b). The Danish government launched a new cross-public sector digitalization strategy (ny fællesoffentlig digitaliseringsstrategi) in 2016. One of the themes being part of the strategy is automatic business reporting. The Danish government strives *"to remove the administrative burdens on companies related to reporting to the public sector through automatic business reporting*" (Ministry of Finance et al., 2016, p. 1).

The public sector in Denmark is driving digitalization through imposing regulations and using the concept of open data. With effect from 2004, every Danish business-to-government (B2G) invoice must follow a Danish invoicing standard, OIOUBL (Offentlig Information Online Universal Business Languages). In April 2020, this standard was converted into a pan-European public procurement online standard (PEPPOL) to comply with EU regulation (EU Commission, 2014) (Erhvervsstyrelsen, 2020). Danish companies file their VAT statement, including financial statements and other obligatory reports, as part of their year-end financial reporting (Retsinformation, 2020). 99 percent of the approximately 300,000 Danish companies are SMEs. These firms have to submit their annual statements digitally in XBRL format (Danish Business Authority, 2019). While annual VAT returns are filed as part of the year-end financial reporting, input and output VAT is also declared in monthly, quarterly, or bi-yearly preliminary summary reports. These are submitted to a custom-built online platform using unique electronic identification numbers (e-ID). The infrastructure is provided by the Danish tax authorities (Agency of Digitalization, 2010).

Due to the digitalization of business reporting in the past, Danish companies and public organizations already meet basic requirements to benefit from advances of a novel distributed ledger technology (DLT). Two fundamental components for the usage of DLT in business reporting is the existence of a digital identity and data standards, particularly for implementing permissioned blockchains. As this is the case for Denmark, it places the country in a unique position to leverage the advantages of DLT. The project's objective is to find solutions to help SMEs in Denmark settle VAT under the new regulations. The primary research idea is to use DLT

to create a prototype of a blockchain-based invoicing platform, which is capable of automatically processing VAT settlements among the involved parties. It is also evaluated whether the technology provides the anticipated benefits to help SMEs and the Danish Business Authority (DBA) comply with the new requirements that resulted from Denmark's new digital strategy.
The project can be categorized as a typical medium-sized DSR project in accordance with empirical findings (Werner, 2019). Five different stakeholders participate in the project: Copenhagen Business School (CBS), Deakin University in Melbourne, Deloitte Denmark (Deloitte Statsautoriseret Revisionspartnerselskab), the DBA, and the Danish Innovation Fund. The core project team consists of a Ph.D. student and an associate professor from CBS, a professor from Deakin University, a software developer, a blockchain architect, and a project manager from Deloitte. Three subject matter experts from the DBA participate as representatives of the application domain. Two SMEs operating in the service and production industries have been involved as additional project partners for requirements analysis and evaluation purposes. A steering committee comprising of decision-makers from CBS, Deloitte, and the DBA as the key stakeholders was established at the beginning of the project.

The degree of involvement of the different stakeholders and research project members has varied with the project's progress (Werner, 2019). As it is common for DSR projects, it is not easy to clearly define the project's duration. Parts of the project have been funded externally by the DBA for a period of nine months. The Danish Innovation Fund has partially funded the involved Ph.D. student externally over three years. The externally funded project budget amounts to USD 190,000 so far. The other stakeholders have funded their resources mostly internally. The research project started by identifying the research problem, preparing the research, and preparing funding proposals in 2018. It is still ongoing and expected to finish at the beginning of 2022. Overall, the duration lies well between the average length of typical medium-sized DSR projects with a period of about four to five years.

The primary application domain for the research project is tax accounting in SMEs – specifically the settlement of VAT. DLT and novel accounting procedures have been perceived as being the most important scientific disciplines that form the knowledge base for researching the project. The project was guided by the overall research question shown in Table 3.

(Overall Research Question)	"How can VAT settlement be automated by designing an IT artifact that is offered by the Danish Business Authority to SMEs to reduce the administrative burden related to financial reporting while maintaining the level of government tax revenue from VAT collection?"

Table 3. Overall Research Question for Case Study Blockchain DSR Project

The main component of the project required by different project stakeholders has been the development of a software prototype. This prototype was supposed to be a blockchain-based invoicing platform as DLT was assumed to be a suitable technology when the project was initiated. The design of a prototype was required for the creation of valuable artifacts for the application domain and derived design principles for the knowledge base.

The different stakeholders have a common goal with the project. However, the understanding of the output and the form differed in the beginning. It was thus necessary to identify which research outputs were critical for the success of the research project, how these related to each other, which scientific approach was adequate for the development and evaluation of research artifacts, and which project team member fitted best to accomplish the different research tasks according to available expertise and skills. It was also necessary to decide on the roles and responsibilities related to the communication with the different stakeholders for specific research aspects, such as the requirements analysis, software development, and evaluation approaches.

To structure the project and divide it into manageable segments, it was decided to use the segmentation framework during the project's set-up phase. The overall research question was broken down into more specific granular research questions as shown in Table 4 to populate the research question dimension.

(Impact on SMEs)	To what extent will SMEs be affected by a new way of VAT settlement if a blockchain-based invoicing platform is implemented, and what will be the consequences?
(VAT Settlement Automation)	Which design principles should be considered when designing a solution to automate VAT settlement, and how should they be embodied to create a blockchain-based invoice platform?
(Integration and Usage)	How can a blockchain-based invoice platform be embedded into existing business procedures, and will it be useful?

Table 4. Research Sub-Questions for Case Study Blockchain DSR Project

The instantiated framework in Figure 9 shows how the project was separated into separate segments. The first part of the project focused on understanding the environment and gathering requirements to build a prototype. Two SMEs, a car repair shop and a production company, participated as representatives from the application domain among participants from DBA. Semi-structured interviews and content analysis were used to gain a sophisticated understanding of the environment and its actors. This built the foundation for formulating four design principles. The principles guided the development of the prototype and were used when making technical design decisions regarding appropriate DLT and data storage types, the application implementation, including smart contracts design alternatives, as well as user and key management.[15]

[15] When using blockchain technology in enterprise settings (private, permissioned), it is important to have mechanisms for creating, distributing, and recovering keys equivalent to user and password management. These requirements are different from public permissionless blockchains (E.g. Bitcoin and Ethereum.) where keys cannot be restored once lost.

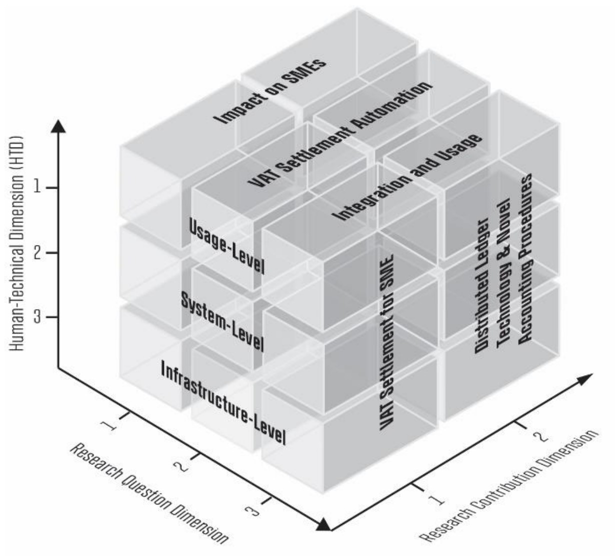

Figure 9. Instantiated Framework for Example Blockchain DSR Project

This process's outcome was a blockchain-based prototype that made it possible to settle VAT in near real-time using smart contracts. Both artifacts and how they relate to the different segments are shown in Figure 10. The diagram shows that each artifact is related to two different segments. Detailed information on the analysis, design, evaluation methods, and diffusion types for one segment is listed in Table 5. The blockchain prototype's design relied on the results gained from the conducted interviews (Gubrium & Holstein, 2002) and content analysis of collected documents. The artifact was designed using prototyping (Naumann & Jenkins, 1982) in iterative implementation cycles and evaluated using computational experiments in an artificial lab environment (Venable et al., 2012) with a purely technical focus on the feasibility of settling VAT in near real-time. The design did not focus explicitly on considering a graphical user interface, usability aspects, or adequacy of information visualization, which were supposed to be designed by involved project partners at later stages of the project. Therefore, the artifact is primarily related to the system and infrastructure levels of the human-technical dimension.

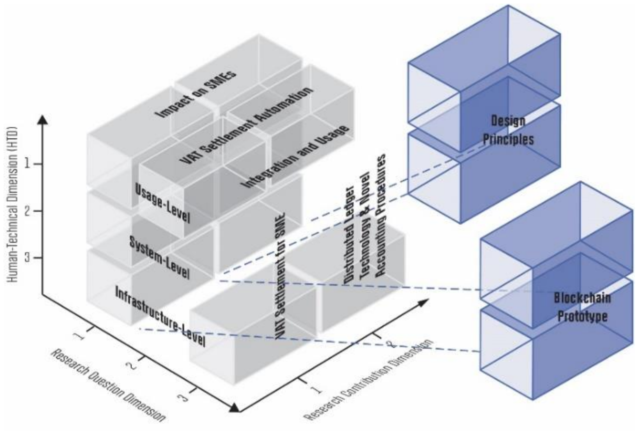

Figure 10. Example Relationship between Segments and Artifacts

Segment	
ID	1,2,2
Artifact	Blockchain invoicing platform for VAT settlement
Research methods	
Analysis	Semi-structured interviews and content analysis
Design	Prototyping
Evaluation	Computational lab experiment
Diffusion	
Type Name	Ph.D. thesis and scientific journal papers

Table 5. Example Segment Description

Whereas the prototype was explicitly designed for VAT settlement, the design principles were considered to act primarily as contributions to the DLT technology knowledge base. The design principles provide general guidance on design decisions on the infrastructure and system, independent of the specific environment that such technology is supposed to operate in. This example illustrates how the different artifacts interacted with each other. The design principles informed the software artifact's prototyping, while the implementation of this artifact also served as a technical evaluation of the principles.

The second part of the project focused on technical feasibility in terms of scalability. The ability to process large amounts of data was perceived as a key requirement for integrating the prototype into business operations and for the usage by companies and public entities. The aim was to determine whether the proposed invoicing platform could also be extended from a national to a European context. Three DLT platforms (Quorum (J.P. Morgan, 2018), Tendermint (Buchman, 2016), Hyperledger Fabric (The Hyperledger Foundation, 2020)), and a centralized ordering technology (Kafka (Kreps et al., 2011)) were analyzed as to their technical features. It was investigated whether the architectural choices of the prototype, which were proposed in the first part of the paper, provided a suitable basis for future scaling into a real-world scenario using the different platforms to be able to process more than 17 billion invoices annually in the European market (Danish National Bank, 2020). The evaluation method was a computational experiment in an artificial lab environment. The test set-up was as close as possible to a real-world scenario. 28 nodes each represented a member state of the European Union (including the UK) spread across five geographies in Europe on a Microsoft Azure (Microsoft, 2019) cloud infrastructure. The results showed that Kafka was approximately 300-650 times faster than Quorum, Tendermint, and Hyperledger Fabric when using the same transaction size and infrastructure.

The previous examples have illustrated how it is possible to use the segmentation framework to identify individual research segments, artifacts, and corresponding research methods. In addition, the framework is also useful to identify dependencies between individual segments and group interdependent segments. Such segment groups can be assigned to individual researchers based on motivational preferences, expertise, and skills. Figure 11 illustrates how the overall research project was divided into three different research scopes that reflect the overall project's different parts. Parts one and two have been completed whereas part three is currently being conducted.

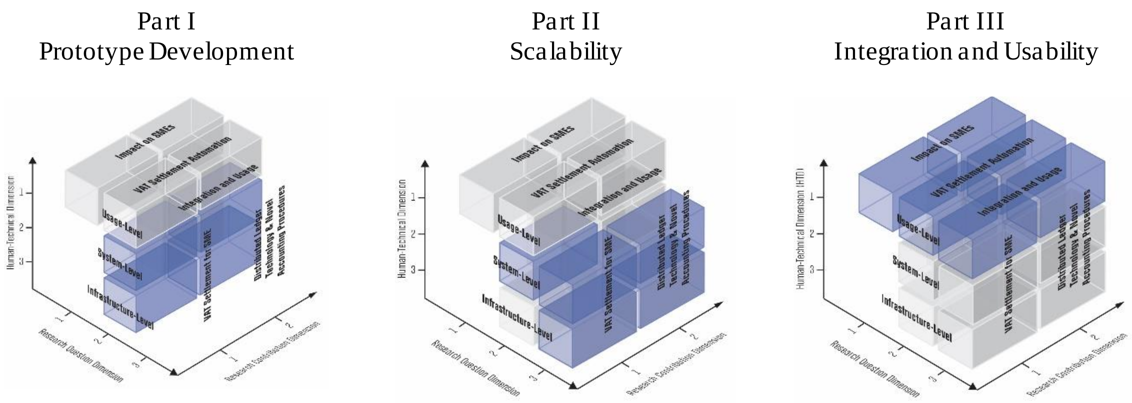

Figure 11. Research Scopes

The illustration also shows that some segments in the model are not covered. This is the case for the segments (1,1,1), (1,1,2), (1,2,1), and (1,2,2). Research relating to (1,1,1) and (1,1,2) could, for example, deal with the question of what impact the implementation of blockchain systems for VAT settlement has on the SMEs' IT infrastructure and IT landscape. It was decided that these aspects were out of the scope of the research project. This is an example of how the framework can effectively set the boundaries for a DSR project and guide to define its scope precisely consciously. The example also shows a balance between those research efforts dedicated to the research segments related to the application domain and those relating to the knowledge base. The identification of segments and segment groups can also foster the publication planning for the involved researchers. In this case, it was the aim to produce at least one major publication for each research scope.

6. FRAMEWORK EVALUATION

Although the DSR project segmentation framework has been applied in several DSR projects successfully, it remains unclear whether it is generally applicable. This section deals with answering that question and describes the results from reviewing selected DSR literature. The aim was to identify information about the underlying DSR projects, described artifacts, and research questions.

The framework relies on different dimensions. The first two were embedded from well-established models used in DSR and ISR. The third one is derived based on empirical evidence about the nature of DSR projects and practical experience in different DSR projects. Although it may be assumed that the dimensions should be generally applicable due to their generic nature, it has not been proved. The first evaluation criterion refers to the adequacy of the model dimensions to test whether:

(a) It is possible to instantiate the different dimensions of the framework.

The second criterion refers to the usefulness of the framework to divide research content. The aim of using the segmentation framework is to facilitate parallel research work by simultaneously encouraging mutual research efforts and synergies by structuring research content and tasks in DSR projects into well-defined pieces. This requires that segments and related artifacts can clearly be identified. The second criterion addressed this requirement by evaluating whether:

(b) Different artifacts can be identified that clearly relate to specific segments.

Ten articles published in DSS and MISQ were reviewed and coded by two researchers independently. The evaluation of the framework stopped when we reached the point of saturation where the incremental new insight provided by one additional article diminished. An overview of the analyzed papers is shown in Table 6. Detailed information is available in Appendix A.

#	Title	Year	Journal	Size	Research questions	Artifacts	Related to segments
1	CyberGate: A Design Framework and System for Text Analysis of Computer-Mediated Communication	2008	MISQ	M	3	5	(1,3,1), (1,3,3), (2,2,1), (2,2,2), (2,2,3)
2	Making Sense of Technology Trends in the Information Technology Landscape: A Design Science Approach	2008	MISQ	S	2	4	(1,2,1), (1,2,2), (2,2,1), (2,2,2), (2,3,1)
3	Process Gramma as a Tool for Business process Design	2008	MISQ	S	2	4	(1,3,1), (1,3,2), (2,2,1), (2,2,2)
4	The Design Theory Nexus	2008	MISQ	M-L	2	4	(1,1,1), (1,1,2), (1,2,1), (1,2,2), (1,3,1), (2,2,1), (2,2,2), (2,3,1), (2,3,2)
5	Using cognitive principles to guide classification in information systems modeling	2008	MISQ	S	1	3	(1,1,1), (1,2,1), (2,1,1), (2,2,1)
6	Knowing What a User Likes: A Design Science Approach to Interfaces that Automatically Adapt to Culture	2013	MISQ	M	4	7	(1,1,3), (1,1,4), (1,2,2), (1,2,3), (1,3,2), (1,3,3), (1,3,4), (2,2,1), (2,2,2), (2,2,3), (2,3,1)
7	Bridging the gap between decision-making and emerging big data sources: An application of a model-based framework to disaster management in Brazil	2017	DSS	M	3	4	(1,2,2), (1,2,3), (2,2,1), (2,2,3)
8	Counterfeit product detection: Bridging the gap between design science and behavioral science in information systems research	2017	DSS	M	3	7	(1,2,1), (1,3,1), (1,3,2), (2,2,1), (2,3,3)
9	A permissioned blockchain-based implementation of LMSR prediction markets	2019	DSS	S	3	7*	(1,1,1), (1,1,2), (1,2,1), (1,2,3), (1,3,1)
10	Operationalizing regulatory focus in the digital age: Evidence from an e-commerce context	2019	MISQ	S	1	2	(1,2,1), (1,3,1), (2,2,1), (2,3,1)

Table 6. Overview of Analysed Papers

Figure 12 shows the instantiation of the segmentation framework for paper #6. It refers to the most complex DSR study found and nicely demonstrates the complexity of real DSR projects. Four research sub-questions were identified that span the RQD. Seven different artifacts related to eleven segments.

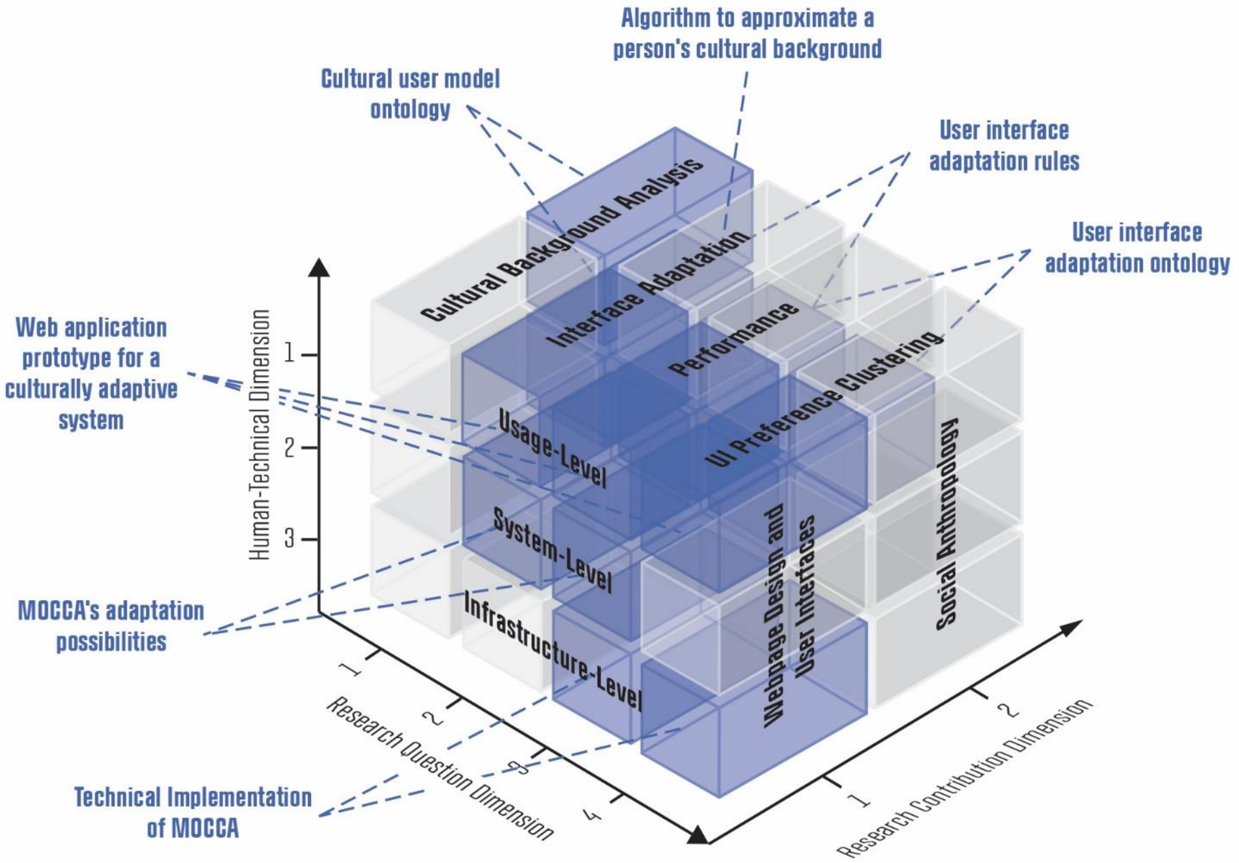

Figure 12. Installation of the Segmentation Framework for Paper #6

Table 6 demonstrates that it was possible to instantiate the framework and to identify separate artifacts and their relation to specific segments for each reviewed study. The overall applicability (criterion a) and the framework's usefulness to separate a DSR project into well-defined segments (criterion b) can therefore be confirmed. No studies were identified where applying the framework was assessed to be unsuitable. However, several observations and limitations should be considered when interpreting the evaluation results. It was assumed that enough information could be gained for the evaluation from reviewing the selected articles. This was the case in general, but the level of detail related to the DSR projects, research questions, and designed artifacts varied significantly among the analyzed studies. A trend was observable to more precise and informative descriptions in newer publications, whereas the information, especially for those published as part of the MISQ special issue in 2008, was partly rather rudimentary. The more details were provided, the easier it was to establish the segmentation framework.

Usually, several publications result from a single DSR project. It is unlikely that all research sub-questions relevant for a specific DSR project are identified by reviewing a single research paper resulting from that project. This is likely to be the case, especially for those projects from which only one or two research sub-questions could be identified (#2 to #5 and #10). The instantiated frameworks most likely only provide an overview of parts of the underlying DSR projects.

The cubes representing the instantiated frameworks were sparse. On average, just a third of the identified segments could be linked to artifacts. This is not surprising because a single publication usually only refers to a subset of created artifacts in a DSR project and a specific research scope as reported in related empirical studies (Daeuble et al., 2015; Werner et al., 2014) and not the complete output of the underlying DSR project.

The literature review confirmed previous empirical studies as it revealed that DSR studies usually produce multiple artifacts (Werner, 2019). Several artifacts and sub-artifacts were identified for each study, which is individually listed in Appendix A. This observation emphasizes the inherent complexity of DSR projects. An identified artifact commonly related to several segments (#1, #2, #4, #5, #6, #7, #9, #10) and different artifacts can relate to the same segment (observed in all reviewed studies), which is in line with the relationships modeled in Figure 7. 39.13 percent of identified artifacts were instantiations and thus level 1 contribution according to Gregor and Hevner's (2013) classification scheme. 60.87 percent of identified artifacts were constructs, methods, and models constituting level 2 contributions. Although no level 3 contributions in terms of design theories were identified, it could be observed that 45.65 percent of the artifacts contributed to a scientific knowledge base. 60.78 percent of the described artifacts contributed to the application domain.[16] A higher degree of imbalance may have been expected when taking into account discussions about the nature of contributions and the sometimes discussed lack of theoretical contributions generated by DSR (Avison & Malaurent, 2014; Beck et al., 2013). It also clearly demonstrates that theory is not necessarily a prerequisite for creating scientific knowledge.

[16] 10,87 percent of identified artifacts contributed to the application domain as well as to the knowledge base.

The majority of identified artifacts related to the system level (69.57 percent), whereas relatively few artifacts related to the infrastructure level (19.57 percent) and about a third to the usage level (32.61 percent).[17] This finding is in line with the understanding of ISR as an interdisciplinary research domain located between its reference disciplines, computer science and business economics (Keen, 1980), where less emphasis exists regarding technical issues that relate to fundamental infrastructural aspects, which would primarily fall into the domain of computer science. However, it remains unclear why only a relatively small number of artifacts relate to the usage level. This may be an interesting investigation for future research.

Although the knowledge base's contributions were comparatively balanced on average, this was not the case for all individual studies. All artifacts described in study #9, for example, are primarily related to the application domain, none to the knowledge base. As the cubes representing the instantiated frameworks were sparse, gaps in the underlying research projects in terms of contributions to the knowledge base or application domain at different levels can easily be detected. When inspecting the instantiated framework for study #6, for example, it could be considered whether it is possible to derive generalized knowledge from the designed web application prototype and its evaluation for clustering user behavior due to cultural background. This may be a relevant contribution to the field of cultural classification or social anthropology in general. The framework can also be used to assess at a detailed level whether the output is balanced on the different dimensions or whether additional research may be necessary to fill in important gaps or at least to consciously decide not to cover certain aspects as described in the case study discussed before.

7. DISCUSSION AND CONCLUSION

This study deals with a segmentation framework for DSR projects following a DSR approach. The segmentation framework has been used in several DSR projects and has proven its usefulness (Daeuble et al., 2015; Werner et al., 2014). The evaluation of the framework, following Venable et al. (2012), confirms that it is generally applicable, that it can be instantiated for different projects, and that it is useful to separate the DSR project's content. These projects are usually complex, and any means to structure them and assign research parts directed by the skills and preferences of those involved in these projects are crucial to success. The segmentation framework

[17] 19.57 percent of the identified artifacts related to more than one level.

itself is not meant to be a project management method for DSR projects in general. A project consists of different phases in which different activities occur (International Organization for Standardization, 2012; Project Management Institute, 2013), and DSR projects are no exception. The segmentation framework is primarily considered to support the set-up and initiation phases of a DSR project, in which resources are assigned to specific tasks. How DSR projects can be managed across the whole project management lifecycle and/or how DSR projects translate into the agile methodology is supposed to be covered in future research.

The evaluation was carried out to a point where no further insights could be gained by reviewing additional DSR studies. In other words, to the point of saturation. Although some observations regarding the nature of DSR projects and designed artifacts are described in this study, it is not meant to be a quantitative study investigating DSR projects' nature in general. However, the framework proved to be a very useful tool to carry out such an analysis. An extended analysis would likely provide interesting insights that could enrich debates in the research community about the role of DSR in ISR by providing empirical evidence. The framework can also be helpful for reviewers who have to assess DSR studies by providing information about the research set-up of a study, the coherence of described artifacts, and any mismatch between the objective of a study in terms of its contributions and the provided artifacts.

DSR is an important research approach in the information systems research community. A variety of publications exist that provide guidance on how to conduct design science-oriented research. However, little attention has yet been paid to the question of how voluminous and complex research projects can be structured, set up, and managed. DSR differs from other types of research due to the duality of the design and epistemological research objectives. This duality commonly leads to research projects that are characterized by the involvement of numerous researchers and stakeholders, long runtimes, large budgets, extensive research scopes, and diversity of research activities and outputs. Research on DSR projects is scarce, although they pose significant challenges to the involved researchers and consume large amounts of research resources. Design science, natural science, and social science research are linked and reinforce each other. Managing DSR projects using adequate tools and methodologies increases the chance that they achieve their desired outcome in terms of contributions to practice and science. Successful DSR projects are important for the progress of ISR in general, and any means to improve the management of DSR projects are likely to have a positive impact.

In conclusion, this study describes and evaluates a segmentation framework that helps structure DSR projects' content by dividing the overall research tasks into manageable segments. The desired outputs and necessary research tasks can be separated and analyzed depending on how they relate to different dimensions. The framework facilitates the coordination of parallel and mutual research work between multiple stakeholders with different aims to successfully conduct voluminous and complex research projects. The framework ensures relevance for the practitioners and rigor for the academics. The applicability of the framework and the benefits that can be gained by applying it has been described utilizing a case study. The evaluation of the general applicability of the framework and its usefulness in terms of dividing segments into smaller components and identifying related artifacts was carried out by reviewing a set of DSR studies published in leading ISR publication outlets. The evaluation confirmed that the framework is generally applicable and useful to identify clearly separated research segments that can be allocated to different researchers in a DSR project team. We hope that it will be useful to design science researchers when setting up their projects.

REFERENCES

Abbasi & Chen. (2008). CyberGate: A Design Framework and System for Text Analysis of Computer-Mediated Communication. *MIS Quarterly*, *32*(4), 811. https://doi.org/10.2307/25148873

Adomavicius, Bockstedt, Gupta, & Kauffman. (2008). Making Sense of Technology Trends in the Information Technology Landscape: A Design Science Approach. *MIS Quarterly*, *32*(4), 779. https://doi.org/10.2307/25148872

Agency of Digitalization. (2010). *NemID*. https://digst.dk/it-loesninger/nemid/om-loesningen/nemid-erhverv/

Alturki, A., Gable, G. G., & Bandara, W. (2011). A Design Science Research Roadmap. In *Service-Oriented Perspectives in Design Science Research* (pp. 107–123). Springer. http://link.springer.com/chapter/10.1007/978-3-642-20633-7_8

Archer, L. B. (1984). Systematic Method for Designers. In N. Cross, *Developments in Design Methodology* (pp. 57–82). John Wiley.

Avison, D., & Malaurent, J. (2014). Is theory king?: Questioning the theory fetish in information systems. *Journal of Information Technology*. https://doi.org/10.1057/jit.2014.8

Baskerville, R. L., Baiyere, A., Gergor, S., Hevner, A. R., & Rossi, M. (2018). Design Science Research Contributions: Finding a Balance between Artifact and Theory. *Journal of the Association for Information Systems*, *19*(5), 358–376. https://doi.org/10.17705/1jais.00495

Baskerville, R., & Pries-Heje, J. (2019). Projectability in Design Science Research. *Journal of Information Technology Theory and Application*, *20*(1), 24.

Beck, R., Weber, S., & Gregory, R. W. (2013). Theory-generating design science research. *Information Systems Frontiers*, *15*(4), 637–651. https://doi.org/10.1007/s10796-012-9342-4

Buchman, E. (2016). *Tendermint: Byzantine Fault Tolerance in the Age of Blockchains* [PhD]. University of Guelph.

Carvalho, A. (2020). A permissioned blockchain-based implementation of LMSR prediction markets. *Decision Support Systems*, *130*, 113228. https://doi.org/10.1016/j.dss.2019.113228

Cascavilla, G., Conti, M., Schwartz, D. G., & Yahav, I. (2018). The insider on the outside: A novel system for the detection of information leakers in social networks. *European Journal of Information Systems*, *27*(4), 470–485. https://doi.org/10.1080/0960085X.2017.1387712

Chen, W., & Hirschheim, R. (2004). A Paradigmatic and Methodological Examination of Information Systems Research from 1991 to 2001. *Information Systems Journal*, *14*(3), 197–235. https://doi.org/10.1111/j.1365-2575.2004.00173.x

Coenen, T., Coertjens, L., Vlerick, P., Lesterhuis, M., Mortier, A. V., Donche, V., Ballon, P., & De Maeyer, S. (2018). An information system design theory for the comparative judgement of competences. *European Journal of Information Systems*, *27*(2), 248–261. https://doi.org/10.1080/0960085X.2018.1445461

Cole, R., Purao, S., Rossi, M., & Sein, M. K. (2005). Being Proactive: Where Action Research Meets Design Research. *Proceedings of the 26th International Conference on Information Systems*. ICIS. http://www.researchgate.net/publication/221599527_Being_Proactive_Where_Action_Research_Meets_Design_Research/file/79e4150c075e7ccf4b.pdf

Daeuble, G., Werner, M., & Nuettgens, M. (2015). Artifact-Centered Planning and Assessing of Large Design Science Research Projects – A Case Study. In B. Donnellan, M. Helfert, J. Kenneally, D. VanderMeer, M. Rothenberger, & R. Winter (Eds.), *New Horizons in Design Science: Broadening the Research Agenda* (Vol. 9073, pp. 343–357). Springer International Publishing. https://doi.org/10.1007/978-3-319-18714-3_22

Danish Business Authority. (2019). *Submission of Annual Report.* https://indberet.virk.dk/myndigheder/stat/ERST/Regnskab_20

Danish National Bank. (2020). *Betalinger mellem virksomheder kostede samfundet 4,2 mia. Kr*. https://www.nationalbanken.dk/da/publikationer/Betalingsraadets_publikationer/Documents/2019/BR_Betalinger%20mellem%20virksomheder%20kostede%20samfundet%204,2%20mia.%20kr.pdf

Däuble, G., Schlömer, I., Müller-Wickop, N., Schultz, M., Werner, M., & Nüttgens, M. (2014). Usability Evaluation – Messung, Bewertung und Verbesserung der Gebrauchstauglichkeit von Informationssystemen. In M. Nüttgens, O. Thomas, & M. Fellmann (Eds.), *Dienstleistungsproduktivität* (pp. 140–154). Springer Fachmedien Wiesbaden. https://doi.org/10.1007/978-3-658-05301-7_9

De Leoz, G., & Petter, S. (2018). Considering the social impacts of artefacts in information systems design science research. *European Journal of Information Systems*, *27*(2), 154–170. https://doi.org/10.1080/0960085X.2018.1445462

Deutsches Institut für Normung. (2009). *DIN 69901—Projektmanagement.* Beuth Verlag GmbH.

Dybå, T., & Dingsøyr, T. (2008). Empirical studies of agile software development: A systematic review. *Information and Software Technology*, *50*(9–10), 833–859. https://doi.org/10.1016/j.infsof.2008.01.006

Eekels, J., & Roozenburg, N. F. M. (1991). A Methodological Comparison of the Structures of Scientific Research and Engineering Design: Their Similarities and Differences. *Design Studies*, *12*(4), 197–203. https://doi.org/10.1016/0142-694X(91)90031-Q

Embley, D. W., & Thalheim, B. (Eds.). (2011). *Handbook of Conceptual Modeling*. Springer Berlin Heidelberg. http://link.springer.com/10.1007/978-3-642-15865-0

Erhvervsstyrelsen. (2020). *Hvad er NemHandel? (What is NemHandel).* https://erhvervsstyrelsen.dk/hvad-er-nemhandel

European Commission. (2014). *PEPPOL*. https://ec.europa.eu/growth/single-market/public-procurement/e-procurement/e-invoicing_en

European Commission. (2020a). *Digital Economy and Society Index 2018*. https://ec.europa.eu/digital-single-market/en/news/international-digital-economy-and-society-index-2018

European Commission. (2020b). *The Digital Economy and Society Index (DESI) Digital Economy and Society Index 2018*. https://ec.europa.eu/digital-single-market/en/desi

Giboney, J. S., Briggs, R., & Nunamaker, Jr., J. (2019). Special Section: Engineering Artifacts and Processes of Information Systems. *Journal of Management Information Systems, 36*(1), 11–13. https://doi.org/10.1080/07421222.2018.1551763

Great Britain, & Office of Government Commerce. (2009). *Managing successful projects with PRINCE2*. TSO.

Gregor, Shirley., & Baskerville, R. (2012). The Fusion of Design Science and Social Science Research. *ISF 2012*. http://cbe.anu.edu.au/media/2302943/isf_2012_-_gregor___baskerville_-_the_fusion_of_design_science_and_social_science_research.pdf

Gregor, Shirley. (2006). The Nature of Theory in Information Systems. *MIS Quarterly*, *30*(3), 611–642. https://doi.org/10.2307/25148742

Gregor, Shirley, & Hevner, Alan R. (2013). Positioning and Presenting Design Science Research for Maximum Impact. *MIS Quarterly*, *37*(2), 337–355. https://doi.org/10.25300/MISQ/2013/37.2.01

Gubrium, J. F., & Holstein, J. A. (2002). *Handbook of Interview Research: Context and Method*. SAGE.

Hays, P. A. (2004). Case study research. In K. B. DeMarrais & S. D. Lapan, *Foundations for research methods of inquiry in education and the social sciences* (pp. 217–234). L. Erlbaum Associates. http://xa.yimg.com/kq/groups/23189647/779073523/name/Sociology+-+Foundations+For+Research+-+Methods+Of+Inquiry+In+Education+And+The+Social+Sciences.pdf#page=234

Hevner, Alan R., & Chatterjee, S. (2010). Design Science Research in Information Systems. In A. Hevner & S. Chatterjee, *Design Research in Information Systems* (Vol. 22, pp. 9–22). Springer US. http://www.springerlink.com/index/10.1007/978-1-4419-5653-8_2

Hevner, Alan R., March, S. T., Park, J., & Ram, S. (2004). Design Science in Information Systems Research. *MIS Quarterly*, *28*(1), 75–105. https://doi.org/10.2307/25148625

Horita, F. E. A., de Albuquerque, J. P., Marchezini, V., & Mendiondo, E. M. (2017). Bridging the gap between decision-making and emerging big data sources: An application of a model-based framework to disaster management in Brazil. *Decision Support Systems*, *97*, 12–22. https://doi.org/10.1016/j.dss.2017.03.001

Innovationsfonden. (2020). *Blockchain-based Accounting: Exploiting the Potential of Distributed Ledger Technology for Financial Reporting Automation*. https://innovationsfonden.dk/da/investeringer/investeringsoversigt?field_program_target_id=16&field_start_year_value=2019&field_area_target_id=All&page=1

International Organization for Standardization. (2012). *ISO 21500 2011 Guidance on Project Management.*

J.P. Morgan. (2018). *Quorum Blockchain*. Quorum. http://docs.goquorum.com/en/latest/

Jukic, N. (2014). *Database systems: Introduction to databases and data warehouses*. Pearson.

Keen, P. G. W. (1980). *MIS Research: Reference Disciplines and a Cumulative Tradition*. 12.

Krcmar, H. (2010). *Informationsmanagement*. Springer.

Kreps, J., Narkhede, N., & Rao, J. (2011). Kafka: A Distributed Messaging System for Log Processing. *NetDB'11*.

Kuechler, B., & Vaishnavi, V. (2008). On Theory Development in Design Science Research: Anatomy of a Research Project. *European Journal of Information Systems*, *17*(5), 489–504. https://doi.org/10.1057/ejis.2008.40

Lee, Wyner, & Pentland. (2008). Process Grammar as a Tool for Business Process Design. *MIS Quarterly*, *32*(4), 757. https://doi.org/10.2307/25148871

Leist, S., & Rosemann, M. (2011). Research Process Management. *Proceedings of the 22nd Australasian Conference on Information Systems (ACIS) 2011-Identifying the Information Systems Discipline*, 1–11. http://eprints.qut.edu.au/49033/

March, S. T., & Smith, G. F. (1995). Design and Natural Science Research on Information Technology. *Decision Support Systems*, *15*(4), 251–266. https://doi.org/10.1016/0167-9236(94)00041-2

Microsoft. (2019). *Microsoft Azure Locations*. https://azure.microsoft.com/en-us/global-infrastructure/locations/

Mingers, J. (2001). Combining IS Research Methods: Towards a Pluralist Methodology. *Information Systems Research*, *12*(3), 240–259.

Ministry of Finance, Ministry of Industry Business and Financial Affairs, Ministry of Taxation, Danske Regioner, & Kommunernes Landsforening. (2016). *Automatic Business Reporting*.

Mullarkey, M. T., & Hevner, A. R. (2019). An elaborated action design research process model. *European Journal of Information Systems*, *28*(1), 6–20. https://doi.org/10.1080/0960085X.2018.1451811

Myers, M. D., & Venable, J. R. (2014). A Set of Ethical Principles for Design Science Research in Information Systems. *Information & Management*, *51*(6), 801–809. https://doi.org/10.1016/j.im.2014.01.002

Nagle, T., Sammon, D., & Doyle, C. (2017). Insights into Practitioner Design Science Research. In A. Maedche, J. vom Brocke, & A. Hevner (Eds.), *Designing the Digital Transformation* (Vol. 10243, pp. 414–428). Springer International Publishing. https://doi.org/10.1007/978-3-319-59144-5_25

Naumann, J. D., & Jenkins, A. M. (1982). Prototyping: The New Paradigm for Systems Development. *MIS Quarterly*, 29–44.

Nunamaker, J. F., Chen, M., & Purdin, T. D. M. (1991). Systems Development in Information Systems Research. *Journal of Management Information Systems*, *7*(3), 89–106. https://doi.org/10.1080/07421222.1990.11517898

Object Management Group. (2017). Unified Modeling Language. *Unified Modeling Language*, 796.

O'Regan, G. (2017). *Concise Guide to Software Engineering*. Springer International Publishing. https://doi.org/10.1007/978-3-319-57750-0

Österle, H., Becker, J., Frank, U., Hess, T., Karagiannis, D., Krcmar, H., Loos, P., Mertens, P., Oberweis, A., & Sinz, E. J. (2010). Memorandum on Design-oriented Information Systems Research. *European Journal of Information Systems*, *20*(1), 7–10. https://doi.org/10.1057/ejis.2010.55

Palvia, P., Leary, D., Mao, E., Midha, V., Pinjani, P., & Salam, A. F. (2004). Research Methodologies in MIS: An Update. *Communications of the Association for Information Systems*, *14*, 526–542.

Palvia, P., Mao, E., Salam, A. F., & Soliman, K. S. (2003). Management Information System Research: What's There in a Methodology? *Communications of the Association for Information Systems*, *11*, 289–309.

Parsons & Wand. (2008). Using Cognitive Principles to Guide Classification in Information Systems Modeling. *MIS Quarterly*, *32*(4), 839. https://doi.org/10.2307/25148874

Peffers, K., Tuunanen, T., Gengler, C. E., Rossi, M., Hui, W., Virtanen, V., & Bragge, J. (2006). The Design Science Research Process: A Model for Producing and Presenting Information Systems Research. *Proceedings of the 1st International Conference on Design Science Research in Information Systems and Technology (DESRIST)*, 83–106. http://6a.1b.7aae.static.theplanet.com/sites/default/files/documents/000designscresearchproc_desrist_2006.pdf

Peffers, K., Tuunanen, T., Rothenberger, M., & Chatterjee, S. (2007). A Design Science Research Methodology for Information Systems Research. *J. Manage. Inf. Syst.*, *24*(3), 45–77. https://doi.org/10.2753/MIS0742-1222240302

Pries, K. H., & Quigley, J. M. (2011). *Scrum project management*. CRC Press.

Pries-Heje & Baskerville. (2008). The Design Theory Nexus. *MIS Quarterly*, *32*(4), 731. https://doi.org/10.2307/25148870

Project Management Institute. (2013). *A guide to the project management body of knowledge: (PMBOK Guide)* (Fifth edition). Project Management Institute.

Reinecke, K., & Bernstein, A. (2013). Knowing What a User Likes: A Design Science Approach to Interfaces that Automatically Adapt to Culture. *MIS Quarterly, 37*(2), 427–453. https://doi.org/10.25300/MISQ/2013/37.2.06

Retsinformation. (2020). *Bekendtgørelse af årsregnskabsloven (Executive Order of the Danish Financial Statements Act)*. www.retsinformation.dk/eli/lta/2019/838

Riege, C., Saat, J., & Bucher, T. (2009). Systematisierung von Evaluationsmethoden in der gestaltungsorientierten Wirtschaftsinformatik. *Wissenschaftstheorie Und Gestaltungsorientierte Wirtschaftsinformatik*, 69–86. https://doi.org/10.1007/978-3-7908-2336-3_4

Schauer, C. (2011). *Die Wirtschaftsinformatik im internationalen Wettbewerb*. Gabler. http://www.springerlink.com/index/10.1007/978-3-8349-6229-4_1

Sein, M., Henfridsson, O., Purao, S., Rossi, M., & Lindgren, R. (2011). *Action design research*. http://bada.hb.se/handle/2320/9888

Søgaard, J. S. (2021). A blockchain-enabled platform for VAT settlement. *International Journal of Accounting Information Systems*, 100502. https://doi.org/10.1016/j.accinf.2021.100502

Sun Yat-sen University, Wu, J., Huang, L., Zhejiang University, Zhao, J. L., & City University of Hong Kong. (2019). Operationalizing Regulatory Focus in the Digital Age: Evidence from an E-Commerce Context. *MIS Quarterly*, *43*(3), 745–764. https://doi.org/10.25300/MISQ/2019/14420

Szyperski, N., & Winand, U. (1989). Informationsmanagement und informationstechnische Perspektiven. In D. Seibt & H. Wagner (Eds.), *Organisation: Evolutionäre Interdependenzen von Kultur und Struktur der Unternehmung* (pp. 133–150). Gabler Verlag.

Takeda, H., Veerkamp, P., & Yoshikawa, H. (1990). Modeling Design Process. *AI Magazine, 11*(4), 37–48. https://doi.org/10.1609/aimag.v11i4.855

The Hyperledger Foundation. (2020). *Hyperledger Fabric*. https://github.com/hyperledger/fabric

Turner, J. R., & Cochrane, R. A. (1993). Goals-and-methods matrix: Coping with projects with ill defined goals and/or methods of achieving them. *International Journal of Project Management, 11*(2), 93–102. https://doi.org/10.1016/0263-7863(93)90017-H

Vaishnavi, V., & Kuechler, W. (2017). *Design Science Research in Information Systems*. http://www.desrist.org/design-research-in-information-systems/

Venable, J., Pries-Heje, J., & Baskerville, R. (2012). A Comprehensive Framework for Evaluation in Design Science Research. *Design Science Research in Information Systems. Advances in Theory and Practice*, 423–438. https://doi.org/10.1007/978-3-642-29863-9_31

vom Brocke, J., & Lippe, S. (2010). Taking a Project Management Perspective on Design Science Research. In *Global Perspectives on Design Science Research* (pp. 31–44). Springer. http://link.springer.com/chapter/10.1007/978-3-642-13335-0_3

vom Brocke, J., & Lippe, S. (2013). Identifying and Managing Creative Tasks in Collaborative IS Research Projects: Identifying and Managing Creative Tasks in Collaborative IS Research Projects. *Project Management Journal, 44*(6), 94–113. https://doi.org/10.1002/pmj.21379 vom Brocke, J., & Lippe, S. (2011). Towards A Situational Approach In Managing Collaborative Research Projects In IS-Finding The Right Contigency Factors. *Pacific Asia Conference on Information Systems (PACIS)*, 202. http://aisel.aisnet.org/cgi/viewcontent.cgi?article=1201&context=pacis2011

Walls, J., Widmeyer, G., & El Sawy, O. (1992). Building an Information System Design Theory for Vigilant EIS. *Information Systems Research*, *3*(1), 36–59. https://doi.org/0.1287/isre.3.1.36

Werner, M. (2019). Exploring Design Science Research Project Characteristics—An Initial Empirical Investigation. *Proceedings of the 52nd Hawaii International Conference on System Sciences (HICSS 2019)*, 5705–5714.

Werner, M., Schultz, M., Müller-Wickop, N., & Nüttgens, M. (2014). Who Is Afraid of the Big Bad Wolf—Structuring Large Design Science Research Projects. *Proceedings of the 22nd European Conference on Information Systems (ECIS 2014)*, 1–16. http://aisel.aisnet.org/ecis2014/proceedings/track19/5/

Wilde, T., & Hess, T. (2007). Forschungsmethoden der Wirtschaftsinformatik. *Wirtschaftsinformatik*, *49*(4), 280–287. https://doi.org/10.1007/s11576-007-0064-z

Wilde, Thomas, & Hess, T. (2006). Methodenspektrum der Wirtschaftsinformatik: Überblick und Portfoliobildung. *Arbeitspapiere Des Instituts Für Wirtschaftsinformatik Und Neue Medien, LMU München*, *2*. http://www.en.wim.bwl.uni-muenchen.de/download/epub/ab_2006_02.pdf

Wimmer, H., & Yoon, V. Y. (2017). Counterfeit product detection: Bridging the gap between design science and behavioral science in information systems research. *Decision Support Systems*, *104*, 1–12. https://doi.org/10.1016/j.dss.2017.09.005

Wollnik, M. (1998). Ein Referenzmodell des Informationsmanagements. *Information Management*, *3*(3).

Yin, R. K. (2008). *Case Study Research: Design and Methods* (Fourth Edition.). Sage Publications.

Appendix A

Appendix A should be considered as one table. However, due to limited space, the table is broken down into three separate tables. The "Paper #"column binds the data points to the given paper. Further, above each of the tables are few abbreviations explained to read the table.

Not available = N/A

No direct information. Assumed the authors = N/I

Paper #	Article title	Author(s)	Year	Source title	Category	Research group size	Project partners	Duration	Budget	Funding	Output	Application domain	Primary Knowledge Base
1	CyberGate: A Design Framework and System for Text Analysis of Computer-Mediated Communication	Abbasi, Ahmed; Chen, Hsinchun	2008	MISQ	Medium	N/I	no project partners mentioned neither for analysis nor for evaluation	N/A	N/A	N/A	5 artifacts (including software prototype)	Computer-mediated communication systems	Communications research
2	Making Sense of Technology Trends in the Information Technology Landscape: A Design Science Approach	Adomavicius, Gediminas; Bockstedt, Jesse C. ;Gupta, Alok ;Kauffman, Robert J.	2008	MISQ	Small	N/I	Two case studies (but without project partners) plus semi-structured interview with 12 IT industry experts	N/A	N/A	N/A	4 artifacts (no software prototype)	Information technology management (in particular information technology investment decisions) (Examples: Digital music & Wi-Fi Technology)	IT Investment
3	Process Gramma as a Tool for Business Process Design	Lee, Jintae; Wyner, George M.;Pentland, Brian T.	2008	MISQ	Small	N/I	no project partners mentioned neither for analysis nor for evaluation	N/A	N/A	N/A	4 artifacts (including software prototype)	Business process design (example: sales process)	Grammar-based design
4	The Design Theory Nexus	Pries-Heje, Jan; Richard Baskerville	2008	MISQ	Medium to large	N/I	Several, the number of companies is rather unclear. At one point, the text says four larger organizations in the financial sector, then it talks of three additional companies	3 years	USD 5 mil.	Clients and university	4 artifacts (no software prototype, just spreadsheet tool)	Decision-making processes for wicked problems (examples: - choice of alternative change management approaches - user involvement approaches)	Multiple criteria decision making of wicked problems

5	Using cognitive principles to guide classification in information systems modelling	Parsons, Jeffrey ;Wand, Yair	2008	MISQ	Small	N/I	No information, evaluation took place with 10 modeling and domain experts from different organizations	N/A	N/A	N/A	3 artifacts (no software prototype)	Systems modeling / Software engineering (Model for characterizing what may be considered useful classes in a given context based on the inferences that can be drawn from membership in a class. e.g., for requirement specifications for IT systems.)	Conceptual modeling
6	Knowing What a User Likes: A Design Science Approach to Interfaces that Automatically Adapt to Culture	Reinecke, Katharina; Bernstein, Abraham	2013	MISQ	Medium	N/I	No partners were mentioned. However, survey participants are recruited at the University of Bangkok, the National University of Rwanda, and the University of Zürich.	N/A	N/A	N/A	7 (5) artifacts (including software prototype)	Webpage design and user interfaces (example: to-do list web application)	Cultural classification
7	Bridging the gap between decision-making and emerging big data sources: An application of a model-based framework to disaster management in Brazil	Horita, Flávio E.A.; de Albuquerque, João Porto; Marchezini, Victor ; Mendiondo, Eduardo M.	2017	DSS	Medium	N/I	National Center for Disaster Risk Management in Brazil	Data collection in Jan and Feb 2016	N/A	N/A	4 artifacts (no software prototype)	Natural Disaster Management in Brazil	Business Process Management

8	Counterfeit product detection: Bridging the gap between design science and behavioural science in information systems research	Wimmer, Hayden; Yoon, Victoria Y.	2017	DSS	Medium	N/I	No information; evaluation through Amazon M Turk, 283 data observations. Do not know if data obs. equals number of participants	N/A	N/A	N/A	7 artifacts (including software prototype)	E-commerce platforms (example: Amazon)	Online product authentication
9	A permissioned blockchain-based implementation of LMSR prediction markets	Carvalho, Arthur	2019	DSS	Small	N/I	No information, evaluation just covered the technical functionality but not usefulness	N/A	N/A	N/A	2 main artifacts with several sub-components (including software prototype)	Prediction markets	Blockchain Technology

10	Operationalizing regulatory focus in the digital age: Evidence from an e-commerce context	Wu, Ji; Huang, Liqiang; Zhao, J. Leon	2019	MISQ	Small	N/I	Online retail store that provided the data, evaluation via questionnaires sent out to customers econometric analysis	N/A	N/A	Partially supported by research grants from National Natural Science Foundation of China, Research Grants Council of Hong Kong, m City University of Hong Kong	Just one artifact, the text mentions also an IT artifact, but this is not further explained	E-commerce platforms (example: Asia proprietary e-commerce platform and forum)	Regulatory focus theory (RFT) Econometrics

I=Infrastructure-level, S=System-level, U=Usage-level, AD=Application domain, KB=Knowledge base

Paper #	Artifact #	Artifact name/description	Artifact type	Level1	Level2	Level3	I	S	U	AD	KB
1	1	Design framework for CMC text analysis systems (Fig. 1. CyberGate System Design)	Model		1			1			1
	2	CyberGate System (software prototype)	Instantiation	1					1	1	
	3	Visualizations (write prints (a), parallel coordinates (b), radar charts(c) MDS plots (d))	Instantiation	1					1	1	
	4	Write prints Process (Fig. 6.)	Method		1			1			1
	5	Ink Blots process (Fig. 7.)	Method		1			1			1
2	1	Model for representing relationships between IT components, products, and infrastructure (Tab. 1., Fig. 1. & 2.)	Model		1			1			1
	2	Method for identifying and representing patterns of technology evolution (Tab. 3.)	Method		1			1	1		1
	3	Patterns of digital music technology evolution (Fig. 3.) and Digital music technology graph-based state diagram (Fig. 4.)	Instantiation	1				1		1	
	4	State Diagram for 802.11b and 802.11g generations and WPA1 and WPA2 generations (Fig. 9 & 10:)	Instantiation	1				1		1	
3	1	Method 1: Building a Process Grammar	Method		1			1			1
	2	Method 2: Using / exploring a Process Grammar for Process Design	Method		1			1			1
	3	Gramma editor (Fig. 1. and 2.)	Instantiation	1					1	1	
	4	Process explorer	Instantiation	1					1	1	
4	1	General method for constructing a design theory nexus	Method		1			1	1		1
	2	General design theory nexus (Fig. 2.) (including goals, environment, alternative design theories, design solutions)	Model		1			1	1		1
	3	Design theory nexus instantiation / tool (spreadsheet)	Instantiation	1			1	1	1	1	
	4	Figure 4. The Strategic Change Nexus Design Theory	Instantiation	1				1		1	
5	1	Model of good classification structures	Model		1		1	1		1	1
	2	Classification principles to develop and formalize a model and rules for constructing good classes (method for constructing structures)	Method		1		1	1		1	1
	3	Partial Conceptual Schema following Classification Rules (Fig. 2)	Instantiation	1			1			1	

6	1	Cultural user model ontology (Fig. 2) (artifact 1)	Model		1			1	1		1
	2	Algorithm to approximate a person's cultural background (Eq. 1 -2) (artifact 2)	Method		1			1			1
	3	User interface adaptation rules (artifact 3)	Method		1			1		1	1
	4	MOCCA's adaptation possibilities (Tab. 3.)	Instantiation	1				1		1	
	5	User interface adaptation ontology (Fig. A1.) (artifact 4)	Model		1			1			1
	6	Web application prototype for a culturally adaptive system (artifact 5)	Instantiation	1					1	1	
	7	Technical Implementation of MOCCA (Fig. B1.)	Model		1		1			1	
7	1	Extended model and notation (oDMN+ metamodel) (Fig. 2.)	Model		1			1			1
	2	Modeling process (Fig.3)	Method		1			1		1	1
	3	Instantiation for a procurement process (Fig. 1.)	Instantiation	1				1		1	
	4	Instantiation for a disaster management (Fig. 5. - 6.)	Instantiation	1				1		1	
8	1	Online counterfeit detection score (OnCDS) consisting of five components	Instantiation	1				1		1	
	2	Behavioral research model / PLS-SEM (Fig. 1. & 5.)	Model		1				1		1
	3	OnCDS system architecture (Fig. 2.)	Model		1			1		1	
	4	Conceptualization of counterfeit score (Eq. 1 -4)	Construct		1			1			1
	5	Browser add-on	Instantiation	1					1	1	
	6	Conceptualization of counterfeit score display (Fig. 4.)	Model		1				1	1	
9	1	Prediction Market Model	Model		1			1		1	
	1a	Business network model for LMSR (Fig. 2.)	Construct		1		1			1	
	1b	Permission rules (Fig. 3.-5.)	Construct		1		1			1	
	1c	Java script code for the transactions (Appendix)	Method		1			1		1	
	2a	Hyperledger Composer playground (Fig. 6. & 13.- 14.)	Instantiation	1					1	1	
	2b	BNA files	Instantiation	1			1	1		1	
	2c	JSON data files (Fig. 7-12.)	Instantiation	1			1			1	

10	1	Regulatory Focus Discovery (Fig. 1.)	Method		1			1	1	1	1
	2	Review intensity variable	Construct		1			1		1	1

I=Infrastructure-level, S=System-level, U=Usage-level, RQ=Research question

		Application domain (1,y,z)			Knowledge base (2,y,z)			Research question (x,y,Z)				Research questions				
Paper #	Artifact #	I (1,1,z)	S (1,2,z)	U (1,3,z)	I (2,1,z)	S (2,2,z)	U (2,3,z)	RQ 1 (x,y,1)	RQ 2 (x,y,2)	RQ 3 (x,y,3)	RQ 4 (x,y,4)	General RQ	RQ 1	RQ 2	RQ 3	RQ 4
1	1	0	0	0	0	1	0	1	1	0		How can patterns be detected in CMC text messages?	How can CMC text analysis systems be designed which support various information types found in message text?	How and which text features should be select?	Which visualization techniques should be employed?	
	2	0	0	1	0	0	0	1	0	0						
	3	0	0	1	0	0	0	0	0	1						
	4	0	0	0	0	1	0	0	0	1						
	5	0	0	0	0	1	0	0	0	1						
2	1	0	0	0	0	1	0	0	1			How can information be structured for improving information technology investment decisions by using tools to aid IT decision-makers in identifying, analyzing, and predicting trends in the IT landscape?	How can the IT landscape and trends in IT be formally identified?	How can information about the IT landscape and trends in IT be visualized?		
	2	0	0	0	0	1	1	1	0							
	3	0	1	0	0	0	0	1	1							
	4	0	1	0	0	0	0	1	1							
3	1	0	0	0	0	1	0	1	0			How can process designers be supported to design process model alternatives by using process grammars?	How can process model alternatives be generated using process grammars?	How can irrelevant process model variants be filtered out?		
	2	0	0	0	0	1	0	0	1							
	3	0	0	1	0	0	0	1	0							
	4	0	0	1	0	0	0	0	1							
4	1	0	0	0	0	1	1	1	1			How can the design of problem-solving approaches be improved where a number of highly dissimilar competing approaches exist?	How can alternative highly-dissimilar competing	How can the fit of alternative approaches		
	2	0	0	0	0	1	1	1	0							
	3	1	1	1	0	0	0	1	0							

	4	0	1	0	0	0	0	1	1				solutions be identified?	be determined?		
5	1	1	1	0	1	1	0	1				How can classifications be made effectively and efficiently?	How can the choice of classes in a collection be limited to those that are useful?			
	2	1	1	0	1	1	0	1								
	3	1	0	0	0	0	0	1								
6	1	0	0	0	0	1	1	1	0	0	0	How can user interfaces be personalized in a comprehensive manner by taking into account a user's cultural background?	How can a user's cultural background be analyzed by not just relying on the user's location?	How can interfaces be adapted to cater to users of any national culture, as well as to users who have been influenced by several different national cultures?	How well can a culturally adaptive system such as MOCCA predict user interface preferences by knowing only a person's (extended) national culture?	Can UI preferences be clustered by culture?
	2	0	0	0	0	1	0	1	0	0	0					
	3	0	1	0	0	1	0	0	1	1	0					
	4	0	1	0	0	0	0	0	1	1	0					
	5	0	0	0	0	1	0	0	1	1	0					
	6	0	0	1	0	0	0	0	1	1	1					
	7	1	0	0	0	0	0	0	0	1	1					
7	1	0	0	0	0	1	0	1	0	0		How can the decision-maker's tasks be connected to emerging big data sources?	How can data sources be integrated into modeling notations?	How can information be obtained about conceptual elements from decision-makers of the application context?	How can guidance be provided for the modeling of business decisions or the relationship between decisions and data sources?	
	2	0	1	0	0	1	0	0	0	1						
	3	0	1	0	0	0	0	0	1	1						
	4	0	1	0	0	0	0	0	1	1						

8	1	0	1	0	0	0	0	1	0	0		How can the consumer's decision-making process be improved by identifying counterfeit goods based on consumer product reviews?	How can CDS be designed for online marketplaces?	How can CDS be integrated into consumer's decision-making process?	Does a CDS improve a consumer's decision-making?	
	2	0	0	0	0	0	1	0	0	1						
	3	0	1	0	0	0	0	1	0	0						
	4	0	0	0	0	1	0	1	0	0						
	5	0	0	1	0	0	0	1	0	0						
	6	0	0	1	0	0	0	0	1	0						
9	1	0	1	0	0	0	0	0	0	1		How can the availability, security, and privacy problems in LMSR be overcome?	Why and how can be a prediction market model be implemented using permissioned blockchains?	How can DSR be used to develop blockchain models?	How can modern tools model and evaluate permissioned blockchains be used?	
	1a	1	0	0	0	0	0	1	0	0						
	1b	1	0	0	0	0	0	1	0	0						
	1c	0	1	0	0	0	0	1	0	0						
	2a	0	0	1	0	0	0	1	0	1						
	2b	1	1	0	0	0	0	0	0	1						
	2c	1	0	0	0	0	0	0	0	1						
10	1	0	1	1	0	0	1	1				What is the effect of participation in a customer brand community on purchase behavior contingent on the customer's Regulatory Focus?	Which online brand community participation has a positive impact on the purchase frequency of promotion-focused customers but a negative impact on the purchase frequency of prevention-focused customers?			
	2	0	1	0	0	1	0	1								

PAPER 2

A Blockchain-enabled Platform for VAT Settlement

Jonas Sveistrup Søgaard

Copenhagen Business School | Department of Accounting | jss.acc@cbs.dk

ABSTRACT: Governments may unintentionally impose heavy administrative burdens on companies as they want to ensure the flow of tax revenue. Drawing on an engagement involving the Danish Business Authority and following a design science research (DSR) approach, this paper develops a prototype of a platform for value-added tax (VAT) settlement that is enabled by distributed ledger technology (DLT) and design principles for designing DLT platforms. The proposed prototype and design principles demonstrate how accounting information systems, DLT, and public governance may be interrelated to enhance social welfare. Regarding its practical implications, this paper provides a use case for governments seeking to reduce administrative burdens on small and medium-sized enterprises (SMEs) while still ensuring the flow of tax revenue.

KEYWORDS: blockchain, distributed ledger technology, VAT, design science research, tax, public sector

1. INTRODUCTION

In the context of increasing digitalization, governments face the challenge of balancing the goal of retaining tax revenue not to impose heavy administrative burdens on companies.[18] Several governments, including those in Brazil, Mexico, Hungary, Italy, and China, have prioritized to retain tax revenue at the expense of increasing administrative burdens (see, e.g., EY, 2018; Hungarian Tax Authority, 2018).

In the Eurozone, the yearly uncollected VAT amounts to EUR 151.5bn. This enormous loss corresponds to more than one percent of the GDP of the 27 EU member states and the UK (Institute for Advanced Studies, 2018, p. 16). In the pursuit of collecting taxes, government efforts to monitor and control business transactions between companies are undertaken through centralization to ensure compliance with reporting and VAT regulations, thereby discouraging fraudulent behavior. The tax authorities in the countries mentioned in the first paragraph force companies to obtain digital stamps of approval on their invoices to comply with legislation and enable them to settle VAT. Requiring digitally signed invoices implies, however, that governments add administrative burdens on companies. Further, fueling critiques of business-to-government (B2G) reporting has been criticized in many countries for being inefficient, complex, and often duplicative (Bozanic et al., 2012; Chen, 2012). It is also significantly more expensive to comply with regulations for small and SMEs than for large companies, which calls for a more straightforward solution focused on SMEs (Ntaliani and Costopoulou, 2017).

Surveying the literature on administrative burdens, the VAT, DLT, and design science research (DSR) make it *conceptually* evident that blockchain technology holds the potential to solve this challenge of minimizing the VAT gap without imposing excessive administrative burdens on companies (Ainsworth et al., 2019, 2016; Ainsworth and Shact, 2016). Regarding administrative burdens, Ntaliani and Costopoulou (2018) provide an example of web-based tools for SMEs that

[18] Administrative burdens focus primarily on relationships between citizens and public agencies (e.g. Bozeman, 2007; Burden et al., 2012). However, this study focuses on relationships between companies, especially SMEs, and the tax authorities and adopts the compliance costs focus from Allers (1994) who defines administrative burdens as the costs that companies have to pay to comply with regulations.

vastly lower administrative burdens related to information search.[19] Three previous studies have examined DLT and VATs. Wijaya et al. (2017) and Alkhodre et al. (2019) present blockchain-based VAT solutions from Indonesia and Saudi Arabia, respectively. Fatz et al. (2019, p. 559) present a "conceptual design and a prototype for compliant process execution in the context of value-added taxes," focusing on customs documents through an Ethereum blockchain-based prototype. However, none of the proposed prototypes is empirically evaluated, and no general knowledge that can easily be applied to other contexts is presented.[20] In examining areas related to tax compliance, Hyvärinen et al. (2017) present a blockchain-based information technology (IT) artifact that avoids double taxation of dividends for investors. Hyvärinen et al. (2017, p. 455) report "the first practical evidence of the applicability of blockchain technology in the public sector" and suggest that related fields, such as VAT settlement, provide a natural next step for authorities to take in addressing the balance of imposing minimal administrative burdens on companies while ensuring tax compliance.[21]

The abovementioned studies emphasize the benefits of the digitalization of administrative processes for both the governments and companies involved, alluding to the need to extend the existing, albeit limited, literature in the area of administrative burdens, DLT, and VATs with more general design knowledge. At the same time, the aim of this paper is to provide an alternative path to the prevailing bureaucratic solutions that use digitalization to centralize and execute bureaucratic procedures.

This research exploits a unique opportunity to engage with the Danish Business Authority that launched a new digital strategy in 2016. The strategy focuses on reducing administrative burdens, with the theme of "automatic business reporting" specifically focused on the SME segment as such companies are paying a relatively higher price for complying with regulatory duties compared with larger companies and at the same time form the backbone of many

---

[19] In this study, SMEs are defined according to the Danish Financial Statements Act, section 7 (Danish Government, 2020). This means that SMEs are companies with up to 250 full-time equivalents, a balance sheet total of DKK 156m, and net sales of DKK 313m.

[20] In this study, general knowledge and general design knowledge are defined as knowledge that can be used in a variety of contexts and not only in the study where it is created.

[21] VAT settlement is the process of settling the VAT on a given transaction.

economies (Ntaliani and Costopoulou, 2017). Furthermore, the government has an ambitious vision “to remove the companies’ administrative burdens related to financial reporting, including VAT, to the public sector through automatic business reporting” (Ministry of Finance et al., 2016, p. 1). This strategy led to a novel research collaboration between the Danish Business Authority, Deloitte, and this researcher to consider how DLT may be used to meet such a vision in regard to VAT compliance. Specifically, this study addresses the following research question:

“How can an IT artifact be designed for VAT settlement so that government revenue is ensured, while the administrative burden on SMEs is reduced?”

This research question is answered via a design science research (DSR) approach that demonstrates how an instantiation of an IT artifact provides an innovative solution for VAT settlement. The IT artifact is designed as a prototype of a nationwide blockchain-based invoicing platform for VAT settlement. Through a purely technical evaluation of the artifact (Venable et al., 2016) and guided by four design principles, the results obtained offer insights into how DLT, with its distinct capabilities, such as tamper-resistant data storage and validated transactions with cryptographic signatures, can be used for VAT settlement.

The evaluation provides insights for both academics and practitioners into the accounting information systems (AIS) field. As a theoretical contribution to the knowledge base, the present work develops four design principles and provides design guidance to AIS researchers, and may be used as a starting point for further studying and designing DLT solutions. Many areas remain to be explored, and therefore this paper does not focus on user adoption strategies, on-chain versus off-chain patterns, electronic identity (e-ID) management, or choices of standard formats for e-invoicing. These areas need further exploration to create a truly global platform ready for production.

The remainder of this paper proceeds with sections 2-4, providing a background to the study, a literature review, and the study’s methodology. Sections 5-7 present design requirements, design principles, and design features, leading to sections 8-9, in which the artifact design is introduced and evaluated. Lastly, in sections 10-11, the study’s implications are discussed, and the paper concluded.

2. BACKGROUND – THE DANISH CONTEXT AND PROJECT INITIATION

Danish companies are obligated by law to report their financial status through their annual financial statements, to complete VAT statement forms, and to provide financial statistics.[22] Approximately 99 percent of the approximately 300,000 active Danish limited companies are SMEs, for which it is mandatory to submit financial statements digitally in XBRL format (Danish Business Authority, 2019). Furthermore, using an e-ID, Danish companies are required to report VAT amounts monthly, quarterly, or bi-annually via a customized portal provided by the tax authorities (Agency for Digitisation, 2010).

As shown in Figure 1, the current VAT settlement process for Danish companies is a five-step process. Step 1 involves transactions between corporate trading partners and the execution of actual business transactions. Step 2 involves recording transactions onto an accounting ledger using an AIS (most companies use an enterprise resource planning (ERP) system). In step 3, a VAT statement is prepared. Some ERP systems perform this step automatically. Depending on the software used and/or the complexity of the transactions involved in a given time period, the preparation of VAT statements may require manual work. Step 4 involves uploading the VAT statement to the tax authorities' web portal by entering figures or uploading a file. Step 5 assumes that a company will either pay VAT to or get a VAT refund from the tax authorities depending on whether input VAT (related to purchasing) or output VAT (related to sales) comprise the larger figure.

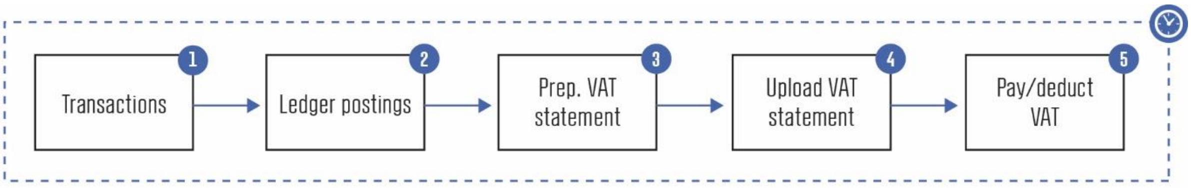

Figure 1. Current VAT settlement process

The public sector in Denmark is driving digitalization through regulatory requirements and open data. This has resulted in Denmark being named the world's most digitalized country in 2018 (European Commission, 2018a), and in 2020, Denmark was proclaimed to be the best at e-government development (United Nations, 2020). Since 2004, every Danish business-to-government (B2G) invoice has been required to follow a Danish invoicing standard (Danish

[22] A VAT statement is a report that provides the basis of what a company needs to pay to or can deduct.

Government, 2004), which, at the point of writing, will be converted into the pan-European public procurement online standard (PEPPOL) to comply with EU regulations. The PEPPOL standard is being deployed throughout Europe following the EU directive 2014/55/EU on e-invoicing, for implementation by April 18, 2019 (European Commission, 2014a). Two components (digital identity and data standards)[23] are cornerstones of every permissioned DLT solution, placing Denmark in a unique position to take advantage of the capabilities of DLT systems.

3. LITERATURE REVIEW OF KNOWLEDGE BASES

This study draws on several fields, theoretically, methodologically, and practically. The work's theoretical foundation is built on constructs and models rooted in the field of DLT and applied in the field of information exchange and specifically related to invoice data sharing and VAT settlement calculations. Interactions between these two fields are commonly referred to as AIS. In surveying the literature on these respective fields with a focus on blockchain-based VAT artifacts, it became evident that the field is currently under-researched. As shown in Appendix B, only Fatz et al. (2019) have conducted DSR with a focus on VAT using DLT. As mentioned in the introduction, though, Wijaya et al. (2017), Alkhodre et al. (2019), and Fatz et al. (2019) do not present any general knowledge that is easily applied to other contexts or that specifically categorize their artifacts.

To contribute to the (existing) literature on VAT and DLT within the AIS field, this study draws on fundamental studies of blockchain technology (Nakamoto, 2008) and smart contracts (Szabo, 1997). The combination of blockchain and smart contracts makes it possible to materialize distributed processes and shared truth without involving any third parties (Berkeley, 2015). Furthermore, this study utilizes academic taxonomical studies (Glaser, 2017; Xu et al., 2019, 2017) of DLT to articulate the specificities of DLT design. In particular, Xu et al. (2017, 2019) discuss blockchain architecture with a focus on more classical software and begin by categorizing DLT systems into four groups: 1) permissioned, 2) permissionless, 3) private, and

[23] A digital identity is information on an entity that computer systems use to represent an external agent, in this case companies and citizens. The information contained in a digital identity allows for the assessment and authentication of a user who is interacting with a business system on the web without the involvement of human operators (Feher, 2019). Data standards are the rules by which data are described and recorded. To facilitate the sharing, exchange, and comprehension of data, standardization defines the format as well as the meaning (Houlding, 2001).

4) public. The public/private groups refer to who is allowed access to the network, whereas the permissioned/permissionless groups refer to the data access rights. E.g., the Bitcoin and Ethereum protocols are categorized as public, permissionless blockchains since everyone can join and since there are *no* permissions on who can see which transactions; it is open to everyone. On the other hand, a Hyperledger Fabric or Corda implementation is a private, permissioned blockchain. Glaser (2017) presents a blockchain architecture in the context of a three-tier architecture, including two blockchain-specific layers: the *decentralized application layer* and the *decentralized fabric layer*. In contrast to Glaser's work, Xu et al. (2019) present a more component-based view, providing a perspective through which the DLT system fits within the rest of the enterprise architecture. For further elaboration of DLT in accounting, see Kokina et al. (2017).

As mentioned in the introduction, the existing literature on DLT and VATs conceptually describes how blockchain technology can address the EU's tax gap (Ainsworth et al., 2019, 2016; Ainsworth and Shact, 2016). Prior studies do not, however, offer any design guidelines or prototypes indicating how this should be done. In moving from the VAT literature into AIS literature, a discussion of new capabilities represented by DLT for accounting and auditing processes should pave the way for a range of opportunities for highly secure information processing and transactional transparency, which are limited in current ERP systems and other AIS. With regard to accounting, Brandon (2016) suggests that DLT replaces traditional information systems, Wang and Kogan (2018) propose a tokenized design to preserve privacy on public blockchains, and Coyne and McMickle (2017) find that public blockchains are not fit for accounting purposes. In focusing on auditing and DLT, Dai and Vasarhelyi (2017, p. 5) describe a new interconnected paradigm with their concept of Audit 4.0 (2016) and continue the discussion regarding whether DLT "could enable a real-time, verifiable, and transparent accounting ecosystem." Rozario and Vasarhelyi (2018) and Rozario and Thomas (2019) show how smart contracts are utilized within the audit process. For accounting and external auditing, there is, however, no consensus regarding how DLT will make an impact. The abovementioned literature may be categorized as conceptual, leaving room for the further empirical validation of DLT in accounting. Many prior studies will, however, be used to inform the design principles proposed in this study (see Appendix B).

4. METHODOLOGY

This study builds on Hevner et al.'s (2004) information systems research framework as a methodological starting point and adopts Peffers et al.'s (2007) six activities in combination with Meth et al.'s (2015) requirement mining system (design requirements, design principles, and design features).[24] This approach is similar to that adopted in Coenen et al. (2018). Furthermore, applying Gregor and Hevner's (2013) classification of DSR contributions, this study contributes with four design principles (level 2) and a prototype instantiation (level 1).

Access to data, including meetings and evaluations of the artifacts, was granted by all participants[25], including ethical clearance by the Copenhagen Business School, on the condition that it would be used only for research purposes and documented through a project logbook.[26] Furthermore, external desk research was applied using both online sources and government-published data provided by the Danish Business Authority. The duration of the interviews/working meetings was between 30 and 80 minutes. An overview of the 14 interviews/meetings conducted and the ten evaluations held is included in Appendix A.

Technology-agnostic design principles were derived as general design statements based on design feature categories derived from the literature on DLT, AIS, and VAT (see Appendix B) combined with the identified design requirements. The implementation of design features followed an agile method for developing the instantiation of the prototype. Information from failed tests and deployments on the Azure Blockchain Workbench was collected and used in the subsequent iteration. The development of the prototype occurred over seven five-day sprints to complete the prototype.[27] During this period, the design principles were the overarching

---

[24] See Geerts et al. (2001) for how DSR methodology is used within the field of AIS.

[25] The Danish Business Authority, the Copenhagen Business School, Deloitte, a production company, and an auto repair company.

[26] While conducting this study (actively participating), I was employed at Deloitte as an industrial PhD focusing on blockchain technology's impact on accounting. The project was funded by Deloitte and the Innovation Fund Denmark. The Danish Business Authority was part of the project's steering committee, allowing project information to be used for publication.

[27] A sprint is a time-boxed event that serves as a container for project activities. Sprints were conducted consecutively without intermediate gaps.

guidelines used to evaluate the artifact's instantiation, following Venable et al.'s (2016) "purely technical" strategy from their Framework for Evaluation in Design Science. As described in their paper, the setting for a purely technical evaluation is carried out "without human users" (Venable et al., 2016, p. 82). This formative, artificial evaluation strategy resonates with the research question as this paper wanted to explore technical possibilities of near real-time VAT settlement with a DLT-based artifact.

5. DESIGN REQUIREMENTS

5.1 Design requirement 1. Increase efficiency and transparency in VAT handling

The main concern of end-users (controllers in finance departments in the auto and production industries and owners of small companies) was to spend time by focusing on value-creating activities rather than on filing VAT statements in fear of misunderstanding the regulations and being fined for not filing the right VAT amount (interview #2 and interview #12 with SME1 and SME2, respectively).[28] Design requirement 1 is derived from these observations and concurs with the general discussion in the literature regarding administrative burdens, providing greater transparency into tax authorities described as "black boxes" (Jørgensen and Bozeman, 2007; Peeters and Widlak, 2018).

5.2 Design requirement 2. Ease the identification and comparability of VAT handling

Interviews with the Danish Business Authority employees focused on regulation and on reducing barriers to doing business in Denmark (interview #3 with DBA and DDT, interview #4 with DBA, interview #10 with DBA, interview #11 with DBA). The main insights from these interviews focus on the Danish Business Authority's need to determine who has and has not been paying VATs and the need to utilize established standards for reporting and invoice documents.

[28]The Danish Business Authority = DBA, Deloitte development team = DDT, Deloitte auditors = DA, Author = A, ERP vendor = EV, auto repair company = SME1, production company = SME2. See Appendix A for an overview of all interviews.

5.3 Design requirement 3. Ensure data privacy and compliance (GDPR)

All interviewees emphasize that complying with GDPR is non-negotiable as it is required by law (interview #4 with DBA, interviews #9-#11 with DBA, interview #13 with DBA and DDT), which is why design requirement 3 is about data privacy and compliance.

5.4 Design requirement 4. Ensure platform scalability

Estimates provided in reports by Deloitte (Deloitte, 2017) and the Danish National Bank (Danmarks Nationalbank, 2019) show that the Danish B2B and B2G markets handle approximately 230 million invoices per year; figures that were also confirmed in interviews #5-#7 with DA, EV1, and EV2. These figures set the requirement for the platform's performance and its capacity to scale.

6. DESIGN PRINCIPLES

To visualize the clear links between the design requirements, design guidelines, and design features, Figure 2 provides an overview of how the constructs are interrelated. The following section provides insights into how the design principles were derived from empirical data and prior literature.

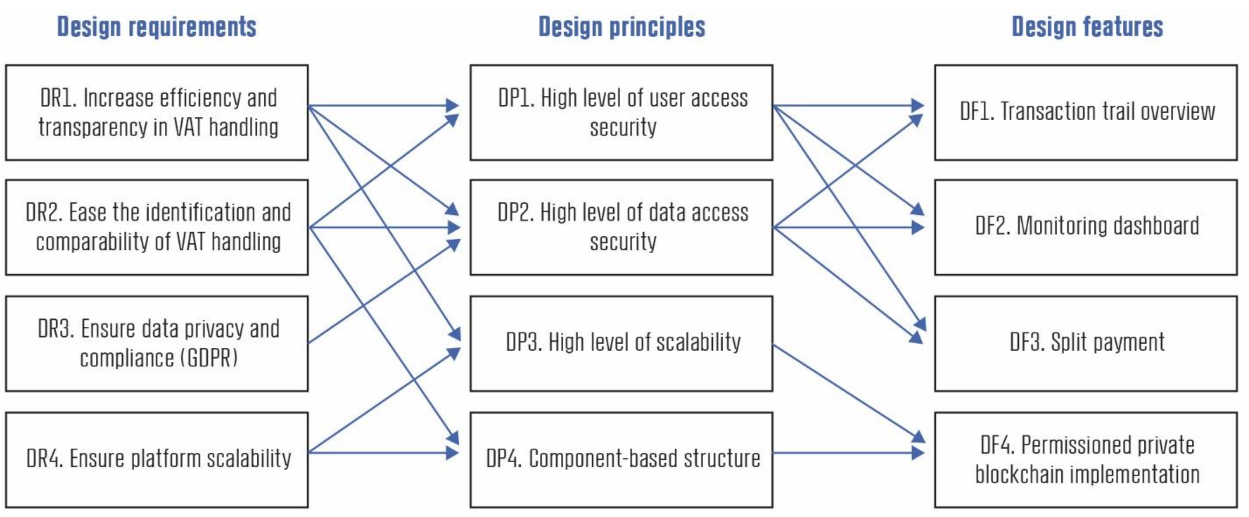

Figure 2. Design requirements, principles, and features

6.1 Design principle 1: High level of user access security

This design principle focuses on how a user accesses the platform and which data are visible to that user. The platform needs to offer digital user authentication through a unique identifier used when signing each transaction. This principle is also in line with prior literature (Ainsworth et al., 2019, 2016; Ainsworth and Shact, 2016; Alkhodre et al., 2019; Fatz et al., 2019; Hyvärinen et al., 2017; McCallig et al., 2019) and interview #2 with SME1, interviews #4-#6 with DBA, DA, and EV1, interview#10 with DBA, interview #12 with SME2, and interview #13 with DBA and DDT. The digital identification component is ensured by using governmental e-IDs, which are already deployed in Europe through the eIDAS directive (European Commission, 2014b) and in similar initiatives carried out in Asian countries. The European Blockchain Services Infrastructure program has selected self-sovereign identity as one of its first use cases (European Commission, 2019), indicating the importance of digital identification.[29]

6.2 Design principle 2. High level of data access security

The data access security principle applies to techniques for working with data protection and local data regulations. The solution must accommodate the necessary information transparency requirements for VAT settlement in B2B and B2G transactions. Companies (buyers and sellers) must be able to trust that the solution sends their invoice data only to the relevant actor(s). For example, a seller may want only the buyer to see an offer and would therefore want assurance that a competitor cannot view the seller's private data. Furthermore, to enable companies to feel safe when reporting transactions to the government in a standardized manner (Fatz et al., 2019), assurance must be provided by the government that companies can trust that their data are tamper-resistant when a VAT statement is created. Today, many tax authorities are black boxes for companies, meaning that companies do not experience transparency in the services they receive from public agencies (Jørgensen and Bozeman, 2007). Given the existing tension between governments and companies, this design principle must ensure a high level of transparency for both companies and government institutions, which is also discussed in the literature (Bogdanov et al., 2015; Fatz et al., 2019; Wang and Kogan, 2018) and confirmed in interview #2 with SME1, interviews #4-#6 with DBA, DA, and EV1, interview #10 with DBA, interview #12 with SME2, and interview #13 with DBA and DDT.

Further, the platform must comply with local data regulations, which in the EU means the GDPR (European Commission, 2018b), and address how regulations and guidelines can be

[29] In this paper, the term "use case" is understood and used as in software and systems engineering (Jacobson et al., 1992). A use case is a list of actions or event steps defining the interactions between actors (companies, banks, authorities, and auditors) and systems (the prototype) designed to achieve a goal (exchanging business documents and settling VATs).

synched with local legislation on VAT statements. For example, the GDPR principle regarding *the right to be forgotten* denotes that companies and people have the right to have their personal data destroyed unless there is good reason to store them, e.g., for government reporting where the name, address, and payment information included in an invoice header are considered information for personal identification. However, the lines between specific reporting purposes and the GDPR remain blurred and must be investigated further. Insofar as most prior research relevant to this study is not EU-focused, GDPR principles are not considered. The privacy-preserving design presented in Wang and Kogan (2018) resonates with this design principle, however, and was confirmed in interview #4 with DBA, interviews #9-#11 with DBA, and interview #13 with DBA and DDT.

6.3 Design principle 3. High level of scalability

Scalability includes two elements: storage and speed. For the storage element, it is assumed that for every transaction executed (the 230 million presented in design requirement 4), an average of five information exchange transactions between a buyer and a seller (e.g., the invoice, purchase order, offer, or a credit note) takes place, which is known as related traffic. This means that Denmark experiences a total of 1.13 billion transactions annually. As mentioned in section 3, Denmark employs a standard for e-invoices that represents invoices in extensible mark-up language (XML). The invoices' size varies from the worst case of 50 kilobytes (KB) to below 1 KB. An average invoice is 2 KB, resulting in a data storage need corresponding to 0.4-10.6 terabytes per year. In terms of speed, the number of transactions presented will not follow an average distribution on weekdays for a whole year (interview #4 with DBA, interview #11 with DBA, and interview #13 with DBA and DDT). Therefore, peak intervals are estimated as it is highly likely that most transactions are conducted during business hours (8 a.m.-6 p.m.) from Monday through to Friday, even though many businesses operate 365 days a year and seasonal peaks occur. The peak intervals also represent an upper limit of the load on the platform. It is estimated that the system must be able to manage 130-150 transactions per average peak second, based on the 1.13 billion transactions figure.[30]

[30] The estimate is derived using this formula: $\frac{\text{Number of Invoices} \times \text{Related Traffic} = \text{Total Traffic}}{12\ (\text{months}) \times 20 \sim (\text{working days}) \times 10 \sim (\text{working hours})}$

6.4 Design principle 4. Component-based (loosely coupled) structure

One of the objectives of this artifact is to test whether DLT is suitable for a nationwide invoicing platform. It is already known that other components are part of the solution architecture (interview #2, interviews #11-#12). Existing tax systems and DLT components are found, for example, in various configurations, as mentioned by Xu et al. (2018), with the general (im)maturity of DLT being defined as only 12 years. Therefore, it is important to apply a component-based structure to the solution so that it is possible to exchange components without compromising the entire architecture. As another important argument for formulating this principle, business requirements will most likely change over time, and without a component-based structure, the required agility level is very difficult to provide from a solution architecture perspective.

7. DESIGN FEATURES

In this section, design choices will be described, and the implementation of the smart contract layer and consensus mechanism. Descriptions of the overall solution architecture and data storage as well as front-end, key, and user management components are presented in the GitHub repository.

7.1 Design feature 1. Transaction trail overview

Immutability through Merkle tree structures and the logic of the smart contract code ensure that it is impossible for actors, including authorities, companies, banks, or auditors, to alter data on their own without the other actors knowing.[31,32]

---

[31] In cryptography and computer science, a hash or Merkle tree is a tree in which every leaf node is labeled with the cryptographic hash of a data block, and every non-leaf node is labeled with the cryptographic hash of the labels of its child nodes. Hash trees allow for the efficient and secure verification of the content of large data structures. Hash trees are a generalization of hash lists and hash chains.

[32] In this repository, https://git.io/Jfu7x, the code from the smart contracts and dashboard is found.

Id	State	Modified By	Modified	Kommentar	Pris	Moms	Filsti	Digitalt fingeraftryk
13	Revision godkendt	Sælger Roll...	06/29/18	Antallet var...	100	25	Faktura_kø...	0x1602ab92b57a81bcd2941a0587420d86...
12	Revision godkendt	Sælger Roll...	06/29/18		200	50	Faktura_kø...	0xd56b9788e5e562dc86277a446c8f9f95f...
11	Faktura oprettet	Sælger Roll...	06/29/18		100	25	sælger:/fak...	0xd103fd27f916f45aad4a9516aecde719e...

Figure 3. Digital fingerprint

Figure 3 shows a screenshot from the prototype (headings in Danish) to demonstrate how an invoice (the contract) is made available in the buyer's and seller's lists. It also shows the hashed value of the invoice in the column titled *Digitalt fingeraftryk*.[33]

7.2 Design feature 2. Monitoring dashboard

Based on design feature 1, the authorities can monitor the use of the platform through a dashboard.

Figure 4. VAT dashboard

The two graphs shown in the upper part of Figure 4 show the number of VAT transactions executed and their values over a given period. This near real-time information delivery makes it easier to identify cases of fraud and abuse as the data are disaggregated at the company level.

[33] "Digitalt fingeraftryk" in Danish means „digital fingerprint'.

The lower part of the dashboard visualizes the use of the platform through three pre-made matrices:

1. The number of invoices sent through the platform in a given period
2. The response rate (how many issued invoices are answered)
3. The number of corrections made (how many transactions are renegotiated).

Authorities are thus provided direct insight into companies' business transaction patterns. Today, authorities have very few touchpoints with companies before they self-declare VATs and submit annual financial reporting.

7.3 Design feature 3. Split payments

The split payment mechanism enables the smart contract to calculate the VAT amount and automates VAT settlement within every transaction as opposed to every month, quarter, or year as in the current VAT settlement paradigm. Whenever a buyer and a seller agree on a transaction, the smart contract performs the split payment from the buyer to the seller and the authorities. In doing so, the smart contract removes the administrative burden on transacting parties of declaring the VAT while ensuring a better basis for the authorities to ensure the VAT revenue flow. The implementation in the artifact is limited to trivial VAT calculations at a fixed rate. As shown in Figure 3, the transacting parties can use the column "Moms" to see the VAT associated with each transaction.[34]

7.4 Design feature 4. Permissioned, private blockchain implementation

Several important findings emerge from analyzing actors' design requirements, design principles, and process flows of the use case. On the one hand, the unambiguous identity of the company, as well as those acting on its behalf, must be determined. This unavoidable requirement speaks for the selection of a *private* DLT. On the other hand, the design principles – providing a high level of user access security and a high level of data access security – meet the requirements for access management and data protection. This would imply a need to select a *permissioned* DLT. After considering both aspects, a permissioned, private DLT implementation appears to be the right fit and is consistent with what other scholars have found (Pedersen et al.,

[34] "Moms" in Danish means "VAT".

2019). Bogdanov et al. (2015) present a secure multi-party approach to balance fraud and privacy concerns in the context of VAT collection in Estonia. The solution also, however, introduces a trusted third party and presents scalability issues, which is why a blockchain set-up was chosen.

Likewise, the key users of the solution are known to be Danish SMEs, the Danish Business Authority, the Danish tax authorities, banks, and auditors. SMEs gain access to the platform only when using the national e-ID (NemID), which ensures an unambiguous identity. The Azure Blockchain Workbench (version 1.1.0) was chosen because it offers an enterprise-oriented platform in which DLT components act as single pieces when deploying large-scale solutions, which is in accordance with design principles that focus on a component-based structure. Furthermore, the Azure Blockchain Workbench offers an Ethereum implementation with a proof-of-authority (PoA) consensus mechanism called Aura.

In the PoA paradigm, validator nodes take the place of traditional miner nodes, which are used in the Bitcoin protocol (Nakamoto, 2008), and the public, permissionless Ethereum platform (Buterin, 2013). The Aura implementation of consensus is essentially an optimized proof-of-stake model that utilizes identity as the type of stake rather than staking tokens (Parity, 2019). The identity is staked by a group of validators who are pre-approved to validate transactions and blocks within their respective networks. If this platform is to be a Danish implementation only, the governance model will imply a high degree of centralization toward authorities, raising questions as to why this use case needs a DLT system. When scaling the solution to include transnational transactions, though, one means of scaling would involve adding validator nodes representing authorities (tax authorities, business registry agencies, national statistics, etc.) from other countries. In this way, the power among network participants (countries) is evenly distributed and by design eliminates this degree of centralization (Lamport et al., 1982). This pattern (segregation of wallets and validator nodes) follows the de facto standards applicable in many other blockchain implementations, e.g., Bitcoin and Ethereum. [35]

[35] In some DLT systems, it is possible to be both a wallet and a node. In this case, though, the chosen design separates these roles.

Blockchain critics (e.g., Coyne and McMickle, 2017) may argue that many of the benefits of blockchain technology are lost using consensus mechanisms such as PoA. However, because the actors within this network are known, we can relax the assumptions of anonymity that result in the need to use the Proof-of-Work consensus mechanism. In this study, PoA ensures that the actors involved are afforded immutability of data and audit trails while ensuring low energy consumption in comparison with Proof-of-Work. Alternative messaging technologies (e.g., Kafka or Spark) offer a distributed deployment (Chintapalli et al., 2016; Kreps et al., 2011), but the audit trail and immutability based on consensus across nodes are not available. In other words, this implementation of a private, permissionless blockchain becomes a true autonomous notary function that opens the black box.

8. ARTIFACT INSTANTIATION

8.1 Artifact ecosystem

Figure 5 visualizes four types of key actors involved in the artifact ecosystem related to VAT processes:[36] SMEs (buyers and sellers), banks, authorities, and auditors (Troshani et al., 2018). Appendix B provides an overview of the key actors referenced in prior literature.

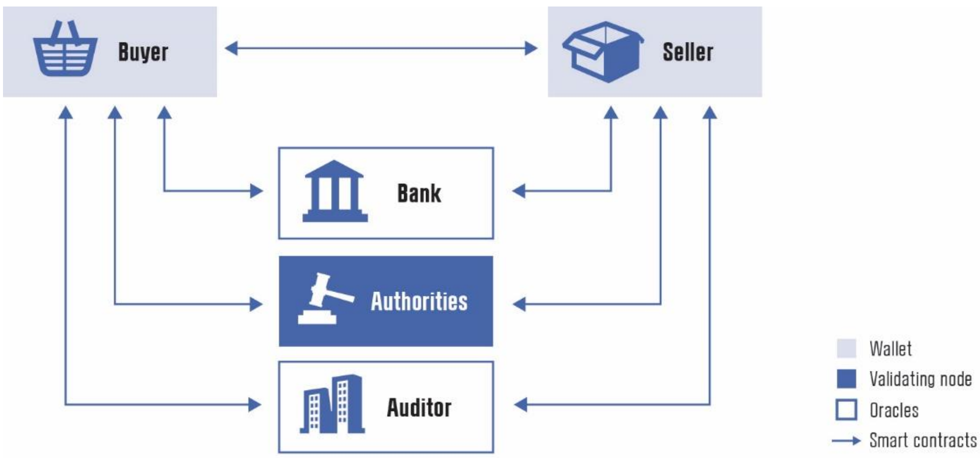

Figure 5. The artifact ecosystem

[36] In biology, an ecosystem is a community of organisms living in conjunction with nonliving components of their environment and interacting as a system (Tansley, 1935). Translated into the context of this study, the artifact ecosystem consists of actors (SMEs, banks, authorities, and auditors) and systems that interact through processes and in the realm of Danish legislation.

SMEs (buyers and sellers) are the key actors within the ecosystem as they carry out transactions. Buyers and sellers are also depicted as wallets, meaning that they interact (through a software application) with the blockchain by proposing, accepting, and/or rejecting business transactions. They do not validate transactions, though, as that would require them to have access to all transactions in the DLT system. An auditor may audit every transaction executed in a controlled environment with cryptographically signed transactions from buyers, sellers, and banks.

During the interview with auditors (interview #5), the question of the auditor's role was brought up. The argument for not appointing the auditor with the responsibility of auditing the smart contract is that a distributed ledger aims to create transparency and remove third parties, such as an auditor. Every participant in the network (companies, authorities, banks, and auditors) can see and review the smart contract code. If the public needed assurance by an auditor that the smart contract code is valid, we could use conventional technology, which needs an element of trust by its users. However, removing the need for third-party trust is the aim of distributed ledger technology. Nevertheless, this does not mean that an auditor should *not* implement VAT settlement rules, but the auditor's stamp of approval should not stand on its own. E.g., there are some scandals on the Ethereum blockchain where audited smart contracts get hacked by nefarious actors; hence relying on a single stamp of approval from the auditor is the very thing DLT want to change.[37] However, for the scope of this prototype, the auditor's role, inspired by Rozario and Thomas (2019), is instantiated as a smart contract function.

Both banks and auditors are categorized as oracles, meaning that they operate outside of the DLT system but provide services on which key actors in the DLT system can be trusted. For this prototype, banks provide payment services, and the auditor provides an opinion on every transaction. The authorities (the Danish tax authorities and the Danish Business Authority) play essential roles as they create policies and legislation for Danish companies' taxation and financial reporting requirements. Furthermore, Figure 5 also shows the authorities as validating nodes that infuse trust into the DLT system by validating transactions.

[37] See https://www.rekt.news/deathbed-confessions-c3pr/ and https://www.rekt.news/akropolis-rekt/ for examples of hacks of audited smart contracts.

8.2 Artifact description

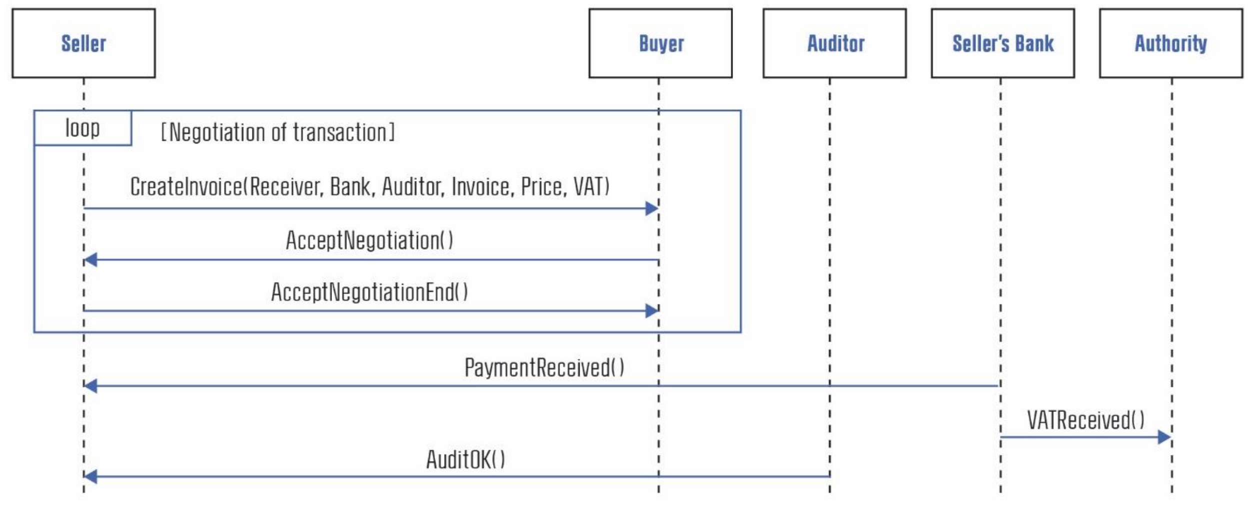

Figure 6. Sequence diagram of a valid transaction – a trivial example

To make the prototype accessible, the built-in web app in Azure Blockchain Workbench was used. The platform also provided user management, which made it possible to meet the design requirements and design principles presented in sections 5 and 6 by presenting only relevant information to the relevant users. For example, to accept a negotiation, a seller must be involved in a transaction. This step was implemented through the smart contract but was also enforced in the user interface. The Azure Blockchain Workbench uses two files to manage the flow of the application and the logic of use cases. The first file is a JSON file containing various metadata on the smart contract. These metadata refer to application roles (buyer, seller, authority, bank, and auditor) and workflows, including properties, constructors, functions, and states. The second file is a Solidity file containing the actual smart contract code. The prototype uses Solidity as the smart contract language as Azure Blockchain Workbench Parity was chosen as the DLT component. In total, the prototype included four roles (seller, buyer, auditor, and bank), and it shows relevant data for these roles only. Figure 3 shows a screenshot of parts of the interface. The role of the authority was presented with a dashboard as the interface (see Figure 4), providing an overview of platform use.

Figure 6 shows a trivial dialog between the actors involved in a business transaction with no renegotiations or rejections – in other words: the “happy path” of this scenario. By implementing the smart contract, it is possible to handle more complex transactions as well, which the state diagram also shows (see Figure 7). The business transactions start off-chain with the buyer indicating its interest in a product or service that the seller offers. Once the willingness to buy has been declared, the on-chain "conversation" begins with the function *CreateInvoice*. In the prototype, the seller populates the fields for the buyer, the bank, the auditor, the price of the product or service, and the VAT amount, as well as a path on the seller's computer to the invoice file. The function, *CreateInvoice*, sets the parameters provided by the seller and creates a hash of the invoice. The hash of the invoice makes it unique and easy to verify later in the process if a disagreement occurs. Storing a hash of the invoice only and not the entire file minimizes the on-chain data load. The function, *CreateInvoice*, updates the state to "Created". After the states "CanBeNegotiated", "IsNegotiating", and "Created" are reached, the function *Negotiate* is invoked. Depending on where in the "conversation" the buyer and the seller are, this function is used over and over again, which the loop in Figure 6 indicates. If the buyer accepts the negotiation, the *AcceptNegotiation* function is called, which changes the state to "CanBeNegotiated". Up to this point, both the buyer and the seller have the option to cancel the transaction. However, if they want to accept the negotiation, they need to accept the invoice, which is accomplished with the *AcceptInvoice* function, updating the state to "InvoiceAccepted".

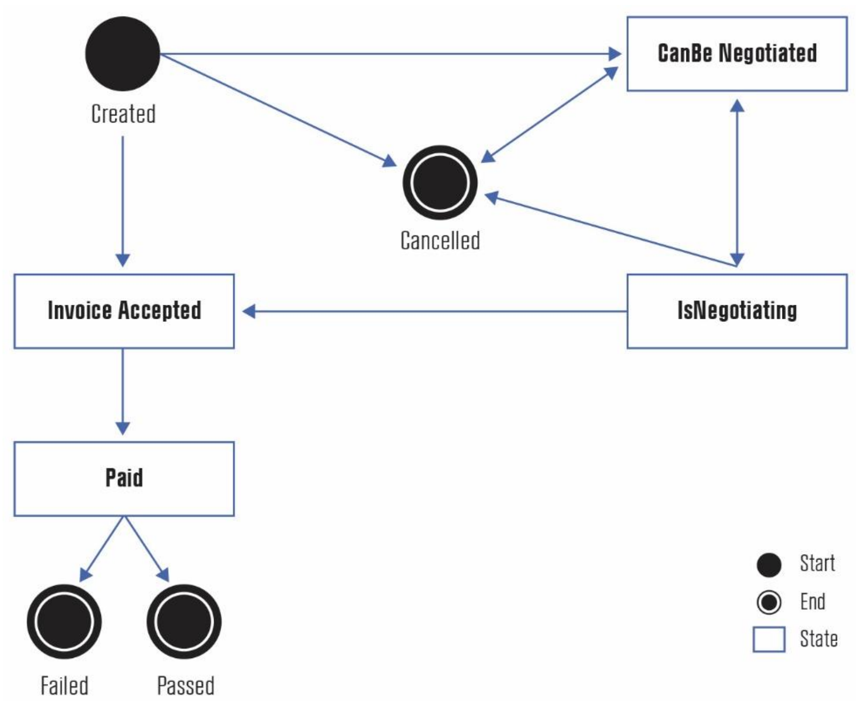

Figure 7. State machine

Once the acceptance of the invoice has taken place, the seller and the buyer have a shared overview of the signed transaction that provides the immutability and audit trail. The bank can accept the payment by calling *AcceptPayment* after it learns of the amount that the seller has to receive and the VAT amount that the authority has to receive, with the state changing to “Paid”.[38] After the payment takes place, the auditor can either accept or reject the transaction. In this case, the auditor accepts the transaction by calling *AuditOK* and changing the state to “Passed”. The transaction is completed, and all of the steps are recorded on the blockchain with cryptographic signatures. All the resources needed for deployment and a video of the process described above can be found on GitHub.[39]

9. EVALUATION

The evaluation of the design features is guided by the design principles (Gregor and Hevner 2013) and presents evidence that the proposed artifact is useful. Evidence obtained from the evaluation both internally within each sprint and externally from the Danish Business Authority, the production company, and the auto repair company indicates that revenue is ensured for government agencies, while the administrative burden on companies is lessened. Even though not all design principles were adhered to throughout the design process, this research nevertheless concludes that the created DLT-based artifact is proven useful. If all design principles had been met, the developed solution would have been ready for production. Table 1 summarizes the evaluation of the four design principles and is followed by a discussion.

[38] In this prototype, the payment layer has not been implemented because the purpose of the prototype was to demonstrate that administrative burdens can be reduced by eliminating the compliance cost from the conversation about the business transactions, rather than to demonstrate which payment channel is optimal knowing that the PSD2 regulation is in place and is widely utilized in the EU market (e.g. Nordic API Gateway). Another option could have been to implement a cryptocurrency payment mechanism on-chain using an ERC20 standard. However, the maturity of central bank digital currency (CBDC) initiatives across the world and in the Nordic region is still too low to implement token schemes that would (possibly) fit a CBDC.

[39] In this repository, the code from the smart contracts and dashboard can be found at https://git.io/Jfu7x.

Category	Design principle	Evaluation	Comments
Data	High level of user access security	Partly met	e-ID should have been integrated
	High level of data access security	Not met	Metadata leakage and split payment mechanism
Architecture	High level of scalability	Met	
	Component-based structure	Met	

Table 1. Design principle evaluation

9.1 High level of user access security

The Azure Blockchain Workbench ensures that the communication between parties is encrypted at the point of distribution so that only the buyer, the seller, their banks, and their auditors can view invoice information distributed across the blockchain. An entire invoice is transferred to bytes and hashed, and its value is added as a part of the transaction. The development team logged in with other users to evaluate whether the access control component of the design principle was complied with through design feature 1 – the transaction trail overview.

Today, authorities have very few touchpoints with companies before the companies self-declare VATs and submit annual financial reporting, which is why design feature 2 – the monitoring dashboard – provides near real-time insight into the Danish economy. It can, therefore, be concluded that DLT features should follow this design principle. In conclusion, because there is no integration with e-ID, the design principle is only partly met. Achieving such integration could strengthen access control and increase companies' trust in the platform, but as such integration would require the creation of a company registration number and a service fee, its added benefit to the evaluation of the prototype would have been minimal and was therefore not pursued.

9.2 High level of data access security

The artifact does not meet the data access security principle, as all information is on-chain. Even though the data are encrypted, it is possible for other actors to see whether company A and company B have made transactions, which is identified as a case of metadata leakage. Further, the prototype does not comply with regulations on data privacy in a European context (GDPR) as the blockchain's immutability capabilities do not allow participants to delete content. A first step toward addressing these problems would involve spending more time analyzing what an on-chain/off-chain architecture would resemble for an improved version of the artifact following the architecture proposed by Xu et al. (2017). Another research area with great potential for enhancing data protection is zero-knowledge proof, which offers ways to manage this design principle (e.g., Wang and Kogan 2018). Further, design feature 3 – split payments – does not integrate with bank accounts in the present artifact. It would be possible to utilize a token on the blockchain. It would be feasible to utilize the PSD2 directive and connect to European banks through standardized APIs or cryptocurrency platforms in future iterations.

9.3 High level of scalability

During building and evaluation iterations, this research found that some transactions were not processed because of the DLT watcher's malfunction. The DLT watcher monitors events occurring on blockchains attached to the Azure Blockchain Workbench, e.g., creating new contract instances, the execution of transactions, and changes in the state of the blockchain. These events are captured and sent to the outbound message broker to be consumed by downstream consumers. This issue was corrected during the seven sprints, but its occurrence shows that the platform remains in its infancy. Documentation of the Azure Blockchain Workbench, however, claims the following: “Using simple transactions, we have benchmarked an average of 400 transactions per second with a network deployed across multiple regions” (Microsoft, 2019). During the evaluation, this researcher did not test this claim, and Microsoft did not explain what “simple transactions” means. However, this claim means that the current level of maturity achieved is likely to manage approximately 230 million invoices per year (130-150 transactions per average peak second), which implies that the current set-up meets this design principle. While this design principle is met in Denmark's case, extensive scalability tests are recommended if the solution is to be extended to other countries. Recently developed DLT solutions, e.g., Hedera and VeChain (Baird et al., 2020; VeChain, 2018), are claimed to offer more mature and scalable solutions.

9.4 Component-based structure

One of the key arguments for using the Azure Blockchain Workbench as the platform for instantiation lies in its component-based structure. Having worked with the Azure Blockchain Workbench and seen the progress and road map from Microsoft’s development team, this researcher judge that it has met the expectations. The component-based structures (31 components in total) of the Azure Blockchain Workbench, which are all interlinked, demonstrate the complexity of a blockchain-as-a-service (BaaS) platform. It can be concluded that the artifact meets this design principle. Further, other scholars are encouraged to test alternative types of BaaS platforms, including those provided by Amazon, Baidu, Google, and IBM. There are still many unknown aspects of the emerging area of BaaS. Based on this study alone, it seems as if some integrations of components (the DLT watcher in this study) may create hidden bottlenecks that must be identified.

9.5 Overall evaluation

The present purely technical evaluation of the instantiation shows that DLT is useful in the context of VAT settlement. While not all design principles were met, the artifact clearly shows that VAT settlements made in near real-time can be managed by a DLT system. As illustrated in Figure 8, the prototype (the line is shown below the process) shows that after starting and agreeing on step 1, i.e., business transactions, the following steps 2-5 can be automated with the use of a smart contract. Step 5 is underlined with a dotted line because this step may include a future cryptocurrency layer, whose implications further research can explore.

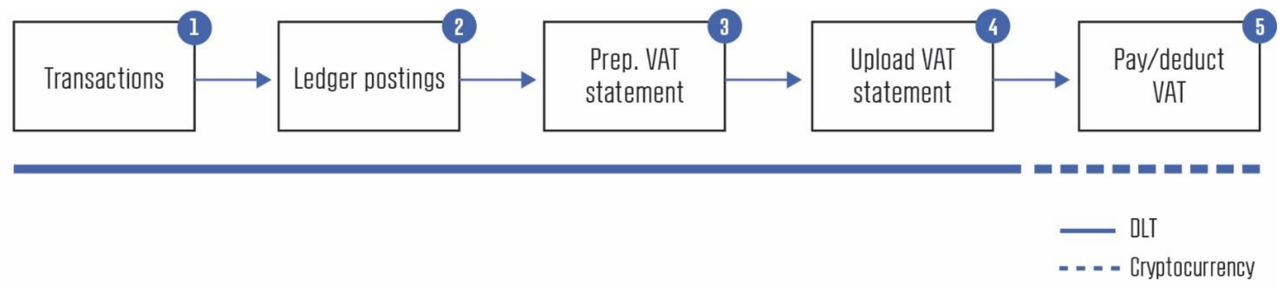

Figure 8. DLT-enabled VAT settlement process

10. DISCUSSION

10.1 Methodology

During the seven sprints of building and evaluating the artifact, this researcher was an integral part of the development team. This researcher did not play the classical role of the merely observant researcher but was an active part in building the artifacts following the DSR approach (Peffers et al., 2007), which builds on Nunamaker et al.'s (1991) work on system development research methodology through the inclusion of action design research (Sein et al., 2011). Being an integral part of the environment being studied introduces the risk of bias. However, the set-up for evaluating the prototype was conducted internally by the development team and externally by the Danish Business Authority's leadership teams, the auto repair company, and the production company. This set-up has mitigated the risk that confirmation bias would color the evaluations' outcome, and it provided the necessary feedback on the proposed design. Further, Meth et al.'s (2015) framework also shows how the empirical data and the literature link the design requirements and design principles to the implemented and evaluated design features, which again limits any bias this researchers' role may have introduced, assuring full transparency.

10.2 Design principles

This paper's generalizable contribution is represented by the four design principles, which were derived from the empirical data, and the literature categorization presented in Appendix B. The appendix makes it evident that no single study presents design principles; they rather focus on specific components of the VAT and/or DLT. This paper extends the literature by formulating design principles in the context of public agencies working on reducing administrative burdens on companies while ensuring compliance (e.g., Bogdanov et al., 2015). In the case of VAT settlement, however, the design principles could be migrated to affiliated areas. Further, this paper shows how design requirements create the basis for design principles that are implemented as design features using a combination of the components presented in the literature. For example, six of the 22 papers mentioned in Appendix B describe digital identity as a core component (Ainsworth et al., 2019; Ainsworth and Shact, 2016; Alkhodre et al., 2019; Brandon, 2016; Fatz et al., 2019; Hyvärinen et al., 2017). The combination of the components from the literature and the context of Denmark provides a novel contribution to AIS research in the public sector field.

10.3 Administrative burdens

Traditional centralized solutions, as indicated by the examples provided in the introduction, do not consider the cost of administrative burdens imposed on companies. This study does not quantify the potential reduction in administrative burdens, as in Ntaliani and Costopoulou (2018) and Braunerhjelm et al. (2019), but it does provide a basis that would enable other researchers to quantify the impact of the artifact presented and extend the literature. Further, the invoicing platform's ultimate purpose is not to serve Danish companies only, and therefore the platform must reduce barriers that prevent governments from coming together. The case of

Denmark as a small, highly digitalized country serves as a useful example and can, and it is hoped, spread across the Nordic countries and the EU and thus address some of the issues that Ainsworth and Shact (2016) and Hyvärinen et al. (2017) point out.

10.4 Generalizing local findings

One of the core challenges of DSR projects involves balancing the identification of solutions to real-world problems, which are typically very context-specific, with contributing to design knowledge that is useful for both scholars and practitioners outside of a specific context. This is what Pöppelbuß and Goeken (2015) call artifact mutability, and they show that it can be interpreted in various ways along 19 dimensions. One way to transcend this study's findings would be to generalize certain context-specific components: 1) the automatic business reporting program that the Danish Business Authority must deliver, 2) the legacy of Danish invoice standards for B2G transactions, and 3) the capacity to uniquely identify companies and persons through e-IDs in the digital world. These local components could be generalized to a global context, including 1) through government willingness and resources to invest in removing the administrative burdens on companies when preparing VAT reports for authorities,[40] 2) by enforcing (by law) data standards for exchanging invoices, and 3) by enforcing the use of e-IDs issued by the government itself or by other highly trusted organizations or communities. Further, the formulation of the technology-agnostic design principle should also support increased artifact mutability.

11. CONCLUSION

This study has created and evaluated an IT artifact for VAT settlement with a strong commitment to reducing administrative burdens designed in collaboration with the Danish Business Authority and Deloitte. From a purely technical perspective, the present work

[40] Already in 2007, the EU program "Reducing Administrative Burdens in the European Union" was established with a target to reduce administrative burdens stemming from EU law by 25 percent by 2012. In 2012, evaluation of the program concluded that the 25 percent reduction in administrative burdens has been implemented. However, in the category of taxations/customs, including VAT, there was still EUR 4.4bn in pending adoption by local authorities, which is equivalent to 3.5 percent of all administrative burdens in the EU (European Commission, 2012).

concludes that DLT is useful for VAT settlement in near real-time. The paper contributes to design knowledge as it presents four design principles and one instantiation of a prototype and thus extends the knowledge bases of VAT and AIS with a focus on DLT. Further, this paper adds practical value to government agencies and other practitioners within the ecosystem. This researcher wants to stress Klein and Meyers's (1999, p. 71) point regarding the need for scholars and practitioners to recognize that "(design) principles are not similar to bureaucratic rules of conduct because the application of one or more of them still requires considerable creative thought." Hence, the design principles that this study offers are principles that should be contextualized and thus should not be considered explicit rules for implementation.

The potential impact of this artifact extends beyond Denmark. One needs, however, to consider the maturity of the Danish e-government services, which is the best in the world (United Nations, 2020), and the limitation of the study by which it focuses only on the communication layer (invoices) and not on problems resulting from linking physical goods to digital ones. Despite these limitations, this paper provides a platform for conducting future research from various perspectives, e.g., from the technical perspective by extending the proposed prototype to other DLT platforms, altering the consensus mechanism, optimizing smart contracts, integrating ERP systems, addressing scalability issues, etc. From an accounting and external auditing perspective, one can ask: What are the implications of such a platform in terms of accounting and auditing standards and practice, and which new skills must an accountant or auditor acquire? Further, from a governance and ecosystem perspective, how should an ecosystem be managed and by whom? How do we make sure that all transactions are recorded on the platform and not just the ones companies want the tax authorities to see? What are the consequences of shared cross-national ownership? These and related questions represent promising research opportunities to further explore the links between AIS, DLT, and how governments can balance the need to maintain tax revenue flows with minimizing administrative burdens.

APPENDIX A. OVERVIEW OF THE EMPIRICAL BASIS AND EVALUATION

The following abbreviations are used: Danish Business Authority = DBA, Deloitte development team = DDT, Deloitte auditors = DA, Author = A, ERP vendor = EV, Auto repair company = SME1, Production company = SME2

#	Type of encounter	Participants	Duration
1	Kick-off meeting for the entire project	DBA, DDT, A	60 mins.
2	Environment: interview with SMEs	SME1, A	45 mins.
3	Use case selection	DBA, DDT, A	60 mins.
4	People: interview focusing on VAT settlement and reporting needs for SMEs	DBA, A	33 mins.
5	People: interview focusing on VAT settlement and reporting needs for SMEs	DA, A	35 mins.
6	People: interview focusing on VAT settlement and reporting needs for SMEs	EV1, A	57 mins.
7	People: interview focusing on VAT settlement and reporting needs for SMEs	EV2, A	60 mins.
8	Steering committee meeting: reporting progress	DBA, DDT, A	60 mins.
9	Organization: interview focusing on DBA's strategic agenda	DBA, A	80 mins.
10	Organization: interview focusing on DBA's operationalization of automatic business reporting program	DBA, A	50 mins.
11	Technology: interview focusing on the current VAT process for SMEs	DBA, A	28 mins.
12	Environment: interview with SMEs	SME2, A	65 mins.
13	IS research: workshop focusing on design principles	DBA, DDT, A	49 mins.
14	Steering committee meeting: reporting progress	DBA, DDT, A	60 mins.
15-21	Internal evaluation after every sprint – seven in total	DDT, A	N/A
22	External evaluation focusing on SMEs	SME1, A	N/A
24	External evaluation focusing on SMEs	SME2, A	N/A
25	External evaluation focusing on authorities, DBA	DBA, DDT, A	N/A

APPENDIX B. DESIGN PRINCIPLES INFORMED BY THE LITERATURE

Author	DSR	VAT	DLT	Actors identified	Inform design principles
Hyvärinen et al. (2017)	X		X	1) Regulatory agencies, 2) Financial third party, 4) Investors	1) Digital identity, 2) Smart contracts
Brandon (2016)			X	1) Accountants, 2) Auditors	1) Blockchain ecosystems, 2) Digital identity
Alkhodre et al. (2019)		X	X	1) Companies, 2) the European Union, 3) Regulatory agencies, 4) Auditors	1) Digital identity, 2) Permissioned blockchain
McCallig et al. (2019)	X		X	1) Auditors, 2) Companies	1) Digital identity
Wang and Kogan (2018)			X	1) Companies, 2) Auditors, 3) Regulatory agencies, 4) Financial third party	1) Zero-knowledge proof, 2) Tokenization
Rozario and Vasarhelyi (2018)			X	1) Auditors, 2) Regulatory agencies, 3) Investors, 4) Auditors	1) Smart contracts
Coyne and McMickle (2017)			X	1) Companies	1) Permissioned blockchain
Dai and Vasarhelyi (2016)				1) Companies, 2) Auditors, 3) Financial third party	1) No design input
Rozario and Thomas (2019)	X		X	1) Auditors, 2) Investors, 3) Regulatory agencies	1) Smart contracts, 2) Blockchain ecosystems, 3) Government participation in blockchain ecosystems
Dai and Vasarhelyi (2017)			X	1) Managers, 2) Accountants, 3) Auditors, 4) Companies	1) Smart contracts, 2) ERP blockchain integration, 3) Tokenization
Fatz et al. (2019)	X	X	X	1) Auditors, 2) Companies, 3) Regulatory agencies, 4) N/A	1) Standardization, 2) Digital identity, 3) Tokenization, 4) Zero-knowledge proof
Xu et al. (2019)			X	1) N/A	1) Blockchain taxonomy
Glaser (2017)			X	1) N/A	1) Blockchain taxonomy
Xu et al. (2017)			X	1) N/A	1) Blockchain taxonomy

Ainsworth and Shact (2016)		X	X	1) Companies, 2) the European Union, 3) Regulatory agencies, 4) Companies	1) Digital identity
Ainsworth, Alwohaibi, Cheetham (2016)		X	X	1) Companies, 2) European Union, 3) Regulatory agencies, 4) Companies	1) Tokenization, 2) Smart contracts 3) Digital Identity
Ainsworth et al. (2019)		X	X	1) Companies, 2) the European Union, 3) Regulatory agencies, 4) N/A	1) Digital identity
Nakamoto (2008)			X	1) N/A	1) Blockchain taxonomy
Szabo (1997)			X	1) N/A	1) Smart contracts
Wijaya et al. (2017)		X	X	1) Regulatory agencies, 2) Companies, 3) Financial third party	1) Tokenization
Bogdanov et al. (2015)		X		1) Regulatory agencies, 2) Companies	1) Privacy for companies, 2) Data utility for investigators, 3) Transparency, 4) Performance

ACKNOWLEDGMENTS

Thanks to Morten Holm, Thomas Riise Johansen, Rasmus Winther Mølbjerg, Lasse Herskind, Nils-Bro Müller, Abigail (Abby) Zhang, Alexander Kogan, Deniz Appelbaum, and Benita Gullkvist for guiding the work. Furthermore, helpful comments from the audience who attended the 2020 Joint Midyear Meeting of the AIS, SET and International Sections are highly appreciated. Lastly, thanks to the International Journal of Accounting Information Systems reviewers and editors for their insightful comments in the review process.

REFERENCES

Agency for Digitisation, 2010. NemID [WWW Document]. URL https://digst.dk/it-loesninger/nemid/om-loesningen/nemid-erhverv/

Ainsworth, R.T., Alwohaibi, M., Cheetham, M., 2016. VATCoin: The GCC''s CryptoTAXcurrency. Bost. Univ. Sch. Law Law Econ. Work. Pap. 17, 1–24.

Ainsworth, R.T., Cheetham, M., Tirand, C. V, Ainsworth, R.T., Cheetham, M., Tirand, C. V, 2019. A VATcoin Solution To Mtic Fraud : Past Efforts , Present Technology , and the Eu ' S 2017 Proposal. Bost. Univ. Sch. Law Law Econ. Ser. Pap. 18.

Ainsworth, R.T., Shact, A., 2016. Blockchain (Distributed Ledger Technology) Solves VAT Fraud. Law Econ. Work. Pap. 16.

Alkhodre, A., Ali, T., Jan, S., Alsaawy, Y., Khusro, S., Yasar, M., 2019. A Blockchain-based value added tax (VAT) system: Saudi Arabia as a use-case. Int. J. Adv. Comput. Sci. Appl. 10, 708–716. https://doi.org/10.14569/ijacsa.2019.0100588

Allers, M.A., 1994. Administrative and compliance costs of taxation and public transfers in the Netherlands. Groningen: Wolters- Noordhoff.

Baird, L., Harmon, M., Madsen, P., 2020. Hedera: A Public Hashgraph Network & Governing Council.

Berkeley, J., 2015. The Trust machine - The technology behind bitcoin could transform how the economy works. Econ.

Bogdanov, D., Jõements, M., Sander, S., Vaht, M., 2015. How the Estonian Tax and Customs Board Evaluated a Tax Fraud Detection System Based on Secure Multi-party Computation, in: Financial Cryptography and Data Security 19th International Conference. pp. 227–334. https://doi.org/10.1007/978-3-662-47854-7

Bozanic, Z., Dirsmith, M.W., Huddart, S., 2012. The social constitution of regulation: The endogenization of insider trading laws. Accounting, Organ. Soc. 37, 461–481. https://doi.org/10.1016/j.aos.2012.06.003

Bozeman, B., 2007. Public values and public interest: Counterbalancing economic individualism. Georgetown University Press, Washington, D.C.

Brandon, D., 2016. The Blockchain - The Future of Business Information Systems? Int. J. Acad. Bus. World 10, 33–40. https://doi.org/10.1364/BOE.6.003898

Braunerhjelm, P., Eklund, J.E., Thulin, P., 2019. Taxes, the tax administrative burden and the entrepreneurial life cycle. Small Bus. Econ. https://doi.org/10.1007/s11187-019-00195-0

Burden, B.C., Canon, D.T., Mayer, K.R., Moynihan, D.P., 2012. The Effect of Administrative Burden on Bureaucratic Perception of Policies: Evidence from Election Administration. Public Adm. Rev. 72, 741–751. https://doi.org/10.1111/j.1540-6210.2012.02600.x

Buterin, V., 2013. A next-generation smart contract and decentralized application platform. Etherum 11, 7. https://doi.org/10.1016/j.jchromb.2013.02.015

Chen, Y.C., 2012. A comparative study of e-government XBRL implementations: The potential of improving information transparency and efficiency. Gov. Inf. Q. 29, 553–563. https://doi.org/10.1016/j.giq.2012.05.009

Chintapalli, S., Dagit, D., Evans, B., Farivar, R., Graves, T., Holderbaugh, M., Liu, Z., Nusbaum, K., Patil, K., Peng, B.J., Poulosky, P., 2016. Benchmarking streaming computation engines: Storm, flink and spark streaming. Proc. - 2016 IEEE 30th Int. Parallel Distrib. Process. Symp. IPDPS 2016 1789–1792. https://doi.org/10.1109/IPDPSW.2016.138

Coenen, T., Coertjens, L., Vlerick, P., Lesterhuis, M., Mortier, A.V., Donche, V., Ballon, P., De Maeyer, S., 2018. An information system design theory for the comparative judgement of competences. Eur. J. Inf. Syst. 27, 248–261. https://doi.org/10.1080/0960085X.2018.1445461

Coyne, J.G., McMickle, P.L., 2017. Can Blockchains Serve an Accounting Purpose? J. Emerg. Technol. Account. 14, 101–111. https://doi.org/10.2308/jeta-51910

Dai, J., Vasarhelyi, M.A., 2017. Toward Blockchain-Based Accounting and Assurance. J. Inf. Syst. 31, 5–21. https://doi.org/10.2308/isys-51804

Dai, J., Vasarhelyi, M.A., 2016. Imagineering Audit 4.0. J. Emerg. Technol. Account. 13, 1–15. https://doi.org/10.2308/jeta-10494

Danish Business Authority, 2019. Submission of Annual Report [WWW Document]. URL https://indberet.virk.dk/myndigheder/stat/ERST/Regnskab_20

Danish Government, 2020. Danish Financial Statements Act [WWW Document]. URL https://danskelove.dk/årsregnskabsloven (accessed 5.25.20).

Danish Government, 2004. Retsinformation [WWW Document]. URL https://www.retsinformation.dk/Forms/R0710.aspx?id=5749

Danmarks Nationalbank, 2019. Betalinger mellem virksomheder kostede samfundet 4,2 mia. kr.

Deloitte, 2017. Analyse af erhvervsøkonomiske konsekvenser af udvalgte e-handelsinitiativer Samlet rapport 15.

European Commission, 2019. European Blockchain Infrastructure Services [WWW Document]. URL https://ec.europa.eu/cefdigital/wiki/display/CEFDIGITAL/EBSI (accessed 9.24.20).

European Commission, 2018a. Digital Economy and Society Index 2018 Report.

European Commission, 2018b. GDPR [WWW Document]. URL https://eur-lex.europa.eu/legal-content/DA/TXT/?uri=CELEX%3A32016R0679

European Commission, 2014a. PEPPOL [WWW Document]. URL https://ec.europa.eu/growth/single-market/public-procurement/e-procurement/e-invoicing_en (accessed 8.27.19).

European Commission, 2014b. eIDAS [WWW Document]. URL https://www.eid.as/home/ (accessed 5.5.20).

European Commission, 2012. Action Programme for Reducing Administrative Burdens in the EU Final Report.

EY, 2018. Worldwide electronic invoicing survey, EY.

Fatz, F., Hake, P., Fettke, P., 2019. Towards Tax Compliance by Design: A Decentralized Validation of Tax Processes Using Blockchain Technology. IEEE 21th Conf. Bus. Informatics 01, 559–568. https://doi.org/10.1109/CBI.2019.00071

Feher, K., 2019. Digital identity and the online self: Footprint strategies – An exploratory and comparative research study. J. Inf. Sci. https://doi.org/10.1177/0165551519879702

Geerts, G.L., 2011. A design science research methodology and its application to accounting information systems research. Int. J. Account. Inf. Syst. 12, 142–151. https://doi.org/10.1016/j.accinf.2011.02.004

Glaser, F., 2017. Pervasive Decentralisation of Digital Infrastructures: A Framework for Blockchain enabled System and Use Case Analysis, in: Hawaii International Conference on System Sciences. pp. 1543–1552.

Hevner, A.R., March, S.T., Park, J., Ram, S., 2004. Design Science in Information Systems

Research. MIS Q. 28, 75–105.

Houlding, S.W., 2001. XML — an opportunity for <meaningful> data standards in the geosciences. Comput. Geosci. 27, 839–849.

Hungarian Tax Authority, 2018. Hungarian Tax Authority [WWW Document]. URL https://onlineszamla.nav.gov.hu/home (accessed 3.4.20).

Hyvärinen, H., Risius, M., Friis, G., 2017. A Blockchain-Based Approach Towards Overcoming Financial Fraud in Public Sector Services. Bus. Inf. Syst. Eng. 59, 441–456. https://doi.org/10.1007/s12599-017-0502-4

Institute for Advanced Studies, 2018. Study and Reports on the VAT Gap in the EU-28 Member States : 2018 Final Report.

Jacobson, I., Christerson, M., Jonsson, P., Ōvergaard, G., 1992. Object-oriented software engineering: a use case driven approach. Addison-Wesley.

Jørgensen, T.B., Bozeman, B., 2007. Public Values. Adm. Soc. 39, 354–381.

Klein, H.K., Myers, M.D., 1999. A Set of Principles for Conducting and Evaluating Interpretive Field Studies in Information Systems. MIS Q. 23, 67–93. https://doi.org/10.2307/249410

Kokina, J., Mancha, R., Pachamanova, D., 2017. Blockchain: Emergent Industry Adoption and Implications for Accounting. J. Emerg. Technol. Account. 14, 91–100. https://doi.org/10.2308/jeta-51911

Kreps, J., Narkhede, N., Rao, J., 2011. Kafka: a Distributed Messaging System for Log Processing, in: NetDB. pp. 1–7. https://doi.org/10.1007/BF00640482

Lamport, L., Shostak, R., Pease, M., 1982. The Byzantine Generals Problem. Trans. Program. Lang. Syst. 4, 382–401.

McCallig, J., Robb, A., Rohde, F., 2019. Establishing the representational faithfulness of financial accounting information using multiparty security, network analysis and a blockchain. Int. J. Account. Inf. Syst. 33, 47–58. https://doi.org/10.1016/j.accinf.2019.03.004

Meth, H., Mueller, B., Maedche, A., 2015. Journal of the Association for Information Designing a Requirement Mining System. J. Assoc. Inf. Syst. 16. https://doi.org/10.17705/1jais.00408

Microsoft, 2019. Azure Blockchain Workbench [WWW Document]. URL https://docs.microsoft.com/en-us/azure/blockchain/templates/ethereum-poa-deployment#what-is-the-expected-transaction-throughput-of-proof-of-authority (accessed 10.23.20).

Ministry of Finance, Ministry of Industry, B. and F.A., Ministry of Taxation, Danske Regioner, Kommunernes Landsforening, 2016. Automatic Business Reporting.

Nakamoto, S., 2008. Bitcoin: A Peer-to-Peer Electronic Cash System.

Ntaliani, M., Costopoulou, C., 2018. E-Government for Lowering Administrative Burden: An Empirical Research on European Rural Businesses. Int. J. Public Adm. 41, 700–711. https://doi.org/10.1080/01900692.2017.1296865

Ntaliani, M., Costopoulou, C., 2017. Reduction of Administrative Burdens for SMEs. Adm. Soc. 49, 1143–1164. https://doi.org/10.1177/0095399714558715

Nunamaker, J.F., Chen, M., Purdin, T.D.M., 1991. Systems Development in Information Systems Research. J. Manag. Inf. Syst. 7, 89–106. https://doi.org/10.1109/isie.1992.279627

Parity, 2019. Aura Proof-of-Authority [WWW Document]. URL https://wiki.parity.io/Aura (accessed 8.1.19).

Pedersen, A.B., Risius, M., Beck, R., 2019. A Ten-Step Decision Path to Determine When to Use Blockchain Technologies. MIS Q. Exec. 18, 99–115. https://doi.org/10.17705/2msqe.00010

Peeters, R., Widlak, A., 2018. The digital cage: Administrative exclusion through information architecture – The case of the Dutch civil registry's master data management system. Gov. Inf. Q. 35, 175–183. https://doi.org/10.1016/j.giq.2018.02.003

Peffers, K., Tuunanen, T., Rothenberger, M.A., Chatterjee, S., 2007. A Design Science Research Methodology for Information Systems Research. J. Manag. Inf. Syst. 24, 45–77. https://doi.org/10.2753/mis0742-1222240302

Pöppelbuß, J., Goeken, M., 2015. Understanding the Elusive Black Box of Artifact Mutability, in: Thomas, O., Teuteberg, F. (Eds.), 12th International Conference on Wirtschaftsinformatik. pp. 1557–1571.

Rozario, A.M., Thomas, C., 2019. Reengineering the Audit with Blockchain and Smart Contracts. J. Emerg. Technol. Account. 16, 21–35. https://doi.org/10.2308/jeta-52432

Sein, M., Henfridsson, O., Purao, S., Rossi, M., Lindgren, R., 2011. Action Design Research. MIS Q. 35, 37–56. https://doi.org/10.2307/23043488

Szabo, N., 1997. Formalizing and Securing Relationships on Public Networks. First Monday 2. https://doi.org/10.5210/fm.v2i9.548

Tansley, A.G., 1935. The use and abuse of vegetational concepts and terms. Ecology 16, 284–307.

Troshani, I., Janssen, M., Lymer, A., Parker, L.D., 2018. Digital transformation of business-to-government reporting: An institutional work perspective. Int. J. Account. Inf. Syst. 31, 17–36. https://doi.org/10.1016/j.accinf.2018.09.002

United Nations, 2020. E-Government Survey 2020 - DIGITAL GOVERNMENT IN THE DECADE OF ACTION FOR SUSTAINABLE DEVELOPMENT.

VeChain, 2018. Development Plan and Whitepaper.

Venable, J.R., Pries-Heje, J., Baskerville, R.L., 2016. FEDS: A Framework for Evaluation in Design Science Research. Eur. J. Inf. Syst. 25, 77–89. https://doi.org/10.1057/ejis.2014.36

Wang, Y., Kogan, A., 2018. Designing confidentiality-preserving Blockchain-based transaction processing systems. Int. J. Account. Inf. Syst. 30, 1–18. https://doi.org/10.1016/j.accinf.2018.06.001

Wijaya, D.A., Liu, J.K., Suwarsono, D.A., Zhang, P., 2017. A New Blockchain-Based Value-Added Tax System, in: Provable Security. pp. 471–486. https://doi.org/10.1007/978-3-319-68637-0

Xu, X., Weber, I., Staples, M., 2019. Architecture for Blockchain Applications, 1st ed. ed. Springer International Publishing, Cham.

Xu, X., Weber, I., Staples, M., Zhu, L., Bosch, J., Bass, L., Pautasso, C., Rimba, P., 2017. A taxonomy of blockchain-based systems for architecture design, in: Proceedings - 2017 IEEE International Conferense Software Architecture. pp. 243–252.

PAPER 3

Crash vs. Byzantine fault tolerance at scale: the cost of distributing trust in a (trans)national invoicing system

Jonas Sveistrup Søgaard

Copenhagen Business School | Department of Accounting | jss.acc@cbs.dk

Peter Eklund

Deakin University | School of Info Technology | peter.eklund@deakin.edu.au

Lasse Herskind

Deloitte | NextGen | lasse.herskind@gmail.com

Jason Spasovski

Deloitte | NextGen | jason@ztlment.com

ABSTRACT: This paper examines the feasibility of a blockchain solution for national and transnational business-to-business and business-to-government (B2B/B2G) compliance frameworks, namely a trust-less, decentralized, self-regulating distributed ledger. In particular, the paper examines whether blockchain platforms scale to support national and transnational blockchain-based invoicing platforms, presented in paper 2. The case study looks at the resources required to operate a B2B/B2G compliance framework in two different geographic scenarios. The first considers a national scale based on Denmark, the tenth-largest European country by GDP. The second scenario considers all 27-member states of the European Union (EU) (and the UK). The paper addresses blockchain solutions' performance; two are Byzantine fault tolerant (BFT), and one is crash fault tolerant (CFT). Specifically, the paper measures the additional cost of the trust that results from BFT at scale compared to CFT.

KEYWORDS: distributed ledger; blockchain; survey of system performance; distributed network scalability.

1. INTRODUCTION

Architectural and performance-related challenges are critical when deploying national and/or transnational information technology (IT) infrastructure. These challenges are especially present when countries want to support the growth of economies on new digital infrastructure. E.g., in China, the Blockchain-based Service Network (BSN) was launched in April 2020 and is intended to be deployed in 200 Chinese cities by the end of 2020 (Stockton, 2020). That effort reflects the emerging idea of adopting blockchain technology as a national business ecosystem. In Europe, compliance to a transnational peer-to-peer business ecosystem has a different purpose to China's BSN efforts. More specifically, Søgaard (2021) presents a Danish case where the Danish business authority examines a blockchain-based platform for value-added tax (VAT) reporting and the implications of tax revenue collection and administrative burdens on small and medium-sized enterprises. The Danish case shows that European countries focus on financial reporting and compliance reporting to government agencies (e.g., VAT) rather than controlling participation in the economy as the Chinese BSN does. Nonetheless, European-scale confronts similar architectural and performance-related challenges on the prospect for a national/transnational e-commerce trading platform.

Specific features of blockchain systems are their peer-to-peer distributed (often decentralized) trust network, their tamper-resistant record of events, and their ability – in the second generation – to execute domain-specific languages within the distributive ledger architecture itself. They are implementing a distributed virtual machine where the persistent logic rules are framed in terms of "smart contracts" (Szabo, 1994).

These characteristics recommend blockchain systems as a decentralized business ledger with embedded transactional logic, accessible for B2B transactions and B2G reporting and compliance. Additionally, some blockchains are highly resistant to malicious nodes and can tolerate up to f malicious or faulty processes out of n s.t. $n \geq 3f + 1$; this is called Byzantine Fault Tolerance (BFT) (Lamport, Shostak, & Pease, 1982). The BFT security property comes with an additional cost of agreement. However, if the environment is not considered hostile, i.e., the only fault that may occur is machine unavailability, it may be good enough to allow up to $n/2$ unavailable nodes; this is called Crash Fault Tolerance (CFT).

This paper compares the performance of two well-known BFT blockchain architectures, Quorum (ConsenSys, 2021) and Tendermint (Buchman, 2016), against the non-BFT Hyperledger Fabric version 1.4 using Kafka (Vukolić, 2017). Kafka is a centralized, replicated, and distributed database (Kreps, Narkhede, & Rao, 2011) and one of the ordering mechanisms that can be used in Hyperledger Fabric (the other is Raft, see Table 1). Further, since Kafka is CFT and not BFT, we also want to isolate Hyperledger Fabric's effect by running similar tests when only deploying Kafka. The premise is that CFT-based protocols should be much faster than BFT variants, and the difference between their performance is a measure of the cost of the additional trust that BFT provides. One could also anticipate that the CFT blockchain variant, Hyperledger Fabric, would be faster than its BFT cousins, a claim often made[41] and tested by this paper. Curiously, and for reasons that we will explore in detail, this proves not to be the case.

A first use-case considers the scenario of a national e-commerce trading system based around the volume of transactions in Denmark, a nation with the tenth-largest GDP in the EU and a well-developed digital economy. According to reports from Deloitte (Deloitte, 2017) and the Danish National Bank (Danmarks Nationalbank, 2019), the Danish B2B and B2G markets handle 225 to 235 million invoices each year. However, before an invoice is finalized between buyer and seller, there are, on average, five documents exchanged (offer, purchase order, invoice, acceptance note, credit note), which we call *related traffic*.[42]

This implies a national e-commerce trading system able to handle the entire volume of B2B and B2G traffic will need to manage 1.12 to 1.17 billion transactions annually. Standards for e-invoices in Denmark (Danish Business Authority, 2019) and the EU[43] mean that the maximum size of the document exchanged is 50 kilobytes (KB). However, on average, these documents are estimated to be 10 KB (OpenPEPPOL, 2019). Computing the product of this quantity of data by the volume of transactions yields (worst case) a data storage requirement for a blockchain corresponding to 11.5 to 12.0 terabytes (TB) p.a., three times larger than the current size of the Ethereum blockchain – for Denmark alone. [44]

---

[41] https://hyperledger-fabric.readthedocs.io/en/release-2.2/whatis.html#performance-and-scalability

[42] For simplicity, related traffic documents are assumed to be the same size as an invoice.

[43] PEPPOL is the Pan-European Public Procurement on-Line According to EU Directive 2014/55/EU on e-Invoicing (implemented April 2019).

[44] https://www.statista.com/statistics/647523/worldwide-bitcoin-blockchain-size/

In terms of throughput, the number of e-commerce transactions entering the B2B/B2G system is not uniform. Most transactions occur during business hours (0800 to 1800) Monday to Friday, on workdays, and traffic peaks around the end-of-calendar-month, end-of-quarter, and end-of-financial-year. Based on peak intervals and transaction volume, the Danish scenario is described by the formula:

$$\frac{\text{Number of Invoices} \times \text{Related Traffic} = \text{Total Traffic}}{12\ (\text{months}) \times 20\ (\text{working days}) \times 10\ (\text{working hours})}$$

Applying the formula above results in the range of 130 to 135 transactions per second (*tps*) during peak periods. There are no hard requirements for response time since the use-case deals with invoices and related traffic only. Payment is assumed to occur off-chain using traditional financial settlement systems, so real-time responses, similar to those required for credit card settlements, are not required.

A second scenario considers a transnational e-commerce trading system for the EU. Extending the use-case across a 27-member EU (and the UK) requires a system that can manage 17-billion invoices (Betalingsrådet, 2015). If the system handles 17-billion transactions, it requires around 2,000 *tps*. However, when related traffic is included in the calculation, 9,000 to 10,000 *tps* is a credible upper range for peak throughput. Because the use-case is both B2B and B2G, there is a strong governance aspect concerning who can read/write to the ledger; thus, another requirement is that the blockchain is permissioned. The two scenarios' results present valuable insight into the feasibility of a blockchain-based invoicing platform presented in Søgaard (2021).

This paper is structured as follows. In section 2, the research design is discussed, the design science research methodology, the possible permissioned blockchains for the study, including those that were excluded and why. A description of the two BFT blockchain technologies chosen is offered, and the CFT enterprise blockchain is presented. In section 3, the paper describes the test protocols, the test platform, and the specific configuration settings for each test. Section 4 presents empirical results. Section 5 discusses the key findings, and in section 6 the paper draws its conclusions.

2. RESEARCH DESIGN

2.1 Design science research

This study employs the design science research (DSR) methodology consisting of the environment, the knowledge base, and information systems (IS) research (Hevner, March, Park, & Ram, 2004). The environment represents problem relevance through people, organizations, and technologies. In this case, the environment consists of the two scenarios described above, the EU zone's VAT problem and the distributed ledger technology (DLT). The knowledge base represents academic rigor and is represented by the field of blockchain performance literature, see Table 1 and the case study by Søgaard (2021) calling for action on “addressing scalability issues” (p. 14). The IS research consists of two components; build and evaluate. The build component is where we deploy the four platforms ready for testing on the same cloud infrastructure. In the evaluate component, we follow Venable et al.’s (2016) evaluation framework using the “Technical Risk & Efficacy” strategy, since the criterion of “… If a critical goal of the evaluation is to rigorously establish that the utility/benefit is due to the artefact, not something else” (p. 82) match the purpose of this paper. Sections 2.2, 2.3, and 3 explain how the selection of the platforms happened, which benchmarking methodology is used during the evaluation, and the testing framework. Note that the learning from the build and evaluate components is an integral part of the relationship between the two components and therefore had multiple iterations of the cycle.

2.2 Selection of platforms

To assemble a list of candidate blockchain platforms, we surveyed (Beck, Eklund, & Spasovski, 2019; Buchman, 2016; Cachin & Vukolic, 2017) and recorded the performance claims in Table 1. In the context of our "in-the-wild" use-case, we select the most popular permissioned enterprise blockchain platform (Gonczol, Katsikouli, Herskind, & Dragoni, 2020), namely Hyperledger Fabric, to serve as a performance baseline. To benchmark against Hyperledger Fabric, three criteria for selection were developed. First, the performance claims found in the literature had to match at least the requirements set by the Danish national scenario, and preferably the EU scenario. The second is the need to secure consensus in the presence of bad actors. Therefore, blockchain platforms' consensus mechanism had to be BFT, so more secure than Hyperledger Fabric. Third, the platform had to be readily available, not proprietary, or performance-limited (throttled). These selection criteria narrowed the pool to three BFT blockchain solutions: Hedera, Quorum Istanbul, and Tendermint. Hedera's consensus service, which would have been well-suited to test for this use-case, had an arbitrary limit of 500 tps set by Hedera's development team at the time of writing, which could not be re-negotiated. This leaves us two BFT blockchain platforms; Quorum Istanbul and Tendermint.

Framework Name	Type	Consensus Algorithm	OpenSource	Throughput (tps)	Response time (secs)
Bitcoin	Open	PoW	Y	3-5	>500
Ethereum	Open	PoW	Y	15-30	360
Kadena	Open	Scalable PoW-BFT	N	10,000	<0.1
Hedera	Open	Hashgraph (aBFT)	(Y)	10,000	<0.1
IOTA	Semi-open	Tangle	Y	200	N/A
NEO	Semi-open	Delegated-BFT	Y	10,000	15-20
EOS	Semi-open	Delegated BFT	Y	3,996	<1
Ripple	Closed	RPCA (Ripple Protocol Consensus Algorithm)	Y	50,000	4
Hyperledger Fabric	Closed	Kafka/Raft	Y	>3,500	<1
Hyperledger Sawtooth	Closed	Proof of Elapsed Time (PoET)	Y	>80,000	<1
MultiChain	Closed	PBFT + MultiChain	Y	1000-1500	5-10
Quorum	Closed	Istanbul BFT (IBFT)	Y	600-900	5
Tendermint	Closed	Tendermint BFT	Y	4,000-14,000	<1
Red Belly	Closed	Democratic-BFT	N	660,000	2-4

Table 1. Some blockchain performance claims, extended from Beck & Eklund (2019), Buchmand (2016), and Cachin & Vukolic (2017). The staging of each experiment reporting throughput. Types of blockchain; Open = Public permissionless; Semi-open = Public Permissioned; Closed = Private Permissionless.

In the above-mentioned selection criteria, we do not emphasize security and performance, as we argue that if a system cannot handle the throughput requirements, then security becomes irrelevant. However, in the inverse scenario, where a less-secure system exists, performance is still relevant. If the performance requirements for this use-case are not met using a BFT platform, we wish to measure the cost of distributing trust by comparing CFT vs. BFT. This puts a value on the cost of BFT trust in blockchains. Hyperledger Fabric using Kafka is selected to identify a CFT blockchain's baseline that runs on identical hardware and network infrastructure as the BFT blockchain platforms. In our experiments, Hyperledger Fabric using Kafka under-performed, so we decided to test a pure CFT implementation without the blockchain Hyperledger Fabric wrapping, this being the reason to run the same tests with Kafka only.

2.2.1 The Quorum blockchain

Quorum (ConsenSys, 2021) is a permissioned implementation of the public permissionless blockchain Ethereum. Being permissioned means that participation in the blockchain is limited to a known set of provisioned nodes in the network. By default, Quorum provides RAFT consensus (Ongaro & Ousterhout, 2014) and Istanbul BFT (IBFT) (Moniz, 2020). Because BFT is required, IBFT consensus is chosen. To understand Quorum, it is essential to highlight some specifics about the Ethereum blockchain. Ethereum can be characterized as a large distributed finite state machine, where transactions can be viewed as state transitions, i.e., a block is a list of transitions. Transactions (and hence transitions) should be well-formed (have the correct number of values) and carry a valid signature (there are other rules, see the Ethereum whitepaper (Buterin first published 2013)). A developer can define the specifics of transactions, and these programmable state transitions are known as smart contracts. In other words, a smart contract is a way to encode a state transition.[45] As Ethereum stores the complete ordered list of transactions (state transitions), it is possible to re-run the blockchain by replaying every state transition from the original state: this occurs when a node is synchronizing.

An example of a state transition is shown in Figure 1, which illustrates how a smart contract located at `bb75a980` transitions the *State* to *State'*.

[45] For additional rules, please see: https://github.com/ethereum/wiki/wiki/White-Paper#ethereum-state-transition-function

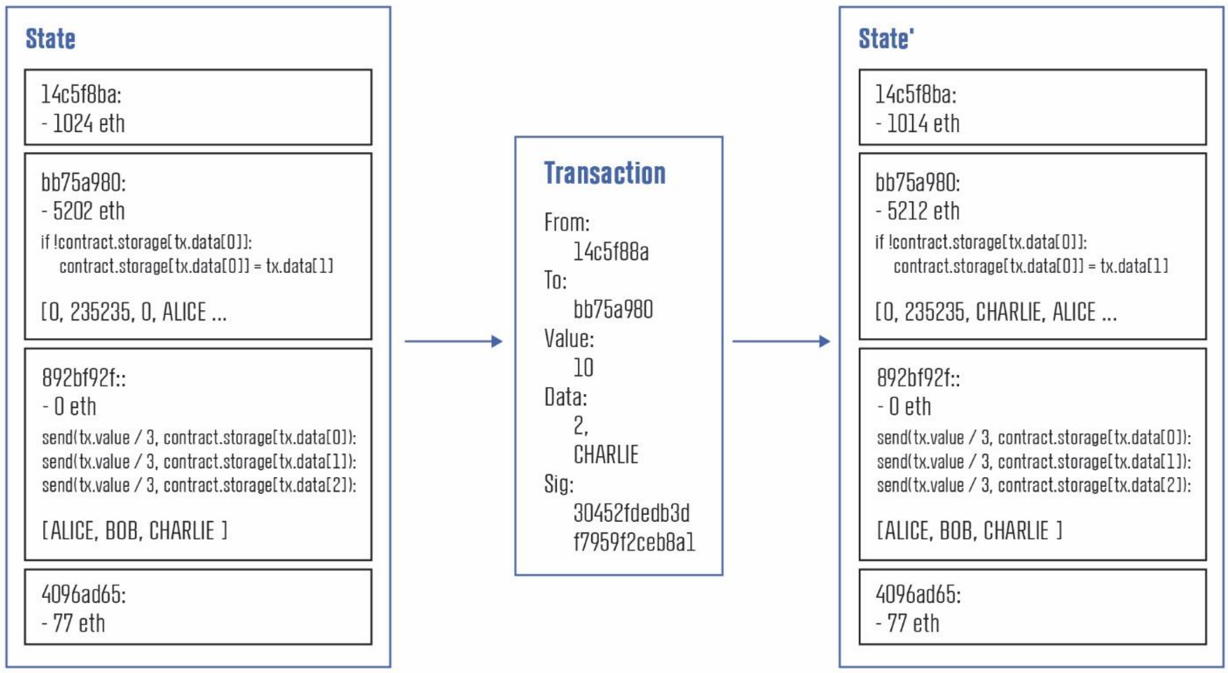

Figure 1. The Ethereum state transition, adopted from the Ethereum whitepaper (Buterin first published 2013)[46]

When a developer defines a smart contract, she must define where data is to be stored. In Ethereum, three locations are available that allow data to persist; these are *Storage*, *Memory*, and *Calldata*, and each of these locations has its own merits and gas-costs. Variables located in *Storage* are written into the *State* for the defined smart contract, i.e., the name CHARLIE is located in *Storage*, and therefore written into *State'*. In this way, variables written into the State persist and can be accessed through a smart contract at a later point in time. Cryptocurrencies built on Ethereum use *Storage* to keep track of wallet balances. *Memory* is a temporary location for mutable variables in a smart contract. Variables in *Memory* do **not** update the *State* and are not later accessible via smart contracts; they persist only within the smart contract execution scope. Lastly, *Calldata*, is an immutable version of *Memory* that can only be passed from an external address as parameters to a function defined with the scope of a smart contract. Recall that Ethereum stores and orders all the transactions that have occurred in the system, so data passed as arguments in any transaction or used internally as a variable in a smart contract remain accessible by examining the transaction, even though they are not retrievable from a smart

[46] https://github.com/ethereum/wiki/wiki/White-Paper#ethereum-statetransition-

function

contract. In Figure 1, the data used in the central transaction (*Memory*), or the parameters passed when it was called, *Calldata* will still be on-chain without changing the *State*. Since the use-case does not require later access via a smart contract, only "proof" that a specific actor committed data, an alternative to recording data in a *State*, is possible. This allows us to utilize on-chain data-availability and use *Memory* or *Calldata* to create a persistent record of data by passing arguments into a *noop* (no operation) smart contract, thus avoiding writing them into the *State*. In so doing, a transaction containing data and a signature is recorded that represents proof that data has been committed. In this way, it is possible for anyone to later look at a specific transaction and examine the data committed to the blockchain.

As a final note, the performance figures in Table 1 for Quorum are quoted from a non-peer-reviewed study by Baliga *et al.* (2018). That study informs our work; in particular, we use the same 30-second time-frame to generate transactions.

2.2.2 The Tendermint blockchain

Tendermint consists of two core components: (i) a consensus engine and (ii) a generic application interface (Buchman, 2016). The consensus engine, called Tendermint Core, ensures that the same transactions are recorded on every machine in the same order. The Tendermint protocol can be configured to support two groups of nodes that comprise the system, namely *validators* and *non-validators*. Only the validators participate in consensus, and non-validators are restricted to read-only access. Unlike many public blockchains, Tendermint does not have a cryptotoken and provides BFT with a claimed throughput of 14,000 *tps* (Buchman, 2016). The consensus engine utilizes a BFT-based voting algorithm that works similarly to classic BFT algorithms such as Practical BFT (PBFT) (Castro & Liskov, 1999). This enforces multiple rounds of voting before data is committed. One main difference between Tendermint's BFT-based algorithm and classical algorithms, such as PBFT, is the introduction of voting power; this allows certain validator nodes to have greater decision-making power within the network. The generic Tendermint API called an Application BlockChain Interface (ABCI), allows smart contracts to be implemented in any programming language, so long as that language implements the ABCI. Smart contracts deployed on Tendermint run on individual nodes as opposed to Quorum, where all smart contracts are run simultaneously across all nodes via the Ethereum Virtual Machine (EVM). Thus smart contracts on Tendermint are not decentralized.

2.2.3 Hyperledger Fabric

Hyperledger Fabric is an open-source permissioned DLT platform designed with enterprises in mind and is established under the Linux Foundation (The Hyperledger Foundation, 2019). Hyperledger Fabric has a modular and configurable architecture that offers a smart contract layer in Java, Go, and `node.js` and supports so-called "pluggable consensus protocols" (Vukolić, 2017). The standard implementation of the consensus protocols is delivered either in Kafka or Raft (up until version 1.4, Kafka was standard where Raft is standard from version 2.0). Kafka and Raft are ordering mechanisms rather than blockchain consensus protocols. A new project between Hedera and Hyperledger Foundation integrates the Hedera Consensus Service with Hyperledger Fabric and provides an alternative BFT consensus mechanism. Hyperledger Fabric leverages the ordering mechanisms and does not require a native cryptocurrency to incent mining or fuel smart contract execution. Hyperledger Fabric introduces their own terminology defining different key constructs such as *peers, organisations, orderers,* and *Certificate Authority (CA)*. An organization consists of peers who participate in one or more channels ordered by an ordering service at a high level. A channel is a private blockchain between its participating "organizations," meaning that users can only interact with contracts in channels where their organization participates. For further clarification on the terminology, see the official glossary (The Linux Foundation, 2020).

2.2.4 Kafka streaming platform

Apache Kafka is a distributed streaming platform first introduced by LinkedIn engineers and later open-sourced (Kreps et al., 2011). Kafka consists of three key capabilities: (i) publish and subscribe to streams of records; (ii) store streams of records in a fault-tolerant durable way; (iii) process streams records in the order they occur. The Kafka architecture has three main components, specifically; *producers, brokers,* and *consumers*. The producer creates data and sends them to a broker, who receives, categorizes, and stores data before the consumer pulls data from the broker. The categorization of data is done through *topics*, and one or more topics are stored in *partitions* on the broker(s). Records written to the partitions are in the form of key, value, and timestamp triples which are: immutable, persistent, and added to an append-only list to preserve message order (Apache Kafka, 2020). The consumers maintain their state and poll for new data when needed. This allows Kafka to persist a single message independently from the number of consumers, resulting in high-throughput for read and write operations (Magnoni, 2015).

2.3 Benchmarking methodology

Performance studies for blockchains (Hao, Li, Dong, Fang, & Chen, 2018; Pongnumkul, Siripanpornchana, & Thajchayapong, 2017; Spasovski & Eklund, 2017; Wang, Dong, Li, Fang, & Chen, 2018) usually follow common distributed system testing practices, keeping as many parameters as possible constant to obtain the best like-for-like comparison around variability in resource demand, throughput and/or transaction latency. In these studies, it is easy to choose an experimental setup that will bias for (or against) a given blockchain framework, so while such studies are self-contained, it is impossible to conclude the performance of different blockchain systems between them. To address this, some researchers have tried to create sophisticated testing frameworks, Blockbench (Dinh et al., 2017) and Chainhammer (Krüger, 2019) are examples, but these are still considered works in progress (Sund et al., 2020).

The downside of most existing blockchain performance tests is that they are mostly artificial, in the sense that the topology of the network, its geographic distribution, message lengths, and transaction volume are not realistic in terms of how the system will be deployed. This paper addresses this; it aims for an "in-the-wild" distributed system test. This is possible because the national and transnational B2B/B2G invoicing system requirements exactly determine performance expectations. This means that during empirical testing, the size and number of transactions arriving at the system will match the use-case as closely as possible, while the number, geographic spread of nodes, and consensus validators will likewise closely match the use-case using common hardware and network infrastructure.

In summary, the test parameters include the following: (i) the number of transacting nodes; (ii) the size of the individual transactions; (iii) the number of nodes that participate in consensus/ordering (for the platforms) and; (iv) the volume of transactions per unit time.

3. TESTING FRAMEWORK

3.1 Testing scenarios

The use-case focuses on sharing documents, invoices, and related business documents, as described in section 1. Each of the test platforms will be described in detail, but each shares the following features:

1. transactions that simulate compressed average PEPPOL[47] invoices (2-KB in size) over a testing time of 30 seconds;
2. transactions that simulate non-compressed average size PEPPOL invoices (10-KB in size) and a testing time of 30 seconds.

3.2 Testing environments

Transactions for all four platforms (Quorum, Tendermint, Hyperledger Fabric, and Apache Kafka) are sent using slave machines. These are virtual machines (VMs) (see details in section 3.2.1) deployed in the Microsoft Azure cloud and controlled by a master testing machine, also on Microsoft Azure. Each slave runs a given test script distributed from the master to the slaves (cf. Figure 2). All test scripts used in this study contain a method for randomizing the order of node addresses to ensure that transactions are randomly distributed among the 28 nodes for the blockchain platforms, namely not following the same order for every user sending transactions. For the Kafka test, each transaction is sent to one of the five brokers and automatically distributed from there to a partition. The test scripts communicate through web calls to each of the nodes/brokers of the four platforms. Logs of transmission data (timestamped when the transaction is sent, success status, and transaction hash) are collected and stored on the master VM. For the blockchain platforms, after all the transactions have been sent and processed from the slaves, a Python script extracts information (time-of-mining, block number, and block size) about the specific transactions using the transaction hash from the transmission data log. These data points make it possible to calculate *tps* and further provide the foundation for the visualizations shown in section 4 (cf. Figures 3, 4, and 5).

[47] PEPPOL is the Pan-European Public Procurement on-Line According to EU Directive 2014/55/EU on e-Invoicing (implemented April 2019).

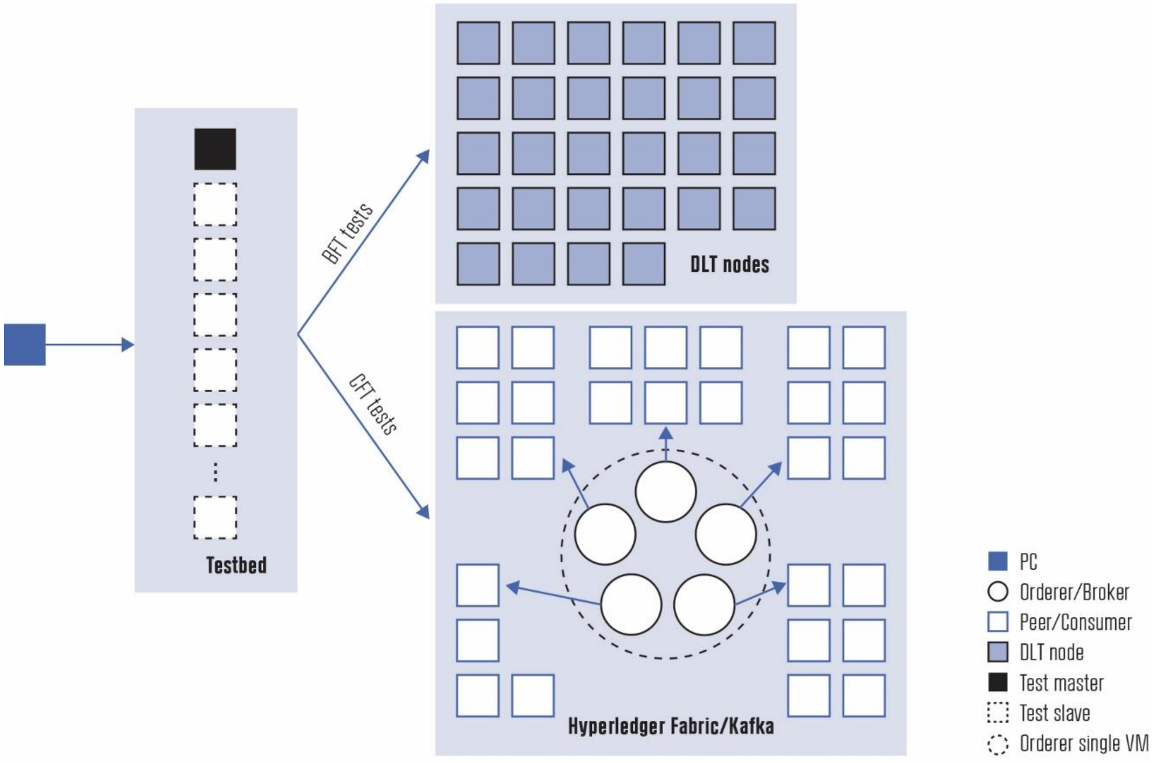

Figure 2. Overview of testing environment

3.2.1 Testing machines

The tests simulate up to 5,000 concurrent users over a 30-second period, and if these tests are executed on a single machine, it induces the JVM garbage collector (GC) mid-test, an artifact of the use of JMeter being used as the measuring instrument, thus polluting test results. The minimum and maximum heap of the JVM is set to be 256-MB and 14-GB, respectively, and the young generation (Eden) of the heap is maximized to ensure that GC induced by JMeter does not pollute the results, GC will not trigger until Eden starts to get close to full. The verbose GC setting is used throughout all tests to provide all GC information. For this reason, all tests are distributed over five slave test machines, cf. section 4 for an overview. All test machines are hosted in Microsoft Azure within the same subnet, located in Western Europe, and the master machine is controlled via an Ubuntu console. All slave machines (and their master) are Azure D4s_v3 with four virtual cores (vCPU) based on a 2.3 GHz Intel XEON E5-2673 v4 (Broadwell) processor, 16 GB RAM, and 32 GB SSD hard disk (Microsoft, 2019). Each of the slave machines runs a Docker image of the slave environment to ensure consistency across the tests (Campean, 2019). The RAM and CPU of the testing machines are monitored throughout the tests.

Parameter	Value
Quorum	
istanbul.blockperiod	5 s
cache	14 GB
txpool.globalslots	100,000 tx
txpool.globalqueue	1,000,000 tx
txpool.accountqueue	1,000,000 tx
block.gasLimit	50,000,000 gas
Tendermint	
mempool.size	560,000 tx
mempool.cache_size	600,000 tx
mempool.max_txs_bytes	1 GB
mempool.recheck	false
Hyperledger Fabric	
endorsement policy	Any
batchsize	300 tx
kafka_default_replication_factor	5
kafka_min_insync_replicas	3
Kafka	
num.network.threads	8
num.io.threads	8
offsets.topic.replication.factor	3
transaction.state.log.replication.factor	5
transaction.state.log.min.isr	3

Table 2. Configuration for Quorum, Tendermint, Hyperledger, and Kafka.

3.3 Cloud computing configuration

Throughout the tests, 28 nodes are spread over the five geographic regions that Microsoft Azure provides in Europe at the time of writing.[48] The infrastructure's geographical spread attempts to replicate a real-world scenario where the nodes are distributed between a consortium of EU-member states (and the UK). The validator nodes are hosted in Microsoft Azure and are likewise D4s_v3s, with the exact specification described above. The validator nodes run Ubuntu Version

[48] Northern Europe, Western Europe, France Central, UK South, and UK West.

18.04 as an OS and are monitored for CPU utilization and RAM usage to ensure that the servers hosting the platform are appropriately provisioned.

3.3.1 Quorum

Quorum has a number of configuration options, see Table 2. Before running the tests, we experimented with various configurations in order to optimize the setup to meet the requirements of use-case best. We experimented with different block periods; 1, 3, 5, and 10 seconds. Maximum throughput is achieved by optimizing for the minimum block period where consensus is reached. In this case, a block period of 5 seconds.

The validator node cache is the amount of memory allocated to internal caching and is set to 14-GB, leaving 2-GB of memory for the OS. In comparison, a default full node on Ethereum's main net has 4-GB allocated to cache. The transaction pool for global slots was set to 100,000 transactions (the default is 4,096), which is the maximum global number of executable transaction slots for all accounts. The transaction pool global and account queue is set to 1,000,000 transactions (the default is 1,024), which is the maximum number of global and account non-executable transaction slots for all accounts. We experimented using 20,000 transactions for global slots and queues, based on the performance review on Quorum's GitHub page[49], but in our experiments, we achieved optimal performance using a value of 100,000. We reserve a single thread for the OS and allocate all remaining threads for each core to validator nodes.

When testing with the default value of 3,758,096,384 as of the gas limit, latency is significant, and we receive a few very large blocks that require multiple minutes of processing each. To optimize our use-case (a preference for a steady flow of blocks), we decreased the gas limit to 50,000,000 (as recommended by Microsoft).[50]

The two scenarios described in section 3.1 were tested with the three different data storage methods allowed by the Quorum blockchain, specifically *State, Memory* and *Calldata*. These three data storage methods are tested through the implementation of three different smart contracts. Since Quorum is based on Ethereum, much of the terminology and functionality is the

[49] See more here: https://github.com/ConsenSys/quorum/issues/467#issuecomment-412536373.

[50] See more on https://docs.microsoft.com/en-us/azure/blockchain/templates/ethereum-poa-deployment

same, e.g., the concept of gas as the computational measure of executing smart contracts. Further, each block has an upper limit on the allowed computational effort (measured in gas). Since the three storage methods have different gas costs, it is important to investigate the performance implications.

3.3.2 Tendermint

As with Quorum, Tendermint has configurable settings that impact performance c.f. Table 2. As our use-case only requires the data to be stored and not otherwise processed, we utilize Tendermint's built-in *noop* "smart contract." Other optimal settings, such as a minimum block time of 1-second, are used, alongside changing the underlying default database (LevelDB) from the GOLANG to the C implementation. We chose to make this swap to the C as it has proven to improve performance under heavy loads.[51] To ensure that the number of test transactions fit within the mempool, its size increased to 560,000 transactions and *max_tps_bytes* to one GB. The cache size is set to 600,000 transactions, which allows for the filtering of up to 600,000 transactions already processed, meaning no two identical transactions in our tests are processed more than once. To optimize throughput, we set *recheck=false*, meaning Tendermint does not recheck if a transaction is still valid after another transaction has been included in a block. The reasoning behind this choice is that all transactions are independent; they do not interact or influence each other – if a financial system were to be evaluated, this would not be the case, and transactions would need to be ordered to avoid double-spending.

3.3.3 Hyperledger Fabric

To fit the Hyperledger Fabric terminology to the use case in the best possible way, 28 organizations were created, so an organization maps to a country, where each of the organizations had one peer, each representing one company per country. We wanted to create an orderer instance containing one Kafka and one Zookeeper in five separate data centers across the Microsoft Azure EU data centers. However, multi-hosting an environment across multiple locations is not presented in the official Hyperledger Fabric documentation. This leads us to a single orderer VM containing five Kafka instances and five zookeepers in one data center. If anything, this configuration should be favorable to overall system performance.

---

[51] See more on https://github.com/tendermint/tendermint/blob/master/docs/tendermint-core/running-in-production.md

Surveying the literature on Hyperledger Fabric performance tests (Gorenflo, Lee, Golab, & Keshav, 2020; Kuzlu, Pipattanasomporn, Gurses, & Rahman, 2019; Sukhwani, Martínez, Chang, Trivedi, & Rindos, 2017; Sukhwani, Wang, Trivedi, & Rindos, 2018; Thakkar, Nathan, & Viswanathan, 2018) and referring to Hyperledger's own performance benchmark tool, Caliper[52], reveals that there have been no reported "in-the-wild" performance tests, at least none we could find. Every performance study cited above uses large machines all located together. For the Caliper benchmark tests, all of the roles, one orderer and two organizations with each one peer, are hosted on a single machine. This means that variability resulting from network dynamics is eliminated. This assumption is likewise applied in Thakkar *et al.* (2018, 12) and noted in their conclusion: *"we assumed that the network is not a bottleneck. However, in a real-world setup, nodes can be geographically distributed and hence, the network might play a role"*. This is verified by Geneiatakis et al. (2020) where the effect of bandwidth limitations in a similar use case across 28 nodes representing EU member states authorities is evaluated.

The *batchsize* parameter is set to 300 transactions per batch (block size), which was found to be an optimum through own testing and confirms the findings of Thakkar *et al.* (2018). The endorsement policy is set to *any*, which means that only one of the 28 peers needs to endorse a transaction before it is sent to the orderer. The replication configuration is altered towards the use-case of this paper. Since invoices are business-critical documents, the replication of data is important to mitigate data loss. Therefore, we replicate data to all five Kafka instances with replication to a minimum of three before data are made available to peers. The three-out-of-five Kafka rule creates leeway for downtime in two of the ordering services without crashing the entire system, hence its crash fault tolerance property. Similar to Tendermint, we deployed a smart contract in each of the channels calling a *noop* function. We run our tests through one, and four channels with all 28 peers enrolled in each of the channels. This serves the purpose of understanding and measuring if channels can be used as a way of scaling (Kuzlu et al., 2019; Thakkar et al., 2018). The specifications and geographical distribution of the VMs used in the Fabric test consist of 28 VMs, each containing a peer and one VM containing the five orderers in separate docker containers.

[52] https://github.com/hyperledger/caliper-benchmarks/

3.3.4 Kafka

The Kafka test aims not to optimize for marginal improvements on the throughput but rather to obtain an indicative benchmark from another paradigm running on the identical infrastructure. Therefore, the values of the parameters for network and I/O threads shown in are chosen, emphasizing the use-case and drawn from configurations from LinkedIn's performance testing (Kreps, 2014). The replication configuration is equivalent to Fabric to achieve CFT. The specifications of the VMs used in the Kafka test are identical to the Quorum, Tendermint, and Hyperledger Fabric tests. In total, 33 VMs are used. Five brokers on separate VMs and 28 VMs act as both producers and consumers to emulate the scenario of companies both sending and receiving invoices. The same geographical distribution applies, leaving one broker per geographic region and five to six producers/consumers in each of the five geographic regions.

4. EXPERIMENTAL RESULTS AND ANALYSIS

4.1 Quorum, results, and analysis

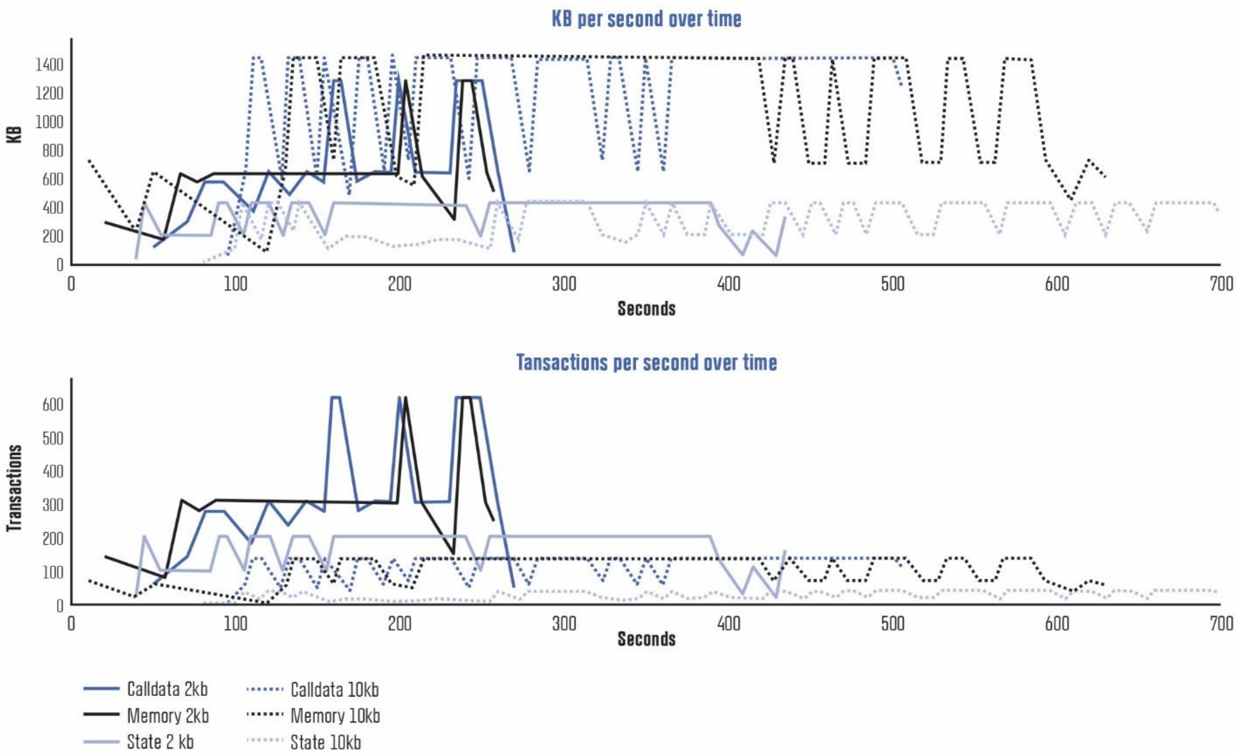

Figure 3. Quorum throughput over time in both KB per second (top) and tps (bottom). All three data storage methods (Calldata, Memory, and State) are compared using both 2-KB and 10-KB transactions. Each marker represents a new block.

As shown in Figure 3, the throughput for *Memory* and *Calldata* with 2-KB messages (black and blue lines), which replicates the average compressed transaction size, lies primarily around 300 *tps*, with occasional spikes above 600 *tps*. For *State* (light blue lines), results are around 200 *tps*, with short bursts of lower throughput. The results show that storage methods that store transactions in *history* (*Calldata* and Memory) outperform the storage method that saves data to the *State*. The figure also shows that *Calldata* and *Memory* are almost identical in performance, with only marginal differences.

The 10-KB tests in (dotted blue, black and light blue lines) show similar patterns to the 2-KB test, where *Memory* and *Calldata* significantly outperform writing data to the *State*. The same pattern is observed for the 10-KB test, however, ranging between 70 and 140 *tps* for *Memory* and *Calldata*, while between 20 and 40 *tps* for *State*. When increasing the volume of transactions and the number of concurrent users, the same phenomena is observed with an increase in the difference between average highs and average lows. During tests, we observed that the network often requires spin-up time before it comes up-to-speed. This is very visible in the results for 2-KB in Figure 3, where the first 20 to 50 seconds are not used to process transactions. This is because transaction data are passed to the nodes, which create and sign the transactions before they are distributed into the network.

Test scenario	Type	Max (*tps*)	Average (*tps*)
2 KB	*Calldata*	622	360
	Memory	620	323
	State	205	182
10 KB	*Calldata*	139	125
	Memory	139	120
	State	43	39

Table 3. Quorum throughput results

The results of the Quorum tests are found in Table 3. In conclusion, from the Quorum tests, at this level of performance, results would satisfy the national B2B/B2G use case for a country the size of Denmark with a need for 130 to 135 *tps* throughput. However, the requirement from the entire Euro-zone of 9,000 to 10,000 *tps* is far from satisfied.

4.2 Tendermint, results and analysis

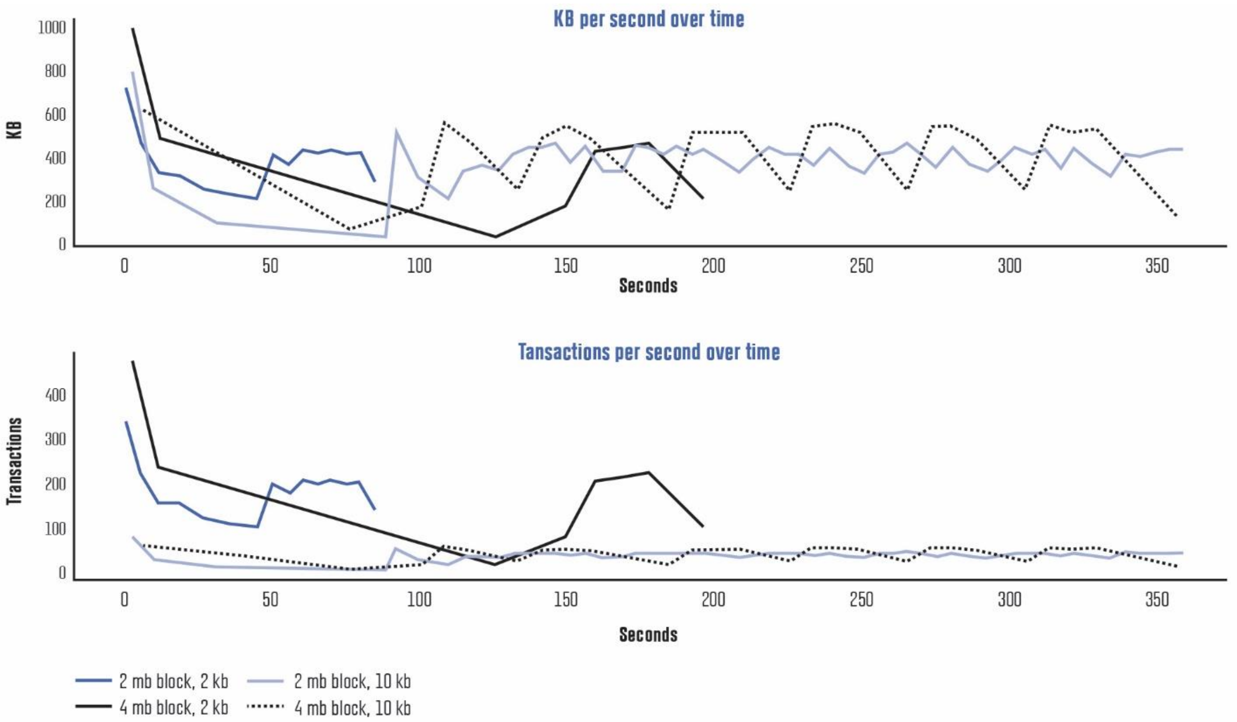

Figure 4. Tendermint throughput over time in both KB per second (top graph) and tps (bottom graph). 2-MB and 4-MB block sizes are compared using both 2KB and 10 KB-sized transactions. Each marker represents a new block.

As seen in Figure 4, the transaction throughput of Tendermint is impacted significantly by the size of the transactions exemplified in the differences in the bottom graph from the 2-KB test (blue and black lines) and the 10-KB test (light blue and dotted black lines). However, the throughput (measured in bytes) is unaffected by the block and transaction size, see top graph in Figure 4. As shown in the graphs, there is an initial spike in throughput across tests; this is due to a commonly known Tendermint performance bottleneck related to indexing transactions when using larger block sizes[53]. Compared to the Quorum tests, Tendermint resembles the Quorum run that writes

[53] https://github.com/tendermint/tendermint/issues/1835#issuecomment-402054099 and https://github.com/syndtr/goleveldb/issues/226

all data to the *State*. Nevertheless, we posit that Tendermint outperforms Quorum in cases where transactions are more computationally intensive due to its smart contracts utilizing GOLANG and running on a single node rather than being executed simultaneously across all nodes on the EVM as is the case with Quorum. When comparing the Tendermint test results with the performance claims from Table 1, it is clear that the two are not comparable. This discrepancy can be solely explained by the transaction size used in the tests carried out by Buchman (Buchman, 2016), as tests were never conducted using transactions larger than 250 bytes. To confirm that Buchman's performance claims hold, we tested our Tendermint setup using a transaction size of 32 bytes and obtained a throughout-peak of over 10,000 *tps*. The Tendermint tests' results can be seen in Table 4 and confirm that the level of performance delivered by Tendermint would only just satisfy the national B2B/B2G use case for a country the size of Denmark of 130 to 135 *tps* when 2-KB transactions are used. As with Quorum, the entire Euro-zone requirement of 9,000 to 10,000 *tps* is far from being satisfied using Tendermint.

Size	Block size	Max *(tps)*	Average *(tps)*
2 KB	2 MB	337	164
	4 MB	472	120
10 KB	2 MB	76	31
	4 MB	58	29

Table 4. Tendermint throughput results

4.3 Hyperledger Fabric, results and analysis

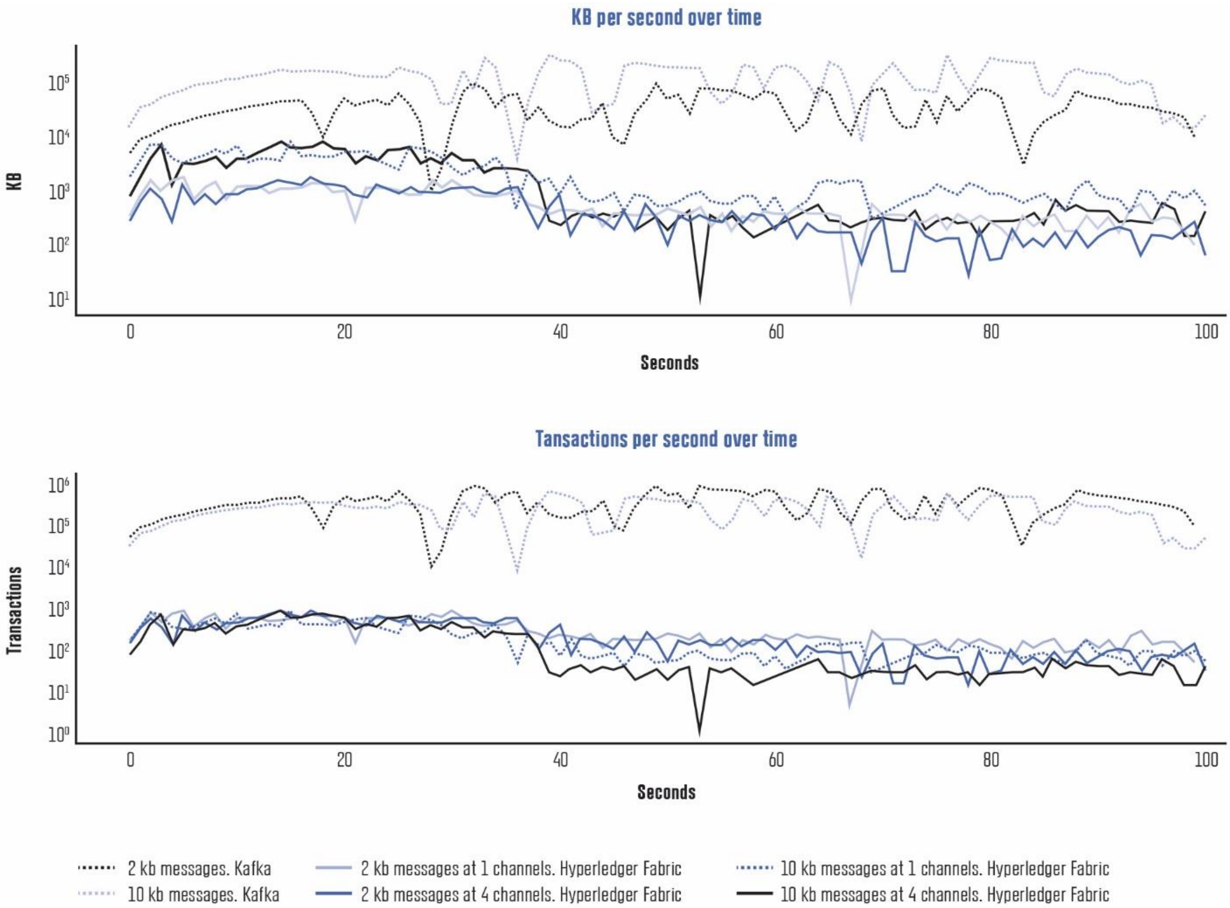

Figure 5. Hyperledger Fabric and Kafka throughput over time, in both KB per second (top) and tps (bottom). Comparing 2-KB and 10-KB transactions.

Figure 5 shows that the peak and initial throughput of Hyperledger Fabric are indifferent to message size because Kafka is the underlying messaging protocol. However, throughput reduces significantly after the first 35-45 seconds, indicating that Hyperledger Fabric struggles under sustained load. Table 5 shows that peak throughput is significantly larger than average performance and that Hyperledger Fabric handles large increases in message-size well. As noted by Thakker et al. (2018) and Kuzlu et al. (2019), Hyperledger Fabric can utilize channels to run multiple "contracts" in parallel and, in so doing, increase transaction throughput. We increased the number of channels, but our experimental results do not reflect this finding. This may be because of limited computing power. To test this assumption, tests were re-run with a larger machine as the orderer. We observed that performance increases 3% for the single-channel case and 18% for the four-channel case, indicating that channels have some overhead but increase throughput when used with more computing power. As noted by Thakker et al. (2018), the endorsement policy is identified as a performance bottleneck. However, our test results did not show any significant difference between the policies *majority* and *any*. Comparing our results to the literature (Geneiatakis et al., 2020; Kuzlu et al., 2019; Sukhwani et al., 2017, 2018; Thakkar et al., 2018) and Hyperledger's Caliper tests [54], a comparable performance was observed.

Size	#ch	Max *(tps)*	Average *(tps)*
2 KB	1	763	245
	4	723	142
10 KB	1	714	137
	4	678	130

Table 5. Hyperledger Fabric throughput results

4.4 Kafka, results and analysis

Apache Kafka can be expected to be much faster than Quorum and Tendermint and not much faster than Hyperledger Fabric since it is used as in the ordering service in Hyperledger Fabric. For Quorum and Tendermint, this proves to be the case. However, for Hyperledger Fabric, it is not what we found. The results, shown in Figure 5, show a significant difference. At peak, for the 2-KB test, Kafka achieves 241,124 *tps*, and on average, around 107,187 *tps*. The spikes seen in are consistent with the phenomena observed by Le Noach et al. (2017) and are the result of *re-balancing*. The re-balancing feature used in Kafka clients (and/or the Kafka coordinator) allows the formation of a common group and distributes a set of resources among the members of that group. Re-balancing occurs every time a member joins or leaves a group. In our case, since we cannot start every producer at the same time, a script starts sequentially, leaving the producers and consumers to gradually join and leave the group over the period of the test run resulting in re-balancing, and therefore a re-allocation of the resources occurs, hence the spikes in performance.

[54] https://hyperledger.github.io/caliper-benchmarks/fabric/performance/2.1.0/goContract/nodeSDK/submit/create-asset/

When comparing these results to other Kafka studies (Du et al., 2018; Le Noac'h, Costan, & Bougé, 2017; Nguyen, Luckow, Duffy, Kennedy, & Apon, 2018), we note that they deploy larger broker machines to manage more transactions. If we had deployed larger machines for the Kafka test, system performance would be better than those we observed.

4.5 Comparison of test results

For the initial comparison, we will look at the most performant 2-KB test across the blockchain platforms. In short, Quorum achieves 360 *tps* with *Calldata*, Tendermint achieves 164 *tps* with 4-MB blocks, and Hyperledger 245 *tps* with a single channel. Working with smaller messages, we observe that Quorum is fastest, with Hyperledger Fabric second followed by Tendermint. This result is unexpected as Hyperledger is often communicated as a highly scalable blockchain[55]. In practice, this means that the "consensus" is performed by fewer peers, increasing the centralization and theoretically throughput as well. When we compare these blockchain solutions to more standardized cloud technologies such as Kafka, the difference is staggering. Kafka is on average more than 298 times faster than Quorum, 654 times faster than Tendermint, and 437 times faster than Hyperledger Fabric.

The purpose of the Kafka test was not to optimize for more *tps*, instead create a baseline for comparison on the same use case, and with the same "in-the-wild" distributed test approach, and draw some conclusions about the efficiency of Kafka as an ordering service in Hyperledger Fabric. The core difference between Hyperledger Fabric and Kafka is the inbuilt components as smart contracts and identity management that Hyperledger Fabric provides. Kafka can satisfy the national B2B/B2G use case for a country the size of Denmark and satisfy the requirement for the entire EU-zone using standardized cloud infrastructure, under the condition that CFT suffices.

5. KEY FINDINGS

A key finding from the tests presented in this paper is the understanding of the relationship between use case and platform selection to achieve a high-performance distributed replication system. From the Quorum tests, we learned that the difference between writing to *State* and *Calldata* or *Memory* is larger than a factor of three, evidenced from the throughput in KB per second from Figure 3. Even though this finding might be logical, even obvious, the concrete

[55] https://www.ibm.com/blogs/blockchain/2019/04/does-hyperledger-fabric-perform-at-scale/

measure of the differences is a valuable contribution; it serves to remind system designers how important it is to consider how much data is needed to be stored in *State* and how much can be more efficiently handled in *Memory* or via *Calldata*. It is also clear that the difference in throughput in KB for Quorum is independent of the transactions' size when updating the *State*.
From the performance claims made in Table 1, we assumed that Tendermint would be faster than Quorum because the smart contract layer is implemented in GOLANG compared to the implementation of smart contracts in Quorum running on the distributed EVM. This proved not to be the case using our testing regime. However, Tendermint might still outperform Quorum in a computational intensive use case – one relying on the presence of many smart contracts. Moreover, this opinion also underscores important learning: tuning the platform choice to the application use case is important and will influence future systems' design choices. System developers need to ask themselves, how much smart contract activity is anticipated and how important are smart contract transactions to the orderly operation of the business ecosystem?
Hyperledger Fabric was included as a baseline since it is the most popular enterprise blockchain framework, and while it is not BFT, it is CFT and would be expected to be faster than its BFT rivals. This proved not to be the case. Kafka, decoupled from Hyperledger Fabric, was tested to have a distributed CFT alternative that runs on the same infrastructure to understand the performance gap between distributed systems that are BFT and more conventional CFT systems in identical circumstances. The enormous performance difference represents the cost of BFT over conventional CFT and thereby putting a price on distributed trust.
From the evidence in Table 5, the findings are that Hyperledger Fabric handles large messages surprisingly well compared to its overall performance. Furthermore, Hyperledger Fabric incurs a performance penalty when using multiple channels with 28 participants on small machines. Even though other work (Thakkar et al., 2018) has shown that endorsement policies are highly influential on performance, our results show that this is not the case for smaller machines as the ordering service is then bounded by computation.

Kafka's performance advantage is achieved because it can write data in parallel; it does not have to achieve consensus before it adds data. This observation implies that systems designers need to consider the cost and need for distributed trust: especially if the proposed system has the nature of being permissioned *and* private. The question needs to be asked, is BFT necessary when participants are known to each other and have a vested interest in the system being trustworthy? In use cases dealing with large dynamic business ecosystems, where one can anticipate bad actors' presence, the overhead of distributed trust may be worthwhile. This is one reason that blockchains are so attractive in applications for supply chain logistics (Sund et al., 2020) because supply chains are dynamic, multi-agent business ecosystems where there is an ever-present economic incentive to disrupt authenticity. System designers need to offset the costs of not trusting data, e.g., reconciling and monitoring the authenticity of data is labor-intensive. A significant hit on system performance might be an acceptable price to pay for immutability with decentralized and inbuilt trust.

6. CONCLUSION

This paper is driven by the use case of operating an e-commerce platform in Europe deploying an "in-the-wild" testing method using four distributed data replication platforms. The use case provides the benchmark for system performance and the topology of the network and infrastructure. Two readily available BFT blockchain platforms, Quorum and Tendermint, one CFT blockchain, Hyperledger Fabric, and one CFT data streaming platform, Apache Kafka, are tested and compared. The overall finding is that the CFT data streaming implementation is significantly faster than the BFT platforms is unsurprising.

Surprising, however, is that the CFT blockchain, Hyperledger Fabric, which uses Kafka as an ordering service, performs so differently from a stand-alone implementation of Apache Kafka. One would expect a more uniform performance improvement. Nevertheless, Gorenflo et al. (2020) present a study of the bottlenecks in Hyperledger Fabric, which can be summarized as message communication overhead internal to architecture.

However, this paper's main contribution is to quantify *how much* faster CFT laid bare is compared to BFT for the same use case running on the same hardware and network infrastructure. Quantifying this difference is a way of putting a price on decentralized trust as a system feature and provides robust evidence to consider carefully whether the decentralized trust is essential. Concerning the use case, it is also clear that BFT protocols, running on standardized cloud infrastructure with realistic transaction volumes and sizes, are not sufficiently performant on an EU scale and only just adequate to work on a national scale. These results imply that the implication on accounting and compliance reporting based on this study is limited.

REFERENCES

Apache Kafka. (2020). Apache Kafka Documentation. Retrieved March 10, 2021, from https://kafka.apache.org/

Baliga, A., Subhod, I., Kamat, P., & Chatterjee, S. (2018). Performance Evaluation of the Quorum Blockchain Platform.

Beck, R., Eklund, P., & Spasovski, J. (2019). How blockchain impacts cloud-based system performance : a case study for a groupware communication application. In *Australasian Conference on Information Systems* (pp. 265–274).

Betalingsrådet. (2015). *Rapport om betalinger mellem virksomheder*.

Buchman, E. (2016). *Tendermint: Byzantine Fault Tolerance in the Age of Blockchains*. https://doi.org/10.1136/adc.53.1.81

Cachin, C., & Vukolic, M. (2017). *Blockchain Consensus Protocols in the Wild*.

Campean, D. (2019). How to build a distributed load testing infrastructure with AWS, Docker, and JMeter. Retrieved from https://medium.com/@DragosCampean/how-to-build-a-distributed-load-testing-infrastructure-with-aws-docker-and-jmeter-accf3c2aa3a3

Castro, M., & Liskov, B. (1999). Practical Byzantine fault tolerance. In *OSDI* (Vol. 99, pp. 173–186). Retrieved from http://pmg.csail.mit.edu/papers/osdi99.pdf

ConsenSys. (2021). Quorum Website. Retrieved from https://docs.goquorum.consensys.net/en/stable/

Danish Business Authority. (2019). Submission of Annual Report. Retrieved from https://indberet.virk.dk/myndigheder/stat/ERST/Regnskab_20

Danmarks Nationalbank. (2019). *Betalinger mellem virksomheder kostede samfundet 4,2 mia. kr.* Retrieved from http://www.nationalbanken.dk/da/bankogbetalinger/betalingsraad/Documents/BR_Betalinger mellem virksomheder i Danmark 2016.pdf

Deloitte. (2017). *Analyse af erhvervsøkonomiske konsekvenser af udvalgte e-handelsinitiativer Samlet rapport 15.*

Dinh, T. T. A., Liu, R., Zhang, M., Chen, G., Ooi, B. C., & Wang, J. (2017). Untangling Blockchain: A Data Processing View of Blockchain Systems. Retrieved from https://arxiv.org/pdf/1708.05665.pdf

Du, Y., Chowdhury, M., Rahman, M., Dey, K., Apon, A., Luckow, A., & Ngo, L. B. (2018). A Distributed Message Delivery Infrastructure for Connected Vehicle Technology Applications. *IEEE Transactions on Intelligent Transportation Systems*, *19*(3), 787–801. https://doi.org/10.1109/TITS.2017.2701799

Eklund, P. W., & Beck, R. (2019). Factors that Impact Blockchain Scalability.

Geneiatakis, D., Soupionis, Y., Steri, G., Kounelis, I., Neisse, R., & Nai-Fovino, I. (2020). Blockchain Performance Analysis for Supporting Cross-Border E-Government Services. *IEEE Transactions on Engineering Management*, 1–13. https://doi.org/10.1109/TEM.2020.2979325

Gonczol, P., Katsikouli, P., Herskind, L., & Dragoni, N. (2020). Blockchain Implementations and Use Cases for Supply Chains-A Survey. *IEEE Access*, *8*, 11856–11871.

Gorenflo, C., Lee, S., Golab, L., & Keshav, S. (2020). FastFabric: Scaling hyperledger fabric to 20 000 transactions per second. *International Journal of Network Management*, (August 2019), 1–18. https://doi.org/10.1002/nem.2099

Hao, Y., Li, Y., Dong, X., Fang, L., & Chen, P. (2018). Performance analysis of consensus algorithm in private blockchain. In *2018 IEEE Intelligent Vehicles Symposium (IV)* (pp. 280–285).

Hevner, A. R., March, S. T., Park, J., & Ram, S. (2004). Design Science in Information Systems Research. *MIS Quarterly*, *28*(1), 75–105. Retrieved from https://wise.vub.ac.be/sites/default/files/thesis_info/design_science.pdf

Kreps, J. (2014). *I ♥ Logs*.

Kreps, J., Narkhede, N., & Rao, J. (2011). Kafka: a Distributed Messaging System for Log Processing. In *NetDB* (pp. 1–7). https://doi.org/10.1007/BF00640482

Krüger, A. (2019). Chainhammer. Retrieved from https://github.com/drandreaskrueger/chainhammer

Kuzlu, M., Pipattanasomporn, M., Gurses, L., & Rahman, S. (2019). Performance analysis of a hyperledger fabric blockchain framework: Throughput, latency and scalability. *2019 2nd IEEE International Conference on Blockchain, Blockchain 2019*, 536–540. https://doi.org/10.1109/Blockchain.2019.00003

Lamport, L., Shostak, R., & Pease, M. (1982). The Byzantine Generals Problem. *Transactions on Programming Languages and Systems*, *4*(3), 382–401. Retrieved from https://www-inst.eecs.berkeley.edu/~cs162/sp16/static/readings/Original_Byzantine.pdf

Le Noac'h, P., Costan, A., & Bougé, L. (2017). A performance evaluation of Apache Kafka in support of big data streaming applications. *Proceedings - 2017 IEEE International Conference on Big Data, Big Data 2017*, *2018-Janua*, 4803–4806. https://doi.org/10.1109/BigData.2017.8258548

Magnoni, L. (2015). Modern Messaging for Distributed Sytems. *Journal of Physics: Conference Series*, *608*, 12038. https://doi.org/10.1088/1742-6596/608/1/012038

Microsoft. (2019). Azure Virtual Machine series. Retrieved from https://azure.microsoft.com/en-us/pricing/details/virtual-machines/series/

Moniz, H. (2020). The Istanbul BFT Consensus Algorithm. *ArXiv Preprint ArXiv:2002.03613*.

Nguyen, D., Luckow, A., Duffy, E., Kennedy, K., & Apon, A. (2018). Evaluation of highly available cloud streaming systems for performance and price. *Proceedings - 18th IEEE/ACM International Symposium on Cluster, Cloud and Grid Computing, CCGRID 2018*, 360–363. https://doi.org/10.1109/CCGRID.2018.00056

Ongaro, D., & Ousterhout, J. (2014). In search of an understandable consensus algorithm. In *2014 USENIX Annual Technical Conference (USENIX ATC 14)* (pp. 305–319). Retrieved from https://www.usenix.org/system/files/conference/atc14/atc14-paper-ongaro.pdf

OpenPEPPOL. (2019). PEPPOL invoice example. Retrieved March 10, 2021, from https://raw.githubusercontent.com/OpenPEPPOL/peppol-bis-invoice-3/master/rules/examples/base-example.xml

Pongnumkul, S., Siripanpornchana, C., & Thajchayapong, S. (2017). Performance analysis of private blockchain platforms in varying workloads. In *2017 26th International Conference* *on Computer Communication and Networks (ICCCN)* (pp. 1–6).

Søgaard, J. S. (2021). A blockchain-enabled platform for VAT settlement. *International Journal of Accounting Information Systems*, 100502. https://doi.org/10.1016/j.accinf.2021.100502

Spasovski, J., & Eklund, P. (2017). Proof of stake blockchain: Performance and scalability for groupware communications. *9th International Conference on Management of Digital EcoSystems, MEDES 2017*, *2017-Janua*(November), 251–258. https://doi.org/10.1145/3167020.3167058

Stockton, N. (2020). China takes blockchain national: The state-sponsored platform will launch in 100 cities. *IEEE Spectrum*, *57*(4), 11–12. https://doi.org/10.1109/MSPEC.2020.9055903

Sukhwani, H., Martínez, J. M., Chang, X., Trivedi, K. S., & Rindos, A. (2017). Performance modeling of PBFT consensus process for permissioned blockchain network (hyperledger fabric). *Proceedings of the IEEE Symposium on Reliable Distributed Systems*, *2017-Septe*(September), 253–255. https://doi.org/10.1109/SRDS.2017.36

Sukhwani, H., Wang, N., Trivedi, K. S., & Rindos, A. (2018). Performance modeling of hyperledger fabric (permissioned blockchain network). *NCA 2018 - 2018 IEEE 17th International Symposium on Network Computing and Applications*, (December). https://doi.org/10.1109/NCA.2018.8548070

Sund, T., Lööf, C., Nadjm-Tehrani, S., & Asplund, M. (2020). Blockchain-based event processing in supply chains—A case study at IKEA. *Robotics and Computer-Integrated Manufacturing*, *65*(March), 101971. https://doi.org/10.1016/j.rcim.2020.101971

Szabo, N. (1994). Smart Contracts. Retrieved from https://www.fon.hum.uva.nl/rob/Courses/InformationInSpeech/CDROM/Literature/LOTwinterschool2006/szabo.best.vwh.net/smart.contracts.html

Thakkar, P., Nathan, S., & Viswanathan, B. (2018). Performance benchmarking and optimizing hyperledger fabric blockchain platform. In *26th IEEE International Symposium on Modeling, Analysis and Simulation of Computer and Telecommunication Systems* (pp. 264–276). https://doi.org/10.1109/MASCOTS.2018.00034

The Hyperledger Foundation. (2019). Hyperledger Fabric. Retrieved from https://github.com/hyperledger/fabric

The Linux Foundation. (2020). Hyperledger Fabric Documentation. Retrieved March 10, 2021, from https://hyperledger-fabric.readthedocs.io/en/release-2.0/

Venable, J. R., Pries-Heje, J., & Baskerville, R. L. (2016). FEDS: A Framework for Evaluation in Design Science Research. *European Journal of Information Systems*, *25*(1), 77–89. https://doi.org/10.1057/ejis.2014.36

Vukolić, M. (2017). Rethinking permissioned blockchains. In *Proceedings of the ACM Workshop on Blockchain, Cryptocurrencies and Contracts, co-located with ASIA CCS 2017* (pp. 3–7). https://doi.org/10.1145/3055518.3055526

Wang, Z., Dong, X., Li, Y., Fang, L., & Chen, P. (2018). Iot security model and performance evaluation: A blockchain approach. In *2018 International Conference on Network Infrastructure and Digital Content (IC-NIDC)* (pp. 260–264).

PAPER 4

Accounting Contracts in Collaboration Space

Jonas Sveistrup Søgaard

Copenhagen Business School | Department of Accounting | jss.acc@cbs.dk

William E. McCarthy

Michigan State University | Department of Accounting and Information Systems | mccarthy@broad.msu.edu

Lasse Herskind

Deloitte | NextGen | lasse.herskind@gmail.com

G. Ken Holman

Crane Softwrights Ltd | *g.ken.holman@gmail.com*

ABSTRACT: This paper proposes a design theory for accounting transaction systems that is based on the resource-event-agent (REA) accounting ontology and distributed ledger technology (DLT). Following a design science research approach, we present a novel blockchain-based prototype that implements the REA ontology as a business process state machine. Our prototype utilizes the unique features of DLT to ensure data integrity and transparency among the economic agents in recorded and distributed repositories that reside outside of the enterprise systems of those parties. This provides evidence that the independent view of business transactions between and among companies and government agencies - in what we call collaboration space - is technologically feasible and opens avenues for exploring innovative ways for performing economic exchanges. Because our business transaction choreography is orchestrated by accountability contracts for reciprocated delivery of economic resources, we title our treatment "accounting contracts in collaboration space."

KEYWORDS: accounting, Resource-Event-Agent (REA) ontology, blockchain, design science research, independent view, collaboration space, distributed ledger technology, distributed business transaction repository (DBTR).

1. INTRODUCTION

In May of 2003, an article on the evolution of accounting and enterprise software practices was published in *Communications of the ACM* by David, McCarthy, and Sommer (2003). That paper examined the landscape of accounting and enterprise business software solutions and typed the various software packages they found in the marketplace into three overall groupings with ten individual categories:

i. **No organizing rationale**: packages that simply tracked transactions and obligations (#1);

ii. **Inwardly organized rationale with two subcategories**:
   a. packages based on double-entry accounting principles (#2, #3, #4);
   b. packages based on enterprise-wide value chains (#5, #6, #7);

iii. **Outwardly organized rationale with two subcategories**:
   a. packages that integrated enterprise computing with upstream and downstream **trading partners** (#8, #9)
   b. packages that kept intercompany exchange transactions in an **independent** collaboration space, stored only once (#10).

These ten categories are displayed in a simpler categorical scheme in Figure 1.

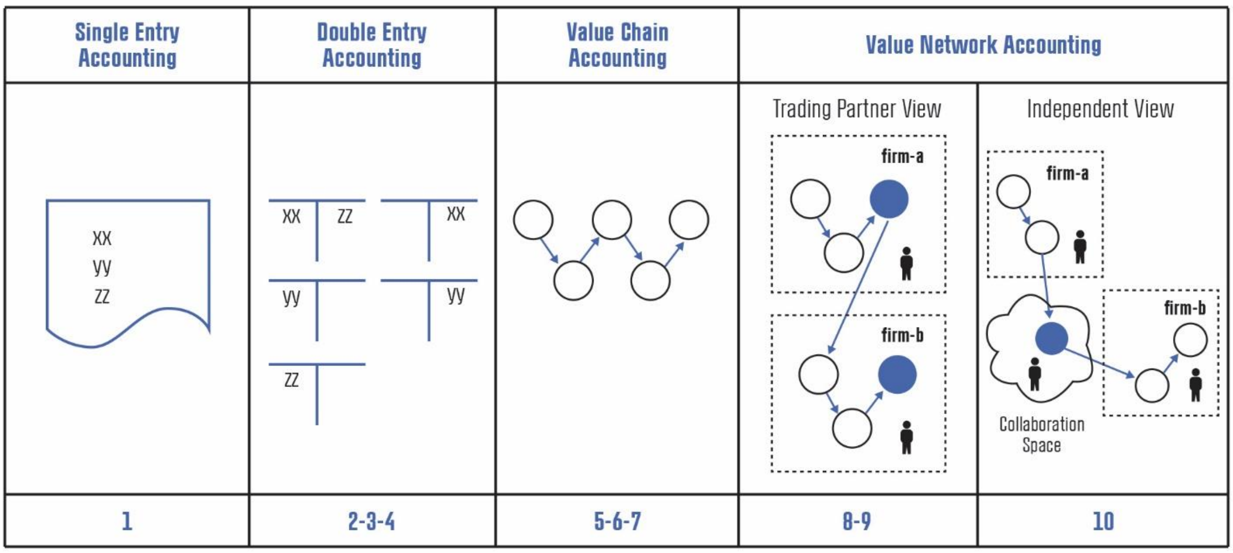

Figure 1. The evolution of accounting systems (adapted from David, McCarthy, and Sommer 2003)

David et al. (2003) noted the emergence of application service providers and portals as mutations in their software ecosystems that might lead to further innovation. Indeed their analysis was correct as categories 1-9 eventually evolved into a mix of on-premise and cloud-based solutions, like software-as-a-service (SaaS), plus best-of-breed Enterprise Resource Planning (ERP) Systems (Hale, 2019).

Category 10 – independent-view repositories of transaction data – was clearly the boldest and most speculative of their groupings, as (unlike categories 1-9) there were no actual software packages to put into that category, nor was there a clear technological path to adoption of such ideas. Indeed, the adjectives applied to their community-based assemblages (**trading partner** to #8 and #9, and **independent** to #10) had originated from a draft of an International Organization for Standardization (ISO) specification on collaboration space computing for which one of the authors (McCarthy) was the editor. The enabling technology for the purest application of that standard did not exist in 2003, but its theoretical foundation did in the form of the Resource-Event-Agent (REA) accounting ontology (Geerts & McCarthy, 2002; McCarthy, 1982), so REA became the backbone of independent-view collaboration space definitions. When the actual standard – ISO/IEC 15944-4 (2007) – was finally published after a long international vetting process, that enabling implementation technology still did not exist, even though its conceptual foundation had been specified. Independent view computing – which for example, would merge a 's*ale requited with a cash-receipt by firm-a*" with a "*purchase requited with a cash-disbursement by firm-b*" into one collaboration space swap of "*goods for money*" -- was clearly possible but not yet implementable.

Then, the blockchain revolution started by Satoshi Nakamoto in 2008 (Nakamoto, 2008) completely changed the possibilities for collaboration space independent view commerce. The merging of two redundant trading partner views of an atomic swap within two separate ERP systems maintained by the seller and the buyer onto one 's*ingle source of the truth*" blockchain repository was an achievable vision. As of 2021, that blockchain revolution of Nakamoto has proceeded slowly with a mix of private permissioned (like the enterprise blockchains Hyperledger Fabric, Corda, ConsenSys Quorum as the most mature), public permissioned (like Hedera and Concordium), and public permissionless (like Bitcoin and Ethereum) implementations.[56] It is the purpose of this paper to explore how we think category 10 of Figure 1 (the independent view) will

[56] Hyperledger Fabric: https://www.hyperledger.org/use/fabric , Corda: https://www.r3.com/corda-platform/ , ConsenSys Qourum: https://consensys.net/quorum/, Hedera: https://hedera.com/ , Concordium: https://concordium.com/ , Bitcoin: https://bitcoin.org/en/ , Ethereum: https://ethereum.org/en/

eventually evolve within accounting and enterprise practice. We intend to do this by using design science methodology (Gregor & Hevner, 2013; Hevner et al., 2004) to construct a working prototype (proof of concept) of multiple business transactions, as they are constrained and ordered by REA-enabled business process state machines. This prototype uses Universal Business Language (UBL) documents to trigger state changes as economic contracts between a buyer, and a seller is formulated, formalized, and fulfilled in independent blockchain collaboration space.[57] Since the collaboration space is a radical new way of doing business, it also calls for a new way of doing accounting. This is why we are proposing here a design theory for accounting transaction systems 8-10 years into the future when blockchain ideas and efficiencies become more developed and when the economic structures of parties and firms using those new competencies evolve to become less hierarchical (as in Berg et al. 2019)

Our projected work here also fits in well with recent calls for integrating information technology into accounting research by Geerts, Graham, Mauldin, McCarthy, and Richardson (2013), and with additional requests for integrating practice into accounting research by Rajgopal (2020). Both of these appeals specifically mention the REA model as a possible research vehicle for advancing accounting practice-improvement ideas, and such a strategy is a key component of our research plans. The rest of this paper proceeds with two sections for a literature review and an analysis of our methodology. Sections 4-5 present our artifact description and design, followed by our evaluation procedures. We finish in sections 6-7 by discussing the implications of our implemented artifact and our analysis of this study's overall contribution.

2. LITERATURE REVIEW

2.1 The REA Ontology

2.1.1 REA introduction and review

The REA accounting and economic ontology constitute the design theory (Geerts et al., 2013) for our proposed collaboration space contract artifact. The origin, structure, and objectives of the

[57] OASIS Universal Business Language (UBL) ISO/IEC 19845:2015

At https://www.oasis-open.org/committees/tc_home.php?wg_abbrev=ubl

REA model were most recently summarized in an autonomous review by Alex Pazaitis, who explained how REA features were used instead of double-entry accounting in an Open Value Network (OVN) constructed and implemented by the Canadian consortium Sensorica:

> The new forms of productive coordination and value creation surfacing in the digital economy have exacerbated some of the limitations that double-entry bookkeeping had already been facing in covering the needs for accounting information. McCarthy (1982] identified four main categories of such deficiencies:
>
> 1. Limited dimensions…
> 2. Not (always) appropriate classification schemes…
> 3. High-level aggregation for stored information…
> 4. Restricted degree of integration with other functional areas of the enterprise…
>
> In the face of these limitations, resources–events–agents (REA) has been presented as a model for accounting systems re-engineered for the information age. It was originally presented by McCarthy (1982) as a generalized framework designed to cover accounting needs for enterprise environments, utilizing shared data amongst their functional constituents. The main motivation behind the development of REA was the limited capacity of double-entry bookkeeping to facilitate information flows in post-industrial business entities. These limitations are addressed by the REA framework through a semantic approach that aims to reflect real-world business activities rather than double-entry accounting objects. As the name implies, the model creates computer objects that represent: (a) resources (e.g., goods, services, cash, assets); (b) events (e.g., processes, transactions, agreements, contracts); and (c) agents (e.g., individuals, groups of individuals, entities, machines). REA preserves the duality of economic events that is typical of double-entry, retaining the causal relationship between inflows and outflows… while providing the same options for financial reporting… The REA [model] as a design theory can provide a common vocabulary to enable the coordination of all involved parties in integrated enterprise and inter-enterprise systems… It poses as a discontinuity in the design paradigm of electronic accounting systems, where instead of focusing on the automation of traditional accounting artefacts, it conceptualizes a new way of representing the complex economic reality." (2020, 5-6)

Despite many technological advances since 1980, we believe that **<u>all</u>** of the double-entry criticisms reiterated by Pazaitis (above) remain true today. That unmoving assessment of all four negative features has been echoed recently by the Institute of Management Accounting (IMA) in its conceptual costing structures work (White & Clinton, 2014). This was expanded further by McCarthy, Geerts, and Gal (2021, 135), who add two more major weaknesses of account-based double entry:

- It <u>cannot support automated reasoning</u> because its embedded semantics are either nonexistent or very weak; and
- It <u>cannot operate well in an independent-view distributed business transaction repository</u> because the fundamental accounting equation (A = L + OE), on which all accounts are based, is a trading-partner view of commerce. Taking one trading partner's ledger accounts and balancing them with another trading partner's ledger simply does not work easily, and it may involve massive amounts of rework to achieve an accounting balancing act that is meaningless in open collaboration space.

Automated reasoning within accounting systems (Geerts & McCarthy, 2000) is beyond the scope of this paper, but the second dysfunctional feature mentioned above (as inferred already) is a key feature in our presentation here as we build our collaboration space artifact.

The REA accounting model has been reviewed in the accounting and information systems literature in multiple places over multiple time periods, most extensively by research teams led by Cheryl Dunn. Two of her overviews are these:

1. Dunn and McCarthy (1997) – This review had two main objectives:
    a. To clarify the historical contributions and links of accounting theorists like Goetz (1939), Schmalenbach (1948), Mattessich (1964), Schrader (1962), Sorter (1969), Colantoni, Manes, and Winston (1971), Ijiri (1975), and McCarthy (1979) to REA structures; and
    b. To categorize by their essential orientations (database, semantic, and structuring) innovative proposals for constructing newer types of accounting systems. Those categories were: events accounting systems, database accounting systems, semantically modeled accounting systems, and REA accounting systems.
2. Dunn, Gerard, and Grabski (2016) – This review was published in the mainstream information systems literature, and it included a much more extensive literature review over multiple REA sub-fields, including its design roots, its developed proofs of concept, and its use in behavioral experiments. It also reviewed the use of REA in accounting teaching (McCarthy, 2003) and in the construction of industrial strength enterprise systems like the *Workday* ERP system (Nittler, 2018).

2.1.2 REA extensions by Geerts and McCarthy

As explained above by Pazaitis, the original REA model consisted of two symmetrical object constellations of Resources-Events-Agents coupled by duality relationships that connected the inputs of a business process (either a market exchange or an internal conversion (Coase, 1937) to its outputs. In Figure 2, we illustrate this metamodel constellation near the bottom of the page as the *accountability layer* of REA; this was the original constellation published in the 1982 paper by McCarthy.

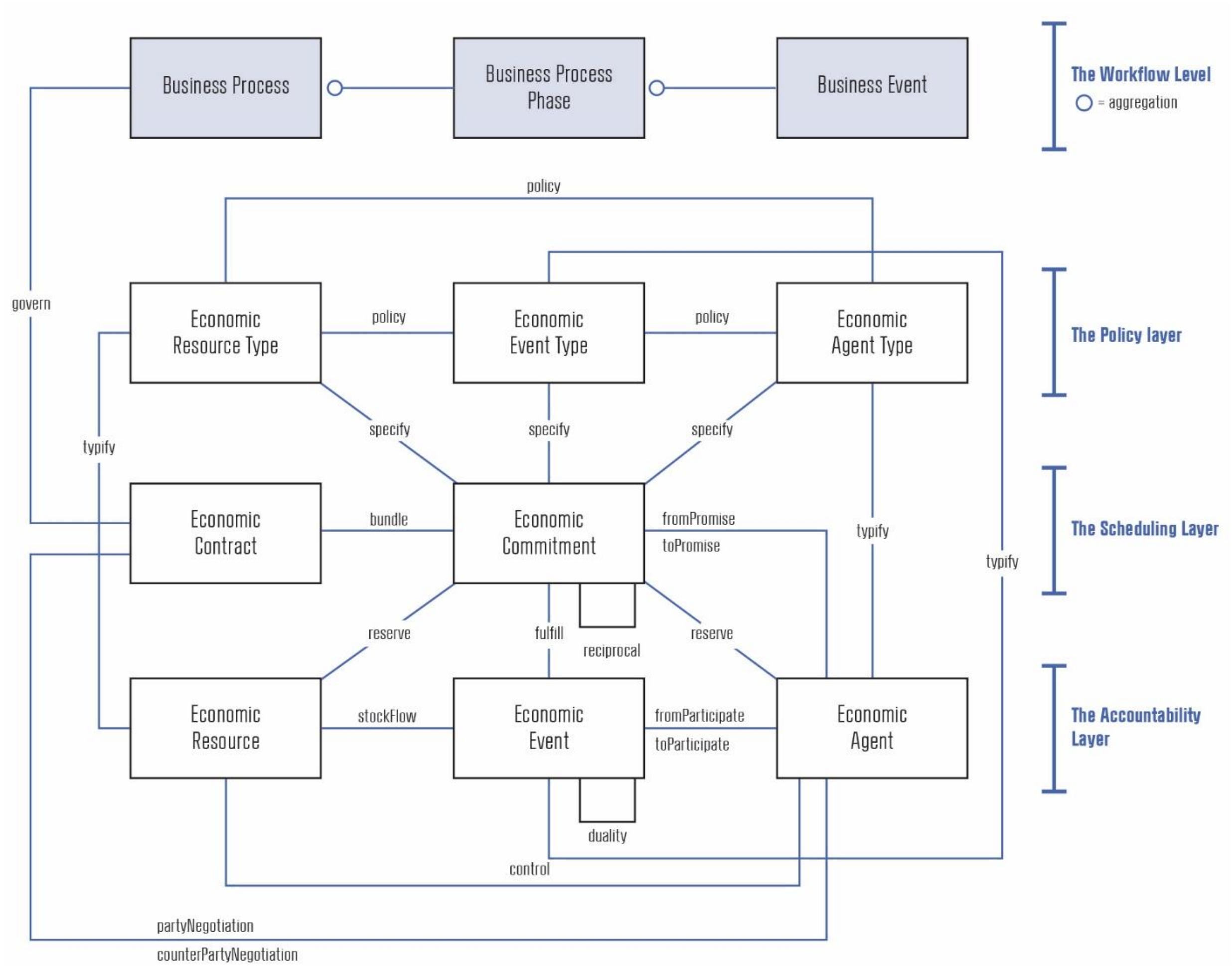

Figure 2. The REA Metamodel (MOF Level-2) (adapted from McCarthy, Geerts, and Gal 2021)

In a series of papers by Geerts and McCarthy (1997, 1999, 2000, 2002, 2006), the original REA model was extended in two different directions:

1. along the **aggregation** plane where business processes were first decomposed into a workflow of business events (see the workflow level at the top of Figure 2), and subsequently aggregated into value chains and into value networks (Porter, 1985)[58], and

58 Readers interested in a video overview of REA basic components, plus its temporal and aggregation expansions may consult a presentation by W. McCarthy given at the 2020 American Accounting Association's SPARK conference: https://doi.org/10.26226/morressier.5ecd173d6abf9730c67a8385

2. along the **temporal** plane to extend economic transactions of the past (normal accounting) with scheduled contracts and policies (see the *scheduling* layer and the *policy* layer in Figure 2).

In the REA monograph to be published in 2021 by the American Accounting Association (McCarthy et al., 2021), expansions in the aggregation plane are explained in chapter 2, while expansions along the temporal plane are explained in chapter 3. The bottom three layers exhibited in Figure 2 are actually the metamodel for the REA ontology expressed at MOF (Meta Object Facility) Level-M3 (Object Management Group, 2014). In MOF terminology, Level M3 is an abstract description of ontology categories (boxes) and their associations (labeled connecting lines). Later in the paper, we give a MOF Level M1 explanation of how that metamodel is applied to a particular situation (in our case, an atomic swap of bicycles for currency in collaboration space), and even later, we describe the particular instances (like an actual bike or an actual buying person) for our prototype (MOF Level M0 instances).

Before we leave our explanation of Figure 2, however, we propose an important additional expansion to the REA metamodel for use in collaboration space. In McCarthy et al. (2021), the accountability layer at the bottom of Figure 2 was recommended as the *normative* (i.e., required) part of an accounting business process model, while the next two layers up (the scheduling layer and the policy layer) were proposed as *informative* (i.e., not required). Here we start to remove this distinction and propose that a full business process frame of semantic components (in bold) be anchored on an **REA economic contract** that **bundles** one or more sets of **commitments** that in turn are **fulfilled** by **economic events.** This structure is a **full REA contract.** Moreover, we propose further in this paper that "self-executing 'smart contracts' – better understood as algorithms that automatically execute transfers of value when preprogrammed conditions have been met" Berg et al. (2019, 3) – in collaboration space be referred to as an **REA smart contract** throughout our discussion and implementation. In the general blockchain literature, the definition of 'smart contracts" varies considerably from reference to reference, but our proposal here is to limit that definition to full REA contract models with reciprocating promises. Thusly, we propose to define "Accounting Contracts in Collaboration Space." Overall, Figure 2 is the design theory for this paper.

2.2 Distributed ledger technology

As an ideological answer to the financial crisis in 2008, Satoshi Nakamoto made the Bitcoin blockchain available for users wanting "cryptographic proof instead of trust". He was tired of the "increases transaction costs, limiting the minimum practical transaction size and cutting off the possibility for small casual transactions" (Nakamoto, 2008, p. 1). In doing so, Nakamoto introduced the first blockchain system by combining existing technology (asymmetric cryptography, Merkel Tree data structures, and Proof-of-Work consensus mechanism) to solve "the double-spending problem using a peer-to-peer distributed timestamp server to generate computational proof of the chronological order of transactions" (Nakamoto, 2008, p. 1). In 2013, Vitalik Buterin (2013), introduced the Ethereum blockchain network that was a new generation of DLT platforms introducing a logic layer that was programmable and thereby allowing participants on the network to execute arbitrary logic for everyone to run and validate. The underlying consensus mechanism and data structure were the same. However, with its vast energy consumption (Li et al., 2019), the Ethereum community is planning to change its consensus mechanism away from Proof-of-Work to Proof-of-Stake.

The Bitcoin and Ethereum blockchain networks are categorized as public permissionless, which means that everyone can join the network and everyone has full transparency into the transactions on the network (Xu, Weber, and Staples 2019). Importantly, robust cryptographic techniques can be deployed readily to protect the privacy of transaction information in such a transparent network only to authorized participants. There are also private permissioned networks, which are typically found in supply chain consortia, where the participants of an ecosystem determine how to become a network member and decide which permissions each participant has, e.g., the large consortia of banks, R3. The private permissioned network belongs to the trading partner view, whereas the public permissionless network is the only technology to date that supports the vision of an independent view and collaboration space. This also is a way - as stated in the introduction – public permissionless DLT systems provide the shift to the core elements of modern economics in terms of trust within a business transaction and inherently also paves the way for a new way of doing accounting.

2.3 DLT in Accounting

Studies on DLT in the domain of accounting are still maturing. Dai and Vasarhelyi (2017) propose a potential design for a triple-entry accounting information system using a blockchain as a repository of "accounting tokens" that represent traditional double-entry postings in a company's ERP system. The tokens on the blockchain should "facilitate the implementation of automatic confirmation by automatically matching the total token value with the supplier's account receivable balance". Wang and Kogan (2018) present a design for a blockchain-based transaction processing system through a prototype demonstration using zero-knowledge proof (ZKP) and homomorphic encryption. The goal of the design is to create a transaction system that enables "real-time accounting, continuous monitoring and fraud prevention". Whereas the two studies described above present conceptual designs, Carlin (2019) discusses the "journey beyond double entry" and sees blockchain technology as an enabler for that without proposing a specific design.

The core design principle of each of the three studies mentioned above still rests with double-entry bookkeeping. This means that the technological features of DLT only incrementally make accounting processes more efficient, and the designs proposed are not radically different since they do not change the underlying accountability infrastructure.[59] These studies can then be categorized, according to David et al. (2003), as the "trading partner" view by focusing on what is going on from the perspective of a commerce participant inside an organization rather than providing the perspective of a neutral observer taking the "independent" view of the shared collaboration space outside of any particular company. Therefore, it is our study's intent to provide a design theory and an artifact instantiation of how an independent view could affect ontological *and* technical changes to the future of accounting. This quote encapsulates our vision: "These higher-order systems will allow users to store, access, and format their information in a manner suited to their own goals. Additionally, these systems may enable new organizational structures. By reducing the cost of inter-organizational coordination, small, nimble firms that focus on one activity in the value chain can flourish, relying on the communication capabilities of firms providing complementary services." (David et al., 2003, p. 68).

[59] Radical innovation is interpreted an innovation that is novel and different from current trajectory of either the current process or the current technology (See e.g. Lynn et al. (1996), Lynn and Akgün (1998)).

2.4 Institutional Cryptoeconomics

Institutional Cryptoeconomics is a term coined by Vitalik Buterin – the founder of Ethereum – in 2017, and we believe that it is best explained by Berg et al. (2019). At the beginning of their book on understanding the blockchain economy, they say that "institutional cryptoeconomics" (p. 1) is the application of the transaction cost economics of Ronald Coase, James Buchanan, Oliver Williamson, and Elinor Nostrom to blockchains; the distributed ledger technology first invented by the pseudonymous Satoshi Nakamoto for the development of the Bitcoin cryptocurrency. They state further that "institutional cryptoeconomics is the study of how blockchains interact with our existing and future social institutions, from the nature of contracts, to the shape of the firm, to the structures of global trade, all the way to the dynamics of capitalism and geopolitics" (p.1). They then proceed to study a number of blockchain topics including: (1) the institutional economics of blockchain; (2) the universal Turing institution; (3) money, equity, and the barter economy of the future; (4) supply chains and identity; and (5) the V-form organization and the future of the firm. Near the end of their book (p.164), they deduce that "Blockchain adoption is beginning a process of entrepreneurially unwinding layers of accumulated market intermediation and organisational hierarchy, and is laying down [a] new economic infrastructure." They conclude that "Capitalism after Satoshi will be flatter, more distributed, more trustful, and less regulated" (p.164).

Williamson (1985) argues that if the parties involved in a deal promise *cooperative behavior* and that if contracts are self-enforcing, the basis for an efficient transaction exists with no opportunistic behavior, and therefore "most forms of complex transacting and hierarchy vanish" (1993, 97). We know, however, that moral hazard and adverse selection occur and create a need for trust-making third parties such as lawyers, accountants, banks, etc., which take up as much as 35 percent of the US economy (Davidson et al., 2018). Untangling the concept of trust, Rousseau, Sitkin, Burt, and Camerer (1998) describe three types of trust: institutional trust, calculative trust, and relational trust. Institutional trust is the underlying trust in systems and institutions that the other party will comply with certain standards. Calculative trust is the remaining trust needed to complete the transaction, otherwise known as the search cost. Relational trust is the trust built over time through repeated interactions between two parties, replacing the need for calculative trust.

DLT and public permissionless blockchains with a smart contract layer, in particular, have been categorized as "Trust Machines" (Berg et al., 2020; Berkeley, 2015). The self-executing smart contract ensures that a contract's promise is executed by an autonomous agent that always acts according to the code by which it is governed. The code, in public permissionless blockchains, e.g., is available and open for everyone to validate. This means that DLT provides a trusted, neutral agent that replaces the need for high *institutional trust* in, e.g., companies, brands, or government. At the time when Williamson made his arguments, no technology existed to create these conditions. However, such was satisfied with the introduction of smart contracts by Szabo (1994, p. 1), whose purpose of the design was not only to eliminate trusted third parties but also to reduce "fraud loss, arbitration and enforcement costs, and other transaction costs." Even though Szabo's vision was grand, it was not until 2013 that the innovative combinations of blockchain technology by Buterin through the Ethereum platform made that vision a reality.

This paper does not investigate, judge, or assimilate the Berg-Davidson-Potts economic analysis enumerated above, although we consider it to be quite sound. However, as detailed below, we intend to use and extend one of the central components of their analysis: the microfoundations of ledgers (Berg et al., 2019). Briefly, we propose that their essential concept of a *general ledger* (which is not the same as the accounting master file of the same name[60]) be replaced by components of the independent view of the REA accounting and economic ontology.

According to Berg et al. (2019), such ledgers are databases of economic transactions that provide "an authoritative accounting of the state of the world at a given moment in time". Further on, at the end of their chapter on the micro-foundations of ledgers, Berg et al. (2019) belatedly announce: "To the extent that the rules of ledgers are shared, they have the property of semantic interoperability: harmonisation and mutual recognition of meaning, so that relationships expressed in one ledger have ontological equivalence with those expressed in another" (p. 72).

We contend that the Berg-Davidson-Potts notion of a ledger is too loosely defined, and it does not sufficiently avail itself of what REA provides in abundant quantities: semantic interoperability via its development and maintenance as an "accounting and economic ontology" (McCarthy et al., 2021). Additionally, their goal of "an authoritative accounting of the state of the world at a given moment in time" demands additional computational development, which we propose to provide detailed state machine mechanics in our computational artifact. If we (somewhat

[60] Berg, Davidson, and Potts (like the authors of this paper) consider double entry ledgers ("A collection of accounting entries consisting of credits and debits" (https://en.wiktionary.org/wiki/ledger) to be too limited of a paradigm to constitute the semantic foundation of a blockchain ledger.

informally) consider an atomic swap between a buyer and a seller as a "deal," then our REA business process state machines should always be able to tell us "where we are in the conduct of the deal" at all times.

In the rest of this paper, we develop a designed artifact that avails itself of the declarative (imposing classifications on observations) and procedural (consulting those semantic structures to create knowledge further) components of the REA ontology.

3. METHODOLOGY

The building blocks of design science research (DSR) originated from engineering and the sciences of the artificial (Simon, 1996). These were further developed by Walls, Widmeyer, and El Sawy (1992), who introduced a framework for information systems design theory. In 2004, Hevner et al. (2004) presented a specific framework for information systems research which we build on in this paper. According to Gregor and Hevner (2013), a DSR paper's contribution can be categorized into the four segments shown in Figure 3 (routine design, improvement, invention, and exaptation) based on the maturity (high/low) of the application domain and existing solutions.

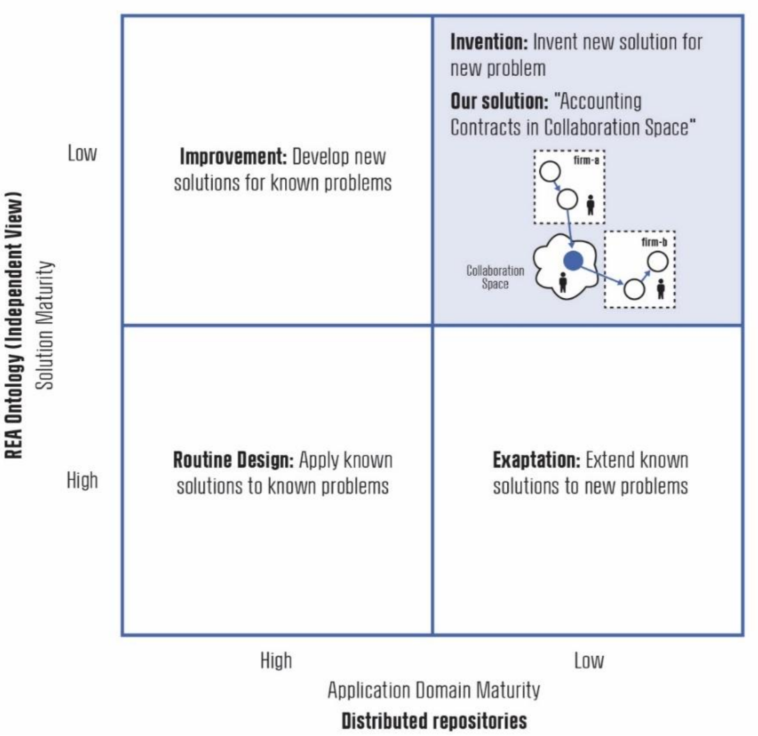

Figure 3. Invention of accounting contracts in collaboration space. Source: adapted from Gregor and Hevner (2013)

Our study contributes to the invention segment since the solution we propose - Accounting Contracts in Collaboration Space - is novel. The solution maturity of the independent view of the REA ontology is low because actual applications are limited as of 2021, and the maturity of the application domain of distributed repositories is also considered below. Thus, we place our prototype efforts in the top-right invention box of Figure 3.

This study follows Peffers, Tuunanen, Rothenberger, and Chatterjee's (2007) model of six activities, which builds on the DSR paradigm presented by Hevner et al. (2004). In activity 1 (identify problem and motivation), we present the theoretical arguments described in our paper's initial sections. In activity 2 (define objectives of a solution), we define the scenarios that the artifact should be able to run. Specifically, we choose two business-to-business transactions between two companies exchanging bicycles: one transaction that runs straight through without exceptions and one that is incomplete. We show that our state machine is able to handle different types of exchange conversations. In activity 3 (design and development), we model the two business transactions by unfolding the exchange of documents that follow the Universal Business Language (UBL) standard and represent our scenario components in extensible markup language (XML). While converting the scenarios from logic to XML, we build a Python-based XML-to-Solidity converter so that the scenarios represented as XML state machines can be implemented on a blockchain. At this point, we start to discuss our blockchain database as a distributed business transaction repository (DBTR) as specified in ISO/IEC 15944-21 (2020). Our converter then takes the XML and converts it into Solidity smart contract code. The reason we choose Solidity as a programming language is that the Ethereum virtual machine (EVM) is implemented in various platforms within the blockchain marketplace (for example, Quorum, Hedera, Tron). The authoring of the state machines in XML is independent of any particular DLT and its programming language, such that the scenarios are able to be implemented in any blockchain smart contract environment.

In activities 4 and 5 of the Peffers et al. methodology (demonstration and evaluation), we assess whether or not the smart contract behaves as expected (according to the prescribed scenarios) by running tests using Truffle, which is a "testing framework and asset pipeline for blockchains using the EVM".[61] Using Truffle optimizes the cycle time between the design, development, and test

[61] Further explanation of the Truffle test framework is given here: https://www.trufflesuite.com/truffle

phases of artifact design because Truffle creates a local blockchain on the computer that is equivalent to an EVM-based blockchain such as Ethereum. It is important to notice that the iteration along activities 2-5 happens fluently during our study, as Peffers et al.'s (2007) model also explains. Further, the evaluation of the artifact is methodologically grounded in Venable, Pries-Heje, and Baskerville's (2016) ”pure technical” appraisal since the nature of the setting is artificial (no test persons), and the iterations of the evaluation move along the horizontal axis from formative to summative as knowledge accumulates. Further, Venable et al. (2016) describe the section criteria for purely technical artifacts as "If [the] artefact is purely technical (no social aspects) or [if the] artefact use will be well in [the] future and not today," This matches our purpose here. In activity 6 (communication) of our paper, we discuss our contribution to the field of accounting, and then we conclude with some last thoughts about the higher-level purposes of our work. As a final note on methodology, we mention here that all code used to build and test our artifact is available on GitHub. The use of this repository will enable scholars and practitioners in their efforts to evaluate and extend our contributions [62]

4. ARTIFACT DESCRIPTION

4.1 The Case of Bill's Bikes Manufacturing

For our example proof of concept of an REA business process state machine in collaboration space, we choose to use a simplified example developed from a graduate accounting database design class: *Bill's Bikes Manufacturing* (BBM) which sells bikes at wholesale to a variety of retail bike shops, which in turn often customize those bikes for individual bikers.
A simplified REA value chain (a trading partner view of how a company purports to create value (Porter, 1985)) for BBM is illustrated in Figure 4, where each oval represents a separate business process (16 total in our example) that cumulatively builds the linkage to a final portfolio of attributes of value presented to customers in the revenue cycle (Lancaster, 1975).

Each business process has at least two REA Economic Events: a decrement economic event signaled by a minus sign and an increment economic event signaled by a plus sign. The labeled arrows going into a business process represent economic resources consumed by the decrement

[62] See the code on https://github.com/Jonassveistrup/accounting-contracts-in-collaboration-space

events, while the arrows coming out of the business process represent economic resources acquired by the increment events. The dotted arrows represent the acquisition and consumption of employee labor. BBM proposes to move its revenue cycle (sales requited by cash receipts) out to collaboration space where it will transact exchanges with bike shops like our chosen example – *Jonas's Bike Shop (JBS)*. Using the language of Berg et al. (2019), this might be the first step in transitioning to a flatter, less hierarchical, more distributed, and more trustful environment. For example, in the future, they might consider inviting open participation in their three logistics processes (truck acquisition, fuel acquisition, and logistics) or in their two advertising processes (advertising services acquisition and advertising campaign construction). For our design artifact, however, we will limit implementation to the BBM revenue cycle.

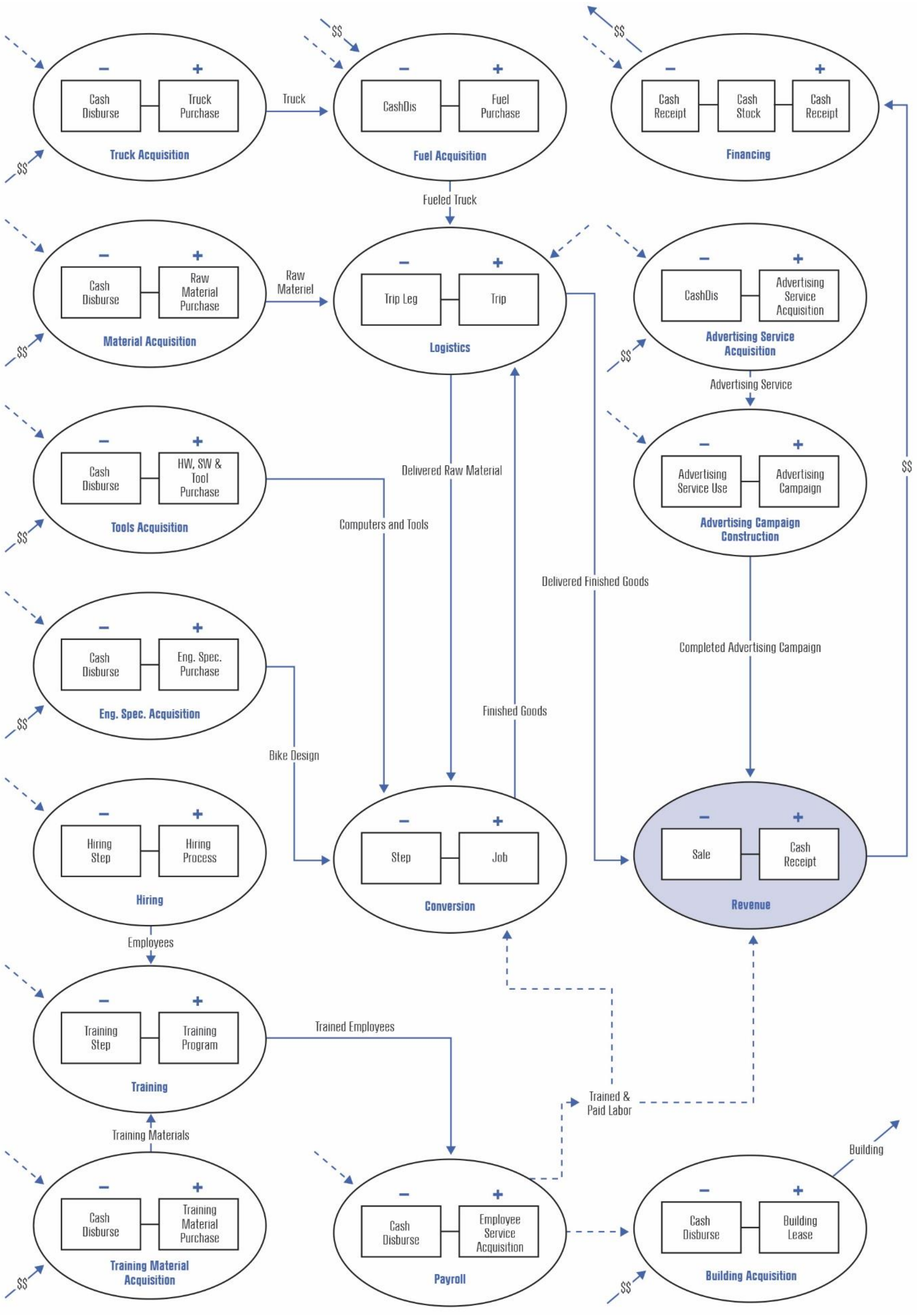

Figure 4. Bills Bikes Manufacturing (value chain)

The movement to collaboration space means that the redundant trading partner views of BBM's revenue cycle and JBS's acquisition cycle now collapse to the non-redundant independent view (one source of the truth) in the distributed business transaction repository (DBTR). We illustrate this in Figure 5, where we portray the logistics cycle of BBM linked to the DBTR in collaboration space and then further on to the customization process of JBS. The shipment event in collaboration space could be seen as a sale for BBM and a purchase for JBS, but its data is stored only once.

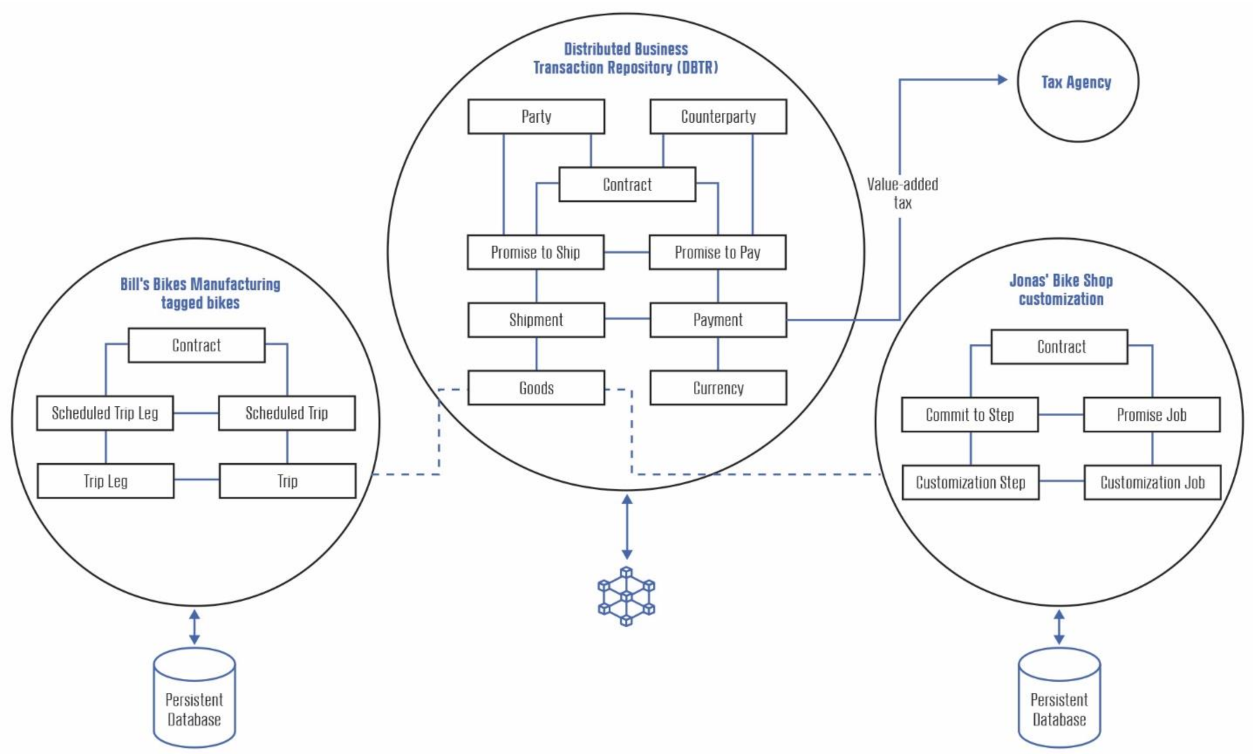

Figure 5. The role of the distributed business transaction repository in the supply chain

More details on this REA process implementation are fully illustrated in Figure 6, which gives actual attributes for each implemented business object on the DBTR. Readers should note that the process data model (see Figure 6) is a MOF Level-1 REA implementation that conforms to the independent view REA metamodel of Figure 2. Figure 6 portrays the architectural lattice for our proposed business process state machine.

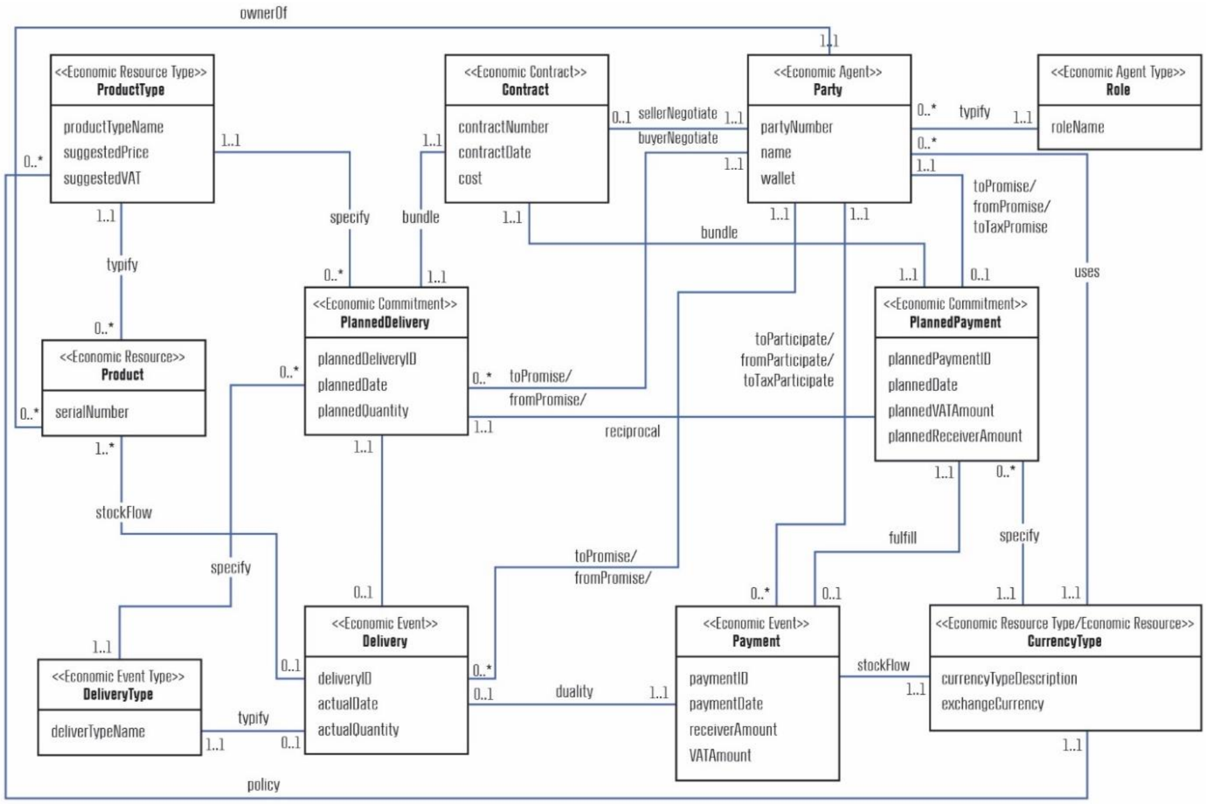

Figure 6. The collaboration space contract for BBM and JBS (MOF Level-1)

In Table 1, we partially illustrate some of the instance data for our artifact example with three occurrences for the Party class, two occurrences for the Product Type class, and 16 occurrences for the Product class. Readers should note that as we proceed downward in MOF levels from Figure 2 (M2) to Figure 6 (M1) to Table 1 (M0), we become less abstract and more concrete. Figure 2 is the REA design theory for our artifact, Figure 6 is the application of that metamodel to the collaboration space between BBM and JBS, and then, finally, Table 1 shows actual instances, such as "PC001" which represents an actual green bike.

Class	Instance ID	Instance description
Party	P100	BBM - Bike manufacturer (seller)
	P200	JBM - Bike shop (buyer)
	P300	Taxing authority
Product type	PT1	Green sportbike
	PT2	Red sportbike
Product	PC001-011	11 instances of green sports bike
	PC100-104	5 instances of red sports bike

Table 1. Instance-level data for agents and resources (MOF Level-0)

The orchestration of business events for an REA state machine follows the aggregation links shown on the workflow level at the top of Figure 2. An Economic Contract (which is a bundle of promises) governs the choreography for a Business Process. Business Processes, in turn, are aggregations of Business Process Phases (planning, identification, negotiation, actualization, and post-actualization) as specified in ISO/IEC 15944-1 (2001) and elaborated further in McCarthy et al. (2021). And finally, the movement through phases is propelled by Business Events that change the states of the business transaction objects. Those business objects are instances of the classes specified in the M1 class diagram of Figure 6.

When two parties participate in a proposed exchange, the messaged conversations they engage in are termed a "conversation for action" (Flores, 2012). In our example, the conversation for action between BBM and JBB consists of a set of Business Events specified using the exchange of UBL documents. In our artifact, we show two different business transaction occurrences between a seller (BBM) and a buyer (JBS), one process fully completed, and one partially completed. The conversation for action for the first is illustrated in Figure 7.

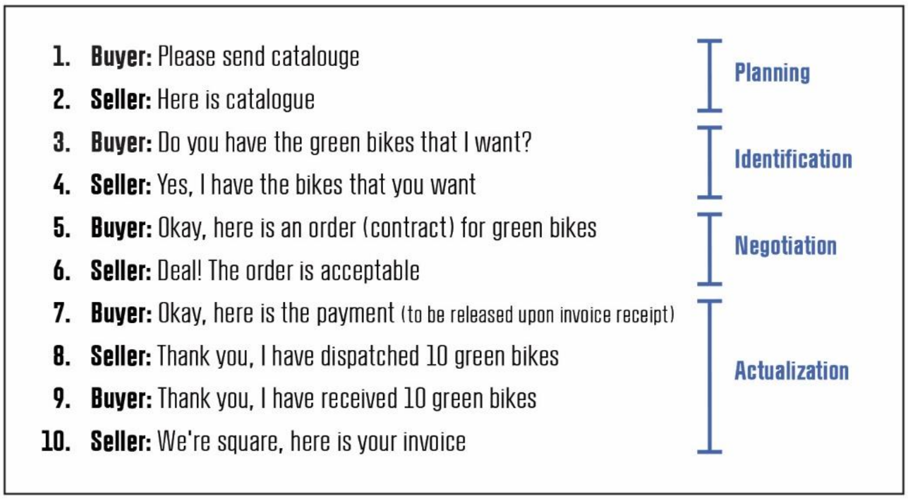

Figure 7. An example "conversation for action" – a choreography of business events that triggers state changes

4.2 Blockchain-artifact description

The artifact presented in this study is an instantiation type (March & Smith, 1995) and a prototype of how a DLT system could look when representing a distributed business transactions repository. This section describes the assumptions made during the creation of that artifact, our reasons for choosing a public platform, and a thorough description of our implementation with state machine mechanics.

For the artifact, we assume that the REA smart-contract will be instantiated on a public ledger that supports general computation. For our specific case, we instantiate it as a Solidity smart contract for EVM-based blockchains. To ensure the integrity of the system, the contract shall be non-updateable, and it should specify the transitions and rules of the REA state machine to the fullest. Further, it must be a public ledger such that any party who wishes to can investigate the history of the transaction. Given the history of the network, which is inherently stored in the ledger, it is possible to fully playback the series of events if such a repetition is of interest. While we have certain helper contracts, we will not go over these in detail as they are merely for convenience. We introduce next the three main smart contracts of the artifact: (1) the currency, (2) the inventory, and (3) the REA-contract. For demonstration purposes, we do not employ any of the cryptographic techniques required to make the publicly available information protected for viewing by only authorized participants.

The currency is a stablecoin emulating the Dai stablecoin.[63] We have chosen Dai in our instantiation because it is widely used in the Ethereum ecosystem and uses the Ethereum fungible token standard ERC20, making it easy to integrate.[64] The inventory is constructed so as to ensure that a seller is incapable of double-spending goods (i.e., selling the same item multiple times without being caught). The contract is a large store of items, where each item has a state, type, price, description, and seller. The most important job of the inventory is to keep track of the states of the item and make sure that only its seller can progress the state from available to unavailable when the item is sold. We enforce these rules with a global store of states; hence, a transfer-specific item state would provide no guarantees on the items' true availability. Furthermore, the global inventory is a control mechanism, as it supports access controls on who can perform what actions. This means that the inventory can be implemented so that only verified sellers can create items. Because the access control is enforced directly in the contract, the granularity makes it possible to specify what type of products a seller can create and sell.

---

[63] See more about the stablecoin DAI here: https://makerdao.com/en/

[64] Read more about the ERC20 standard here: https://ethereum.org/en/developers/docs/standards/tokens/erc-20/

The REA smart contract is a mechanism for controlling the flow of a deal, a finite state machine with clearly defined stimuli. It is implemented, as seen in, enforcing rules on who can perform what actions in which sequence. This means that it is impossible to progress the state of the deal in an unspecified manner. Further, it implies that with a proper state machine specification, safety is ensured, and the worst thing that can happen is that the deal does not progress. These defined rules mean that certain business events such as a *despatch-advice* are only possible if all the items are available, and payments are enforced in such a manner that either you pay value-added tax (VAT) and the seller or no payment is performed at all.[65]

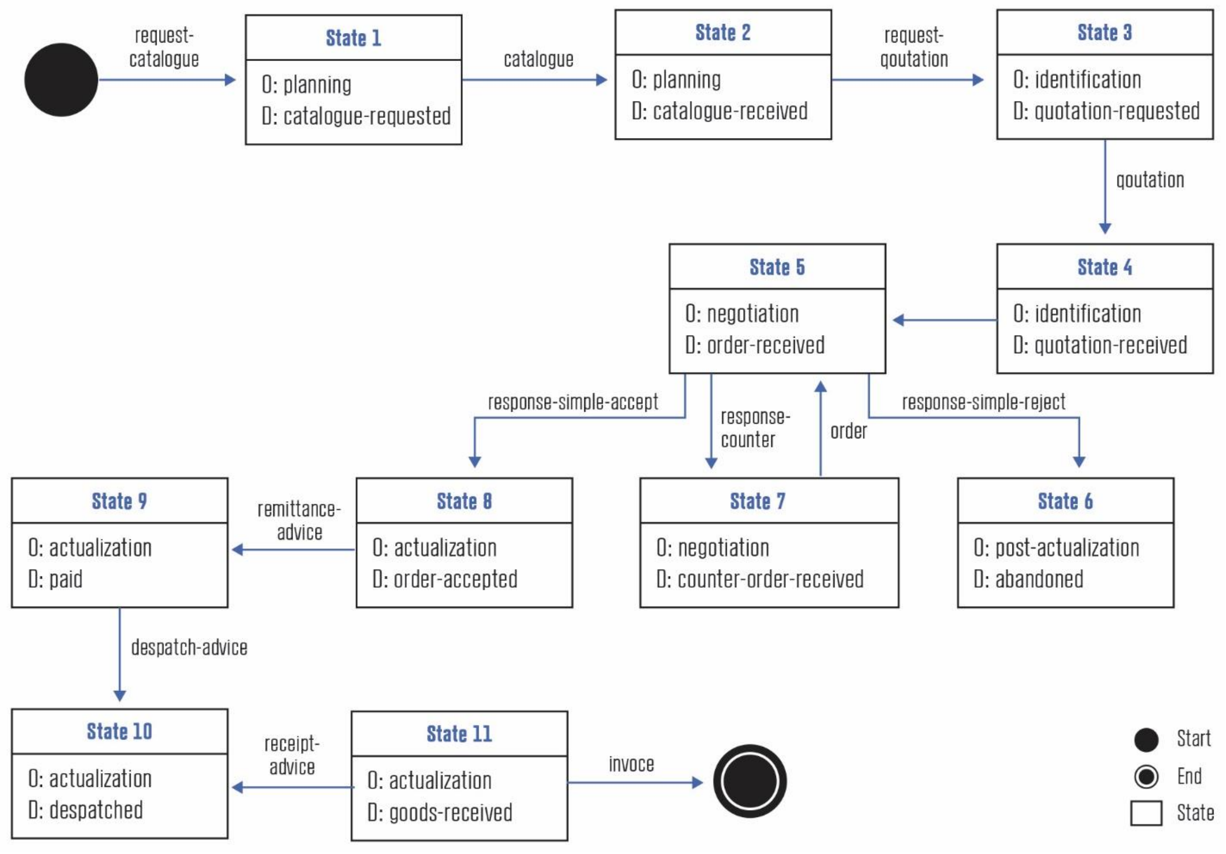

Figure 8. State machine

With the Figure 8 outline in mind, we provide a short description of the individual stimuli and the states that occur throughout the flow of the deal. We have marked actions that only the seller can

[65] See how the current VAT process works in the appendix

perform with a dashed line and actions that only the buyer can perform with a dotted line (for example, only the buyer in a deal can perform *request-catalogue*). Further, we note that users may abandon the deal at any state, leading to the *post-actualization* abandoned state. We have not drawn these edges in Figure 8 to enhance readability. Note that if a buyer was to abandon a deal prior to payment, but after the goods have been sent, the blockchain contract can be used as evidence that he or she acted opportunistically.

4.3 State machine mechanics

A state machine is a graph that consists of vertices (called states) and edges (called stimuli). For a given state, it is possible to alter the state using the stimuli at an outgoing edge. If one provides a stimulus to some state that does not have an outgoing edge with that stimulus, there is no change in state, and the state transition is rejected. With this in mind, we review the different kinds of stimuli that can be performed on our machine. The value "O" in the state is the Business Process Overview state, and "D" is the Business Process Detail state.

Our state machine is initiated by *request-catalogue* where the buyer requests a catalog. The next stimulus is the actual *catalogue,* where the seller provides a catalog to the buyer. The *request-quotation* is carried out by a buyer who provides a list of goods that are needed for purchase from the seller. The list is not binding. An example might be "1 blue bike and 1 bell." Next is the *quotation* where the seller provides a status on the goods that the buyer initially wanted. After ensuring the availability of the quotation, the *order* is where the buyer provides a list of goods that he is ordering. Note that this stimulus can be performed from two different states (5 and 7). The cycle means that parties can negotiate until the seller either accepts (*response-simple-accept*) or rejects (*response-simple-reject*) the order. If the seller wants to negotiate, he or she can provide a *response-counter,* which is a rejection of the order that the buyer provided, but answers with a counter-order. When the seller accepts the order, he or she will specify what exact items are to be transferred.

Assuming that the buyer and seller agree at some point in time, the buyer will perform the *remittance-advice* meaning that the buyer reserves in the smart contract the payment both to the seller and to the tax agency. Following this payment, the *despatch-advice* shows when the seller loads the goods. The state will only transition if every specified good is of the correct type **and** is available in the inventory. The *receipt-advice* is where the buyer notes that the goods have been received, and the *invoice* is where the seller completes the business transaction, thus triggering the transfer of the reserved funds out of the smart contract.

Figure 9 portrays the process-level DBTR mechanics for the first three steps of a business process, and readers should note how it relates to the workflow structures at the top of Figure 2. A process proceeds through its overview phases (planning, identification, negotiation, actualization, and post-actualization) propelled by business events which are actually the exchanges of UBL documents (Business Process Detail).

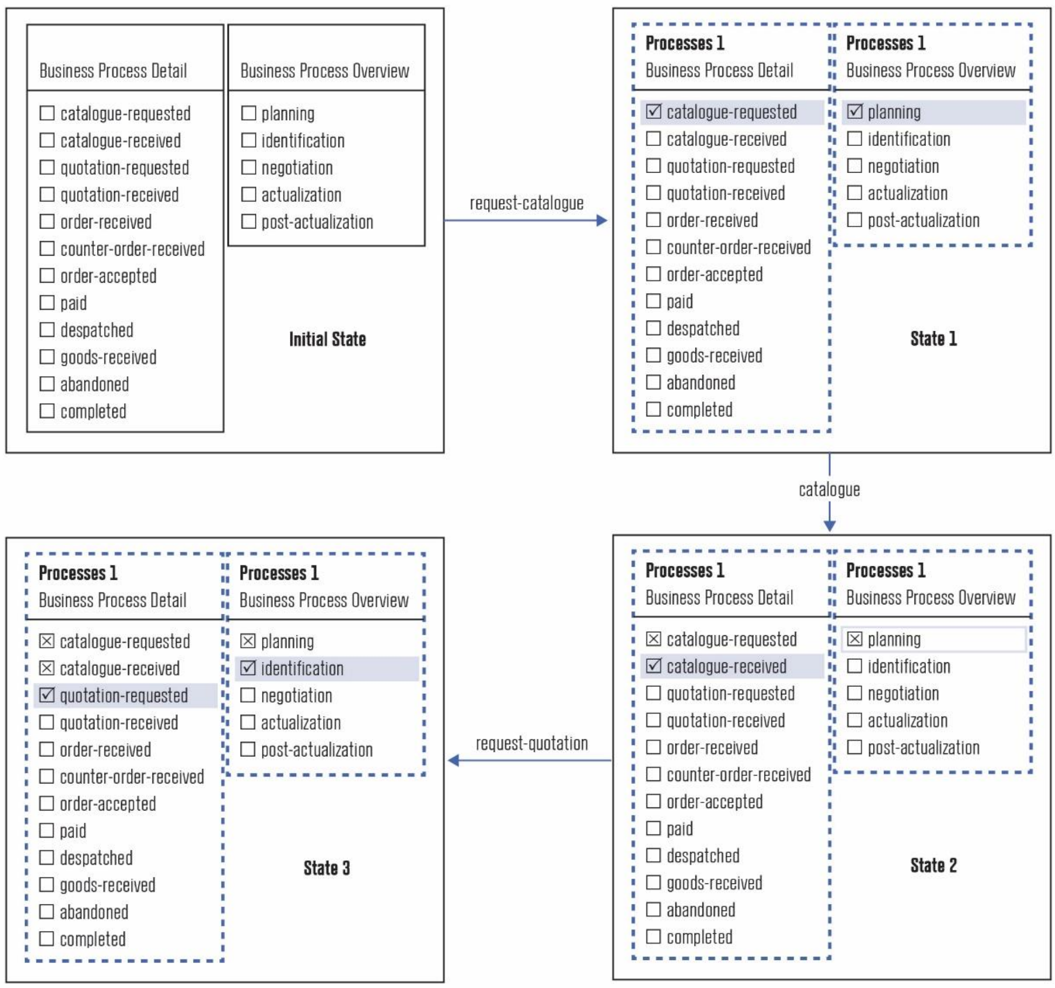

Figure 9. The DBTR state machine first three steps

5. EVALUATION

5.1 Scenarios

To instantiate our overall state machine, we outline two scenarios as practical examples of how an independent view state machine would work. Scenario 1 starts on the 1st of June where the bike shop (buyer) orders ten green bikes to be delivered on the 15th of June from the bike manufacturer (seller). The payment for the ten green bikes, a total value of 12,000 Dai (1,200 Dai for each bike), is completed on the 10th of June. Scenario 2 starts a month later, on the 1st of July, where the bike shop (buyer) orders five red bikes to be delivered on the 15th of July from the bike manufacturer (seller). However, we pause the scenario on the 12th of July before the second bike shipment occurs. In each scenario, planned payment and actual payment include the planned and actual VAT amount based on the sales price.

5.2 Evaluation through Truffle

In our evaluation of the prototype, we instantiated scenario data (see Table 1) into Truffle. For our instantiation, we had four parties: buyer, seller, tax agency, and bank. In the production implementation, there should be no bank because we would use Dai directly. However, we used a bank as the creator of some placeholder Dai for the purpose of showcasing the system.

As seen in Figure 10, we initially created the emulated Dai and transferred 100,000.00 to the buyer. After providing the buyer with funds, two item types were created (the green and red sports bikes). After that, the seller instantiates 11 green bikes of 1,200.00 Dai each and five red bikes of 800.00 Dai each. Finally, JBS (the buyer) initiates an REA smart contract between itself and the seller.

```
beforeEach('Setup for each test', async function() {
    // Setup currency, cap = 1000000.000000000000000000
    dai = await DAI.new({from: bank});

    // Transfer 100000 dai to the buyer. Recall 18 decimals.
    await dai.transfer(buyer, BigNumber(100000).times(1e18), {from: bank});

    inventory = await Inventory.new(dai.address, {from: tax});

    await inventory.createItemType("Green sports bike");
    await inventory.createItemType("Red sports bike");

    // Create 11 green bikes of price 1200 and 5 Red of price 800
    for (let i = 0 ; i < 11; i++){
        await inventory.createItem(0, "#" + i, BigNumber(1200).times(1e18), {from: seller});
        if (i < 5){
            await inventory.createItem(1, "#" + i, BigNumber(800).times(1e18), {from: seller});
        }
    }

    // Create REA smart contract with between seller and buyer with the specified inventory.
    rea = await REA.new(inventory.address, seller, {from: buyer})
});
```

Figure 10. Test instantiation

Figure 11 shows eight selected tests that we ran for the final evaluation. These eight were chosen because they encapsulate the most critical aspects of our exchange process.

```
Contract: REA with inventory
  √ Happy path, no negotiation (1886ms)
  √ Happy path with re-negotiation (1785ms)
  √ Happy path with seller rejecting  (1271ms)
  √ Buyer with (amount < funds < vat + amount) unable to execute remittance_advice (11042ms)
  √ Buyer unable to accept order on behalf of seller (727ms)
  √ Buyer unable to perform despatch (1573ms)
  √ Seller unable to perform receipt-advice (5044ms)
  √ Seller unable to double-spend items, e.g., have the same item in two orders (4310ms)

8 passing (1m)
```

Figure 11. Evaluation output of automated test

The first three tests are all in what is called the “happy path”, where no user behaves maliciously or unexpectedly. Test 1 is the shortest path through the state machine, with everything going according to plan. In test 2, the buyer and the seller are negotiating (moving from state 5 to state 7 in Figure 8), and in test 3, the seller rejects the buyer (state 6). In test 4, the buyer has enough money to pay the seller but not enough to pay the VAT to the tax agencies. Therefore, the machine is unable to execute the entire transaction. In test 5, the buyer tries to accept an order on behalf of the seller but is unable to do that (which is the expected outcome). In test 6, we ensure that the seller is the only one able to perform despatch-advice transition. Similarly, in test 7, we make sure that it is only the buyer that can perform receipt-advice transitions. And finally, in test 8, we check for double-spending of items meaning that we evaluate whether the same item can be sold twice (it cannot).

With all tests passed, we conclude that the implementation of the state machine follows the specification and since the specification is useful, so is the artifact. Further, it proves the technical feasibility of economic agents moving their transactions into the collaboration space.

5.3 Materialization of Account Balances

In REA theory, the provision of account balances for uses like the preparation of financial statements is (by default) effected with procedures instead of declarations (Gal & McCarthy, 1983, 1986); that is, such balances are database views (McCarthy, 1982; Nittler, 2018). McCarthy et al. (2021) formalized this distinction and proposed a procedural hierarchy for account materialization based on *Statement of Financial Accounting Concepts No. 6 - Elements of Financial Statements* (Financial Accounting Standards Board, 1985) within a trading partner view of an enterprise's economic activities. As illustrated in Figure 12, this means that "Each trading partner extracts information from the DBTR as if it is light seen through different prisms" (Holman, 2019).

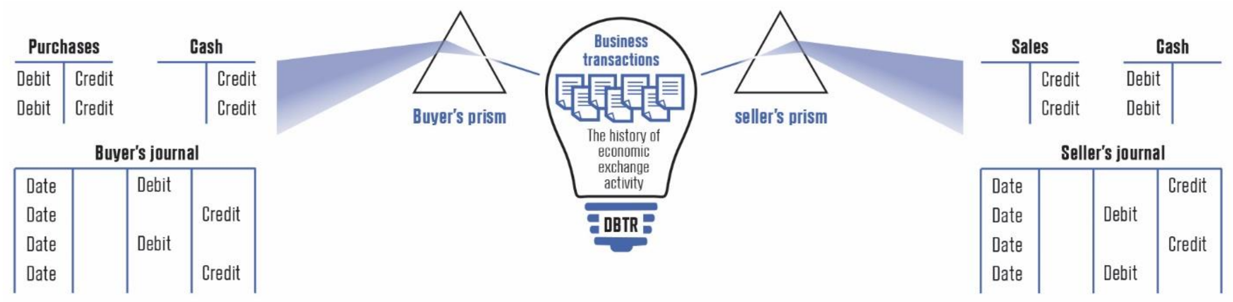

Figure 12. Components of general ledgers as database views. Source: Adapted from Ken Holman presentation at Exchange Summit Singapore on November 4th, 2019

For both JBS (the buyer) and BBM (the seller) in our example scenarios, views materialized immediately after our two business transactions would necessitate the following:

- For BBM on transaction #1, entries to accounts for sales, currency account balances, and VATIn, plus quantity delivered for green bikes to be used in calculating cost-of-goods-sold internally. For transaction #2 (incomplete), no entries would be needed.

- For JBS on transaction #1, entries for purchases, currency account balances, and VATOut, for transaction #2, entries for products-receivable and prepaidVATOut.

Code for producing these materializations was invoked for our prototype, with the results shown in Figure 13. For actual companies, these materialization procedures would be done separately for each firm, depending on their reporting requirements.

Initial

```
{
  "deals":{
    "0x2E2D...ad":{
      "productsreceivable":"0",
      "prepaidVatOut":"0",
      "expectedVat":"0",
      "expectedAmount":"0",
      "balance":"0"
    },
    "0x86BA...4f":{
      "productsreceivable":"0",
      "prepaidVatOut":"0",
      "expectedVat":"0",
      "expectedAmount":"0",
      "balance":"0"
    }
  },
  "sellerBalance":"0",
  "buyerBalance":"100000",
  "taxBalance":"0",
  "buyerItems":{

  },
  "sellerItems":{
    "Green sports bike":11,
    "Red sports bike":5
  }
}
```

Intermediate

```
{
  "deals":{
    "0x2E2D...ad":{
      "productsreceivable":0,
      "prepaidVatOut":0,
      "sellerVatIn":"3000",
      "buyerVatOut":"3000",
      "sales":"12000",
      "purchases":"12000",
      "deliveries":{
        "Green sports bike":10
      },
      "expectedVat":"3000",
      "expectedAmount":"12000",
      "balance":"0"
    },
    "0x86BA...4f":{
      "productsreceivable":"0",
      "prepaidVatOut":"0",
      "expectedVat":"0",
      "expectedAmount":"0",
      "balance":"0"
    }
  },
  "sellerBalance":"12000",
  "buyerBalance":"85000",
  "taxBalance":"3000",
  "buyerItems":{
    "Green sports bike":10
  },
  "sellerItems":{
    "Green sports bike":1,
    "Red sports bike":5
  }
}
```

Final

```
{
  "deals":{
    "0x2E2D1...ad":{
      "productsreceivable":0,
      "prepaidVatOut":0,
      "sellerVatIn":"3000",
      "buyerVatOut":"3000",
      "sales":"12000",
      "purchases":"12000",
      "deliveries":{
        "Green sports bike":10
      },
      "expectedVat":"3000",
      "expectedAmount":"12000",
      "balance":"0"
    },
    "0x86BA...4f":{
      "productsreceivable":"4000",
      "prepaidVatOut":"1000",
      "expectedVat":"1000",
      "expectedAmount":"4000",
      "balance":"5000"
    }
  },
  "sellerBalance":"12000",
  "buyerBalance":"80000",
  "taxBalance":"3000",
  "buyerItems":{
    "Green sports bike":10
  },
  "sellerItems":{
    "Green sports bike":1,
    "Red sports bike":5
  }
}
```

Figure 13. Materialization snapshots

6. DISCUSSION

6.1 Methodology for the DBTR state machine

During our development and evaluation phases (activities 5 and 6), we used GitHub as a repository for version control of the different iterations of state machines and the smart contract code. By keeping track of the iterations and visualizing each of the state machines (see, for example, a snapshot illustrated as Figure 14), the phase transitions between development and evaluation happened easily and transparently as learning from each version was codified.

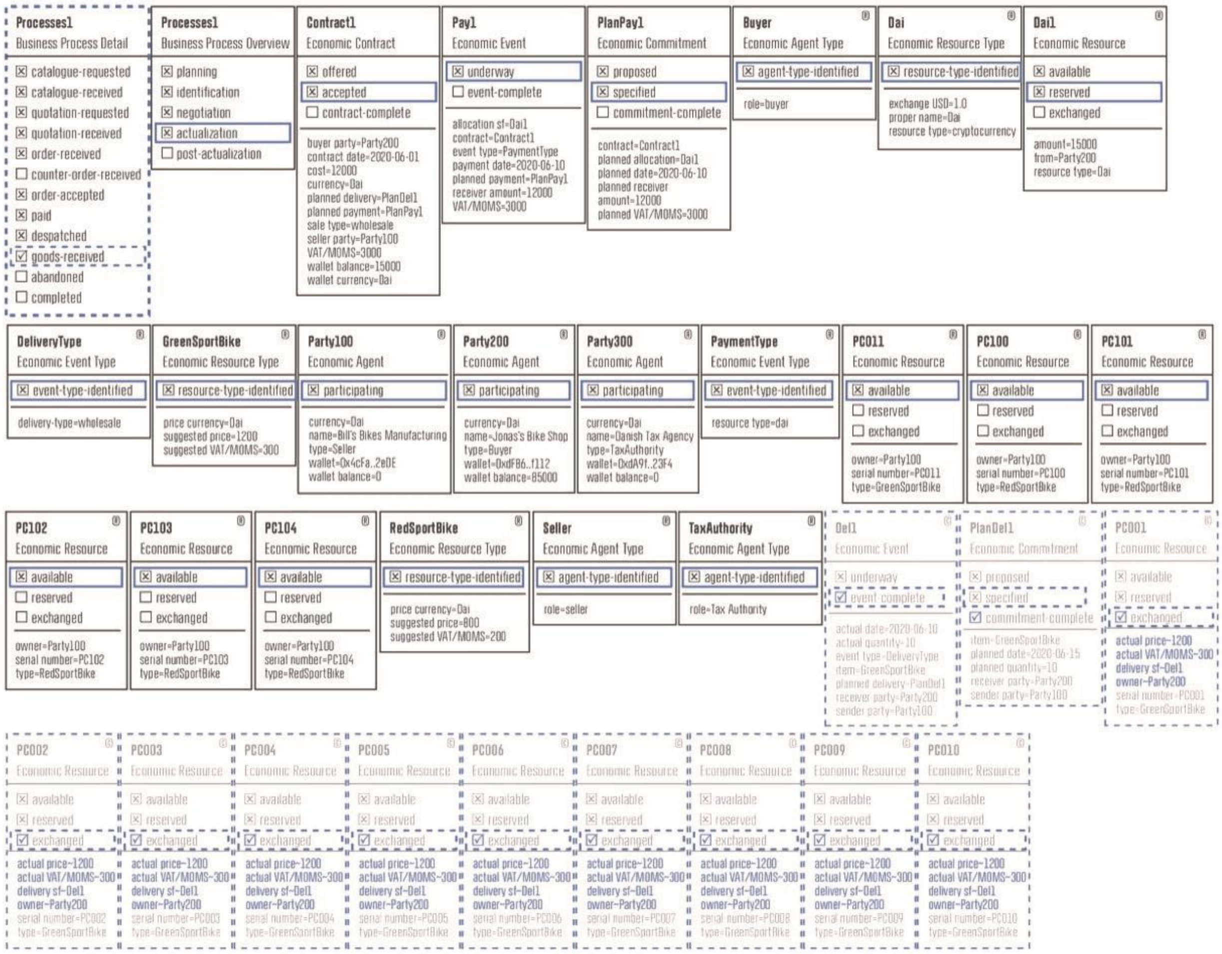

Figure 14. The DBTR state machine snapshot

In doing our development this way, the changes became visible for every member of the research team. This technique not only followed the core idea of Hevner et al. (2004) through the build/evaluate loop and Peffers et al. (2007) for activities 5 and 6, it also aided knowledge creation for the various fluctuations of the state machines and smart contract code within the team. This approach also matched the evaluation strategy from Venable et al. (2016) as the iterations served to accumulate knowledge and move from formative to summative on the horizontal axis in their Framework for Evaluation in Design Science.

6.2 Implications for collaboration space

In section 2, we analyzed how the combination of DLT and REA might affect the economic constructs of transaction cost, trust, and organizational boundaries in the context of a business-to-business transaction. With the evaluation of the prototype, we can discuss what this means.

Since the smart contract code and, therefore the REA state machine is available for everyone to inspect, that platform institutionalizes the trust levels organizations need today to build and prosper in e-commerce. The two strategic options, *build* or *buy*, have been discussed by managers in practice and in the academic literature since the introduction of organizational boundaries by Coase (1937). With the introduction of blockchain technology and the suggestion of collaboration space use, firms need to consider a third option: *network* (as also mentioned by Berg et al. (2019)). This means that instead of having a binary mindset of either/or, the network option provides an opportunity for co-creating and co-owning information, assets, and individual representations of assets in the forms of tokens in a network among suppliers, vendors, competitors, customers, and governmental agents. Even without blockchain technology, organizations have been forming such partnerships. However, the effectiveness of solidifying parts of a business contract into code is the turning point that supports a true alternative to build or to buy. This third option may also imply changes to what Simon (1996) conceptualizes as an *artifact*, an interface between an inner and outer environment. Our artifact created a radical new interface between these two environments since the interpretation of what constitutes inner vs. outer is not binary and includes collaboration space instantiated as the DBTR.

6.3 Further developments

Future iterations of the prototype that we have for DBTR could include Zero-Knowledge Proofs (ZKP) technique introduced by Goldwasser, Micali, and Rackoff (1989). A ZKP is a technique to share knowledge without sharing data by using mathematical proof. For example, a seller could prove a buyer having enough liquidity to pay for a given order without revealing how much liquidity the buyer has. In the case of the DBTR, this would mean that designs including ZKP could provide the needed and aspired transparency for transacting parties and tax agencies without needing to reveal every detail of every transaction to everyone on the network. ZKP could prove valuable in the search for replacing institutional trust with a trustless system, the combination of REA smart contracts, DLT, and ZKP, such that transaction cost for all involved parties would decrease while ensuring high levels of reporting and tax compliance. In the case of our prototype, the business events could be contained within a ZKP. Even though Wang and Kogan (2018) use ZKP in the context of double-entry bookkeeping, they still provide a good example of how ZKP can be incorporated within the domain of DLT and accounting.

7. CONCLUSIONS

Research that combines the field of accounting (which in the last 50 years is essentially *positive* in research outlook with its empirical orientation) with the field of computer science (which is essentially *normative* with its engineering orientation) is relatively rare in 2021. Fortunately, the design science approach of Hevner et al. (2004), Peffers et al. (2007), and Gregor and Hevner (2013) does provide us with a methodological road map for this combination. However, long before Hevner et al. crystalized the term *design science* in 2004, there were notable computer scientists who provided examples and inspirational guidance of a higher nature (societal benefit) for such combination attempts. For us in particular, we note the words of Alan Newell and Herbert Simon in their Turing Award lecture (1976, 114):

> "Computer science is an empirical discipline. We would have called it an experimental science, but like astronomy, economics, and geology, some of its unique forms of observation and experience do not fit a narrow stereotype of the experimental method. None the less, they are experiments. Each new machine that is built is an experiment. Actually constructing the machine poses a question to nature; and we listen for the answer by observing the machine in operation and analyzing it by all analytical and measurement means available. Each new program that is built is an experiment. It poses a question to nature, and its behavior offers clues to an answer. Neither machines nor programs are black boxes; they are artifacts that have been designed, both hardware and software, and we can open them up and look inside.
>
> We can relate their structure to their behavior and draw many lessons from a single experiment…We build computers and programs for many reasons. We build them to serve society and as tools for carrying out the economic tasks of society. But as basic scientists we build machines and programs as a way of discovering new phenomena and analyzing phenomena we already know about. Society often becomes confused about this, believing that computers and programs are to be constructed only for the economic use that can be made of them (or as intermediate items in a developmental sequence leading to such use). It needs to understand that the phenomena surrounding computers are deep and obscure, requiring much experimentation to assess their nature. It needs to understand that, as in any science, the gains that accrue from such experimentation and understanding pay off in the permanent acquisition of new techniques; and that it is these techniques that will create the instruments to help society in achieving its goals."

We have followed the advice of these two exemplars in constructing new methods here for building accounting contracts in the independent collaboration space of e-commerce, and we certainly found some techniques (for example, REA state machine mechanics) that need further examination. Our approach is built on two recently-conceived computer science advances: the development of ontologies (as evidenced in accounting by McCarthy et al. (2021)) and the development of DLT technology (as evidenced by Nakamoto (2008) and Buterin (2013)). Schumpeter (1934, 1942) once described radical innovation as the key to economic development through a process of creative destruction leading to a revolutionary change – a breakthrough in product, process, or organization. We believe that here we have taken some of the early steps in promoting radical innovation to build better accounting transaction systems.

Appendix

Danish VAT settlement process

As shown in Figure 15, Danish companies must carry out the current VAT settlement process follows a five-step procedure. Step 1 involves transactions between corporate trading partners and the execution of actual business transactions. Step 2 involves recording transactions onto an accounting record using an enterprise system (most companies use an ERP for this). In step 3, a VAT statement is prepared. Some ERP systems perform this step automatically. Depending on the software used and/or the complexity of the transactions involved in a given time period, VAT statements' preparation may require considerable manual work. Step 4 involves uploading the VAT declaration to the tax authority web portals by keying in figures or uploading a file. Step 5 assumes that a company will either pay or receive a VAT to/from the tax authorities depending on whether VAT receivables (related to purchases) or VAT payables (related to sales) comprise the larger figure.

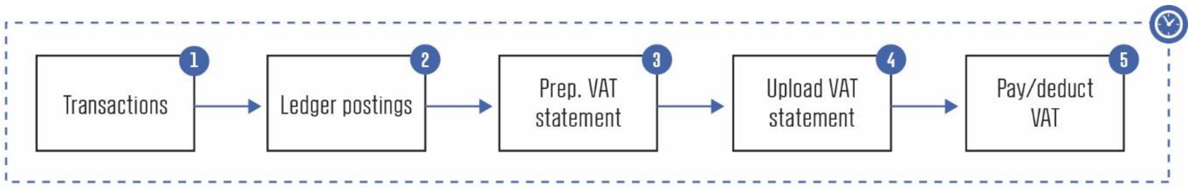

Figure 15. Danish VAT settlement process

REFERENCES

Berg, C., Davidson, S., & Potts, J. (2019). *Understanding the Blockchain Economy - An Introduction to Institutional Cryotoeconomics*. Edward Elgar Publishing Limited.

Berg, C., Davidson, S., & Potts, J. (2020). Proof of Work as a Three-Sided Market. *Frontiers in Blockchain*, *3*(January), 1–5. https://doi.org/10.3389/fbloc.2020.00002

Berkeley, J. (2015). The Trust machine - The technology behind bitcoin could transform how the economy works. *The Economist.*

Buterin, V. (2013). A next-generation smart contract and decentralized application platform. *Etherum*, *11*(January), 7. https://doi.org/10.1016/j.jchromb.2013.02.015

Carlin, T. (2019). Blockchain and the Journey Beyond Double Entry. *Australian Accounting Review*, *27*(2), 305–311. https://doi.org/10.1111/auar.12273

Coase, R. H. (1937). The Nature of the Firm. *Economica*, *4*(16), 386–405.

Colantoni, C. S., Manes, R. P., & Whinston, A. (1971). A unified approach to the theory of accounting and information systems. *The Accounting Review*, *46*(1), 90–102.

Dai, J., & Vasarhelyi, M. A. (2017). Toward Blockchain-Based Accounting and Assurance. *Journal of Information Systems*, *31*(3), 5–21. https://doi.org/10.2308/isys-51804

David, J. S., McCarthy, W. E., & Sommer, B. S. (2003). Agility - The Key to Survival of the Fittest in the Software Market. *Communications of the ACM*, *46*(5), 65–69.

Davidson, S., Novak, M., & Potts, J. (2018). The Cost of Trust: A Pilot Study. *The Journal of the British Blockchain Association*, *1*(2), 1–7. https://doi.org/10.31585/jbba-1-2-(5)2018

Dunn, C., Gerard, G. J., & Grabski, S. V. (2016). Resources-events-agents design theory: A revolutionary approach to enterprise system design. *Communications of the Association for Information Systems*, *38*(1), 554–595. https://doi.org/10.17705/1CAIS.03829

Dunn, C. L., & McCarthy, W. E. (1997). The REA accounting model: Intellectual heritage and prospects for progress. *Journal of Information Systems*, *11*(1), 31–51. http://search.ebscohost.com/login.aspx?direct=true&db=afh&AN=697364&site=ehost-live

Financial Accounting Standards Board. (1985). *Statement of Financial Accounting Concepts No. 6 - Elements of Financial Statements*. Financial Accounting Standards Board.

Flores, F. (2012). *Conversations for action and collected essays: Instilling a culture of commitment in working relationships*. CreateSpace Independent Publishing Platform.

Gal, G., & McCarthy, W. E. (1983). Declarative and procedural features of a CODASYL accounting system. In *Entity-Relationship Approach to Information Modeling and Analysis* (pp. 197–213). North-Holland.

Gal, G., & McCarthy, W. E. (1986). Operation of a relational accounting system. *Advances in Accounting*, *3*, 83–112.

Geerts, G. L., Graham, L. E., Mauldin, E. G., McCarthy, W. E., & Richardson, V. J. (2013). Integrating information technology into accounting research and practice. *Accounting Horizons*, *27*(4), 815–840. https://doi.org/10.2308/acch-50573

Geerts, G. L., & McCarthy, W. E. (1999). An accounting object infrastructure for knowledgebased enterprise models. *IEEE Intelligent Systems and Their Applications*, *14*(4), 89–94. https://doi.org/10.1109/5254.784089

Geerts, G. L., & McCarthy, W. E. (2000). Augmented Intensional Reasoning in Knowledge-Based Accounting Systems. *Journal of Information Systems*, *14*(2), 127–150. https://doi.org/10.2308/jis.2000.14.2.127

Geerts, G. L., & McCarthy, W. E. (2002). An ontological analysis of the economic primitives of the extended-REA enterprise information architecture. *International Journal of Accounting Information Systems, 3,* 1–16. https://doi.org/10.1016/S1467-0895(01)00020-3

Geerts, G. L., & McCarthy, W. E. (2006). Policy-Level Specifications in REA Enterprise Information Systems. *Journal of Information Systems*, *20*(2), 37–63. https://doi.org/10.2308/jis.2006.20.2.37

Geerts, G. L., & McCarthy, W. E. (1997). Modeling Business Enterprises as Value-Added Process Hierarchies with Resource-Event-Agent Object Templates. In J. Sutherland, C. Casanave, J. Miller, P. Patel, & G. Hollowell (Eds.), *Business Object Design and Implementation* (pp. 94–113). Springer London.

Goetz, B. E. (1939). What's wrong with accounting. *Advanced Management*, *Fall*, 151–157.

Goldwasser, S., Micali, S., & Rackoff, C. (1989). The Knowledge Complexity of Interactive Proof Systems. *Journal on Computing*, *18*(1), 186–208.

Gregor, S., & Hevner, A. R. (2013). Positioning and Presenting Design Science Research for Maximum Impact. *MIS Quarterly*, *37*(2), 337–355. https://doi.org/10.25300/MISQ/2013/37.2.01

Hale, Z. (2019). *Postmodern ERP*. Software Advice. https://www.softwareadvice.com/resources/postmodern-erp-defined/

Hevner, A. R., March, S. T., Park, J., & Ram, S. (2004). Design Science in Information Systems Research. *MIS Quarterly*, *28*(1), 75–105. https://wise.vub.ac.be/sites/default/files/thesis_info/design_science.pdf

Holman, G. K. (2019). *Blockchain and eBusiness - The Open-edi Distributed Business Transaction Repository*. Exchange Summit Singapore. https://github.com/CraneSoftwrights/CraneSoftwrights.github.io/tree/master/articles/BlockchainAndeBusiness

Ijiri, Y. (1975). *Theory of accounting measurement* (Issue 10). American Accounting Association.

International Organization for Standardization. (2001). *ISO/IEC15944-1 - Information Technology - Business Operational View - Part 1: Operational Aspects of Open-edi for Implementation*. International Standards Organizations.

International Standards Organization. (2007). *ISO/IEC 15944-4 - Information Technology - Business Operational View - Part 4: Business Transaction Scenarios - Accounting and Economic Ontology.* International Standards Organization.

International Standards Organization. (2020). *ISO/IEC DIS 15944-21 - Information technology — Business operational view — Part 21: Application of Open-edi business transaction* *ontology in distributed business transaction repositories, under development.* International Standards Organization.

Lancaster, K. (1975). Socially Optimal Product Differentiation. *The American Ecnomic Review*, *65*(4), 567–585.

Li, J., Li, N., Peng, J., Cui, H., & Wu, Z. (2019). Energy consumption of cryptocurrency mining: A study of electricity consumption in mining cryptocurrencies. *Energy*, *168*, 160–168. https://doi.org/10.1016/j.energy.2018.11.046

Lynn, G. S., & Akgün, A. E. (1998). Innovation strategies under uncertainty: a contingency approach for new product development. *Engineering Management Journal*, *10*(3), 11–18.

Lynn, G. S., Morone, J. G., & Paulson, A. S. (1996). Marketing and discontinuous innovation: the probe and learn process. *California Management Review*, *38*(3), 8–37.

March, S. T., & Smith, G. F. (1995). Design and natural science research on information technology. Decision Support Systems. *Decision Support Systems*, *15*, 251–266.

Mattessich, R. V. (1964). *Accounting and Analytical Methods* (R. D. Irwin (ed.)).

McCarthy, W. E. (1979). An Entity-Relationship View of Accounting Model. *The Accounting Review*, *54*(4), 667–686.

McCarthy, W. E. (1982). The REA Accounting Model: A Generalized Framework for Accounting Systems in a Shared Data Environment. *The Accounting Review*, *57*(3), 554–578.

McCarthy, W. E. (2003). The REA Modeling Approach to Teaching Accounting Information Systems. *Issues in Accounting Education*, *18*(4), 427–441.

McCarthy, W. E., Geerts, G. L., & Gal, G. (2021). *The REA Accounting Model as an Accounting and Economic Ontology*. 1–144.

Nakamoto, S. (2008). *Bitcoin: A Peer-to-Peer Electronic Cash System*. www.bitcoin.org

Newel, A., & Simon, H. A. (1976). Computer science as empirical inquiry: Symbols and search. *Communications of the ACM*, *19*(3), 113–126.

Nittler, M. (2018). A Cloud Journey. *3rd Journal of Information Systems Research Conference*, 1.

Object Management Group. (2014). *Interaction Flow Modeling Language. Needham, MA: Object Management Group.* Object Management Group.

Pazaitis, A. (2020). Breaking the Chains of open innovation: Post-blockchain and the case of sensorica. *Information (Switzerland)*, *11*(2), 1–18. https://doi.org/10.3390/info11020104

Peffers, K., Tuunanen, T., Rothenberger, M. A., & Chatterjee, S. (2007). A Design Science Research Methodology for Information Systems Research. *Journal of Management Information Systems*, *24*(3), 45–77. https://doi.org/10.2753/mis0742-1222240302

Porter, M. E. (1985). *Competitive Advantage: Creating and Sustaining Superior Performance*. Free Press.

Rajgopal, S. (2020). Integrating Practice into Accounting Research. *Management Science, Special Issue of Management Science: 65th Anniversary*, 1–25. https://doi.org/10.1287/mnsc.2020.3590

Rousseau, D., Sitkin, S., Burt, R., & Camerer, C. (1998). Not So Different After All: A Cross-discipline View of Trust. *Academy of Management Review*, *23*(3), 393–404.

Schmalenbach, E. (1948). *Pretiale Wirtschaftslenkung. Band 2: Pretiale Lenkung des Betriebes.* JSTOR.

Schrader, W. J. (1962). An inductive approach to accounting theory. *The Accounting Review*, *37*(4), 645.

Schumpeter, J. A. (1934). *The Theory of Economic Development: An Inquiry into Profits, Capital, Credits, Interest, and the Business Cycle*. Transaction Publishers.

Schumpeter, J. A. (1942). *Capitalism, Socialism and Democracy*. George Allen & Unwin.

Simon, H. A. (1996). The Sciences of the Artificial. In *Technology and Culture*. https://doi.org/10.2307/3102825

Sorter, G. H. (1969). An "events" Approach to Basic Accounting Theory. *The Accounting Review*, *44*(1), 12–19.

Szabo, N. (1994). *Smart Contracts*. https://www.fon.hum.uva.nl/rob/Courses/InformationInSpeech/CDROM/Literature/LOTwinterschool2006/szabo.best.vwh.net/smart.contracts.html

Venable, J. R., Pries-Heje, J., & Baskerville, R. (2016). FEDS: A Framework for Evaluation in Design Science Research. *European Journal of Information Systems*, *25*(1), 77–89. https://doi.org/10.1057/ejis.2014.36

Walls, J. G., Widmeyer, G. R., & El Sawy, O. A. (1992). Building an Information System Design Theory for Vigilant EIS. *Information Systems Research*, *3*(1), 36–59. https://doi.org/10.1287/isre.3.1.36

Wang, Y., & Kogan, A. (2018). Designing confidentiality-preserving Blockchain-based transaction processing systems. *International Journal of Accounting Information Systems*, *30*(June), 1–18. https://doi.org/10.1016/j.accinf.2018.06.001

White, L. R., & Clinton, B. D. (2014). *Conceptual Framework for Managerial Costing*.

Williamson, O. E. (1993). Opportunism and its critics. *Managerial and Decision Economics*, *14*, 97–107.

Xu, X., Weber, I., & Staples, M. (2019). *Architecture for Blockchain Applications* (1st ed.). Springer International Publishing.

TITLER I PH.D.SERIEN:

2004

1. Martin Grieger
Internet-based Electronic Marketplaces and Supply Chain Management

2. Thomas Basbøll
LIKENESS
A Philosophical Investigation

3. Morten Knudsen
Beslutningens vaklen
En systemteoretisk analyse of moderniseringen af et amtskommunalt sundhedsvæsen 1980-2000

4. Lars Bo Jeppesen
Organizing Consumer Innovation
A product development strategy that is based on online communities and allows some firms to benefit from a distributed process of innovation by consumers

5. Barbara Dragsted
SEGMENTATION IN TRANSLATION AND TRANSLATION MEMORY SYSTEMS
An empirical investigation of cognitive segmentation and effects of integrating a TM system into the translation process

6. Jeanet Hardis
Sociale partnerskaber
Et socialkonstruktivistisk casestudie af partnerskabsaktørers virkelighedsopfattelse mellem identitet og legitimitet

7. Henriette Hallberg Thygesen
System Dynamics in Action

8. Carsten Mejer Plath
Strategisk Økonomistyring

9. Annemette Kjærgaard
Knowledge Management as Internal Corporate Venturing
– a Field Study of the Rise and Fall of a Bottom-Up Process

10. Knut Arne Hovdal
De profesjonelle i endring
Norsk ph.d., ej til salg gennem Samfundslitteratur

11. Søren Jeppesen
Environmental Practices and Greening Strategies in Small Manufacturing Enterprises in South Africa
– A Critical Realist Approach

12. Lars Frode Frederiksen
Industriel forskningsledelse
– på sporet af mønstre og samarbejde i danske forskningsintensive virksomheder

13. Martin Jes Iversen
The Governance of GN Great Nordic
– in an age of strategic and structural transitions 1939-1988

14. Lars Pynt Andersen
The Rhetorical Strategies of Danish TV Advertising
A study of the first fifteen years with special emphasis on genre and irony

15. Jakob Rasmussen
Business Perspectives on E-learning

16. Sof Thrane
The Social and Economic Dynamics of Networks
– a Weberian Analysis of Three Formalised Horizontal Networks

17. Lene Nielsen
Engaging Personas and Narrative Scenarios – a study on how a user-centered approach influenced the perception of the design process in the e-business group at AstraZeneca

18. S.J Valstad
Organisationsidentitet
Norsk ph.d., ej til salg gennem Samfundslitteratur

19. Thomas Lyse Hansen
Six Essays on Pricing and Weather risk in Energy Markets

20. Sabine Madsen
Emerging Methods – An Interpretive Study of ISD Methods in Practice

21. Evis Sinani
The Impact of Foreign Direct Investment on Efficiency, Productivity Growth and Trade: An Empirical Investigation

22. Bent Meier Sørensen
Making Events Work Or,
How to Multiply Your Crisis

23. Pernille Schnoor
Brand Ethos
Om troværdige brand- og virksomhedsidentiteter i et retorisk og diskursteoretisk perspektiv

24. Sidsel Fabech
Von welchem Österreich ist hier die Rede?
Diskursive forhandlinger og magtkampe mellem rivaliserende nationale identitetskonstruktioner i østrigske pressediskurser

25. Klavs Odgaard Christensen
Sprogpolitik og identitetsdannelse i flersprogede forbundsstater
Et komparativt studie af Schweiz og Canada

26. Dana B. Minbaeva
Human Resource Practices and Knowledge Transfer in Multinational Corporations

27. Holger Højlund
Markedets politiske fornuft
Et studie af velfærdens organisering i perioden 1990-2003

28. Christine Mølgaard Frandsen
A.s erfaring
Om mellemværendets praktik i en transformation af mennesket og subjektiviteten

29. Sine Nørholm Just
The Constitution of Meaning
– A Meaningful Constitution?
Legitimacy, identity, and public opinion in the debate on the future of Europe

2005

1. Claus J. Varnes
Managing product innovation through rules – The role of formal and structured methods in product development

2. Helle Hedegaard Hein
Mellem konflikt og konsensus
– Dialogudvikling på hospitalsklinikker

3. Axel Rosenø
Customer Value Driven Product Innovation – A Study of Market Learning in New Product Development

4. Søren Buhl Pedersen
Making space
An outline of place branding

5. Camilla Funck Ellehave
Differences that Matter
An analysis of practices of gender and organizing in contemporary workplaces

6. Rigmor Madeleine Lond
Styring af kommunale forvaltninger

7. Mette Aagaard Andreassen
Supply Chain versus Supply Chain
Benchmarking as a Means to Managing Supply Chains

8. Caroline Aggestam-Pontoppidan
From an idea to a standard
The UN and the global governance of accountants' competence

9. Norsk ph.d.

10. Vivienne Heng Ker-ni
An Experimental Field Study on the

Effectiveness of Grocer Media Advertising
Measuring Ad Recall and Recognition, Purchase Intentions and Short-Term Sales

11. Allan Mortensen
Essays on the Pricing of Corporate Bonds and Credit Derivatives

12. Remo Stefano Chiari
Figure che fanno conoscere
Itinerario sull'idea del valore cognitivo e espressivo della metafora e di altri tropi da Aristotele e da Vico fino al cognitivismo contemporaneo

13. Anders McIlquham-Schmidt
Strategic Planning and Corporate Performance
An integrative research review and a meta-analysis of the strategic planning and corporate performance literature from 1956 to 2003

14. Jens Geersbro
The TDF – PMI Case
Making Sense of the Dynamics of Business Relationships and Networks

15 Mette Andersen
Corporate Social Responsibility in Global Supply Chains
Understanding the uniqueness of firm behaviour

16. Eva Boxenbaum
Institutional Genesis: Micro – Dynamic Foundations of Institutional Change

17. Peter Lund-Thomsen
Capacity Development, Environmental Justice NGOs, and Governance: The Case of South Africa

18. Signe Jarlov
Konstruktioner af offentlig ledelse

19. Lars Stæhr Jensen
Vocabulary Knowledge and Listening Comprehension in English as a Foreign Language
An empirical study employing data elicited from Danish EFL learners

20. Christian Nielsen
Essays on Business Reporting
Production and consumption of strategic information in the market for information

21. Marianne Thejls Fischer
Egos and Ethics of Management Consultants

22. Annie Bekke Kjær
Performance management i Proces-innovation
– belyst i et social-konstruktivistisk perspektiv

23. Suzanne Dee Pedersen
GENTAGELSENS METAMORFOSE
Om organisering af den kreative gøren i den kunstneriske arbejdspraksis

24. Benedikte Dorte Rosenbrink
Revenue Management
Økonomiske, konkurrencemæssige & organisatoriske konsekvenser

25. Thomas Riise Johansen
Written Accounts and Verbal Accounts
The Danish Case of Accounting and Accountability to Employees

26. Ann Fogelgren-Pedersen
The Mobile Internet: Pioneering Users' Adoption Decisions

27. Birgitte Rasmussen
Ledelse i fællesskab – de tillidsvalgtes fornyende rolle

28. Gitte Thit Nielsen
Remerger
– skabende ledelseskræfter i fusion og opkøb

29. Carmine Gioia
A MICROECONOMETRIC ANALYSIS OF MERGERS AND ACQUISITIONS

30. Ole Hinz
Den effektive forandringsleder: pilot, pædagog eller politiker?
Et studie i arbejdslederes meningstil-skrivninger i forbindelse med vellykket gennemførelse af ledelsesinitierede forandringsprojekter

31. Kjell-Åge Gotvassli
Et praksisbasert perspektiv på dynami-ske
læringsnettverk i toppidretten
Norsk ph.d., ej til salg gennem Samfundslitteratur

32. Henriette Langstrup Nielsen
Linking Healthcare
An inquiry into the changing perfor-mances of web-based technology for asthma monitoring

33. Karin Tweddell Levinsen
Virtuel Uddannelsespraksis
Master i IKT og Læring – et casestudie i hvordan proaktiv proceshåndtering kan forbedre praksis i virtuelle lærings-miljøer

34. Anika Liversage
Finding a Path
Labour Market Life Stories of Immigrant Professionals

35. Kasper Elmquist Jørgensen
Studier i samspillet mellem stat og erhvervsliv i Danmark under 1. verdenskrig

36. Finn Janning
A DIFFERENT STORY
Seduction, Conquest and Discovery

37. Patricia Ann Plackett
Strategic Management of the Radical Innovation Process
Leveraging Social Capital for Market Uncertainty Management

2006

1. Christian Vintergaard
Early Phases of Corporate Venturing

2. Niels Rom-Poulsen
Essays in Computational Finance

3. Tina Brandt Husman
Organisational Capabilities, Competitive Advantage & Project-Based Organisations
The Case of Advertising and Creative Good Production

4. Mette Rosenkrands Johansen
Practice at the top
– how top managers mobilise and use non-financial performance measures

5. Eva Parum
Corporate governance som strategisk kommunikations- og ledelsesværktøj

6. Susan Aagaard Petersen
Culture's Influence on Performance Management: The Case of a Danish Company in China

7. Thomas Nicolai Pedersen
The Discursive Constitution of Organi-zational Governance – Between unity and differentiation
The Case of the governance of environmental risks by World Bank environmental staff

8. Cynthia Selin
Volatile Visions: Transactons in Anticipatory Knowledge

9. Jesper Banghøj
Financial Accounting Information and Compensation in Danish Companies

10. Mikkel Lucas Overby
Strategic Alliances in Emerging High-Tech Markets: What's the Difference and does it Matter?

11. Tine Aage
External Information Acquisition of Industrial Districts and the Impact of Different Knowledge Creation Dimen-sions

A case study of the Fashion and Design Branch of the Industrial District of Montebelluna, NE Italy

12. Mikkel Flyverbom
Making the Global Information Society Governable
On the Governmentality of Multi-Stakeholder Networks

13. Anette Grønning
Personen bag
Tilstedevær i e-mail som inter-aktionsform mellem kunde og med-arbejder i dansk forsikringskontekst

14. Jørn Helder
One Company – One Language?
The NN-case

15. Lars Bjerregaard Mikkelsen
Differing perceptions of customer value
Development and application of a tool for mapping perceptions of customer value at both ends of customer-supplier dyads in industrial markets

16. Lise Granerud
Exploring Learning
Technological learning within small manufacturers in South Africa

17. Esben Rahbek Pedersen
Between Hopes and Realities: Reflections on the Promises and Practices of Corporate Social Responsibility (CSR)

18. Ramona Samson
The Cultural Integration Model and European Transformation.
The Case of Romania

2007

1. Jakob Vestergaard
Discipline in The Global Economy
Panopticism and the Post-Washington Consensus

2. Heidi Lund Hansen
Spaces for learning and working
A qualitative study of change of work, management, vehicles of power and social practices in open offices

3. Sudhanshu Rai
Exploring the internal dynamics of software development teams during user analysis
A tension enabled Institutionalization Model; "Where process becomes the objective"

4. Norsk ph.d.
Ej til salg gennem Samfundslitteratur

5. Serden Ozcan
EXPLORING HETEROGENEITY IN ORGANIZATIONAL ACTIONS AND OUTCOMES
A Behavioural Perspective

6. Kim Sundtoft Hald
Inter-organizational Performance Measurement and Management in Action
– An Ethnography on the Construction of Management, Identity and Relationships

7. Tobias Lindeberg
Evaluative Technologies
Quality and the Multiplicity of Performance

8. Merete Wedell-Wedellsborg
Den globale soldat
Identitetsdannelse og identitetsledelse i multinationale militære organisationer

9. Lars Frederiksen
Open Innovation Business Models
Innovation in firm-hosted online user communities and inter-firm project ventures in the music industry
– A collection of essays

10. Jonas Gabrielsen
Retorisk toposlære – fra statisk 'sted' til persuasiv aktivitet

11. Christian Moldt-Jørgensen
Fra meningsløs til meningsfuld evaluering.
Anvendelsen af studentertilfredshedsmålinger på de korte og mellemlange videregående uddannelser set fra et psykodynamisk systemperspektiv

12. Ping Gao
Extending the application of actor-network theory
Cases of innovation in the telecommunications industry

13. Peter Mejlby
Frihed og fængsel, en del af den samme drøm?
Et phronetisk baseret casestudie af frigørelsens og kontrollens sameksistens i værdibaseret ledelse!

14. Kristina Birch
Statistical Modelling in Marketing

15. Signe Poulsen
Sense and sensibility:
The language of emotional appeals in insurance marketing

16. Anders Bjerre Trolle
Essays on derivatives pricing and dynamic asset allocation

17. Peter Feldhütter
Empirical Studies of Bond and Credit Markets

18. Jens Henrik Eggert Christensen
Default and Recovery Risk Modeling and Estimation

19. Maria Theresa Larsen
Academic Enterprise: A New Mission for Universities or a Contradiction in Terms?
Four papers on the long-term implications of increasing industry involvement and commercialization in academia

20. Morten Wellendorf
Postimplementering af teknologi i den offentlige forvaltning
Analyser af en organisations kontinuerlige arbejde med informationsteknologi

21. Ekaterina Mhaanna
Concept Relations for Terminological Process Analysis

22. Stefan Ring Thorbjørnsen
Forsvaret i forandring
Et studie i officerers kapabiliteter under påvirkning af omverdenens forandringspres mod øget styring og læring

23. Christa Breum Amhøj
Det selvskabte medlemskab om managementstaten, dens styringsteknologier og indbyggere

24. Karoline Bromose
Between Technological Turbulence and Operational Stability
– An empirical case study of corporate venturing in TDC

25. Susanne Justesen
Navigating the Paradoxes of Diversity in Innovation Practice
– A Longitudinal study of six very different innovation processes – in practice

26. Luise Noring Henler
Conceptualising successful supply chain partnerships
– Viewing supply chain partnerships from an organisational culture perspective

27. Mark Mau
Kampen om telefonen
Det danske telefonvæsen under den tyske besættelse 1940-45

28. Jakob Halskov
The semiautomatic expansion of existing terminological ontologies using knowledge patterns discovered

on the WWW – an implementation and evaluation

29. Gergana Koleva
European Policy Instruments Beyond Networks and Structure: The Innovative Medicines Initiative

30. Christian Geisler Asmussen
Global Strategy and International Diversity: A Double-Edged Sword?

31. Christina Holm-Petersen
Stolthed og fordom
Kultur- og identitetsarbejde ved skabelsen af en ny sengeafdeling gennem fusion

32. Hans Peter Olsen
Hybrid Governance of Standardized States
Causes and Contours of the Global Regulation of Government Auditing

33. Lars Bøge Sørensen
Risk Management in the Supply Chain

34. Peter Aagaard
Det unikkes dynamikker
De institutionelle mulighedsbetingelser bag den individuelle udforskning i professionelt og frivilligt arbejde

35. Yun Mi Antorini
Brand Community Innovation
An Intrinsic Case Study of the Adult Fans of LEGO Community

36. Joachim Lynggaard Boll
Labor Related Corporate Social Performance in Denmark
Organizational and Institutional Perspectives

2008

1. Frederik Christian Vinten
Essays on Private Equity

2. Jesper Clement
Visual Influence of Packaging Design on In-Store Buying Decisions

3. Marius Brostrøm Kousgaard
Tid til kvalitetsmåling?
– Studier af indrulleringsprocesser i forbindelse med introduktionen af kliniske kvalitetsdatabaser i speciallægepraksissektoren

4. Irene Skovgaard Smith
Management Consulting in Action
Value creation and ambiguity in client-consultant relations

5. Anders Rom
Management accounting and integrated information systems
How to exploit the potential for management accounting of information technology

6. Marina Candi
Aesthetic Design as an Element of Service Innovation in New Technology-based Firms

7. Morten Schnack
Teknologi og tværfaglighed
– en analyse af diskussionen omkring indførelse af EPJ på en hospitalsafdeling

8. Helene Balslev Clausen
Juntos pero no revueltos – un estudio sobre emigrantes norteamericanos en un pueblo mexicano

9. Lise Justesen
Kunsten at skrive revisionsrapporter.
En beretning om forvaltningsrevisionens beretninger

10. Michael E. Hansen
The politics of corporate responsibility:
CSR and the governance of child labor and core labor rights in the 1990s

11. Anne Roepstorff
Holdning for handling – en etnologisk undersøgelse af Virksomheders Sociale Ansvar/CSR

12. Claus Bajlum
Essays on Credit Risk and Credit Derivatives

13. Anders Bojesen
The Performative Power of Competence – an Inquiry into Subjectivity and Social Technologies at Work

14. Satu Reijonen
Green and Fragile
A Study on Markets and the Natural Environment

15. Ilduara Busta
Corporate Governance in Banking
A European Study

16. Kristian Anders Hvass
A Boolean Analysis Predicting Industry Change: Innovation, Imitation & Business Models
The Winning Hybrid: A case study of isomorphism in the airline industry

17. Trine Paludan
De uvidende og de udviklingsparate
Identitet som mulighed og restriktion blandt fabriksarbejdere på det aftayloriserede fabriksgulv

18. Kristian Jakobsen
Foreign market entry in transition economies: Entry timing and mode choice

19. Jakob Elming
Syntactic reordering in statistical machine translation

20. Lars Brømsøe Termansen
Regional Computable General Equilibrium Models for Denmark
Three papers laying the foundation for regional CGE models with agglomeration characteristics

21. Mia Reinholt
The Motivational Foundations of Knowledge Sharing

22. Frederikke Krogh-Meibom
The Co-Evolution of Institutions and Technology
– A Neo-Institutional Understanding of Change Processes within the Business Press – the Case Study of Financial Times

23. Peter D. Ørberg Jensen
OFFSHORING OF ADVANCED AND HIGH-VALUE TECHNICAL SERVICES: ANTECEDENTS, PROCESS DYNAMICS AND FIRMLEVEL IMPACTS

24. Pham Thi Song Hanh
Functional Upgrading, Relational Capability and Export Performance of Vietnamese Wood Furniture Producers

25. Mads Vangkilde
Why wait?
An Exploration of first-mover advantages among Danish e-grocers through a resource perspective

26. Hubert Buch-Hansen
Rethinking the History of European Level Merger Control
A Critical Political Economy Perspective

2009

1. Vivian Lindhardsen
From Independent Ratings to Communal Ratings: A Study of CWA Raters' Decision-Making Behaviours

2. Guðrið Weihe
Public-Private Partnerships: Meaning and Practice

3. Chris Nøkkentved
Enabling Supply Networks with Collaborative Information Infrastructures
An Empirical Investigation of Business Model Innovation in Supplier Relationship Management

4. Sara Louise Muhr
Wound, Interrupted – On the Vulnerability of Diversity Management

5. Christine Sestoft
Forbrugeradfærd i et Stats- og Livsformsteoretisk perspektiv

6. Michael Pedersen
Tune in, Breakdown, and Reboot: On the production of the stress-fit self-managing employee

7. Salla Lutz
Position and Reposition in Networks – Exemplified by the Transformation of the Danish Pine Furniture Manufacturers

8. Jens Forssbæck
Essays on market discipline in commercial and central banking

9. Tine Murphy
Sense from Silence – A Basis for Organised Action
How do Sensemaking Processes with Minimal Sharing Relate to the Reproduction of Organised Action?

10. Sara Malou Strandvad
Inspirations for a new sociology of art: A sociomaterial study of development processes in the Danish film industry

11. Nicolaas Mouton
On the evolution of social scientific metaphors:
A cognitive-historical enquiry into the divergent trajectories of the idea that collective entities – states and societies, cities and corporations – are biological organisms.

12. Lars Andreas Knutsen
Mobile Data Services:
Shaping of user engagements

13. Nikolaos Theodoros Korfiatis
Information Exchange and Behavior
A Multi-method Inquiry on Online Communities

14. Jens Albæk
Forestillinger om kvalitet og tværfaglighed på sygehuse
– skabelse af forestillinger i læge- og plejegrupperne angående relevans af nye idéer om kvalitetsudvikling gennem tolkningsprocesser

15. Maja Lotz
The Business of Co-Creation – and the Co-Creation of Business

16. Gitte P. Jakobsen
Narrative Construction of Leader Identity in a Leader Development Program Context

17. Dorte Hermansen
"Living the brand" som en brandorienteret dialogisk praxis:
Om udvikling af medarbejdernes brandorienterede dømmekraft

18. Aseem Kinra
Supply Chain (logistics) Environmental Complexity

19. Michael Nørager
How to manage SMEs through the transformation from non innovative to innovative?

20. Kristin Wallevik
Corporate Governance in Family Firms
The Norwegian Maritime Sector

21. Bo Hansen Hansen
Beyond the Process
Enriching Software Process Improvement with Knowledge Management

22. Annemette Skot-Hansen
Franske adjektivisk afledte adverbier, der tager præpositionssyntagmer indledt med præpositionen à som argumenter
En valensgrammatisk undersøgelse

23. Line Gry Knudsen
Collaborative R&D Capabilities
In Search of Micro-Foundations

24. Christian Scheuer
Employers meet employees
Essays on sorting and globalization

25. Rasmus Johnsen
The Great Health of Melancholy
A Study of the Pathologies of Performativity

26. Ha Thi Van Pham
Internationalization, Competitiveness Enhancement and Export Performance of Emerging Market Firms:
Evidence from Vietnam

27. Henriette Balieu
Kontrolbegrebets betydning for kausativalternationen i spansk
En kognitiv-typologisk analyse

2010

1. Yen Tran
Organizing Innovationin Turbulent Fashion Market
Four papers on how fashion firms create and appropriate innovation value

2. Anders Raastrup Kristensen
Metaphysical Labour
Flexibility, Performance and Commitment in Work-Life Management

3. Margrét Sigrún Sigurdardottir
Dependently independent
Co-existence of institutional logics in the recorded music industry

4. Ásta Dis Óladóttir
Internationalization from a small domestic base:
An empirical analysis of Economics and Management

5. Christine Secher
E-deltagelse i praksis – politikernes og forvaltningens medkonstruktion og konsekvenserne heraf

6. Marianne Stang Våland
What we talk about when we talk about space:
End User Participation between Processes of Organizational and Architectural Design

7. Rex Degnegaard
Strategic Change Management
Change Management Challenges in the Danish Police Reform

8. Ulrik Schultz Brix
Værdi i rekruttering – den sikre beslutning
En pragmatisk analyse af perception og synliggørelse af værdi i rekrutterings- og udvælgelsesarbejdet

9. Jan Ole Similä
Kontraktsledelse
Relasjonen mellom virksomhetsledelse og kontraktshåndtering, belyst via fire norske virksomheter

10. Susanne Boch Waldorff
Emerging Organizations: In between local translation, institutional logics and discourse

11. Brian Kane
Performance Talk
Next Generation Management of Organizational Performance

12. Lars Ohnemus
Brand Thrust: Strategic Branding and Shareholder Value
An Empirical Reconciliation of two Critical Concepts

13. Jesper Schlamovitz
Håndtering af usikkerhed i film- og byggeprojekter

14. Tommy Moesby-Jensen
Det faktiske livs forbindtlighed
Førsokratisk informeret, ny-aristotelisk ἦθος-tænkning hos Martin Heidegger

15. Christian Fich
Two Nations Divided by Common Values
French National Habitus and the Rejection of American Power

16. Peter Beyer
Processer, sammenhængskraft og fleksibilitet
Et empirisk casestudie af omstillingsforløb i fire virksomheder

17. Adam Buchhorn
Markets of Good Intentions
Constructing and Organizing Biogas Markets Amid Fragility and Controversy

18. Cecilie K. Moesby-Jensen
Social læring og fælles praksis
Et mixed method studie, der belyser læringskonsekvenser af et lederkursus for et praksisfællesskab af offentlige mellemledere

19. Heidi Boye
Fødevarer og sundhed i senmodernismen
– En indsigt i hyggefænomenet og de relaterede fødevarepraksisser

20. Kristine Munkgård Pedersen
Flygtige forbindelser og midlertidige mobiliseringer
Om kulturel produktion på Roskilde Festival

21. Oliver Jacob Weber
Causes of Intercompany Harmony in Business Markets – An Empirical Investigation from a Dyad Perspective

22. Susanne Ekman
Authority and Autonomy
Paradoxes of Modern Knowledge Work

23. Anette Frey Larsen
Kvalitetsledelse på danske hospitaler
– Ledelsernes indflydelse på introduktion og vedligeholdelse af kvalitetsstrategier i det danske sundhedsvæsen

24. Toyoko Sato
Performativity and Discourse: Japanese Advertisements on the Aesthetic Education of Desire

25. Kenneth Brinch Jensen
Identifying the Last Planner System
Lean management in the construction industry

26. Javier Busquets
Orchestrating Network Behavior for Innovation

27. Luke Patey
The Power of Resistance: India's National Oil Company and International Activism in Sudan

28. Mette Vedel
Value Creation in Triadic Business Relationships. Interaction, Interconnection and Position

29. Kristian Tørning
Knowledge Management Systems in Practice – A Work Place Study

30. Qingxin Shi
An Empirical Study of Thinking Aloud Usability Testing from a Cultural Perspective

31. Tanja Juul Christiansen
Corporate blogging: Medarbejderes kommunikative handlekraft

32. Malgorzata Ciesielska
Hybrid Organisations.
A study of the Open Source – business setting

33. Jens Dick-Nielsen
Three Essays on Corporate Bond Market Liquidity

34. Sabrina Speiermann
Modstandens Politik
Kampagnestyring i Velfærdsstaten.
En diskussion af trafikkampagners styringspotentiale

35. Julie Uldam
Fickle Commitment. Fostering political engagement in 'the flighty world of online activism'

36. Annegrete Juul Nielsen
Traveling technologies and transformations in health care

37. Athur Mühlen-Schulte
Organising Development
Power and Organisational Reform in the United Nations Development Programme

38. Louise Rygaard Jonas
Branding på butiksgulvet
Et case-studie af kultur- og identitetsarbejdet i Kvickly

2011

1. Stefan Fraenkel
Key Success Factors for Sales Force Readiness during New Product Launch
A Study of Product Launches in the Swedish Pharmaceutical Industry

2. Christian Plesner Rossing
International Transfer Pricing in Theory and Practice

3. Tobias Dam Hede
Samtalekunst og ledelsesdisciplin
– en analyse af coachingsdiskursens genealogi og governmentality

4. Kim Pettersson
Essays on Audit Quality, Auditor Choice, and Equity Valuation

5. Henrik Merkelsen
The expert-lay controversy in risk research and management. Effects of institutional distances. Studies of risk definitions, perceptions, management and communication

6. Simon S. Torp
Employee Stock Ownership:
Effect on Strategic Management and Performance

7. Mie Harder
Internal Antecedents of Management Innovation

8. Ole Helby Petersen
Public-Private Partnerships: Policy and Regulation – With Comparative and Multi-level Case Studies from Denmark and Ireland

9. Morten Krogh Petersen
'Good' Outcomes. Handling Multiplicity in Government Communication

10. Kristian Tangsgaard Hvelplund
Allocation of cognitive resources in translation - an eye-tracking and key-logging study

11. Moshe Yonatany
The Internationalization Process of Digital Service Providers

12. Anne Vestergaard
Distance and Suffering
Humanitarian Discourse in the age of Mediatization

13. Thorsten Mikkelsen
Personligheds indflydelse på forretningsrelationer

14. Jane Thostrup Jagd
Hvorfor fortsætter fusionsbølgen udover "the tipping point"?
– en empirisk analyse af information og kognitioner om fusioner

15. Gregory Gimpel
Value-driven Adoption and Consumption of Technology: Understanding Technology Decision Making

16. Thomas Stengade Sønderskov
Den nye mulighed
Social innovation i en forretningsmæssig kontekst

17. Jeppe Christoffersen
Donor supported strategic alliances in developing countries

18. Vibeke Vad Baunsgaard
Dominant Ideological Modes of Rationality: Cross functional

integration in the process of product innovation

19. Throstur Olaf Sigurjonsson
Governance Failure and Icelands's Financial Collapse

20. Allan Sall Tang Andersen
Essays on the modeling of risks in interest-rate and inflation markets

21. Heidi Tscherning
Mobile Devices in Social Contexts

22. Birgitte Gorm Hansen
Adapting in the Knowledge Economy Lateral Strategies for Scientists and Those Who Study Them

23. Kristina Vaarst Andersen
Optimal Levels of Embeddedness The Contingent Value of Networked Collaboration

24. Justine Grønbæk Pors
Noisy Management A History of Danish School Governing from 1970-2010

25. Stefan Linder
Micro-foundations of Strategic Entrepreneurship Essays on Autonomous Strategic Action

26. Xin Li
Toward an Integrative Framework of National Competitiveness An application to China

27. Rune Thorbjørn Clausen
Værdifuld arkitektur Et eksplorativt studie af bygningers rolle i virksomheders værdiskabelse

28. Monica Viken
Markedsundersøkelser som bevis i varemerke- og markedsføringsrett

29. Christian Wymann
Tattooing The Economic and Artistic Constitution of a Social Phenomenon

30. Sanne Frandsen
Productive Incoherence A Case Study of Branding and Identity Struggles in a Low-Prestige Organization

31. Mads Stenbo Nielsen
Essays on Correlation Modelling

32. Ivan Häuser
Følelse og sprog Etablering af en ekspressiv kategori, eksemplificeret på russisk

33. Sebastian Schwenen
Security of Supply in Electricity Markets

2012

1. Peter Holm Andreasen
The Dynamics of Procurement Management - A Complexity Approach

2. Martin Haulrich
Data-Driven Bitext Dependency Parsing and Alignment

3. Line Kirkegaard
Konsulenten i den anden nat En undersøgelse af det intense arbejdsliv

4. Tonny Stenheim
Decision usefulness of goodwill under IFRS

5. Morten Lind Larsen
Produktivitet, vækst og velfærd Industrirådet og efterkrigstidens Danmark 1945 - 1958

6. Petter Berg
Cartel Damages and Cost Asymmetries

7. Lynn Kahle
Experiential Discourse in Marketing A methodical inquiry into practice and theory

8. Anne Roelsgaard Obling
Management of Emotions in Accelerated Medical Relationships

9. Thomas Frandsen
Managing Modularity of Service Processes Architecture

10. Carina Christine Skovmøller
CSR som noget særligt
Et casestudie om styring og menings-skabelse i relation til CSR ud fra en intern optik

11. Michael Tell
Fradragsbeskæring af selskabers finansieringsudgifter
En skatteretlig analyse af SEL §§ 11, 11B og 11C

12. Morten Holm
Customer Profitability Measurement Models
Their Merits and Sophistication across Contexts

13. Katja Joo Dyppel
Beskatning af derivater
En analyse af dansk skatteret

14. Esben Anton Schultz
Essays in Labor Economics
Evidence from Danish Micro Data

15. Carina Risvig Hansen
"Contracts not covered, or not fully covered, by the Public Sector Directive"

16. Anja Svejgaard Pors
Iværksættelse af kommunikation
- patientfigurer i hospitalets strategiske kommunikation

17. Frans Bévort
Making sense of management with logics
An ethnographic study of accountants who become managers

18. René Kallestrup
The Dynamics of Bank and Sovereign Credit Risk

19. Brett Crawford
Revisiting the Phenomenon of Interests in Organizational Institutionalism
The Case of U.S. Chambers of Commerce

20. Mario Daniele Amore
Essays on Empirical Corporate Finance

21. Arne Stjernholm Madsen
The evolution of innovation strategy
Studied in the context of medical device activities at the pharmaceutical company Novo Nordisk A/S in the period 1980-2008

22. Jacob Holm Hansen
Is Social Integration Necessary for Corporate Branding?
A study of corporate branding strategies at Novo Nordisk

23. Stuart Webber
Corporate Profit Shifting and the Multinational Enterprise

24. Helene Ratner
Promises of Reflexivity
Managing and Researching Inclusive Schools

25. Therese Strand
The Owners and the Power: Insights from Annual General Meetings

26. Robert Gavin Strand
In Praise of Corporate Social Responsibility Bureaucracy

27. Nina Sormunen
Auditor's going-concern reporting
Reporting decision and content of the report

28. John Bang Mathiasen
Learning within a product development working practice:
- an understanding anchored in pragmatism

29. Philip Holst Riis
Understanding Role-Oriented Enterprise Systems: From Vendors to Customers

30. Marie Lisa Dacanay
Social Enterprises and the Poor
Enhancing Social Entrepreneurship and Stakeholder Theory

31. Fumiko Kano Glückstad
Bridging Remote Cultures: Cross-lingual concept mapping based on the information receiver's prior-knowledge

32. Henrik Barslund Fosse
Empirical Essays in International Trade

33. Peter Alexander Albrecht
Foundational hybridity and its reproduction
Security sector reform in Sierra Leone

34. Maja Rosenstock
CSR - hvor svært kan det være?
Kulturanalytisk casestudie om udfordringer og dilemmaer med at forankre Coops CSR-strategi

35. Jeanette Rasmussen
Tweens, medier og forbrug
Et studie af 10-12 årige danske børns brug af internettet, opfattelse og forståelse af markedsføring og forbrug

36. Ib Tunby Gulbrandsen
'This page is not intended for a US Audience'
A five-act spectacle on online communication, collaboration & organization.

37. Kasper Aalling Teilmann
Interactive Approaches to Rural Development

38. Mette Mogensen
The Organization(s) of Well-being and Productivity
(Re)assembling work in the Danish Post

39. Søren Friis Møller
From Disinterestedness to Engagement
Towards Relational Leadership In the Cultural Sector

40. Nico Peter Berhausen
Management Control, Innovation and Strategic Objectives – Interactions and Convergence in Product Development Networks

41. Balder Onarheim
Creativity under Constraints
Creativity as Balancing 'Constrainedness'

42. Haoyong Zhou
Essays on Family Firms

43. Elisabeth Naima Mikkelsen
Making sense of organisational conflict
An empirical study of enacted sense-making in everyday conflict at work

2013

1. Jacob Lyngsie
Entrepreneurship in an Organizational Context

2. Signe Groth-Brodersen
Fra ledelse til selvet
En socialpsykologisk analyse af forholdet imellem selvledelse, ledelse og stress i det moderne arbejdsliv

3. Nis Høyrup Christensen
Shaping Markets: A Neoinstitutional Analysis of the Emerging Organizational Field of Renewable Energy in China

4. Christian Edelvold Berg
As a matter of size
THE IMPORTANCE OF CRITICAL MASS AND THE CONSEQUENCES OF SCARCITY FOR TELEVISION MARKETS

5. Christine D. Isakson
Coworker Influence and Labor Mobility
Essays on Turnover, Entrepreneurship and Location Choice in the Danish Maritime Industry

6. Niels Joseph Jerne Lennon
Accounting Qualities in Practice
Rhizomatic stories of representational faithfulness, decision making and control

7. Shannon O'Donnell
Making Ensemble Possible
How special groups organize for collaborative creativity in conditions of spatial variability and distance

8. Robert W. D. Veitch
Access Decisions in a
Partly-Digital World
Comparing Digital Piracy and Legal
Modes for Film and Music

9. Marie Mathiesen
Making Strategy Work
An Organizational Ethnography

10. Arisa Shollo
The role of business intelligence in
organizational decision-making

11. Mia Kaspersen
The construction of social and
environmental reporting

12. Marcus Møller Larsen
The organizational design of offshoring

13. Mette Ohm Rørdam
EU Law on Food Naming
The prohibition against misleading
names in an internal market context

14. Hans Peter Rasmussen
GIV EN GED!
Kan giver-idealtyper forklare støtte
til velgørenhed og understøtte
relationsopbygning?

15. Ruben Schachtenhaufen
Fonetisk reduktion i dansk

16. Peter Koerver Schmidt
Dansk CFC-beskatning
I et internationalt og komparativt
perspektiv

17. Morten Froholdt
Strategi i den offentlige sektor
En kortlægning af styringsmæssig
kontekst, strategisk tilgang, samt
anvendte redskaber og teknologier for
udvalgte danske statslige styrelser

18. Annette Camilla Sjørup
Cognitive effort in metaphor translation
An eye-tracking and key-logging study

19. Tamara Stucchi
The Internationalization
of Emerging Market Firms:
A Context-Specific Study

20. Thomas Lopdrup-Hjorth
"Let's Go Outside":
The Value of Co-Creation

21. Ana Alačovska
Genre and Autonomy in Cultural
Production
The case of travel guidebook
production

22. Marius Gudmand-Høyer
Stemningssindssygdommenes historie
i det 19. århundrede
Omtydningen af melankolien og
manien som bipolære stemningslidelser
i dansk sammenhæng under hensyn til
dannelsen af det moderne følelseslivs
relative autonomi.
En problematiserings- og erfarings-
analytisk undersøgelse

23. Lichen Alex Yu
Fabricating an S&OP Process
Circulating References and Matters
of Concern

24. Esben Alfort
The Expression of a Need
Understanding search

25. Trine Pallesen
Assembling Markets for Wind Power
An Inquiry into the Making of
Market Devices

26. Anders Koed Madsen
Web-Visions
Repurposing digital traces to organize
social attention

27. Lærke Højgaard Christiansen
BREWING ORGANIZATIONAL
RESPONSES TO INSTITUTIONAL LOGICS

28. Tommy Kjær Lassen
EGENTLIG SELVLEDELSE
En ledelsesfilosofisk afhandling om
selvledelsens paradoksale dynamik og
eksistentielle engagement

29. Morten Rossing
Local Adaption and Meaning Creation in Performance Appraisal

30. Søren Obed Madsen
Lederen som oversætter
Et oversættelsesteoretisk perspektiv på strategisk arbejde

31. Thomas Høgenhaven
Open Government Communities
Does Design Affect Participation?

32. Kirstine Zinck Pedersen
Failsafe Organizing?
A Pragmatic Stance on Patient Safety

33. Anne Petersen
Hverdagslogikker i psykiatrisk arbejde
En institutionsetnografisk undersøgelse af hverdagen i psykiatriske organisationer

34. Didde Maria Humle
Fortællinger om arbejde

35. Mark Holst-Mikkelsen
Strategieksekvering i praksis – barrierer og muligheder!

36. Malek Maalouf
Sustaining lean
Strategies for dealing with organizational paradoxes

37. Nicolaj Tofte Brenneche
Systemic Innovation In The Making
The Social Productivity of Cartographic Crisis and Transitions in the Case of SEEIT

38. Morten Gylling
The Structure of Discourse
A Corpus-Based Cross-Linguistic Study

39. Binzhang YANG
Urban Green Spaces for Quality Life - Case Study: the landscape architecture for people in Copenhagen

40. Michael Friis Pedersen
Finance and Organization:
The Implications for Whole Farm Risk Management

41. Even Fallan
Issues on supply and demand for environmental accounting information

42. Ather Nawaz
Website user experience
A cross-cultural study of the relation between users´ cognitive style, context of use, and information architecture of local websites

43. Karin Beukel
The Determinants for Creating Valuable Inventions

44. Arjan Markus
External Knowledge Sourcing and Firm Innovation
Essays on the Micro-Foundations of Firms' Search for Innovation

2014

1. Solon Moreira
Four Essays on Technology Licensing and Firm Innovation

2. Karin Strzeletz Ivertsen
Partnership Drift in Innovation Processes
A study of the Think City electric car development

3. Kathrine Hoffmann Pii
Responsibility Flows in Patient-centred Prevention

4. Jane Bjørn Vedel
Managing Strategic Research
An empirical analysis of science-industry collaboration in a pharmaceutical company

5. Martin Gylling
Processuel strategi i organisationer
Monografi om dobbeltheden i tænkning af strategi, dels som vidensfelt i organisationsteori, dels som kunstnerisk tilgang til at skabe i erhvervsmæssig innovation

6. Linne Marie Lauesen
Corporate Social Responsibility in the Water Sector: How Material Practices and their Symbolic and Physical Meanings Form a Colonising Logic

7. Maggie Qiuzhu Mei
LEARNING TO INNOVATE: The role of ambidexterity, standard, and decision process

8. Inger Høedt-Rasmussen
Developing Identity for Lawyers Towards Sustainable Lawyering

9. Sebastian Fux
Essays on Return Predictability and Term Structure Modelling

10. Thorbjørn N. M. Lund-Poulsen
Essays on Value Based Management

11. Oana Brindusa Albu
Transparency in Organizing: A Performative Approach

12. Lena Olaison
Entrepreneurship at the limits

13. Hanne Sørum
DRESSED FOR WEB SUCCESS? An Empirical Study of Website Quality in the Public Sector

14. Lasse Folke Henriksen
Knowing networks How experts shape transnational governance

15. Maria Halbinger
Entrepreneurial Individuals Empirical Investigations into Entrepreneurial Activities of Hackers and Makers

16. Robert Spliid
Kapitalfondenes metoder og kompetencer

17. Christiane Stelling
Public-private partnerships & the need, development and management of trusting A processual and embedded exploration

18. Marta Gasparin
Management of design as a translation process

19. Kåre Moberg
Assessing the Impact of Entrepreneurship Education From ABC to PhD

20. Alexander Cole
Distant neighbors Collective learning beyond the cluster

21. Martin Møller Boje Rasmussen
Is Competitiveness a Question of Being Alike? How the United Kingdom, Germany and Denmark Came to Compete through their Knowledge Regimes from 1993 to 2007

22. Anders Ravn Sørensen
Studies in central bank legitimacy, currency and national identity Four cases from Danish monetary history

23. Nina Bellak
Can Language be Managed in International Business? Insights into Language Choice from a Case Study of Danish and Austrian Multinational Corporations (MNCs)

24. Rikke Kristine Nielsen
Global Mindset as Managerial Meta-competence and Organizational Capability: Boundary-crossing Leadership Cooperation in the MNC The Case of 'Group Mindset' in Solar A/S.

25. Rasmus Koss Hartmann
User Innovation inside government Towards a critically performative foundation for inquiry

26. Kristian Gylling Olesen
Flertydig og emergerende ledelse i folkeskolen
Et aktør-netværksteoretisk ledelsesstudie af politiske evalueringsreformers betydning for ledelse i den danske folkeskole

27. Troels Riis Larsen
Kampen om Danmarks omdømme 1945-2010
Omdømmearbejde og omdømmepolitik

28. Klaus Majgaard
Jagten på autenticitet i offentlig styring

29. Ming Hua Li
Institutional Transition and Organizational Diversity:
Differentiated internationalization strategies of emerging market state-owned enterprises

30. Sofie Blinkenberg Federspiel
IT, organisation og digitalisering:
Institutionelt arbejde i den kommunale digitaliseringsproces

31. Elvi Weinreich
Hvilke offentlige ledere er der brug for når velfærdstænkningen flytter sig – er Diplomuddannelsens lederprofil svaret?

32. Ellen Mølgaard Korsager
Self-conception and image of context in the growth of the firm – A Penrosian History of Fiberline Composites

33. Else Skjold
The Daily Selection

34. Marie Louise Conradsen
The Cancer Centre That Never Was
The Organisation of Danish Cancer Research 1949-1992

35. Virgilio Failla
Three Essays on the Dynamics of Entrepreneurs in the Labor Market

36. Nicky Nedergaard
Brand-Based Innovation
Relational Perspectives on Brand Logics and Design Innovation Strategies and Implementation

37. Mads Gjedsted Nielsen
Essays in Real Estate Finance

38. Kristin Martina Brandl
Process Perspectives on Service Offshoring

39. Mia Rosa Koss Hartmann
In the gray zone
With police in making space for creativity

40. Karen Ingerslev
Healthcare Innovation under The Microscope
Framing Boundaries of Wicked Problems

41. Tim Neerup Themsen
Risk Management in large Danish public capital investment programmes

2015

1. Jakob Ion Wille
Film som design
Design af levende billeder i film og tv-serier

2. Christiane Mossin
Interzones of Law and Metaphysics
Hierarchies, Logics and Foundations of Social Order seen through the Prism of EU Social Rights

3. Thomas Tøth
TRUSTWORTHINESS: ENABLING GLOBAL COLLABORATION
An Ethnographic Study of Trust, Distance, Control, Culture and Boundary Spanning within Offshore Outsourcing of IT Services

4. Steven Højlund
Evaluation Use in Evaluation Systems – The Case of the European Commission

5. Julia Kirch Kirkegaard
AMBIGUOUS WINDS OF CHANGE – OR FIGHTING AGAINST WINDMILLS IN CHINESE WIND POWER
A CONSTRUCTIVIST INQUIRY INTO CHINA'S PRAGMATICS OF GREEN MARKETISATION MAPPING CONTROVERSIES OVER A POTENTIAL TURN TO QUALITY IN CHINESE WIND POWER

6. Michelle Carol Antero
A Multi-case Analysis of the Development of Enterprise Resource Planning Systems (ERP) Business Practices

Morten Friis-Olivarius
The Associative Nature of Creativity

7. Mathew Abraham
New Cooperativism:
A study of emerging producer organisations in India

8. Stine Hedegaard
Sustainability-Focused Identity: Identity work performed to manage, negotiate and resolve barriers and tensions that arise in the process of constructing or ganizational identity in a sustainability context

9. Cecilie Glerup
Organizing Science in Society – the conduct and justification of resposible research

10. Allan Salling Pedersen
Implementering af ITIL® IT-governance - når best practice konflikter med kulturen Løsning af implementerings-problemer gennem anvendelse af kendte CSF i et aktionsforskningsforløb.

11. Nihat Misir
A Real Options Approach to Determining Power Prices

12. Mamdouh Medhat
MEASURING AND PRICING THE RISK OF CORPORATE FAILURES

13. Rina Hansen
Toward a Digital Strategy for Omnichannel Retailing

14. Eva Pallesen
In the rhythm of welfare creation
A relational processual investigation moving beyond the conceptual horizon of welfare management

15. Gouya Harirchi
In Search of Opportunities: Three Essays on Global Linkages for Innovation

16. Lotte Holck
Embedded Diversity: A critical ethnographic study of the structural tensions of organizing diversity

17. Jose Daniel Balarezo
Learning through Scenario Planning

18. Louise Pram Nielsen
Knowledge dissemination based on terminological ontologies. Using eye tracking to further user interface design.

19. Sofie Dam
PUBLIC-PRIVATE PARTNERSHIPS FOR INNOVATION AND SUSTAINABILITY TRANSFORMATION
An embedded, comparative case study of municipal waste management in England and Denmark

20. Ulrik Hartmyer Christiansen
Follwoing the Content of Reported Risk Across the Organization

21. Guro Refsum Sanden
Language strategies in multinational corporations. A cross-sector study of financial service companies and manufacturing companies.

22. Linn Gevoll
Designing performance management for operational level
- A closer look on the role of design choices in framing coordination and motivation

23. Frederik Larsen
Objects and Social Actions
– on Second-hand Valuation Practices

24. Thorhildur Hansdottir Jetzek
The Sustainable Value of Open Government Data
Uncovering the Generative Mechanisms of Open Data through a Mixed Methods Approach

25. Gustav Toppenberg
Innovation-based M&A
– Technological-Integration Challenges – The Case of Digital-Technology Companies

26. Mie Plotnikof
Challenges of Collaborative Governance
An Organizational Discourse Study of Public Managers' Struggles with Collaboration across the Daycare Area

27. Christian Garmann Johnsen
Who Are the Post-Bureaucrats?
A Philosophical Examination of the Creative Manager, the Authentic Leader and the Entrepreneur

28. Jacob Brogaard-Kay
Constituting Performance Management
A field study of a pharmaceutical company

29. Rasmus Ploug Jenle
Engineering Markets for Control: Integrating Wind Power into the Danish Electricity System

30. Morten Lindholst
Complex Business Negotiation: Understanding Preparation and Planning

31. Morten Grynings
TRUST AND TRANSPARENCY FROM AN ALIGNMENT PERSPECTIVE

32. Peter Andreas Norn
Byregimer og styringsevne: Politisk lederskab af store byudviklingsprojekter

33. Milan Miric
Essays on Competition, Innovation and Firm Strategy in Digital Markets

34. Sanne K. Hjordrup
The Value of Talent Management
Rethinking practice, problems and possibilities

35. Johanna Sax
Strategic Risk Management
– Analyzing Antecedents and Contingencies for Value Creation

36. Pernille Rydén
Strategic Cognition of Social Media

37. Mimmi Sjöklint
The Measurable Me
- The Influence of Self-tracking on the User Experience

38. Juan Ignacio Staricco
Towards a Fair Global Economic Regime? A critical assessment of Fair Trade through the examination of the Argentinean wine industry

39. Marie Henriette Madsen
Emerging and temporary connections in Quality work

40. Yangfeng CAO
Toward a Process Framework of Business Model Innovation in the Global Context
Entrepreneurship-Enabled Dynamic Capability of Medium-Sized Multinational Enterprises

41. Carsten Scheibye
Enactment of the Organizational Cost Structure in Value Chain Configuration
A Contribution to Strategic Cost Management

2016

1. Signe Sofie Dyrby
Enterprise Social Media at Work

2. Dorte Boesby Dahl
The making of the public parking attendant
Dirt, aesthetics and inclusion in public service work

3. Verena Girschik
Realizing Corporate Responsibility Positioning and Framing in Nascent Institutional Change

4. Anders Ørding Olsen
IN SEARCH OF SOLUTIONS
Inertia, Knowledge Sources and Diversity in Collaborative Problem-solving

5. Pernille Steen Pedersen
Udkast til et nyt copingbegreb
En kvalifikation af ledelsesmuligheder for at forebygge sygefravær ved psykiske problemer.

6. Kerli Kant Hvass
Weaving a Path from Waste to Value: Exploring fashion industry business models and the circular economy

7. Kasper Lindskow
Exploring Digital News Publishing Business Models – a production network approach

8. Mikkel Mouritz Marfelt
The chameleon workforce:
Assembling and negotiating the content of a workforce

9. Marianne Bertelsen
Aesthetic encounters
Rethinking autonomy, space & time in today's world of art

10. Louise Hauberg Wilhelmsen
EU PERSPECTIVES ON INTERNATIONAL COMMERCIAL ARBITRATION

11. Abid Hussain
On the Design, Development and Use of the Social Data Analytics Tool (SODATO): Design Propositions, Patterns, and Principles for Big Social Data Analytics

12. Mark Bruun
Essays on Earnings Predictability

13. Tor Bøe-Lillegraven
BUSINESS PARADOXES, BLACK BOXES, AND BIG DATA: BEYOND ORGANIZATIONAL AMBIDEXTERITY

14. Hadis Khonsary-Atighi
ECONOMIC DETERMINANTS OF DOMESTIC INVESTMENT IN AN OIL-BASED ECONOMY: THE CASE OF IRAN (1965-2010)

15. Maj Lervad Grasten
Rule of Law or Rule by Lawyers?
On the Politics of Translation in Global Governance

16. Lene Granzau Juel-Jacobsen
SUPERMARKEDETS MODUS OPERANDI – en hverdagssociologisk undersøgelse af forholdet mellem rum og handlen og understøtte relationsopbygning?

17. Christine Thalsgård Henriques
In search of entrepreneurial learning – Towards a relational perspective on incubating practices?

18. Patrick Bennett
Essays in Education, Crime, and Job Displacement

19. Søren Korsgaard
Payments and Central Bank Policy

20. Marie Kruse Skibsted
Empirical Essays in Economics of Education and Labor

21. Elizabeth Benedict Christensen
The Constantly Contingent Sense of Belonging of the 1.5 Generation Undocumented Youth
An Everyday Perspective

22. Lasse J. Jessen
Essays on Discounting Behavior and Gambling Behavior

23. Kalle Johannes Rose
Når stifterviljen dør…
Et retsøkonomisk bidrag til 200 års juridisk konflikt om ejendomsretten

24. Andreas Søeborg Kirkedal
Danish Stød and Automatic Speech Recognition

25. Ida Lunde Jørgensen
Institutions and Legitimations in Finance for the Arts

26. Olga Rykov Ibsen
An empirical cross-linguistic study of directives: A semiotic approach to the sentence forms chosen by British, Danish and Russian speakers in native and ELF contexts

27. Desi Volker
Understanding Interest Rate Volatility

28. Angeli Elizabeth Weller
Practice at the Boundaries of Business Ethics & Corporate Social Responsibility

29. Ida Danneskiold-Samsøe
Levende læring i kunstneriske organisationer
En undersøgelse af læringsprocesser mellem projekt og organisation på Aarhus Teater

30. Leif Christensen
Quality of information – The role of internal controls and materiality

31. Olga Zarzecka
Tie Content in Professional Networks

32. Henrik Mahncke
De store gaver
- Filantropiens gensidighedsrelationer i teori og praksis

33. Carsten Lund Pedersen
Using the Collective Wisdom of Frontline Employees in Strategic Issue Management

34. Yun Liu
Essays on Market Design

35. Denitsa Hazarbassanova Blagoeva
The Internationalisation of Service Firms

36. Manya Jaura Lind
Capability development in an off-shoring context: How, why and by whom

37. Luis R. Boscán F.
Essays on the Design of Contracts and Markets for Power System Flexibility

38. Andreas Philipp Distel
Capabilities for Strategic Adaptation: Micro-Foundations, Organizational Conditions, and Performance Implications

39. Lavinia Bleoca
The Usefulness of Innovation and Intellectual Capital in Business Performance: The Financial Effects of Knowledge Management vs. Disclosure

40. Henrik Jensen
Economic Organization and Imperfect Managerial Knowledge: A Study of the Role of Managerial Meta-Knowledge in the Management of Distributed Knowledge

41. Stine Mosekjær
The Understanding of English Emotion Words by Chinese and Japanese Speakers of English as a Lingua Franca
An Empirical Study

42. Hallur Tor Sigurdarson
The Ministry of Desire - Anxiety and entrepreneurship in a bureaucracy

43. Kätlin Pulk
Making Time While Being in Time
A study of the temporality of organizational processes

44. Valeria Giacomin
Contextualizing the cluster Palm oil in Southeast Asia in global perspective (1880s–1970s)

45. Jeanette Willert
Managers' use of multiple Management Control Systems: The role and interplay of management control systems and company performance

46. Mads Vestergaard Jensen
Financial Frictions: Implications for Early Option Exercise and Realized Volatility

47. Mikael Reimer Jensen
Interbank Markets and Frictions

48. Benjamin Faigen
Essays on Employee Ownership

49. Adela Michea
Enacting Business Models An Ethnographic Study of an Emerging Business Model Innovation within the Frame of a Manufacturing Company.

50. Iben Sandal Stjerne
Transcending organization in temporary systems Aesthetics' organizing work and employment in Creative Industries

51. Simon Krogh
Anticipating Organizational Change

52. Sarah Netter
Exploring the Sharing Economy

53. Lene Tolstrup Christensen
State-owned enterprises as institutional market actors in the marketization of public service provision: A comparative case study of Danish and Swedish passenger rail 1990–2015

54. Kyoung(Kay) Sun Park
Three Essays on Financial Economics

2017

1. Mari Bjerck
Apparel at work. Work uniforms and women in male-dominated manual occupations.

2. Christoph H. Flöthmann
Who Manages Our Supply Chains? Backgrounds, Competencies and Contributions of Human Resources in Supply Chain Management

3. Aleksandra Anna Rzeźnik
Essays in Empirical Asset Pricing

4. Claes Bäckman
Essays on Housing Markets

5. Kirsti Reitan Andersen
Stabilizing Sustainability in the Textile and Fashion Industry

6. Kira Hoffmann
Cost Behavior: An Empirical Analysis of Determinants and Consequences of Asymmetries

7. Tobin Hanspal
Essays in Household Finance

8. Nina Lange
Correlation in Energy Markets

9. Anjum Fayyaz
Donor Interventions and SME Networking in Industrial Clusters in Punjab Province, Pakistan

10. Magnus Paulsen Hansen
Trying the unemployed. Justification and critique, emancipation and coercion towards the 'active society'. A study of contemporary reforms in France and Denmark

11. Sameer Azizi
Corporate Social Responsibility in Afghanistan – a critical case study of the mobile telecommunications industry

12. Malene Myhre
The internationalization of small and medium-sized enterprises: A qualitative study

13. Thomas Presskorn-Thygesen
The Significance of Normativity – Studies in Post-Kantian Philosophy and Social Theory

14. Federico Clementi
Essays on multinational production and international trade

15. Lara Anne Hale
Experimental Standards in Sustainability Transitions: Insights from the Building Sector

16. Richard Pucci
Accounting for Financial Instruments in an Uncertain World Controversies in IFRS in the Aftermath of the 2008 Financial Crisis

17. Sarah Maria Denta
Kommunale offentlige private partnerskaber Regulering I skyggen af Farumsagen

18. Christian Östlund
Design for e-training

19. Amalie Martinus Hauge
Organizing Valuations – a pragmatic inquiry

20. Tim Holst Celik
Tension-filled Governance? Exploring the Emergence, Consolidation and Reconfiguration of Legitimatory and Fiscal State-crafting

21. Christian Bason
Leading Public Design: How managers engage with design to transform public governance

22. Davide Tomio
Essays on Arbitrage and Market Liquidity

23. Simone Stæhr
Financial Analysts' Forecasts Behavioral Aspects and the Impact of Personal Characteristics

24. Mikkel Godt Gregersen
Management Control, Intrinsic Motivation and Creativity – How Can They Coexist

25. Kristjan Johannes Suse Jespersen
Advancing the Payments for Ecosystem Service Discourse Through Institutional Theory

26. Kristian Bondo Hansen
Crowds and Speculation: A study of crowd phenomena in the U.S. financial markets 1890 to 1940

27. Lars Balslev
Actors and practices – An institutional study on management accounting change in Air Greenland

28. Sven Klingler
Essays on Asset Pricing with Financial Frictions

29. Klement Ahrensbach Rasmussen
Business Model Innovation The Role of Organizational Design

30. Giulio Zichella
Entrepreneurial Cognition. Three essays on entrepreneurial behavior and cognition under risk and uncertainty

31. Richard Ledborg Hansen
En forkærlighed til det eksisterende – mellemlederens oplevelse af forandringsmodstand i organisatoriske forandringer

32. Vilhelm Stefan Holsting
Militært chefvirke: Kritik og retfærdiggørelse mellem politik og profession

33. Thomas Jensen
Shipping Information Pipeline: An information infrastructure to improve international containerized shipping

34. Dzmitry Bartalevich
Do economic theories inform policy? Analysis of the influence of the Chicago School on European Union competition policy

35. Kristian Roed Nielsen
Crowdfunding for Sustainability: A study on the potential of reward-based crowdfunding in supporting sustainable entrepreneurship

36. Emil Husted
There is always an alternative: A study of control and commitment in political organization

37. Anders Ludvig Sevelsted
Interpreting Bonds and Boundaries of Obligation. A genealogy of the emergence and development of Protestant voluntary social work in Denmark as shown through the cases of the Copenhagen Home Mission and the Blue Cross (1850 – 1950)

38. Niklas Kohl
Essays on Stock Issuance

39. Maya Christiane Flensborg Jensen
BOUNDARIES OF PROFESSIONALIZATION AT WORK An ethnography-inspired study of care workers' dilemmas at the margin

40. Andreas Kamstrup
Crowdsourcing and the Architectural Competition as Organisational Technologies

41. Louise Lyngfeldt Gorm Hansen
Triggering Earthquakes in Science, Politics and Chinese Hydropower - A Controversy Study

2018

1. Vishv Priya Kohli
Combatting Falsifi cation and Counterfeiting of Medicinal Products in the E uropean Union – A Legal Analysis

2. Helle Haurum
Customer Engagement Behavior in the context of Continuous Service Relationships

3. Nis Grünberg
The Party -state order: Essays on China's political organization and political economic institutions

4. Jesper Christensen
A Behavioral Theory of Human Capital Integration

5. Poula Marie Helth
Learning in practice

6. Rasmus Vendler Toft-Kehler
Entrepreneurship as a career? An investigation of the relationship between entrepreneurial experience and entrepreneurial outcome

7. Szymon Furtak
Sensing the Future: Designing sensor-based predictive information systems for forecasting spare part demand for diesel engines

8. Mette Brehm Johansen
Organizing patient involvement. An ethnographic study

9. Iwona Sulinska
Complexities of Social Capital in Boards of Directors

10. Cecilie Fanøe Petersen
Award of public contracts as a means to conferring State aid: A legal analysis of the interface between public procurement law and State aid law

11. Ahmad Ahmad Barirani
Three Experimental Studies on Entrepreneurship

12. Carsten Allerslev Olsen
Financial Reporting Enforcement: Impact and Consequences

13. Irene Christensen
New product fumbles – Organizing for the Ramp-up process

14. Jacob Taarup-Esbensen
Managing communities – Mining MNEs' community risk management practices

15. Lester Allan Lasrado
Set-Theoretic approach to maturity models

16. Mia B. Münster
Intention vs. Perception of Designed Atmospheres in Fashion Stores

17. Anne Sluhan
Non-Financial Dimensions of Family Firm Ownership: How Socioemotional Wealth and Familiness Influence Internationalization

18. Henrik Yde Andersen
Essays on Debt and Pensions

19. Fabian Heinrich Müller
Valuation Reversed – When Valuators are Valuated. An Analysis of the Perception of and Reaction to Reviewers in Fine-Dining

20. Martin Jarmatz
Organizing for Pricing

21. Niels Joachim Christfort Gormsen
Essays on Empirical Asset Pricing

22. Diego Zunino
Socio-Cognitive Perspectives in Business Venturing

23. Benjamin Asmussen
Networks and Faces between Copenhagen and Canton, 1730-1840

24. Dalia Bagdziunaite
Brains at Brand Touchpoints A Consumer Neuroscience Study of Information Processing of Brand Advertisements and the Store Environment in Compulsive Buying

25. Erol Kazan
Towards a Disruptive Digital Platform Model

26. Andreas Bang Nielsen
Essays on Foreign Exchange and Credit Risk

27. Anne Krebs
Accountable, Operable Knowledge Toward Value Representations of Individual Knowledge in Accounting

28. Matilde Fogh Kirkegaard
A firm- and demand-side perspective on behavioral strategy for value creation: Insights from the hearing aid industry

29. Agnieszka Nowinska
SHIPS AND RELATION-SHIPS Tie formation in the sector of shipping intermediaries in shipping

30. Stine Evald Bentsen
The Comprehension of English Texts by Native Speakers of English and Japanese, Chinese and Russian Speakers of English as a Lingua Franca. An Empirical Study.

31. Stine Louise Daetz
Essays on Financial Frictions in Lending Markets

32. *Christian Skov Jensen*
Essays on Asset Pricing

33. Anders Kryger
Aligning future employee action and corporate strategy in a resource-scarce environment

34. Maitane Elorriaga-Rubio
The behavioral foundations of strategic decision-making: A contextual perspective

35. Roddy Walker
Leadership Development as Organisational Rehabilitation: Shaping Middle-Managers as Double Agents

36. Jinsun Bae
Producing Garments for Global Markets Corporate social responsibility (CSR) in Myanmar's export garment industry 2011–2015

37. Queralt Prat-i-Pubill
Axiological knowledge in a knowledge driven world. Considerations for organizations.

38. Pia Mølgaard
Essays on Corporate Loans and Credit Risk

39. Marzia Aricò
Service Design as a Transformative Force: Introduction and Adoption in an Organizational Context

40. Christian Dyrlund Wåhlin-Jacobsen
Constructing change initiatives in workplace voice activities Studies from a social interaction perspective

41. Peter Kalum Schou
Institutional Logics in Entrepreneurial Ventures: How Competing Logics arise and shape organizational processes and outcomes during scale-up

42. Per Henriksen
Enterprise Risk Management Rationaler og paradokser i en moderne ledelsesteknologi

43. Maximilian Schellmann
The Politics of Organizing Refugee Camps

44. Jacob Halvas Bjerre
Excluding the Jews: The Aryanization of Danish-German Trade and German Anti-Jewish Policy in Denmark 1937-1943

45. Ida Schrøder
Hybridising accounting and caring: A symmetrical study of how costs and needs are connected in Danish child protection work

46. Katrine Kunst
Electronic Word of Behavior: Transforming digital traces of consumer behaviors into communicative content in product design

47. Viktor Avlonitis
Essays on the role of modularity in management: Towards a unified perspective of modular and integral design

48. Anne Sofie Fischer
Negotiating Spaces of Everyday Politics: -An ethnographic study of organizing for social transformation for women in urban poverty, Delhi, India

2019

1. Shihan Du
ESSAYS IN EMPIRICAL STUDIES BASED ON ADMINISTRATIVE LABOUR MARKET DATA

2. Mart Laatsit
Policy learning in innovation policy: A comparative analysis of European Union member states

3. Peter J. Wynne
Proactively Building Capabilities for the Post-Acquisition Integration of Information Systems

4. Kalina S. Staykova
Generative Mechanisms for Digital Platform Ecosystem Evolution

5. Ieva Linkeviciute
Essays on the Demand-Side Management in Electricity Markets

6. Jonatan Echebarria Fernández
Jurisdiction and Arbitration Agreements in Contracts for the Carriage of Goods by Sea – Limitations on Party Autonomy

7. Louise Thorn Bøttkjær
Votes for sale. Essays on clientelism in new democracies.

8. Ditte Vilstrup Holm
The Poetics of Participation: the organizing of participation in contemporary art

9. Philip Rosenbaum
Essays in Labor Markets – Gender, Fertility and Education

10. Mia Olsen
Mobile Betalinger - Succesfaktorer og Adfærdsmæssige Konsekvenser

11. Adrián Luis Mérida Gutiérrez
Entrepreneurial Careers: Determinants, Trajectories, and Outcomes

12. Frederik Regli
Essays on Crude Oil Tanker Markets

13. Cancan Wang
Becoming Adaptive through Social Media: Transforming Governance and Organizational Form in Collaborative E-government

14. Lena Lindbjerg Sperling
Economic and Cultural Development: Empirical Studies of Micro-level Data

15. Xia Zhang
Obligation, face and facework: An empirical study of the communicative act of cancellation of an obligation by Chinese, Danish and British business professionals in both L1 and ELF contexts

16. Stefan Kirkegaard Sløk-Madsen
Entrepreneurial Judgment and Commercialization

17. Erin Leitheiser
The Comparative Dynamics of Private Governance
The case of the Bangladesh Ready-Made Garment Industry

18. Lone Christensen
STRATEGIIMPLEMENTERING: STYRINGSBESTRÆBELSER, IDENTITET OG AFFEKT

19. Thomas Kjær Poulsen
Essays on Asset Pricing with Financial Frictions

20. Maria Lundberg
Trust and self-trust in leadership identity constructions: A qualitative exploration of narrative ecology in the discursive aftermath of heroic discourse

21. Tina Joanes
Sufficiency for sustainability
Determinants and strategies for reducing clothing consumption

22. Benjamin Johannes Flesch
Social Set Visualizer (SoSeVi): Design, Development and Evaluation of a Visual Analytics Tool for Computational Set Analysis of Big Social Data

23. Henriette Sophia Groskopff Tvede Schleimann
Creating innovation through collaboration – Partnering in the maritime sector

24. Kristian Steensen Nielsen
The Role of Self-Regulation in Environmental Behavior Change

25. Lydia L. Jørgensen
Moving Organizational Atmospheres

26. Theodor Lucian Vladasel
Embracing Heterogeneity: Essays in Entrepreneurship and Human Capital

27. Seidi Suurmets
Contextual Effects in Consumer Research: An Investigation of Consumer Information Processing and Behavior via the Applicati on of Eye-tracking Methodology

28. Marie Sundby Palle Nickelsen
Reformer mellem integritet og innovation: Reform af reformens form i den danske centraladministration fra 1920 til 2019

29. Vibeke Kristine Scheller
The temporal organizing of same-day discharge: A tempography of a Cardiac Day Unit

30. Qian Sun
Adopting Artificial Intelligence in Healthcare in the Digital Age: Perceived Challenges, Frame Incongruence, and Social Power

31. Dorthe Thorning Mejlhede
Artful change agency and organizing for innovation – the case of a Nordic fintech cooperative

32. Benjamin Christoffersen
Corporate Default Models:
Empirical Evidence and Methodical Contributions

33. Filipe Antonio Bonito Vieira
Essays on Pensions and Fiscal Sustainability

34. Morten Nicklas Bigler Jensen
Earnings Management in Private Firms:
An Empirical Analysis of Determinants and Consequences of Earnings Management in Private Firms

2020

1. Christian Hendriksen
Inside the Blue Box: Explaining industry influence in the International Maritime Organization

2. Vasileios Kosmas
Environmental and social issues in global supply chains:
Emission reduction in the maritime transport industry and maritime search and rescue operational response to migration

3. Thorben Peter Simonsen
The spatial organization of psychiatric practice: A situated inquiry into 'healing architecture'

4. Signe Bruskin
The infinite storm: An ethnographic study of organizational change in a bank

5. Rasmus Corlin Christensen
Politics and Professionals: Transnational Struggles to Change International Taxation

6. Robert Lorenz Törmer
The Architectural Enablement of a Digital Platform Strategy

7. Anna Kirkebæk Johansson Gosovic
Ethics as Practice: An ethnographic study of business ethics in a multinational biopharmaceutical company

8. Frank Meier
Making up leaders in leadership development

9. Kai Basner
Servitization at work: On proliferation and containment

10. Anestis Keremis
Anti-corruption in action: How is anti-corruption practiced in multinational companies?

11. Marie Larsen Ryberg
Governing Interdisciolinarity: Stakes and translations of interdisciplinarity in Danish high school education.

12. Jannick Friis Christensen
Queering organisation(s): Norm-critical orientations to organising and researching diversity

13. Thorsteinn Sigurdur Sveinsson
Essays on Macroeconomic Implications of Demographic Change

14. Catherine Casler
Reconstruction in strategy and organization: For a pragmatic stance

15. Luisa Murphy
Revisiting the standard organization of multi-stakeholder initiatives (MSIs): The case of a meta-MSI in Southeast Asia

16. Friedrich Bergmann
Essays on International Trade

17. Nicholas Haagensen
European Legal Networks in Crisis: The Legal Construction of Economic Policy

18. Charlotte Biil
Samskabelse med en sommerfugle-model: Hybrid ret i forbindelse med et partnerskabsprojekt mellem 100 selvejende daginstitutioner, deres paraplyorganisation, tre kommuner og CBS

19. Andreas Dimmelmeier
The Role of Economic Ideas in Sustainable Finance: From Paradigms to Policy

20. Maibrith Kempka Jensen
Ledelse og autoritet i interaktion - En interaktionsbaseret undersøgelse af autoritet i ledelse i praksis

21. Thomas Burø
LAND OF LIGHT: Assembling the Ecology of Culture in Odsherred 2000-2018

22. Prins Marcus Valiant Lantz
Timely Emotion: The Rhetorical Framing of Strategic Decision Making

23. Thorbjørn Vittenhof Fejerskov
Fra værdi til invitationer - offentlig værdiskabelse gennem affekt, potentialitet og begivenhed

24. Lea Acre Foverskov
Demographic Change and Employment: Path dependencies and institutional logics in the European Commission

25. Anirudh Agrawal
A Doctoral Dissertation

26. Julie Marx
Households in the housing market

27. Hadar Gafni
Alternative Digital Methods of Providing Entrepreneurial Finance

28. Mathilde Hjerrild Carlsen
Ledelse af engagementer: En undersøgelse af samarbejde mellem folkeskoler og virksomheder i Danmark

29. Suen Wang
Essays on the Gendered Origins and Implications of Social Policies in the Developing World

30. Stine Hald Larsen
The Story of the Relative: A Systems-Theoretical Analysis of the Role of the Relative in Danish Eldercare Policy from 1930 to 2020

31. Christian Casper Hofma
Immersive technologies and organizational routines: When head-mounted displays meet organizational routines

32. Jonathan Feddersen
The temporal emergence of social relations: An event-based perspective of organising

33. Nageswaran Vaidyanathan
ENRICHING RETAIL CUSTOMER EXPERIENCE USING AUGMENTED REALITY

2021

1. Vanya Rusinova
The Determinants of Firms' Engagement in Corporate Social Responsibility: Evidence from Natural Experiments

2. Lívia Lopes Barakat
Knowledge management mechanisms at MNCs:
The enhancing effect of absorptive capacity and its effects on performance and innovation

3. Søren Bundgaard Brøgger
Essays on Modern Derivatives Markets

4. Martin Friis Nielsen
Consuming Memory: Towards a conceptualization of social media platforms as organizational technologies of consumption

05. Fei Liu
Emergent Technology Use in Consumer Decision Journeys: A Process-as-Propensity Approach

06. Jakob Rømer Barfod
Ledelse i militære højrisikoteams

07. Elham Shafiei Gol
Creative Crowdwork Arrangements

08. Árni Jóhan Petersen
Collective Imaginary as (Residual) Fantasy: A Case Study of the Faroese Oil Bonanza

09. Søren Bering
"Manufacturing, Forward Integration and Governance Strategy"

10. Lars Oehler
Technological Change and the Decomposition of Innovation:
Choices and Consequences for Latecomer Firm Upgrading: The Case of China's Wind Energy Sector

11. Lise Dahl Arvedsen
Leadership in interaction in a virtual context:
A study of the role of leadership processes in a complex context, and how such processes are accomplished in practice

12. Jacob Emil Jeppesen
Essays on Knowledge networks, scientific impact and new knowledge adoption

13. Kasper Ingeman Beck
Essays on Chinese State-Owned Enterprises:
Reform, Corporate Governance and Subnational Diversity

14. Sönnich Dahl Sönnichsen
Exploring the interface between public demand and private supply for implementation of circular economy principles

15. Benjamin Knox
Essays on Financial Markets and Monetary Policy

16. Anita Eskesen
Essays on Utility Regulation:
Evaluating Negotiation-Based Approaches inthe Context of Danish Utility Regulation

17. Agnes Guenther
Essays on Firm Strategy and Human Capital

18. Sophie Marie Cappelen
Walking on Eggshells: The balancing act of temporal work in a setting of culinary change

19. Manar Saleh Alnamlah
About Gender Gaps in Entrepreneurial Finance

20. Kirsten Tangaa Nielsen
Essays on the Value of CEOs and Directors

21. Renée Ridgway
Re:search - the Personalised Subject vs. the Anonymous User

22. Codrina Ana Maria Lauth
IMPACT Industrial Hackathons:
Findings from a longitudinal case study on short-term vs long-term IMPACT implementations from industrial hackathons within Grundfos

23. Wolf-Hendrik Uhlbach
Scientist Mobility: Essays on knowledge production and innovation

24. Tomaz Sedej
Blockchain technology and inter-organizational relationships

25. Lasse Bundgaard
Public Private Innovation Partnerships:
Creating Public Value & Scaling Up Sustainable City Solutions

26. Dimitra Makri Andersen
Walking through Temporal Walls:
Rethinking NGO Organizing for Sustainability through a Temporal Lens on NGO-Business Partnerships

27. Louise Fjord Kjærsgaard
Allocation of the Right to Tax Income from Digital Products and Services:
A legal analysis of international tax treaty law

28. Sara Dahlman
Marginal alternativity: Organizing for sustainable investing

29. Henrik Gundelach
Performance determinants:
An Investigation of the Relationship between Resources, Experience and Performance in Challenging Business Environments

30. Tom Wraight
Confronting the Developmental State: American Trade Policy in the Neoliberal Era

31. Mathias Fjællegaard Jensen
Essays on Gender and Skills in the Labour Market

32. Daniel Lundgaard
Using Social Media to Discuss Global Challenges: Case Studies of the Climate Change Debate on Twitter

33. Jonas Sveistrup Søgaard
Designs for Accounting Information Systems using Distributed Ledger Technology

TITLER I ATV PH.D.-SERIEN

1992
1. Niels Kornum
Servicesamkørsel – organisation, økonomi og planlægningsmetode

1995
2. Verner Worm
Nordiske virksomheder i Kina
Kulturspecifikke interaktionsrelationer ved nordiske virksomhedsetableringer i Kina

1999
3. Mogens Bjerre
Key Account Management of Complex Strategic Relationships
An Empirical Study of the Fast Moving Consumer Goods Industry

2000
4. Lotte Darsø
Innovation in the Making
Interaction Research with heterogeneous Groups of Knowledge Workers creating new Knowledge and new Leads

2001
5. Peter Hobolt Jensen
Managing Strategic Design Identities
The case of the Lego Developer Network

2002
6. Peter Lohmann
The Deleuzian Other of Organizational Change – Moving Perspectives of the Human

7. Anne Marie Jess Hansen
To lead from a distance: The dynamic interplay between strategy and strategizing – A case study of the strategic management process

2003
8. Lotte Henriksen
Videndeling
– om organisatoriske og ledelsesmæssige udfordringer ved videndeling i praksis

9. Niels Christian Nickelsen
Arrangements of Knowing: Coordinating Procedures Tools and Bodies in Industrial Production – a case study of the collective making of new products

2005
10. Carsten Ørts Hansen
Konstruktion af ledelsesteknologier og effektivitet

TITLER I DBA PH.D.-SERIEN

2007
1. Peter Kastrup-Misir
Endeavoring to Understand Market Orientation – and the concomitant co-mutation of the researched, the re searcher, the research itself and the truth

2009
1. Torkild Leo Thellefsen
Fundamental Signs and Significance effects
A Semeiotic outline of Fundamental Signs, Significance-effects, Knowledge Profiling and their use in Knowledge Organization and Branding

2. Daniel Ronzani
When Bits Learn to Walk Don't Make Them Trip. Technological Innovation and the Role of Regulation by Law in Information Systems Research: the Case of Radio Frequency Identification (RFID)

2010
1. Alexander Carnera
Magten over livet og livet som magt
Studier i den biopolitiske ambivalens