White Paper

Inclusive Deployment of Blockchain for Supply Chains:
Part 1 – Introduction

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Blockchain and distributed ledger technology in supply chain and trade flows emerged as a top area of exploration – and a topic of much debate – in recent World Economic Forum events, including the 2018 and 2019 Annual Meetings in Davos-Klosters. Building on vital insights from these and other Forum meetings and research, the World Economic Forum's Centre for the Fourth Industrial Revolution formally launched a project focused on blockchain governance within supply chains in 2018.

Blockchain has the lasting potential to alter global supply chains, but it must also overcome several challenges standing in the way of widespread uptake. Because it is a nascent technology, supply-chain decision-makers do not yet have clear guidelines to ensure that blockchain deployment carefully considers unintended consequences and minimizes risks. To answer this need, the project focuses on the co-creation of new tools and frameworks to shape the deployment of blockchain technology in supply-chain systems towards interoperability, integrity and inclusivity. Without such guidance, unscalable, fragmented solutions that risk integrity could dominate the marketplace. It further aims to harmonize the application of blockchain technology across different industries, such as between manufacturers and transportation providers or asset-based operators and fourth-party logistics providers.

The project methodology reflects the mission of the Centre for the Fourth Industrial Revolution: to provide an international platform of expertise, knowledge-sharing and public-private collaboration to co-design and pilot innovative new approaches to policy and governance in the Fourth Industrial Revolution. The project community draws upon the Forum's robust supply chain, logistics and digital-trade communities and consists of 60-plus supply-chain and blockchain experts spanning 40-plus countries, representing governments, companies, start-ups, academic institutions and civil society. After co-designing and piloting the framework, the community will scale international adoption using the World Economic Forum's platform. Collectively resolving problems and unlocking opportunities will guarantee deployment that considers the needs of all players in the ecosystem.

This introductory white paper introduces the project, summarizes the main findings from the project's design-and-research phase and acts as a primer on blockchain (explaining the main concepts). It is designed to be accessible to those with varying degrees of blockchain knowledge, including those who are just getting started with the technology. The subsequent white papers – to be published over the next eight months – will cover important and specific governance considerations for decision-makers deploying blockchain solutions throughout international trade and supply-chain systems. The main deliverable and eventual outcome of the project (at the end of 2019) will be a concise, easy-to-use framework guiding decision-makers towards interoperability, integrity and inclusiveness with blockchain deployment in supply chains.

Introduction

Distributed ledger and blockchain technology promise to have far-reaching implications for global trade and supply chains. In fact, providing increased efficiency, transparency and integration throughout supply chains has been one of the most fertile areas for blockchain experimentation. Whether or not your organization or business unit is an early adopter, there is a high likelihood that most supply chains will be affected by blockchain technology at some point – whether using blockchain technology directly or at the application level, with connectivity or integration into an underlying blockchain-enabled data layer.

The extent to which this new technology realizes its potential for your organization depends substantially upon how well supply-chain actors steward its development. Therefore, the system needs clear guidelines and resources for leaders to better understand how to deploy the technology responsibly, to de-risk early adoption and to ensure future interoperability. To answer this need, the World Economic Forum has launched a systemic, multistakeholder project focusing on creating guidelines for blockchain deployment within supply chains. This paper kicks off the Redesigning Trust: Blockchain for Supply Chain project. The paper serves as a precursor to the two main project deliverables:

1. A series of white papers delving into the main considerations for blockchain deployment in the supply-chain context to be released over the next eight months
2. A pilotable toolkit consisting of main considerations and guidelines for blockchain deployment for supply-chain decision-makers that will be released at the end of 2019

This paper is designed to lay the groundwork for future white papers through basic alignment on blockchain features and the sharing of insights gained during the project design phase. It highlights the most pressing concerns of supply-chain decision-makers with blockchain deployment – coming from a wide group representing various global regions, stages of the supply chain and levels of blockchain knowledge. This paper does not present answers to these concerns, serve as a technical deep-dive or act as an achievable framework. Rather, it aims to align supply-chain decision-makers with varying levels of blockchain knowledge and present questions raised consistently during the design phase that will be answered in follow-up white papers and the project toolkit. The blockchain primer is also undertaken in simple terms to bring understanding about essential blockchain technology concepts. For these reasons, the paper will not delve into the multitude of technical layers, complexities, hypotheticals and exceptions that exist with blockchain and distributed ledger technology, though the authors recognize their existence and importance.

While blockchain is one type of distributed ledger technology (explained in more detail later in the paper), for simplicity, the terms are used interchangeably in this paper.

Supply chains of the future

While many focus today on specific blockchain use-cases for supply chains, it is important for supply-chain leaders to incorporate this technology into overall strategic planning. One opportunity for such thinking is maintaining a competitive advantage amid an emerging platform model – hallmarks of an increasingly digital world where new market leaders have the potential to rise through a digital platform model (examples typically cited for a digital platform model include Uber, Airbnb and Pinterest).

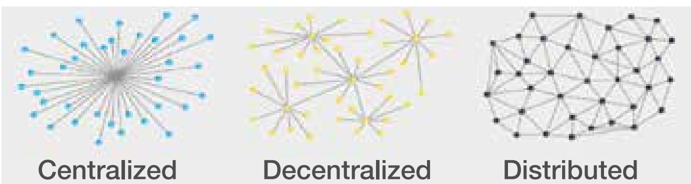
These new marketplaces provide access to network participants and assets – and harvest data from various sources to ensure "one version of the truth". By design, the platforms have access to – and control of – data regarding stakeholder relationships and interactions, and the interfaces and processes among network partners, in addition to detailed information on suppliers and customers. For example, electronic logistics marketplaces, end-to-end orchestration tools or fourth-party logistics providers and community systems have created digital and comprehensive networks of supply-chain partners ranging from suppliers to shippers in regard to processes, modes and geographies.

The deployment of platform systems is fuelled by a desire to simplify the complexities of day-to-day transactions among supply-chain stakeholders. Online platforms bring all such stakeholders together, allowing them to communicate seamlessly and enabling the reuse of data so that it needs to be entered into the system only once.

Due to the platform effect, the model can trend towards a "winner-takes-all" business model that grows through monopolistic participant capture. Blockchain technology, on the other hand, provides an alternative business model wherein the data layer is collaboratively owned and managed by its participants.

The decentralization elements of blockchain or even distributed systems can be a direct assault on competitive advantages enabled by the centralized digital platform business model. In defending against this threat, incumbents can look to blockchain technology to retain control of information collection, the interface and trust-building – without the need for a single entity guaranteeing the quality of the collaborative features and system optimization characteristic of centrally owned platforms.

Figure 1: Difference between a centralized platform model and decentralized and distributed blockchain models



(Source: Baran, 1964)

On the surface, the supply chain of the future very likely looks like those we know today, yet under the covers we can anticipate far-reaching changes that enable better communication, fewer disputes, higher system resiliency and substantial gains in operational efficiency. The resulting capabilities that blockchain enables range from consumers using their mobile devices to validate the authenticity or pedigree of products before a purchase to insurance providers offering dynamic rates on single supply-chain transactions based on their ability to view transactions unfold in near real time and to validate all requisite events on the blockchain. As digital technologies such as blockchain increasingly encourage higher levels of trust among supply-chain partners, they will have effects on processes in the physical world as well. As a result, fragmentation within and across industries could diminishes, the occurrence of errors and exceptions could declines, and operators could require fewer resources to complete the same tasks.

What Is a Blockchain?

Note: This section is not an exhaustive primer on blockchain technology. Details do vary from protocol to protocol and differ greatly depending on whether they are public or private, but the paper aims to lay out the features of blockchain at a higher level. It describes the foundations of the technology without delving into the multitude of technical complexities, layers, hypotheticals and exceptions that exist with blockchain and distributed ledger technology, though the authors recognize their existence and importance.

A typical supply chain may involve hundreds or thousands of business transactions every day. These transactions generally take place in a bilateral manner – for instance, between a supplier and a manufacturer or between a retailer and a logistics service provider – and are stored in each of the supply-chain actor's own ledgers. As a product travels from its origin to its destination in a supply chain, there may be many organizations involved. Each holds its own version of "truth" about the product's journey. The multiple ledgers (hence the multiple "truths") often lead to error, fraud, delays and inefficiency.

Blockchain, as distributed ledger technology, can reduce those complex bilateral communications and informational linkages and leakages by providing a single, shared, tamper-evident ledger that records the transactions as they occur. Transactions in a blockchain are typically confirmed by all participants via a consensus mechanism. Once validated and recorded in a blockchain, a transaction becomes permanent. No single participant, even a system administrator, is able to delete or change a transaction unilaterally. Therefore, blockchain enables supply-chain actors to share control over access to – and evolution of – the data.

While several preconditions must be met, and depending on the type of blockchain, in general all related participants in a business network can simultaneously have an identical copy of the data at any moment in time.

Getting technical

Blockchain is a shared, distributed ledger of records or transactions that is open to inspection by every participant but not subject to any form of central control.

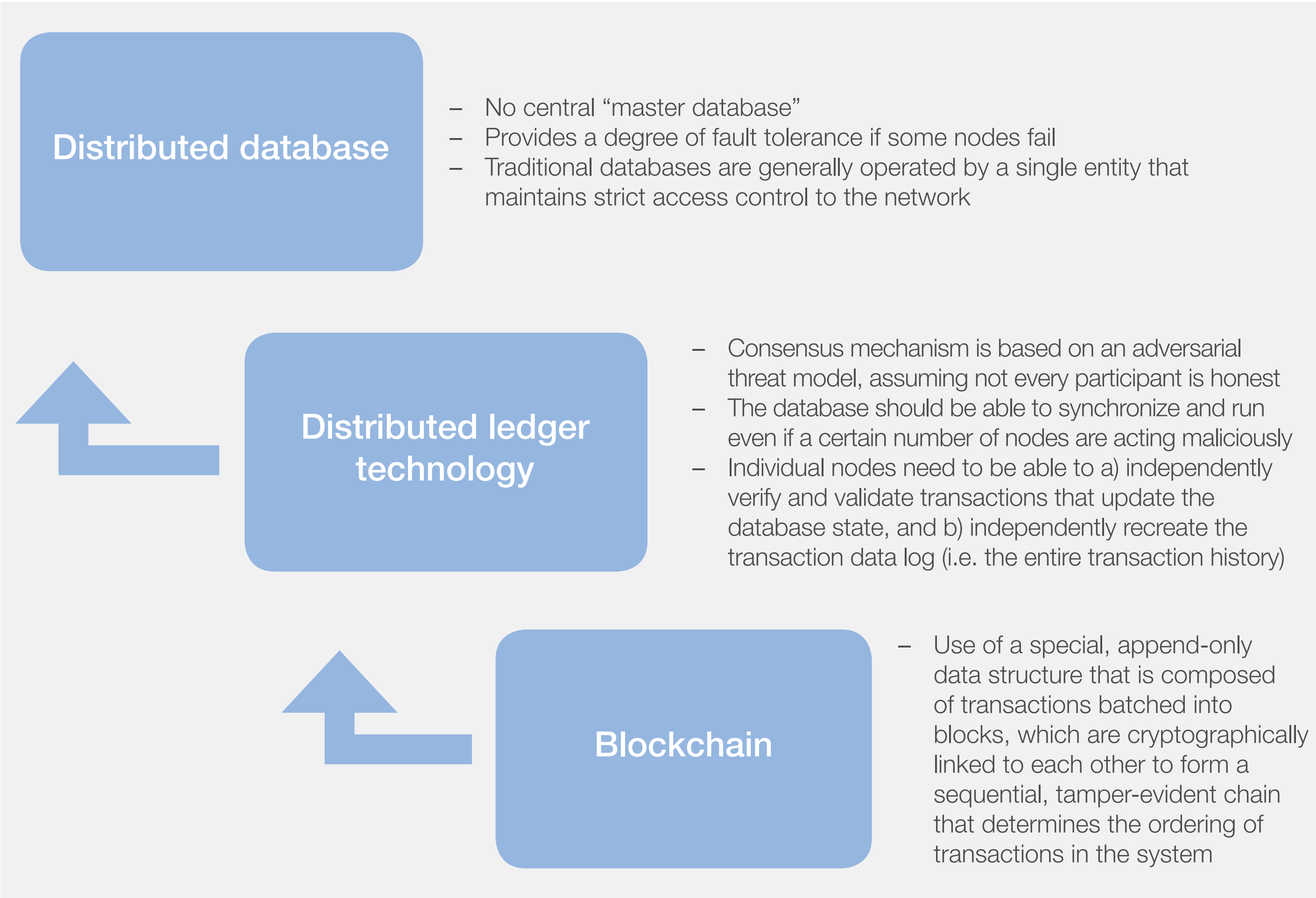
In technical terms, blockchains are peer-to-peer distributed networks that are cryptographically secure, append-only, tamper-resistant (extremely hard to change) and updateable only through distributed consensus. Blockchain technology and distributed ledger technology (DLT) are often used interchangeably but, strictly speaking, blockchain is an architectural subset of DLT and shares the same principle of enabling distributed control over the evolution of data without a central party.

A blockchain is composed of a chain of cryptographically (explanation and definition of technical concepts are listed in the Glossary at the end of the paper) linked "blocks" containing batched transactions. Shortly after each transaction occurs, it is put into a block. These blocks are mathematically "chained" together. The blocks are verified and managed by the network nodes (computers or users participating in a blockchain network) via a shared governance protocol. Each node contains a complete record of all of the transactions ever recorded in that blockchain. No single node can change or delete a block. Nodes collectively agree on valid transactions to include in the blocks through a consensus mechanism.

Blockchain technology was invented by someone using the name Satoshi Nakamoto in 2008, and in fact is an innovative combination (peer-to-peer networking, distributed timestamping, cryptography hash functions and pointers, digital signatures and Merkle trees, among others) that have in some cases existed for decades.

Blockchains are the most popular DLT deployed in practice; however, other types of DLT have also emerged. One example is those based on Directed Acyclic Graph such as IOTA's Tangle.[1]

Figure 2: The relationship between distributed databases, DLT and blockchain



(Source: Hileman and Rauchs, 2017)

Many supply chains currently handle large, complex datasets to store and share information. A central question is how blockchain can add value to existing technologies and business processes. To answer this question, we need to look at some core characteristics of blockchain:

– *Disintermediation.* Blockchain’s peer-to-peer network reduces reliance on a third-party intermediary. Network participants can independently verify the integrity of – and have shared control over – the ledger. In general, disintermediation of traditional intermediaries may take place if the cost of traditional intermediaries exceeds the value they add. There may well be new forms of intermediaries emerging.

– *Auditability*. The information within a blockchain can be easily made visible to all participants who have been authorized to view it and in general cannot be altered by a single entity. Depending on the underlying technology and use of cryptographic techniques, it can usually be designed around what information is available to whom. This improves auditability, creates trust and reduces fraudulent behaviour.

– *Cryptographic constructs*. This relates to the protection of information: cryptographic techniques, including cryptographic hash functions and digital signatures, are deployed to safeguard the records in the database. With careful integration of cryptographic constructs, supply-chain actors can encrypt and protect sensitive and commercial information using blockchain technology. Certain cryptographic features are not unique to blockchain technology and can be ensured with traditional cryptography.

– *Resilience.* Blockchain technology can be more resilient to certain types of cyber-attacks, such as denial-of-service attacks, whereby a server is halted via flooding it with internet traffic. Blockchain networks are harder to take down because their distributed, redundant nature creates potentially thousands of targets instead of just one. It is important to note that there are many aspects and requirements to an effective cybersecurity strategy. Effective cybersecurity is dependent on careful engineering, code review, system design and other organizational, legal and standards factors – using a blockchain alone generally does not add value in this respect.

- *Single-version-of-truth*. All blockchain transactions are time-stamped and tamper-proof, providing a single source of data integrity. There is no need for reconciliation among the different participants; reliable information exists only in one place on the distributed ledger. The participants can, therefore, expect that everyone works on the same information and rely on the information on the shared ledger.

- *Immutability*. Data recorded cannot be changed or deleted by a single actor. Instead, it is verified and managed using governance protocols. This set-up can effectively secure the data in blockchain ledgers against unauthorized manipulation. However, it is important to note that absolute immutability does not exist. Transactions can be removed or adjusted in theory, if enough nodes collude (wittingly or unwittingly).

- *Smart contracts.* Blockchains can be programmed to automate business processes (e.g. making payments) in different entities. A smart contract is a computerized transaction protocol that automatically executes the terms of a contract upon a blockchain once predefined conditions are met. This can potentially reduce the costs and delays associated with traditional contracts. More information

Public vs private blockchain

As blockchain is a nascent technology, the exact categorization and definitions of different blockchain structures and types are subject to some debate, and the terms are in flux. Typically, it is recognized that there are two broad categories of blockchain technology: private and public. The distinction is based on access – in other words, who can read and submit transactions to a blockchain and participate within the consensus process. In a public blockchain, anyone can access and take part in the ledger, while, in a private blockchain, only selected parties can access and make changes to the distributed ledger.
In a public blockchain, transactions are broadcast to every single participant (node) and every node thus keeps a complete record of the entire transaction history. Economic incentives are built in to encourage behaviour; for instance, rewarding validators (e.g. miners) with tokens (note that exceptions do exist, e.g. IOTA's Tangle technology, which does not rely on miners but on collaboration and thus has no transaction fees).[1] Today, Bitcoin is the most familiar example of a blockchain network that is public.

In addition to public blockchains, there have been multiple efforts to create private ones, often used by industry consortia, which apply the principles of the technology, but, due to privacy, regulatory or system performance concerns, limit access to the blockchain to only those organizations that have been admitted into the network. A follow-up white paper in the series will review the respective strengths and weaknesses of public and private blockchain for supply chains and explore the topic.

Both public and private blockchains need to have their transactions verified, and this is done by consensus. There are different consensus mechanisms available. Generally, they deploy an incentive structure that rewards participants who contribute to the network. The most popular consensus mechanism in a public blockchain is proof-of-work (PoW), where miners must solve complex mathematical problems to verify transactions (a process known as mining), and they are rewarded in the form of cryptocurrency. Though an effective verification technique, PoW is often criticized as time consuming and power intensive – resulting in slow transaction speed and high electricity costs. Consensus in a private blockchain is not achieved through mining. While today the major consensus algorithm is PoW, there are other alternatives. The alternatives typically require only a small expenditure of computational resources by participating miners.

According to Hileman and Rauchs (2017), blockchain can be further segmented by distinguishing between different types of permission models (Table 1). The permission model refers to the different types of permissions that are granted to participants of a blockchain network.

Read: Who can access the ledger and see transactions
Write: Who can generate transactions and send them to the network
Commit: Who can update the state of ledger

Table 1: Different types of permission models

			Read	Write	Commit
Blockchain types	Open	Public permissionless	Open to anyone	Anyone	Anyone
		Public permissioned	Open to anyone	Authorized participants	All or subset of authorized participants
	Closed	Consortium (multiple organizations)	Restricted to an authorized set of participants	Authorized participants	All or subset of authorized participants
		Enterprise (different units within a single organization)	Fully private or restricted to a limited set of authorized nodes	Network operator only	Network operator only

Other blockchain solution concepts

"Hybrid" or "consortium" are terms used to explain a blockchain solution that can cause confusion for some supply-chain decision-makers. These terms are used in different ways by different parties. So, it is important to align on definitions within the context of use to avoid confusion. There follows one interpretation of each term.

A "hybrid solution" combines both private (preserves privacy and restricts visibility) and public (provides better transparency and immutability) blockchain networks. It allows participants to use permissioned networks that limit access to some data, while also interacting with any public blockchain when there is a need to do so.

A "consortium solution" is a blockchain where the consensus process is controlled by a preselected set of nodes; for example, one might imagine a consortium of 15 financial institutions, each of which operates a node and of which ten must sign every block for the block to be valid.

On-chain versus off-chain

On-chain: process or transaction that takes place directly on a blockchain.

Off-chain: process or transaction that is external to a blockchain.

Blockchain Use-Cases in Supply Chains

The concrete value brought by blockchain technology can best be understood based on use-cases. The following section outlines some of the most popular use-cases in the supply chain context to date. Once again, this section does not delve into all of the complexities and technical details involved in the application of the technology. It strives to keep the explanations accessible to those who are just getting started with the technology.

Product provenance and traceability

Due to an increasing demand from customers for the proof of legitimacy and authenticity of the products they purchase, there is a strong interest in the deployment of blockchain for product provenance, often referred to as pedigree. These products range from luxury items, such as diamonds, to aerospace and automotive parts, and organic and fair-trade food products.

In general, blockchain has features that can help trace a product's digital footprint. The enhanced data integrity (aided by the immutability feature of blockchain) can lead to increased confidence from customers of products' legitimacy. Moreover, the use of timestamping (the process of establishing a chronological order among sets of events) in the blockchain can prove the existence of certain data at a point in time. The fact that the data is timestamped (tamper-proof) provides a single source of data integrity and allows users to retrieve a full history of activities. Information completeness can be enhanced as well, as blockchain can accommodate a wide range of data, including ownership, location, product specification and cost. Blockchain is a way to prove the existence of tracking data (as well as the fact that it hasn't been changed) at a given point in time.

While blockchain technology can guarantee that the data is not tampered with (the provenance and traceability data cannot be modified), it does not guarantee that the data recorded is accurate. Additional checks and balances may still be necessary to ensure increased data integrity.

Streamlining (global) supply-chain operations

A blockchain-based platform can support the digitization of paper-based documentation, and establish an immutable, shared record of all transactions among network participants in near real time. In this sense, blockchains are suited to large networks of disparate parties and are a solution to making the complexity of global supply chains much more manageable. It is important to note that digitization is a prerequisite for blockchain (digital product identity at some level, for instance, is a prerequisite to traceability using the blockchain).

Blockchain technology can enhance end-to-end supply-chain integration. Currently, some companies use enterprise resource planning (ERP) systems to manage their internal processes and other systems – such as customer/supplier relationship management (CRM/SRM) – to interact with their customers and suppliers. They also use communication tools such as Electronic Data Interchange (EDI) and Extensible Markup Language (XML) messaging to enable information flows between different organizations. Together, these systems create somewhat more integrated supply-chain information systems, if only for parts of the data that exist in several places. However, this should not mask the fact that each participating entity still tends to have a limited view of where the products are at all times.

While some platforms already aim to provide higher levels of visibility for all supply-chain participants, blockchains make such visibility more secure and immutable for all actors by allowing them to share and agree on important information. This removes data redundancy, double entries and crosschecking, which are very common in today's bilateral communications.

Automation and smart contract

There are still instances where current operations, processes and data exchange in supply chains are manual and error-prone.

Secure data-sharing and, specifically, smart contracts allow for increased automation and efficiency through avoidance or redundant data entry, acceleration of transaction execution and reduction of errors and misunderstandings. Smart contracts can help with cascading of purchasing orders, invoices, changing orders, receipts, ship notifications, other trade-related documents and inventory data within a supply chain (Wang et al., 2018).

Smart contract

A smart contract is a self-executing software program that automatically performs a function (e.g. makes a payment, releases documents or transfers ownership).

In the blockchain context, smart contracts are computer codes running on top of a blockchain containing a set of rules under which the parties to that smart contract agree to interact with each other. If and when predefined rules are met, the agreement is automatically executed. The smart-contract code facilitates, verifies and enforces the performance of an agreement or transaction automatically without the need for any one party to intervene or trigger an action.

The concept of a smart contract was originally proposed by Nick Szabo in 1997. A smart contract was referred to as a computerized transaction protocol that executes the terms of a contract (such as collateral, bonding, delineation of property rights, payment terms etc.). In 2013, Vitalik Buterin (who co-founded Ethereum) first introduced smart contracts with blockchain.

Smart contracts are not unique to blockchain. Quoting the example offered by Szabo, a vending machine can be considered as a primitive ancestor of a smart contract. The rules of a transaction are programmed into a vending machine. The machine takes in coins and, via a simple smart contract mechanism, dispenses change and product according to the displayed price.

Traditional databases can execute a smart contract, but they still need a trusted central coordinator and cannot enforce immutability (i.e. a single user with administrator rights can undo a transaction without the agreement of others). A smart contract built for blockchain transactions provides added security and tamper-resistance, and decreases reliance on trusted intermediaries. Also, smart contracts on blockchain are guaranteed by system rules and the outcomes are verifiable and auditable by all network participants. In other words, because no single party executes a smart contract on its own, they provide a higher level of reliability and trust.

Trade finance

The Asian Development Bank estimates there was a $1.5 trillion trade financing gap in 2017, representing roughly 10% of global merchandise trade volumes. SMEs (small and medium-sized enterprises) and mid-cap companies represent 75% of the total trade gap. Left unsolved, the trade finance gap will rise to more than $2.4 trillion by 2025, according to Bain & Company estimates. However, a viable solution has emerged. Bain's modelling estimates that new digital technologies, especially distributed ledger technology, can reduce a large part of this gap, facilitating about $1.1 trillion of new trade volumes globally (World Economic Forum, 2018a).

Blockchain used in trade finance helps to remove inefficiencies from existing processes. Over time, it creates records that allow entities such as banks to enhance KYC (know your customer) processes and improve assessments of, in particular, SMEs in emerging markets. For example, blockchain can enable processes that can be used for faster credit risk assessment, minimized human errors in documentation checks, instant verification and reconciliation of records, automatic execution of workflow steps via smart contract, and instant and secure exchange of data (World Economic Forum, 2018b).

An application is the securitization of assets on the blockchain, which enables them to act as collateral in previously unavailable supply-chain finance opportunities. This securitization allows for financing models, such as inventory financing, to flourish at scale compared to their relatively obscure and cost-prohibitive existence in a pre-blockchain world.

Anti-corruption and humanitarian operations

Trust afforded by blockchain may help prevent supply-chain actors from behaving unethically or opportunistically. Because every transaction builds on every other transaction in a blockchain, corruption or unethical behaviour should be more readily visible to network participants. The technology can make it more difficult for unethical behaviour to occur; however, it is still important to recognize that existing and new checks-and-balances may still be necessary.

Equally, a blockchain system could help to expose and eliminate corruption witnessed in certain public-private interactions. Blockchain could increase transparency and trust in humanitarian supply chains as well, where financial aid could not reach or was perceived to be unable to reach target beneficiaries (Hyndman and McConville, 2017).

Use-cases	Description	Supply-chain objective	Examples
Product provenance and traceability	Blockchain-based systems support safeguarding the accuracy of product certificates and reduce risks of fraud and adulteration.	Improved product safety, authenticity, provenance and pedigree resulting in a reduction of fraud. The provenance link also helps producers and channel partners to create more intimate ties to consumers. Equally important, tracking goods throughout the production process improves the accuracy of forecasting and collaborative planning within the supply chain.	**OriginTrail solution** delivers verifiable supply-chain traceability and product authenticity, with existing applications including traceability for GMO (genetically modified organism)-free dairy products, free-range poultry and fresh vegetables, preventing counterfeiting in wine exported to China, and an integration with the internet of things (IoT) smart products platform.[2] **Skuchain's** solution enables tracking of goods on the stock-keeping unit (SKU) level and their transformations in production, particularly useful for tracking critical components such as sub-assemblies, parts and raw materials used to make finished products.[3]
Streamlining (global) supply-chain operations	Blockchain enables efficiencies for information transfers and data-sharing as well as for transaction execution among multiple entities in a supply-chain environment.	To digitalize global trade ("paperless trade"), provide end-to-end visibility and allow secure information sharing between organizations. This allows parties to take full advantage of essential blockchain features (information cannot be altered, more secure and jointly agreed upon) when sharing or transferring electronic documents or other information.	A few solutions exist today where blockchain is used to automate and digitize the bill of lading (BOL) or other trade documents. Examples include **Wave**[4] and **CargoX**.[5] Ocean carrier **Zim** (using Wave's solution) offers customers the opportunity to switch to blockchain-based electronic BOLs on select trades.[6] Separately, some port community systems (members of International Port Community System Association/IPCSA), carriers, shippers and banks participate in the development of a BOL proof of concept based on blockchain and smart contracts.[7] **Truckl,** a start-up focused on over-the-road transportation, writes every supply-chain event that occurs to the public blockchain, enabling higher trust between supply-chain partners while ensuring that parties act responsibly.[8]
Automation and smart contracts	Blockchain systems can automatically enforce rules and process steps. Once launched, smart contracts are fully autonomous: When contract conditions are met, pre-specified and agreed-to actions occur automatically.	To increase transaction efficiency through faster and more automated supply-chain processes, which takes cost out of the supply chain and also enhances the trust multiple parties place in each other.	The **IPCSA** example above exploits smart contracts for BOLs. The smart contract controls the endorsement process of the BOL while the application synchronizes the logistic process for entities holding the BOL. In addition, delivery orders are released automatically upon the presentation of the BOL from the importer back to the import shipping agent.[9]

Trade finance	Bringing trade finance products and processes (such as a letter of credit) onto the blockchain enables more secure commercial transactions as well as the sharing of information between exporters, importers and their respective banks on a secure blockchain-based platform.	To enable secure financial transactions in global trade along with increased efficiencies for transactional processes and reductions in operating costs.	Project **Voltron** (Documentary Credits) and Project **Marco Polo** (Open Account) each provide solutions that expand finance to a greater number of SMEs and introduce new opportunities to finance trade.[10] The **Bank of America Merrill Lynch** (BofAML), **HSBC** and the **Infocomm Development Authority of Singapore** (IDA) have developed a prototype to bring the paper-intensive letter of credit (L/C) process onto a blockchain (DHL, 2018).
Anti-corruption and humanitarian operations	Blockchain can deter supply-chain actors from behaving unethically or opportunistically while providing a full audit trail of the spending of financial aids.	To build a "fairer", transparent, efficient and more reliable humanitarian supply chain.	The **World Food Programme's** Building Blocks pilot project uses blockchain technology to help refugees of the Syrian Civil War. In the Azraq refugee camp in Jordan, 10,000 people receive food from entitlements recorded on a blockchain-based computing platform. Refugees purchase food from local supermarkets in the camp by using a retina scan instead of cash, vouchers or e-cards (WFP.org, 2017).

Main Blockchain Concerns

The design phase (completed in 2018) for the Redesign Trust: *Blockchain for Supply Chain* project included issue identification, literature review and user-centric and governance gap research. Throughout the multistakeholder discussions, dialogues and workshops, the team identified consistent fears and concerns. Such concerns can undermine or even stifle blockchain technology's potential to bring about positive transformation in the supply-chain environment and necessitates finding appropriate collective responses.

The goal of this section is to share the main concerns and related insights identified during the project's design phase. It aims to provide a nuanced understanding of these concerns – not provide solutions or possible answers to the concerns. In so doing, it hopes to enable a better grasp of the tools necessary to support trust in blockchain deployment.

The list of concerns does not include technological challenges (e.g. performance and scaling issues), as supply-chain decision-makers recognize the progress underway in this area.

Hype

So far we have seen a lot of enthusiasm around blockchain in the supply-chain space. It is these high expectations that brought the blockchain topic to the board agenda – and, in many ways, this has opened the door to discussing various supply-chain system standardization issues that have long been lacking in the industry. Experts are worried that promoting blockchain in supply chains where other technologies suffice, or are a better fit, will damage the technology in the long term. This creates frustration, consumes resources in pointless experimentation, slows the development of solutions for the problems at hand and can even lead to the absorption of unrecoverable investments and costs.

How the Forum is addressing this:

Blockchain Beyond the Hype – A Practical Framework for Business Leaders (World Economic Forum, 2018b) is a toolkit designed to assist executives in understanding whether blockchain is an appropriate and helpful tool for their business needs – and lead them through considerations for decision-making and deployment.

Lack of impartial education

There is also much misunderstanding and confusion about the technology in the supply-chain space.

At present, most blockchain education comes from the media and company representatives promoting their solutions. In many cases, the solutions address the same problem (e.g. putting the bill of lading/BOL on the blockchain), but vendors use very different narratives to position their way as the best. This has created confusion and led to many misconceptions – complicating the task of creating trust in an environment that is prone to mistrust. In addition, in some cases those developing blockchain technologies do not have sufficient knowledge about the logistics industry, or the logisticians do not understand blockchain technology.

How the Forum is addressing this:

To ensure impartial content and guidance, the Blockchain for Supply Chain project codesigns with a multistakeholder community and represents diverse perspectives and interest. The project methodology reflects the purpose of the Centre for the Fourth Industrial Revolution: to provide an impartial international platform of expertise, knowledge-sharing and public-private collaboration to co-design and pilot innovative new approaches to policy. Collectively resolving problems and unlocking opportunities will guarantee deployment that considers the needs of all players in the system.

Data security and integrity

Findings from the project design phase showed an important concern at all levels of the organization about what blockchain technology means for security. As with any emerging technology, parties worry about the vulnerabilities that nascent blockchain technology presents, especially as blockchain is still poorly understood.

Fears are also fuelled by reports about cryptocurrency hackings and blockchain companies disappearing with millions of dollars of people's money. However, cryptocurrency is not relevant for most supply-chain solutions today. Furthermore, it is important to make a distinction between attacks on an application – and the platform itself.

With data integrity concerns, many beneficial cargo owners (BCOs) and logistic companies spend extensive resources on "data scrubbing" and data reconciliation ("garbage in, garbage out") – so the impact of blockchain on data integrity is naturally a big focus. With data integrity, there is confusion over how data changes can be made when necessary, given the immutable quality of the technology.

How the Forum is addressing this:

In addition to the inclusion of data security measures in the final framework, one white paper will be dedicated to security within blockchain deployment in supply-chain solutions. This will be co-designed in collaboration with the World Economic Forum's Centre for Cybersecurity together with a group of top experts in the field.

Data protection and privacy

Data protection and privacy is critical to supply-chain actors as business transactions often contain highly sensitive commercial information, and governments do not want to reveal or trade information. Many of the concerns go back to lack of clarity on data ownership on the blockchain (and how data ownership correlates to freight ownership) – and whether the technology can distort data ownership.

At present, some supply-chain actors are using misconceptions and myths around data-management compliance as an excuse not to participate in data-sharing and blockchain projects. Experts and industry insiders feel that this is due, in part, to a desire to protect their leading position. As a result, these companies are then using data-protection concerns with blockchain to artificially create barriers to sharing data.

How the Forum is addressing this:

A white paper and a component in the toolkit will be dedicated to data protection and privacy in relation to blockchain deployment in supply chains. While promoting transparency with blockchain, the framework will help business decision-makers still ensure that data is managed (exchanged/transferred, recorded, processed, stored) in a compliant way.

This will be a collaborative effort with top data-protection and policy experts, legal, data-protection regulation experts and with the Data Policy team at the World Economic Forum's Centre for the Fourth Industrial Revolution.

Interoperability

Since Maersk and IBM announced their collaboration to use blockchain technology in trade in March 2017, distributed ledger technology – with blockchain as its most prominent technology – proof of concepts have flourished in the shipping industry. For instance, Port of Antwerp, Pacific International Lines and PSA International have all carried out blockchain pilots, and there is no shortage in blockchain technology start-ups and consortia. In fact, members of the supply-chain environment feel confronted with many solution options and there is a general concern that different blockchains do not currently speak to each other. Decision-makers have also highlighted worries about choosing solutions that are future-proof and interoperable.

How the Forum is addressing this:

The toolkit will include the conditions decision-makers can create to encourage a blockchain solution that is as future-proof as possible.

Access

A recurring theme throughout the research phase was the need to ensure that the benefits of the technology are globally accessible by both large and small players. This desire was particularly prevalent with government actors (e.g. ports or those managing trade single-window systems) who want to ensure their smaller, local beneficial cargo owners or supply-chain providers do not lose out.

Industry experts also point out that lack of transparency and misalignment can be by design, as it forms the base and raison d'être of certain businesses. Those in monopolistic or leading positions may maintain control of their business opportunities and prefer a lack of transparency, which is counterproductive to accelerating the benefits of blockchain.

How the Forum is addressing this:

The framework development will be intentional in including considerations and a code of conduct that ensure SMEs and civil society have access to the benefits and opportunities of blockchain technology. This guidance drives open, neutral and fair solutions so that there is not a greater separation of the haves and have-nots.

Corruption

Corruption within trade is one of the most persistent and difficult challenges to overcome – and at its core lies lack of transparency. Due to its ability to increase transparency, many stakeholders have cited blockchain technology as a tool that can reduce corruption. Others, however, warn that the disruptive potential of blockchain might be reduced by those in power with a vested interest in discouraging transparency – a kind of "by-design" state of parts of the supply chain. Customs clearance processes in developing countries were cited as one such area of created complexity.

How the Forum is addressing this:

In a separate project, the World Economic Forum is assessing the potential of blockchain for trade single-window systems (aimed at helping to curb corruption).

The following table is a summary of questions and perspectives from supply-chain actors that were shared during the design phase of the project. These are useful as they reveal the fears and concerns of potential users; however, they also reveal some misconceptions about blockchain technology. While some of the questions can easily be addressed through a common understanding of blockchain technology, others require further debate. It is not an exhaustive list and the questions do not necessarily accurately reference blockchain technology terms accurately (since they were taken directly from supply-chain actors).

Type of concern	Typical questions asked by supply-chain actors learning
Hype	– What is the real cost of and ROI on blockchain? – Is the hype of blockchain all it's meant to be? – When is it too early/too late to develop blockchain solutions?
Lack of impartial education	– Will regulations stem from not understanding the technology, which leads to poor regulations? Is the only endgame either no regulation or poor regulation? Can there be a sweet spot above those two options? – Some technology vendors claim their system is the only open and neutral solution. What constitutes open and neutral?
Data protection and privacy	– Do we risk exposing our commercial information? – Who owns data that is recorded and stored by blockchain – especially where blockchains are open and public or hybrid? – Who has the right to gather, access, alter, delete or commercialize this data? – Where data is "owned" by the system, who is liable?
Data integrity	– How can we ensure that the data represents the related off-chain reality? What about the accuracy and authenticity of data put on to the chain or handled "off-chain"? – Can we correct wrong data ("scrub data") on blockchain? – What does data accountability mean with blockchain? – How do you delete data? How do you remove consent later? – How do we make sure we do not enable competitors?
Data security	– Can the code be trusted? – Who wishes to entrust the processing of data flows of the core processes of the business to start-ups with no track record? – How resilient are smart contracts?
Interoperability	– Can blockchains speak to each other? – Will the industry get to one global blockchain to rule them all? – What blockchain platform do you use? – Why don't we simply enhance our communication protocols to APIs?
Standards	– How do we align standards from different international bodies and associations? – How might we enable everyone to see the value of driving to these standards in such a way that they are not financially discouraged? – Setting new standards may allow certain people to move ahead. How do we avoid power players doing all the work?
Access	– How can we be proactive in levelling the playing field? – Can you avoid making the wealthy wealthier by executing this plan to digitize supply chains? – Lack of incentives: How much would we save from deploying this technology? How much more would we make?
Corruption	– When on the blockchain, how can we be sure who is putting the data in, who is accessing it and what is ultimately done with it? – How do we identify and encourage actors who may show resistance to blockchain as they want to maintain a lack of transparency?

Blockchain is a Team Sport

Blockchain is a team sport – it requires collaboration. By its very nature, blockchain and distributed ledger technology make transformation from an isolated approach to end-to-end value-chain integration within fragmented and complex systems more attainable. However, chief executive officers are recognizing that even the largest players cannot set up solutions alone. In turn, industries are starting to understand the need for industry-wide collaboration with blockchain so that proof-of-concept, standards and solutions can be adopted at industry scale. A lack of collaboration can undermine or even block the transformation that blockchain technology has the potential to bring about in a given ecosystem.

While the rewards from collaboration can be high, agreeing on what constitutes a fair and well-designed consortium governance system – let alone a consortium joint blockchain platform – can be challenging. This is where many industry collaboration efforts have fallen apart.

Two examples of the value of industry collaboration:

Mobility Open Blockchain Initiative (MOBI)
Industry collaboration in conducting proof of concepts (POCs) is vital in a mobility industry, where rideshares/carshares are increasingly becoming the norm and autonomous vehicles are on the horizon. In these instances, vehicles manufactured by different OEMs (original equipment manufacturers) need to communicate in efficient and effective ways. While POCs are important to understand the technology and assess its benefits, without jointly developed and agreed governance and standards that ensure interoperability, the independent POCs have little value.[11]

Maersk and a customer
Even between only two organizations, there can be value in developing a prototype together. Especially where a topic can be explored together, learnings shared and potentially more collaborators eventually invited. Together with a long-term customer, Maersk has developed a prototype for a decentralized freight calculation tool. The tool is based on a smart contract that enables both organizations to tap into the same information when they calculate freight costs, solving the current isolated-thinking approach to a shared, cross-organizational activity.[12]

Looking Ahead

This paper represents the first step in a project with a multistakeholder approach to co-design a framework guiding deployment of blockchain in supply chains. The aim of the project is to help decision-makers at deployment stage to unlock blockchain's potential in a way that ensures interoperability, integrity and inclusion. Considerations for decision-makers to contemplate will cover, among others, security, data protection and privacy, interoperability, trustworthy digital-identity verification, type of blockchain structure and more. Exploratory white papers will be issued on each of these topics over the next months leading up to the framework release.

Through this project, the Forum will, in the coming year, spur action in the supply-chain space in the following ways:

– **Partnership.** The Forum will continue to nurture partnerships and convene the foremost international communities of governmental, corporate, civil society and technical leaders committed to shaping the governance and application of blockchain in supply chains.

– **Public-private cooperation.** The Forum will bring together stakeholders to ensure that responsible blockchain deployment in supply chains is a matter of cooperation between government, business and civil society.

– **Drive responsible international adoption.** The Blockchain for Supply Chain projects will use the Forum's global platform to scale internationally to ensure we shape the future of blockchain technology for the next generation of supply chains.

With a richer, more collective and nuanced understanding of the opportunities and risks, supply-chain decision-makers will be better equipped to deploy blockchain solutions that best support their strategy while engendering trust.

Glossary

Consensus protocol: Set of rules and process(es) that determine how nodes reach agreement about a set of data and whether to approve (validate) transactions in the network. As per MIT Center for Information Systems Research, it is defined as the algorithm used to validate transactions and blocks. Consensus may rely on cryptography and a percentage of participant votes (nodes) to validate a block. Consensus protocols must also provide a mechanism for resolving block conflicts. At the other end of the spectrum, in some privately owned blockchains, the owner may decide that only the transacting parties and one other node are required to validate. The amount of time and computing power necessary to run a blockchain vary significantly based on the consensus type and percentage of nodes required.

Consensus (for a blockchain network): The collaborative process that members of a distributed blockchain network use to agree that a transaction is valid and to keep the ledger consistently synchronized. In a business blockchain context, a wide variety of consensus mechanisms are available to choose from. Where trust is high, simple majority voting may suffice, or the network may choose to use a more sophisticated method.

Cryptocurrency: The generic term for any digital asset or "token" that can be mined, purchased or transacted within a blockchain or distributed ledger network. The most famous cryptocurrency is bitcoin and others include ether, Litecoin and NEO, among over one thousand others.

Cryptographic hashing functions and pointers: Cryptography tools used in blockchain networks. Hashing functions turn any input (e.g. a password, or jpeg file) into a string of characters that serves as a virtually unforgeable, unique and encrypted digital fingerprint of the data, called a **hash**. A hash pointer records where some information is stored. Cryptographic hash functions have many information security applications, notably in digital signatures, message authentication codes (MACs) and other forms of authentication.

Cryptographic techniques/Cryptography: The methods of using mathematical cyphers (codes) to protect or "encrypt" transactions as they are being stored or shared.

Digital signature: A mathematical scheme used for averring the authenticity of digital assets.

Distributed timestamping: In computing, timestamping refers to the use of an electronic timestamp to provide a temporal order among a set of events. In a blockchain, timestamps show the blocks are connected in chronological order. It marks the time for each transaction on the blockchain. A timestamp proves when and what has happened on the blockchain and is tamper-proof. It plays the effective role of a notary and is more credible because it is extremely difficult to alter the records.

Immutability: Refers to the ability not to be changed – data stored in a blockchain is very hard to be changed, even by administrators. However, absolute immutability does not exist.

Merkle trees: In 1979, Ralph Merkle patented the concept of hash trees, better known as a Merkle tree (the patent expired in 2002). The basic idea behind a Merkle tree is to have one set of data or data point linked to another, tying them together and rendering the data difficult to adjust due to the interlinking. Hash trees can be used to verify any kind of data stored, handled and transferred in and between computers. They can help ensure that data blocks received from other peers in a peer-to-peer network are undamaged and unaltered, and even to check that network participants have not removed, altered or added illegitimate blocks in the system.

Network nodes: Nodes represent network agents or participants, such as banks, government agencies, individuals, manufacturers and securities firms within a distributed network. Depending on the permissions set in the network, they may be able to approve/validate, send or receive transactions and data. They may validate transactions through a consensus protocol before committing them to a shared ledger (though not all nodes perform validations depending on the system, architecture and other).

Token (for a blockchain network): A digital asset used in a blockchain transaction. A token can be native to the blockchain, such as a cryptocurrency, or it can be a digital representation of an off-chain asset (known as tokenized asset) such as the title to a house.

Validator: A "validator" refers to the computer/entity that performs a computational review process on each "block" of data in a "blockchain" before a block is considered confirmed/approved. A "miner" is an example of a validator in the context of a proof-of-work consensus protocol. Miners also create new blocks and compete for the right to create the next block in a blockchain through solving a computational challenge.

Contributors

The World Economic Forum's Centre for the Fourth Industrial Revolution Blockchain for Supply Chain project is a global, multi-industry, multistakeholder endeavour aimed at co-designing and co-creating frameworks. The project engages stakeholders across multiple industries and governments from around the world. This report is based on numerous discussions, workshops and research and the combined effort of all involved opinions expressed herein may not necessary correspond with each one involved with the project.

Sincere thanks are extended to those who contributed their unique insights to this report.

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Endnotes

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