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Zuid-Holland

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Yvonne Lont Rotterdam University of Applied Sciences
Klara Paardenkooper Rotterdam University of Applied Sciences
Ron van Duin Rotterdam University of Applied Sciences, Delt University of Technology

ABSTRACT

This paper contains a cross-case analysis of 21 feasibility studies on the application of blockchain in 16 companies, performed at two Universities of Applied Sciences as a part of the research SIA-Raak project 'From hype to reality' between 2018 and 2020 and the affiliated BlockStart project. The paper analyses the effect of blockchain on the KPIs of the companies, by inventorying and classifying the KPIs and connecting them with the logistics processes. The research findings show that the main benefits of blockchain for these companies are transparency and traceability, especially in food chain companies. The advice for these companies is to invest in blockchain. Reasons for companies why they do not invest in blockchain are related to preferences for proven technologies. In these situations, it shows that a better business case can be exploited, or companies already trust each other and do not feel the need to secure trust even more. This cross-case analysis is a first attempt to understand the main drivers for blockchain implementation at companies. For future analysis on blockchain feasibility studies, we advise to use a more standardized set of KPIs and the application of a methodology developed during this project to connect the use of blockchain to the companies' strategies.

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Introduction

Blockchain, a decentral database, is a system that can facilitate trusted transactions including automated payments as it is secure, immutable, and smart contacts can be included in it. According to the literature, it has the potential to circumvent using middlemen, such as banks, notaries, and forwarders as the trust that these parties supply is transferred to the code, which is free of intentional or unintentional human errors. Blockchain is a disruptive technology for logistic processes as it facilitates direct decentral transactions between parties in the supply chain, without the traditional cooperation of trusted third parties (Casino, 2019). Trust in intermediaries is replaced by trust in the program code and consensus rules (including smart contracts), which make well-applied blockchains safe (Capgemini, 2018). Blockchain has numerous applications, in health, education, privacy and security, business and industry, data management, finance, integrity verification, governance and Internet of Things (Casino, 2019). Despite the fact that it is a relatively new technology, there is a consensus in the literature about the prospects of blockchain technology to make logistics processes more efficient. In ports, for example, it can be used for cargo documentation transactions, substituting the paper flows, and, in combination with Internet of Things applications, for process traceability and trade finance (Francisconi, 2017; Paardenkooper, 2020). Kshetri (2018) identifies the benefits of the application of blockchain in the supply chain as costs, speed, dependability, risk reduction, sustainability and flexibility. This potential of blockchain has been recognized by major stakeholders in supply chains, such as Maersk and Kuehne + Nagel. These parties often control extensive door-to-door logistics processes and have the financial means for reaping the advantages of the application. SMEs however, do not have these advantages (Beije, 2016). SMEs often act as intermediaries; their business models might even be endangered by blockchain. Not surprisingly there are only a few proven user cases and in general, these companies are reluctant to adopt this new technology (Gartner 2020). This paper presents the results of a cross-case analysis of research that was performed by students of the universities of applied sciences (HR and Windesheim) within the SIA RAAK project 'From hype to reality' between 2018 and 2020 and the affiliated BlockStart project 'Blockchain-based applications for SME competitiveness'. The majority of the projects was carried in close cooperation with companies. In this paper the specific company names are omitted and companies are just mentioned in accordance with their size, activities, and the industry they belong to, as some of the reports are confidential.

The central research question of the student reports is: 'Is the use of blockchain technology feasible and how can it improve processes of the company(ies)?'. The papers have delivered useful insights on a singular case study level. This publication aims to aggregate the results to show (SME) companies the potential prospects and threats for blockchain for their positions in the supply chain. In order to achieve that the effects of blockchain on the KPIs of the individual cases are analyzed. Thus, the central research question of this paper is:

Which KPIs are (positively) affected by using blockchain?

After this introduction, Section 2 analyses the provenance of the students' reports. Section 3 classifies the companies, followed by the identification of the targeted logistics domains in Section 4. Section 5 inventories and classifies the KPIs that companies have meant to improve by the application of blockchain. Section 6 explains why companies choose to invest in blockchain, links the targeted KPIs to processes, and reveals the reasons why some companies decide against blockchain implementation. We conclude by answering the central research question in Section 7.

Educational background of the student case reports

The cross-case analysis is performed on 21 student reports from two universities of applied sciences, on the applicability of blockchain in companies. Table 1 gives an overview of the educational background of the students and reports. 19 student reports are from the Rotterdam University of applied sciences (RUAS) and two student reports are from the Windesheim University of applied sciences (WUAS). The reports from the master program are 10 individually written master theses, while the International Project report is work performed by a group of students. Seven Bachelor papers are individually written, one is a third-year internship report. The Field integration report from Logistics engineering and the report written within a Minor program are both group work. The reports from RUAS have one Master in Financial Administration, nine students of the Master in International Supply Chain Management (MISCM), and the international project is group work is from MISCM as well.

Table 1 The educational background of the students and the reports

Institute	Educational program	Type of report	Nr
Institute of Built Environment	Logistics Management	Bachelor thesis	5
		Minor Innovative Logistics & IT	1
Rotterdam Mainport Institute	Logistics Engineering	Field Integration project	2
Rotterdam Business School	Master in International Supply Chain Management	Master thesis	9
		International Project	1
	Master in Financial Administration	Bachelor thesis	1
Windesheim university of applied sciences	Supply Chain Finance	Bachelor thesis	1
	Financial Services Management	Bachelor thesis	1

It can be concluded that the student reports are heterogeneous regarding educational background, level, and function. Some students worked individually, others in groups. The educational programs often demanded different ways of analyzing.

The participating companies

The research has been conducted for 16 companies. However, two reports are written at a supply chain level, not connected to a specific company and three reports are written for the same company. Nine of the companies are small and medium size companies (less than 250 employees) and seven are big companies (more than 250 employees). As can be seen in Table 2 the activity of the companies is quite diverse. The largest group is formed by the forwarders with six companies. It can be argued that despite the relatively small sample size the distribution of the cases over the different sectors can be seen as broad. One of the reports at the supply chain level enhances the avocado chain and the other report at the supply chain level focusses on the possibilities of blockchain in procurement. The results of the three reports at the same company are aggregated and counted as one.

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Table 2 The segmentation of the companies

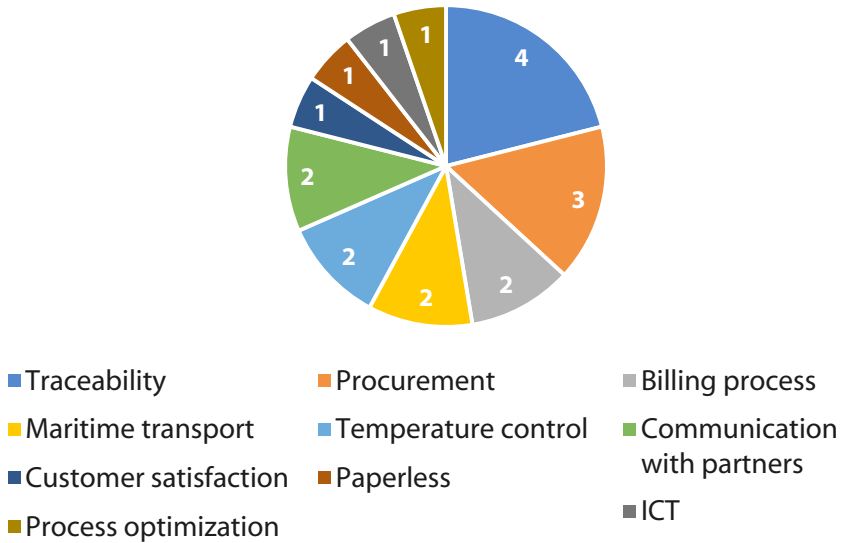| Category	Characteristic	Nr
Company size	SMEs	11
	Big company	7
	Not related to the size of the company (Other)	2
Activity of the company	Freight forwarder	6
	Broiler farm	1
	Dairy ingredients	1
	Importer/ exporter fruit	1
	Marine contractor	1
	Maritime transport	1
	Mobile app and service provider	1
	Oil and gas contractor	1
	Oil transporter	1
	Provenance platform provider in fashion	1
	Software provider	1
	Avocado chain	1
	Procurement	1
	Wholesaler petfood	1
The industry in which the company is active	Food chain	7
	Transport	6
	Energy	3
	Fashion	1
	ICT	1
	Miscellaneous	1
Business model of the company	Service provider	16
	Production	2
	General	1

The number of forwarders (6) is remarkable. These companies act as trusted third parties between the shippers and the transportation companies. Their high representation in this sample shows that they see their business model becoming obsolete, as supply chains become more digitalized. The trust they provide to their clients is being transferred to computer codes and smart contracts. Regarding the industry, companies are involved in a food chain (7), in the transportation sector (6), in the energy sector (1), in the fashion logistics (1), in the ICT sector (1), and in industry (1). This spectrum is in accordance with the literature. Most publications on the use of blockchain in the supply chain refer to the food chain, as traceability gains increasing attention (Kshetri, 2018; Paardenkooper, 2020). The energy companies are big companies, trying to make their processes more efficient as there is pressure on companies dealing with fossil fuels due to the greening of the industry. Literature on fashion shows also growing attention to supply chain transparency for provenance, to empower the consumer to make choices considering fair working conditions and environmental-friendly practices. ICT providers are interested in blockchain, in order to improve their services. The industry 'miscellaneous' refers to the research which analyses the role of blockchain in procurement in general, which is not connected to any specific industry.

The analysis of the business models of companies shows that the vast majority of the companies are service providers (16), and a minority are producers (2) and others (1). The large number of service providers is significant as the services of those companies might be endangered by the wide adoption of blockchain technology (Musigmann, Gracht, & Hartmann, 2020).

The domain of application

The student reports show 10 targeted domains of application of blockchain. One of the reports aims at consumer satisfaction, one report focusses at an ICT application, one report focusses at a digitalized paperless solution connected to transportation, one report has a general objective 'optimizing the whole primary process of the company', two reports focus on the billing process, two reports focus on the communication within partners, two reports aim at maritime transport (on temperature control), three reports focus on procurement and four reports focus on tracking & tracing. The distribution of the domains is in accordance with the literature, which recognizes the most important areas of application of blockchain in information and financial flows connected to transport, paperless application, communication, temperature control and tracking, especially in food chains (Paardenkooper, 2020). Procurement is also a well-known application of blockchain, by means of smart contracting (Sánchez, 2019). Figure 1 gives an overview of the domains of application of blockchain in the reports.

Traceability
Procurement
Billing process
Maritime transport
Temperature control
Communication with partners
Customer satisfaction
Paperless
ICT
Process optimization

Figure 1 The domain of the BCT-applications

KPI analysis

In order to answer the central research question, we analyzed the prevalence of the Key Performance Indicators (KPIs). As shown in the study of Ziles & Strazdina (2018) about blockchain use cases and their feasibility, it is a logical step to use the KPIs as supply chain drivers for the introduction of blockchain technology. Figure 1 shows that Traceability is the most often mentioned domain of the BCT applications, it counts four times. In accordance with this finding, traceability is reported four times as a domain and as a KPI it has the highest prevalence, 9 times mentioned in the case reports (Figure 2). Improving Transparency and Efficiency are also frequently the main objectives of companies; nine companies aim at improving these two indicators. Cost(s) is the KPI that is counted six times as a general term, additionally 'transaction costs' are also mentioned in one of the studies. Accountability is observed four times, Product quality, Product safety, and Paperless each three times. 'Value' is the main concept under study: What and where does blockchain add value to the company? To answer this question 'Value' needs to be operationalized and therefore the other KPIs are introduced such as Sustainability or Speed. Value, Trust, Negotiation power, Lead time, Human hours, Data sharing, Communication and Accuracy are all observed twice. Figure 2 shows the reported frequency per KPI. This figure helps to identify generic insights.
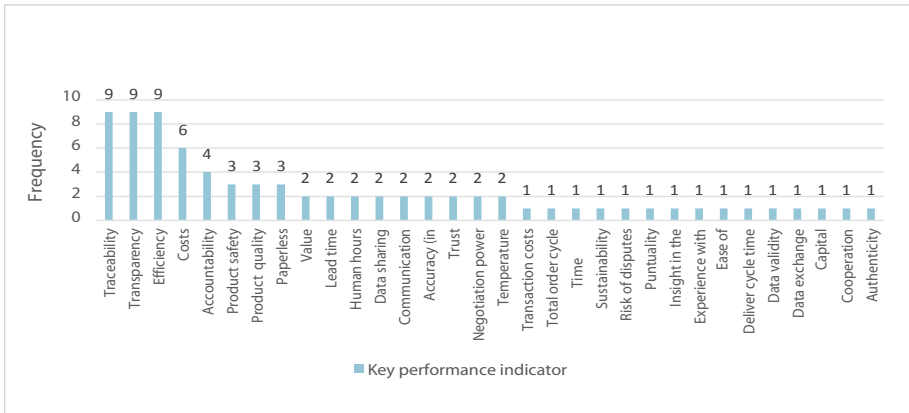
Figure 2 Prevalence of KPIs

16 KPIs are mentioned only once (Figure 2). It concerns Transaction Costs, Total order cycle time, Time, Temperature control, Sustainability, Punctuality, Risk of disputes, Insight in the supply chain, Experience with innovation, Ease of prequalification, Deliver Cycle time, Data Validity, Data exchange, Capital reservation, (Better) cooperation, Authenticity.

It should be mentioned here that most KPIs are connected to each other's or overlap (such as costs and transaction costs) and some of them are also dependent variables (for example cost and time). Therefore, in order to get a better overview all KPIs are categorized into clusters (see Table 3). Still there remains an overlap in the KPIs and more importantly, there exists interdependency between them.

KPIs that are closely related are grouped (see Table 3). For example, this is the case for the general indicators data exchange, communication and (safe) data sharing. Cooperation is a general term as well and requires extensive communication. Communication is not a performance indicator or a final objective in itself. In the cases that mention 'general communication', other indicators are reported as well. These cases further specify the term 'communication' into more specific or measurable KPI's. Next, the KPIs based on Kshetri's performance dimensions are applied (Kshetri, 2018). This is the case for KPIs that can be related to Cost, Speed, Risk reduction and Sustainability. Surprisingly, contrary to the work of Paardenkooper (2019), no KPIs belong to 'Dependability' or 'Flexibility'. From the KPIs that are not yet allocated, some are identified as attributes of Data quality, in accordance with Olsen (2003). Last but not least the concept 'Value' is excluded from the categories, because it is the dependent variable related to most of the KPIs.

Table 3 Categories of KPIs influenced by BCT

General communication	Monitoring the SC	Costs	Speed	Sustainability	Risk reduction	Data quality	Other
Data exchange	Insight in the SC	Costs	Time	Sustainability	Risk of disputes	Authenticity	Experience with innovation
(Safe) data sharing	Transparency	Transaction costs	Lead time			Data security	
(Better) cooperation	Traceability	Efficiency	Deliver order cycle time			Accuracy	Negotiation power
Communication	Trust	Paperless	Total order cycle time			Data validity	Ease of prequalification
	Product quality	Capital reservation	Punctuality				
	Product safety		Human hours				
	Temperature control						

The KPIs are interdependent and have major overlaps. All KPIs are related to costs. To optimize any of them, investments are needed, which will increase efficiency and in the long term decrease the costs. General communication has different aspects. High-quality communication can increase the speed of the process. In order to ensure good communication, high data quality is essential. For monitoring the supply chain, good data quality is needed, while data quality and monitoring the supply chain together reduce the risks, by having better control of the supply chain. Better control of the supply chain means less waste, for example in the form of food spoilage, which relates to sustainability. Sustainability and the category 'other' are also all related to costs. The interdependence and overlap of the KPIs complicate the analysis as the reports define KPIs differently. For example, in the case of monitoring cool transport risk reduction is not mentioned as it is already defined as the goal of the project. KPI's are often grouped in terms of processes (see for instance Kaplan (1992); Neely (2003)). Figure 3 provides an illustrative overview of the interdependencies and overlap between the KPIs.
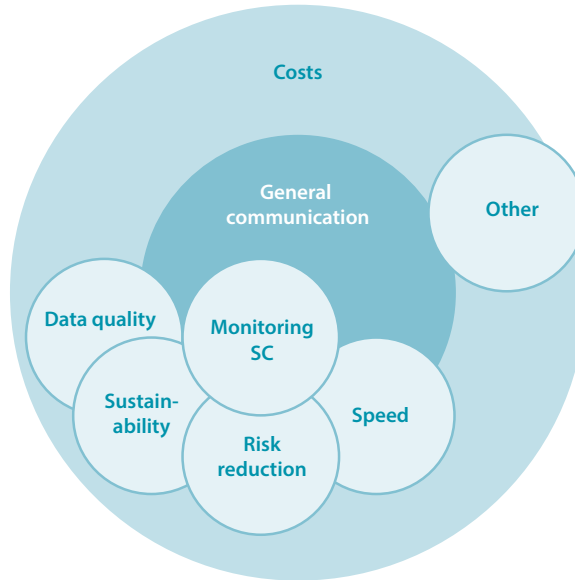
Figure 3 The overlap between the different KPIs

General communication between companies

Having a closer look at the papers reveals the importance of the general concept of communication or data exchange. They are closely related: Communication is a means of sending and receiving information, while data exchange is sharing data (structured information) between systems and organizations. Better cooperation is likely to be facilitated by better communication. Also (safe) data sharing has a quite similar meaning of data exchange between companies but adds the aspect of 'safety'. BCT supports safe or secure data exchange based on the attributes of its technology (encrypted and immutable).
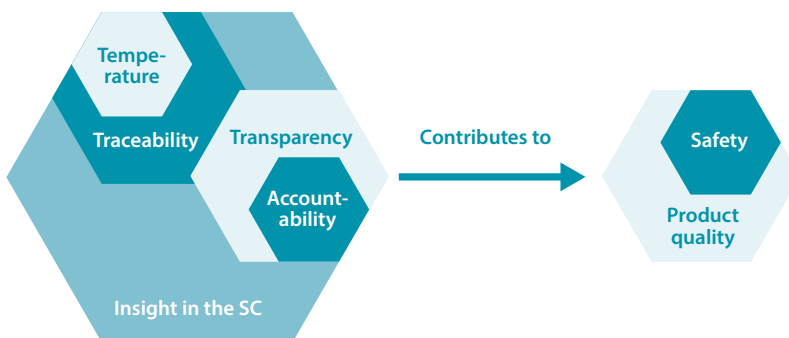
Monitoring the supply chain

The terms in this category contribute or concern (better) monitoring of the supply chain. Monitoring of and insight into the supply chain can be described at high and a detailed level. The activity, similar to general communication, is not an end objective in itself. Traceability is detailed insight and is defined as 'the ability to trace the product batch and its history by gaining insight into all or part of the production chain from raw materials obtained through

transportation, storage, processes, distribution to sales (chain traceability) or internally in one of these steps of the chain, e.g. the production process (internal traceability' (Moe, 1998). Consequently, by introducing traceability, information about the product quality of the product (batch) can be stored and communicated, thus 'Insight in the supply chain' is at least partly achieved. Transparency is a more abstract term that is used in different ways within different sectors: transparency is a metaphor for visibility. Transparency in supply chains relates to the extent to which the company can manage the incoming flows by more visibility in the information and origin from the suppliers. Secondly, it relates to the extent that the company is able to give insight into their performances to the customers and the end consumers. Currently, consumers require more information concerning the origin of the products, especially in cases of growing interest in sustainability (provenance). Transparency is supposed to generate accountability, making it easy to see the actions performed. Trust belongs to the same category as Transparency and Traceability. They are both based on agreements made with the partners in the network. The agreements are registered in smart contracts. The immutability of blockchain creates trust.

Traceability plays an important role in assuring Product safety at each step of the chain. Producers have to certify that their food is safe to consume, and all of the partners and activities on the supply side have to control the chain to contribute to the transparency of the origin of the food product (provenance). The same situation exists in tracking the temperature to improve the product quality. By controlling the temperature, the product can be kept at the right level of quality during transport and storage in the whole supply chain. Using sensor technology and entering the data in the blockchain makes the data is immutable. The case reports of the wholesalers in pet food and the avocado chain address these KPIs of blockchain.

Figure 4 Relations within the category Monitoring the supply chain

Figure 4 visualizes an overview of the relations within the category Monitoring the supply chain. Traceability and Transparency give insight into the supply chain. Transparency

implies accountability; within the nodes of the chain by showing who is performing which action. Therefore, accountability is a specific element of the insight. The temperature is an important element that can be traced and controlled during transport or storage. It contributes to higher product safety. Product safety is an intrinsic part of product quality, especially important in the food chain.

Costs

Using blockchain reduces costs in the supply chain. It is possible to avoid all kinds of third parties and therefore reduce transaction costs, and courier costs for transporting documents. Also working 'paperless' is a cost-saving mechanism caused by the digitalisation of the process. At the same time, other categories also have a positive influence on the costs, e.g., a higher speed reduces logistic costs because less inventory is needed (Paardenkooper, 2019).

Working paperless has two implications: the first one means the reduction of costs for printing and sending paper sheets. This implication contributes to the company's sustainability. The second one is the impact on the speed; sending documents by couriers is more time-consuming than uploading data to a blockchain. In the blockchain, the information is available for all the parties in the network at once. For example, the case 'importer of exotic fruits' shows that it is able to work paperless if the producer of pineapples in Costa Rica uses the blockchain for the required quality certificate and if the transporter uploads the bill of lading to the blockchain. Working paperless contributes to an efficient way of working.

Data quality

The companies mention different attributes of data quality. The attributes concern authenticity, accuracy, data security, and data validity. The mathematical algorithms of blockchain technology verify the transactions within the chain and therefore guarantee all attributes of the data quality once the data is in the system. The higher the data quality, the higher the reliability of a stakeholder in the supply chain. An example is the case of the producer of dairy ingredients, where the student advises blockchain technology to improve the accuracy of the information in the documents.

Speed

The KPI speed contains lead time, time, deliver order cycle time or total order cycle time and punctuality, and human hours. The use of blockchain technology will reduce the lead time by making the information available at an earlier moment in the processes and therefore reducing waiting and lead times. Furthermore, manual transactions can be digitalized by smart contracts, which affects the speed of handling of transactions. An example is the current food chain of pineapples, where couriers transport relevant documents to the importer and the independent quality control office.

Risk reduction

Supply chain risk management encompasses a wide variety of strategies aiming to identify, mitigate and monitor unexpected events or conditions which may have an impact on any part of a supply chain. (Baryannis, 2019) Better monitoring of the supply leads to earlier identification and more specific information about the affected part of the supply chain in case of an unexpected event. Only one case report mentions risk management, more specific the risk of disputes as part of the problems within the billing process. These financial disputes tie up capital. By the use of smart contracts, the risk of mutual different administrations between shipping companies and forwarders will become superfluous. The reduction of risks leads to a smaller capital reservation or reduction of (insurance) costs, or higher revenues by a higher product quality (safety). Although risk reduction is not explicitly mentioned in the case reports it can be argued that for the companies in the food sector risk reduction is a positively affected KPI.

Sustainability

Consumers can make better, more sustainable decisions if they get more reliable information about the provenance of products. Blockchain technology can contribute to sustainability, by safely sharing the information within the partners in the chain network. One of the reports on fashion lists sustainability as the main KPI. If more accurate information is available about the origin and circumstances under which clothes are produced, consumers can make a more sustainable decision.

Other

The category 'other' contains the experience of innovation, negotiation power, and ease of prequalification. They don't belong to one of the other categories. Two of them, ease of prequalification and negotiation power, have their origin in the general report about the procurement process. The negotiation power increases due to the rule 'more data contributes to better decision making and therefore leads to more power'. An example of this indicator is in the broiler case, where the farmer experiences an underdog position in relation to their slaughterhouse. Blockchain technology will make it possible for the farm to share its valuable information with its competitors (horizontal collaboration) and create co-operations.

Cross-case analysis

In this section first, the reasons for investing in blockchain are discussed and how the KPIs are linked to the processes supported by the BCT. The section ends with the reasons, why companies do not make a choice to invest in blockchain.

Investing in blockchain and the targeted processes

At the end of the research reports, the most relevant question remains whether companies should implement blockchain or not. Eleven reports do advise to invest in blockchain technology, based on the predicted positive impacts on their KPIs. Especially companies that focus on traceability and transparency are advised to adopt blockchain technology.

Table 4 provides an overview of the targeted processes in the different branches. In one case the targeted domain is customer satisfaction in the fashion industry. The case is related to the provenance of the clothes and in fact, is a tracking application. In one case the process is data sharing, it concerns a company offering tracking solutions. In this case obviously the goal is also tracking. The paperless solution is meant for maritime transport, as it is an electronic bill of lading for a company involved. For a freight forwarder the blockchain application is meant to optimize the whole process of the company. In two cases, both freight forwarders, their targeted process is the billing process. The billing process is notoriously inefficient, because of the high number of disputes and the procedures to solve them. Communication with partners is the process under study in 2 cases (a service provider and a broiler farm). In 2 cases blockchain is intended to improve maritime transport, for a company in the food chain and a major company in the energy sector. In fact, the applications in the maritime transport are related to tracking as well. In 2 cases the application is meant for temperature control in the food chain, which also needs to be tracked. In 3 cases blockchain is meant to improve the procurement process, 2 at oil and gas companies, and 1 in the general case. Finally, most (4) cases of tracking are applied in food chains. From the linking of the processes to the business model of the companies it can be concluded that most applications are connected to tracking in food chains, which is in line the literature findings (Kshetri, 2018; Paardenkooper, 2020) stating that this is the most important existing application of blockchain.

Table 4 Overview of the targeted processes linked to the branches

Targeted processes	Number of cases	Branche
Customer satisfaction	1	Fashion
Data sharing as a service	1	ICT provider
Digitization of the administrative part of the transport process (Paperless)	1	Maritime transport
Process optimization	1	Freight forwarder
Billing process	2	Freight forwarders
Communication with partners	2	Service provider, broiler farm
Maritime transport process	2	Food chain and Energy
Temperature control during the transport process	2	Food chain
Procurement process	3	2 Oil and Gas and 1 general case
Tracking during the transport process	4	Food chain

Reasons for avoiding investments in blockchain (limitations)

Five of the reports advise avoiding investments in blockchain technology in the short term. Three of them argue that EDI is already a proven technology, in contradiction with blockchain technology. Therefore, in the EDI scenario, the financial benefits and costs can be predicted more accurately, and the risk in investing in new technology is therefore lower. The second reason is that the financial business case comparing EDI to blockchain is in favour of EDI information exchange. The fourth report states additionally the risk of ´being vulnerable from major parties who take advantage of the information you share. Therefore, it is also important to identify the company´s new strategic position in the supply chain (Heeroma-ten Katen et al., 2020). The fifth case shows that the suppliers and case company already trust each other, so there is no need to create additional trust.

Conclusions

This paper presents the cross-case analysis of 21 papers of students of two universities of applied sciences on the topic of blockchain. The papers are written by individual students and student groups at different educational programmes, which makes the sample heterogeneous. Also, the educational programs often demanded different ways of analysing. This could be denoted as a weakness of the comparison study. However, it could also lead to a more rigorous view on the outcomes of the study and likely it will reflect also the heterogeneity in patterns that can be seen in the research. At least they have in common the general approach to analyse the supply chain processes by introducing BCT. For a preliminary study, the approach fits well to provide some first insights on the influence of the application of blockchain technology in logistics chains.

Some clear patterns can be found. More than the half of the companies are SMEs, the rest are large companies, and some cases are not company or industry specific. The companies' activities are diverse, varying from a broiler farm to a provenance factor in fashion, however the largest group is the group of forwarders. The majority of the companies are involved in the food chain and transport. Almost more than three quarters of them are service providers. The classification of the sample companies is in accordance with the literature as these are the areas where blockchain is applied most. The KPIs are inventoried and clustered in seven categories: costs, general communication between companies, monitoring the supply chain, data quality, speed, sustainability, risk reduction and other. The KPIs are compared to the advantages of blockchain described by Kshetri (2018). The biggest benefits of blockchain for the companies are Transparency and Traceability, especially in the food chain companies. The advice for these companies is to invest in blockchain. Traceability is found to influence the cost, quality, the speed, reduces risks, and impacts provenance value to customers and supports flexibility (Batwa & Norman, 2020). Forwarders mention explicitly

the risk of disputes, and therefore the improvements in data quality are mentioned here. For companies in this traditional sector, it is necessary to introduce and carry out an organizational readiness instrument and risk analysis. In other words, there has to be a fit to the current status of digitization and awareness within the company, in relation to the advice to take the next step (Heeroma-ten Katen et al., 2020). Understanding the process of technology acceptance could support the companies to get the use of blockchain software accepted (Tan & Sundarakani, 2020).

Reasons, why companies do not invest in blockchain, are related to a preference for proven technology, such as EDI, which has a better business case, according to one company. Another reason is that companies already trust each other and do not feel the need to secure trust even more. On the other hand, one company does not want to implement blockchain because of its fear of vulnerability in case of transparent data sharing. Likely, this is a typical forwarder company whose business has been thriving by the lack of transparency.

To improve insights on opportunities and threats for SMEs for a blockchain application on their position in their chain, new insights can be added step by step and individually evaluated per added case report. For future reports it is advised to standardize the KPIs in an early stage of the research, to be able to draw more clear conclusions at a cross-case analysis. Furthermore, more focus should be on the mutual interdependency of the KPIs, and definitions of the KPIs to clarify the real supply chain objective. Researchers should define what categorization and standardized KPIs can be used, based on the literature. Future research might also employ a standardized methodology – we recommend a feasibility scan that is developed based on the combination of these cases and a literature study (Heeroma-ten Katen et.al., 2020).

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