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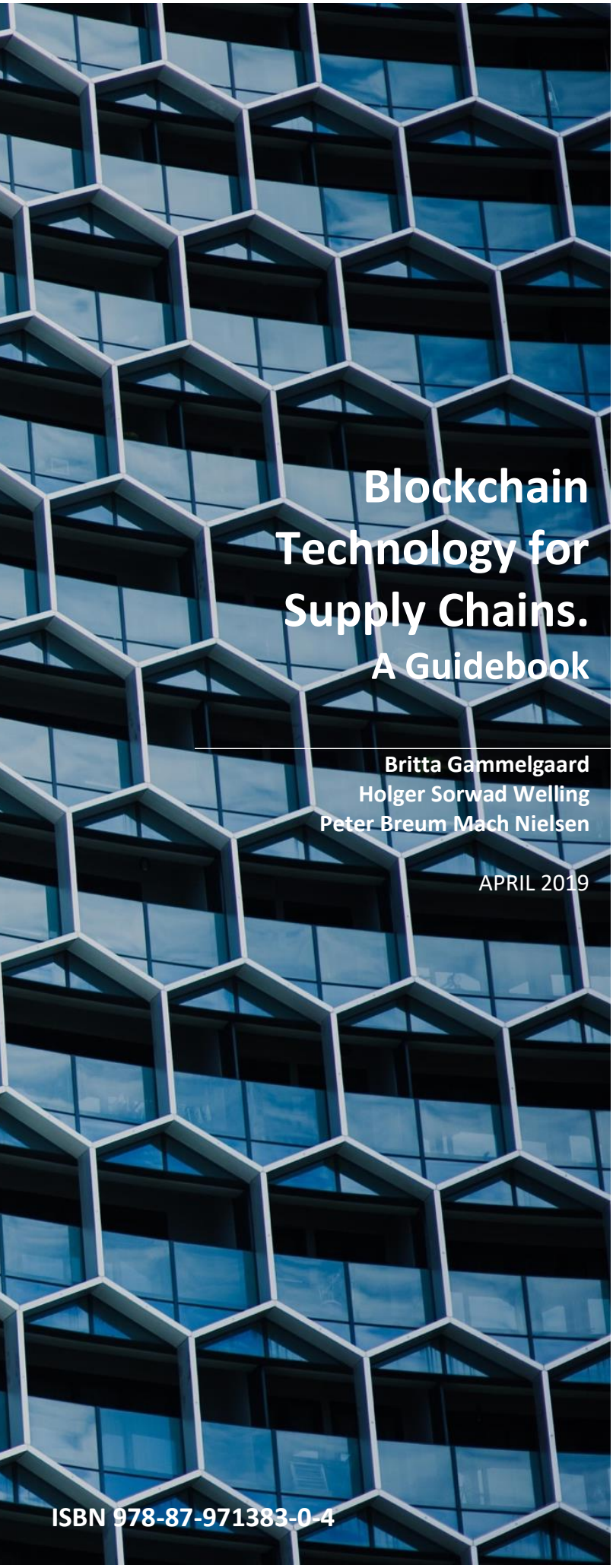

Blockchain Technology for Supply Chains.
A Guidebook

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Executive summary

This guidebook represents an elaborative study of blockchain technology and its potential in common supply chain management practices. Our aim is to create an easy-to-read handbook with which supply chain management professionals can develop a basic understanding of blockchain and how it can be applied within the industry. This is achieved through a practical approach by which we shed light on some of the key value drivers that blockchain can provide in modern supply chains, while elaborating on how the technology is already being tested in industry. Accordingly, this paper aims at enhancing the reader's understanding of blockchain and how it can be applied in a supply chain context.

While blockchain is still in its early adoption stage, the potential of the technology continues to prove itself through various pilot projects around the world. In particular, the combination of blockchain and Internet of Things (IoT)[1] devices have proven particularly promising as it provides an automated and secure way to connect physical assets to the cloud. In multiple pilot projects, blockchain has been successful in facilitating end-to-end supply chain visibility. Blockchain is, however, not necessarily the right solution for all companies when it comes to creating supply chain visibility. Therefore, it is important for managers to thoroughly understand the fit between their supply chain and the desired technology, before considering implementing a blockchain solution.

Firstly, the guidebook provides an understanding of the main elements of blockchain and its characteristics. In this section, we describe blockchain from both a technical and a practical point of view. Secondly, the characteristics of blockchain are analyzed in view of supply chain management and an overview of the various benefits it may provide, if implemented successfully, is presented. This part is complemented by other new technologies such as IoT, where we illustrate how blockchain can create synergies with other existing technologies that are used in the transport industry. This section concludes with an outline of challenges that are yet to be resolved regarding blockchain and its adoption in the supply chain industry. Thirdly, the guidebook discusses various real-life business cases to provide an overview of how blockchain is used to improve current processes. Finally, this guidebook provides an analysis of the current adoption stage of blockchain before rounding off with some practical steps for management to consider before commencing their first blockchain project.

[1] IoT is the network of devices able to gather and share information through sensors. This enables physical products to be connected to the cloud to achieve connectivity of devices. Examples of such devices could be Radio Frequency Identification (RFID) providing information from physical assets to the could.

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1. Introduction

Blockchain was introduced for the first time in 2008 by the anonymous founder of Bitcoin who goes under the pseudonym “Satoshi Nakamoto”. Bitcoin was initially invented to create a digital, distributed currency with no central authority. Blockchain technology is the backbone of Bitcoin, which uses cryptography to control the creation and transfer of digital money.

Despite having existed for more than 10 years, blockchain has only recently caught up amongst the public. The technology was initially met with large skepticism. That being said, corporations are starting to see the potential of the technology and many are fearful to be left behind if they do not embrace the blockchain technology. This interest is confirmed in a recent PWC survey where 84% of respondents reported to be actively engaged in blockchain.

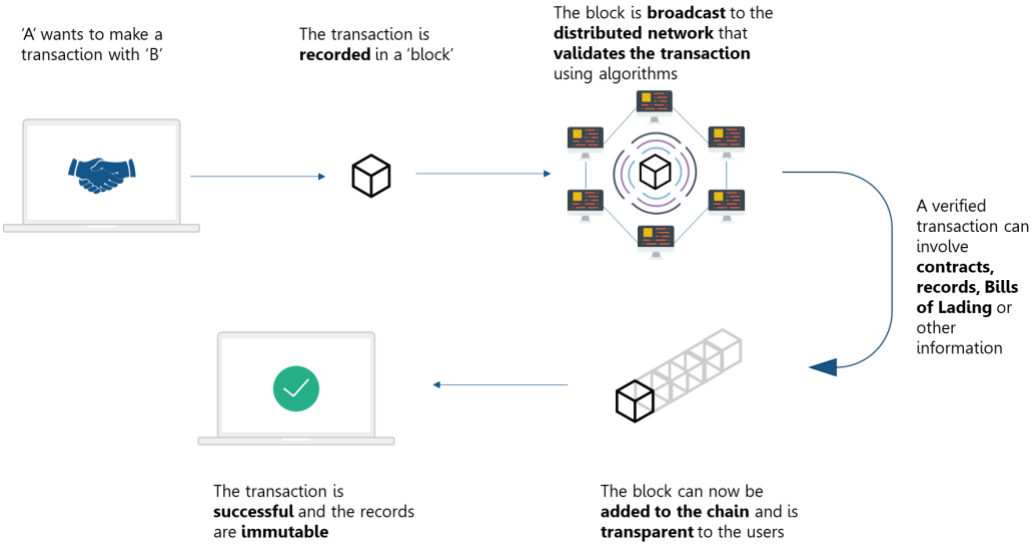
Since Bitcoin’s first attempt to cut out the central authority, initiatives have been taken in other industries where blockchain is used to disintermediate where intermediaries have always been the second nature. Case in point: Supply chain management. While there has been put great emphasis on the conceptual understanding of blockchain, little attention has been given to the benefits blockchain can provide to supply chains and how those benefits can be achieved. The key elements in scope are hence how blockchain can be used as a tool to obtain trust, authenticity and visibility for their operations and broader supply chains. While the business environment generally agrees on the importance of increased visibility in supply chains, an effective means of achieving this is yet to be found. Other industries have successfully implemented various solutions to provide visibility to their customers, however, most B2B transactions lack this feature. To put this in perspective: “*(...) if Domino’s Pizza customers can track their order from oven to doorstep, why shouldn’t business customers expect the same level of transparency and convenience when ordering a skid-steer loader?*” (Bain & Company, 2016).

2. Defining blockchain

In layman’s terms a blockchain is essentially a back-end database (called a digital ledger) that is distributed amongst all users of the database who each have their own copy of the ledger. This allows a blockchain to have no central party running it. Information is added to the blockchain in batches (called ‘blocks’), which are interconnected line-items of the database, linked together in a chronological fashion, forming a continuous ‘chain of blocks’. Every line-item on the blockchain will exist in perpetuity as data cannot be overwritten. In order to make a change of any information in the blockchain, the

change will be stored in a new block, recording that 'A' changed to 'B' at a certain date and time. This makes the blockchain immutable and allows users to have a full view of historical transactions, which makes all data on a blockchain credible. In normal databases, each company will typically have their own record of a transaction which may or may not correspond to each other. With blockchain on the other hand, there will be a single source of truth mitigating this issue. An illustration of the basic elements of how a blockchain works can be found below in figure 1.

Figure 1: How a blockchain works



Source: Adapted from Blockgeeks (2018)

2.1 Blockchain in detail

When it comes to transactions, the blockchain technology is characterized by a specific verification process, whereby existing connected nodes in the network identify a new transaction taking place in the network. Whenever any member of the network (a "node") posts a new transaction, that transaction will be added to the digital ledger of existing transactions once it has been verified by the members. An overview of some key characteristics of a blockchain is listed in Table 1.

Transactions can be distinguished based on the different scope or area of work the blockchain is set up to support. Examples are business and legal transactions. In business transactions, a blockchain works as a way of exchanging value between peers which could be digital assets such as insurances, currencies or data. For legal transactions, a blockchain can eliminate the risk of falsification of documents including but not limited to contracts, insurances and patent claims.

Table 1: Key characteristics of a blockchain

Key characteristics of blockchain	
Distributed ledger	Identical copies of all information are shared on the blockchain. Information is independently validated by all participants without a central authority, making it virtually impossible to attack.
Chronological and time-stamped	Each block contains information related to a transaction including a link to the previous block forming a chronological, auditable trail of each transaction.
Cryptographically authentic	Uses public/private cryptographic signature technology to create transactions that are immutable. This makes it impossible to delete, alter or copy existing blocks, which hinders the possibility of fraud in the database.
Shared	Each participant on the blockchain holds the same validated copy of the ledger giving the blockchain the feature of a single, agreed-upon source of truth across the users.
Consensus based	The consensus mechanism is the process by which blocks are validated and hence added on the blockchain.
Immutable and auditable	Once something is written and validated on the blockchain it can never be overwritten or deleted. This makes information on the blockchain reliable and auditable.

Source: Adapted from Deloitte (2017)

2.1.1 Consensus in blockchains

The need for a consensus mechanism in a blockchain is caused by its distributed structure. This is essentially the way in which decisions are made (such as agreeing on the validity of data entries) with no central authority. One potential drawback, that the distributed composition of blockchain may cause, is an increase in overhead costs. This is associated with shuffling data between participants, which is a main challenge of blockchain. No matter *how* data is recorded and processed by every user, it has to be done. Otherwise, the system by definition does not represent an open distributed network.

The bottom line is that a blockchain can be set up in different ways with different systems that operate it. No matter how these systems work, they are often less efficient than centralized databases because information must travel through all users of the network in a blockchain. That is, the more users in the blockchain, the more complex it will become. As a result, it is crucial from a development perspective to set up the blockchain in a way that can enable it to run with the desired number of users.

2.2 Public and private blockchains

As with any other emerging technology, there is much confusion about the blockchain and what business models it may support. In many cases, this confusion can be attributed to the different blockchain structures: public and private blockchains. The original understanding of blockchain is that of a public one where everyone has permission to read and write on the ledger and takes part in the consensus process. A private blockchain, on the other hand, acts as a closed ecosystem in which authorized participants can share information and record transactions. While a public blockchain is better suited for B2C or C2C transactions where crypto-economics are part of the business model, a private blockchain is mainly used in B2B ecosystems to instill trust, transparency and efficiency into B2B exchanges.

2.2.1 Characteristics of a public blockchain

In distinguishing between public and private blockchains, it's important to note that a public blockchain can be audited by anybody, making it easier to detect fraud on the chain. Since a public blockchain is open to anyone, it provides a higher level of transparency at the cost of increased complexity, operating expenses and energy usage. A greater number of nodes exist in a public network, where each user must authorize every new transaction that takes place before it can be added to the network.

To put this in perspective, some large public blockchains supporting for example Bitcoin and Ethereum are only capable of making 5-10 transactions per second (TPS) compared to VISA's transaction system which as per 2015 could sustain a maximum of 40.000 TPS. In this example, a public blockchain system looks rather inferior and inefficient next to the existing transaction systems we use today. However, there are still potential for public blockchains to shine, in particular in industries where transactions happen less frequently or when benefits from increased security outweighs the increased complexity. The insurance industry is a good example. In this case, the transaction would only trigger if an insurance claim would be valid. This happens less frequently than for example financial transactions, however, when it does happen it is crucial for the parties involved to avoid misunderstandings and discrepancies regarding the claim.

2.2.2 Characteristics of a private blockchain

A private blockchain is increasingly the preferred method amongst businesses as they mostly prefer to disclose only information that is relevant for their business counterparts. Few businesses can

be imagined to be willing to provide their back-office functions to any arbitrary viewer, which explains why most blockchain users in the business would most likely choose to apply a private blockchain. This type of blockchain is restricted only to trusted users. A private blockchain is also called *permission-based* meaning that restrictions are set on those participants who have been granted access to the network.

A real-life example of a private blockchain is TradeLens: a blockchain-based platform by Maersk and IBM with the vision to digitize global trade. The goal is to create an ecosystem in the shipping industry, allowing shipping counterparts to seamlessly share information and interact with each other. Given that most of the expenses for sending a container overseas is associated with administrative paperwork, estimations are that the shipping industry potentially can save billions of dollars annually if the new blockchain based ecosystem manages to cut out multiple intermediaries in the transportation process.

2.3 Smart contracts

In short, smart contracts are conditional agreements ('digital contracts') that self-execute when predetermined conditions are met. These conditions can be written into the code of the blockchain. This will in effect automatically hold parties reliable for their actions in a transaction, which in a supply chain context brings forth the potential to reduce uncertainty and supply chain complexity. An illustrative example from a supply chain context could be a contract between a freight forwarder and their customer. Upon receipt of the shipment, payment will automatically be released if terms and conditions of the contract are met.

From a more technical perspective, a smart contract is composed of three different mechanisms: "*The contractual agreements between the parties, the governance of preconditions necessary for the contractual obligations to take place, and the actual execution of the contract*" (Sillaber & Walti, 2017). The main problem being solved by smart contracts is related to the lack of trust that is often seen between individuals when making agreements and therefore how these aspects of human judgement can be eliminated.

Bringing this into a supply chain context, an abundant amount of use cases become apparent, including for example insurance and automation of contractual agreements. The French insurance company, AXA, is the first insurance group in the world to have developed a blockchain-driven insurance product, called Fizzy. Fizzy is an automated and secure insurance product against delayed flights for policyholders. Their smart contract is connected to global air traffic databases that automatically trigger reimbursement to policyholders as soon as a delay of more than two hours is observed without the

need to report the claim. This not only provides convenience for customers but also strengthens the trust that customers can have in AXA and their insurance policy.

Below is an illustrative example related to trade in supply chains: assume that a contract stipulates that the price will be X dollars if a certain service level is met, however, the price will be Y dollars if the service level is not met. Moreover, issues must be reported within 10 days of delivery, and the smart contract includes dynamic pricing to take account for volatile transportation prices. This code can be written into the blockchain. As new blocks are added to the blockchain, it will automatically check to determine if all the conditions are met and - if not - prevent those records from being entered. An additional benefit of smart contracts is increased speed and effectiveness as it can automate repetitive manual processes such as billing and handling of shipping documents.

2.4 Blockchain and the Internet of Things

The first applications of blockchain were seen in the financial sector due to the mostly intangible nature of the sector. For a blockchain to work in conjunction with physical assets, such as in a supply chain, it will usually require the use of ancillary technologies, such as IoT devices. These devices can measure and track the state of various goods, collect the data and share it on the internet.

IoT devices, such as Radio Frequency Identification (RFID), will provide data inputs to the blockchain based on real-time events. In other words, IoT devices are the tools that generate the data, and the blockchain is the underlying ledger that records and stores the information safely and securely. Once data is transmitted to the blockchain, all members of the network are able to access it.

3. Blockchain in supply chain management

Supply chain is deemed as one of the industries where blockchain has the biggest potential to disrupt. The number of use-cases for blockchain in supply chain management keep increasing as the industry increasingly gains more awareness of the technology. Amongst other things, blockchain can be used to improve contract management, improve supply chain visibility and security and create product provenance.

3.1 Blockchain's relative advantage in supply chains

The way supply chains are managed is arguably ineffective when it comes to facilitating information sharing and coordinating the operations among involved entities. The time that must be devoted to solving a problem or untangling a specific communicative discrepancy will likely increase as

the network grows. Taking a step back, the main benefits of blockchain in supply chain management can be bucketed into two major categories being either 1) operational efficiencies or 2) improving trust and security. While other technologies exist in order to create supply chain visibility (such as API's[2] and Supply Chain Control Towers[3]), a blockchain does not have the drawbacks of being centralized and increasingly susceptible to security risks. That being said, a blockchain is not necessarily the right tool for all supply chains as the applicability depends on the level of complexity of the supply chain and the value created from increased visibility over the supply chain. While a blockchain could potentially solve a large amount of supply chain challenges, one must evaluate whether the effects of blockchain with regard to supply chain visibility and security outweighs the complexity of implementing a blockchain. Hence, it is important for managers to thoroughly understand their supply chain structure before considering implementing a blockchain solution. In line with this, managers must also consider the rationale behind implementing a blockchain and how supply chain visibility and security can provide significant improvements and benefits to their supply chain.

These benefits could for example relate to verifying branded products against counterfeit products, as well as providing a certified audit trail for organic fresh products. Moreover, as a blockchain facilitates enhanced information sharing between supply chain actors, it will allow faster and more efficient vendor selection processes. As a result, blockchain provides a safe and immutable way to share sensible information in vendor evaluation processes such as financial performance and quality standards. This is important in modern supply chains where vendor changes are increasingly frequent.

3.2 Supply chain ecosystems

As the business environment constantly changes, the requirements for supply chains to evolve naturally follow. Online retailers, such as Amazon, are experimenting with dynamic pricing, while the production cycle in industries such as fashion is being drastically reduced by data-driven supply chains. As speed and adaptability becomes increasingly important in meeting customer needs, the supply chain must evolve to facilitate this need.

Traditionally, supply chains consist of sequential links each with behavioral attributes that cause information to become distorted and inaccurate the further away it has to be communicated. This brings

[2] An 'application program interface' (API) is a gateway between multiple software components that specifies how those components should interact together. Essentially, API's allow multiple software components to communicate together.
[3] A supply chain control tower is a system that gathers information centrally in order to provide supply chain visibility. Traditionally, supply chain control towers only focused on the immediate trading partners, however, it is increasingly adapting the vision towards end-to-end supply chain visibility.

forth more digitized supply chains that evolve from being linear in their communication systems to becoming more like a global ecosystem. In linear supply chains, information must travel through the nearest link and onwards, increasing the risk of making different interpretations of the information being shared along the way. In addition, a linear supply chain structure can be inefficient as the entities in the supply chain are dependent on each other, and the information being communicated from link to link takes longer time to execute on. This can result in more time-consuming decision making, based on less accurate and relevant information; this phenomena is also known as the bullwhip effect.

In order to improve in these areas, organizations need to build more efficient communication systems that range across the business, enabling all entities to communicate more seamlessly. Comparing a linear supply chain to one in which the underlying foundation is built on blockchain technology, information need not to travel through one link at a time. Instead, information can be communicated more seamlessly from link to link no matter their distance or relation. Thus, a blockchain based ecosystem enables its users to share information fast and with minimal friction between the parties.

A good example of how information is accurately measured and communicated is in cold chain transportation. An IoT device can be placed inside a container, thereby constantly measuring the temperature of the product on its journey. Rather than having the information stored centrally, blockchain can identify and eliminate single points of failure with its distributed composition and thereby create a more resilient ecosystem for the devices to run on. Blockchain can provide scalability, reliability and privacy in storing massive amounts of data related to cold chain transportation. Other examples are visibility through real-time data on inventory in transit and more accurate point-of-sales data. Ultimately, the desired results of these improvements could lead to better forecasting results and more effective decision making in supply chains.

3.3 Technological challenges by implementing blockchain in supply chain management

While the potential for blockchain to disrupt supply chains is evident, the technology is still in its early stages with limited adoption in the industry. Individuals and organizations are still learning how to use the technology and its implications on current business practices. One of the main challenges for supply chains in implementing blockchain solutions is the gap between the tangible nature of the physical supply chain and the digital nature of blockchain technologies. While the blockchain may be immutable by design, the input to the blockchain can in theory still be manipulated. Hence, the old saying of ‘garbage in - garbage out’ still applies. While some pilot projects simply digitize paperwork

where data inputs are manual and capable of being manipulated, other pilot projects rely on IoT devices such as RFID as the main source of data inputs. Therefore, while a blockchain may be immutable and secure, it cannot control what happens outside the system.

While it may sound contradictory as blockchain technology itself is seen as the enabler of trust between parties, it is essential that potential adopters trust the technology itself. This may be particularly troublesome - especially for a technology that promises to fundamentally change the way data is managed and shared. Doubts exist regarding blockchain's reliability, security, interoperability and ease of implementation. Moreover, as blockchain is still in its early stages of adoption, the regulatory environment remains unsettled. Adding to this concern is also a lack of understanding of the technology. Due to the intangible nature of blockchain, the concept is still unclear to most managers, despite the public narrative slowly moving past Bitcoin and to its application in businesses around the world.

Finally comes the issue of developing the blockchain ecosystem and agreeing on the blockchain setup, which is one of the main barriers to adoption. The network needs to set up the initial architecture on the blockchain to make sure that the blockchain will operate as desired. This includes agreeing on a fair cost-benefit split as well as the rules for participation and governance mechanisms. For a private blockchain, which often will be more applicable in supply chains, this will include agreeing on various users' permission to view and write information, or conduct a transaction in the blockchain.

4. Blockchain enabled supply chains

In the following example, we will illustrate how a blockchain setup could work as the backbone technology in a supply chain that operates with high quality perishable goods. The aim is to illustrate how a given food product (coffee in this example) can be safely and reliably traced from its origin and all the way to the end-consumer; in other words, how can we ensure that the coffee we drink is based on a coffee bean that has been sourced from a local, organic farm and with no unethical labor involved in the process?

The journey of the coffee bean can be a long complex one with many intermediaries involved. Consider the case of mapping its journey, whereby it would be possible to see how it got from the farm and all the way to the supermarket. Such visibility can be obtained by use of blockchain technology while at the same time ensuring that the information is reliable and trustworthy.

With many actors involved in every step in the supply chain, data must be verified before exchange of custody. The ever-growing flow of goods often puts the current logistical structure under more pressure than it can handle. Critical documents sometimes go missing, which leads to bottlenecks

in the physical flow[4]. As it turns out, the delays and increased lead times are often not due to the inconsistency in moving the physical goods but instead due to delays associated with the administrative procedures necessary for further distributing the goods. Ultimately, this inhibits distributors from getting the products at the right time, along with a decrease in the quality of the perishable good they are to distribute.

As a result, products are delayed. In the case of perishable goods, this can lead to disastrous outcomes, due to the product's short lifetime. At worst, food products can deteriorate and lose its value. It is estimated by UN FAO that roughly 30% of the food produced for human consumption is lost or wasted somewhere along the supply chain – a fact that further emphasizes the severity of this issue.

4.1 How blockchain can enable supply chain visibility

By implementing blockchain, a single version of truth is established as the entire supply chain can be logged on a tamper proof distributed ledger. This allows all involved parties to review the *what, where and when* of the product's journey. Because the blockchain uses distributed records rather than centralized records and therefore are more tamper-proof than other databases, they are useful and value-adding in industries where strict record-keeping for valuable or sensitive products is critical.

However, it is important to note that the monitoring of the *what, where, and how* is not done by the blockchain itself but instead by supporting IoT devices that process and communicate data. From here, the data is embedded and kept safely within the blockchain. Examples of IoT devices are RFID tags, NFC (Near-Field-Communication) tags or other types of technological measurement tools that enable machines to automatically monitor. The IOT tags' function is to constantly monitor and then derive data that is relevant for the product's condition, ranging from the temperature of the container to the exact location of the goods. With this information safely stored in the blockchain, the data doesn't just belong to one central authority but instead it is kept by the system's users. Every time a new entry of data is registered, it is cryptographically linked to the ones before and after it. This allows a structured, transparent overview of every process that takes place throughout the journey of the coffee bean. Every time new information is embedded into the blockchain, the data is transmitted to the receiver and encrypted to ensure the authentication of the transaction source.

Although many blockchain projects are still tentative, more companies are trying to take action in the blockchain space. For example, blockchain has been effectively used in connection with the

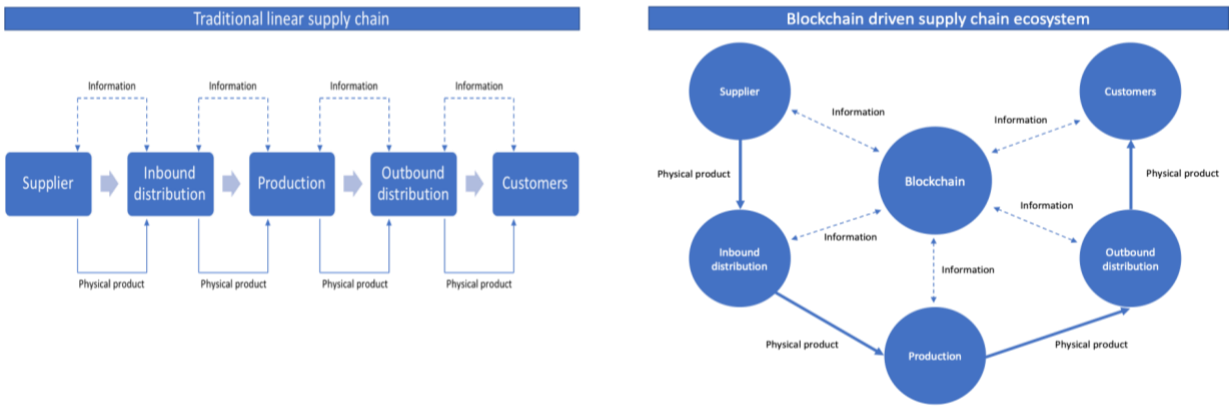
[4] In fact, paper-based work in sending a container from A to B often accounts for by far the largest single cost of the entire venture of that container.

production of jewelry and fashion. As those industries have often been exposed by gloomy questions about ethical labor and sustainable sourcing, blockchain can serve as a critical tool in ensuring transparency within various stages of production.

Further, the ability to prove the origin of a product is not only useful because of security, transparency and compliance. Blockchains, to a greater extent, further allow the user to tell the complete story, it gives credit to all involved contributors in the supply chain and awareness for the end-consumer. As a customer, it is easy to ignore or forget the journey of the product and the whole process taking place before it is placed on the shelves. Attention towards the origin of products are, however, increasingly demanded from consumers. To illustrate this, Provenance found that 30% of consumers in the UK are concerned about the origin of products without having information to act accordingly.

In summary, the blockchain technology enables the possibility of a global ecosystem whereby all nodes can communicate to each other. This is a major improvement from the current setup in many supply chains, where data sharing happens in a more linear fashion from link to link. Figure 2 provides visual comparison of a linear supply chain and a blockchain-driven ecosystem with greater transparency.

Figure 2: From linear supply chains to supply chain ecosystems



Source: Adapted from Strategy& (2016)

4.2 Alternative ways to obtain supply chain visibility

While there have been many attempts to increase supply chain visibility, it has shown to be particularly complex due to the lack of interoperability of the current systems. In modern maritime transportation, the predominant technology used to obtain supply chain visibility (SCV) is Electronic Data Interchange (EDI) which is a technology originating from the 1960's. EDI is a pre-internet system without the sophisticated ability to create end-to-end visibility. While facilitating communication

between parties, EDI still heavily relies on manual tasks and is prone to errors. As maritime transportation is a key player in many supply chains, this practice establishes precedent and affects other actors in the supply chain.

Application program interfaces (API's) is a technology which is seen to have the potential to create SCV. If a user needs to extract data from a source, an API will function as the gateway, allowing entities in complex information systems to access data by driving information from one system to another by aggregating the information from the data source it is connected to. The drawback of an API is, however, that the commercial structure employed by the API owner tends to be centralized. This point is important for supply chains as it does not overcome the fundamental issue of intermediaries used in sharing sensitive information; arrangements in which one central organization controls all information.

Another way of achieving SCV today is by the use of supply chain control towers. Capgemini Consulting defines control towers as: "*(...) cross-divisional organizations with system integrated 'information hubs' that provide Supply Chain Visibility*". This will in return enhance decision making and improve efficiency. A supply chain control tower gathers information from inbound and outbound shipments as well as manufacturing processes in a central software system. A supply chain control tower is a great tool at providing visibility in supply chains, however, it does not have the same level of security as a blockchain.

As seen from the above explanations, blockchain is not a standalone solution for achieving supply chain visibility. Firstly, it requires a full transformation of the supply chain, digitizing many of the previous functions that have been carried out manually.

4.3 Industry-specific blockchain applications

While an extensive number of pilot projects have taken place, we seek to provide an overview of two interesting examples of how blockchain is being used to enhance business processes in relation to port operations and maritime insurance. This will be further elaborated below.

4.3.1 Maritime Insurance

In section 2.3 it is discussed how AXA uses blockchain and smart contracts to improve its insurance processes. Blockchain does, however, also have the potential to disrupt other insurance processes, particularly within maritime insurance. EY, Microsoft, Maersk and a group of industry players

are working on a blockchain based maritime insurance solution named Insurwave, with the goal to reduce administrative costs, reduce insurance risk and improve process speed.

Insurwave is a technology platform that pools data from all parties in the insurance proposition and feeds the data to the insurers and brokers in real time, allowing privacy, security and access to relevant data for all parties. This will enable insurers to better quantify risks and hence allow them to provide a better price. Smart contracts will allow claims to be signed immediately while real-time access to data will underpin the insurance policy. Hence, policies can automatically be updated to reflect the risk covered through the use of blockchain, IOT and smart contracts. This will help all supply chain actors improve efficiency and risk management and is expected to improve cost efficiency significantly.

4.3.2 Port Operations

Ports, just like many other players in the supply chain ecosystem of cross-border trade, still operate in an environment where manual paperwork is the norm. With several stakeholders, traditional communication methods and a high number of transactions and interactions, efficiency is challenging to achieve.

Blockchain has substantial benefits and use-cases in and around ports. Integrating information flows from the supply chain provides greater visibility over port processes, allowing for substantial process optimization, including customs clearance. This is realized by having all documents readily available on a digital, trusted and secure platform. This will in return not only reduce processing time but also significantly reduce administrative costs. Some prominent ports developing blockchain solutions are Port of Singapore and Port of Antwerp. Port of Antwerp succeeded with a pilot project using blockchain to digitize document transfer in a secure way while improving process efficiency. Port of Singapore is trialing a multitude of blockchain solutions to various processes amongst which they are looking to facilitate trade flows through a blockchain solution to enhance customs clearance in collaboration with IBM.

4.4 Proof of concept - tracking tuna on the blockchain

In the following section, a proof of concept will be presented that showcases how blockchain can be used to improve supply chain transparency. Provenance, a leading blockchain-solutions company, has several proven use-cases whereby they allow product traceability for products such as food products and fashion. The following case study summarizes a 6-month pilot project conducted by Provenance whereby they used blockchain in combination with smart tagging and mobile technology to

provide traceability to end-consumers by tracking tuna from the origin in Indonesia to the point of sale. The solution proved successful by creating product traceability in the complex supply chains of the Southeast Asian fishing industry.

Provenance created a proof of concept in order to support the need for data interoperability. The seafood industry in Southeast Asia was chosen as it compromised the wellbeing of wildlife, environment and human beings. This has been reported to be an issue for seafood sourced in Southeast Asia and sold by European retailers. By introducing product traceability, socially and environmentally responsible practices can be certified and proven to the customer at the Point of Sale.

The phases in which the fish were registered and tracked all the way from the fishing boat to the end consumer were as follows:

Phase 1: Registering the Tuna at first mile. Provenance worked with fishermen at the point of capture whereby they would record the fish as a digital asset on the blockchain by sending an SMS as a new tuna was caught. These would be verified through trusted local NGO's. As the physical products were transferred to the tuna suppliers, so was the accompanied information on the blockchain.

Phase 2: Linking the blockchain with existing systems. The challenge was to develop interoperability with existing systems. The blockchain was developed with an open interface making it interoperable by default as long as each entity along the supply chain commits to recording their transaction in some way on the blockchain. By digitizing the supply chain from the first mile, the items sold in stores were accompanied by a digital record whereby it was possible to track the tuna back to the time it was caught in the ocean. As the tuna was processed into convenience goods, the corresponding assets on the blockchain were updated accordingly.

Phase 3: The consumer experience and building an interface for trust. The customer experience was developed with a combination of a mobile app and smart stickers such as NFC and QR (Quick Response) codes. By hovering a smartphone over the stickers, one could gain access to the product provenance including all the producers and suppliers involved.

Takeaways: While product traceability is desirable for multiple stakeholders, benefits must be in place for the principal company implementing the solution: Either through a market premium position or other cost saving opportunities it may create in the supply chain. It can easily be imagined that customers would be willing to pay a premium for products with known origins and proven compliance with sustainability standards. While customers may only use the product tracking a few times, the critical goal is to ensure that this information will make the customer trust the product for all future purchases. An important takeaway is, however, that blockchain isn't a technology that will solve

traceability by itself. While it provides a strong platform on which traceability can be built, digitizing information in a secure manner is just as big a part of the puzzle.

5. Current adoption stage of blockchain technologies

While there is a large discrepancy in experts' views on the maturity level of the blockchain technology, most agree that a more widespread adoption beyond early adopters is still several years down the road. According to Gartner's hype cycle, blockchain remains at the peak of inflated expectations assuming a plateau within the next 5 to 10 years. Moreover, the industry characteristics are also expected to have an impact on this, as some industries may be more fitting for blockchain than others. Examples of such industries are food and pharmaceuticals. Although this study has tried to emphasize many of the positive potential outcomes of applying the blockchain technology in a business context, it has to be said that there is still uncertainty and unknown factors that should be addressed at best effort before going for widespread adoption. Among these is the tendency of public media to put blockchain in bad light and the influence it bears on the general perception of the technology. Moreover, the internal integration in companies trying to integrate blockchain may possess significant barriers to a successful adoption due to the low digitization level of most companies' supply chains. To emphasize this matter, 60-70% of organizational change management projects tend to fail.

6. Steps in considering your first blockchain application

Even with a solid understanding of the core components of blockchain, it can be difficult to identify whether a particular business could benefit from implementing the technology.
The following steps are therefore identified in order to properly guide anyone who may consider applying blockchain in their business.

6.1 Determine how blockchain fits in your industry

Table 2 below presents an overview of some key questions that firms must ask themselves before considering applying blockchain in their business. If 'yes' can be answered to more of the following questions, blockchain can likely benefit business processes in that particular industry.

6.2 Identify inefficiencies in current business processes and transaction network

No system or network is stronger than its weakest link. Therefore, it is key to identify these and look at the different areas in which blockchain can make a difference. To get closer to an answer, you may want to investigate the following:

- Identify specific use cases. It is recommended to start small by aiming for use-cases that are less complex in nature (organizationally as well as technologically)
- Identify feasibility of blockchain to solve that problem - ask yourself the questions: is blockchain the right solution to solve this problem? Could other, more mature technologies be used to solve the same problem?
- Determine your goals of the blockchain pilot and identify the potential for future rollout of a more complete version.

Table 2: Questions in considering a new blockchain venture

QUESTION	ELABORATION
Is establishing trust, transparency and accountability between all the parties an issue?	Many businesses rely on work that is carried out by suppliers in less developed countries. In these countries, that are often responsible for manufacturing or possess valuable natural resources for production, governmental bureaucracy and corruption may interfere in the various business procedures.
Is the current system prone to errors from manual processes or duplication of effort?	Although production and transportation is increasingly becoming more automated, there is often a lot of paperwork associated with it; paperwork that tend to be carried out on a manual basis.
Is it critical to have a tamper-proof permanent record of transactions?	Some businesses, such as pharmaceutical companies may put more emphasis on the quality of historical data. If they can secure that old information is kept securely and won't be altered, they will likely operate under much better conditions and become more compliant.
Are we securing the ownership or management of a finite resource?	If double spending is an issue for your business, a blockchain will be able to mitigate this. A finite resource is a product that can be replicated such as a bill of lading or the transfer of ownership of an asset.
Does this ecosystem benefit from improved transparency?	If the business processes are simple and supply chain complexity is low, it is less demanding to establish transparency and trust between supply chain partners. Hence it might be achieved easily without advanced modern technologies.
Is the current transaction system vulnerable to fraud and IT security (cyberattacks)?	In many cases, companies cannot be too sure about the security level of their IT systems. Since businesses are shifting more and more away from paper-based information to digital backup solutions, a new key priority has become the ever-increasing awareness on resilient IT systems. Due to its composition, blockchain is one type of such resilient IT system.

Source: Based on Gupta (2018)

6.3 Identify dependencies and roadblocks

No matter how modern, advanced, or automated a system may be, it can never operate fully independently. To some extent, human intervention is always necessary, and blockchain is no exception. While this is true, the adoption process of blockchain will naturally have obstacles along the way. Firstly, mapping and connecting all links in the supply chain can be a daunting and resource-demanding task. Secondly, the up-front cost of developing a blockchain which is suitable for the business' needs can also scare potentially interested parties away. Thus, it is important to ask yourself the following:

- Do you need partnerships with technological or industry participants? Will the network be interested in participating in a trial project?
- Are there any regulatory uncertainties or potential roadblocks? Do we have internal buy-in?

6.4 Choosing a technological blockchain provider

Depending on the scope of the corporate unit, and the ambitions regarding the size of the desired network, one must consider *how* the blockchain setup should be structured. Most businesses would choose to build a private blockchain in order to maintain some degree of control, and in that way separate information sharing from parties who are not related to the business. It is hence crucial to investigate the following:

- Make a choice regarding a blockchain provider[5] as well as a platform that fits your needs (public/private) preferably in conjunction with other industry participants.
- If a private blockchain is chosen, how should it operate, and what should be the rules that govern the ledger?

Moreover, it is important to understand the current landscape of use-cases in your industry. This includes how blockchain is being used to solve similar problems and how these solutions fit with your desired results and strategy. If similar projects have been piloted by other companies, consider a partnership to leverage their platform and/or experience.

6.5 Deploy, Evaluate and Amend

In a feedback loop, it is essential to continually evaluate the value generated of the blockchain project and fine-tune the blockchain in conjunction with your blockchain network.

[5] Vendor selection to find the most suitable technological partner to develop the blockchain with.

7. Conclusion

Despite not being at a mature stage yet, several preparatory attempts have been initiated with decent outcomes. Among these, we looked at the case of Provenance, who made an attempt to track tuna from boats in Indonesia to retail stores in Europe. In particular, the combination of blockchain and IoT devices has proven a promising potential, as it provides a connection between physical assets and the blockchain.

The increase in transparency and material traceability due to the authenticity of the data stored in the individual blocks, allows for a greater degree of quality control of activities in other entities in the supply chain. Through the support of IoT devices, blockchain therefore allows a firm to monitor activities that add value to its products beyond its own boundaries. However, despite the promising outcomes of a well-functioning blockchain ecosystem in theory, blockchain is not necessarily superior when it comes to creating supply chain visibility. Blockchain's competitive advantage lies in its security networks and ability to potentially disintermediate old fashioned manual documentation treatment.

However, in smaller organizations the issue of lacking transparency and complex transaction networks might not exist, makes blockchain irrelevant. That being said, a blockchain ecosystem could greatly facilitate end-to-end visibility for businesses and the end-consumer; something that is demanded more than ever. Proving the origin of the product to a customer could be valuable for the company's brand image, while at the same time boosting their reliability.

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