On Network-like Structures in Business and Their Underlying Digital Technologies

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"Subjects' unwillingness to deduce the particular from the general was matched only by their willingness to infer the general from the particular."

R. E. Nisbett & E. Borgida, 1975

Abstract

Network-like structures exist everywhere and have many and different facets. In combination with emerging digital technologies, new network structures develop, provide new opportunities, and pose new risks to organizations. In this thesis, I provide a brief overview on the various network types and then derive a general approach for organizations to handle networks. The three-step RAS approach proposes to **r**ecognize networks as networks (step 1 – R), **a**nalyze them by adhering to their specific properties (step 2 – A), and **s**hape their development according to an organization's goals (step 3 – S). For each step, the RAS approach comes with specific guidelines to consider key aspects of network structures.

I then introduce the four research papers included in this thesis and outline how they contribute to the RAS approach. Research papers 1 and 2, *Forging a Double-edged Sword: Resource Synergies and Dependencies in Complex IT Project Portfolios* (Radszuwill and Fridgen 2017) and *Modeling Project Criticality in IT Project Portfolios* (Neumeier et al. 2018), recognize IT project portfolios as IT project networks and analyze them particularly regarding their interactions. In Radszuwill and Fridgen (2017), we analyze IT projects and their resource synergies and dependencies using alpha centrality. In Neumeier et al. (2018), we provide an approach to compute the risk exposure of each project within an IT project network using Bayesian network modeling. With both research papers, we provide new approaches that look at IT project portfolios from a network perspective, i.e. we consider projects and the interactions between them. Research paper 3, *When Your Thing Won't Behave: Security Governance in the Internet of Things* (Fridgen et al. 2018a), analyzes the security risk of technology platform use in the Internet of Things (IoT). We model the risks of technology platform use, outline and discuss the model's parameters, and derive governance implications that can help to shape technology platform use's development in IoT. Research paper 4, *Blockchain Won't Kill the Banks: Why Disintermediation Doesn't Work in International Trade Finance* (Fridgen et al. 2018c), analyzes the current process of a letter of credit and proposes an improved, re-engineered process that leverages the potentials of blockchain technology and can change existing market structures.

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1 Introduction

1.1 Networks and Digital Technologies

"Networks are everywhere" (Newman et al. 2006, p. 1). "We live life in the network" (Lazer et al. 2009, p. 1). These statements by recognized scientists emphasize that, in our globalized world, network-like structures are ever-present and reveal many and differing facets. Various environments contain structures that can be thought of as networks: There are social networks such as Facebook or LinkedIn, financial networks that underlie the international monetary system, supply and transportation networks for production and trade, energy networks, communication networks, organizational networks, biological networks, computer networks, and many more. Naturally, the study of networks is interdisciplinary, combining scientific research from various fields such as mathematics, physics, computer science, and social sciences (Newman 2013). Our economy and our daily routines are closely bound to these network structures, which we use to communicate, to organize, and to collaborate. But: What is a network? What do all these network structures have in common? Simply put, a network can be regarded as "a collection of points joined together in pairs by lines" (Newman 2018, p. 1). The points are often referred to as nodes or vertices and the lines as edges (Newman 2018).

Today, many network structures are either enabled or supported by the use of information technology (IT), or both. IT has been prevailing in businesses for decades (Legner et al. 2017) and has made our world more global and interconnected (Buhl 2013). IT's importance has risen continuously, IT spending is still increasing (Gartner 2018), and IT project portfolios become complex IT project networks (Radszuwill and Fridgen 2017). IT has developed from a support function for businesses into a more strategic role (Venkatraman et al. 1993) towards a "digital business strategy" (Bharadwaj et al. 2013, p. 471). IT is considered crucial for competitiveness (Powell and Dent-Micallef 1997), and has long been regarded as an enabler of business operations and business networks (Venkatraman 1994). In the past few years, the emergence speed and adoption of new digital technologies such as the Internet of Things (IoT), blockchain, or artificial intelligence (AI) have increased (Berger et al. 2018). Although we lack a universal definition of digital technologies (Denner et al. 2018), they differ from earlier technologies since they are reprogrammable, homogenize data, and are self-referential (Yoo et al. 2010). Self-reference means that the uses and the diffusion of digital technologies lead to positive network externalities that "accelerate the creation and availability of digital devices, networks, services, and contents" (Yoo et al. 2010, p. 726). Thus, digital technologies not only increase their own diffusion, but also their interconnectedness levels. For instance, IoT connects previously non-digital devices to our "networked society" (Püschel et al. 2016, p. 2), and blockchain technology creates new distributed networks (Fridgen et al. 2018d). Thus, network structures that emerge in relation to digital technologies are a key success factor for almost every organization.

1.2 Classification of Networks

There are various possibilities to classify network structures. As a broad overview, Newman (2013, p. 17) introduced four generic network classes: "technological networks, social networks, information networks, and biological networks"; these can overlap. Examples of technological networks or "physical infrastructure networks" are telephone networks, power grids, or transportation networks (Newman 2013, p. 17).

Likely the best-known example of a technological network is the Internet, a network of wired or wireless "data connections between computers, phones, tablets, and other devices" (Newman 2018, p. 15) that is based on network protocols such as IP (Internet Protocol) and TCP (Transport Control Protocol) (Newman 2013). As a network, the Internet keeps growing and changing. For instance, new cloud networks emerge (Keller and König 2014), and the blending of physical things with sensor and communication technologies (Püschel et al. 2016) extends the Internet to previously non-digital things, i.e. to IoT. The literature regards IoT as the third generation of the Internet, after the Internet of information, and the Internet of services (Iansiti and Lakhani 2017; Prinz 2018). Further, the emerging blockchain technology is said to be an enabler of the fourth generation of the Internet, the Internet of trust (Prinz 2018). This makes clear that network structures are rarely isolated and static, but interconnected and dynamic. The Internet is also the basis of many social networks, for instance, of online social networks such as Facebook or LinkedIn.

In social networks, the nodes are the people and the edges are the connections between them (such as friendship or affiliation). The study of social networks dates back to the end of the nineteenth century, which saw examinations of relationships between children at school (Newman 2013). More recent research into social networks deals for instance with online firestorms (Drasch et al. 2015), social networks' roles in disaster management (Kim and Hastak 2018), or in project management (Chinowsky et al. 2010). Since the network classes are fuzzy, social networking websites can also be regarded as information networks (Newman 2013).

Information networks consist of data linked together; thus, the World Wide Web and the information in it can be regarded as an information network. Other closely related examples include e-mail communication networks or online journals (Newman 2013). The last network class, as introduced by Newman (2013), is biochemical networks, which describe the interactions between biological elements, such as metabolic networks, neural networks, or ecological networks.

Unambiguous allocations of networks to a single class is often not possible. Also, other network classifications exist in the literature. Besides a contextual classification, networks can also be approached from a mathematical perspective, using the primary attributes of graph theory. For instance, graphs may or may not contain cycles, and can consist of weighted or unweighted edges and directed or undirected edges (Newman 2013). As a similar example, Economides (1996) distinguished between one-way and two-way networks, i.e. networks without (one-way) or with (two-way) a direction. No matter which particular classification, a structured overview on network types can help organizations, as a first step towards understanding their network structures.

1.3 The Nature of Networks

Network structures have various associated benefits (Helbing 2013), depending on the network type. Social networks can increase communication opportunities for individuals, can generate employment connections, or can maintain existing social connections (Ellison et al. 2007). In supply networks, companies seek to minimize costs and maximize value creation (Klibi and Martel 2013). Thus, most networks have in common that the network's value increases with every additional participant (Economides 1996; Katz and Shapiro 1985, 1994). This effect is known as network externality or consumption externality (Economides 1996; Katz and Shapiro 1985, 1994). Katz and Shapiro (1985, p. 424) provided a simple and intriguing example: "The utility that a consumer derives from purchasing a telephone, for example, clearly depends on the number of other households or businesses that have joined the telephone network." Generally, the utility that a user of a good or service derives from it depends on the number of other users in the network (Katz and Shapiro 1985).

With a large number of nodes and edges, any network type can become very complex. The presence of network structures can yield consequences that can be indirect (Basu et al. 2003) and not easy to foresee or comprehend, and can be more impactful than estimated at first glance. To understand such systems, one must understand their "counter-intuitive nature" (Helbing 2013, p. 51) and one must shift the perspective from a single-instance to a network-oriented perspective (Helbing 2013). Today's network structures have already grown so far that they can even be regarded as systems of systems or networks of networks (Helbing 2013), i.e. one node in a network represents an entire network. Again, the Internet is a good example. First, the Internet is a technological network that serves as infrastructure. Further, this network forms the basis for various other networks: social networks, supply chain networks, information networks, and so on. Thus, it is a network of networks, i.e. an Internet of information, an Internet of services, and an Internet of Things (Prinz 2018). Moreover, many other networks have reached a complexity level that can only rarely be grasped by a single person or a group of persons. Helbing (2013, p. 51) even stated that "man-made systems can become unstable, creating uncontrollable situations even when decision-makers are well-skilled, have all data and technology at their disposal, and do their best."

Thus, network structures also add new risk types such as "identity theft or manipulation by personalized information" (Helbing 2013, p. 54), cyber-crime, or risk through cascade effects (Ash and Newth 2007; Helbing 2013). Cascade effects iteratively spread through a network from node to node, emerging from a small number of nodes and affecting a large part of the network or even the whole network (Buldyrev et al. 2010). Owing to their high connectivity level, network structures are particularly prone to cascade effects or so-called systemic risk, a term that has drawn increased attention in light of the financial crisis from 2007 (Haldane and May 2011). Centeno et al. (2015, p. 68) defined systemic risk generally as the threat that individual failures "present to a system through the process of contagion", thus, via cascade effects. These effects can be observed in many network structures.

Considering the sheer number of networks, and their benefits, risks, and diversity, it is fair to say that networks have significant economic impacts (Casson and Della Giusta 2008). With all these networks affecting our private lives, our economy, and society, the question arises: What are the implications for business in an environment that consists of many and manifold networks? In this thesis, I address this question, looking at selected network structures that relate closely to digital technologies. I will focus on the connections between organizations and networks. Based on the literature and the primary properties of networks, I provide a three-step approach for organizations on how to handle the various network structures in their environment.

2 The Role of Networks for Organizations

2.1 Businesses and Networks

Traditionally, there was an understanding that every network belonged to one organization; thus, initially, the research focus was on efficiency and cost allocation in these networks (Economides 1996). In their early days, even telephone networks belonged to a single organization. While this has certainly changed, besides so-called intra-organizational networks, inter-organizational networks (i.e. networks between various organizations) became increasingly important (Grandori and Soda 1995)[1]. Business relationships are one of the most diverse structures, consisting of intra-organizational and inter-organizational networks and are today closely related to IT. Looking at these relationships between businesses, Håkansson and Ford (2002) regard business markets as networks in which organizations are the nodes and their relationships are the edges. Further, this definition is closely related to the understanding of ecosystems as networks of affiliated organizations (Adner 2017). Comparing this definition to the aforementioned classifications (e.g. technological, social, information, and biological networks) illustrates two matters: First, the very broad occurrence of network structures; second, that there are various perspectives on how to look at network structures. For instance, business networks in this widespread definition are likely to contain – or, rather, to consist of – multiple networks, such as technological networks, social networks, information networks, and so on. Each is a network by itself, emphasizing the notion of networks of networks (Helbing 2013).

Our society and our organizations must deal with a new era of increasing

[1] The scientific literature also uses *intra-firm/inter-firm* or *intra-company/inter-company* to describe relationships between the various entities. In this thesis, I use *intra-organization/inter-organization* as an umbrella term. Further, I use *organization* instead of *company* or *firm*, in part so as to include reference to not-for-profit organizations and public institutions.

interdependency, interconnectivity, and complexity (Helbing 2013). Faced with many and ever-present networks structures, the question is how organizations can handle this complex environment. One way to cope with this development can be network intelligence, i.e. to "decipher many of the phenomena shaping the future of business" (Sawhney and Parikh 2001, p. 80). Network intelligence is the networks' functionalities, "its ability to distribute, store, or modify information" (Sawhney and Parikh 2001, p. 80). Knowing how a network functions, and using this information, can add significant economic value (Sawhney and Parikh 2001), as summed up in this statement: "In a networked world, more money can be made in managing interactions than in performing actions" (Sawhney and Parikh 2001, p. 82).

The business network, i.e. the organization and their interrelationships, is one of the most important network (of networks) for each company. Håkansson and Ford (2002) provided an insightful combination of three guiding managerial questions about relationships, networks, and related network paradoxes that organizations and their decision-makers should be aware of.

The first paradox is that the more intense the relationship between two organizations is (i.e. between two nodes), the more it will provide the organization with opportunities, but the more it will also restrict it in its freedom to change (Håkansson and Ford 2002). Business networks consist of economic, social, and technical dimensions that have been built over time. In their current state, they are the result of that building process and of the resources invested in that relationship. However, the organization is also bound to these relationships; it is restricted by them, and cannot change unidirectionally (Håkansson and Ford 2002). Organizations should consider the following question (1) concerning this paradox:

(1) "What kind of special opportunities and restrictions does a network bring to [an organization]?" (Håkansson and Ford 2002, p. 134)

The second paradox is that an organization's relationships are the result of its actions, but the organization is also the result of its relationships. Thus, an organization can influence networks and is influenced by its networks (Håkansson and Ford 2002). This relates to the fact that an organization cannot only act and influence its business network, but must also be able to react to changes in the networks it is part of. Thus, an organization should consider the question (2):

(2) "What is the interplay between influencing others and being influenced by them?" (Håkansson and Ford 2002, p. 134)

The third paradox is that the more an organization controls a network, the less innovative and effective this network will be (Håkansson and Ford 2002). Typically, an organization seeks to develop a network in a specific direction that is beneficial for that organization. The more successful an organization is in this regard, the more the network will be influenced by that organization; thus, the network will be more like a hierarchy (Håkansson and Ford 2002). New developments are limited, and change and innovation slow down: "A controlled network cannot develop faster than the [organization] that controls it" (Håkansson and Ford 2002, p. 137). This paradox can be summed up in this question:

(3) "How can [an organization] control a network and what are the effects on the network and on the [organization]?" (Håkansson and Ford 2002, p. 134)

These questions and paradoxes emphasize the diverse aspects to consider when faced particularly with business networks. However, they also provide a solid basis when approaching other network structures faced by an organization, and when thinking about key aspects to consider in this regard. I will now transfer the content provided by Håkansson and Ford (2002) to network structures generally, before focusing on specific examples that directly relate to digital technologies and various networks.

2.2 A Three-step Approach to Network Structures

Helbing (2013, p. 51) sums up the primary challenge concerning network structures today: "We do not understand and cannot control [them] well." Thus, the challenge for organizations is to overcome this state, and to understand and control existing and emerging network structures. This implies that organizations should be aware of their business networks, and – ideally – also of all the networks they participate in.

I propose a three-step approach towards an awareness, analysis, and shaping of network structures. First, an organization needs to recognize the network-like structures it is part of as networks (R). Second, an organization needs to analyze the networks (A) in order to gain an understanding of them. Third, an organization should seek to actively shape these networks (S). Thus, I refer to the RAS approach (recognize, analyze, shape).

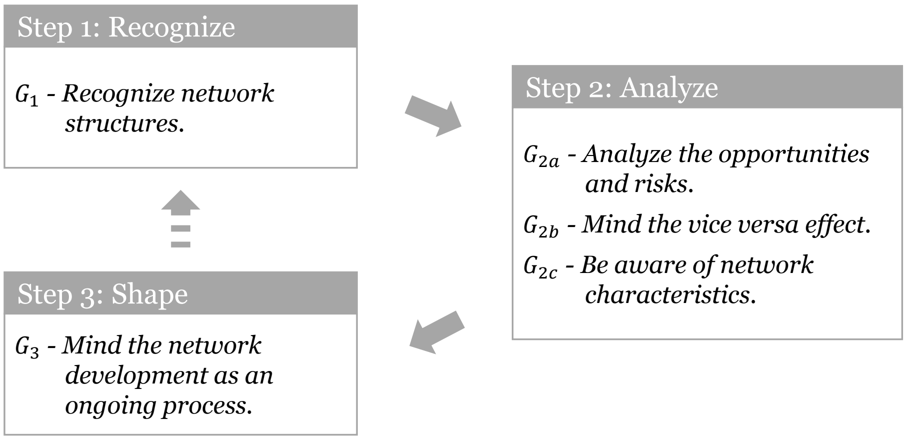

Figure 1. The RAS approach (recognize, analyze, shape).

In Figure 1, I depict the three steps of the RAS approach, which I will now outline. In particular, I formulate five generic guidelines for organizations on which aspects are important to consider in the RAS approach. Thus, the guidelines are not to be understood as mandatory tasks to perform or a checklist, but rather as a proposal of important aspects to consider on a meta-level. There is one guideline (G1) in the R-step, three (G2a to G2c) in the A-step, and one in the S-step (G3). I base G2a, G2b, and G3 on Håkansson and Ford's (2002) findings and extend them to allow for a more generic perspective on network structures. I add G1 in the initial and important R-step, to develop an awareness of network structures. I add G2c, since it reflects a core property of networks: the possibility of cascade effects.

Step 1: Recognize (R)

G1 Recognize network structures.

Organizations should be aware of their networks. This refers not only to a specific network type, but to all types (technological, social, information, and so on), also regardless of the network classification, i.e. whether the network is intra-organizational or inter-organizational, directed or undirected, and so on.

Step 2: Analyze (A)

G2a Analyze the opportunities and risks.

Organizations should be aware of the opportunities and risks that accompany networks. In particular, organizations should carefully analyze before entering or using a network, and while they are part of the network, regardless whether or not joining the network is an option. Networks also have restrictions that can be risks.

G2b Mind the vice versa effect.

Organizations should be aware that single nodes can influence the network and, particularly, that the network can also influence single nodes.

G2c Be aware of network characteristics.

Organizations should be aware that networks have specific properties such as cascade effects that spread through the network. This can yield positive and negative effects. This also holds true for intra-organizational networks.

Step 3: Shape (S)

G3 Mind the network development as an ongoing process.

Organizations should be aware that networks usually change continuously. This provides opportunities to shape such development (to a certain extent). However, full control of a network is not likely, and too much control may also unintentionally limit a network's development.

The RAS approach and the related guidelines illustrate the key challenges when dealing with networks: First, creating an awareness of network structures when they are present (step 1); second, analyzing these structures from a network perspective to better understand their impacts on the organization (step 2); third, shaping the network in a way that benefits the organization (step 3).

2.2.1 Step 1: Recognize (R)

G1 emphasizes the importance of network awareness. Without an awareness of network affiliations, the related effects cannot be considered, and an understanding will not develop. Further, organizations should seek to holistically picture all network affiliations, otherwise specific networks or network properties will likely be neglected.

Thinking of certain structures from a network perspective allows one to gain insights into the relationships in the environment. Mouzas et al. (2008) positioned the network perspective as one of three managerial perspectives that look at business networks. As noted, one approach is to look at network structures at different levels, for instance, at the individual level, the intra-organizational level, and the inter-organizational level (Mouzas et al. 2008). However, for organizations, the latter two are likely crucial. Thus, concerning G1, a straightforward approach for organizations could be to differentiate between their intra-organizational and inter-organizational networks. Looking ahead to steps 2 and 3, this segmentation has various advantages. First, the differentiation between what happens inside an organization and what happens outside it is intuitive. Second, the control level can be assumed to correspond to this segmentation as intra-organizational networks are (in principle) under the organization's control. Notably, this does not mean that all effects and the dynamics in intra-organizational networks can be controlled by the organization (G3); yet the organization can actively shape many aspects of intra-organizational networks whereas, in inter-organizational networks, the organization can only influence certain parts of the network and its development. Third, this distinction does not restrict further subclassification, because intra-organizational and inter-organizational networks comprise all network types.

Once an organization has gained an overview of which networks it is part of, as a second step, the questions arise how to analyze the networks and what the implications are.

2.2.2 Step 2: Analyze (A)

Analyzing networks is important to understand the specific outcomes that networks produce (Provan and Kenis 2007). Yet, the question how to analyze a certain network is not an easy one. Considering the sheer number and diversity of network types, it is unsurprising that there is "no definite methodological approach for studying networks" (Jack 2010, p. 127). However, quantitative methods are dominant, compared to qualitative ones (Jack 2010). Both quantitative and qualitative methods have their advantages and disadvantages. For instance, single case studies have limited representativeness and limited generalizability, and quantitative measures are technical and limited in their ability to explain relationships content-wise (Jack 2010). Since networks contain both qualitative and quantitative dimensions, methods for network analysis should ideally contain both aspects (Coviello 2005). Further, because networks are dynamic, approaches should ideally consider a time perspective (Ahn et al. 2014; Coviello 2005). Since the choice of an appropriate approach is case-specific, and to not exceed the scope of this thesis, I focus on selected methods for network analysis in the various papers (see Section 6).

Regardless of subsequent actions, continuing the distinction from step 1 between intra-organizational and inter-organizational networks aligns well with the guidelines for step 2. Then, the beginning of an analysis from a network perspective can be any type of visualization, which is a good start to understanding network structures (Ahn et al.

2014). It can clarify the structure of the network, its members, and interactions (Ahn et al. 2014), and can support strategic decision-making (Killen and Kjaer 2012). For instance, the visualization can go hand in hand with modeling a network using graph theory.

Subsequently, using quantitative models or specific network algorithms is an often-used approach to analyze and understand complex network structures. Researchers have applied various techniques in different research fields. For instance, centrality measures were applied to social network analysis early on (Bonacich and Lloyd 2001, Freeman et al. 1979). Because uncertainty prevails in many real-world scenarios (Koller and Friedman 2009), structured probabilistic models such as Bayesian network modeling have been applied for instance to supply chain networks (Garvey et al. 2015), process plants (Khakzad and Reniers 2015), and to organizational risk analysis (Trucco et al. 2008). Further, cascade algorithms can be applied to various network structures, for instance to model power grids (Shao et al. 2011) or the spread of diseases (Brockmann and Helbing 2013). Altogether, there are many and diverse methods to analyze networks so as to develop a better understanding of them, no matter whether the models are quantitative or qualitative, or both. In this thesis, I primarily use quantitative methods for analysis, and outline the methods in the individual papers in Section 6.

G2a to G2c can provide guidance when choosing and applying network analysis methods. Appropriate methods should ideally allow to analyze both opportunities and risks (G2a), depending on various aspects, for instance the network type. If the network is supposed to only depict risks, for instance, an analysis can only be risk-related.

An important consideration closely related to G2b is whether a network should be regarded as a whole from a bird's eye view or from the perspective of a single node. For instance, there can be a difference between minimizing the risk for the entire network, or for one node in it. G2b emphasizes that single nodes influence the network, and vice versa. Here again, this aligns well with the distinction between intra-organizational and inter-organizational networks. For intra-organization networks, an organization implicitly already has a bird's eye view whereas, in inter-organizational networks, only certain parts or single nodes may be of particular importance to an organization. However, this distinction is by no means mandatory.

G2c focuses on specific properties of networks, such as the possibility of cascade effects. Cascade effects can have strong impacts, and can be the "result of the inherent system dynamics rather than of unexpected external events" (Helbing 2013, p. 52). This implies that almost any network can be subject to cascade effects. Thus, cascade effects should be carefully considered when analyzing networks.

While the guidelines I outline here are supposed to work at a meta-level, the choice of an appropriate method of analysis and the subsequent interpretation are very case-specific tasks. Nonetheless, considering the guidelines can help along the journey towards a better understanding of an organization's networks.

2.2.3 Step 3: Shape (S)

Since the possibilities to influence and shape a network (step 3) depend on the network type and the specific case, I emphasize only one generic guideline (G3) in this step: Because networks usually develop continuously, an awareness of such development is needed.

In line with steps 1 and 2 of the RAS approach, when thinking about shaping a network (i.e. guiding its development in a particular direction), distinguishing between intra-organizational and inter-organizational networks is a good starting point. Intra-organizational networks are presumably easier to influence than inter-organizational ones, because all nodes and all edges are within the organization, i.e. the entire network as well as every node and edge can be influenced directly. For instance, technological networks in an organization such as its Wi-Fi network are easy to alter. Yet, within an organization, social dynamics in a specific business unit may be harder to influence. Yet, influencing social dynamics between organizations is most likely even harder than for intra-organizational networks, because an organization's influence depends on its position in the network (Håkansson and Ford 2002). However, in both cases, organizations should be aware of the changes in the network. New nodes and new edges can develop, and connections can become stronger or weaker.

Particularly newly developing technologies lead to newly developing network-like structures. This provides opportunities to ongoingly shape their development, or their application fields. New products provide opportunities for organizations to actively shape them and how we use or interact with them in the future. For instance, IoT will increase the potential attack surfaces for cyber-criminals in the future (Lee and Lee 2015). Thus, defining standards for IoT-related technologies is a possibility to shape their development and the development of related networks. As another example, organizations are increasingly looking for viable blockchain use cases (Fridgen et al. 2018b). Thus, the design of blockchain protocols, software, and standards will depend among others on legislation, regulation levels, and adoption.

In this process of technological development, organizations face the challenge to interact with these new concepts, for which no standard approach is available. Thus, we need research into how to shape these emerging networks as well as to use the opportunities and mitigate the risks of new technological concepts.

3 Networks from Underlying Digital Technologies and Their Business Relevance

I look at interactions in IT project portfolios (ITPPs) (Paper 1: Radszuwill and Fridgen 2017; Paper 2: Neumeier et al. 2018), governance implications of technological platform use in IoT (Paper 3: Fridgen et al. 2018a), and the use of blockchain technology for letters of credit in international trade finance (Paper 4: Fridgen et al. 2018c). Thus, I address the roles of three distinct network structures that are closely related to digital technologies. ITPPs constitute an example of primarily intra-organizational networks, while IoT and the networks related to international trade and blockchain are examples of inter-organizational networks. I briefly outline and provide relevant background information for every paper, before describing how each contributes to the RAS approach I have introduced. I sum up the results in Figure 2. I distinguish whether a guideline is considered: ✓, partly considered: (✓), or not considered: ×. Papers 1 and 2 focus on steps 1 and 2, while Papers 3 and 4 focus on step 3 of the RAS approach.

	Intra-organizational network		**Inter-organizational network**	
	Paper 1: Radszuwill and Fridgen (2017)	Paper 2: Neumeier et al. (2018)	Paper 3: Fridgen et al. (2018a)	Paper 4: Fridgen et al. (2018c)
Step 1: guideline G1	✓	✓	(✓)	(✓)
Step 2: guideline G2a	✓	(✓)	(✓)	✓
guideline G2b	(✓)	✓	(✓)	(✓)
guideline G2c	✓	✓	(✓)	×
Step 3: guideline G3	(✓)	×	✓	✓

Figure 2. Classification of the research papers concerning the RAS approach.

3.1 IT Project Portfolios

Owing to the increasing spending on IT (Gartner 2018), the importance of IT projects – particularly to large organizations – is clear. An IT project is not necessarily a project that implements or adjusts an IT system; rather, it can be understood as a project associated with IT. Between IT projects in an organization, many and varied interactions exist; these make an ITPP an IT project network (Radszuwill and Fridgen 2017). In the literature, there is no one definition or categorization of these interactions; we even lack an unambiguous wording (Radszuwill and Fridgen 2017). Thus, I follow Eilat et al. (2006) and Heinrich et al. (2014), using *interaction* as an umbrella term that encompasses all connections within an ITPP (Radszuwill and Fridgen 2017). Further, I use *(inter)dependency* to depict interactions that constitute one project that depends on another, and *synergy* to depict interactions that both projects benefit from.

There has been little research into ITPPs from a network perspective. Wolf (2015) and Beer et al. (2015) were the first to take such a perspective. Following their network interpretation of ITPPs, we take on a network perspective on ITPPs in Paper 1: Radszuwill and Fridgen (2017) and Paper 2: Neumeier et al. (2018). Thus, we perform step 1 of the RAS approach, recognizing ITPPs as networks, and follow G1 in both research projects. Accordingly, we model the ITPPs using directed or undirected acyclic graphs, depending on the interactions and their properties, addressing step 2 and providing a visualization of IT project networks – a first step towards a network analysis.

Interactions between IT projects can lead to cascading effects in case one project fails to deliver the desired output. This can affect an entire ITPP. Thus, IT project failures have been linked to a lack of considering interactions between IT projects (Buhl 2012). However, interactions such as resource-sharing can also yield positive effects such as cost savings. In Radszuwill and Fridgen (2017), we focus on step 2 of the RAS approach and analyze resource interactions, particularly in IT project networks. By looking at resource interactions and their specific properties, we introduce the distinction between personnel and non-personnel/technical resource interactions. We follow G2a, analyzing both resource synergies and dependencies, i.e. the opportunities and risks arising from resource interactions in IT project networks. This is reflected in our research question:

How can (candidate) IT projects be ranked considering both resource synergies and dependencies with regard to the specific IT project network characteristics?

By using alpha centrality as a quantitative approach for network analysis, we follow G2c, addressing the network characteristics. We provide an application example and illustrate how an analysis of the network (step 2) can be used in project portfolio selection processes. We also partly address step 3 (G3), since this knowledge provides opportunities to shape the development of an organization's IT project network in the future.

In Paper 2: Neumeier et al. (2018), we follow a similar research approach, but with a focus on dependencies, the associated risk analysis, and the criticality of single projects on the entire ITPP. Thus, in this paper, we focus on G2b, analyzing the criticality of single IT projects via a Bayesian network modeling approach that integrates two dependency types between projects: technical and resource dependencies. Thus, we bridge the lack in the research of an incorporation of different dependency types and transitive dependencies. We regard an IT project as "more critical when it is more critical for the ITPP's success" (Neumeier et al. 2018, p. 834). We address this research question:

How can the criticality of single IT projects in interdependent ITPPs be analyzed and assessed using a Bayesian network modeling approach?

We use a Bayesian network modeling approach to compute the risk exposure for every project in the ITPP. To illustrate and analyze our model, we use a real-world ITPP of a medium-sized research organization. We illustrate the importance of looking at the criticality of single projects for the entire network (G2b, G2c), since one node in a network can strongly influence the network, and vice versa.

3.2 Technology Platforms in the Internet of Things

IoT is a newly developing network-like structure based on digital technologies. Although we lack a common definition for IoT (Wortmann and Flüchter 2015), it generally refers to a multitude of physical objects connected to the Internet – thus, objects integrated "into the networked society" (Oberländer et al. 2017, p. 486). With more than 25 billion devices estimated for IoT by 2020 (Yu et al. 2015), IoT will constitute one of the largest real-world network structures. Many of these devices will be based on the same technological platforms, be it software, hardware, or standards (Fridgen et al. 2018a). Something that is somewhat specific to IoT is that not only devices of the same model (with the same physical shape) are based on the same technological platform; further, different devices are based on the same software platform (e.g. the D-Link Wi-Fi web camera and TomTomGo navigation systems use the same software platform, BusyBox) (BusyBox 2018). This implies that potential security vulnerabilities in such technological platforms constitute a huge risk for single devices and for IoT generally. What makes the situation even more complex is that various stakeholder and interest groups are involved in IoT, owing to different products using the platform and IoT's globality. The interests of manufacturer companies, supplier companies, end-users, and regulatory agencies must be balanced against one another. Since IoT's development is still in its early stages, there are opportunities to guide IoT governance in a direction that maximizes the opportunities and minimizes the risks.

Thus, in Paper 3: Fridgen et al. (2018a), we look at influencing parameters for technology platform security and governance implications in IoT. We address this research question:

What are implications for security governance at the individual, company, and regulatory levels to deal with technology platforms in IoT?

We transfer a model for platform risk analysis from the automotive industry (Kang et al. 2015) to IoT. We analyze how certain parameters influence security exploits in IoT technology platforms, partly addressing G2a. We then derive and discuss various governance measures at the levels of individuals, companies, and regulatory agencies. Thus, we particularly contribute to step 3 of the RAS approach. We discuss how IoT can be shaped (G3) using specific governance measures.

3.3 Blockchain Technology for Letters of Credit

Blockchain technology builds new network structures owing to its inherent distributed nature. Blockchain, first introduced as the technology behind Bitcoin (Nakamoto 2008), has since developed and will most likely change various industries, particularly the financial services industry (Fanning and Centers 2016; Glaser 2017; Guo and Liang 2016; Walsh et al. 2016). In short, blockchain technology is a decentralized data structure that stores transactions in a tamper-proof way in a distributed network

(Fridgen et al. 2018d). Like the IoT, blockchain is still in the early stages of development. This provides opportunities to simultaneously explore and leverage the technology's potential while actively shaping its development.

Blockchain's core properties provide various opportunities in international trade finance. In Paper 4: Fridgen et al. (2018c), we explore whether and how blockchain technology can be an alternative to a letter of credit (LoC), a payment instrument in international trade finance. For LoCs, the processes remain slow and bulky (Fridgen et al. 2018d). By re-engineering existing processes based on blockchain, we propose a change in the network characteristics, in two ways. First, we establish a new network structure via the use of blockchain technology; second, we challenge existing network structures for business processes for LoCs. Thus, we ask:

Can blockchain technology provide an alternative compared to centralized approaches for a letter of credit?

In our design science research process, we mostly address steps 2 and 3 of the RAS approach. We address G2a, since we analyze the opportunities and risks that accompany the use of blockchain for LoCs. Thus, we investigate different approaches to improve current LoC processes and look at specific network properties from a process perspective (G2c). We then develop a re-engineered process for LoCs using blockchain that implies changing the network participants, their interactions, and the underlying technology, particularly addressing step 3 of the RAS approach and providing guidance about what future networks for LoCs can look like – thus, how blockchain as a new digital technology can be used to shape the future of a technological and business network.

4 Conclusion

4.1 Contribution, Limitations, and Outlook

Network-like structures occur in various circumstances, and often relate to digital technologies. In this thesis, I provide a short introduction to general network structures before I propose the RAS approach (recognize, analyze, shape) for organizations on how to handle networks. This is a structured procedure for both research and practice based on the insights provided by Håkansson and Ford (2002). I extend their focus on business networks to a more general perspective. Each RAS step contains guidelines that focus on important aspects for organizations to consider when dealing with networks. Thus, I provide an approach that generally applies to network structures and allows one to integrate more specific network analysis procedures in each step. I outlined how the four papers in this thesis align with the RAS approach's steps and the guidelines. In Radszuwill and Fridgen (2017) and Neumeier et al. (2018), we contribute primarily to steps 1 and 2. We contribute that IT project portfolios should be recognized as IT project networks (step 1) and provide first methods for analysis of these networks (step 2). In Radszuwill and Fridgen (2017), we analyze the opportunities and risks of resource interactions using alpha centrality as analysis method. In Neumeier et al. (2018), we provide an approach to compute the risk exposure of each project in an IT project network based on Bayesian network modeling. In Fridgen et al. (2018a) and Fridgen et al. (2018c), we focus on step 3 of the RAS approach. In Fridgen et al. (2018a), we analyze the risk related to technology platform use in IoT and derive governance implications on how to shape future IoT in this regard. In Fridgen et al. (2018c), we focus on the use of blockchain technology to improve the process for a letter of credit. We analyze the current state of the process and provide a blockchain-based re-engineered process, outlining how future business networks can be shaped by blockchain technology. Overall, we illustrate how digital technologies change current network structures and how they may shape future network structures. Further, we provide methods for analysis of specific networks and propose solutions to prevailing and future challenges in such networks.

The RAS approach has limitations[2]. First, the approach is a general one and must be adapted and used with care in every specific case. Second, for each RAS step, a more detailed analysis is necessary depending on the application field and further context. Third, the approach is based on the work of Håkansson and Ford (2002), which is concerned with business networks in particular. Although extended to consider general network properties, the approach may still best fit business networks. Fourth, the provided guidelines intend to reflect the most important aspects to consider when dealing with networks. However, there may be further context-specific aspects that are not reflected in the RAS approach.

The approaches to network structures need further research. For the RAS approach, a

[2] For limitations on each research paper, kindly refer to that paper.

further specification of single steps and guidelines in greater detail, and the evaluation of the applicability of the approach, are necessary. Network structures in the application fields of this thesis also need further research. In IT project networks, while first research steps that relate to steps 1 and 2 of the RAS approach have been conducted, there is room for research into how these network structures affect IT project and IT project portfolio management in practice. In particular, there is room for research into step 3, for instance, how IT project networks can be shaped to mitigate the risk of IT project failure. IoT and blockchain technology are still in their early development stages. Since both comprise inherent network structures at various levels, there are many research opportunities. For instance, since IoT challenges IT security, more research on security-related aspects such as cascade effects at the global scale is needed. For blockchain, there are still many open questions to consider for specific use cases. Thus, research at the intersection of technology development and practical application is needed in various application fields.

Since our world is becoming more equipped with digital technologies and is becoming increasingly interconnected, we need to recognize the newly developing network structures and analyze their potentials and threats. This will put us in a position to shape their development in ways that maximize the opportunities and minimize the risks.

4.2 Acknowledgement of Previous Work

I conducted all my research with colleagues at the Finance and Information Management (FIM) Research Center and the Project Group Business and Information Systems Engineering of the Fraunhofer Institute for Applied Information Technology (FIT). Thus, I point out how my research builds on these organizations' previous work. The papers by Radszuwill and Fridgen (2017) and Neumeier et al. (2018) continue a key research stream of the FIM Research Center that has addressed IT project management and IT project portfolio management. In particular, the work of Buhl (2012), Beer et al. (2013), Fridgen et al. (2015), Beer et al. (2015), Fridgen and Zare Garizy (2015), and Wolf (2015) has set the path for this research. Fridgen et al. (2018a) continues preliminary work in the IoT field by Püschel et al. (2016), Oberländer et al. (2017), and Berger et al. (2018), and applies mathematical models to the IS domain – as in Fridgen and Müller (2009), Fridgen and Müller (2011), and Fridgen et al. (2016), for instance. Fridgen et al. (2018c) continues a young research stream on blockchain technology, building on groundwork by Schlatt et al. (2016), Schweizer et al. (2017), Fridgen et al. (2018d), and Fridgen et al. (2018e).

Thus, this thesis fits well with this preceding work, continuing successful research streams relating to IT project and project portfolio management, and contributing to new streams for future research into IoT and blockchain.

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6 Appendix

6.1 Papers Relevant for This Thesis

Paper 1

Radszuwill, S.; Fridgen, G. (2017): Forging a Double-edged Sword: Resource Synergies and Dependencies in Complex IT Project Portfolios.

In: *Proceedings of the 38th International Conference on Information Systems*, Seoul, South Korea, 2017. (VHB Jourqual 3 Category A)

Paper 2

Neumeier, A.; Radszuwill, S.; Zare Garizy, T. (2018): Modeling Project Criticality in IT Project Portfolios.

In: *International Journal of Project Management*, (36:6), pp. 833-844. (VHB Jourqual 3 Category C, Impact Factor 2017: 4.328)

Paper 3

Fridgen, G.; Jöhnk, J.; Radszuwill, S. (2018): When Your Thing Won't Behave: Security Governance in the Internet of Things.

Paper 4

Fridgen, G.; Radszuwill, S.; Schweizer, A.; Urbach, N. (2018): Blockchain Won't Kill the Banks: Why Disintermediation Doesn't Work in International Trade Finance.

6.2 Declaration of Co-authorship and Individual Contribution

In this section, I outline the individual contribution of all co-authors to the included papers[3].

Paper 1: Forging a Double-edged Sword: Resource Synergies and Dependencies in Complex IT Project Portfolios.

I co-authored this research paper with Gilbert Fridgen. The co-authors have contributed to the paper in the following way.

Sven Radszuwill (leading co-author)

Sven Radszuwill contributed by introducing and developing the entire research project. He conducted the literature analysis, developed the model, carried out the simulation, and the textual elaboration. Thus, Sven Radszuwill's co-authorship is reflected in the entire research project.

Prof. Dr. Gilbert Fridgen (subordinate co-author)

Gilbert Fridgen supervised the research project and provided mentorship. He contributed by providing feedback to the article structure and the article's foundations.

Paper 2: Modeling Project Criticality in IT Project Portfolios.

I co-authored this research paper with Anna Neumeier and Tirazheh Zare Garizy. The co-authors have contributed to the paper in the following way.

Anna Neumeier (co-author)

Anna Neumeier contributed to the article structure and textual elaboration. Thus, Anna Neumeier's co-authorship is reflected in the entire research project and has a focus on Sections 1 and 2.

Sven Radszuwill (co-author)

Sven Radszuwill contributed to the article structure and textual elaboration, and by further developing the paper's evaluation and discussion section. In particular, he revised the model, and carried out simulation and textual elaboration. Thus, Sven

[3] A signed copy declaring the authors' individual contribution for each paper has been submitted with this thesis. This section's content has been translated from these German original documents.

Radszuwill's co-authorship is reflected in the entire research project with a focus on Sections 3 to 6.

Tirazheh Zare Garizy (co-author)

Tirazheh Zare Garizy contributed by introducing the research idea and developing it initially. In particular, Mrs. Zare Garizy contributed by conceptualizing the model. Thus, Tirazheh Zare Garizy's co-authorship has a focus on the paper's model section.

Paper 3: When Your Thing Won't Behave: Security Governance in the Internet of Things.

I co-authored this research paper with Gilbert Fridgen and Jan Jöhnk. The co-authors have contributed to the paper in the following way.

Gilbert Fridgen (co-author)

Gilbert Fridgen supervised the research project and provided mentorship. He contributed by providing feedback to the research idea, research content, article structure, and textual elaboration. Thus, Gilbert Fridgen's co-authorship is reflected in the entire research project with a focus on Sections 1, 2, 4, and 5.

Jan Jöhnk (co-author)

Jan Jöhnk contributed by introducing, developing, and elaborating the entire research project. In particular, Jan Jöhnk contributed to the literature analysis and the elaboration of governance implications in the research context. Thus, Jan Jöhnk's co-authorship is reflected in the entire research project with a focus on Sections 1, 2, 4, and 5.

Sven Radszuwill (co-author)

Sven Radszuwill contributed by introducing, developing, and elaborating the entire research project. In particular, he conducted the model analysis and carried out textual elaboration. Thus, Sven Radszuwill's co-authorship is reflected in the entire research project with a focus on Sections 3 to 5.

Paper 4: Blockchain Won’t Kill the Banks: Why Disintermediation Doesn’t Work in International Trade Finance.

I co-authored this research paper with Gilbert Fridgen, André Schweizer, and Nils Urbach. The co-authors have contributed to the paper in the following way.

Gilbert Fridgen (co-author)

Gilbert Fridgen supervised the research project and provided mentorship. He contributed by providing feedback to the research idea, content, article structure, and textual elaboration. In particular, Gilbert Fridgen’s co-authorship is reflected in the various concepts for future blockchain-based international trade finance solutions.

Sven Radszuwill (co-author)

Sven Radszuwill contributed by introducing, developing and elaborating the entire research project. In particular, he conducted the literature analysis, developed various concepts for future blockchain-based international trade finance solutions, conducted the evaluation, and carried out textual elaboration. Thus, Sven Radszuwill’s co-authorship is reflected in the entire research project.

André Schweizer (co-author)

André Schweizer contributed by developing and elaborating the entire research project. In particular, he conducted the literature analysis, developed various concepts for future blockchain-based international trade finance solutions, conducted the evaluation, and carried out textual elaboration. Thus, André Schweizer’s co-authorship is reflected in the entire research project.

Nils Urbach (co-author)

Nils Urbach supervised the research project and provided mentorship. Further, Nils Urbach’s conducted textual elaboration.

6.3 Paper 1: Forging a Double-Edged Sword: Resource Synergies and Dependencies in Complex IT Project Portfolios

Authors: Radszuwill, Sven; Fridgen, Gilbert

Published in: Proceedings of the 38th International Conference on Information Systems, Seoul, South Korea, 2017

Abstract: These days, due to the high level of interactions between individual projects, IT project portfolios are best described as IT project networks. While varied and frequent interactions between single IT projects create additional risks, they also generate the possibility of additional synergistic effects. This, however, is not reflected in current methods for IT project portfolio evaluation and project portfolio selection, which neither account for specific network characteristics nor do they clearly distinguish between the types of interaction and their effects. In this paper, we model resource synergies and dependencies within IT project networks by means of weighted, undirected and directed graphs and describe how alpha centrality allows for an assessment of both. We further illustrate the importance of accounting for network characteristics and the equal importance of distinguishing between resource synergies and resource dependencies. Our model can therefore be applied to gain practical insights on IT project portfolios.

6.4 Paper 2: Modeling Project Criticality in IT Project Portfolios

Authors: Neumeier, Anna; Radszuwill, Sven; Zare Garizy, Tirazheh

Published in: International Journal of Project Management (36:6), pp. 833-844

Abstract: Today's IT project portfolios (ITPP) contain many projects and varied interdependencies. Depending on a project's criticality to the ITPP, a failure can have massive consequences. However, existing methods usually only assess overall project portfolio risk and do not account for the criticality of single projects and their dependencies. Applying Bayesian network modeling to ITPPs, we bridge this gap and extend the current body of knowledge for the information systems and project management literatures. Our new method analyzes single projects' criticality in a portfolio context by considering both transitive dependencies and different dependency types in an integrated way. Since we demonstrate that single projects' criticality can vary substantially, being aware of which projects are critical is a key success factor for ITPP management. For practitioners, our method provides a straightforward procedure to enhance ITPP risk management.

6.5 Paper 3: When Your Thing Won't Behave: Security Governance in the Internet of Things

Authors: Fridgen, Gilbert; Jöhnk, Jan; Radszuwill, Sven

Extended Abstract[4]

The Internet of Things (IoT) constitutes a new paradigm, with interconnected smart things enabling new products and services in a blended, physical and digital world. Smart things inherit IT security risks from their digital component, emphasizing them via IoT-specific vulnerabilities such as physical representation, connectivity, or use of technology platforms (TPs). In IoT, TPs describe a tangible (e.g. hardware) or intangible (e.g. standards) general-purpose technology that is shared between different smart things. TPs are evolving rapidly owing to their functional and economic benefits. Yet, this is partly to the detriment of security and governance cannot keep pace with technological development, as several recent IoT security incidents demonstrate.

We address this problem by explaining the situation's dynamics with a risk quantification approach from platforms in the automotive industry (Kang et al. 2015). We define an *IoT platform* as any component type (hardware, software, or standard) that is shared between smart things. We regard a smart thing as the product, which is a "previously nondigital physical artifact" (Yoo et al. 2012, p. 1399) that is now equipped with digital technology (Yoo et al. 2012). We consider an *IoT model* to be a type of smart thing that is based on a specific TP. This implies that different IoT models' physical shapes can vary substantially. We consider an *IoT unit* as one specific smart thing.

Further, we transfer the concepts of TP defect and failure (Kang et al. 2015) to the specifics of TPs in IoT. We follow the classification of Howard and Longstaff (1998) and draw on the notion of *vulnerability* and *exploit*, to account for the IS specifics of TPs. A *vulnerability* is "a weakness [in the design, implementation, or configuration] of a system allowing unauthorized action" (Howard and Longstaff 1998, p. 14). An *exploit* is a successful "group of attacks that can be distinguished from other attacks

[4] At the time of publication of this thesis, this paper is in the review process of a scientific journal. Thus, I provide an extended abstract that covers the paper's content.

because of the distinctiveness of the attackers, attacks, objectives, sites, and timing" (Howard and Longstaff 1998, p. 15). An *attack* is a combination of vulnerabilities, tools, actions, targets, and unauthorized results (Howard and Longstaff 1998). Analogous to Kang et al.'s (2015) definition of a defect, a *vulnerability* refers to a flawed design. Thus, an *exploit* constitutes a manifestation of a vulnerability of the IoT TP.

Using the following parameters: *correlation* between different models of a TP (homogeneity/heterogeneity), *vulnerability probability*, *exploit probability*, *platform size*, as well as TP *connectivity*, we outline and discuss the implications for security risks of TP use in IoT. We argue that these parameters should be considered in IoT governance decisions and delineate governance implications. We distinguish the following levels for IoT governance measures: *Individual level*, i.e. professional or private end-users of smart things; *supplier company level,* i.e. companies developing the TP as well as *manufacturer company level*, i.e. companies adopting the TP in their smart things; and r*egulatory level*, i.e. policymakers, regulators, and authorities.

Based on the parameter's impact, we then identify several potential governance measures at the individual, company, and regulatory levels. For example, from the individual perspective, IoT TPs are often not apparent, limiting the potential governance measures to increasing awareness and security-focused behaviors. However, we see the need for stronger collaboration at the company and regulatory levels to find an appropriate balance between regulation and open interfaces of IoT. This is especially challenging considering the requirement for international regulation frameworks owing to a global IoT.

With our research, we provide initial evidence on promising governance measures for IoT TPs. Thus, we contribute to the descriptive body of knowledge by elucidating TP use in IoT as well as the associated risks. By transferring Kang et al.'s (2015) risk quantification approach from the automotive industry, we explain the situation's dynamics by addressing "the underlying causal structure of the theory" (Meredith et al. 1989, p. 303). We outline which parameters of TPs affect the risks of TP use in IoT and delineate governance implications. Thus, we help to reveal the relevant cause-and-effect relationships, which individuals, companies, and regulators can incorporate for sound risk assessments.

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6.6 Paper 4: Blockchain Won't Kill the Banks: Why Disintermediation Doesn't Work in International Trade Finance

Authors: Fridgen, Gilbert; Radszuwill, Sven; Schweizer, André; Urbach, Nils

Extended Abstract[5]

Particularly in the financial services industry, blockchain is assumed to have significant impact. From research and practice, we observe two main paradigms of how organizations interact with blockchain technology. First, organizations use blockchain to optimize existing processes (blockchain-based business process optimization – BPO). Second, organizations regard blockchain as an approach to disrupt existing processes, foster disintermediation, and enable disruptive business models (blockchain-based business process disruption – BPD). Although the technology is entering the market and promises significant improvements compared to existing approaches, scientific research that evaluates its de facto potential is scarce.

We bridge this gap by following a design science research approach (Hevner et al. 2004; Peffers et al. 2007) aiming at a blockchain-based business process re-engineering (BPRE) for a letter of credit (LoC) that combines the advantages of BPO and BPD. We conduct three design cycles and develop three artefacts: a BPO, a BPD, and a BPRE approach. We particularly investigate how the BPO and BPD prototypes differ and which approach may be favored in which regard. The BPO prototype is still very close to the current process of an LoC, and primarily aims at incremental process improvements. In contrast, the BPD prototype builds on an entirely different, disintermediated process for LoCs. We evaluate the approaches in detail by examining eight design evaluation criteria (process time, process flexibility, process transparency and tracking, process costs, reliable and secure transaction processing, trust and identification mechanism, dependency on intermediary services, capital tie-up period) and through expert interviews. The evaluation indicates that both the BPO and BPD

[5] At the time of publication of this thesis, this paper is in the review process of a scientific journal. Thus, I provide an extended abstract that covers the paper's content.

approach are not a perfect fit for the LoC process requirements. However, it also reveals a striking match between the BPO prototype's weaknesses and BPD prototype's strengths, and vice versa. Thus, combining the two approaches, the BPRE solution seeks to leverage the blockchain-specific characteristics and potential advantages, while incorporating the holistic business objectives. Although full disintermediation seems unlikely for LoCs, we outline that blockchain-based processes like the BPRE approach can lead to increased efficiency and new market structures including fewer participants in the future.

With our research we address four of the future research directions for blockchain technology in business process management raised by Mendling et al. (2018). First, with our design science research, we developed two prototypes, evaluated them comprehensively, and derived a re-engineered solution for an LoC. Thus, we not only demonstrate the feasibility of blockchain as basis of execution and monitoring systems (process-aware information systems), but also indicate benefits and challenges of different implementations. Second, our research approach responds to the call for valid methods of analysis and engineering for business processes based on blockchain. Third, through our iterative research and the integration of experts from practice, we illustrate and confirm how blockchain allows for redesigning processes. Fourth, we demonstrate how blockchain influences existing structures and roles of ecosystem participants.

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