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Transformation Design for a Decentralized, Value-Sharing Economy

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I, Nusret Drljevic (exp. nr. 75382), hereby declare that this dissertation has been composed independently by myself for the Doctoral Programme in Economics and Business Studies at the University of Granada (B17.56.1). Unless otherwise stated by reference or acknowledgement, the work presented is entirely my own. This dissertation has not been submitted for conferral of degree elsewhere.

Nusret Drljevic

Berlin, November 2021

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LIST OF ABBREVIATIONS

5G	Fifth-generation wireless technologies
AI	Artificial intelligence
ASU	Active system use
BI	Behavioral intentions
CMM	Capability maturity model
DOI	Diffusion of innovations theory
IIoT	Industrial internet of things
IoT	Internet of things
IU	Intention to use
K-Wave	Kondratieff Wave
LK	Level of knowledge
MM	Maturity model
OECD	Organization for Economic Co-operation and Development
PBFT	Practical byzantine fault tolerance
PEU	Perceived ease of use
PU	Perceived usefulness
PR	Perceived risk
TAM	Technology acceptance model
TCP/IP	Transmission control protocol/internet protocol
TRA	Theory of reasoned action
U&G	Uses and gratification theory
UNECE	United Nations Economic Commission for Europe
WEF	World Economic Forum

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1 General introduction and definitions

1.1 Introduction to the research topic and problem definition

Blockchain technology holds the potential to impact and transform economies and business models at the systemic level. Like foundational technologies of the past, blockchain also faces a set of risks and barriers, which can influence the adoption process along the path to such transformation. Research in the area of risk management for sustainable blockchain use is still in its infancy. With this thesis, I aim to contribute to academic and industry communities by creating an adoption model, which could support the design of blockchain-driven business transformation towards decentralized systems. The results of this research should aid in paving the way to manage risks for the sustainable usage of blockchain technology. This thesis encompasses the review of 100+ research publications, 50+ market and business reports, over 600 special media articles and a primary survey with 125 business and technology leaders from large enterprises, small and medium businesses, and start-up companies.

Blockchain is a so-called distributed ledger technology, which was created in 2008 and has since experienced a significant hype across global industries and media and, to some extent, in scientific research. Public mainstream interest peaked in 2017 when its most famous application, the cryptocurrency known as bitcoin, reached a value of $20,000 per unit (Higgins, 2017). In addition to this abstract highlight, blockchain brings great expectations for a leap toward open, democratic means of conducting business, and, in turn, toward a decentralized economy. Blockchains are decentralized platforms in that they enable value sharing across user networks. These networks are characterized by conducting and recording transactions autonomously and transparently, based upon consensus and user-validation. This eliminates the controlling power of one single party within a business network. This technology will likely transform business and the way transactions are conducted, shifting from centralized and human-based systems to a shared, algorithm-based trust model. Industry-wide interest in this format for conducting transactions can be observed. As of 2018, the technology saw marked development beyond its initial cryptocurrency focus. Industries, businesses and governments now recognize blockchain's potential relevance for numerous use cases and applications.

Despite great interest, high speculation in blockchain as the "next big thing" has already been met with disappointment and surprising failure rates for projects among early adopters. Nevertheless, blockchain applications appear to be on the agendas of leading corporations, as well as small and medium businesses, and start-ups. Researchers, industry reports and specialized media continue to publish and circulate views on the blockchain-enabled business transformation. In the wake of the initial hype, however, it is becoming more apparent that this transformation will take much longer than many experts claim.

The reason for this lies in the fact that blockchain applications require fundamental changes to strategies, business models, operations and users' mindsets. It brings unprecedented levels of technological, regulatory and collaborative complexity. Simply implementing a blockchain system within business-as-usual operations is not possible. As described above, blockchain is about re-envisioning business models, stakeholder relationships and the way transactions are conducted and recorded. It is only through a thorough and mindful process of transformation, that blockchain technologies can be used sustainably, and this foundational change is what characterizes blockchain.

This transformation is marked by radical perspective shifts, regarding business relationships (trust and transparency), information and data usage (shared and distributed), and the execution of transactions (autonomous and consensus-based). Thus, blockchain holds major significance for sustainably designing new business models, products, services and experiences, and this represents a strongly growing global demand for managing this transformation design process.

Two dimensions of this foundational technology are affecting this demand: “The first is novelty—the degree to which an application is new to the world. The more novel it is, the more effort will be required to ensure that users understand what problems it solves. The second dimension is complexity, represented by the level of ecosystem coordination involved—the number and diversity of parties that need to work together to produce value with the technology” (Iansiti & Lakhani, 2017).

These two perspectives of novelty and complexity serve as the central insights and drivers for this thesis. In applying these perspectives to blockchain, researchers Iansiti & Lakhani argue in their 2017 Harvard Business Review report that adoption of this technological innovation will take years. The authors expect that the sum total of blockchain applications won’t reach broad adoption and critical mass for at least another decade and probably more. However, I propose that businesses cannot wait. Even in this early stage, it is already crucial to consider the risks and processes, which are relevant for the sustainable adoption and use of this transformative, foundational technology.

While there is no comprehensive, scientific basis or working definition for foundational technologies, the economic theory known as the Kondratieff Cycles (often called "theory of the long waves") provides a historical arc, outlining the evolution of other transformative innovations and their impact on their respective historical economies. With his theory, Russian economist Nikolai Kondratieff (1892-1938) posited that Western capitalist economies have long-term, 50 to 60-year cycles of boom followed by depression. Out of each phase of economic crisis, new waves arise when basic technological innovations cluster to launch new technological revolutions, which actually define each era by creating new industries and markets (Allianz, 2010). Each wave brings about new forms of business models and new ways of working.

Considering this historical context helps to understand the patterns and enormous impacts of adopting foundational technologies (see Figure 1). The 1st Kondratieff Wave (K-Wave) of 1780-1830 relates to the Industrial Revolution and the rise of both industrial textile production and steam engine technology. This set the tone for transforming work and designing business models, and this pattern of evolution can be traced up to today. The 2nd K-Wave saw the rise of railway technology and the steel industry. The 3rd spanned the turn of the 20th century and brought economic booms around electrification and chemicals industries. The 4th K-Wave rose out of the Great Depression with the invention of automobiles and petrochemicals. The 5th K-Wave is characterized by the emergence of distributed information and communications technology in the 1970's, which laid the groundwork for the development of the internet. Prior to this foundational shift to TCP/IP (transmission control protocol/internet protocol), telecommunications architecture was based on circuit switching - the classic image of operators manually controlling and maintaining all connections between two parties. Billions were invested to build out physical systems of lines as communications channels. TCP/IP revolutionized this notion by creating a digitized, open, shared public network without any central authority or party responsible for its maintenance and improvement (Allianz, 2010). Blockchain follows this legacy by translating and further evolving these notions into transactional terms.

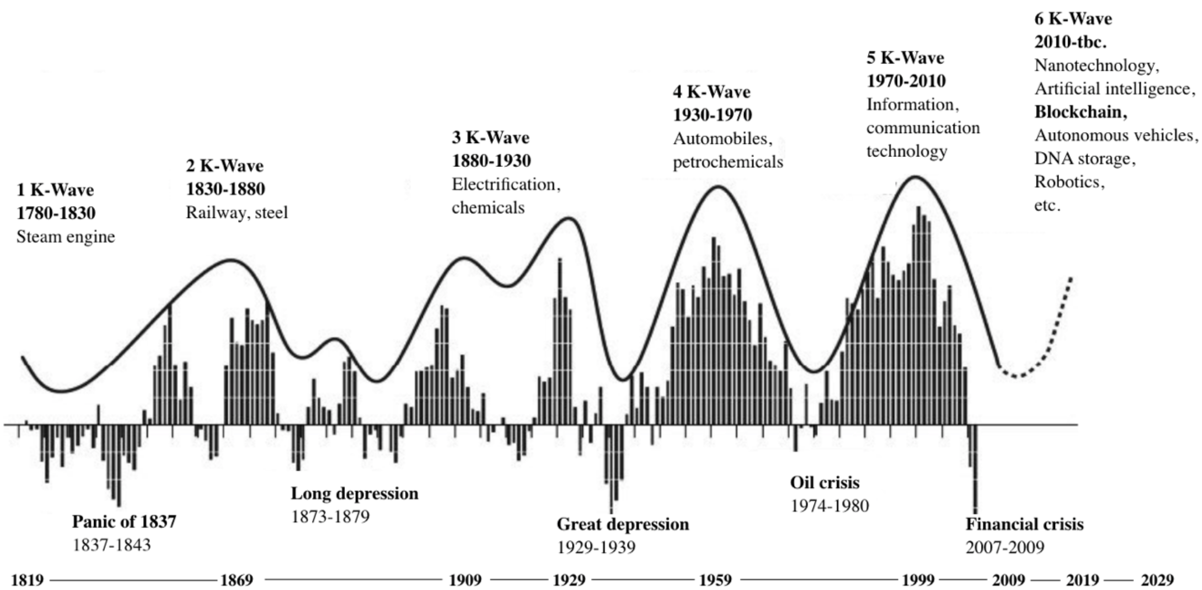

Figure 1: Kondratieff Wave Theory (Allianz, 2010)

In keeping with this theory, we are entering the 6th Kondratieff cycle, which is aligned with the so-called 4th Industrial Revolution. The World Economic Forum (WEF) executive chairman, Klaus Schwab coined this term in 2015. Schwab includes the notion of fourth era technologies that combine hardware, software, and biology (cyber-physical systems), and emphasizes advances in communication and connectivity. Schwab expects this era to be marked by breakthroughs in emerging technologies in fields such as robotics, artificial intelligence, nanotechnology, quantum computing, biotechnology, the internet of things (IoT), the industrial internet of things (IIoT), decentralized consensus, fifth-generation wireless technologies (5G), 3D printing and fully autonomous vehicles. The WEF compiled a list in 2016, naming ten emerging technologies with potential for global economic transformation. Blockchain is on this list, along with autonomous vehicles, open AI ecosystems, optogenetics and systems metabolic engineering. These characteristic 4th Industrial Revolution innovations are defined by the fusion of technologies that blur the lines between the physical, digital, and biological spheres (Schwab, 2017). With their report on Kondratieff Waves and technological revolutions, Grinin et al. (2016) assume that in the 2030's and 2040's, the 6th K-Wave will merge with the final phase of the Cybernetic Revolution, which the authors call a phase of self-regulating systems. American mathematician and philosopher Norbert Wiener (1894-1964) defined cybernetics in 1948 as "the scientific study of control and communication in the animal and the machine." The era of this 4th Industrial Revolution is characterized by the simultaneous rise of several foundational, emerging technologies, which are based on these self-regulating, cybernetic principles. Blockchain technology belongs to this category.

This technology can be applied to a wide array of use cases across many industries, where businesses and users need common repositories, common systems of record, common directories and cases where coordination is needed between multiple different parties in a business ecosystem (Warren & Treat, 2019). The benefits of blockchains are often discussed according to these key main elements of value creation: greater transparency, enhanced security, improved traceability, increased efficiency and speed, and cost reduction across business networks (Hooper, 2018). These elements can provide benefits for a variety of potential use cases in industries such as finance and banking (executing letters of credit in hours instead of weeks), transportation and supply chain (transparent tracking and tracing of goods), healthcare (securely connecting and recording health data), insurance (transparently managing claims via smart contracts), media (secure and transparent digital rights management), public sector (errorless tax management, identity management, voting) and many more.

The latest developments in the blockchain market point to emergent increases in interest despite low success rates among early projects. Aside from bitcoins, there are already more than 2,529 cryptocurrencies registered worldwide, with a total market capitalization of $249T, as reported by leading online source Coinmarketcap (status: September 1, 2019). According to their website's members' page, the leading platform for permissioned blockchains, Hyperledger, has seen a jump in membership from 150 companies in 2017 to 360 in August 2019 (Hyperledger, 2019). As of 2017, Japan was already accepting bitcoin as legal tender in more than 260,000 stores (Scott, 2017). Hundreds of initiatives across the world are creating new, decentralized business models and applications using blockchain technology. This includes established enterprises such as IBM, Intel, Microsoft, SAP (all technology), Daimler (transportation), Toyota (automotive), Samsung (consumer electronics), Thomson Reuter (media), TUI (travel), Maersk (logistic), Sony (entertainment), but also promising start-ups like StorJ (distributed storage), Blockstack (distributed internet), Binded (copyright management), Snip (distributed news publisher), Civic (identity verification), Bitland (land capital registration), Stellar or Ripple (payment systems), Brave (web browser), Moeco (IoT data routing platform) and many more.

On the other hand, there is a high rate of project failure, as mentioned, which indicates the need for further scientific work in this field. Despite the rapid rise of applications and use cases, research in the area of risk management for sustainable blockchain use is lacking. The research gaps in this field are due, in part, to the lack of longer-term analyses of blockchain projects (Burg et al., 2018). However, the gaps could also be attributed to the need for comprehensive frameworks for managing the processes of adoption, which could lead blockchain to higher acceptance levels and market maturity levels and, in turn, enable the sustainable use of this foundational technology.

The mindset shifts to open, shared and decentralized business systems is inevitable, and this requires that businesses begin planning and managing the transformation design process now.

1.1.1 Research objectives

The main objective of this thesis is the design of a model for blockchain technology adoption in the context of business transformation. This model should serve two aims: 1) to support companies with risk management across the entire process of blockchain-driven business transformation at the individual, company level, and 2) to estimate the measure of default risk at the industry level, which might arise without an adoption model that could support the sustainable use of blockchain technology.

Furthermore, a key objective of designing this model is to identify the current acceptance and maturity levels of various companies and industries with regard to blockchain-enabled business transformation. In this way, the model can become a tool for assessing how ready and equipped business leaders are to apply blockchain technology for business transformation in a sustainable way.

Additionally, I aim to provide a statistical method in order to estimate the risk related to blockchain adoption without the use of such a tool. This works with the assumption that higher risks could emerge when no model is applied, and these risks represent barriers to blockchain-driven business transformation.

To reach the aforementioned aims of supporting risk management at the company scale, and estimating levels of default risk at the industry scale, primary research has been conducted. Firstly, the research serves to understand and devise an integrated model as a tool for managing risk parameters related to blockchain adoption. Furthermore, the purpose of this research is to apply and test a statistical method within the framework of the integrated adoption model, which can estimate levels of risks related to blockchain-enabled business transformation on an aggregated, industry level. Such a tool of predictive analysis could hold great potential for industry-wide thought leaders, investors and other actors of transformation design.

The desired outcome of this thesis is a strongly conceptual and integrated approach to supporting companies on their paths toward decentralized and value sharing business models. To achieve this aim, contemporary design principles have been applied, and a stable, structured understanding of business transformation is advanced throughout this thesis.

The thesis is written with a wider audience in mind, including researchers, business leaders, experience designers, technology specialists, software developers and anyone who is curious and equipped to design decentralized, future-ready business models and applications.

This research also serves to prove that this customized model could be technology agnostic. In this case, this means that the model could potentially be applied to any number of different technologies and could serve as a useful tool for risk management - not only for blockchain, but also for AI, IoT, autonomous intelligent systems, or other drivers of business transformation.

1.1.2 Research scope and methodology

This thesis is organized according to various phases of secondary and primary research, which subsequently build upon on one another, beginning with exploration, moving on to problem definition, and further to ideation and qualified testing.

The scope of this research includes the analysis of 600 industry reports and special media articles from 2016 to 2017, which represents the exploration and problem definition phases of this thesis. During this time, I analyzed and observed the rise of blockchain technologies across various regions, industries and use cases. The outcome of this phase was the creation of a blockchain industry and use-case map, which helped me to identify the spaces of opportunity for the thesis, and to identify research gaps, define problems and contextualize further research steps.

Resulting from additional secondary research, I devised two systemic literature reviews by analyzing more than 60 academic papers in the areas of blockchain-related risk management and blockchain-related technology adoption models. These systematic literature reviews were necessary in order to identify the current state of scientific research in the field and, at the same time, to qualify the need for creating an adoption model for the sustainable use of blockchain technology in the context of business transformation. The literature reviews were key in identifying concrete research gaps and further defining the problem. With this phase, it became more evident that there is a need for comprehensive, holistic methods of risk management for the sustainable use of blockchain technology.

Based on the outputs of these research phases, I then designed an integrated adoption model by merging and customizing two existing adoption models, which I identified with the systematic literature reviews. Designing an adoption model to manage risk for the sustainable use of blockchain technology became the main purpose of this research.

I then carried out substantial primary research from 2018 to 2019, to test and qualify the newly designed, integrated adoption model. This primary research consists of a survey that was conducted across 125 executive business and technology leaders from 20 industries. The participating companies represent a sampling of large enterprises, small and medium businesses and start-up companies. The survey could present real value for current research, due to the high rate of executive level participation and high relevance of the industries represented, in terms of real, applicable blockchain use cases.

The following Table 1 provides an overview of the 8 key steps as they related to the phases of secondary and primary research. The chapters of this thesis also relate to this flow of research and delivery (outputs).

Table 1: Thesis research and project delivery phases

Phase	Insights and tasks	Research scope	Timing
1. Exploration	Blockchain named one of the top 10 emerging technologies of the 4th Industrial Revolution with many promises for a better economy.	Reviewed 600 special media articles, 100 industry reports, 20 research papers	2017
2. Problem identification	Blockchain is a foundational technology, that requires transformational change at system level in order to increase the adoption rate and business value creation.		2017
3. Challenge	How to manage the adoption process to ensure a sustainable usage of blockchain technology. This process is characterized by various risks.		2017
4. Systematic literature reviews (SLRs)	Conduct SLRs in context of risk, risk management, adoption models that could support the blockchain adoption process.	Reviewed ca. 60 research papers	2018-2019
5. Filter list	Based on SLRs, evaluate and select suitable adoption models, that could support the adoption and sustainable usage of blockchain technology.		2018-2019
6. Solution	Design and customize a new adoption model that could improve risk and maturity level management for the sustainable usage of blockchain technology: TAM + CMM.		2018-2019
7. Primary research and testing the solution	Conduct primary survey with industry leaders to test the designed and customized adoption model (TAM + CMM). Testing the solution.	Conducted primary research, surveys with 125 executive business and technology leaders across 20 industries, using the new adoption model.	2018-2020
8. Composing, writing, editing	Composing, writing and editing of the thesis. Demonstrating how the newly designed and customized model could positively impact the sustainable usage of blockchain technology in the future.		2020 - 2021

According to this outline, the following phases correspond to this thesis document as follows: The first 3 phases – exploration, problem identification and challenge - are covered in Chapter 1; phase 4 - the systematic literature reviews - accounts for Chapter 2; phases 5 and 6 are filtering collected data on risk parameters and devising a solution for risk management, as presented in Chapter 3; during phase 7 the solution was tested via a primary survey, which is presented in Chapter 4; phase 8 is the conclusion phase and the definition of outlooks and potential further steps, which are discussed in Chapter 5.

Thesis chapter description

Chapter 1 presents an introduction of terms and an overview of blockchain technology. It also provides a theoretical basis for understanding blockchain as a foundational technology and locating this innovation within a historical development, leading up to self-regulating, decentralized systems as they are emerging today. Additionally, Chapter 1 defines the functionality of blockchain technology to a point, which is sufficient for this exploration of risk management for adoption and sustainable use. The focus here was to define problems and identify challenges in the area of blockchain-related risk management.

Chapter 2 is comprised of two systematic literature reviews, focused on risk and adoption, respectively, as these relate to blockchain. I took a quantitative approach to data and information retrieval and employed methods such as keywording across titles and abstracts in search of combinations of terms, as further described in Sections 2.1.2 and 2.2.2. The key purpose here was to present an overview of current research, and to arrive at sound definitions of risk and adoption, which are most relevant for blockchain-driven business transformation. The key outcomes of the literature reviews are a lists of risk parameters as well as numerous available adoption models.

Chapter 3 presents the design of a customized, integrated adoption model for risk management across all stages of adoption and levels of maturity, i.e. throughout the end-to-end process of blockchain-driven business transformation. By filtering the various models explored in

Chapter 2, I identified the technology acceptance model (TAM) and capability maturity model (CMM) as the best suited to working with blockchain technology adoption. By exploring the methodology of merging models, and by researching some examples of merged models in Chapter 2, I created the framework for TAM + CMM, which could act a solution for blockchain-related risk management.

Chapter 4 presents the results of testing this integrated model. I defined research questions and hypotheses, which lead the line of questioning for a customized survey across 20 industries. This survey serves to test the framework developed with 125 business executives. With 35 survey questions, I could quantify and qualify various levels of acceptance and maturity with blockchain technology.

Finally, Chapter 5 presents a conclusion based upon the results of testing the model. Furthermore, outlooks for continuing to develop, test and optimize the model are discussed, along with future opportunities for applying the model to other technologies and markets.

The thesis is not a critical evaluation of blockchain technology. Deeper explorations of technological questions, deployment, compliancy and software code were excluded from the scope of this research, due to the breadth of scientific publications dealing with the technological functionality of blockchains.

1.1.3 Relevance and motivation of research topic

The relevance of research in the area of risk management for the sustainable adoption and usage of blockchain technology could be confirmed by the rapid and dynamic blockchain market growth. Furthermore, there is global interest across all industries in blockchain's potential for transparent and decentralized businesses.

The fact that so many large enterprises, small and medium businesses, start-up companies and governmental and non-governmental organizations are exploring blockchain technologies confirms the need for, and relevance of research into the adoption and sustainable use of this technology.

The blockchain enabled market is young and currently undergoing the introduction phase. This technology offers many promises for a better business world, but also leaves many open questions and gaps, especially where risks are concerned.

Despite the hype, there appears to be a lack of knowledge surrounding the sustainable usage of blockchain technologies. According to a survey, which was carried out in eleven global markets in mid-2017, 59% of consumers polled said they'd never heard of blockchain technology. Furthermore, 80% of those who have heard of the technology said they don't understand what it is (HSBC, 2018).

Due to its radical shift in the perspective on business relationships (trust and transparency), how information and data are used (shared and distributed) and transactions are executed (autonomous and consensus-based), blockchain has major implications when designing new business models, products, services and experiences - with a strongly growing global demand in managing this transformation design process.

As previously described, two dimensions impact the evolution of this demand: “The first dimension is novelty - the degree to which an application is new to the world. The more novel it is, the more effort will be required to ensure that users and audiences understand what problems it solves. The second dimension is complexity, represented by the level of ecosystem coordination involved - the number and diversity of parties that need to work together to produce value with the technology” (Iansiti & Lakhani, 2017).

The main motivation and purpose of this thesis is to close knowledge gaps and provide a comprehensive and accessible approach with useful, initial solutions for both described dimensions. I define this approach as “transformation design for a decentralized economy.” I also advance that such an approach is necessary and justified by the relevance and growing demand in this field, as discussed above.

This transformation design process is characterized by a number of risk parameters, which impact the acceptance and maturity levels of blockchain technology. Therefore, it becomes apparent that methodologies for measuring and managing risk are relevant and needed. Without methods for operationalizing risk management throughout the entire adoption process, these risk parameters remain as obstacles to blockchain adoption.

The scale and speed of expansion in this field also reflects the relevance of research into risk and adoption. The latest developments in the blockchain market point to sharp increases in interest despite low success rates among early projects. The specialized media platform Distributed reports on top blockchain stories, covering such current developments in this field. For example: As of August 12th, 2019, New Zealand's tax authorities are allowing for employee salaries to be paid in cryptocurrency (Singh, 2019); The U.K.'s Department for Work and Pensions is considering blockchain technology to oversee the country's systems of pensions and welfare (Bitnews Today, 2019); UNICEF aims to leverage blockchain technology for internet hosting in schools in regions of poor connectivity (Kim, 2019). Such examples anticipate the systemic changes emerging in finance, in bureaucracy and in education and international development, which, in turn, represents a rising demand for research to accompany this development.

On the other hand, there is a high rate of project failure, as mentioned, which indicates the need for further scientific work in this field. Despite the rapid rise of applications and use cases, research in the area of risk management for sustainable blockchain use is lacking. The research gaps in this field are due, in part, to the lack of longer-term analyses of blockchain projects (Burg et al., 2018). However, the gaps could also be attributed to the need for holistic frameworks for managing the processes of adoption, which will lead blockchain to higher acceptance levels and market maturity levels and, in turn, enable the sustainable use of this foundational technology.

In summary, the following perspectives and drivers confirm the motivation of research in this field. The following statements have motivated my research in this area and highlight the uniqueness of the present moment, with respect to this foundational technology.

1. Blockchain has been named as one of the 10 emerging technologies of the 4th Industrial Revolution, which is on the path to transform businesses.
2. The global blockchain technology market size is expected to reach $57Bn by 2025, registering a CAGR of 69.4% from 2019 to 2025 (PRNewswire, 2019).
3. Research in the area of blockchain in general has significantly increased over the past 5 years.
4. Blockchain sees a large amount of early mover initiatives worldwide (from large enterprise, to small and medium businesses to start-ups) confirming broad interest in the technology.
5. It has been stated that up to 92% of blockchain initiatives have failed due, in part, to a lack of risk management (James, 2018).
6. Creating understanding and awareness for the technology and its potential for systemic change present great challenges and opportunities for novel forms of management.
7. Educating and involving communities on the creation and use of blockchain applications present great challenges and opportunities to ensure that solutions serve the whole user ecosystem.
8. Managing the costs and risks of transitioning to blockchain-based systems require businesses (or other users) to either completely overhaul their previous system or find a way to integrate legacy systems. This required business transformation presents great challenges and opportunities for optimizing adoption models, which could aid in managing risks and leading to higher maturity levels.

1.1.4 Blockchain

Blockchain is a shared, distributed and synchronized ledger that facilitates the process of recording transactions and tracking assets in a business network. An asset can be tangible, such as a house, car, money or land, or intangible, such as intellectual property, energy, patents or copyright. Virtually anything of value can be tracked and traded on a blockchain network. A blockchain is the best-known example of distributed ledger technology, or DLT. A ledger is comprised of unchangeable (immutable) digitally recorded data in blocks. These blocks are stored in a chain and are spread across multiple servers in a public or private peer-to-peer network with the aim to eliminate manipulation. The synchronization of the ledger database i.e. the agreement of content and transactions within the ledger requires a validating consensus protocol between all parties (Bugle et al., 2018). Blockchains can be organized according to various, distinct, so-called “architecture types”. Three main blockchain types are public, federated and private. Section 1.1.5 describes and explains these different architecture types and their individual mechanisms in more detail.

Blockchain’s potential for transforming traditional business models to decentralized models is being explored across different industries, and its benefits are being measured according to these five key areas (Hooper, 2018):

Greater transparency

Blockchain is an open, distributed ledger that documents transaction histories. All network participants share the same records as opposed to holding individual copies. That shared version can only be updated through consensus, meaning everyone must agree on it. Changes to any single transaction record require the agreement of the entire network, which keeps the data on a blockchain more accurate, consistent and transparent than when it moves through paper-heavy, centralized processes.

Enhanced security

Blockchain functions to prevent fraud and unauthorized activity, thus making it more secure than other record-keeping systems. Transactions require consensus from the entire network before they can be recorded to the system. Once a transaction is approved, it is encrypted and linked to the previous transaction, forming a “chain” of immutable records or ledgers. Information is stored across a network of computers as opposed to a single server, which greatly hinders manipulation to the transaction data.

Improved traceability

The trade and transfer of goods and services through a complex supply chain makes it difficult to trace a product back to its origin. When exchanges are recorded on a blockchain, an audit trail shows where an asset came from and every stop it made on its journey. This historical transaction data can help to verify the authenticity of assets and prevent fraud.

Increased efficiency and speed

Traditional, paper-heavy processes are time-consuming, prone to human error, and often require third-party mediation. Blockchain functions to streamline and automate these processes so that transactions can be completed faster and more efficiently. Record keeping is performed using a single digital ledger that is shared among participants. This eliminates steps to reconcile multiple ledgers and prevents room for error, along with volumes of paperwork.

Reduced costs

Blockchain enables users to trust in the data on the blockchain itself, eliminating the need for third parties or middlemen guarantors. As every participant has access to a single, immutable version of each transaction record, less documentation must be reviewed to complete a trade. With such changes, overhead costs can be lowered.

Blockchains function to order and verify the digitally recorded data related to transactions into blocks, which are programmed with various means of protection against tampering and revision of these transactions. This is what makes the blocks immutable. A network of participants forms an ecosystem of computers, each serving as a ‘node’ within the network. These nodes maintain a record of all transactions written into the system. The process of validating transactions occurs by means of reaching consensus. Various consensus protocols exist, and these represent the core of the blockchain system. In its most basic definition, consensus is a way to make decisions as a diverse group without conflict. This requires the common acceptance of laws, rules and norms, as well as a sense of identity or unity as a group. Protocols for reaching consensus are carried out within a blockchain ecosystem by means of various algorithms. This distributed, algorithm-based validation process eliminates the need for third-party, centralized authorization of transactions. Once validated by the consensus process, transactions are recorded and saved as blocks, forming a cryptographic audit trail. This trail is the chain of blocks that forms a blockchain (Seibold & Samman, 2016).

The transactions executed, validated and recorded within a blockchain ecosystem can be understood generally as (1) exchange of assets, (2) creation of contracts and (3) the sharing of data parameters associated with the transactions. The basic functionality of transacting with a blockchain system is roughly visualized in Figure 2.

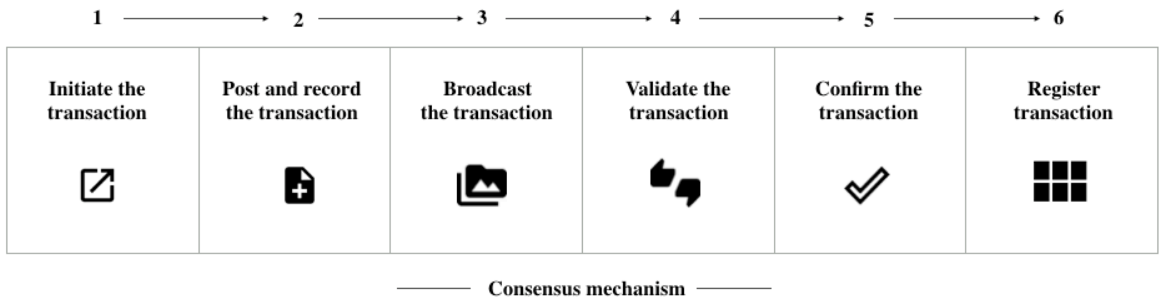

Figure 2: Blockchain functionality – how blockchain works

As visualized in Figure 2, a blockchain functions according to the following steps:

Step 1: Initiate the transaction

Transaction is initiated by nodes (participants) within a blockchain system.

Step 2: Post and record the transaction to the network

Transaction is posted to a "block" of the network as a ledger, or record within the network.

Step 3: Broadcast transaction

Block is broadcast to every network participant (or select participants) and their nodes (computers), which then run an algorithm-based consensus protocol.

Step 4: Validate transaction via consensus

Block is validated and confirmed among all nodes (or selected nodes) via algorithm-based consensus protocol.

Step 5: Confirm transaction

Confirmed block is added to the chain, and this provides a permanent, immutable, transparent record of the transaction.

Step 6: Register transaction completion

Transaction is completed and remains accessible to all nodes as a shared, single truth.

A key challenge to the success of blockchain could lie in the notion of how users work together within the network and how to create and capture ecosystem value. “The whole point of doing blockchain is that it’s a team sport,” explains Christopher G. McDaniel, President of the Institutes RiskBlock Alliance (Warren & Deshmukh, 2019). McDaniel stresses that joining with others is crucial to taking a blockchain project beyond a proof-of-concept standpoint in order to gain real production value. This foundational and widespread shift to decentralized ways of thinking and acting will require transformational design of new business models and processes.

Founder and Managing Partner of the Enterprise blockchain software firm R3, David Rutter, also argues that organizations must get better at working together to create an environment of shared values and partner up to solve additional obstacles and to ensure that proof of concepts (POCs), standards and solutions are adopted at industry scale. Rutter claims: “In the early days, it was getting everyone to understand the technology and its uses. Now it’s more about how the operational and legal construct works with the new technology" (Warren & Treat, 2019). This necessitates a solid framework for risk management.

1.1.4.1 Types of Blockchains

There are various types of blockchains, which differ from one another in their so-called 'architecture'. Each has its own approach and allows for different forms of access, control, consensus, speed, and reading and editing of information on the blockchain. Three key blockchain architectures are public, federated and private (Brakeville & Perepa, 2018; Lastovetska, 2019; Schiller, 2019; Agrawal, 2019).

Public blockchain

Public blockchains are, as the name suggests, blockchains of the public. These are shared systems, where anyone can participate in reading/writing/auditing the blockchain. Another aspect of public blockchains is that they are open and transparent; hence anyone can review anything at a given point of time on a public blockchain (Agrawal, 2019). The prototypical example of this is Bitcoin, but there are many others. With blockchains such as Bitcoin, anyone can read the chain, anyone can make legitimate changes, and anyone can write a new block into the chain (as long as they follow the rules). Due to the open nature of public blockchains and the lack of owner or centralized control, decision making – or consensus – occurs via various decentralized consensus mechanisms, such as proof of work (POW) and proof of stake (POS) etc. (see Figure 3 below).

Federated blockchain

Federated blockchains are a sort of hybrid form, which provides for situations where authorized access is required for reading, writing and auditing the blockchain, but all the transactions should be publicly viewable. A group of members form a federation or consortium, and the decision-making process is carried out between all members. A primary example of this blockchain type is seen with government applications, where only members should be able to write to the network, but all transactions can be publicly verified (WEF, 2018). For example, R3 and Energy Web are structured as federated blockchains (Agrawal, 2019).

Private blockchain

Private blockchains, as the name suggests, are the private property of an individual or an organization. This type requires authorized access, meaning that only those people with permission can read or write to such systems. They may have one or many owners – often consortia are formed to manage the ownership (Warren & Treat, 2019). It is still debatable whether this type can be called a 'blockchain', as it fundamentally defeats the purpose of blockchain that Bitcoin introduced to us. Bankchain is an example of a private blockchain.

Figure 3 illustrates these three architecture types within the broader blockchain landscape. Examples of blockchain providers are shown for each of the three types, as well as examples of consensus mechanisms utilized by each blockchain type and various applications and use cases that are suited to these types.

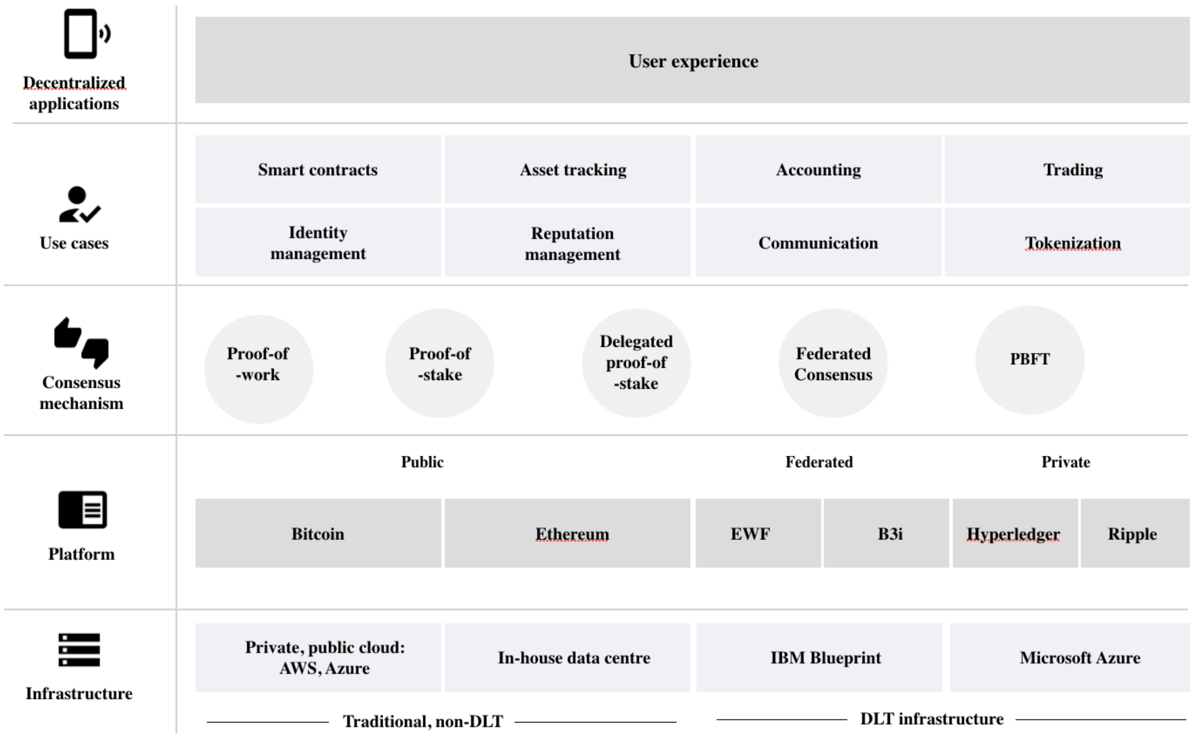

Figure 3: Blockchain architecture

Table 2 illustrates the parameters and functionalities of the three different blockchain architecture types. As no integrated list of functionalities measured across all three types could be located within the scope of this research, I created this table from various sources in order to provide a clear overview and a way to compare the blockchain types against one-another.

Table 2: Functionalities of blockchain types

Functionalities	**Public blockchain**	**Federated blockchain**	**Private blockchain**
Identity	Anonymous users	Identified users	Identified users
Read	Public	Public or restricted	Public or restricted
Write	Anyone	Authorized participants	Network operator only
Immutability	Almost impossible to tamper	Collusion attacks possible	Collusion attacks possible
Consensus mechanism	Costly proof-of-work, proof-of-stake: all miners - permissionless	Light proof-of-work, federated consensus: Selected set of nodes - permissioned	Practical byzantine fault tolerance (PBFT), federated consensus: centralized organization - permissioned
Protocol efficiency	Low level	Higher level	High level
Energy consumption	High level	Lower level	Low level
Transaction speed	Order of minutes	Order of milliseconds	Order of milliseconds
Hosting	Public servers	Private servers	Private servers
Scalability	Low level	Medium level	High level
Examples	Bitcoin, Ethereum	EWF, B3i	Hyperledger, Ripple

Note. Adapted from Lastovetska, 2019; Carson et al., 2018; OECD, 2018; Voshmgir, 2019; Seibold & Samman, 2016

As shown in Table 2, the functionalities for defining and rating these three types of blockchain architecture can be understood as follows: Identity refers to whether users are anonymous or identified within a network; Read signifies who may access and read the encrypted ledgers or blocks; Write signifies who may initiate and validate transactions, which will become the encrypted ledgers or blocks; Immutability describes the extent to which ledgers or blocks can be tampered with or altered; Consensus mechanisms are trust-based (algorithmic) methods for authenticating and validating transactions without the need for centralized authorities; Protocol efficiency describes the time and resources required by the method for reaching consensus and validating a transaction; Energy consumption refers to how much energy is required by the system for operation and storage; Hosting refers to whether the blockchain is hosted on a public or private server, which also has implications for security; Scalability refers to the potential for the blockchain system to be easily scaled (Lastovetska, 2019; Carson et al., 2018; OECD, 2018; Voshmgir, 2019; Seibold & Samman, 2016).

1.1.4.2 Blockchain use cases

Since 2016, I have been observing and analyzing the evolution of blockchain use cases as well those companies, which belong to the early movers in blockchain-enabled business transformation. This includes established enterprises such as IBM, Intel, Microsoft, SAP (all technology), Daimler (transportation), Toyota (automotive), Samsung (consumer electronics), Thomson Reuter (media), TUI (travel), Maersk (logistic), Sony (entertainment) but also start-ups like StorJ (distributed storage), Blockstack (distributed internet), Binded (copyright management), Snip (distributed news publisher), Civic (identity verification), Bitland (land capital registration), Stellar or Ripple (payment systems), Brave (web browser), Moeco (IoT data routing platform) and many more.

Altogether, I have recorded over 600 companies, which I have clustered into 20 industries. Table 3 illustrates an excerpt of the identified industries, use cases and examples.

Table 3: Blockchain use cases and industry examples

Industry	Use case	Examples
Advertising	Eliminating advertising fraud	Lucidity, Metax, Rebell AI, Nyax, IBM
Automotive	Car connectivity, involving third parties such as insurance, maintenance, cleaning services to disclose confidential information	Hyundai, BMW
Consulting	Consultancy and implementation of blockchain	KPMG, McKinsey
E-commerce	Reduction of processing fees, elimination of chargebacks	Expedia, Overstock, Microsoft
Education	Degree verification, secure and share students' records	Disciplina, Sony University, IBM
Fashion	Origin tracking and protection of intellectual property	Martin Jarlgaard London
Finance	Eliminate transaction fees, speed up cross-border transactions	Corda, IBM
FMCG	Better tracking provenance of stock, supply chain safety	KCO, Slock
Healthcare	Ensuring safety, security and interactiveness of patient data	Guardtime, BurstIQ
HR services	Faster and effective recruiting matchmaking and time tracking	Dream, Talao
IT	Increase infrastructure security, mass-scale data authentification	Xage, Guardtime, Brave, Blockstack
Law	Smart contracting, digital automated better intellectual property management	Advoretto, Rocket Lawyer, Monax
Lighting engineering and manufacturing	Enhancing traceability, cost savings, risk reduction, increasing transparency	SAP, IBM, Hitachi, Mitsubishi
Logistics	Inventory tracking, shipping process efficiency, higher transparency	Maersk, IBM
Marketing	Authentification and provenance, better targeting, increase transparency	Lucidity, Metax, Rebell AI, Nyax, IBM
Media	Eliminating advertising fraud	Lucidity, Metax, Rebell AI, Nyax, IBM
Pharmaceuticals	Verifying drugs, prevention of counterfeit drugs, compliancy and transparency in supply chain	Quest Diagnostics, Pfizer, Mediledger, Roche
Retail	Better tracking provenance of stock, supply chain safety	Walmart, Open Bazaar, Shopin, Paytomat, Amazon
Software	Providing platform, cloud services for blockchain applications	Microsoft, IBM, SAP
Travel & transportation	Direct peer-to-peer marketplaces, universal travel currency	Beenest, Winding Tree, MeetnGreetMe, Travelflex

The specific overview in Table 3 shows examples taken from the reviewed industry reports and specialized media articles. This sampling visualizes and expresses the current state of the market, and these categories function as an industry map for the primary research in Chapter 4. It is important to note that the leitmotif of this thesis – risk management for adoption and sustainable use of blockchain technology as a driver of business transformation – repeatedly proves to be coherent with such examples. Resulting from the exploration phase, this categorization of industries has been defined as relevant for this common thread, due to their use cases. Therefore, I sought companies within these industries as participants in the primary survey, presented in Chapter 4.

As described in Section 1.1, blockchain could provide benefits for a variety of potential use cases in key industries such as finance and banking, transportation and supply chain, healthcare, insurance, media, public sector, and many more. Initiatives across the world are creating new, decentralized businesses and applications, utilizing blockchains. Some of the common blockchain use cases could have relevance for any and every industry, including information sharing across organizations, supply chain management, logistics coordination, payments, financial terms and contract rules, auditing cases, and smart contracts with pre-defined rules for transactions between two or more partnering companies.

The benefits and value added by such use cases could be manifold. Supply chain processes can be tracked in real-time with end-to-end visibility. Records can be verified instantly. In the case of compliance, entire processes can be tracked against regulations with pre-defined rules.

Consortiums of stakeholders can own, operate and enforce rules within their ecosystem (Baran, 2018).

Carson et al. (2018) suggest that companies should design optimal blockchain strategies, based on use cases, and depending upon their market position. Market leaders describe the necessity for industry leaders to become active in designing blockchain-driven transformation. It is the market leaders who establish industry standards. The authors stress that market leaders should focus on use cases with the highest potential value and network effects. In their report for global consultants KPMG, the authors state that the greatest risk for these companies is inaction, which would cause them to lose the opportunity to strengthen their competitive advantages compared to competitors (KPMG, 2017). They present an example of a leader following this strategy: Change Healthcare, one of the largest independent healthcare IT companies in the United States. In 2018, it launched an enterprise-scale healthcare blockchain for claims processing and payment.

Beside the private industry sector, governments are also investing huge resources in the technology. Dubai aims to be the first blockchain powered government by 2020 (D'Cuhna, 2017); In 2016, Senegal developed currencies that are entirely digital (Gallego, 2016); Japan is accepting bitcoin as legal tender in more than 260,000 stores (Scott, 2017); the Ukraine is considering to introduce blockchain to fight against corruption (Bitcoin Exchange Guide, 2018); and Estonia plans to build a digital e-residency nation with a nationwide cryptocurrency, called estcoin (Galeon, 2017).

The NGO sector also presents opportunity for blockchain use cases. Arias-Aranda et al. (2019) discuss the value added by integrating IoT and blockchain applications into the field humanitarian aid and catastrophic disaster relief. Humanitarian aid supply chains (HASC) represent complex networks involving local and international NGOs, governmental institutions and services, military or individual initiatives, among others. In order to operationalize impactful disaster relief, various agencies must work together effectively under extreme emergency circumstances. The authors advance that blockchain technology could well serve aid supply chain strategies as a use case, which is highly complex due to geographical and political variables.

Despite so many promising use cases, the high failure rate signifies the lack of sustainable adoption practices. Keeping a focus on industry use cases, and their respective risk parameters, I present the following systematic literature reviews in Chapter 2 as valuable sources for the design of an integrated adoption model, and for the whole transformation design process towards a decentralized economy.

1.1.5 Business transformation

Although the term business transformation is widely applied, a comprehensive, sound definition could not be identified, which adequately serves the purposes of this paper. I advance this definition, which is derived from a combination of sources: Business transformation is the process of fundamentally changing a business model, its patterns, processes, people and technology with the aims of achieving measurable improvements to stakeholder value creation and reducing risks. The transformation can affect the consumer experience, value proposition, value chain, operating model, culture, collaboration, cost structures, profit mechanisms etc.

The main goal of business transformation is to create and capture new stakeholder value. Many businesses succeed in creating value for customers, but not themselves, especially when it comes to the adoption of new technologies. To create value for all, business models, people and technology need work as one to reap great rewards. Realizing such an ambition requires focused and mindful investments and risk management during the transformation process.

By citing the following sources, I would like to present a recent development of different perspectives on the definition and components of business transformation. Anthony (2016) discusses three levels of business transformation - operational, operational model and strategic – and argues that lasting change must occur at all levels in order to avoid short-term solutions and ensure long-term sustainability.

According to Kotter's Harvard Business Review article (2007), such transformation can be organized and managed across several stages: (1) recognizing the need to change; gaining consensus amongst stakeholders that change is necessary, (2) agreeing on the form and objectives of the change; defining a vision that describes a better future, (3) understanding what the organization is changing from and what needs to change in detail, (4) designing the new organizational way of working and its support and management, (5) testing and implementing changes, usually in waves, typically over a number of years, (6) bedding in the change so that the organization cannot move back to how it was and achieves the intended benefits.

Oliver Gassmann and his research team at the renowned University of St. Gallen conducted a long-term study in 2014, with which they analyzed the most revolutionary business model innovations over the past 50 years to determine their core predictable and systematic patterns. The researchers argue that the future competitive advantage of companies will not be based on innovative products and processes, but on innovative business models. “In sum, a business model defines who your customers are, what you are selling, how you produce your offering, and why your business is profitable” (Gassmann, 2014, p. 7).

To their surprise, they discovered that over 90% of all business model innovations simply recombine existing business model patterns from other industries (Gassmann, 2014, p. 3). Their finding is that there are 55 so-called business model patterns that can be used to innovate and transform a business. Examples of these so-called business model patterns are add-on, barter, crowdsourcing, freemium, integrator, long tail, mass customization, peer-to-peer, self-service and subscription, to name a few.

It can be assumed, that technology adoption can only be successful if it is natively and well integrated within a future-ready, innovative business model. This is highly relevant in the case of blockchain, as both perspectives - blockchain as a foundational technology, and Gassmann’s systematic business innovation approach - are well aligned to one another.

In more recent years, business transformation has been strongly associated with digital transformation, as digital technologies play a continuously larger role when it comes to business transformation. There are various definitions on offer. I would like to draw from and advance a practical approach to modern, future-driven business transformation, which is influenced by technology giant IBM - a company which has successfully transformed itself over the past decades from a hardware technology producer to a software, cloud computing, cognitive computing, artificial intelligence and design services provider. IBM is one of the leading corporations, early movers and thought leaders in the area of blockchain-enabled business transformation. IBM takes a progressive and practical approach to digital business transformation, applying the following seven areas, which can be employed in blockchain-enabled business transformation (Bellissimo, 2019):

Define your platform

By clearly defining a business' purpose and key strengths, a platform can be defined and designed, which serves to reinvent the core of the business and to stake its claim on the market. A platform can be built upon proprietary data, expertise and workflows, and the customer should represent the "center of gravity" – the focus of all processes and activities.

Build it on data

The notion of "curating data" is relevant to building a business platform. This business specific data should meet specific business needs, functions and workflows. A robust framework for data governance should be put in place. Data is what differentiates a business, and the way that data is utilized informs the core business strategy.

Architect for change

Scale, speed and flexibility should be built into every area of the business, starting with the platform. A manifesto for continuous change could define the processes of technology adoption, which lead to transformation. Business architecture, or structures, should be newly designed and aligned with the emerging technology architecture. Changes to the legacy system should be linked to the company's vision of future states.

Design intelligent workflows

This step describes a fusion of machine and human intelligence into customer-facing workflows. Today's customers expect to be engaged in ways that are humanized, founded in empathy and attuned to context. Strategic workflows can be designed for automation, intelligence and efficiency; these should serve to support employees with decision-making and customer engagement.

Get agile

Agile work refers to fast, purposeful practices, which have one goal in mind: to meet customer needs quickly. By assembling an agile team and breaking down internal boundaries, ideas and insights can be better shared, and customer needs can be met faster. Strategic agility is the foundation for culture transformation, new ways of working and exponential growth.

Scale up security

Cybersecurity is critical to the longevity of any business platform. A balance must be found between user experiences and trusted transactions. In the case of blockchains, cybersecurity must also be scalable to accommodate growing networks. Ease of customer use plus high security at any scale can allow for a smooth transformation to blockchain-based business models.

Empower people

Hiring curious, inventive people, and up-skilling existing talent supports business transformation from the inside, out. Employees require the appropriate tools for growth in line with the business vision. Skills gaps should be regularly reviewed, and personalized learning programs can be designed to mobilize people across new roles and opportunities. Such steps can sustain the necessary shifts in working habits and mindsets.

This final point touches upon the most important aspect of successful business transformation: the need for mindset shifts and cultural changes to meet new business needs. These necessary changes to employee work culture must be endorsed and funded by C-level and executive stakeholders in order to guarantee sustainable transformation. At the end of the day, even digital transformation is people driven. Thus, the human element must be considered as equal to technological changes. Not only the technologies, but also decentralized ways of working and collaborating must be adopted and matured within any business context.

Over the past decade, we are witnessing the transformation of many industries towards more open, decentralized and broadly distributed modes of interaction and transaction. Platforms like YouTube have transformed how we create and consume media. Amazon has caused a major shift away from brick-and-mortar shops, and toward globalized, virtual retail. PayPal has democratized banking and vastly increased the ease and velocity of financial transactions. Each of these examples enhances the power of the user to produce and consume more freely. Blockchain is very similar to this concept, except that it allows individuals to exchange money and other assets with one another, without requiring an intermediary to do so (Warren & Treat, 2019).

The transformation of business to accommodate new models like these requires management across the entire adoption process and along all levels of maturity. I argue that the transformation design required for blockchain adoption and sustained use is contingent upon an integrated and holistic framework for risk management. In the case of blockchain, it is not possible to integrate an application within business-as-usual operations. Blockchain business transformation means shifting from centralized, third party consensus to open systems where multitudes of ecosystem users can validate transactions. With the example of banking, this means a shift to peer-to-peer payments, which do not require banking intermediaries. While this shows promise for reduced settlement times and reduced costs associated with these payments, the actual transformation of business processes must be designed and managed in terms of the risks that arise with such changes. Even positive changes have great implications at the systemic scale.

1.1.6 Risks

This research is centered on an understanding that risks could impact the sustainable usage of blockchain technology, and that an integrated framework for risk management could be a key to designing successful blockchain-driven business transformation. With this work, I consider the general understanding of risk, which refers to uncertainty and undesirable outcomes. For the blockchain context, I regard the additional perspectives and areas of business, technology and project management, as sets of risks arise in each of these areas. Examples of blockchain technology-related risk areas are discussed in further detail in Chapter 2, e.g. governance, scalability, architecture design, security, privacy, performance, liquidity, interoperability, consensus protocol and change management.

An understanding of how risks are perceived – in terms of risk levels, threats posed by risks, potential for risk mitigation and risk management is significantly important for the adoption of any technological innovation. Considering and managing risks in an adequate way throughout the entire adoption process and across all levels of maturity could also be beneficial in the blockchain context.

It can be assumed that many of these areas of perceived risk result from uncertainty surrounding blockchain technology as a relatively novel and complex innovation. At this early stage of development, higher levels of uncertainty could influence higher levels of perceived risk (Caron, 2017; Khan, 2017) and thus act as a barrier to adoption. Despite uncertainty, we may reach a point where refusal to adopt is no longer an option. This can be observed in the cases of past foundational technologies, such as TCP/IT and internet.

Due to the increasing prevalence of blockchain technology, failure to adopt also presents risks in terms of missing early-mover value and potential market share. By not engaging with the technology, businesses might risk being left out of impactful decision-making processes and overall market activities. Those who are willing to adopt and use blockchain technology face the need to consider risks at all stages, otherwise the technology could have a negative ripple effect and actually hinder sustainable growth (Kim & Kang, 2017; Khan; 2017). In order to counter uncertainty and to ensure sustainable use, it can be expected that business leaders and decision makers would be eager to apply a normative, integrated framework for risk management in the blockchain context. The theoretical foundation for my treatment of risk in the blockchain context is presented with the literature review in Section 2.1.

1.1.7 Adoption

In the context of business transformation, adoption is the process, by which any novel application, operation, product or service is accepted, implemented, optimized and further utilized. This can be a complex process due to the amount of risks, barriers and parties involved. Adoption describes the entire end-to-end business transformation process, which is required when taking on new technological systems. I advance, that there are two key expressions of this process: acceptance and maturity. Acceptance is a decision-based process, which is determined by user attitudes, values and users' intention to use a system or a technology (Alomary & Woollard, 2015; Rathore & Panwar, 2015). The identification and analysis of risks is an important factor in such acceptance processes.

It is assumed that blockchain adoption is not merely a technological decision; it is also a business decision. Therefore, the acceptance process can be characterized by making a business case for this novel and complex technology. The use cases presented by blockchain must solve real problems for organizations, and the technology must have comparative value over other solutions, such as centralized databases or another forms of ledger systems. These are key determinants for acceptance.

As a second expression of adoption, maturity is the degree to which any novel aspect of a business or organization has been adopted and applied (Wendler, 2012). Maturity can be understood as various stages of evolution, which users in business contexts move through during the adoption process.

Section 2.2 of this paper introduces several key adoption models and theories, which could help to design an integrated adoption model that considers both expressions with the aim of managing risks for sustainable blockchain use.

2 Theoretical foundation and literature review

This chapter is comprised of two literature reviews, both supporting an understanding of risk management in relation to the sustainable adoption and use of blockchain technology. The first is a review of literature on perceived risk and risk management as related to blockchain applications. The second focuses on adoption models and the role of adoption for managing blockchain-related risks.

2.1 Risks and risk management that affect the usage of blockchain technology

2.1.1 Introduction

This literature review aims to support a deeper understanding of risk factors affecting the sustainable use of blockchain technology, as well as to provide an overview of perceived risks related to blockchain and current methods for managing these.

There appears to be high expectations and potential promise for blockchain technology's contribution to business transformation and sustainable socio-economic advances, due to the technology's functions for increasing the transparency and traceability of goods, services and any other assets, facilitating market access and improving the efficiency of transactions. However, questions arise in various literature and specialized media as to whether the technology is far enough in its development to be adopted and sustainably applied.

As described in Section 1.1, Iansiti and Lakhani (2017) suggest in their Harvard Business Review that two dimensions affect how any foundational technology and its business use cases evolve. The first is the degree novelty and the second dimension is complexity, represented by the level of ecosystem coordination involved, i.e. the number and diversity of parties that need to work together to produce value with the technology. I advance that blockchain is a technological innovation with relative high novelty and complexity, and, thus, functional frameworks for risk management are key to successful adoption and to sustainable use. As discussed in the introduction, blockchain is a foundational technology with strategic change effort, which opens up spaces for new business models and new ways of conducting transactions (WEF, 2018; Kim & Kang, 2017).

A clear understanding of perceived risks surrounding blockchain technology could provide insights and guidance for transforming businesses, not only in terms of becoming decentralized and transparent, but also for the sustainable application of this technology itself. Furthermore, without considering potential risks and challenges, the price to pay due to reverse effects might surpass the potential socio-economic benefit expected from blockchain (Kim & Kang, 2017).

My assumption is that both a deeper, focused discussion and a normative framework for risk management in the relatively young blockchain business context has yet to emerge, and I seek to highlight, advance and contribute to the discourse in this domain. This assumption could be rooted in the following hypotheses:

(1) Business leaders and decision makers are eager to apply a normative risk management framework to enhance the sustainable adoption of blockchain technology in the context of business transformation.

(2) Business leaders, decision makers and users depend upon integrated guidelines in order to sufficiently manage blockchain risks along the entire adoption process.

This literature review identifies a selection of existent frameworks and models for managing blockchain-related risks. While primarily focused on scientific, peer-reviewed journals, reports from leading global consultancy firms such as Deloitte, KPMG and global policy making bodies such as OECD (Organisation for Economic Co-operation and Development) or UNECE (United Nations Economic Commission for Europe) were also screened.

Following from the aforementioned hypotheses, sources on blockchain-related risks are reviewed. Particular focus is placed on barriers to blockchain's potential for re-envisioning business processes. Sources focused on blockchain technology, itself, as a method for use in risk management are not included in this review. Literature on blockchain applications solely focused on trading bitcoins or other cryptocurrencies is also excluded.

2.1.2 Research method

This review considers the following four research questions:

RQ1: How is risk defined within business and technology contexts, and why is it relevant?

RQ2: What are the perceived risks across various industries and use cases that affect the adoption and sustained use of blockchain technology?

RQ3: What methods are in current use for assessing and managing these risks?

RQ4: What are the current research gaps in the area of risk management within the adoption and sustainable application of blockchain technology?

In approaching these research questions, a quantitative secondary research method was taken for data and information retrieval. Sources from this research field were drawn from the databases and citation indexes Web of Science, Elsevier's Science Direct, SSSR, Research Gate and Academia.edu, and methods such as keywording across titles and abstracts were employed.

The research is aimed at identifying existent frameworks and models for managing blockchain-related risks. While the available scientific research in this field has increased along with the increased application of blockchain across various industries, the number of sources specifically focused on risk management for adoption and use of blockchain technology remains comparably low.

A search conducted on Elsevier's Science Direct database yielded 623 results for "risk management blockchain" with an increase in publication volume from 13 articles in 2015 to 219 articles in 2019. Only a selection of these academic publications directly treats the risks involved with adopting and implementing blockchain. The majority addresses the value of the technology as a method of risk management in various use-case categories (Zhao et al., 2016; Zheng et al., 2018). For this review alone, 27 primary sources were reviewed. The relevance of these publications was assessed based upon frequency of viewings, citations, and sharings.

2.1.3 Definitions

With research question 1, I explore definitions and relevance of risk within business and technology contexts. The term risk is used and defined in a variety of ways, depending on the context and use case. Most definitions support the common understanding that risk refers to uncertainty and undesirable outcomes. Table 4 presents definitions of risk and risk management from the four different perspectives of general, technology, business and project management.

Table 4: Risk definition as identified from the literature review

Perspectives	Definition
General	A situation involving exposure to danger. The possibility that something unpleasant or unwelcome will happen (Investopedia, 2019).
Business	A probability of threat of damage, injury, liability, loss or any other negative occurrence that is caused by external or internal vulnerabilities, and that may be avoided through preemptive action (Investopedia, 2019).
Technology	A possible event that could cause harm or loss or affect the ability to achieve objectives. A risk is measured by the probability of a threat, the vulnerability of the asset to that threat, and the impact it would have if it occurred. Risk can also be defined as uncertainty of outcome and can be used in the context of measuring the probability of positive outcomes as well as negative outcomes (ITIL, 2019).
Project management	Dual perspective: Overall risk is defined as the effect of uncertainty on the project as a whole. Individual risk is defined as an uncertain event or condition that, if it occurs, has a positive or negative effect on a project's objective (Hilson, 2014).

A consideration of risk is relevant from these multiple perspectives, as all four approaches highlight the need for risk management as a key management practice during any value creation process. Risk management is applied across various industries and specific use cases and applications. The Information Technology Infrastructure Library (ITIL) defines risk management as the process, which is responsible for identifying, assessing and controlling risks.

Risk management can be understood as two phases within an overall process, the first being the identification and assessment of risks. This includes the analysis of assets to the business, identifying threats to those assets, and evaluating how vulnerable each asset is to those threats. Risks can be assessed both quantitatively and/or qualitatively. The second phase is the on-going management of these risks, as well as the measures for their mitigation (Investopedia, 2019).

Exposure to business risk is a factor that could lower revenue, profit or even lead to failure for any company. Anything that threatens a company's ability to meet its objectives is understood as a business risk. These risks can be of various natures and derive from different areas.

General business risks include low customer satisfaction, market acceptance, slower time-to-market, lack of intelligence and data analytics, unmet product or service fit, cashflow, brand fatigue, data security, exchange rates, lack of expertise, dynamic market changes, poor leadership, regulatory compliance, technology downtime (Hilson, 2014). In the context of blockchain adoption and sustainable use, it seems that a certain degree of perceived risk can be a key decision-making factor, and that this level of perceived risk could vary between industries and use cases.

Kim & Kang (2017) highlight the importance of risk consideration throughout the end-to-end transformation process of adopting blockchain applications. With their 2017 report on blockchain's role as a technology to combat corruption, the authors site mainstream institutions (i.a. UN, Word Wide Web Consortium, RAND Corporation, IMF) that currently explore blockchain technology as a tool to empower global communities. The authors conclude, however, that blockchain is a double-edged sword: without considering risks across the entire lifecycle of this innovation, the technology could have a negative ripple effect and actually hinder sustainable growth.

Looking at the current blockchain market, there is evidence that 92% of blockchain projects over the past few years have failed due to a lack of identifying and managing a broad set of risks (Manski, 2017). This stands in contradiction to the vision and ambition of sustainable use.

The recent collaboration between blockchain technology provider IBM and shipping and logistics giant Maersk is an example, which has received broad global public attention. Officially launched in August 2018, the joint venture is a platform called TradeLens, which aims to simplify the cost, complexity and size of global shipping networks, while offering more transparency and efficiency. The product uses distributed ledger technology to establish a shared, immutable record of all the transactions that take place in the network, so that various permissioned trading parties can gain access to that data in real-time (Hill, 2018).

IBM has admitted that its blockchain-based trade platform is struggling to gain traction with other carriers. This signifies risk inherent to building networks amongst competitors. Hapag Lloyd CEO Rolf Jansen is reported to have commented: "Technically the solution by Maersk and IBM could be a good platform, but it will require a governance that makes it an industry platform and not just a platform for Maersk and IBM. […] This is the weakness we're currently seeing in many of these initiatives, as each individual project claims to offer an industry platform that they themselves control. This is self-contradictory." In devising an industry-wide blockchain standard, issues of ownership and governance currently represent risks and are thus hurdles to adoption. In attempts to manage such risks, Maersk has established an operational subsidiary to "ensure TradeLens' independence from other Maersk business units" and the duo say they are in the process of setting up an advisory board to work with TradeLens leaders "to address key issues such as the use of open and fair standards" (Hill, 2018).

2.1.4 Perceived risks

Research question 2 looks at perceived risks across various industries and use cases that affect the adoption and sustained use of blockchain technology. The World Economic Forum's 2019 report highlights the need for a new analytic framework for assessing and managing blockchain technology-related risks. Blockchain's unique properties place increased control into the hands of individuals, rather than large-scale entities such as corporations, governments and research institutions (Warren & Treat, 2019). This shift toward open, democratized means of conducting transactions is at the core of blockchain business transformation in this area. Understanding how decision makers perceive the risks involved with transitioning to blockchain is central to the risk management process.

It appears that some risks and barriers to sustainable blockchain use are perceived as standard across all industries and use cases, whereas others are based on specific applications of blockchain technology. In either case, no normative taxonomy of blockchain risks could be located within the scope of this research. Among the sources reviewed, these key areas of risk appear to be prevalent and overarching: issues of scalability, performance, governance, security and change management (KPMG, 2017; Khan, 2017; Kim & Lee, 2018; Maull et al., 2017; Santhana & Biswas, 2018). A broad range of risks relevant to more specific blockchain applications are identified throughout the sources reviewed as presented below in Table 5. Most journal reports included in this literary review attempt to identify and treat individual risk considerations, rather than to present integrated solutions.

For example, Zheng et al. (2018) present a survey of blockchain challenges and opportunities. Herein, they summarize scalability, privacy leakage and selfish mining as three typical, standard challenges particular to blockchain. These are then broken-down – e.g. scalability into issues such as performance and latency – in order to take individual approaches to mitigating and managing the risks these challenges present.

The aforementioned Kim & Kang (2017) focus on the following risks and challenges of the technology: data governance and privacy, technology-related issues and resistance by the incumbent market players.

Multiple sources identify the realm of governance or regulatory frameworks as an area of weakness and, thus, a key risk category (Beck, 2018; Caron, 2017; Gikay, 2019; Gewal-Carr & Marshall, 2016; Khan, 2017; Kim & Lee, 2018; KPMG, 2017; Tapscott & Tapscott, 2018). Table 5 provides an overview of key risks identified in the literature. This list in not exhaustive but should provide an overview of the range of risks among the reviewed publications.

Table 5: Areas of perceived risk as identified from the literature review, in alphabetical order

#	Identified risk	Reference	#	Identified risk	Reference
1	Access and user rights	KPMG	**15**	Interoperability	KPMG
2	Architecture design	Caron	**16**	Key management	Deloitte
3	Authorizing and provisioning management	KPMG	**17**	Legal liability	Deloitte, Kim, OECD
4	Business continuity	Deloitte	**18**	Liquidity	Deloitte
5	Change management	KPMG	**19**	Performance	KPMG
6	Compliance	Caron	**20**	Privacy	KPMG
7	Consensus protocol	Deloitte	**21**	Regulatory	Deloitte
8	Costs	OECD	**22**	Reputation	Deloitte
9	Customer experience	Panchev	**23**	Scalability	KPMG
10	Data confidentiality	Deloitte	**24**	Security	Deloitte, KPMG
11	Energy consumption	OECD	**25**	Strategy	Deloitte
12	Enforcement of contract	Deloitte	**26**	Supplier	Deloitte
13	Governance	Deloitte, Beck et al.	**27**	User experience	Panchev
14	Integration	Caron			

In most cases, it appears that risks are treated on a case-by-case basis. With the example of governance, no standardized framework that is unique to blockchain seems to be available. Gikay (2019) argues, however, that while blockchain is a new technology, the legal transactions it enables are not entirely novel and could largely be managed under the existent regulations. His report works with the assumption that identifying and utilizing existing legal frameworks could be a method of risk management in this area.

The scope and speed of blockchain adoption speaks for change management being a standard area of perceived risk. It has been said that 80% of the blockchain technology is related to the change in business processes and 20% to implementation of the technology (Manski, 2017). Even for those who refrain from blockchain adoption, a degree of change management will be required for continuing cooperation with partners who adopt and implement blockchain into their business models. Manski (2017) explores blockchain as a possible means of "technological commonwealth" and refers to sectors of the global economy that are predicted to be impacted more quickly than others by the introduction of blockchain technology. These are particularly those industries that benefit from less centralized and more accelerated interconnectivity between different systems, for example healthcare, identity management, media, public services, finance and supply chain management. For these industries, the risk considerations surrounding change management – including the risks involved with not adopting blockchain – should be of primary concern.

Business and technology consultancy firm KPMG outlines eight key areas of risk consideration: access and user management, authorizing and provisioning management, data management, interoperability, scalability and performance, change management, privacy, and security (KPMG, 2017).

In their 2018 treatment, the OECD identifies a list of possible risks and obstacles as these relate to individual sectors. For example, they identify risks related to supply chain, such as fragmentation, difficulty controlling data quality, upfront costs and lack of access. Additionally, they state risks to healthcare, such as privacy rules and data security. Finally, the report addresses risks to energy, such as scalability, technical performance and energy consumption (OECD, 2018).

In addition to scientific journals and reports from global consultancies and policy makers, there is a wealth of references to blockchain across specialized media publications. Valuable insights into perceived risks and risk management can also be culled from these sources. For instance, a discussion of hurdles to blockchain's becoming mainstream defines performance, scalability, as well as the lack of user experience (UX) or customer experience (CX) as risk considerations (Panchev, 2019). Other identified risks include security, compliance, architecture & design and system integration (Caron, 2017). Lack of originality – or the question of blockchain's value in comparison with other database technologies – is often cited as a risk, along with lack of transparency, lack of evaluation methodology and consensus inefficiencies, and energy consumption (Deshwali, 2019). Overarching, standard risk considerations such as governance and system design are also frequently mentioned among specialized media sources (Baydakova, 2019).

It can be assumed that many of these areas of perceived risk result from uncertainty surrounding blockchain technology as a relatively novel and complex innovation. At this early stage of development, higher levels of uncertainty could influence higher levels of perceived risk (Caron, 2017; Khan, 2017). The aforementioned hypotheses were formed based upon this assumption. In order to counter uncertainty, it can be expected that business leaders and decision-makers would be eager to apply a normative risk management framework – complete with integrated guidelines for governance – to enhance the sustainable adoption of blockchain technology in the context of business transformation.

2.1.5 Risk management

With research question 3, I explore what methods are in current use for assessing and managing such perceived risks. It appears that researchers and organizations hold the common belief that, in order to respond to blockchain risks, stakeholders should consider establishing a robust risk management strategy, along with a framework for governance and controlling. It seems that various examples are arising, albeit fragmentary and not normative. Kim & Lee (2018) present a guideline specifically for investors to aid in preventing potential threats to investments. The authors also suggest using international standards such as from NIST (National Institute of Standards and Technology) and ISO (International Organization for Standardization) to develop risk management policies based upon individual needs. Table 6 provides an overview of additional models and approaches for managing risks as a basis of sustainable blockchain usage.

Table 6: Models and approaches for management of blockchain-related risk

Publisher/Author	Type of Model	Key Functions	Benefits
CohnReznick (Bugle et al., 2018)	Singular risk-based strategy	Risk mitigation	Identification of risk considerations and respective control areas across six levels of blockchain focus
Deloitte (Santhana & Biswas, 2018)	Framework for blockchain risk management	Risk management	Framework for embedding 3 perceived risk categories - standard, value transfer, smart contract – within business objectives and operations
KPMG 2017	Blockchain Maturity Model	Risk identification and maturity scoring	Identification of maturity levels and spotting of opportunities for improvement when implementing and using blockchain technology
OECD 2018	Blockchain Primer	Risk identification	Pairing of risk across three policy areas

CohnReznick (Bugle et al., 2018), for instance, focus on six self-defined "high-level risks related to adoption of blockchain technology": scalability, technology implementation and acquisition, data security and confidentiality, regulatory hurdles, jurisdiction, storage limitations. Different considerations within each of these six categories are then paired with a blockchain focus level (platform, nodes, development, user, security incidents, asset management) and assigned certain control areas, which can be understood as individual methods for managing risks.

Leading global technology consultancy firms such as Deloitte and KPMG deal with blockchain risks systematically and strive to define methods for managing their defined risks as an enhancement to their profile of consulting services. In each of these cases, individual hierarchies of risks were presented. Deloitte (Santhana & Biswas, 2018) provides a risk management framework, which embeds three categories of risk considerations - "standard", "value transfer" and "smart contract" – within wider business objectives and processes, then assigns operating models for dealing with these categories, respectively. KPMG identifies eight specific blockchain risk areas and applies these through a maturity model in order to assess and manage blockchain adoption and implementation throughout the whole innovation lifecycle, i.e. throughout end-to-end transformation process (KPMG, 2017).

The OECD Blockchain Primer (OECD, 2018) also takes an individual approach to identifying risks according to three policy areas: 1) upfront costs for supply chain; 2) data security for healthcare applications; 3) energy consumption, which presents a particularly contradictory issue when looking for value creation regarding blockchain usage in the energy sector.

An additional method of risk management is the establishment of common standards. For instance, interoperability is a key risk area, as the connecting of different types of blockchains with each other for transactions and trading present new risks and barriers. In 2017, multiple projects launched protocols for how independent blockchains could best communicate in a decentralized and scalable way. Companies Aion, ICON and Wanchain came together to launch the Blockchain Interoperability Alliance. This alliance is focused on developing a common set of standards for blockchain interoperability to ensure that the shared vision of a global ecosystem of connected blockchains will be achieved (de Castillo, 2017).

2.1.6 Research gaps

Research question 4 focuses on current research gaps in the area of risk management for the adoption and sustainable use of blockchain technology. Due to the novelty of the technology, there appears to be a range of research gaps. In the context of risk, three major gaps could be highlighted.

First, a general lack of focused research into sustainable blockchain use was recognized, which becomes apparent through initial keyword searches. Moreover, research and documentation of the impact of blockchain projects is lacking, thus creating a gap in content to support optimization and sustainable practices (Burg et al., 2018; Vota, 2018).

Furthermore, there is currently no normative, universally applicable framework for risk management of blockchain technology. Each of the reviewed sources employ different risk terminologies, categories, taxonomies etc. An integrated, comprehensive risk management framework could be beneficial for businesses and users across industries and use cases.

The third gap identified within the scope of this literature review is the lack of applied studies, which track the development of risks to blockchain applications over the short and long-term. An example from the development sector makes this lack evident. MERL (monitoring, evaluation, research, and learning) practitioners Burg et al. (2018) examined 43 blockchain use cases and reported on the sheer lack of documentation or evidence supporting value claims of blockchain in the international development space, and the authors cite this as a critical gap for potential adopters.

2.1.7 Discussion and outlook

Risk management is key to the adoption and sustainable use of blockchain technology. This review of literature cites various industries and use cases and highlights the need for a normative framework for risk management, along with integrated guidelines in order to manage blockchain-related risks throughout the entire process of adoption. Due to the novel, complex and transformative nature of blockchain technology, the practice of risk management takes on a particular importance in the context of business transformation. To cite the World Economic Forum, a blockchain application does not represent an end goal. Conversely, blockchain technology should be understood as a strategic change effort, which requires rethinking business models, rethinking relationships between companies and between companies and customers (Warren & Treat, 2019). This level of transformation calls for a fitting level of risk management.

As primary next steps, broader research activity, as well as incentives for conducting research into risk management for sustainable blockchain usage, are required. A focused discussion of risk management and a normative framework for the sustainable application of blockchain have yet to emerge. Closing both gaps could provide great opportunity in terms of identifying novel forms of leadership, consultancy and - most importantly - managing the end-to-end process of applying blockchain technologies in a sustainable way.

I propose that risk management within various blockchain environments could benefit from a consideration of risk parameters in alignment with the understanding of risk from the four viewpoints previously defined - general, business, technology and project management.

To close the gap in terms of applied studies that track the development of risks to blockchain applications over the short and long-term, real-time case studies with a normative blockchain risk management framework could be conducted. Findings and insights could be fed into a collaborative, shared, transparent platform in order to support the enhancement of sustainable blockchain adoption. For instance, the aforementioned IBM and Maersk project (Hill, 2018) could have been monitored and evaluated with a normative, holistic risk management tool which could then provide insights across a globally accessible database for shared learning and crowd-sourced optimization.

I also propose an exploration of MERL methods in conducting blockchain interventions. These methods of monitoring, evaluation, research and learning could aid in separating fact from fiction in terms of project success, and as a means of countering risks to failure.

Based upon high interest - and lack of solutions - across various industries and use cases, my hypotheses point to sound methods for managing risk throughout the entire adoption process as being key to the sustainable use of blockchain technology. A concrete outlook could be the conception of an integrated, normative framework for operationalizing risk parameters. Such a framework could then be applied and tested across industries and use cases, then optimized based upon results and further developed for market maturity. Chapter 3 of this thesis will pick up on this approach and present a potential solution.

2.2 Adoption models for managing blockchain-related risks

This second literature review aims to support a deeper understanding of adoption models as they can affect the sustainable use of blockchain technology.

2.2.1 Introduction

Adoption is related to risk management, which could be considered as a cornerstone of blockchain business transformation. Currently, lack of experience and uncertainty surround blockchain technology as a relatively novel and complex innovation. As discussed in Chapter 1 and Section 2.1, managing the blockchain adoption and transformation process is characterized by particular risks for business leaders and users in business contexts. As discussed, 80% of the blockchain technology is related to the change in business processes and 20% to implementation of the technology (Manski, 2017).

As with any new technology, successful blockchain adoption is contingent upon the two key expressions: acceptance and maturity. Comprehensively managing risks that arise with novel technologies can enhance acceptance rates and increase maturity levels throughout the entire lifecycle.

As described in the previous literature review, risk, in general, refers to uncertainty and undesirable outcomes. There are numerous definitions for risk, and several were outlined above in Section 2.1.3 according to the general perspective, as well as to business, technology and project management. Examples of blockchain technology-related risk areas were also presented in Section

2.1.4, such as governance, scalability, architecture design, security, privacy, performance, liquidity, interoperability, consensus protocol and change management.

Risk management can be observed as two phases or processes, the first being the identification and assessment of risks. The second is the on-going management of these risks, as well as the measures for their mitigation (Hillson, 2014). These two processes could be seen as complementary to the expressions of adoption. Identification and assessment relate to acceptance, as it is important to identify risks and evaluate their potential impacts prior to accepting. On-going risk management and the establishment of risk mitigation measures relates to maturity, as management is central to reaching higher levels of maturity (Muller et al., 2005; Kuczmarskl, 2001).

In working with the viewpoints of technology adoption, and its two expressions, acceptance and maturity, one aim of this literature review is to explore how companies can maintain a competitive advantage within the dynamic market of blockchain technology by managing these perspectives. The degree to which any technology is accepted and applied can determine the success of the innovation and business transformation. Furthermore, the success of innovative technologies and their application can be important to increase the productivity and competitive position of any business (Joshi, 1991). Understanding the reasons behind users' accepting or rejecting any new technology has always been one of the most important areas in the information technology field. Studying individuals' acceptance, adoption and use of information technologies (IT) and information systems (IS) has been recognized since the 1970s, because it is a prerequisite for technology's utilization and realization (Momani & Jamous, 2017).

In this review, sources are cited, which address adoption and its two resilient expressions: acceptance, which is tightly linked to user attitudes and behavioral intention (BI) (Allomary & Woollard, 2015; Rathore & Panwar, 2015), and maturity, i.e. the various stages of evolution, which users in business contexts move through during the adoption process (Wendler, 2012). Acceptance and maturity level management are critical to adopting, implementing and using any new technology. Numerous models and theories exist for understanding and tracking both acceptance and maturity, and I seek to identify and introduce those with potential for operationalizing risk management in the field of blockchain technology.

In this context, the following hypotheses are advanced: 1. Business leaders and decision makers are eager to apply a comprehensive technology acceptance model to enhance the sustainable adoption and use of blockchain technology in the context of business transformation. 2. Business leaders, decision makers and users are eager to apply a comprehensive capability maturity model to enhance the sustainable adoption and use of blockchain technology in the context of business transformation.

2.2.2 Research method

This review of 32 research articles aims to provide a general overview of the current state of research into adoption models and places a special focus on those, which could create value for blockchain-related risk management. I take a quantitative approach to data and information retrieval and employ methods such as keywording across titles and abstracts in search of combinations of the terms “adoption”, “acceptance”, “maturity”, “adoption models”, “maturity levels", "maturity models", "blockchain risks", "sustainable blockchain". Databases reviewed include Academia.org, Elsevier Science Direct, Research Gate, Google Scholar, IEEE.

The sources reviewed aid in identifying mission critical risk areas and defining criteria for their on-going management. The selected literature covers a selection of six adoption models and theories: theory of reasoned action (TRA), diffusion of innovation theory (DOI), motivational model (MM), theory of use and gratification (U&G), capability maturity model (CMM) and technology acceptance model (TAM), as well as examples of merged or integrated models. Key publications, which support this review include Wendel's (2012) systematic mapping study of maturity model research, Wang et al.'s (2016) maturity model for blockchain adoption, Moumani and Jamous' (2017) evolution of technology acceptance models, and Lou and Li's (2017) integration of diffusion of innovation theory and the technology acceptance model. By merging two adoption models together, the authors analyze the adoption of blockchain technology from business managers' perspective. This serves as an example, demonstrating how the integration of models can potentially add value for the entire process of blockchain technology-related risk management.

In support of the aforementioned hypotheses, this literature review considers three main research questions:

RQ1: How are adoption, acceptance and maturity defined within business and technology contexts, and why is it relevant?

RQ2: Which adoption models are available for risk management with blockchain technology?

RQ3: What are the current research gaps in the area of adoption models in the context of blockchain technology-related risks?

2.2.3 Definitions

With research question 1, I explore the definitions and relevance of adoption, acceptance and maturity. Generally speaking, adoption is the act of taking on something new as one's own. In business, adoption is the process, by which any novel application, operation or product is accepted, implemented, optimized and further utilized. The dimension of novelty is inherent to innovation, and basically, anything that is new to a company qualifies as innovation (Edison, et al., 2014). In the contexts of business and technology, the term adoption can be linked to the notions of innovation and transformation, which can be a complex process due to the amount of parties being involved.

Innovation is widely regarded as a critical source of competitive advantage in an increasingly changing environment (Dess & Pickens, 2000; Crossan & Apaydin, 2010). Crossan & Apaydin (2010) synthesize the following meaning from literature published on innovation over the past 27 years: "Innovation is production or adoption, assimilation, and exploitation of a value-added novelty in economic and social spheres; renewal and enlargement of products, services, and markets; development of new methods of production; and the establishment of new management systems. It is both a process and an outcome" (Crossan & Apaydin, 2010, p.1115).

To activate and realize any innovation, it must be adopted and consistently managed overtime. In their discussions of the metrics of innovation, both Edison et al. (2014) and Muller et al. (2005) stress the importance for companies to continually innovate, or else they tend to lose their position to emerging companies with innovative offerings. Adoption could be understood as a process of innovating, and the key phases of this process are the two expressions: acceptance and maturity. Acceptance is determined by user attitudes and values, and it is tightly coupled to behavioral intention (BI) (Allomary & Woollard, 2015; Rathore & Panwar, 2015). Maturity is the degree to which any novel aspect of a business or organization has been adopted and applied (Wendler, 2012). As described in Section 2.2.1, while acceptance is a decision-making process, based upon users' behavior and beliefs, maturity is a dynamic process of evolution, which is related to ongoing business operations.

Business leaders, decision-makers, designers and developers of technology must understand why users accept a particular system or not, as well as how users reach higher levels of maturity with that system. These decision-making factors are part of the user experience, and they must be taken into account throughout the technology's development phase and entire lifecycle (Matheison, 1991). Understanding the user experience as a critical risk parameter is an approach to assessing and managing risk, as discussed in Section 2.1. Table 7 below outlines definitions of these three expressions: adoption, acceptance, maturity.

Table 7: Adoption definition

Expression	**Definition**
Adoption	The extent by which a given technology becomes accepted and incorporated into approved business practices (Cuofano, 2019)
Acceptance	A favorable decision for the use of any product or process, based upon behavioral factors (Rathore & Panwar, 2015)
Maturity	Stages of evolution toward full operationalization of technological processes (Goksen, 2015)

The expressions acceptance and maturity describe stages throughout the entire innovation lifecycle, and are therefore key for successful adoption, as well as for measuring and sustaining innovation (Kuczmarskl, 2001). In the next section, six models and theories are outlined and related to risk management, in particular in the case of blockchain technology adoption.

2.2.4 Adoption models

Research question 2 explores which adoption models are available for risk management with blockchain technology. Models are needed to navigate the complexity of acceptance and maturity, as these expressions influence the successful adoption and sustainable use of technological innovations. Understanding what motivates users to decide for or against any technological innovation makes it possible to gauge how and why any particular technology will gain market traction, or not. And, understanding how a technology reaches maturity with any company is central to the company's management process. The following six theories and models shown in Table 8 are among the most widely used for managing technology adoption and could be of benefit in the context of sustainable blockchain adoption. They have been further developed over the years and resulted, in part, as extensions of each other.

Table 8: Adoption models and theories

Adoption Model	Characteristics
Theory of reasoned action (TRA)	Prediction of human behavior via three cognitive components: (1) attitudes, (2) subjective norms, (3) behavioral intentions (Moumani & Jamous, 2017)
Diffusion of innovation theory (DOI)	Four factors to measure the rate of any innovation's adoption: (1) the innovation itself, (2) communication channels, (3) time, (4) social system (Lee et al., 2011) Five innovation characteristics: (1) compatibility, (2) relative advantage, (3) complexity, (4) trialability, (5) observability (Lee et al., 2011)
Motivational model (MM)	Two forms of motivation to adopt and use technology: (1) extrinsic motivation, (2) intrinsic motivation (Davis, 1992)
Use & gratification theory (U&G)	Three parameters for socio-psychological aspects of use: (1) motivation, (2) behavioral usage, (3) gratification (Katz et al., 1973)
Capability maturity model (CMM)	Process-based model designed across five phases: (1) initial, ad hoc processes, (2) repeatable, (3) defined, (4) managed, (5) optimizing (Goksen, 2015)
Technology acceptance model (TAM)	Two determinants for technology acceptance in IT field: (1) perceived usefulness, (2) perceived ease of use (Alomary & Woollard, 2015)

2.2.4.1 Theory of reasoned action (TRA)

The theory of reasoned action (TRA) was developed by Martin Fishbein and Icek Ajzan in 1967 (Al-Suqri & Al-Kharusi, 2015). Moumani & Jamous (2017) discuss TRA as a fundamental theory of attitudes and behavior, and a key source for later technology acceptance models. TRA is used to predict and explain any human behavior through three main cognitive components: attitudes (favorable or unfavorable feelings), subjective norms (social influence according to several factors like society, economy, politics, demographic factors etc.), and behavioral intentions (motivation to decide for or against any action). The theory suggests that a person's behavioral intentions (BI) will depend on his attitudes (A) and subjective norms (SN). BI = A+SN.

The founders of this theory invented a simple formula, that is BI = (AB)W1 + (SN)W2

In which:

BI = behavioral intention

(AB) = one's attitude toward performing the behavior

W = empirically derived weights

SN = one's subjective norm related to performing the behavior (Moumani & Jamous, 2017).

2.2.4.2 Diffusion of innovation theory (DOI)

Rogers' diffusion of innovation theory (DOI) is a model that seeks to explain how, why and at what rate new ideas and technology spread. Rogers (2003) discusses innovation in terms of ideas, practices or objects, that are perceived as new by those adopting and using them. Furthermore, diffusion is discussed as the process by which an innovation is communicated through certain channels over time among the members of a social system (Rogers, 2003). Therefore, the DOI theory argues that "potential users make decisions to adopt or reject an innovation based on beliefs that they form about the innovation” (Agarwal, 2000, p. 90). The model introduces four factors to measure the rate of any innovation’s adoption: the innovation itself, communication channels, time, and social system. The rate of adoption is expressed in terms of percentage of innovativeness, and this value is then categorized across five lifecycle stages, according to five adopter types: innovators, early adopters, early majority, late majority and laggards, as pictured in Figure 4.

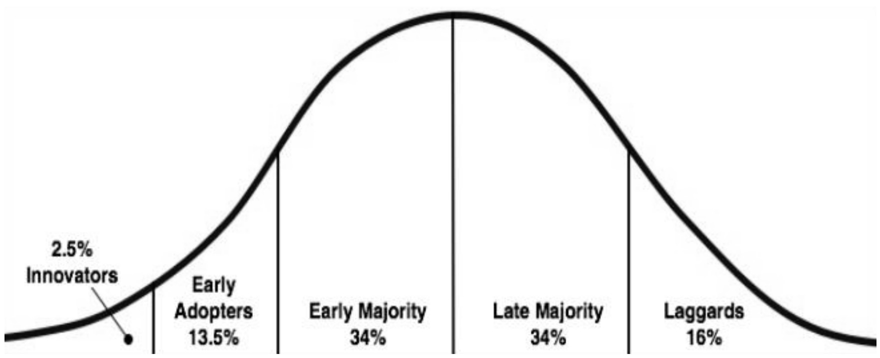

Figure 4: Rogers’ Diffusion of Innovation Theory (Rogers, 2003)

The curve depicted in Figure 4 represents the spread (diffusion) of innovation across these adopter categories. DOI also highlights the point at which any technology reaches the state of critical mass (Alomary & Woollard, 2017) and tries to explain the innovation decision process by predicting the likelihood and rate of adoption of an innovation (Chen et al., 2002). In essence, DOI is a dynamic model, which measures the evolution of innovation amongst different users over time.

2.2.4.3 Motivational Model

Numerous motivational models (MM) are available, and these derive from motivation theory and the field of motivation research, which has developed since the 1940's (Moumani & Jamous, 2017). Davis, Bagozzi and Warshaw (1992) advanced a model, which works with two forms of motivation to adopt and use a technological innovation: extrinsic motivation and intrinsic motivation. Extrinsic motivation describes the desire to achieve some outcome distinct from the technology itself, e.g. using the technology for the purpose of improved job performance. Intrinsic motivation drives the use of the technology simply for the purpose of the activity, per se. Davis et al. (1992) align extrinsic motivation with "perceived usefulness" and intrinsic motivation with "perceived enjoyment" and conclude that enjoyment with any system increases with the perception that the system is useful. Proença & Borbinha (2016) analyzed circa 22 motivational models with their 2016 review, providing an overview of the structures, support, and assessment of leading models. This serves as a valuable tool for comparing models.

2.2.4.4 Uses and gratification theory (U&G)

The uses & gratification theory (U&G) is an approach to understanding why and how people decide to use specific media rather than others. The uses and gratification approach was introduced by Elihu Katz in the early 1970's. Katz and his two colleagues, Jay Blumler and Michael Gurevitch came up with the notion that people use the media to their benefit and actively seek out specific media and content to achieve certain results or gratifications that satisfy their personal needs. At the time of the theory's emergence, it contradicted the overarching view of the audience as a passive group (Katz et al., 1973). The uses and gratifications theory employs three main parameters - motivation, behavioral usage (e.g. amount, duration and type of use) and gratification – to address the driving question: Why do people use media, and what do they use them for? Today, U&G gains in relevance as a tool for understanding how we as individuals connect with the technologies around us (Ruggiero, 2000).

While this theory has been most relevant for the field of mass communications, Ruggiero (2000) argues for a renewal of U&G – a retrofit of this model for the 21st century. The author claims that the emergence of computer-mediated communication has revived the significance of uses and gratifications, and that contemporary and future models must include concepts such as interactivity, demassification, hypertextuality, and asynchroneity. He also argues that researchers must be willing to explore interpersonal and qualitative aspects of mediated communication, in order to ensure a more holistic methodology (Ruggiero, 2000).

2.2.4.5 Technology acceptance model (TAM)

The technology acceptance model (TAM) is a further expression of Ajzen and Fishbein's theory of reasoned action (TRA) (Al-Suqri & Al-Kharusi, 2015). TAM is the most widely applied model of users' acceptance and usage of technology (Venkatesh, 2000). Davis developed an extension in 1989, which replaces TRA's multitude of parameters with two measures for technology acceptance: perceived usefulness (PU) and perceived ease of use (PEU) (Silva, 2015). As seen in Figure 5, any and all external variables determine the values of these two parameters, which then influence the attitude of the user, which can be assessed as either favorable or unfavorable with regard to technological innovations. PU also directly influences behavioral intention (BI) to use a technological system. This, in turn, determines the actual use of the system.

Following from this simple model, initiatives to market technologies and to increase levels of adoption can be easily focused at the two determinants PU and PEU.

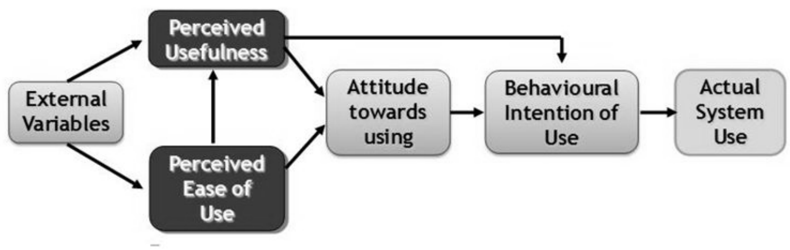

Figure 5: Technology acceptance model TAM (Davis et al., 1992)

However, in order to more deeply analyze factors influencing acceptance, external variables and further determinants should be considered. Many extensions of TAM exist, and all are designed to measure the degree of acceptance and users' satisfaction regarding any technology or information system. This can be measured from different points of view, depending on the constructs or determinants, which represent the structure of the model. Moumani & Jamous (2017) refer to numerous determinants common to the many acceptance models, for example, attitude, beliefs, image, job relevance, relative advantage, anxiety, complexity, perceived usefulness and perceived. In further TAM extensions, such determinants extend the "external variables" affecting attitude, and in turn, intention to use and actual use. Such extensions can aid in contexts of high complexity, such as with blockchain technology. An analysis of additional determinants to levels of acceptance may also aid in identifying risks. This displays the previously discussed relation of acceptance to risk identification, as these relate to the overall risk management process.

TAM was developed for the IT field as a highly simplified model, which reduces the factors to PEU (perceived ease of use) and PU (perceived usefulness) and, thus, excludes many of the subjective norms of other models (Moumani & Jamous, 2017). Because of its specificity and simplicity, TAM has limitations in terms of social and cultural dimensions. On the other hand, it lends itself well to combination with other models. For instance, the methodology of integrating TAM with other models is seen in cases where it is beneficial to extend the IT focus of TAM. For example, in 1995, Taylor and Todd combined the predictors of the theory of planned behavior (TPB) with perceived usefulness from TAM to provide a hybrid model (Safeena et al., 2013). By combining the TPB model from the social psychology field with TAM from information technology field, the assessment of technology acceptance could be enhanced by examining further BI constructs. Safeena et al. (2013) tested this integrated model within the context of internet banking adoption. In the following case, presented in Section 2.2.4.7, the methodology of merging models was employed to deepen the analysis of factors influencing attitudes and BI in the case of blockchain technology.

2.2.4.6 Capability maturity model (CMM)

The capability maturity model (CMM) is a dynamic, process-oriented model, which can be used to measure a company's current maturity level with any innovation in a meaningful way. This enables stakeholders to clearly identify strengths and improvement points, and accordingly prioritize what to do in order to reach higher maturity levels (Proença & Borbinha, 2016).

CMM refers specifically to the first such model, developed in the mid-1980s by the Software Engineering Institute (SEI) at Carnegie Mellon University, as well as the family of process models that followed. It was originally developed to meet the needs and characteristics of governmental organizations. In 1986, SEI began to develop a maturity framework that would help developers improve their software processes (Wendler, 2012).

Maturity models are based on the premises that people, organizations, functional areas, processes, etc., evolve through a process of development or growth in the direction of a more advanced maturity, going through a distinct number of levels. The model's structure is most commonly based on five maturity levels: (1) initial, (2) repeatable, (3) defined, (4) measured, (5) optimizing (Goksen, 2015). A level in the model is a base from which an evolution to a higher maturity level can be planned and implemented. The aim of maturity models is to quantify the activities carried out, make them measurable and develop them – i.e. allow them to mature - over time (Park et al., 2012; Wang et al., 2016).

The design of a CMM can range from very general to highly specified. Over the past three decades, numerous standardized models have been developed, and these ready-made models are generally adopted by businesses, whereas tailored models have been created for specific applications. Wendler (2012) presents a systematic mapping study of 237 articles, showing that current research into maturity models at the time was applicable to more than 20 domains, heavily dominated by software development and software engineering.

Branch-specific models exist as well, for example, Pigosso, Rosenfeld & Seliger (2011) analyze the Ecodesign Maturity Model (EcoM2), which was developed to support manufacturing companies in the field of ecodesign with the adoption of environmental legislation into product requirements. This model was created based on the findings that the majority of companies in the field still present a non-systematic and ad hoc approach, and that many were eager for a formalized, comprehensive method for measuring their maturity throughout the innovation process (Pigosso et al., 2011).

Leading global consultancy KPMG devised a blockchain maturity model based upon eight areas of identified risk, which could influence the rate of blockchain adoption. For example, the risk area “data management” contains multiple risks, and for each of these a number of controls have been defined to allow KPMG to assess the user’s maturity on the specific risk. This can be seen a consultancy tool for risk management (KPMG, 2017).

Wang et al. (2016) provide a maturity model for blockchain technology, identifying these fourteen areas of risk to be managed across five stages of maturity: (1) network load, (2) reliability, (3) architecture, (4) upgrading, (5) integration, (6) maintenance, (7) storage, (8) scalability, (9) business efficiency, (10) standardization, (11) computational complexity, (12) privacy, (13) data security, (14) transaction security. Additionally, the authors apply four indicators of technology maturity, as defined by the Association for Computing Machinery’s ACM Computing Classification System: (1) networks, (2) information systems, (3) computing methodologies, and (4) security and privacy. Each risk area is assigned a lower or higher level of maturity, displaying their assessment of the state of blockchain maturity at the time of the study.

The authors conclude that their model serves as a guide for more systematic decision-making regarding blockchain adoption. An assessment of the current state of the product (i.e. blockchain application) by an organization is necessary prior to adoption into a strategic plan.

However, despite the emerging importance of blockchain maturity and accessibility, the authors recognize that little research into assessing blockchain maturity has been covered in previous literature (Wang et al., 2016). They argue for the importance of measuring maturity, because, if you can't measure it, you can't manage it (Park et al., 2012).

2.2.4.7 Integrated model (TAM & DOI)

Two examples from the literature employ the methodology of merging the TAM and DOI models. In both cases, the research models hold that the five innovative characteristics (compatibility, complexity, relative advantage, trialability and observability) exert an important effect on the users' perceived use (PU), perceived ease of use (PEU) and intention to use technological innovations (Lee et al., 2011; Lou & Li, 2017). These significant innovation characteristics are a key aspect of DOI. Compatibility refers to the degree to which innovation is regarded as being consistent with the potential end-users' existing values, prior experiences, and needs. Complexity is the end-users' perceived level of difficulty in understanding innovations and their ease of use. Relative advantage is defined as the degree to which an innovation is considered as being better than the idea it replaced. This construct is found to be one of the best predictors of the adoption of an innovation. Trialability refers to the degree to which innovations can be tested on a limited basis. Observability is the degree to which the results of innovations can be visible by other people (Lou & Li, 2017).

Lee et al. (2011) advanced the integrated TAM and DOI model for the purpose of supporting employee's intentions to use e-learning systems. Lou and Li (2017) suggest an integrated TAM and DOI model in assessing the adoption of blockchain technology from the business manager's perspective. Their research aims to deliver and test a unified framework for investigating the continual process of blockchain technology adoption.

For their integrated model, Lou and Li take three of the five significant characteristics of innovation from DOI – compatibility (CPT), relative advantage (RAD), and complexity (CPX) – and merge these with the two TAM measures perceived usefulness (PU) and perceived ease of use (PEU) in order to assess attitudes (A), behavioral intentions (BI) and actual use (USE) involved with adopting blockchain technology (see Figure 6).

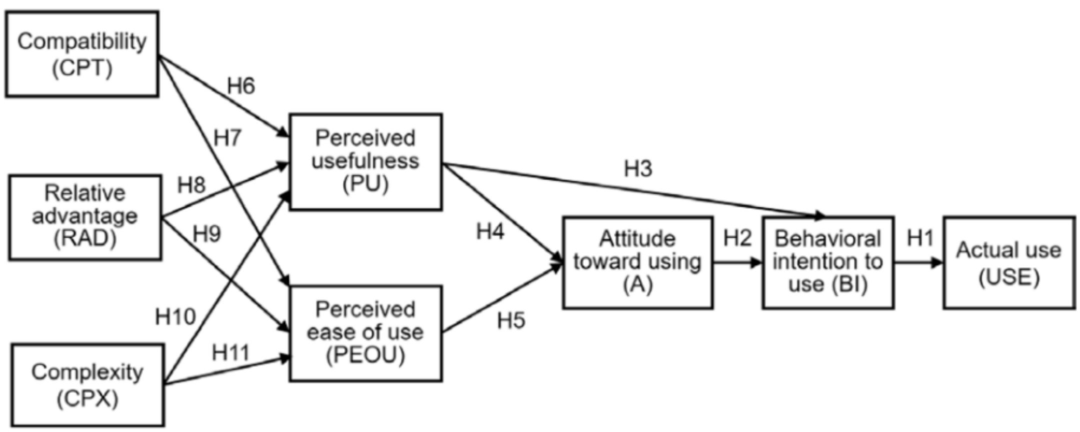

Figure 6: Example of integrated TAM and DOI model (Lou & Li, 2017)

This model yields eleven hypotheses about how the characteristics of innovation influence the acceptance metrics, which, in turn, influence attitudes and behavioral intentions and, finally, the actual use of blockchain technology. These hypotheses will be tested against the results of an industry survey in further research. The authors will collect data via a non-random sample of blockchain users across all industries in Taiwan, using a survey questionnaire based upon a five-point Likert-type scale, ranging from "strongly disagree" (1) to "strongly agree" (5). The questionnaire serves to operationalize the TAM and DOI constructs included in the proposed model (see Figure 6).

Based upon this example, I suggest that TAM, as a stable, decision-based model, could also be combined with a process-based model, such as CMM, in order to better assess and manage blockchain technology-related risks over time. The merger of TAM with CMM into a comprehensive model is further discussed in Chapter 3.

2.2.5 Research gaps

As discussed in the previous literature review (Section 2.1), the novelty of blockchain technology gives way to a breadth of gaps in current research. Specific to the context of adoption, three gaps can be highlighted.

A general lack of focused research into "sustainable blockchain adoption" was identified again, as with the prior literature review. This becomes apparent through initial keyword searches. A lack of research is observable, as well as a lack of documentation of adoption models applied to specific blockchain projects. Thus, there is a gap in content to support the sustainable adoption and use of blockchain technology (Burg et al, 2018; Vota, 2018).

Secondly, there appears to be potential for more focused studies in the area of adoption models as methods for risk management, particularly in the context of blockchain technology. This research gap could be closed with further research to identify existing models, which could best contribute to a universally applicable framework for risk management of blockchain technology. In this context, methods could be defined and customized for measuring levels of general perceived risk and individual, application-based risks surrounding blockchain.

A third gap identified within the scope of this review is the lack of applied studies that focus on integrated, comprehensive adoption models. While I could locate some studies on models combining TAM with DOI (Lee, et al., 2011; Lou & Li, 2017), or comparing TAM against the theory of planned behavior (TPB) (Mathieson, 1991), further research and development initiatives could support the active testing of these integrated models, for example with various blockchain use cases. Further investigation of work like Lou & Li's (2017) analysis of the Taiwanese blockchain market is needed. Additional studies like this could provide insight into integrated adoption models, which extend the analysis of behavioral factors influencing acceptance, or process-related factors influencing maturity.

Closing these research gaps would account for great advances in navigating the novelty and complexity, which characterize blockchain.

2.2.6 Discussion and outlook

As a conclusion, concentrated research into the methodology of merging models could be beneficial for a better understanding of acceptance and maturity as key aspects of the adoption process. I propose that by applying, combining and optimizing existing models, new value can be created for the management of blockchain-related risks.

With the first literature review, I suggest next steps toward establishing a normative risk management framework, along with integrated guidelines for managing risks across the entire adoption process.

With this second literature review, I suggest concrete next steps toward establishing a customized adoption model, which combine behavioral factors (acceptance) with process-related factors (maturity). As a concrete outlook, such an integrated, tested adoption model could help with managing risks from the perspectives of acceptance and maturity, as this holistic approach is strongly related to the sustainable adoption and use of blockchain technology.

As blockchain technology requires transformation at the systemic level, further research into customized adoption models could be beneficial for businesses and users across industries and use cases.

I observe a gap in comprehensive scholarship and holistic management methods in the area blockchain-related risks. Therefore, I advance that true challenges and opportunities lie in the establishment of a customized adoption model for managing these risks. Additional primary research is needed in order to construct and test a robust model for the simultaneous management of risks and adoption in the context of blockchain technology. Chapters 3 and 4 of this paper further explain how this could be approached and solved.

3 Integration and customization of TAM and CMM models to manage blockchain related risks

3.1 Introduction

As discussed in Chapters 1 and 2, advocates of blockchain technology see great promise for transforming businesses towards a decentralized and transparent system, as well as numerous benefits associated with this shift. This development has, thus far, been characterized by various, disparate methods and models for adopting blockchain technologies in a sustainable way.

The high failure rates, which have been reported for young blockchain projects (Vota, 2018; Deshwali, 2019; James, 2018), could perhaps be attributed to the lack of available, tested, integrated models, which pave the path to higher levels of market maturity. It can be assumed in this early phase, that the transformation efforts toward decentralized business and economy are not yet matured, and that the terminology and taxonomy of standardized risk parameters and mindset changes needed for designing this transformation have not yet been defined and tested sufficiently.

Therefore, it is critical to consider risk management as a cornerstone of the blockchain adoption process, and a central aspect of transformation design for a decentralized economy. Research contributions into risk management are scarce, and an easy-to-apply framework for managing blockchain-related risks has yet to emerge.

As discussed above, the two dimensions that characterize these risks are novelty and complexity (Iansiti & Lakhani, 2017). The relatively high degree of novelty and complexity inherent to blockchain calls for a risk management framework, which provides a context for the sustainable adoption and use of this technology. Adoption is the extent by which a given technology becomes accepted and incorporated into approved business practices (Cuofano, n.d.). As defined in Section 2.2, I work with acceptance and maturity as two key expressions of technology adoption. In order to work with these expressions simultaneously, I have merged two models, taking an integrative approach to acceptance and maturity level management as a methodology that supports the sustainable usage of blockchain technology.

3.2 Solution: Integrating TAM and CMM models

Based on the analysis and systematic literature review in Chapters 1 and 2, I chose to integrate and customize two well-established, commonly used adoption models, which could potentially provide the solution for applying blockchain technology in a sustainable way: the technology acceptance model (TAM) and the capability maturity model (CMM). The motivation for integrating these models are the following benefits and the unique value proposition, which result from merging TAM and CMM: (1) simultaneously analyzing and managing the adoption dimensions of novelty and complexity; (2) simultaneously analyzing and managing acceptance and maturity as expression of those dimensions; (3) analyzing and managing risks related to each expression throughout the entire transformation process - beginning with early awareness and continuing on to the final optimization phase.

TAM measures the extent by which a technology becomes accepted, and CMM measures the extent by which a technology is incorporated into approved business practices. Referring back to the definitions presented in Section 2.2.3, acceptance is a favorable decision for the use of any product or process, based upon behavioral factors (Rathore & Panwar, 2015), and maturity refers to the stages of evolution toward full operationalization of technological processes (Goksen, 2015).

To qualify my decision for these two models, I will highlight the function and benefits of both TAM and CMM and demonstrate their beneficial relationship for a sustainable blockchain adoption process.

TAM is structured around parameters of human behavior, as they influence technology acceptance. This model deals with factors of motivation and serves as a method for identifying to what extent users will decide for or against a novel technology.

Thus, this model relates to the dimension of novelty, which characterizes blockchain. The more novel a technology, the more effort is required to ensure that users understand what problems it solves (Iansiti & Lakhani, 2017) and, thus, decide to use it or not.

TAM was established by Davis in 1989 and derives from a fundamental theory of attitudes and behavior known as the theory of reasoned action (TRA), which was developed in 1967. This theory suggests that a person's behavioral intentions will depend on his or her attitudes and subjective norms. This key theory took a wide lens to predict any human behavior by considering many determinants for behavioral intentions. TAM narrowed the focus down to the acceptance of technology and reduced the model to two parameters: perceived usefulness (PU) and perceived ease of use (PEU). As a value, PU describes how useful users find any technology to be. PEU values describe users' perception of how easy a technology is to work with, or to use. Both PU and PEU can be influenced by any number of external factors, such as experience, beliefs, job relevance, or image. The degrees of PU and PEU, in turn, influence users' attitudes toward the technology and their behavioral intention or "intention to use" (IU). IU values indicate the degree to which users will likely decide for or against the use of a technological system, and this is a key output of the TAM model. The active system in use (ASU) describes the real use of the technology.

TAM has been customized and extended numerous times, for example with Davis' later expression, the motivational model (MM) from 1992, which defines two types of motivation to adopt and use a technology. MM defines extrinsic motivation in terms of "perceived usefulness" and intrinsic motivation in terms of "perceived enjoyment", pairing these to conclude that levels of enjoyment increase with the perception that a system is useful. I mention this example to show how TAM can be extended to include further human behavioral factors and, in doing so, to extend the understanding of 'acceptance'. In my customized model, I also extend the parameters for assessing acceptance. In addition to perceived usefulness (PU), perceived ease of use (PEU) and intention to use (IU), the customized model also includes active in use (ASU), level of knowledge (LK) and perceived risk (PR) (see Section 3.3). While this model is very useful for understanding users' motivation and behavior, TAM is not a process-based model, as it does not show the development of these acceptance parameters over time.

CMM, on the other hand, is a dynamic, process-oriented model that can be used to measure a user's (company's) current maturity level with any technology in a meaningful way. Maturity models are mostly organized across five maturity levels: (1) initial, (2) repeatable, (3) defined, (4) measured, (5) optimizing (Goksen, 2015). A CMM can be used to help manage the dimension of complexity, which characterizes a blockchain ecosystem. With this model, the levels of maturity can be tracked for all parties involved in the network.

CMM was first developed in the mid-1980s by the Software Engineering Institute (SEI) at Carnegie Mellon University. While it appears that maturity models are applied to numerous fields, the predominant usage is seen in IS and IT contexts (Wendler, 2012). For the purposes of this research, I take Wendler's definition of maturity as the degree to which any novel aspect of a business or organization has been adopted and applied. I understand the 'maturity level' as the stage of evolution toward full operationalization of technological processes (Goksen, 2015). These levels have been defined in numerous ways with the wealth of branch-specific maturity models in existence. Regardless of how the levels are named, the aim of maturity models is to quantify the activities carried out, make them measurable and develop them across these levels (Park et al., 2012; Wang et al., 2016). With my customized model, I extended and defined the following seven levels to assess maturity: awareness, knowledge, initiation, implementation, standardization, scale, optimization (see Section 3.3).

3.3 TAM and CMM framework design

In this section, I will describe the customized framework for the new, integrated adoption model as shown in Figure 7. Both individual models have been extended from the originally developed TAM and CMM, which are discussed above and in further detail in Sections 2.2.4.5 and 2.2.4.6, respectively.

CMM = capability maturity level

TAM - Technology acceptance model

	Awareness = level 1	Knowledge = level 2	Initiation = level 3	Implementation = level 4	Standardization = level 5	Scale = level 6	Optimization = level 7
Level of knowledge = LK							
Perceived usefulness = PU							
Perceived risk = PR							
Perceived ease of use = PEU							
Intention to use = IU							
Active system use = ASU							

Figure 7: TAM and CMM. Customized, integrated adoption model to manage risks for blockchain adoption and sustainable use

The TAM parameters shown on the y-axis have been extended from the original model to include a total of six parameters. Beginning from top to bottom, the following definitions apply for technology acceptance. "Level of knowledge" (LK) refers to how aware users are of the technology in question. Some degree of knowledge about a technological system can be understood as a prerequisite to acceptance. "Perceived usefulness" (PU) is a factor of motivation to accept and use a technology. As explained in Section 3.2, if users do not perceive a technology as useful, they are unlikely to accept and use it. “Perceived risk” (PR) is the level of subjective uncertainty among users when deciding whether to accept a technology. The possibility that the technology will not live up to users’ expectations is represented by PR. “Perceived ease of use” (PEU) is also a crucial factor influencing sustainable acceptance and use of a technology. Any system must be perceived as easy-to-use, or it is less likely to be accepted by users. Whereas PU deals with a technology’s usefulness or relevance, PEU is a measure of how operable or easy a technology is perceived to be. “Intention to use” (IU) refers to the degree of concrete future plans to use a technology. This indicates a clear intention and a relatively advanced stage of acceptance. “Active system use” (ASU) refers to the technology or aspect of the technology, which is currently in use. This is an indicator of the actual level of acceptance. If a system is active in use, it has already been accepted.

With the CMM, I have customized and extended the model to define the seven levels of maturity shown along the x-axis: (1) awareness, (2) knowledge, (3) initiation, (4) implementation, (5) standardization, (6) scale, and (7) optimization. As each subsequent level is reached, each of the acceptance factors will be influenced, e.g., IU can be more precisely defined as we move from awareness to knowledge; PR can be newly measured as we mature from knowledge to initiation projects. The individual levels can be defined as follows.

Awareness is an indicator of having heard about the technology; the level of awareness increases when a specific technology becomes more widely diffused. Knowledge of a technology goes beyond awareness and indicates that a potential user has invested in understanding and learning about the system in question. As knowledge of a system is gained, risks can be more precisely defined, and values of PU, PEU and PR become more precise and relevant. This precision is needed to reach the next level of maturity. Initiation refers to projects which initiate the transformation process by introducing the novel technology into existent business operations.

Implementation is the process of making something active or effective. At this level of maturity, real transformation begins in terms of changing operations, working processes and habits and behaviors of all parties involved. Once a project has been implemented, these changes and new operations can be tested, and new standards can be defined. Standardization is the next maturity level, at which these the once novel technology moves beyond the project stages to become a new standard. The highest level of maturity with this model is optimization. At this point, a technology adoption is matured, and processes of improvement can be carried out to increase functionality or effectiveness.

The following Tables 9 and 10 highlight the parameters and levels, which have been added for this customized model.

Table 9: TAM parameter extensions

Extensions to TAM model	**Relevance for integrated TAM and CMM model**
Level of knowledge (LK)	Shows share of awareness and knowledge about technology. Signifies how much facilitating activity is needed to become familiar with the technology
Perceived risk (PR)	Shows levels of uncertainty and risk

Here, the TAM model was extended to include the parameters LK, and PR. I added these in order to provide a more complete picture of acceptance, taking early stages of awareness (LK) into consideration along with the subjective uncertainty (PR) surrounding the technology in question.

"Level of knowledge" (LK) has been added as a parameter for assessing acceptance because this is an important signifier of how much users already know about the technology and, in turn, how much facilitating activity is needed to bring awareness of the technology's value. "Perceived risk" (PR) is a risk value based upon uncertainty of the outcomes of deciding for or against the technology in question. Business leaders and users have several goals or expectations when accepting a novel technology, and the possibility of these goals and expectations not being met is represented by a degree of perceived risk. Several types of perceived risk can be involved in technology acceptance, for instance, financial risk, performance risk, physical risk, psychological risk, social risk, or convenience risk (Li & Huang, 2009). Due to the general nature of PR, it is difficult to gain data to measure this risk value by means of a survey. However, I have applied a statistical formula to this integrated model, which allows for aggregating values of perceived risk across industries. For this reason, PR is a significant parameter for risk management, as technology designers and all agents of transformation design can predict levels of readiness or resistance among technology users. This statistical formula and method for analysis is further discussed in Chapter 4.

Table 10 shows the extensions to the maturity model's parameters. I added the levels of "awareness" and "knowledge" as the two initial phases.

Table 10: CMM parameter extensions

Extensions to CMM model	Relevance for integrated TAM and CMM model
Awareness (level 1)	Awareness of a technology is a key prerequisite for adoption
Knowledge (level 2)	The degree of knowledge about a technology influences adoption rate

I have extended the model to include these levels of maturity in order to create space for processes that take place prior to initiating a novel technology project within business operations. For example, risks parameters should be identified prior to initiation.

The design and customization of this adoption model is based on principles of transformation design for a decentralized economy, and the role that risk plays in this process. I advance that this customized adoption model could have unique value for risk management as a solution for the sustainable usage of blockchain technology. Furthermore, as the main objective of this thesis, the design of the model should serve two aims: 1) to aid companies with risk management across the entire process of business transformation, at the individual, company level and 2) to estimate risk levels across industries at the broader, market level. Both aims deal with risk management for blockchain-driven business transformation and the necessary shift from a centralized to a decentralized system when implementing blockchain technology. This model should be understood as a possible solution to sustainably meet these objectives. Chapter 4 presents the results of testing this model based on five research questions and their related hypotheses.

4 Testing the customized adoption model with 125 business executives across 20 industries

After identifying risk management as the problem for adoption and sustainable usage of blockchain technology, I explored various opportunities to solve the issue of risk management by means of applying adoption models, which deal with technology acceptance and maturity as the two key expressions of adoption. I have customized two models in order to present a solution, which takes an integrated approach to managing acceptance and maturity simultaneously. The focus of this chapter is the results of testing this solution through primary research. A survey was conducted with 125 business executives, representing 20 industries, and the results yielded a descriptive and empirical analysis of the functionality of this adoption model.

4.1 Research design

In order to test the merger of the technology acceptance model (TAM) and the capability maturity model (CMM), I designed an online questionnaire with 35 questions.

4.1.1 Survey framework

The survey is an online survey, which consists of 21 predefined, closed-ended questions, 8 Likert scale-type closed-ended questions, and 6 open-ended questions: a total of 35. With this uniquely designed survey framework, I have analyzed the following parameters for TAM (Table 11) and CMM (Table 12):

Table 11: Parameters of Technology Acceptance Model (TAM)

Parameter	Abbreviation
Perceived usefulness	PU
Perceived ease of use	PEU
Level of knowledge	LK
Perceived risk	PR
Intention to use	IU
Active system use	ASU

Perceived risk (PR) was not explicitly surveyed at this stage. Level of knowledge (LK) has been added as an additional parameter to the original TAM model (see Section 3.3).

Table 12: Parameters for Capability Maturity Model (CMM)

Parameter	Abbreviation
Awareness	1
Knowledge	2
Initiation	3
Implementation	4
Standardization	5
Scale	6
Optimization	7

Awareness and knowledge have been added as parameters to the original capability maturity model (see Section 3.3).

These sets of parameters from their respective models were then merged into the following customized, integrated model. Each of the TAM and CMM parameters were mapped into the survey questions, as visualized in Table 12. The survey questions (Q) are listed by number within the matrix, illustrating which levels of acceptance and maturity are simultaneously investigated with each question, as seen here in Figure 8.

CMM = capability maturity level

TAM - Technology acceptance model	Awareness = level 1	Knowledge = level 2	Initiation = level 3	Implementation = level 4	Standardization = level 5	Scale = level 6	Optimization = level 7
Level of knowledge = LK	Q 6, 7, 8	Q 11, 12	Q 11, 12, 16	Q 11, 12, 20	Q 11, 12, 24	Q 11, 12, 28	Q 11, 12, 32
Perceived usefulness = PU	Q 10	Q 13	Q 13, 16	Q 13, 20	Q 13, 24	Q 13, 28	Q 13, 32
Perceived risk = PR							
Perceived ease of use = PEU	Q 9	Q 14, 15	Q 17, 18	Q 21, 22	Q 25, 26	Q 29, 30	Q 33, 34
Intention to use = IU			Q 19	Q 23	Q 27	Q 31	Q 35
Active system use = ASU			Q 16	Q 20	Q 24	Q 28	Q 32

Figure 8: Customized framework: Integrated TAM and CMM model, related survey questions

To follow the overarching goal of this survey, questions were designed in a way that responses could indicate the levels of these acceptance and maturity parameters. In this way, it is possible to identify how ready and equipped business leaders are to apply blockchain technology for business transformation. The central question pursued is: Are business leaders knowledgeable enough - with regards to awareness, perceived usefulness, perceived ease of use, intention to use and active use - to use blockchain technology across these different maturity levels?

4.1.2 Research questions and hypotheses

To direct the line of questioning in the survey, I defined the following 4 research questions (RQ) and 5 hypotheses (H). With the third research question, 2 different hypotheses were defined, each addressing different aspects of acceptance and maturity.

RQ1: Which blockchain acceptance and maturity levels do executive business leaders have across different industries and company sizes, in terms of awareness, knowledge and created value?
H1: Executives are knowledgeable of blockchain technology and its value in terms of perceived usefulness (PU).

RQ2: Do executive business leaders use a methodology, which enables them to apply blockchain technology in an easy way across different capability maturity levels?
H2: Executive business leaders are knowledgeable of blockchain technology and its value in terms of perceived ease of use (PEU).

RQ3: Do executive business leaders use a comprehensive methodology, which enables them to initiate and implement blockchain technology in an easy way?
H3: Executive business leaders are eager to apply a comprehensive, easy to use methodology to initiate blockchain-enabled services for their business.

H4: Executive business leaders are eager to apply a comprehensive, easy to use methodology to implement blockchain-enabled services for their business.

RQ4: What is the risk measure across industries, which arises by not using an integrated adoption model with respect to TAM and CMM when applying blockchain technology?
H5: Will be defined in Chapter 4.3.2

4.2 Survey description

The format is an online survey. The survey is comprised of a total of 35 questions – 21 predefined, closed-ended questions, 8 Likert scale-type closed-ended questions, and 6 open-ended questions, as outlined below in Table 13. With the survey, I approach the question of whether business leaders are knowledgeable enough - in term of awareness, perceived usefulness, perceived ease of use, intention to use and active use - to apply blockchain technology across the different maturity levels. I also investigate the demand for methodologies to aid in applying blockchain. This demand could represent the added value of a comprehensive framework for risk management for the sustainable use of blockchain technology.

Table 13: List of all survey questions

Question number	Question
Q1	What is your name?
Q2	Which company are you working for?
Q3	What is your position/role in your company?
Q4	Which size is your company?
Q5	Which industry does your company belong to?
Q6	Have you heard about blockchain technology?
Q7	When did you hear first about blockchain technology?
Q8	In which context did you hear about blockchain technology?
Q9	Are you aware of a comprehensive, structured methodology that could help you apply blockchain technology for your business?
Q10	Are you aware of which value blockchain technology could create for your business?
Q11	Do you know what blockchain is and how it functions?
Q12	How good is your knowledge about blockchain technology?
Q13	Which value can you create for your business with blockchain technology?
Q14	Is your company actively using a comprehensive, structured methodology that helps you apply blockchain technology for your business?
Q15	How satisfied are you with the methodology your company is using to apply blockchain technology?
Q16	Do you have any blockchain initiatives in your company?
Q17	Do you apply a comprehensive, structured methodology when initiating a blockchain project in your company?
Q18	How satisfied are you with the methodology you are applying to initiate a blockchain project in your company?
Q19	Are you planning any blockchain initiatives in your company in the next 12 months?
Q20	Do you have any blockchain implementation projects in your company?
Q21	Do you apply a comprehensive, structured methodology when implementing a blockchain project in your company?
Q22	How satisfied are you with the methodology you are applying to implement a blockchain project in your company?
Q23	Are you planning any blockchain implementation projects in your company in the next 12 months?
Q24	Do you offer standardized products and/or services based on blockchain technology in your company?
Q25	Do you apply a comprehensive, structured methodology to standardize blockchain products and/or services in your company?

Q26	How satisfied are you with the methodology you are applying to standardize blockchain products and/or services in your company?
Q27	Are you planning to standardize blockchain products and/or services in your company in the next 12 months?
Q28	Do you scale standardized blockchain products and/or services in your company?
Q29	Do you apply a comprehensive, structured methodology to scale standardized blockchain products and/services in your company?
Q30	How satisfied are you with the methodology you are applying to scale standardized blockchain products and/or services in your company?
Q31	Are you planning to scale standardized blockchain products and/or services in your company in the next 12 months?
Q32	Do you optimize standardized and scaled blockchain products and/or services in your company?
Q33	Do you apply a comprehensive, structured methodology to optimize standardized and scaled blockchain products and/services in your company?
Q34	How satisfied are you with the methodology you are applying to optimize standardized and scaled blockchain products and/or services in your company?
Q35	Are you planning to optimize standardized and scaled blockchain products and/or services in your company in the next 12 months?

4.2.1 Interviewees

The 125 survey participants represent a sampling from small, medium and large businesses, 6 levels of executive positions and 20 industries. None of the companies represented are direct blockchain startups, as this would represent a different perspective of acceptance and maturity with the technology. It was highly important that the survey results stem from executive level, key decision- makers and business leaders within the industries represented. While identifying and acquiring 125 executives to participate in the survey proved to be quite challenging, I was successful in activating personal, established contacts, gaining recommendations and also initiating new contact to executives identified via LinkedIn and other online research. The executive survey participants represent large enterprises, medium and small businesses, and startups. It should be noted, that no two survey participants represent the same company. The rate of completion was very high, as only 2 additional participants did not complete the survey. From

127 invited, 125 participants responded to all questions, which were applicable to their respective companies' experience with blockchain technology.

Table 14 shows the shares of survey participants according to three categories of company size.

Table 14: Survey question 4: "What is the size of your company?"

Company size	Number of survey respondents	Share of survey respondents
Small businesses (1-99 employees)	48	38.4%
Medium businesses (100-999 employees)	31	24.8%
Large businesses (1,000+ employees)	46	36.8%

Note. (Survey n=125 March 2018-July 2019)

Small businesses with 1-99 employees represent the majority with 48 respondents and 38.4% of the survey shares. Large businesses with 1,000+ employees account for 46 respondents and 36.8%, and 31 respondents represent medium businesses with 100-999 employees, making up 24.8%.

Table 15 shows the breakdown of the 125 respondents according to six levels of management positions, shown according to corporate hierarchy.

Table 15: Survey question 3: "What is your position in your company?"

Position	Number of survey respondents	Share of survey respondents
C-level	47	37.6%
Managing Director	13	10.4%
Senior + Vice President	8	6.4%
Director	25	20%
Head of department	14	11.2%
Senior manager	18	14.4%

Note. (Survey n=125. March 2018-July 2019)

47 C-level respondents make up the majority with 37.6% of the survey share; 13 managing directors make up for 10.4%; 8 senior and vice presidents make up 6.4%; 25 directors account for 20%; 14 heads of department make up 11.2%; 18 senior managers account for 14.4% of survey respondents.

4.2.2 Industries

The survey provides a sampling of 125 different companies across 20 industries, excluding the blockchain startup industry. These industries include blockchain use case-relevant fields such as retail, logistics, consulting, healthcare, e-commerce, finance, advertising, marketing, media, fashion and travel & transportation. Table 16 shows the shares of respondents according to the 20 industries represented in the survey.

Table 16: Survey question 5: "Which industry does your company belong to?"

Industry	Number of respondents	Share of survey respondents
Advertising	8	6,4%
Automotive	5	4,0%
Consulting	7	5,6%
E-commerce	6	4,8%
Education	7	5,6%
Fashion	4	3,2%
Finance	2	1,6%
FMCG	3	2,4%
Healthcare	5	4,0%
HR services	11	8,8%
IT	4	3,2%
Law	9	7,2%
Manufacturing	4	3,2%
Logistics	15	12,0%
Marketing	9	7,2%
Media	4	3,2%
Pharma	5	4,0%
Retail	7	5,6%
Software	6	4,8%
Travel & transportation	4	3,2%

Note. (Survey n=125 March 2018-July 2019)

4.2.3 Timeline

The survey was conducted between March 2018 and July 2019. Over the entire 16-month time frame, an average of 8 executives were interviewed per month. Thus, changes to awareness levels and to degrees of blockchain acceptance and maturity could be tracked over time.

4.3 Survey evaluation

This rest of this chapter presents both a descriptive analysis and an empirical analysis of the survey results. Firstly, each of the survey questions is analyzed in terms of the research questions 1-3 and their related hypotheses 1-4 in Chapter 4.3.1. These hypotheses were tested via the 35 survey questions and a Fisher test for proportions. Secondly, the empirical analysis, regarding risk measure across industries, presents the results of testing research question 4 and hypothesis 5 via a binomial test in Chapter 4.3.2.

4.3.1 Descriptive analysis

As mentioned, the survey questions investigate the levels of blockchain technology acceptance and the degree of maturity with the 125 companies represented in the survey. There is a general flow to the questions, moving across the various levels of maturity: awareness, knowledge, initiation, implementation, standardization, scaling and optimization. Further questions investigate the usage of methodologies for support at each of these maturity levels. Then, satisfaction levels are investigated for those respondents, who use such methodologies. Finally, questions are stated regarding future plans for reaching these maturity levels with blockchain technology.

The survey questions are designed to expand upon these 2 research questions as presented in Section 4.1.2 and further discussed in 4.3.2.

RQ1: Which blockchain acceptance and maturity levels do executive business leaders have across different industries and company sizes, in terms of awareness, knowledge and created value?

RQ2: Do executive business leaders use a comprehensive methodology, which enables them to apply blockchain technology in an easy way across different capability maturity levels?

The following survey results provide the data basis for further empirical analysis, as presented in Section 4.3.2.

Figure 9 shows the results of the question: “Have you heard of blockchain?” 91.2% of the survey participants responded positively, which translates to 114 respondents. 8.8% accounts for 11 respondents, who responded negatively. 2 respondents skipped this question, for whatever reason. This demonstrates that the strong majority is at least aware of the term ‘blockchain’. It can be assumed that the level of current awareness is high among these participants and the industries that they represent.

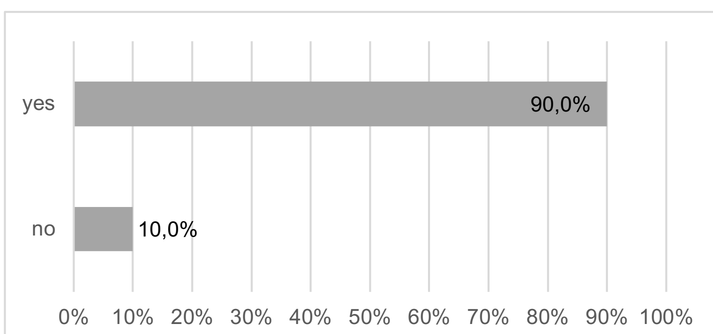

Figure 9: Survey question 6
“Have you heard of blockchain?”
Note. (N/total=125, N/Q6=125, March 2018-July 2019)

The next question describes the development of awareness over a three-year time period. Results of the question “When did you first hear about blockchain technology?” are shown in Figure 10.

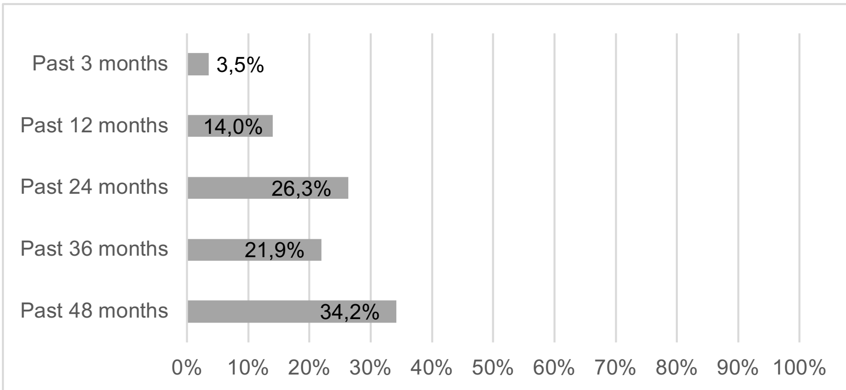

Figure 10: Survey question 7
“When did you first hear about blockchain technology?”
Note. (N/total=125, N/Q7=114, March 2018-July 2019)

34.2% have been aware of blockchain for at least 48 months, making up the majority with 39 respondents. 26.3% (30 respondents) have been aware of blockchain for 24 months. The next highest group of 21.9% (30 respondents) have become aware during the past 36 months, followed by 14% (16 respondents) in the past 12 months and 3.51% (4) during the past 3 months. 11 respondents skipped this question. As the initial blockchain hype peaked in 2017, it makes sense that the majority became aware of the technology at this time, i.e., up to two years prior to the time of survey.

The next survey question investigates the awareness of a comprehensive, structured methodology that could help with applying blockchain technology to business transformation.

Figure 11 shows that 69.3% (79 respondents) answered negatively: they are not aware of such a methodology. 30.7% (35 respondents) are aware, and 11 respondents skipped this question.

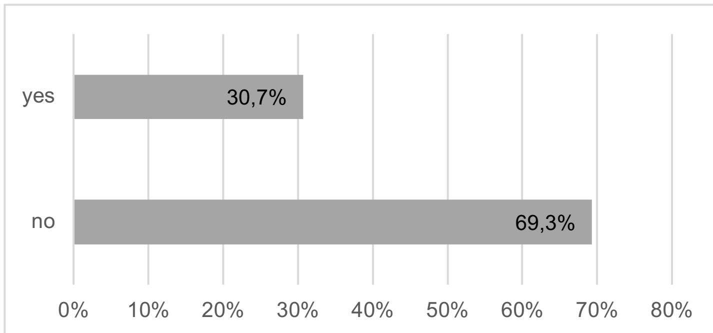

Figure 11: Survey question 9
"Are you aware of a comprehensive, structured methodology
that could help you apply blockchain technology for your business?"
Note. (N/total=125, N/Q9=114, March 2018-July 2019)

These results show a relatively low level of awareness of methodologies to assist with blockchain applications. This lack of awareness could be considered as a barrier to adoption, as a comprehensive, structured method for blockchain adoption could be a valuable tool for designing blockchain-driven business transformation. The relatively high novelty and complexity of blockchain technology speaks for the benefits of a structured method or model, which could aid in adopting and evolving to higher maturity levels with blockchain applications. This question serves to test the research hypotheses H3 and H4. The other survey questions into comprehensive, structured methodologies for initiating, implementing, optimizing and scaling blockchain projects test these hypotheses as well (see Section 4.3.2).

Staying with the topic of awareness, the next question investigates knowledge of the value blockchain technology could create for a business. Figure 12 shows that 57% (65 respondents) are aware of what value blockchain could create for their business. 42.9% (49 respondents) are not aware of potential value created, and 11 skipped this question.

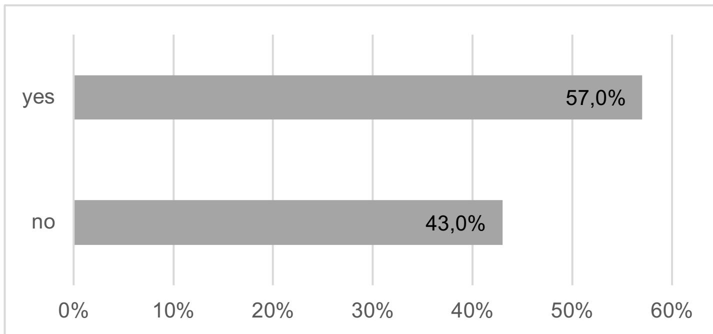

Figure 12: Survey question 10
"Are you aware of which value blockchain technology could create for your business?"
Note. (N/total=125, N/Q10=114, March 2018-July 2019)

An open-ended survey question then requested concrete input from respondents, as to which value dimensions they are aware of with blockchain. "Which value could blockchain technology create for your business?"

Figure 13 demonstrates the levels of knowledge of blockchain and its functionality. 83.5% (96 respondents) answered, yes, they know what blockchain is and how it functions. 16.5% (19) answered no to this question, and 10 skipped it. However, this does not reveal the degree to which respondents truly understand how this technology functions.

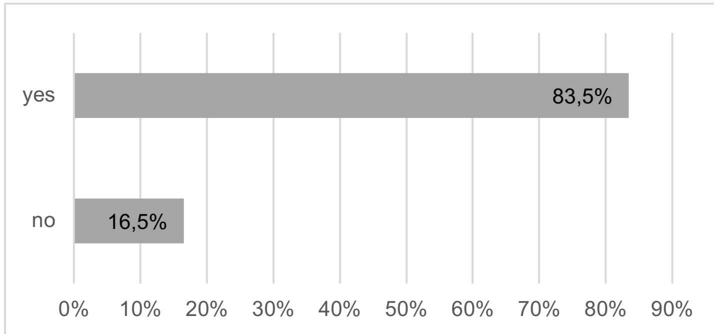

Figure 13: Survey question 11
"Do you know what blockchain technology is and how it functions?"
Note. (N/total=125, N/Q11=115, March 2018-July 2019)

This question of knowledge of blockchain and its functionality is further qualified in the next question with a 5-point Likert-type scale. Here, the survey goes a step beyond to investigate knowledge levels about this technology amongst respondents. As seen in Figure 14, 56.3% claim their blockchain knowledge is "somewhat" good, making up the strong majority with 54 respondents. The next largest group of 19.8% (19 respondents) have a "good" understanding; 15.6% (15 respondents) answered "not so good"; only 6.3% rate their understanding as "very good" (6 respondents); the minority of 4.2% respondents answered that their understanding is "not good at all" (4). It should be noted that almost a third of respondents (29) skipped this question, for whatever reason.

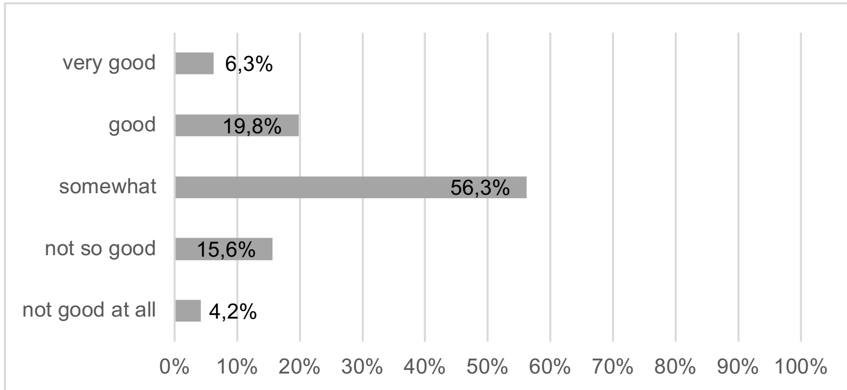

Figure 14: Survey question 12
"How good is your knowledge about blockchain technology?"
Note. (N/total=125, N/Q12=96, March 2018-July 2019)

These results point to a real demand for tools to harness this existent knowledge and to support further understanding, in order to lead to better adoption rates due to higher acceptance and maturity levels.

The next question emphasizes the vast potential for developing and introducing methods to support blockchain adoption. Figure 15 shows that with 92.6%, the majority of respondents (88) are not using a comprehensive, structured methodology for the application of blockchain within their business. This could mean, however, that they either use no methodology, or that they have no current blockchain applications. Only 7.4% (7 respondents) answered yes to this question, and 30 skipped it.

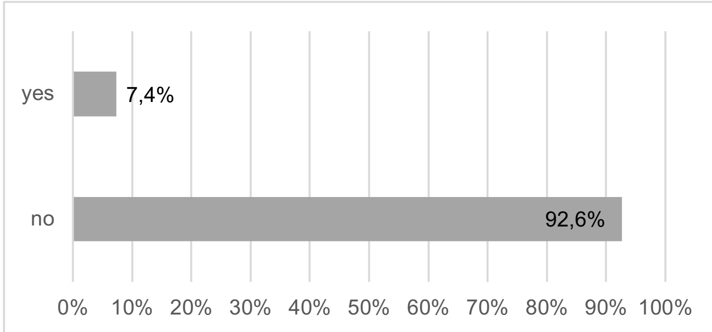

Figure 15: Survey question 14
"Is your company actively using a comprehensive, structured methodology that helps you apply blockchain technology for your business?"
Note. (N/total=125, N/Q14=95, March 2018-July 2019)

Considering the results shown in Figure 15, it becomes quite clear that such low levels for using methodologies could be due to very low levels of awareness. For the question "Are you aware of a comprehensive, structured methodology that could help you apply blockchain technology for your business?", 69.3% of respondents answered that they are unaware that any methods exist for supporting blockchain application. It would add value to the overall research to explore such results further. For example, which methods are utilized by this minority of companies shown here in Figure 15? Additionally, to what can the high numbers of skips be attributed?

From this minority of respondents, who confirmed that they do work with a methodology for aiding in blockchain applications, 6 responded to the next question of how satisfied they are with this methodology. As shown in Figure 16, 50% (3 respondents) claim they are "somewhat" satisfied with their methodology, and the other 50% claim they are "satisfied". No one selected the answers "very satisfied", "not so satisfied", or "not satisfied at all", and 119 skipped this question, as the majority already responded that they are not actively using any methodologies (see Figure 15).

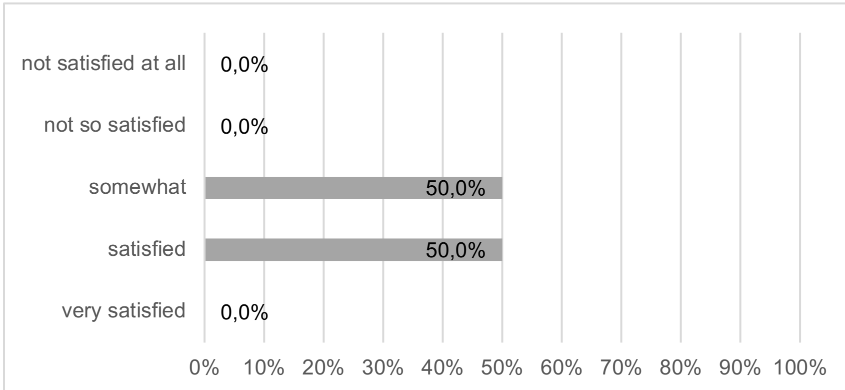

Figure 16: Survey question 15
"How satisfied are you with the methodology your company is using to apply blockchain technology for your business?"
Note. (N/total=125, N/Q15=6, March 2018-July 2019)

Figure 17 shows that only a minority of 20.7% (19 respondents) have active blockchain initiatives in their companies. The majority – 79.4% (73 respondents) – has no active initiatives. 33 respondents skipped this question.

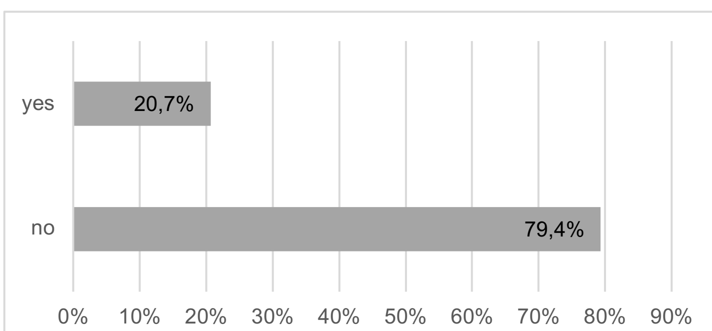

Figure 17: Survey question 16
"Do you have any active blockchain initiatives in your company?"
Note. (N/total=125, N/Q16=92, March 2018-July 2019)

The next question asks if companies are applying a comprehensive, structured methodology when initiating blockchain projects. Figure 18 shows that from the 19 respondents, who answered positively to having active blockchain initiatives in their companies, 10 state that they do not apply a methodology for the initiation of blockchain projects, representing 52.6% of the survey share. 9 respondents do apply methodologies to blockchain initiatives, representing 47.4%. The remaining 106 skipped the question, as the majority had no active blockchain initiatives at the time of the survey (see Figure 17).

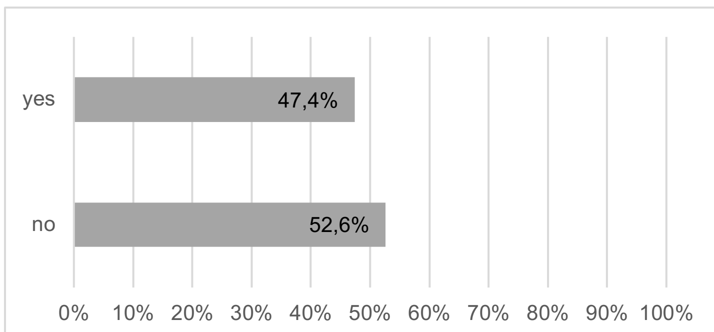

Figure 18: Survey question 17
"Do you apply a comprehensive, structured methodology when initiating a blockchain project in your company?"
Note. (N/total=125, N/Q17=19, March 2018-July 2019)

As Figure 19 shows, 66.7% are "somewhat" satisfied with the applied methodology for initiating blockchain projects (6 respondents). The other 44.4% (4 respondents) are "satisfied" with the applied methodology. No one selected the answers "very satisfied", "not so satisfied", or "not satisfied at all", and 116 skipped this question, as the majority already responded that they have no active blockchain initiatives (see Figure 17), or they are not applying any methodologies (see Figure 18).

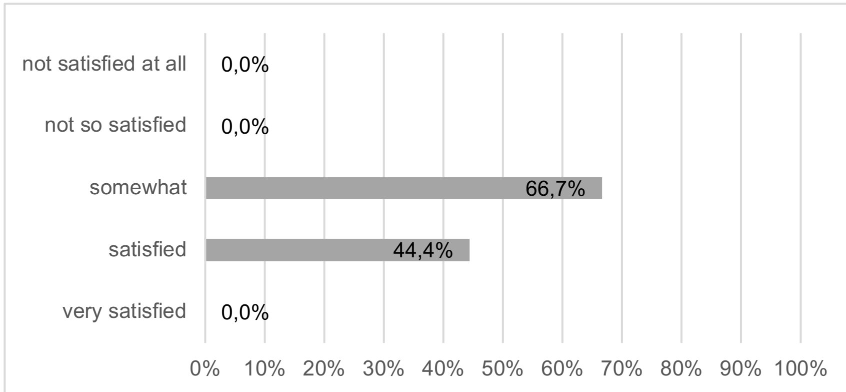

Figure 19: Survey question 18
"How satisfied are you with the methodology you are applying to initiate a blockchain project in your company?"
Note. (N/total=125, N/Q18=9, March 2018-July 2019)

The following question investigates future plans. Figure 20 shows that only 16.7% (12 respondents) are planning blockchain initiatives in their respective companies over the next 12 months, from the time of the survey. 83.3% (60 respondents) have no plans for blockchain initiatives within a year. 53 respondents skipped this question.

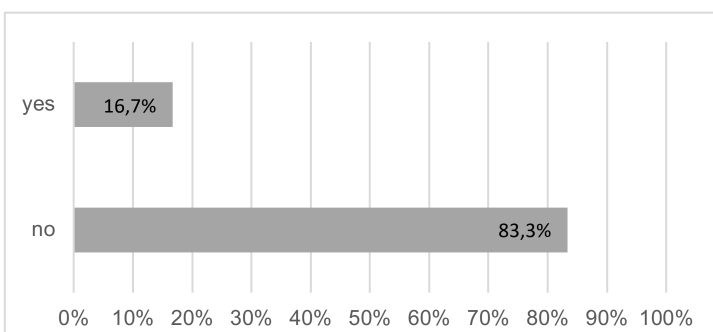

Figure 20: Survey question 19
"Are you planning any blockchain initiatives in your company in the next 12 months?"
Note. (N/total=125, N/Q19=72, March 2018-July 2019)

The next question investigates the rate of companies with active blockchain implementation projects at the time of survey. Figure 21 shows that 61.1% (11 respondents) replied "yes" – they have active blockchain implementation projects - and 38.9% (7 respondents) replied "no"- they have no current implementation projects. 107 respondents skipped this question.

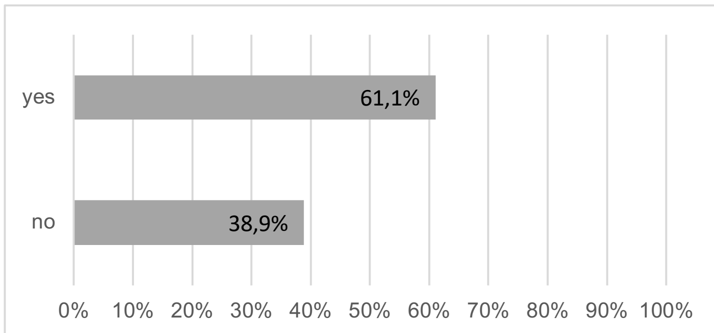

Figure 21: Survey question 20
"Do you have any active blockchain implementation projects in your company?"
Note. (N/total=125, N/Q20=18, March 2018-July 2019)

With Figure 21, the difference to question Figure 17 should be noted, and to the difference in rates of initiation projects versus implementation projects. The majority - 79.4% - has no blockchain initiatives, and only 20.7% do have initiatives. The perspective of the rate of active initiation projects (20.7%) versus the rate of implementation projects (61.1%) provides a key insight to the overall state of adoption and maturity levels.

Following the flow of questioning, from maturity level to use of methodologies at these respective maturity levels, Figure 22 shows the rate of using a methodology when implementing a blockchain project. 122 respondents skipped this question, as they likely have no blockchain implementation projects (see Figure 21), and 13 respondents answered. 61.5% (8) of them do not apply any comprehensive, structured methodology, and the remaining 38.5% (5) do apply a methodology.

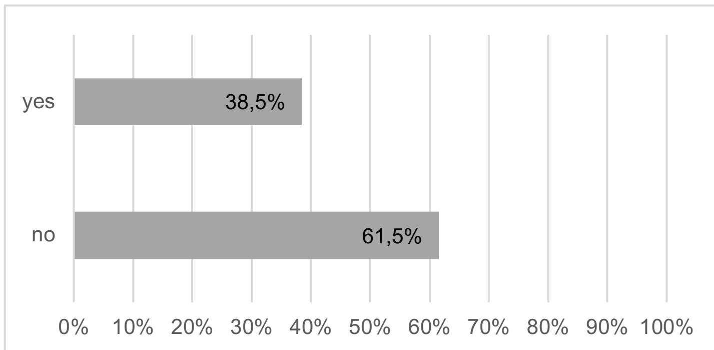

Figure 22: Survey question 21
"Do you apply a comprehensive, structured methodology when implementing a blockchain project in your company?"
Note. (N/total=125, N/Q21=13, March 2018-July 2019)

The next question goes further to investigate levels of satisfaction among users of methodologies for implementing blockchain projects. As seen in Figure 23, 50% (2 respondents) state that they are "somewhat" satisfied with the methodology applied. 75% of respondents (3) state that they are "satisfied" with the methodology applied. 120 respondents skipped this question, probably because they apply no methodology for implementing a blockchain project, or because they are not currently implementing any blockchain projects.

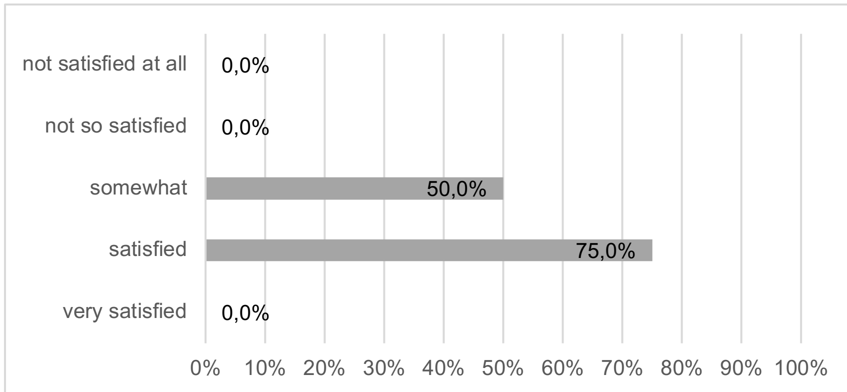

Figure 23: Survey question 22
"How satisfied are you with the methodology you are applying to implement a blockchain project in your company?"
Note. (N/total=125, N/Q22=5, March 2018-July 2019)

Next, Figure 24 shows results from a question of future plans for implementing blockchain projects within the next 12 months, from the time of survey. A total of 7 respondents replied, and 118 skipped this question, for whatever reason. 85.7% (6 respondents) say "yes" they have such plans, and 14.3% (1 respondent) replied with "no".

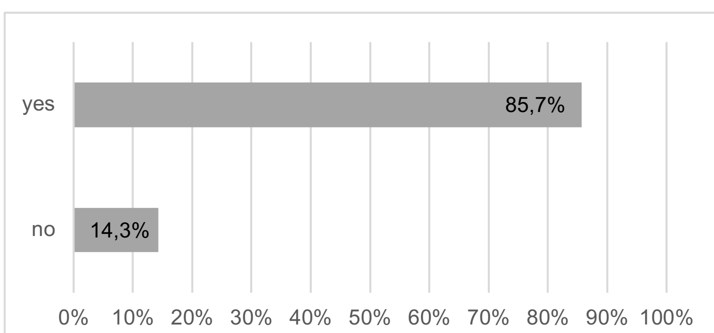

Figure 24: Survey question 23
"Are you planning any blockchain implementation projects in your company in the next 12 months?"
Note. (N/total=125, N/Q23=7, March 2018-July 2019)

The rate of companies that offer standardized, blockchain-based products and/or services is shown in Figure 25. Again, for the majority – 112 respondents – this question was irrelevant, as it can be assumed that these companies do not yet work with blockchain technology. 7.7% relates to 1 respondent, who stated that his or her company offers standardized blockchain-based products and/or services, whereas 92.3% (12 respondents) do not offer this.

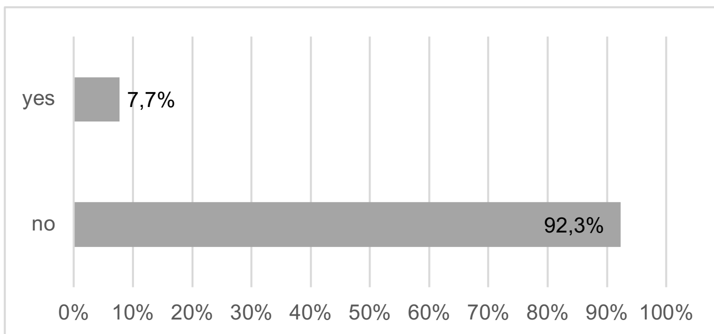

Figure 25: Survey question 24
"Do you offer standardized products and/or services based on blockchain technology in your company?"
Note. (N/total=125, N/Q24=13, March 2018-July 2019)

From the results shown in Figure 26, it can be assumed that the same 1 respondent answered positively regarding the use of a comprehensive, structured methodology to standardize blockchain products and/or services in your company?" The remaining 124 respondents skipped this question, as it is not applicable.

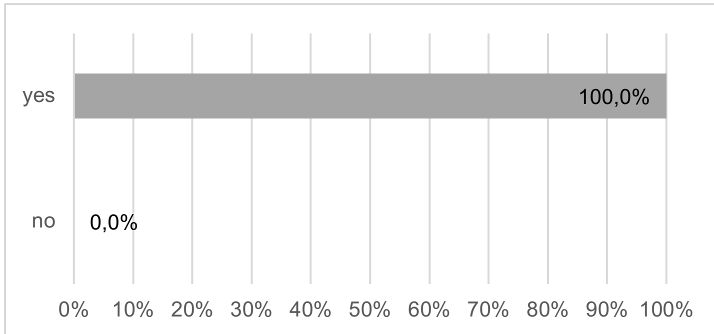

Figure 26: Survey question 25
“Do you apply a comprehensive, structured methodology to standardize blockchain products and/or services in your company?”
Note. (N/total=125, N/Q25=1, March 2018-July 2019)

Figure 27 also shows that 1 respondent’s company offers standardized blockchain products and/or services. He or she responded with “satisfied” regarding his or her opinion of the methodology his or her company applies to creating these offers. The remaining 124 respondents skipped this question, as it is not applicable.

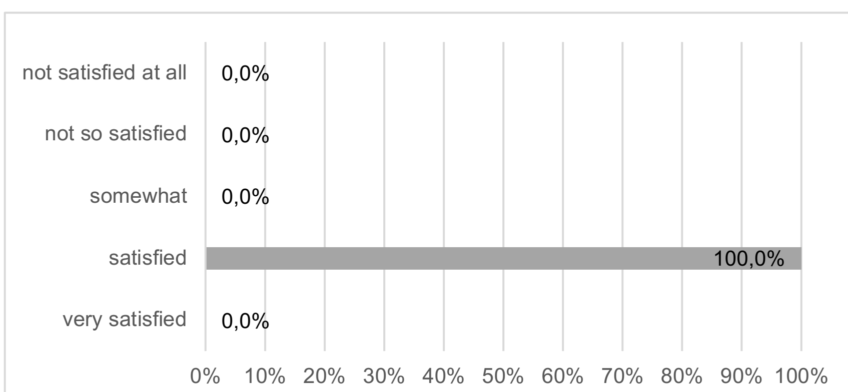

Figure 27: Survey question 26
“How satisfied are you with the methodology you are applying to standardize blockchain products and/or services in your company?”
Note. (N/total=125, N/Q26=1, March 2018-July 2019)

The next question also refers to future plans. Figure 28 shows the shares of respondents, whose companies plan to standardize blockchain products and/or services in the next 12 months, from the time of the survey. With 58.3%, 7 respondents state that their companies do not plan on this within a year. The other 41.7% (5 respondents) do have such plans for standardization of products/services. 113 skipped this question for whatever reason.

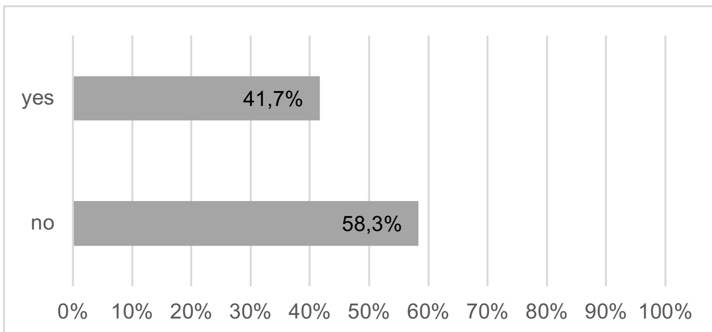

Figure 28: Survey question 27
"Are you planning to standardize blockchain products and/or services in your company in the next 12 months?"
Note. (N/total=125, N/Q27=12, March 2018-July 2019)

Scaling, as the next indicator of increasing maturity levels, is investigated with the next question. Figure 29 shows that 1 respondent's company scales standardized blockchain products and/or services. The remaining 124 respondents skipped this question, as it is not applicable, due to lower maturity levels within the respective companies.

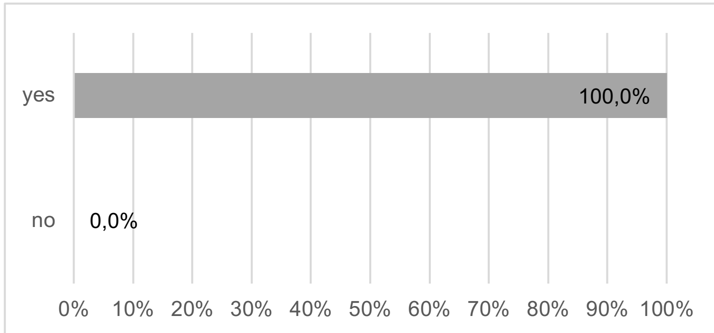

Figure 29: Survey question 28
"Do you scale standardized blockchain products and/or services in your company?"
Note. (N/total=125, N/Q28=1, March 2018-July 2019)

From the results shown in Figure 30, it can be assumed that the same 1 respondent answered positively regarding the use of a comprehensive, structured methodology to scale standardized blockchain products and/or services in his or her company. The remaining 124 respondents skipped this question, as it is not applicable.

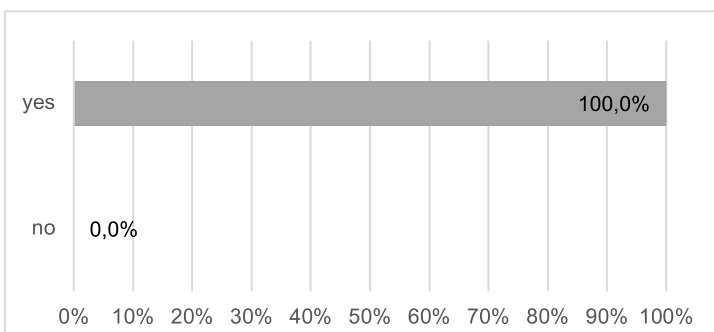

Figure 30: Survey question 29
"Do you apply a comprehensive, structured methodology to scale standardized blockchain products and/or services in your company?"
Note. (N/total=125, N/Q29=1, March 2018-July 2019)

Again, in Figure 31, it can be assumed that the same 1 respondent, whose company applies a methodology to scale standardized blockchain products and/or services in his or her company replied with "satisfied" regarding the methodology applied. The remaining 124 respondents skipped this question, as it is not applicable.

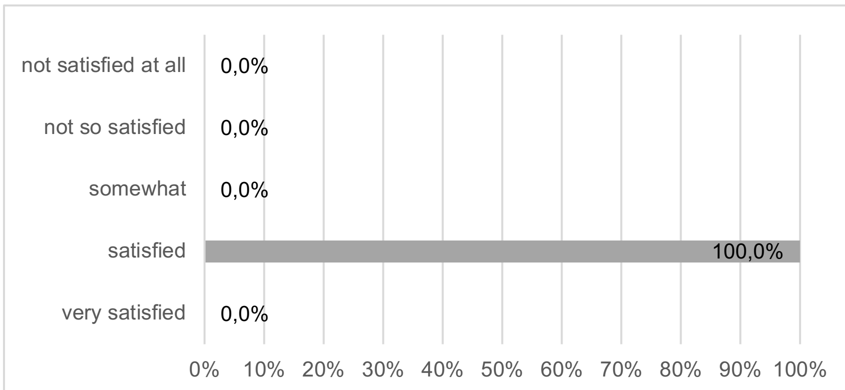

Figure 31: Survey question 30
"How satisfied are you with the methodology you are applying to scale standardized blockchain products and/or services in your company?"
Note. (N/total=125, N/Q30=1, March 2018-July 2019)

None of the respondents answered the survey question, "Are you planning to scale standardized blockchain products and/or services in your company in the next 12 months?" It can be assumed that the 1 respondent whose company offers standardized blockchain products and/or services either has no further plans for scaling or is unaware of furthers company plans to scale in the next year.

Figure 32 shows results of the question: "Does your company optimize standardized and scaled blockchain products and/or services?" 1 respondent replied positively, and the remaining 124 respondents skipped this question, as it is not applicable.

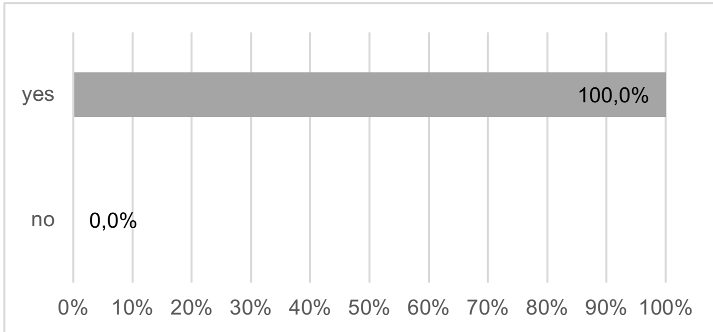

Figure 32: Survey question 32
"Do you optimize standardized and scaled blockchain products and/or services in your company?"
Note. (N/total=125, N/Q32=1, March 2018-July 2019)

Figure 33 shows that 1 respondent replied positively that his or her company applies a comprehensive, structured methodology to optimize standardized and scaled blockchain products and/or services offered. The remaining 124 respondents skipped this question, as it is not applicable.

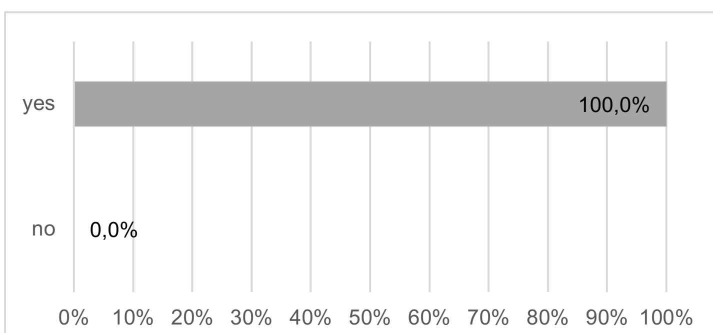

Figure 33: Survey question 33
"Do you apply a comprehensive, structured methodology to optimize standardized and scaled blockchain products and/or services in your company?"
Note. (N/total=125, N/Q33=1, March 2018-July 2019)

It can be assumed, that the same 1 respondent replied with “satisfied” regarding the methodology applied to optimize standardized and scaled blockchain products and/or services at his or her company, as shown in Figure 34. The remaining 124 respondents skipped this question, as it is not applicable.

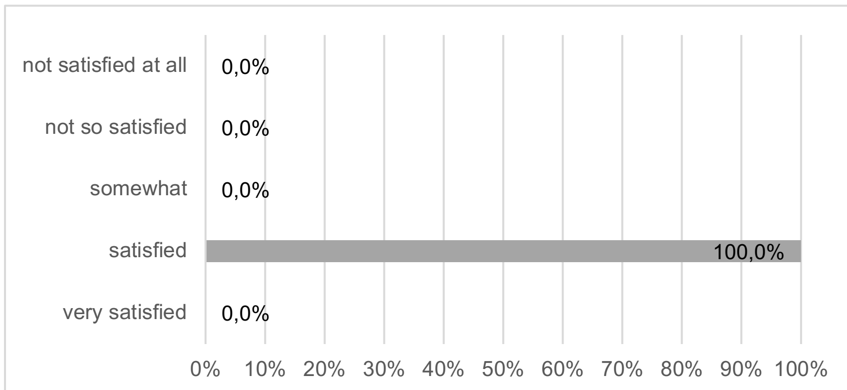

Figure 34: Survey question 34
“How satisfied are you with the methodology you are applying to optimize standardized and scaled blockchain products and/or services in your company?”
Note. (N/total=125, N/Q34=1, March 2018-July 2019)

The final survey question investigates plans to optimize standardized and scaled blockchain products and/or services in respondents’ companies in the next 12 months, from the time of survey. None of the respondents replied to this question. Thus, it can be assumed that none of the companies represented have such plans within a year, or that the respondents are unaware of such plans for optimization.

In summary, the topic of blockchain technology in the context of business transformation seems to be relevant. This can be qualified by a high awareness rate, as 91.2% of respondents have heard about blockchain technology (LK), and 76.8% of respondents claim to know what blockchain technology is and how it functions (LK).

However, a strong decline in TAM parameters (level of knowledge, perceived usefulness, perceived ease of use, intention to use, active system use) across the CMM maturity levels, regardless of industry sector or company size, indicates that there is a substantial gap in managing the blockchain adoption process in a sustainable way. Only 5% of respondents are using a comprehensive methodology to apply blockchain for business transformation. Furthermore, only 1 out of 125 respondents responded positively across all 7 maturity levels (CMM) and TAM parameters.

These survey results point to a demand for measures to increase solutions for methods that assist in the blockchain adoption process. Furthermore, it appears that there is potential for improvement and new design of adoption models, which support companies at each phase of acceptance and level of maturity.

4.3.2 Empirical analysis

In this chapter, we empirically analyze the status quo of blockchain technology across specified industries. In particular, representatives from select industry sectors responded to questions concerning their acceptance and maturity levels with blockchain technology applications. These technology acceptance and maturity levels refer respectively to TAM and CMM, as discussed thoroughly in Chapter 2.2 and Chapter 3.3

The empirical analysis of certain companies within an industry is conducted via the hypotheses H1-H4 and a Fisher test for proportions. The empirical analysis regarding risk measure at the industry scale, as explored with H5 is conducted via a binomial test.

As described above, I conducted a survey of 125 respondents from the upper management levels - so-called executives - and created questions, which relate to the integrated adoption model (TAM and CMM). The goal was to measure the TAM parameters (see Table 10) at each of the CMM maturity levels throughout the transformation process.

The main assumption is that if executives possess a certain level of knowledge about blockchain technology, it can be concluded that there is a real tendency to accept this new technology, based, in part, upon TAM parameters PU and PEU.

I expected a significant correlation between the survey answers related to acceptance of blockchain technology, on the one hand, and to applying blockchain across maturity levels, on the other hand. In other words, I expected a correlation in responses to questions of TAM and CMM, respectively. I show the following Table 16 again here (as repeated from above in Table 12), as this presents the matrix of survey questions, which simultaneously relate to TAM and CMM.

CMM = capability maturity level

TAM - Technology acceptance model

	Awareness = level 1	**Knowledge = level 2**	**Initiation = level 3**	**Implementation = level 4**	**Standardization = level 5**	**Scale = level 6**	**Optimization = level 7**
Level of knowledge = LK	Q 6, 7, 8	Q 11, 12	Q 11, 12, 16	Q 11, 12, 20	Q 11, 12, 24	Q 11, 12, 28	Q 11, 12, 32
Perceived usefulness = PU	Q 10	Q 13	Q 13, 16	Q 13, 20	Q 13, 24	Q 13, 28	Q 13, 32
Perceived risk = PR							
Perceived ease of use = PEU	Q 9	Q 14, 15	Q 17, 18	Q 21, 22	Q 25, 26	Q 29, 30	Q 33, 34
Intention to use = IU			Q 19	Q 23	Q 27	Q 31	Q 35
Active system use = ASU			Q 16	Q 20	Q 24	Q 28	Q 32

Figure 35: Matrix of survey questions within the integrated TAM and CMM adoption model

With the following discussion, I describe which individual survey questions (Q) relate to the research questions and their related hypotheses.

<u>Research question 1 and hypothesis 1:</u>

Q11: Do you know what blockchain technology is and how it functions?

Q13: Which value can you create for your business with blockchain technology?

TAM advocates that there are some external variables, which influence the perceived usefulness (PU) and perceived ease of use (PEU), at the very beginning phases of technology acceptance. The impact of these external variables results in the initial level of knowledge about a new technology. In my case, the initial level of knowledge about the blockchain technology is measured by the question Q11, which, in turn, relates to maturity levels 2-7.

Question 13 asks for the identifiable value that can be created with blockchain in the context of business transformation, which relates to maturity level 2 of the CMM. Moreover, question 13 focuses clearly on the fact that there is an existing and visible perceived usefulness (PU).

The relevant parameters here are:

TAM: Level of knowledge (LK), perceived usefulness (PU)

CMM: Level 1, level 2

Hence, combining these two questions in terms of TAM and CMM relates back to the first concrete research question:

Research question 1: Which blockchain acceptance and maturity levels do executive business leaders have across different industries and company sizes, in terms of awareness, knowledge and created value?

Based on this research question, the first testable hypothesis could be established:

Hypothesis 1: Executives are knowledgeable with blockchain technology and its value in terms of perceived usefulness (PU).

Generally speaking with regard to hypothesis 1, if executives really know how blockchain functions, they should also have an idea of how to increase the value of their business by using blockchain technology. In this case, the answers from Q11 and Q13 may not be statistically independent.

<u>Research question 2 and hypothesis 2:</u>

For the next research question, we go a step further to analyze the question of whether executives are knowledgeable enough in terms of applying a comprehensive methodology for the adoption of blockchain technology in the context business transformation. This research question and hypothesis are based on questions 11 and 14.

Q11: Do you know what blockchain technology is and how it functions?

Q14: Is your company actively using a comprehensive, structured methodology that helps you apply blockchain technology for your business?

In contrast to the first research question, now it is asked whether executives have a concrete, applicable methodology to increase the business value of their company. Having a methodology in use for applying blockchain technology can be interpreted as a proof for the perceived ease of use (PEU).

The relevant parameters for these questions are:

TAM: Level of knowledge (LK), perceived ease of use (PEU)

CMM: level 2

Thus, deriving from the question about the level of knowledge (LK) and perceived ease of use (PEU) for blockchain, I defined the second research question.

Research question 2: Do executive business leaders use a methodology, which enables them to apply blockchain technology in an easy way across different capability maturity levels?

Hypothesis 2: Executive business leaders are knowledgeable with blockchain technology and its value in terms of perceived ease of use (PEU).

If this hypothesis can be rejected, then we can conclude that the knowledge of executives is not at the level needed to easily adopt blockchain technology.

Research question 3 and hypotheses 3 and 4:

The next level within the integrated approach is level 3 and 4 of CMM, which is focusing on the initiation and implementation of blockchain projects together, in relation to perceived usefulness (PU) and perceived ease of use (PEU) from TAM. This research question and hypothesis are based on questions 16 and 17, with regard to initiation projects (H3), and 20 and 21, with regard to implementation projects (H4).

Q16: Do you have any active blockchain initiatives in your company?

Q17: Do you apply a comprehensive, structure methodology when initiating a blockchain project in your company?

The relevant parameters here are:

TAM: Level of knowledge (LK), active system use (ASU)

CMM: level 3

Research question 3: Do executive business leaders use a comprehensive methodology, which enables them to initiate and implement blockchain technology in an easy way?

Hypothesis 3: Executive business leaders are eager to apply a comprehensive, easy to use methodology to initiate blockchain-enabled services for their business.

If the answers from Q16 and Q17 are statistically independent, one can conclude that there is no comprehensive methodology in use with the companies represented in the survey, in order to ensure sustainable success with of blockchain projects.

Last but not least, I focus on the question of whether executives are currently implementing blockchain projects by applying a comprehensive methodology. Questions 20 and 21 were formulated to gain insight for this purpose.

Q20: Do you have any active blockchain implementation projects in your company?

Q21: Do you apply a comprehensive, structure methodology when implementing a blockchain project in your company?

The relevant parameters here are:

TAM: Level of knowledge (LK), active system use (ASU)

CMM: level 4

Hypothesis 4: Executive business leaders are eager to apply a comprehensive, easy to use methodology to implement blockchain-enabled services for their business.

The above hypotheses are evaluated with Fisher test as follows:

To test the hypotheses 1-4, I applied the Fisher's exact test, due to the small sample sizes. With the Fisher's exact test, one can test whether proportions from two variables are independent of one another. For two by two contingency tables, with sample proportions of a, b, c, and d in the first, second, third, and fourth cells, respectively, one can calculate the exact probability for obtaining a set of proportions by using the following formula:

Equation 1: Fisher test equation

$$p = \frac{(a+b)!\,(c+d)!\,(a+c)!\,(b+d)!}{a!\,b!\,c!\,d!\,n!}$$

The exclamation mark (!) indicates the factorial operator. To test whether the proportions of two variables are independent from one another, which represents the null-hypothesis here, one needs to calculate the P-value, which is the probability of obtaining the empirical result under the null-hypothesis. This P-value must be calculated over all extreme cases with the same marginal totals. If this P-value is then smaller than the common level of significance, one can reject the null hypothesis. The common levels of significance are 0.01, 0.05, and 0.10, or 1%, 5%, and 10%, respectively.

Furthermore, I used the two-tailed Fisher's exact test, due to interest in testing the mutual independency. In my case, when testing whether answers from two different questions are independent, one can reject the null hypothesis on common level of significance and conclude that those answers from two questions are statistically independent. For more detail about the Fisher's exact test and calculation of P-values for this test, we refer to Agresti (2002). The data gathering provides the following answers' distribution across the integrated approach.

CMM = capability maturity level

TAM - Technology acceptance model

	Awareness = level 1	Knowledge = level 2	Initiation = level 3	Implementation = level 4	Standardization = level 5	Scale = level 6	Optimization = level 7
Level of knowledge = LK	114	96	19	7	1	1	1
Perceived usefulness = PU	65	53	19	7	1	1	1
Perceived risk = PR							
Perceived ease of use = PEU	35	7	9	5	1	1	1
Intention to use = IU			12	6	5	0	0
Active system use = ASU			17	7	1	1	1

Figure 36: Distribution of positive survey answers within the integrated TAM and CMM model

It can be clearly seen that the responses rapidly decrease with increasing CMM levels. It can be seen that from the point of the CMM implementation level (level 4), only a few responses remain, which are sufficient for empirical hypothesis testing. Beyond the implementation level, i.e., for CMM levels 5,6, and 7, an empirical analysis is no longer possible due to the low number of responses.

A similar phenomenon of decreasing number of positive responses can be seen with the TAM parameters, although to the extent of the example above. Perceived usefulness (PU) seems to be more available to respondents than perceived ease of use (PEU). Overall the perceived usefulness (PU), perceived ease of use (PEU) and the intention to use (IU) blockchain technology applies in relatively small numbers for the initiation and implementation levels of CMM.

The logical conclusion could be that executive business leaders are in need of a comprehensive methodology to adopt blockchain technology in a sustainable way, in order to increase the evolution to higher maturity levels.

The evaluation results are distributed as follows:

Hypothesis 1: The survey answers result in the following 2x2 contingency table:

	Yes (Q11)	**No (Q11)**	**Total**
Yes (Q13)	53	0	53
No (Q13)	43	29	72
Total	96	29	125

The association between positive answers of question 11 (Q11) and question 13 (Q13) is considered to be statistically significant. This statement is based on P-value = 8.16E-09. Hence, we can assume with sufficient statistical security that the answers from both questions are dependent. Thus, executives who know about blockchain technology may indeed know how blockchain could be used in their company, as well. At this point, it may be highlighted that we consider CMM level 2: the level of knowledge.

Hypothesis 2: The survey answers result in the following 2x2 contingency table:

	Yes (Q11)	**No (Q11)**	**Total**
Yes (Q14)	7	0	7
No (Q14)	89	29	118
Total	96	29	125

The association between positive answers of question 11 (Q11) and question 14 (Q14) is considered to be statistically not significant. This statement is based on P-value = 0.199. Hence, we can assume with sufficient statistical security that the answers from both questions are independent. Therefore, the statement of executives' knowledge of how blockchain functions may not be supported by an appropriate methodology for applying blockchain technology in their company.

Hypothesis 3: The survey answers result in the following 2x2 contingency table:

	Yes (Q16)	**No (Q16)**	**Total**
Yes (Q17)	9	0	9
No (Q17)	10	106	116
Total	19	106	125

The association between positive answers of question 16 (Q16) and question 17 (Q17) is considered to be statistically significant. This statement is based on P-value = 6.04e-09. Hence, we can assume with sufficient statistical security that the answers from both questions are dependent. Thus, the companies that have blockchain projects running currently may also use some comprehensive methodology when conducting blockchain projects.

Hypothesis 4: The survey answers result in the following 2x2 contingency table.

	Yes (Q20)	No (Q20)	Total
Yes (Q21)	5	0	5
No (Q21)	2	118	120
	7	118	125

The association between positive answers of question 20 (Q20) and question 21 (Q21) is considered to be statistically significant. This statement is based on P-value = 8.95E-08. Hence, we can assume with sufficient statistical security that the answers from both questions are dependent. In other words, the companies that have implemented some blockchain projects in their companies may also use some comprehensive methodology at this implementation level.

From the economic point of view, we can conclude the following:

Based on the results from hypothesis 1, executives may have heard about blockchain technology, and they may know how it functions. Therefore, the perceived usefulness (PU) may be available at CMM level 2 (knowledge). Based on the results of hypothesis 2, executives might lack in perceived ease of use (PEU) at the same CMM level.

From the CMM perspective, hypotheses 3 and 4 may be more interesting, as they deal with higher maturity levels. Based on the results of hypotheses 3 and 4, one cannot reject that executives may use a comprehensive methodology when initiating and implementing blockchain projects.

However, this could be an erroneous belief, when considering the survey results from a macro perspective. Having looked at the distribution of answers, one can recognize that only a few companies have indeed started a blockchain project. Moreover, there is only one company that has applied and advanced their blockchain project across all maturity levels. Due to this fact, a risk analysis is necessary. The aim is to analyze the measure of risk for each industry sector, in terms of gaining or losing momentum and potential competitive advantage regarding the general development of the blockchain technology market at present. Risk factors in this context are explained in Section 2.1.

All of these risks are factors, which can influence the opinions and overall attitude of executive business leaders, regarding the initiation and implementation of blockchain technology within their companies. Hence, a risk analysis is performed at the industry scale, in order to analyze the aggregated levels of PU and PEU within particular industry sectors, and the degrees of blockchain technology acceptance amongst executives. Actually, risk factors play a relevant role at each maturity level, and thus, the risk analysis can be carried out at each maturity level, as well. However, the number of responses in the survey allows only for the risk analysis at the CMM level of knowledge (level 2), which corresponds to survey questions Q13 for PU and Q14 for PEU.

Generally speaking with regard to all of these hypotheses, if the answers from the two particular questions related to each hypothesis are statistically independent – meaning, if they are not correlated – then this hypothesis can be rejected. This is the reason for applying the Fisher exact test.

However, at present, only a few companies have achieved the maturity level of implementation, and with only a few blockchain projects. That will be shown via empirical results in the following Section 4.3.2. This section will present the analysis of risk measure across industries (or at the level of single industry sectors), as well as at the company level, in terms of losing momentum and thus missing the market advantages of blockchain. However, the first question is: how can that kind of risk be measured?

Risk measurement poses a problem, in that risk cannot be observed. By nature, risk is a latent, possible threat - one that refers to future impacts and cannot be perceived per se. Furthermore, quantifying the variables and scale of any risk is generally very difficult, as the relevant scale cannot be directly or explicitly ascertained. The volatility of the financial market could be taken as an example: the likelihood that particular events, such as credit defaults, will occur can be inferred, but not observed. Ultimately, the assessment of risk is a complex process, in and of itself. For my research, I would like to measure the risk for certain industry sectors by not adopting blockchain, as this could have an impact in terms of missing out on business opportunities that come with the sustainable usage of blockchain technology.

Due to the complexity, however, the assessment of risk was not included within the scope of this survey. Instead, I present the following formula for quantifying risk within select industry sectors:

Equation 2: Binomial test equation

$$P(X = i) = B(i|p_0, n) = \binom{n}{i} p_0^i (1 - p_0)^{n-i}$$

Here, *i* represents the index number across all industry sectors, and N_i^+ shows the number of positive answers per questions. In my case, the PU (perceived use) and PEU (perceived ease of use) among individual industry sectors are of particular interest. The interval for measure of risk (R) is between 0 and 1 and can be interpreted as follows: a lower R indicates a lower estimated risk to miss out on blockchain adoption and the related business opportunities, and a higher R indicates a higher estimated risk to miss out on blockchain adoption and the related business opportunities. More precisely speaking, if the risk measure is lower than 50%, the risk is lower than the opportunity for applying blockchain technology within a particular industry sector and vice versa. This raises the final research question.

Research question 4: What is the risk measure across industries, which arises by not using an integrated adoption model with respect to TAM and CMM when applying blockchain technology?

The related hypothesis can be formulated as follows:

Hypothesis 5: The risk measure, as proposed in Equation 2, is higher than 50%.

Binomial test to evaluate hypothesis 5:

For this purpose, the binomial test has been applied to test if risk measures are higher than 50%. I can use this test to establish whether the proportion of 'Yes' and 'No' answers within a group is higher than 50%, which yields my hypothesis 5. The statistic of the binomial test is distributed as shown with the following Equation 2:

$$P(X = i) = B(i|p_0, n) = \binom{n}{i} p_0^i (1 - p_0)^{n-i}$$

Here n is the number of answers, and p_0 is the assumed proportion of 'Yes' answers, which are coded with 1. In my case, I test whether p_0 is higher than 50%: $0.5 < p_0$. The binomial distribution is discrete, and one must compare this empirical value from Equation (2) with the critical values on the particular significance level.

The binomial test is an exact test, so that it can be used in the case of small data sets. Actually, there is no alternative to the binomial test when analyzing small data samples. (Conover, 1971, pp. 97–104). This is the case for my data.

I would like to point out that the risk measure I introduce in Equation 1 is based upon 'No' answers. Hence, testing whether this risk measure is statistically significantly higher than 50% is equivalent to testing whether the number of 'No' answers is higher than 50%. With the calculation, I only consider industry sectors with two or more responses.

In doing this, I differentiate between individual industry sectors. The following table shows the results for hypothesis 5 across different industry sectors. All missing responses are interpreted as ‘No’ answers.

Table 17: Risk measure tested on the example of TAM parameters PU and PUE at the CMM knowledge level

			TAM: Perceived usefulness (PU) TAM: Perceived risk (PR) CMM: Level of knowledge (LK)			**TAM: Perceived ease of use (PEU) TAM: Perceived risk (PR) CMM: Level of knowledge (LK)**		
	Industry sector	**# of respondents**	**# of positive respondents**	**R**	**p-value**	**# of positive respondents**	**R**	**p-value**
1	Advertising	8	4	0,50	0,6367	1	0,88	0,0352
2	Automotive	5	3	0,40	0,8125	2	0,60	0,5000
3	Consulting	7	4	0,43	0,7734	0	1,00	0,0078
4	E-commerce	6	2	0,67	0,3437	0	1,00	0,0156
5	Education	7	2	0,71	0,2266	0	1,00	0,0078
6	Finance	2	1	0,50	0,7500	0	1,00	0,2500
7	Fashion	4	1	0,75	0,3125	0	1,00	0,0625
8	Healthcare	3	3	0,00	1,000	0	1,00	0,1250
9	Human Resource	5	1	0,80	0,1875	1	0,80	0,1875
10	IT	11	5	0,55	0,7256	2	0,82	0,0327
11	Law	4	2	0,50	0,6875	0	1,00	0,0625
12	Logistics	4	2	0,50	0,6875	1	0,75	0,3125
13	Manufacturing	9	1	0,89	0,0195	0	1,00	0,0019
14	Marketing	15	4	0,73	0,0592	0	1,00	0,0000
15	Media	9	5	0,44	0,7461	0	1,00	0,0019
16	Pharma	4	3	0,25	0,9375	0	1,00	0,0625
17	Retail	5	3	0,40	0,8125	0	1,00	0,0312
18	Software	7	5	0,29	0,9375	0	1,00	0,0078
19	Travel	6	1	0,83	0,1094	0	1,00	0,0156
20	Others	4	2	0,60	0,5000	0	1,00	0,3125

Table 17 consists of the following columns, from left to right: number of the industry sectors (according to alphabetical order), name of the industry sectors represented in the survey, number of answers submitted for each industry sector, and the number of ‘Yes’ answers submitted for each industry sector, the risk measure R and the P-values for both perceived usefulness (PU) and perceived ease of use (PEU), respectively.

The P-value indicates the level of significance, at which the null hypothesis can be rejected. If the P-value is lower than 0.10, 0.05 or 0.01, the null hypothesis can accordingly be rejected at a significance level of 10%, 5%, or 1%. In this case, it can be assumed that the empirically estimated measure of risk is higher than 50%. A risk measure of higher than 50% means that the risk of missing out on blockchain by not adopting the technology in a proper or timely manner is higher than the measure of opportunity to realize blockchain adoption.

With the P-values for PU, the statistical security of the risk confirmation is applicable for the industry sectors Marketing (10%) and Manufacturing (5%). With PEU's P-values, the statistical security of the risk confirmation is applicable for the industry sectors Advertising, Consulting, Education, Fashion, IT, Law, Manufacturing, Marketing, Media, Pharma, Retail, Software and Travel.

5 Conclusion and outlook

5.1 Conclusion

The main objective of this thesis is the design of a model for blockchain technology adoption in the context of business transformation. This model should serve two aims: 1) to support companies with risk management across the entire process of blockchain-driven business transformation at the individual, company level, and 2) to estimate the measure of default risk at the industry level, which might arise without an adoption model that could support the sustainable use of blockchain technology.

The main conclusion drawn from the research for this thesis is that the customized adoption model, which has been designed by integrating the two existing adoption models TAM and CMM, holds the potential to support risk management for the sustainable use of blockchain technology. The integrated TAM and CMM adoption model provides a resilient framework for managing the transformation design at the company level, and also to estimate risks at the industry level.

In keeping with the insight that blockchain technology is a foundational technology, which is characterized by the dimensions of novelty and complexity, a comprehensive framework is required for the management of both dimensions. This newly designed, customized adoption model can manage these simultaneously. TAM provides the solution for the novelty dimension, while CMM provides the solution for the complexity dimension. The combination of both seems to be a valuable solution to increase and optimize blockchain technology adoption across any industry, use case and maturity level. The extension of both models to include further levels and parameters (e.g. level of knowledge, perceived risk, awareness, knowledge), as presented in Chapter 3, provides additional value for the business transformation design process and for the adoption of blockchain technology in a sustainable way.

This main conclusion can be qualified by the following set of detailed conclusions:

Based upon the sources reviewed in Chapter 2, I conclude that research activity into risk management for sustainable blockchain adoption and use is scarce. While individual discussions of risk can be found - primarily arising from leading global consultancy companies - focused academic discussions of adoption and risk management are lacking. Also, there appears to be a definite need for applied methods and a comprehensive model for risk management in this context. Closing the identified gaps with deeper research in the area of blockchain adoption could provide great opportunity in terms of defining the forms of business leadership, usage and risk management that are needed for successful and sustainable blockchain-driven business transformation.

Based on the descriptive and empirical analysis in Chapter 4.3.1 and Chapter 4.3.2, I conclude that the customized adoption model (TAM and CMM), along with the survey designed to test this, seems to be a resilient and valuable model for identifying acceptance and maturity levels. Moreover, this model can be qualified by the very high survey closure rate of 98.5% of respondents.

The topic of blockchain technology in the context of business transformation seems to be relevant. This can be qualified by a high awareness rate, as 91.2% of respondents have heard about blockchain technology (LK), and 76.8% of respondents claim to know what blockchain technology is and how it functions (LK).

However, a strong decline in TAM parameters (level of knowledge, perceived usefulness, perceived ease of use, intention to use, active system use) across the CMM maturity levels, regardless of industry sector or company size, indicates that there is a substantial gap in managing the blockchain adoption process in a sustainable way.

While 15% of respondents are currently initiating a blockchain project (maturity level 3) and 5% of respondents have a blockchain implementation project in progress (maturity level 4), only one company or 0.8% of respondents is standardizing (maturity level 5), scaling (maturity level 6) and optimizing (maturity level 7) blockchain projects. The majority of interviewed companies are not even initiating any blockchain projects.

These low maturity levels across so many industry sectors indicate low adoption rates. It is necessary to identify and manage the risks, which act as barriers to increased blockchain adoption. By merging the TAM and CMM parameters, the levels of acceptance can be observed at each maturity level. Thus, this model serves as a dynamic tool for managing risk. If risk parameters can be managed and influenced at the right point in time, maturity levels with blockchain technology can be increased, sustainably. With the rise of blockchain technology, a significant shift towards decentralized ways of conducting business can be observed. Such a transformational shift, and the risks that come with it, requires models of this nature, which are tailored to the entire business transformation design and blockchain adoption process.

There is a verifiable risk for companies to lose momentum at the industry level, due to the lack of an appropriate adoption model and sufficient approach to business transformation design. Such risk could negatively impact competitive advantage within their industry sector. This indicates that further education and immersion into transformation design for a decentralized economy is required, and the customized adoption model could offer a great solution for this need.

This brings me to my two final conclusions, which I believe confirm the initial research objectives set out for this thesis. Based upon my research, I deduct that the customized adoption model (TAM and CMM) seems to be a resilient and valuable model for managing risks across the end-to-end business transformation process at the company level. Any area of risk can be evaluated by applying questions of this risk to the extended TAM parameters across the 7 maturity levels. This applies to the set of risk parameters as defined in Chapter 2.1, such as privacy, governance, interoperability, architecture design, compliance, change management, scalability, liability, customer experience, user experience.

Additionally, I advance that the customized adoption model (TAM and CMM) seems to be a resilient and valuable model to estimate risk measures across industry sectors by applying the binomial equation to the TAM and CMM framework.

Thus, I propose that this customized TAM and CMM adoption model holds to potential for managing risks for the sustainable usage of blockchain technology, and that this might be a significant contribution for the transformation design for a decentralized economy.

5.2 Outlook

As a result of my research in this field, I believe that blockchain is laying a foundation for near-future, decentralized economies. This emergent technology for decentralized ways of conducting businesses is in its early phases. This fact presents a situation where both demand and potential are high for methods and models that help pave the way to this decentralized business transformation design context.

This insight also represents the primary outlook for subsequent work with this topic. To continue working with the integrated TAM and CMM adoption model, steps to refine and hone the framework can be valuable. By adjusting and evolving the adoption model, the risk parameters identified in Section 2.1.4 (see Table 5) can be integrated and tested across each of the 7 levels of maturity. Then, by applying a scoring card to assess risk measures at each level, the data retrieved from the model can become far more focused and granular, thus enabling better matching and educating activities for different defined audiences. In other words, risk parameters can be matched with various audiences according to relevancy. In this way, risks can be managed in a more distributed, collective and sustainable way.

In order to evolve and adjust the model for these purposes, larger scope surveys should be conducted, which take these risk parameters into consideration. As a next step, a survey of thousands of participants could serve to gather larger data sets, which will then allow for better segmentation, analytics and prediction at the industry sector level. This would also yield far more insights into use case-based blockchain issues and their relevance at the company scale.

Due to the open, decentralized nature of blockchain networks, it is of great importance to operate in terms of open source knowledge sharing. For further work with the adoption model, an open environment should be created for communities to share knowledge. This requires the design of a community-centric model with real-time interactions. Once a community and community structure have been established, the model can be tested in real case study situations. Establishing this community structure is a necessary step of the transformation design from internal, privately secured information sharing to open source, shared, distributed ways of working.

With such a structure in place, the adoption model should be tested and optimized in as many commercial environments as possible to learn what works well, and what needs to be optimized. This merger of science and commercial, industry knowledge is key in taking the research model to market. Outcomes of the tests should be shared amongst the established community. The importance and relevance of real-time case studies is qualified, and this was identified as a key research gap in Chapter 2.

It should be highlighted that this adoption model not only holds value for blockchain applications, but also for other emerging technologies, such as nanotechnology, AI, robotics and additional innovating technologies of the 4th Industrial Revolution. Currently, we are experiencing the convergence of the 4th Industrial Revolution with the 6th Kondratieff Wave, as discussed in Chapter 1. Our contemporary era is characterized by the simultaneous rise of several foundational, emerging technologies, which possess relatively high degrees of novelty and complexity. This adoption model can be considered as technology agnostic, meaning it can also be applied for these other technologies' adoption processes and broader business transformation design.

Therefore, I highlight that there is great opportunity to further test and customize this model for contexts of business transformation beyond blockchain. I propose that this research has a relevant value for the audiences defined, including researchers, business leaders, experience designers, technology specialists, software developers and anyone who is curious and equipped to design decentralized, future-ready business models and applications. The predictive capacity of this model, in terms of estimating technology adoption-related risks across industry sectors, could hold great potential for industry-wide thought leaders, investors and other actors of transformation design.

In closing, I conclude that there is a great opportunity to design and develop a TAM and CMM adoption model software-as-a-service (SaaS) application. Large user groups would be empowered to use this application to operationalize, measure and manage innovation processes across any industry or use case. Looking at the social sustainability aspect of community development, the captured data of the SaaS application could be made available to business innovation communities in order to learn from each other and to grow with each other.

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