A CONSENSUS ON THE TRUTH?

Blockchain Applications in Supply Chain Management

MIT CTL Supply Chain Exchange
Roundtable Report
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MIT Center for Transportation & Logistics

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Blockchain Applications in Supply Chain Management

The Roundtable

Representatives participated from the following sectors.

- Startups
- Transportation Companies
- Manufacturers
- Industry Associations
- Retailers

The Moderators

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Deputy Director

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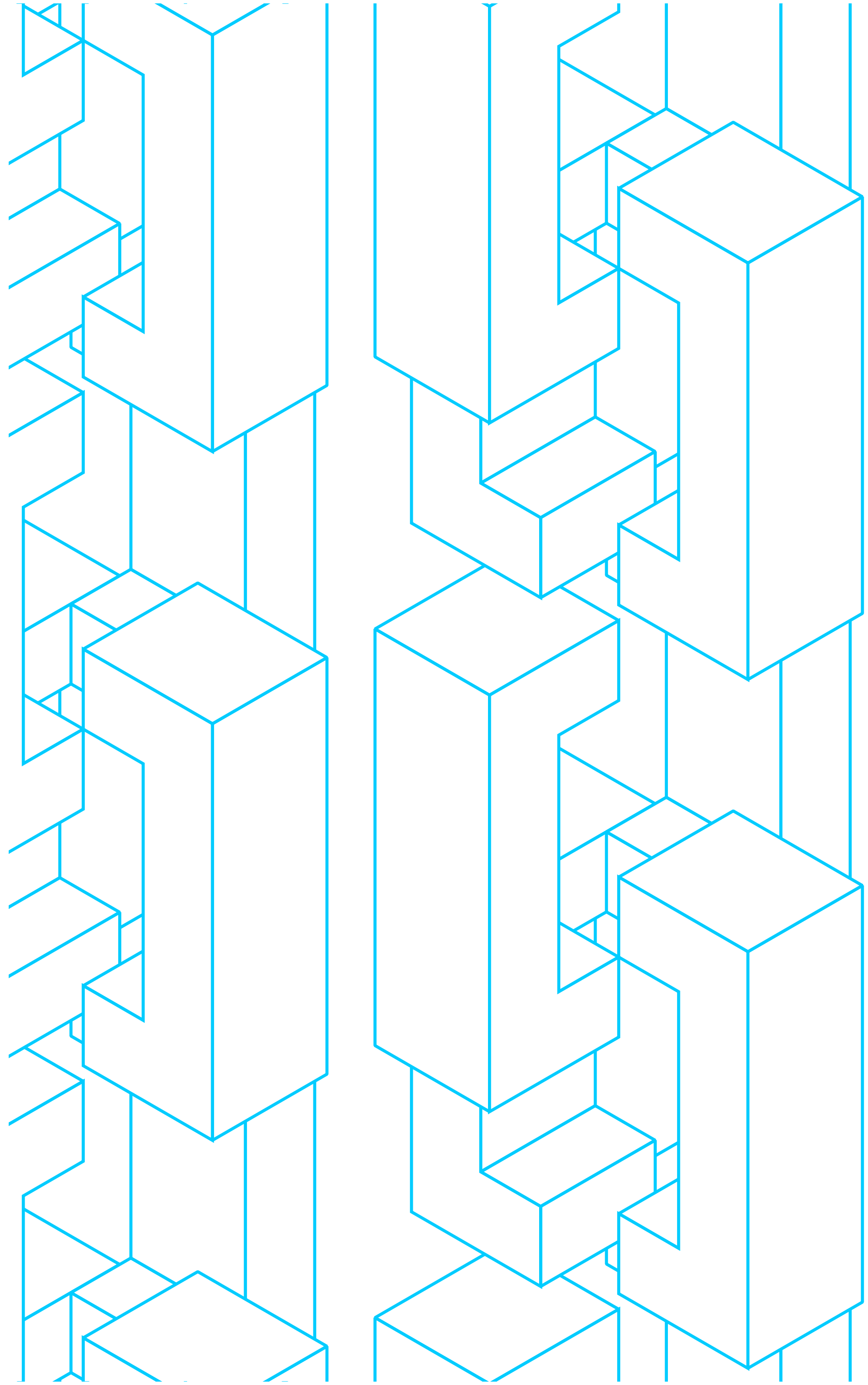


Executive Summary

Representatives from nine manufacturers, eight transportation companies, eight startups, a retailer, and an industry association joined experts from MIT for a highly interactive one-and-a-half-day roundtable on the use of blockchain technology in the supply chain. A variety of industries were represented, including healthcare, aerospace, food, mining, electronics, chemical, fashion, and logistics.

The first half-day consisted of a series of lectures focused on blockchain technology itself, to give participants a basic understanding and a common language for subsequent discussions. Blockchain technology was defined as a data structure that stores data in a continuously growing series of time-stamped blocks, and operates as a distributed ledger where participants must reach consensus before recording any new input. Roundtable attendees learned about the main constituent elements of blockchain technology, including hash functions, public-key cryptography, and consensus mechanisms (see Section 1).

On the second day, the roundtable explored supply chain applications of blockchain in four areas: traceability, sustainability, trade documentation, and dispute resolution. For each application, pre-selected participants described an example wherein they were using blockchain. Each specific, real-world example led to a wide-ranging discussion. Examples ranged from food safety in Vietnamese pork supply chains to ethically-sourced Congolese cobalt, carrier-shipper dispute resolution, better management of bills-of-lading in international trade, and automated handling of demurrage events.

Participants discussed the main challenges to using blockchain and how those challenges might be overcome.

There was an overall agreement about the need to ensure the collection and recording of accurate data, to develop inter-operable standards, and to understand and promote incentives for adoption. The potential impact of blockchain on intermediaries was also discussed. To the extent that blockchain can facilitate both transparency and greater opportunities for secure transactions between parties, it could enable some members of a supply chain to eliminate intermediaries. Blockchain has the potential to force many supply chain actors to rethink their value proposition.

Participants wondered whether existing centralized databases and cloud computing could not solve supply chain management problems in a more cost-effective way than a blockchain. Some participants suggested that in many cases where blockchain is currently applied, a simple centralized solution might be an easier, more efficient way of dealing with the problem. Other participants highlighted that blockchain makes sense when there is a lack of trust in the dominant supply chain players, technology vendors, or governments that might develop, deploy, and oversee the data management systems.

Informal polling suggested that most participants thought blockchain would create some changes to their business but not be transformational. Opinions on the time required for blockchain to add value were evenly split across a 1-2 year, 3-5 year, 5-year plus time horizons.

Overview of Blockchain

The first half-day of the roundtable began with an in-depth overview of blockchain by Dr. Connor Makowski, Research Associate, MIT Center for Transportation & Logistics (MIT CTL), in order to develop a common understanding of the technology among the participants. Many people associate blockchain with the cryptocurrency Bitcoin.

But blockchain is much more than Bitcoin. At some level, Bitcoin is like a sports car -- cool, exciting, but perhaps not for everyone. And if Bitcoin is the car, then blockchain is the internal combustion engine hidden under the hood of the car. In contrast to the sports car, the engine is very useful for a great many more applications than just powering a car. Even if people and companies don't need sports cars or cryptocurrencies, they may find the engines and blockchain useful.

Briefly, **blockchain was defined as: a data structure that stores data chronologically in blocks that are chained together in a continuously growing series**. **A blockchain is operated as a distributed ledger where distributed, independent participants must reach consensus to record any new input**. Blockchain offers promise because it stores data in a secure (through encryption and its block structure), sequential (time-stamped), quasi-immutable (flags data tampering) way.

A Definition of Blockchain

At its most basic level, a blockchain is a data structure that stores data in a continuously growing series of time-stamped blocks that are connected or chained together sequentially. Various types of data such as financial transactions, inventory records, food shipment records, parts certifications, or sensor data can be stored in the blocks.

But a blockchain system is more than a data structure. It operates as a distributed digital ledger, a specific type of distributed database with no central authority, where participants must reach consensus to record any new input.

Blockchains allow users to create decentralized, self-perpetuating data systems that enable people to transact with each other without having to trust each other or rely on a central authority such as an owner or a government.

Blockchain is not a new technology, but a combination of existing technologies pieced together in an innovative way. The pillars of blockchain technology are: public key cryptography, hash functions and consensus mechanisms.

Public Key Cryptography

Blockchain depends heavily on public key cryptography to ensure the integrity of messages and the security of the transacting parties. In a public key cryptographic system each participant has two keys: the eponymous public key and a second private key. The owner of the two keys can freely publish his public key to give others a way of sending him secret (encrypted) messages securely. That public key can be used to encrypt any message, but knowledge of the public key does not enable decryption of the message. Only the owner of the private key can decode the encrypted message. Thus, the sender using someone's public key knows that only the intended recipient can access the encrypted information.

Public key cryptography can be used in a second way that enables secure digital signatures. Here, the sender uses her private key to create an encrypted tag that she adds to her message.

The recipient then uses the sender's public key to confirm that only the owner of the private key could have made that tag from that message. This feature offers benefits that the recipient can verify three facts: the sender sent the message; the message was not tampered with; and the sender cannot repudiate that she sent the message.

Overall, public key cryptography enables transacting parties to interact privately over the public Internet and also enables users of blockchain technology to verify blockchain data.

Hash Functions

A hash function is a specialized mathematical function that can take any chunk of data and compute a nearly unique fingerprint. Hash functions have two essential properties. First, even the tiniest change or addition to the data creates a large, virtually random change in the hash function value.

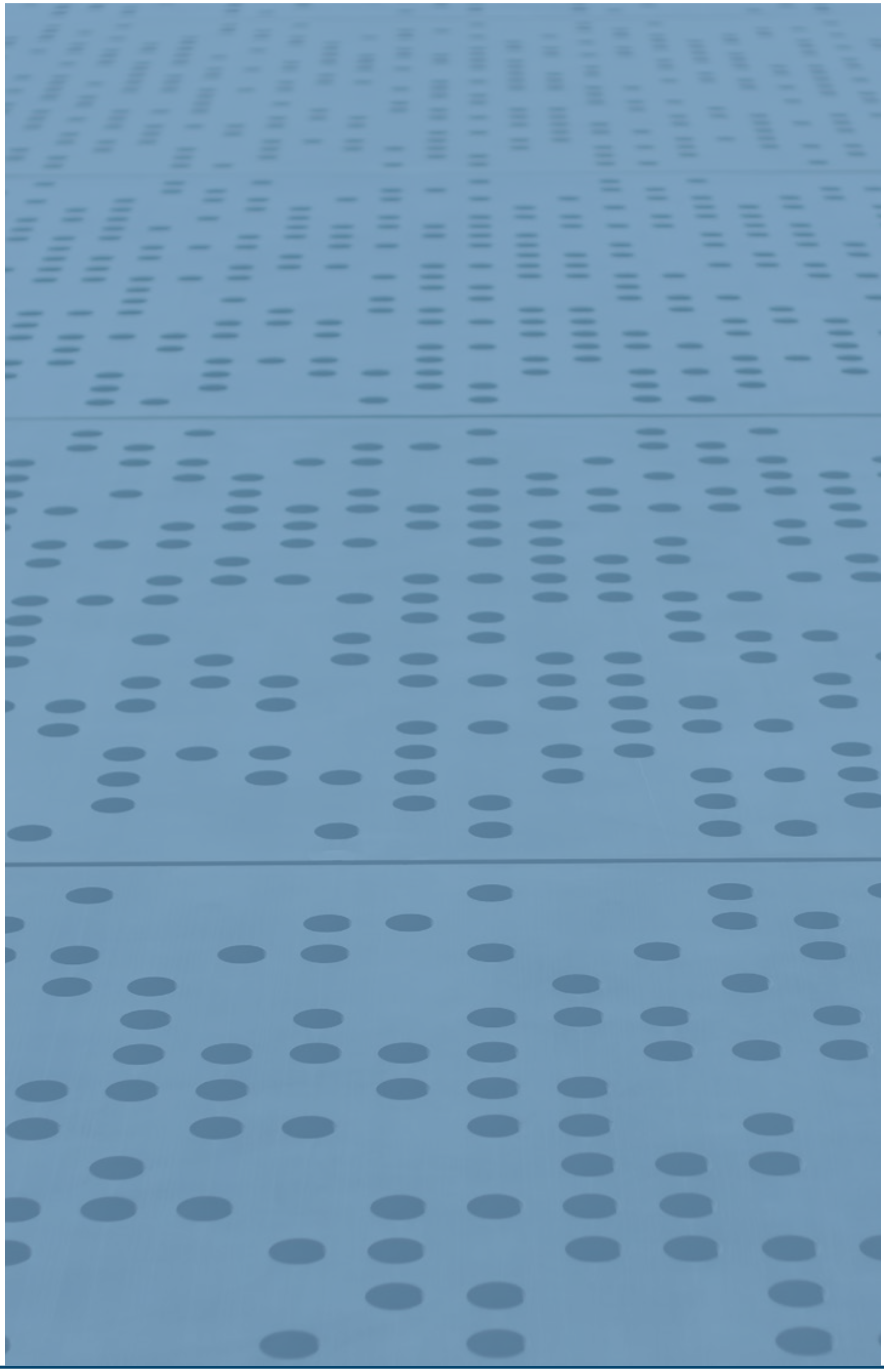
Second, the hash function is relatively easy to compute. Thus, anyone can easily verify that a block of data has not been tampered with by checking the hash of the data against the previously computed and stored hash value for that data. It's also worth noting that each block stores in its data the hash of the previous block, this is how they are "chained".

Different blockchain implementations use different hash functions. The chance that two chunks of data (or an original chunk of data and a clever attempt at a fraudulent copy of the data) have the same hash value is less than the chance of winning nine consecutive Mega Millions lotteries.

Consensus Mechanisms

Consensus in a blockchain refers to the process of achieving agreement among the blockchain participants as to the correct state of data on the system. Before adding any new piece of data to the blockchain, consensus needs to be reached. Hence, the participants share the exact same data. The way to achieve consensus in a blockchain is determined by a consensus mechanism (or consensus algorithm).

Proof-of-Work is the standard approach to determining consensus about the correct state of data on the blockchain system, and it is currently used in the two biggest public blockchains: Bitcoin and Ethereum. However, other algorithms have been proposed that attempt to reduce the energy inefficiency inherent in Proof-of-Work. Some of these other algorithms are lottery-based: a validator is randomly selected among the blockchain nodes, and the probability of being selected increases with the amount of stake held by the node. The stake can be shared memory space on a computer (Proof-of-Capacity), cryptocurrencies (Proof-of-Stake) or others. Another set of algorithms are voting-based, and rely on a smaller set of trusted or delegated nodes to do the work. Overall, the intent is to try to create a stable system that consistently reaches consensus within a reasonable amount of time and effort in a secure and tamper-proof way.



Operating a Blockchain

The net effect of participants competing to add new blocks of data to a blockchain is that exact replicas of the blockchain are stored in a network of different computers. Moreover, the participants also have incentives to weed out invalid or inconsistent data to reach consensus. In the context of Bitcoin blockchain, the process ensures no one can double-spend a Bitcoin by simultaneously submitting two or more transactions to different parts of the network. One transaction or the other would percolate through the blockchain process and eventually become the accepted extension of the blockchain while the other transaction would be rejected. In supply chain terms, this property would mean that a distributor or middleman cannot send the same tagged or traced product to two places or two customers -- attempting to duplicate the valued property of certification with a counterfeit copy of the product.

Although the blockchain data structure is almost immutable, that does not mean no one can correct a mistake. But instead of correcting the error by replacing the erroneous data, the parties add a new visible piece of data that corrects the mistake. In that way, history cannot be rewritten but new events that correct old events can be added to the chain.This process of correction enables the fixing of mistakes, but it also can provide transparency onto when a change was made and who made the change.

Finally, blockchain is also a design philosophy born in the turmoil of the 2008 financial crisis when Bitcoin was first invented by a famously unknown inventor name Satoshi Nakamoto. That philosophy is one that fundamentally distrusts powerful centralized institutions such as the huge banks that were being bailed out at the time. The underlying philosophy esteems distributed consensus, open source software, transparency, and community over institutional control.

At a deeper level, the blockchain system is meant to be trustless but not untrustworthy. That is, the parties who want to collaborate or transact do not necessarily fully trust each other. Nor do they trust any system owner or a government. Instead, the participants put their trust in software, the complex math, and the system of incentives built into the blockchain. Those built-in incentive systems give independent participants a motivation to maintain a copy of the blockchain data, perform the work of adding data to the blockchain, and coordinate with others to achieve consensus. And by having multiple copies of cryptographically secured blockchain data stored by multiple independent parties, no single party, corporate owner, or government can hold the data hostage or tamper with it.

Some commercial blockchain systems use a permissioned model by which participation in the system is restricted to permitted or vetted members. Yet some roundtable participants argued that permissioned systems are not true blockchain systems because permissions depend on some central entity to manage them. Thus, permissioned blockchains require trust that the permission-granting organization won't corrupt the system for its own profit, hold the permissions process hostage, or abandon the blockchain after a change of business strategy or political direction. Some roundtable members were concerned about the lack of a clear agreed definition of blockchain in the business environment. They pointed out that the existing confusion between blockchain, distributed ledger systems and traditional databases is creating noise, hindering constructive conversations and obscuring advances in this field.

APPLICATIONS

The second day of the roundtable explored five supply chain areas where blockchain is being applied. Each area was discussed by the group, following a short presentation by representatives of a company or organization who had delved into the use of blockchain for that application. The wide-ranging sessions explored the application, its issues, and how other companies were thinking about blockchain uses in that area. Application areas included: traceability, sustainability, trade documentation, and dispute resolution.

TRACEABILITY AND PROVENANCE

A representative from a German company described their use of blockchain for a range of product traceability applications for food supply chains in Vietnam, the US, the UK, and other countries. The company started working in Vietnam three years ago following a government request to improve food traceability in the pig industry to help combat foodborne illness. Worldwide, foodborne illness causes over 400,000 deaths a year, 80% of which occur in emerging markets and 80% of the victims are children due to their undeveloped immune systems. Traceability would accelerate back-tracing of the source of an outbreak and then forward tracing of the use of contaminated food to accelerate product recalls.

The company developed a solution that spans from farm to retail -- the whole logistics and production process -- to support food safety in the system.

The solution can be used not only by larger supermarkets but also by smaller traditional markets that are not as organized and developed. Even consumers can trace the source of their food. Furthermore, given the modest average wages in Vietnam, the solution had to be as inexpensive as possible to make it affordable for farmers, the whole supply chain, traditional market stalls, and consumers. To do this, the company created business-to-business (B2B) and business-to-consumer (B2C) phone apps that scan simple printed QR codes.

Initially, the company used a centralized solution but switched to a blockchain solution in 2017. It implemented a blockchain supported by masternodes, whereby everyone who registered and signed a contract could download the whole blockchain, and receive a certain compensation for their services in maintaining a distributed copy of the blockchain. The masternode users could be part of the community.

The company provides the apps, the blockchain platform and the product identification. Product IDs use the GS1 standard as the serial number that defines the product, animal, and packaging throughout the logistics process. Currently, the company handles 400,000 business transactions per day.

For the public, the company provides a free mobile app through Apple and Google Play to enable anyone to view the record associated with the food that they buy. The company then rolled the product out not only to pig farmers but also for chicken, fruit, vegetables and seafood. Now, 40 million Vietnamese in 22 provinces get food traceability on these products.

The company has traceability projects in other nations, too. A pilot project in the UK is addressing the traceable food certification needs for halal food for Muslim consumers. Another project is rolling out traceability for fresh foods in half a dozen countries on behalf of a French grocery chain. The food traceability solutions not only improve health but can also have a social impact by giving small farmers and rural communities access to the technology.

In another application, a blockchain system enables traceability of cattle and beef products for ranchers in the state of Wyoming, US. The system tracks proof of origin, vaccinations, feedlot records, slaughter, and packaging. The blockchain is used to address strict traceability requirements in valuable export markets in Asia, such as Japan and Taiwan.

Roundtable participants mentioned other applications for blockchain to manage information about products or control products in the supply chains. For example, industries such as pharmaceuticals, medical devices, and aerospace also care about traceability. In particular, companies in these industries are often concerned with counterfeit products that endanger lives.

An airline noted the potential for using blockchain for maintaining secure inspection certificates on aircraft parts. These certificates are required by aviation regulators such as the US Federal Aviation Administration to verify that parts have been properly inspected and certified. Previously, these certificates were stored in a massive, paper-based libraries, but the airline is prototyping a system to digitize the certificates and use cryptographic electronic signatures from inspectors. The service lifetime of these parts can be decades, and airlines may sell parts to other airlines as their fleets evolve. That suggests the need for a solution that is not dependent on any given airline's IT systems. Blockchain could provide long-term, secure storage of the inspection certificates that can be used by multiple airlines and multiple regulators around the world.

Blockchain could also be used to secure the digital rights to make 3D printed copies of products or replacement parts. In such an application of blockchain, a customer would buy a "copy" of the item from the original maker and that purchase would be recorded as a blockchain transaction. The customer could then transfer that single-copy authorization to any 3D printing service who would print the item and deliver it to the customer. The use of the blockchain to secure the digital files and rights would prevent the customer or a 3D printing company from making surreptitious extra copies of the item.

Sustainability

Blockchain presents a number of opportunities in the realm of sustainability, where reliable data from suppliers is often lacking. Lack of visibility in the supply chain can open companies up to significant risk when unknown social or environmental issues in the supply chain become exposed.

Blockchain also has the potential to shore up efforts to track progress towards climate goals. Companies are increasingly under pressure to disclose and reduce their emissions, which has taken on a new level of scrutiny as the Paris Accords enters implementation. The status quo of emissions tracking often relies on default databases, rather than supplier data, leaving a gap in understand that tends to underestimate environmental impacts. Blockchain shows promise of collecting and sharing emissions data up the supply chain, taking the guesswork out of reporting and offering a solution to other stakeholders, such as governments, that struggle to track industry's climate impact.

While carbon tracking may be a way off, tracing products to a supplier is closer at hand. A presenter from a Canadian resource company described how they are piloting blockchain technology to ensure ethical cobalt sourcing from the Democratic Republic of the Congo (DRC).

Cobalt is a strategic metal used in batteries for electric vehicles, smartphones, solar power, as well as in high-tech alloys. Sixty-five percent of all cobalt mined comes from DRC, and 20% of that comes from artisanal miners. The artisanal supply has grown significantly in recent years and is a huge employer; it provides the primary source of income for more than 2 million people in DRC. But some of these artisanal mines have poor pay and working conditions and unsafe tools, especially in the rainy season when sites can collapse. Recently, evidence of child labor in artisanal cobalt mines in DRC have led to media and NGO attacks on the brand name companies that depend heavily on so-called "blood batteries."

Governments around the world are grappling with how to regulate cobalt. The Dodd-Frank Act's regulation of conflict minerals does not cover cobalt because the ore does not come from the parts of DRC subject to armed conflict. At present, there is no legislation, but the EU is considering adding something like Dodd-Frank to cobalt. Public criticism and the threat of regulation led some companies to attempt to source cobalt only from Canada and Australia, but the volume of these supplies is insufficient to satisfy the growing demand for cobalt. That fact is pushing brand name technology and automotive companies to look into better traceability solutions for DRC, including blockchain solutions.

The presenter from the Canadian resource company explained that they are creating a blockchain-based certification platform to provide manufacturers and end-users greater certainty of provenance and further assurance that cobalt procured is ethically-sourced. However, it is challenging to ensure that the mine is safe and sustainable and that all the cobalt introduced in the blockchain actually comes from that specifically controlled mine. To address this challenge, the company has established protocols and strict controls in the mines it sources from. Each mine is ring fenced with access control using RFID and facial recognition of each miner to ensure that no children are working there. The company also implemented KYC (know your customer) at each site, with cameras and video recordings of the comings and goings at the mine site. The company is introducing safer and more productive practices with the help of mining engineers and qualified geologists who help define the ore body and ensure the mine won't collapse.

Miners work in collectives of five to ten workers, digging and sorting ore to produce sacks of high-quality cobalt concentrates. The ore is weighed and barcoded to scan who mined it and from which mine it came. Then, they move the tagged sacks to the processing depot where there is chain of custody information. The ore is put into bigger sacks and payment is processed. When the delivery reaches one ton it is dumped out, assayed, reweighed, and batched before moving from the regional depot to the main one for export.

The company also collects social and environmental data in addition to mineral traceability data. On a quarterly basis, they collect information on each miner's age and number of dependents and how long they have lived in the community. They share this information with NGOs and the government so that these entities can spot migration trends and issues.. In short, many kinds of data can help build sustainable development initiatives and ensure social and environmental conditions at the source. But it is hard and costly to ensure the reliability of the data, and market incentives for ethically-sourced raw materials should exist for initiatives like this one to proliferate and scale.

Trade Documentation

A presenter from an ocean carrier described the processes that underpin international shipping documentation and the opportunities to use blockchain to improve the efficiency of these processes. Currently, shippers might print seven to 10 copies of the bill of lading (BOL) that are distributed to multiple parties including the carrier, overseas consignee, destination port, and the bank (if there is a letter of credit). If the carrier loses the BOL, the legal process required to replace it can delay shipment by days or weeks. Multiple startups are working on a blockchain that securely stores the documentation in digital form, and enables the parties to use encryption keys to control access to the data.

In the discussion that followed, participants discussed their international trade process and views on whether blockchain might be useful. Two manufacturers saw the issue in very pragmatic terms. One said it used freight forwarders but did not care whether the freight forwarders used blockchain or not, as long as the application didn't increase the shipper's costs. Shippers need a return on investment (ROI) and hold the purse strings. They can be a catalyst for blockchain adoption if it provides value for them, but ultimately, it's the freight forwarders and carriers that need to do the work because the shipper is outsourcing the transportation task to them.

The other manufacturer wanted to know the value proposition for blockchain. As the company saw it, if a current process wasn't broken -- and the company wasn't paying much more -- there was no need to use blockchain. The company representative didn't want to spend two or three years of effort just achieve a cost saving of two to three percent. Moreover, if trust, collaboration, and consensus were needed, then all parties would have to benefit to ensure adoption.

Examples of the possible benefits include increased supply chain velocity,, quicker customs clearances and less time processing time.. If blockchain increased velocity or reduced the two-foot tall stack of customs paperwork per shipment, the manufacturer said it would support the technology's adoption.

A joint venture between a leading ocean carrier and a leading technology firm is attempting to digitize global trade and put it on a permissioned blockchain. But two transportation providers at the roundtable were skeptical. One saw the effort as creating another information silo. Although many port operators were on board, only one other carrier was participating, and that raised the issue of whether providers in the transportation industry would be able and willing to join an initiative that was set up by a major competitor. Moreover, paperwork, email, and Excel spreadsheets remain the entrenched ways of working in the industry. Could blockchain actually replace these existing older systems, or would it merely add complexity by adding yet another system on top of the current ones?

A big issue was the scale of the adoption problem for trade documentation in international shipping. For example, when the US Coast Guard added a simple requirement for verified weight of containers, adding just that one bit of data to the existing shipping documentation took the entire industry one year. Another participant illustrated the scale of the issue by noting that one of its customers works with 1200 freight forwarders and has two million providers. Overall, the presenter suggested that blockchain might be more doable for areas of international trade other than shipping documentation.

Dispute Resolution

A large logistics company described its application of blockchain to solve a business problem: dispute resolution for shipments. For example, say a big box retailer orders 100 units of an item from a supplier. If 40 units fit on a pallet, the supplier might decide to prepare two full pallets. The carrier then gets a BOL for two pallets, collects the two pallets, and delivers two pristine pallets, not knowing what's inside each pallet. The carrier has clear proof of delivery, but some time later the retailer complains that the carrier failed to deliver all 100 units of the order and threatens to pull business from the carrier. Under the current system, the carrier has no idea of the contents of the pallet but is on the hook for goods that are missing even if they never shipped.

To help reduce these kinds of shipper-carrier disputes, the parties need better transparency to understand what is inside the wrapped, boxed, and palletized shipment. They need to be able to drill down into the shipment and see how it relates to the purchase order (PO). Yet the parties also need secure control of sensitive information. Blockchain might help to make these processes more transparent and supply chain actors accountable.

A presenter from MIT described the use of blockchain at a subsidiary of a Swedish shipping company that owns 130 tankers. The company is in the early stage of deploying blockchain to the business challenge of determining demurrage involving shippers, truckers, and the ports. Demurrage is a charge incurred by shippers judged to be responsible for delays in loading or unloading a ship. Since demurrage claims are often contentious because the incentives of the parties involved are misaligned, using a blockchain to provide a single source of truth could make the claims process more efficient.

The challenge in most blockchain applications is to establish the value of blockchain, which the company did by proving the value incrementally. For example, the company on-boarded the multiple stakeholders incrementally to capture benefits incrementally.

In the presenter's view, one of the main benefits of blockchain in this application is understanding what happened in different ports and who is liable when a demurrage claim occurs. That is, the data recorded in the blockchain helps resolve what really happened. The low-hanging fruit is to provide transparency or testimony on what was submitted, so that carriers, shippers, suppliers, and customers can enforce a much better process.

The concept of recording events related to transportation and demurrage naturally led to the consideration of smart contracts to automate the contractual payments associated with demurrage. The events are recorded on the blockchain, and the smart contracts housed on the blockchain can map that data into the dispute resolution agreement. Smart contracts can accelerate dispute resolution and payment, moving from slow, paper-based processes to fast automatic execution.

However, smart contracts raise a number of open issues. Are smart contracts a true legal document or are they just a logic-driven self-triggering mechanism that allows a business process to continue? Another participant cautioned that smart contracts can be risky due to the effects of contract logic errors, software bugs, or criminal hacking opportunities. To the extent that the contract is both entirely automatic and legally binding, it could cause the rapid and irreversible loss of millions of dollars. Careful design of the smart contract and clear terms within the contract that permit corrective updates to it would be required.

A food traceability company suggested that smart contracts are the biggest last step in blockchain adoption. Ultimately, smart contracts could take over the role of an authority. If Internet of Things (IOT) connections are well-structured, then the smart contract can control the whole process like an authority, and a human authority would not be needed, which is both good and bad. Two presenters concluded that visibility and permanency can drive benefits from blockchain and smart contracts. Whether a smart contract itself is legally binding or not, it would be on the blockchain and visible, and show what the company intends to do.

Payments

Although it was not a separate session, several presenters and roundtable participants mentioned the use of blockchain for payments to supply chain partners and for incentivizing participation in the blockchain system.

For example, a transportation company is looking at a payment settlement blockchain application for truck drivers. The company offers its drivers a 50% cash advance option for accepting a load based on evidence of the BOL. A blockchain solution linked to the BOL and geofencing might speed the process and release the driver's funds less expensively. Yet hurdles remain, such as identifying all the participants and then motivating adoption and rollout. In this specific case, the drivers preferred to stick to their usual way of doing things; it proved difficult to change established practices despite the 50% cash advance incentive.

An MIT presenter described an application of blockchain to secure warehouse receipts in emerging economy agricultural supply chains. Currently, farmers bring their products to a warehouse, which issues a paper receipt documenting the quantity, type, and quality of the delivered commodity. The farmer can then present the receipt as collateral for a loan, sell the receipt to facilitate trade, or use the receipt to settle a futures contract. Yet the current paper-based system suffers from problems such as theft of the receipts and double or stacked-use of receipts as fraudulent collateral for multiple loans. A blockchain-based system would create a secure ledger of these receipts and would record claims against the receipt.

Another interesting blockchain-related issue is the potential of tokenization. Should companies implementing blockchain create their own tokens or use cryptocurrencies? The presenter from the food traceability company created an Initial Coin Offering (ICO) for fundraising purposes. Getting a license to make it compliant with EU and German laws took about six to seven months. Cryptocurrencies might be one option to make blockchain payments to supply chain partners. However, at the moment, cryptocurrencies are too volatile and risky, which makes companies reluctant to accept them for payments. If someone finds a way to stabilize a cryptocurrency or link it to a popular fiat currency, then receivables may become a thing of the past.

The MIT presenter described how national currencies could go digital. Central banks around the world are studying the potential for a cashless economy, enabling some of the secure transactional features provided by cryptocurrencies without the volatility of them.

Addressing Challenges

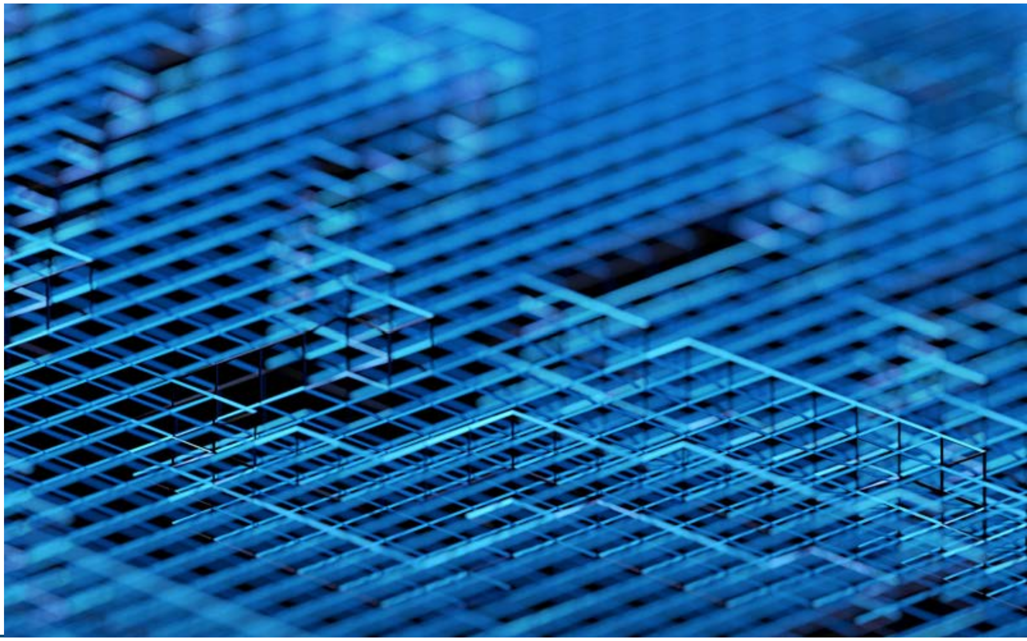
Throughout the second day, the group discussed the many challenges associated with blockchain such as digitization, interoperability, standards, incentives, governance, and legislation. Addressing these challenges will affect whether and how blockchain is deployed in each of the many potential supply chain applications. In turn, blockchain solutions might affect how supply chains operate and the future of companies.

Physical vs. Digital Truth

Several participants noted that applying blockchain to the physical world of supply chains comes with a significant challenge of ensuring that the digital records reflect physical reality. This comes with two serious challenges. The first is simply getting data on the physical world entered onto the blockchain in the first place. The participants in the supply chain must be willing and able to collect the data. And the second is ensuring that the said data is accurate and remains accurate as the goods move through the supply chain. The challenge is especially serious for blockchain applications such as traceability and sustainability, which can involve small players in developing countries that may or may not have access to blockchain-related technology.

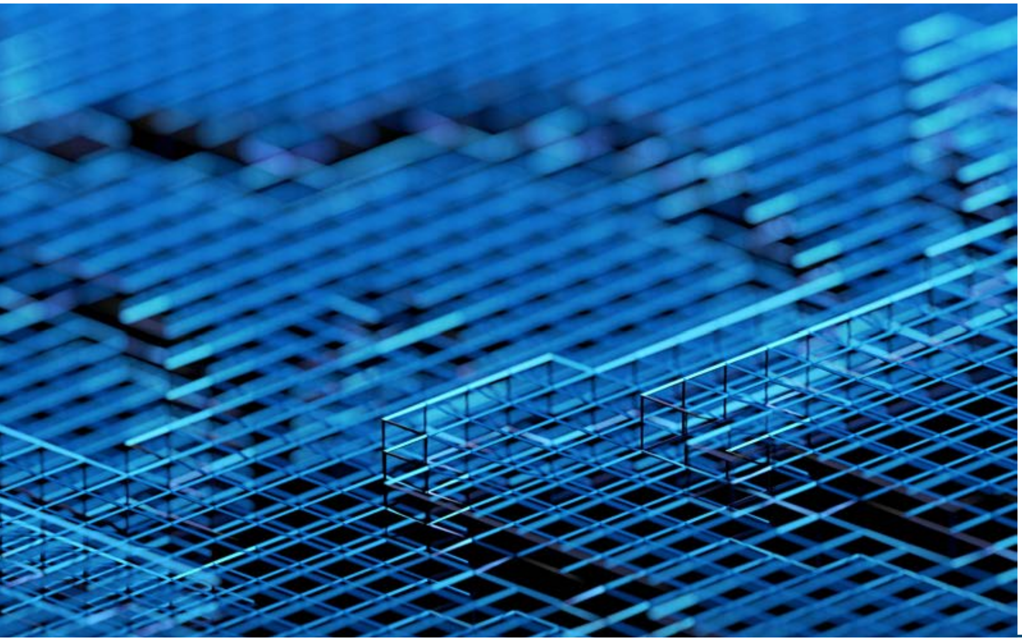
A food traceability company solved this problem of getting the data by creating a simple mobile app. In total, the company created four ways to record the data. First, most farmers use the mobile app and manual entry. Farmers enter the chemicals, feeding, fertilizer, and type of food into the mobile app. The mobile app also collects GPS coordinates, timestamps, and identity information. A second way of data collection uses a general website, which also requires manual entry. Third is a web interface into a company's local IT system with that local system relaying the data to the blockchain system. Fourth, the most desirable solution used IoT to automatically collect data and avoid manual entry. But IoT adoption is still very low due to costs, even in the US. The company working on ethical sourcing of cobalt uses similar methods with miners being given inexpensive ($20) cellphones and mines using a laptop with a bluetooth link to a barcode scanner.

A challenge discussed by roundtable participants is how to verify that the data entering a blockchain is accurate. That's a problem for all approaches to providing traceability, provenance, and anti-counterfeiting; not just blockchain-based ones.



One category of solutions mentioned by several participants is the deployment of third-party inspectors who might be trusted local authorities, selected professionals (e.g., veterinarians in the case of food safety) or NGOs (e.g., in the case of ethical sourcing of cobalt). Data validity issues could also be managed by trust scores analogous to an Uber driver score or a credit score.

If a blockchain is tracking the movement of Apple iPhones, for example, and someone swaps an Apple phone for a cheaper Samsung model, the tampering may not be noticed for some time. A food traceability company suggested that if a product is switched at some point, it would be possible to go back through the chain to see when it was last identified as an iPhone, and all the points thereafter could be deemed untrustworthy. Spot inspections along the chain could pin-point where the swap was occurring. A company involved in tracking for aerospace and defense said those industries employ stealth tagging systems such as nanoparticles to combat these kinds of problems with counterfeiting. This issue also implies that any hardware and software involved in digitizing supply chains needs to be trustworthy, traceable, and tamperproof.



Standards & Interoperability

The entire point of blockchain systems in both cryptocurrency and supply chain applications is to enable secure transactions and interactions between people. That is, blockchain is a connective technology. And yet competition between blockchain creators seems to be building islands rather than bridges, according to one MIT presenter.

In the afternoon, discussion of the challenges, many participants mentioned interoperability as a key challenge. A presenter from a trade organization described their efforts to create interoperable blockchain standards. The organization started in 2017 with a focus on trucking but quickly expanded to transportation and is now focusing on supply chain. One concern is that shippers have been slow to join standards organizations, which could bring a challenge if shippers create their own standards.

According to the trade organization presenter, for blockchain technology to move forward in transportation and supply chain, standards that ensure interoperability need to be created. Although standards setting typically requires 2-3 years, blockchain technology is moving much faster, so the organization is trying to move faster, too. For example, supply chain participants have to decide what "location" means. Thus, the standards organization will create a specification on location data in 2018 and also one for proof of delivery.

A transportation provider noted that some of the companies on the standards organization council are fierce competitors. And yet they also share some tough problems. For example, competing carriers all need to deliver to addresses, manage bills of lading, invoice shippers, and so on. There are many places in which competitors share a common problem that might be solved by blockchains that adhere to standards. Thus, the standards organization council is not a place where companies compete but where they agree. That's especially true for blockchain, in which the founding ethos is about creating an open community that uses mutual self-interest to create a permanent, self-sustaining system that is robust to the failure of any one member.

Other organizations are also working on developing blockchain standards, either at a broader level, or for other verticals such as finance. That implies the need for the various standards bodies to work together even if each must also create some specialized standards that are not needed by everyone. Ultimately, many blockchain systems might need to co-exist across different functions and verticals. Companies with a diverse supply or customer bases might face the inefficiency of multiple platforms unless the different standards settings groups and technology creators find commonality.

While some organizations are developing technology standards for blockchain, other organizations such as governments are developing application standards such as those required for product traceability. Regulatory bodies are determining what data should be collected and how it must be shared in the supply chain, with authorities, and with the public. This raises both the issue of interoperability between technology standards and regulatory standards as well as the bigger issue of interoperability of regulatory standards across borders. For a supply chain application such as traceability, it's important that the data be understandable for the next member and acceptable to the next governmental body.

Interoperability is also challenge at the technology level. A blockchain system -- and especially a smart contract system -- needs to interoperate with enterprise IT systems such as ERP and supply chain communications systems such as EDI. That implies the need for APIs that intermediate between the various technologies. The standards organization presenter thought that blockchain could complement EDI, moving from a two-party visibility system to a multi-party visibility system.

The broader point is that for blockchain to become successfully implemented it has to be seen as a team sport. It requires collaboration between competing companies, different standards bodies, governments, and technology vendors.

Incentives for Adoption

Throughout the day, presenters and participant discussions raised the issue of incentives that drive (or hinder) adoption of blockchain-based systems.

Regulatory mandates related to product safety, composition and authenticity are a strong driver for companies to consider adopting a blockchain system. Since blockchain provides a single version of the truth and it can record data in a secure and tamper-proof way, it is considered a promising technology to provide end-to-end supply chain visibility. However, there are concerns about whether a blockchain-based system is a cost-effective and regulator-approved approach to meeting the end-to-end visibility requirement. When rolling out an implementation of this type of system, larger companies might need to help smaller supply chain partners defray the costs of compliance.

In a second category of applications described by various roundtable participants, a blockchain-based system might enable or support differentiation of the product, such as ethically-sourced cobalt or halal food. For these applications to make business sense, the final seller of the differentiated product should garner a higher price or higher market share. Adoption of blockchain deeper in the supply chain to support product differentiation depends on educating deeper tier suppliers and helping establish a differentiated market in raw materials that offers a price incentive.

A third category of blockchain adoption is driven by the potential of capturing operational efficiencies. Examples included trade documentation, dispute resolution, and smart contracts in which a blockchain-based system might be able to reduce administrative costs, improve reliability, or accelerate supply chain processes.

In these cases, the company driving the adoption of the blockchain project would need to educate supply chain partners about the expected benefits and share costs and gains with them.

A related challenge is that one party's incentives may be another party's disincentives. A carrier trying to encourage the adoption of blockchain and smart contracts to accelerate demurrage payments, for example, faces the problem that the counterparties would prefer to delay said payments. And yet if the blockchain system and smart contracts also reduces overhead costs and dispute resolution costs for those counterparties, they may be amenable to making faster payments, too.

Another challenge mentioned by an ocean carrier is the lack of a clear business case for blockchain. Adopting new technology is usually a costly and lengthy process, that involves dealing with legacy systems and employee-related change management issues. Until the ROI is clear, many companies are reluctant to embark in this adventure.

The overall point is that incentives matter and that understanding the incentives that different parties have for adopting blockchain will help shape blockchain systems to make them more likely to be adopted. In addition, there has to be a clear business case for the adoption of this technology, and the costs and gains associated with blockchain implementation should be fairly allocated along the supply chain.

Is Blockchain Needed?

Many participants challenged the notion that blockchain was really needed. They argued that most of the cited applications of blockchain could be handled by existing off-the-shelf information technologies such as centralized databases and cloud computing services. Even smart contracts can be implemented with existing cloud technologies without use of a blockchain. Moreover, some of the "blockchain" solutions being peddled by large technology vendors seem to be nothing more than mainframe applications with a veneer of this buzzword technology. Some argued that blockchain seemed like a hammer in search of a nail, and that the better approach was a careful analysis of each problem and an unbiased selection of the best solution for the job.

However, non-blockchain alternatives require significant trust in the supply chain partner or technology vendor who is maintaining the centralized database. A food traceability company initially created a centralized database solution but switched to blockchain to assuage users' mistrust of supply chain partners and their country's own government. Although even the centralized solution secured all the data, it was important to show the people involved that the information was on a blockchain and the immutability that blockchain provided more confidence in it.

Issues such as mismatched incentives, cybersecurity risks, up-time reliability, and long-term commitment of the database owner present risks that can be mitigated by a true decentralized blockchain solution. Even the best cloud vendors can suffer disruptions that could be avoided by a truly distributed, decentralized solution such as blockchain. Non-blockchain solutions can also require trust in the government where the managing partner, vendor, or data center resides.

Although participants understood the value of blockchain in countries with low trust, they wondered about its advantages in a country like the US where there is more trust. A food traceability company replied that blockchain-based traceability is also relevant in countries like the US because the food is being imported and exported. There is increasing pressure from governments and other stakeholders in food supply chains to provide reliable proof of provenance. A key feature of a blockchain solution is that no single company, authority, or government controls the data.

One of the key benefits mentioned by several presenters is the potential for blockchain solutions to help reveal and remove middlemen that add little value. In many supply chains, middlemen take control of the flow of materials, under-pay small producers, charge high mark-ups, but fail to add commensurate value. Creating end-to-end supply chain transparency would enable small producers to connect directly with further downstream customers rather than only sell to local middlemen.

Shortening the supply chain might benefit farmers, artisanal miners, and other small players by giving them a greater share of the end-to-end profits of the supply chain. Removing superfluous middlemen could shorten supply chains, making it potentially more responsive to both demand and exceptions (e.g., food recalls). Improving transparency and shortening supply chains might also reduce corruption and tax evasion.

One unusual perspective is that blockchain may well be hype, but it is hype that can drive investment in solving problems. It may be true that blockchain is a hammer in search of a nail and not the best solution for every candidate nail-like object. Yet as a buzzword and exciting new technology, it might actually foster investment in solving many long-running, ignored problems in supply chains such as improving traceability, promoting sustainability, increasing the efficiency of trade documentation and dispute resolution. That is, blockchain may not be the best solution, but at least it gets companies to think critically about existing problems, consider the alternatives and adopt a solution.

A presenter recommended that companies ask themselves three questions when considering deploying blockchain as a solution, and he used the BOL trade documentation application as an example for the answers. First, is the use case meaningful? In the case of a BOL for international trade, it is. Second, is blockchain a must-have, nice-to-have, irrelevant, or harmful feature? In the case of the BOL, it's almost a must-have. Third, who is in the best position to implement blockchain? In the case of the BOL, startups are doing it, but it is the carriers and shippers who have the data and who run the operations, so they should be the ones taking the lead.

The Future

Will blockchain technology be widely applied in supply chains? Does it have the potential to radically transform supply chain management? Is it just technological hype that will fade away?

A presenter from MIT saw three possible futures for the integration of blockchain technology into business: 1) the technology becomes a part of the way business is done but doesn't change the structure of the ecosystem; 2) it becomes an entirely new way to transact business and creates entirely new ways to capture value; and 3) blockchain is positioned somewhere in the middle of these possible futures, where we see some changes but not many. An informal poll of the participants found that most of them thought the middle road (option 3) would occur, although more were biased toward the optimistic, transformational scenario (option 2).

A second informal poll asked participants the following question: Will blockchain implementations start to generate business in 1-2 years, in 3-5 years, or in more than 5 years? The participants were fairly evenly divided on the topic. Two participants from the same manufacturing company had different opinions on this issue because they worked on opposite ends of the supply chain. Blockchain was less likely to have a near-term impact on the back-end of the company's well-established and trustworthy network of suppliers and more likely to impact on the customer-facing front-end of the supply chain due to customers demanding a blockchain solution.

Many at the roundtable were taking a wait-and-see attitude toward blockchain and whether or not the technology is likely to add value. This may be a sensible strategy to any veteran executive who is accustomed to seeing hyped technologies rise and fall.

Yet wait-and-see is not without its risks. Unlike many enterprise information technologies that primarily go inside a company to potentially affect internal operations, blockchain is a technology that typically resides outside the company to potentially affect external relationships. That means that those companies currently collaborating to create blockchain applications in the supply chain will likely get to define how those sitting on the sidelines will have to work in the future.

Blockchain technology is still in its infancy, and it may evolve in many different ways depending on the area of application. An eye should be kept on the latest technological developments such as "zero knowledge proofs", which allows a party to prove something to another party without revealing the actual data. Zero knowledge proofs might augment blockchain potential for supply chain applications. For example, two competing companies could prove to each other who has the lower bid on an RFQ without either company revealing their bid to the other. Or a company could prove it has paid all the requisite taxes for an export shipment without revealing all the numbers. Nevertheless, many unknowns remain around blockchain technology (e.g. regulation, efficiency, interoperability…) and the ROI needs to be clearly stated for more companies to adopt it.

Companies currently have an opportunity to define how blockchain is used in their supply chains, assuming it is used at all. But even if the attempt reveals that blockchain is a just another hammer that cannot find its nail, all that scrutiny of potential applications for blockchain may give rise to other solutions to the many inefficiencies and opportunities latent in today's complex global supply chains.

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